

TITANIUM TODAY

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MEDICAL EDITION



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Editorial

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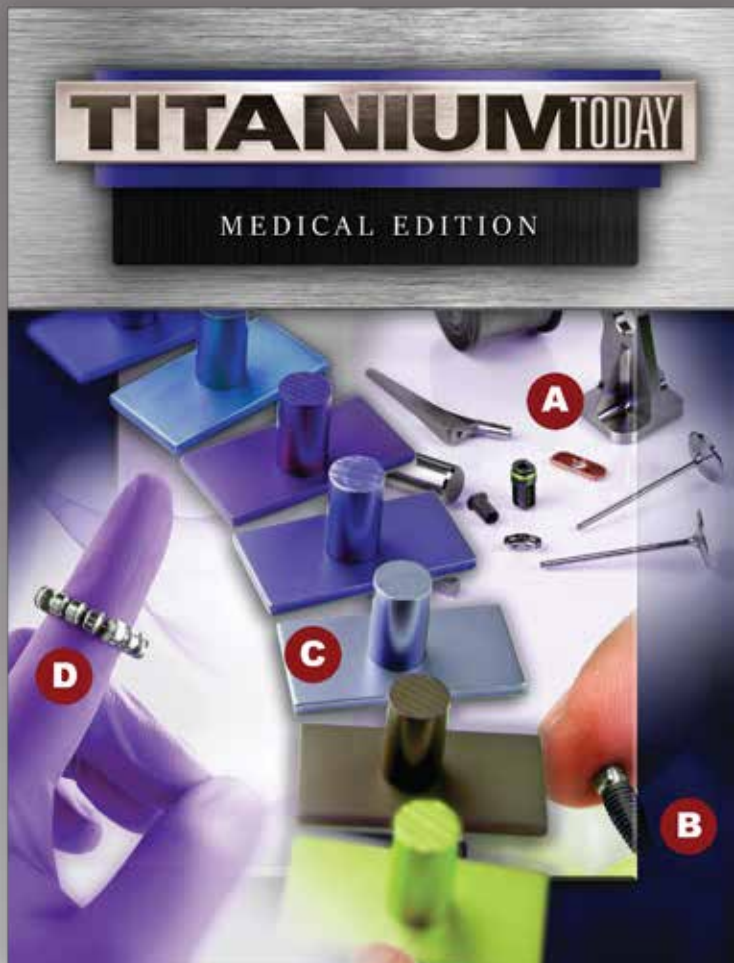


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B A dental implant is essentially a titanium screw or cylinder, between 8 and 16 mm long, which is inserted into a prepared bony socket in the jaw and acts as a replacement root for the missing tooth. A special attachment called the abutment, which is fitted to the top of the implant, forms the external connection for the new replacement tooth (crown) or teeth (bridge or denture). During healing, the titanium surface of the implant fuses with the surrounding bone, in a process known as osseointegration, which can take about 3-6 months. After this time, the implant is stable enough to support one or more false teeth. Titanium improves the quality of individual lives when it is used for medical and dental implants, prosthetic devices, eyeglasses and even lightweight wheelchairs.



These titanium **C** dowels and plates are anodized by Titanium Finishing Company and supplied as customer samples to illustrate the base colors available in the titanium anodize process. In this instance, Hub Wilson Photography out of Allentown, Pennsylvania decided to exercise their creative side and create abstract photos in the shape of a spine. A very fitting representation, as titanium anodize is used heavily in the medical field for both product and size identification, as well as product appeal and enhancement. Titanium Finishing Company www.titaniumfinishing.com

The Fenix System has **D** three components: an implant, an anal sphincter sizing tool and an introducer tool. The implant is a series of titanium beads with magnetic cores that are connected by titanium wires to form a ring shape. The attractive force of the magnetic beads augments the anal sphincter to minimize involuntary opening of the anal canal, reducing the likelihood of severe fecal incontinence. The implant device is offered in multiple sizes to accommodate variation in sphincter size. The sizing tool is used to associate the anal sphincter size to an appropriate implant. The introducer tool is used to guide the sizing tool and the implant into position. The Fenix System is designed by Torax Medical www.toraxmedical.com/fenix/

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Welcome to the 2017 Medical edition of Titanium Today.

I am Viv Helwig, President of Vested Metals International, a Specialty Metals Distributor, ITA Member and I am pleased to be the current Chair of the ITA Medical Technology committee.

The Medical Technology committee is comprised of a variety of ITA Member organizations, all which have an interest in titanium used for medical applications. After being dormant for a few years, we relaunched a committee for the Medical market last Fall at the TITANIUM USA 2016 conference in Scottsdale, AZ. The committee is pleased to host the Ti in Medical Technology session at the TITANIUM USA 2017 conference this October 8-11th in Hollywood, Florida. Speakers include Don Urbanowicz, Principal at Urbanowicz Consulting, LLC; Dr. Prabhu Gubbi, Manager – Chemical, Microscopy & Materials Testing for ZimmerBiomet; Dean Hutchinson, Product Manager, Shoulder Arthroplasty Team for Arthrex; and Gene Kulesha Senior Director, Platform Technology Engineering; R&D (Additive Manufacturing) for Stryker

We were encouraged by the turnout and positive feedback we received from last year's Medical market session where we looked at the challenges and opportunities facing different sectors of the supply-chain ranging from the OEM level to the subcontract precision machine manufacturers to the raw material suppliers. Some of our goals as a committee have been to drive up-to-date market intelligence to you, our ITA members, as well as engage new ITA participants and members from the titanium Medical community, specifically, OEM's and finished component manufactures or subcontractors. Our theme at this year's panel will be two-fold in that we will look at current global and regulatory factors facing OEM's and how they affect the rest of the supply-chain. And secondly, we will focus on applications in the Medical market and what emerging technologies raw material suppliers will need to focus on to meet future demands.

As it relates to this Medical issue of Titanium Today, it's been two years now since our last medical issue and we are excited to bring you annual content again. We have put together some insightful topics in the pages ahead that we feel will help engage you more in the current happenings of this critical market to the titanium industry.

In the pages ahead, we'll give an overview and refresher on medical applications for titanium, new potential alloys and applications, explore Additive Manufacturing in this market further, as well as hear from some key experts as they give an overview on the global market.

A special thank you to the other committee members who have engaged in launching this initiative, Jennifer Simpson of the ITA, Stephen Smith of Edge International, Ric Snyder of Fort Wayne Metals, Bob Fletcher of Structure Medical, and Tom Zuccarini of Carpenter Technology for his input as well.

I will end by encouraging you to view the pages that detail the current and new members of the ITA and think about how your organizations can collaborate with each other to grow and move forward the mission of the ITA and ultimately the titanium industry.

I hope you will enjoy this edition and we hope to see you this October in Florida. Please contact the International Titanium Association with your thoughts and suggestions for future coverage.

Viv Helwig

President & Founder
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TITANIUM EUROPE Conference Speakers Spell-Out Trends for World Supply & Demand

International Titanium Association (ITA), Denver, Colorado USA, hosted the fifth annual TITANIUM EUROPE 2017 conference and exhibition on 17-19th May at the Grand Hotel Krasnapolsky, Amsterdam, the Netherlands. Conference speakers shared their outlooks and insights on titanium world supply and demand, the global supply chain, near-term business conditions and trends, new manufacturing technologies and the dynamics of industrial markets. A total of 398 delegates from 30 countries attended the gathering.

Special guest speaker, Dr. Arne Burzlaff of EBRC Consulting, Hannover, Germany, a researcher with expertise in Materials Chemistry, Inorganic Chemistry, Toxicology, addressed a "Proposal for Classifying Titanium Dioxide as Inhalation Carcinogen and its Effect on Titanium Metal. Burzlaff said the French competent authority ANSES (the French agency for food, environmental and occupational health and safety) proposed a harmonized classification of titanium dioxide (TiO₂) as a category 1B carcinogen, H350i, "which may cause cancer by inhalation." According to Burzlaff, the ANSES proposal rests on the results of inhalation studies with rats conducted over 20 years ago, "which used extremely high concentrations of dust resulting in lung overload effects."

The ANSES dossier was published by the European Chemical Agency (ECHA) in May 2016, followed by a 45-day public consultation a record number of 514 responses were submitted with 97 percent of these opposing the proposal. Burzlaff said that in July 2016, TDMA/ TDIC submitted its detailed response to the ECHA public consultation, concluding that the ANSES proposal is scientifically unjustified, and TiO₂ should not be classified. "It has been conclusively shown that the response to these lung overload studies

with poorly soluble particles is unique to the rat and not relevant to man," he said. "Detailed studies of over 24,000 workers in 18 manufacturing sites over several decades have confirmed no adverse health effects from exposure to TiO₂."

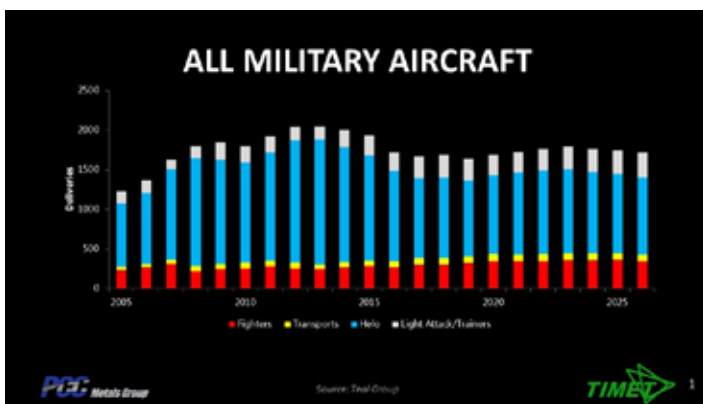
Dietmar Fischer, appearing at the conference as another special guest speaker, reviewed his long career in the German titanium industry, in a presentation titled "Looking back at 66 Years of Titanium Production in Germany." After looking back at his accomplishments, Fischer concluded his talk by identifying additive manufacturing/3-D printing as "the future of industrial production" for titanium. Born in 1942, Fischer became the head of ThyssenKrupp's titanium technical division.

Katja Staartjes, who hails from the Netherlands and is a mountaineer, adventurer, professional coach, author and motivational speaker, presented "Together to the Summit," included inspirational words and stunning photographs of high-altitude mountain scenery. Staartjes' delivered a commentary on business issues, citing themes such as team spirit, trust and resilience. Seventeen years ago she founded her business, "Katja Staartjes Inspiratie" and is the author of three books. The focus of her work involves providing motivation to people and organizations to climb their respective "mountains" and achieve desired goals.

ITA's Women in Titanium (WiT) committee held a reception during the confer-

ence—part of the group's outreach efforts to engage and mentor women in the field. The mission of WiT is to develop a networking group of collegial women presently in the titanium industry; and to promote, attract, and encourage high school and college women to enter the titanium industry.

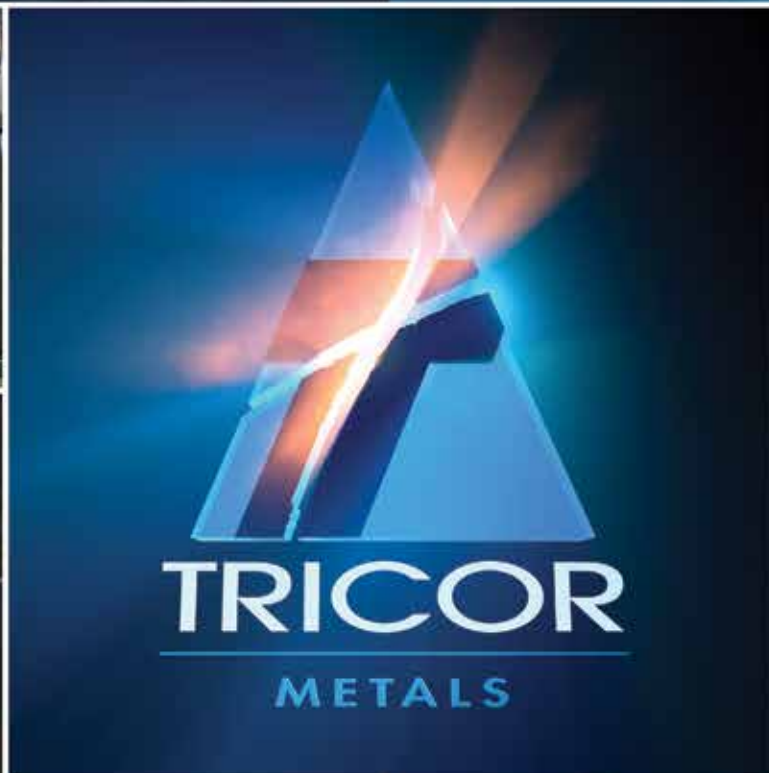
A presentation by Judith Peeters during the WiT reception titled "Diversity" stated that there are neurological and behavioural differences between men and women. "These differences lead to conscious and unconscious biases that cause big differences in salaries and opportunities. For many years diversity has been on the agenda of politics and companies. Steps have been made over the years, but we are far from a solution. A big responsibility lies with companies: creating flexibility to combine work and family life; educating decision makers on diversity; and making diversity a board responsibility."



Henry Seiner, Vice President – Business Strategy - TIMET, Titanium Metals Corporation

World Titanium Demand Trends

During the session "World Titanium Industry Demand Trends," Henry Seiner, Timet vice president of business strategy, outlined "Trends in the Defense Market: A Titanium Perspective." Seiner, who also serves as president of the ITA's



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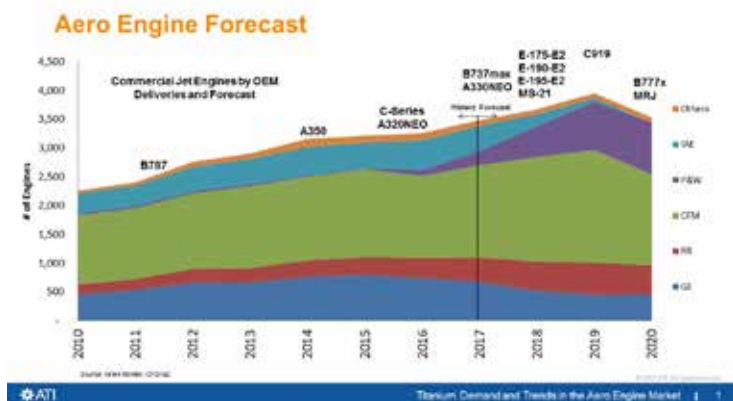
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board of directors, said that, based on market analysis and projected Teal Group build rates, Timet forecasts that titanium demand from the global defense market will reach around 16,000 metric tons in 2021, up from an estimated 15,000 metric tons this year.

For all military aircraft, which includes fighter, transports, helicopters and light attack/trainer, deliveries will be about 1,700 units each year between 2017 and 2025. The number of deliveries for the Lockheed Martin Joint Strike Fighter (JSF) F35 is expected to peak at 160 planes in 2024, dipping slightly to 156 planes in 2025. He noted that the forecasts are subject to change and revision due to global uncertainty—tense situations involving the Korean peninsula, the Middle East, Brexit, and relations between the United States, Russia and China.



Wade Leach, Senior Vice President, Commercial - ATI Specialty Materials

Wade Leach, senior vice president-commercial for ATI Specialty Materials, examined “Titanium Demand and Trends in the Jet Engine Market.” A chart presented by Leach projected that commercial jet engines deliveries from original equipment manufacturers would peak at around 4,000 units by the year 2019, and then fall to 3,500 units in 2020, slightly above engine deliveries anticipated this year. Engine manufacturers accounting for the most deliveries include CFM International, the General Electric/Safran Aircraft Engines joint venture; Pratt & Whitney; Rolls Royce; and GE.

Key trends for the development of next-generation aero engines will include advances in “Green” technology and additive manufacturing, enhanced fuel efficiency (with elevated engine temperatures and increased thrust), and lower operating costs, according to Leach. Titanium will continue to find applications in jet engine fans (along with composites); low-pressure and high-pressure compressors; and low-pressure turbines (gamma titanium aluminides).

Raphaël Duflos, the lead buyer for Airbus SAS and vice president of metallic materials procurement, reviewed “Titanium Aerospace Demand and the Integrated Supply Chain.” The presentation, in essence, was a call to action for all companies participating in the Airbus global supply chain. In order to secure a stable, long-term supply of titanium, Airbus will unveil its “2021 Global Call for Tender” at the end of this year. The “way forward,” as stated by Duflos, will involve a systematic “de-risking” of the supply chain in order to achieve operational excellence and supplier development.

One element of this will be to deploy “lean initiatives” to upgrade processes in the supply chain.

Airbus Global Supply Chain Titanium demand

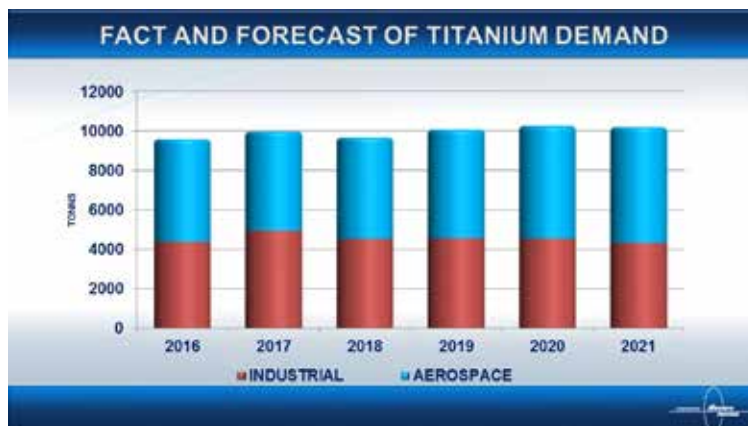


Raphaël Duflos, Vice President Metallic Materials Procurement, Airbus S.A.S.

The Airbus A350 platform will serve as the “key driver for growing opportunities for titanium introduction into the Airbus supply chain,” Duflos declared, adding that “titanium is key for Airbus.” Each working day Airbus manufacturing requires over 30 tons of titanium.

Michael Metz, the president of VSMPO Tirus US, addressed the Russian titanium market, with a forecast indicating that annual Russian demand will remain virtually constant each year between 2017 and 2021 at a level of around 10,000 metric tons. The Russian aerospace sector makes up roughly 60 percent of the annual demand levels.

Metz, who has served on the ITA’s board of directors since 2007, offered further details on the Russian aerospace market, showing a bar chart that indicated engine and aircraft building will account for



Michael Metz, President - VSMPO – Tirus, US



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much of the demand, followed by smaller shares for rocket and helicopter production. Engine and aircraft building reflected 55 percent of overall Russian titanium demand in 2016, followed by 20 percent for ship building. The 25-percent balance in the overall market for 2016 includes categories such as power engineering and chemical processing.

He also provided a snapshot of Russian sponge production in 2016, with Avisma registering an output of about 350,000 metric tons, compared with 2,000 metric

materials and processes.

The aerospace industry forecasts a need for 40,000 new aircraft over the next 20 years, with an estimated dollar value of \$5.9 trillion. To meet this demand, titanium and composites, as critical aerospace materials, will see a compound annual growth rate of 4 percent and 5.8 percent, respectively, through the year 2020. Halford anticipated that titanium's innovations for solving customer challenges during this time frame will involve improvements in fine-grain sheet,

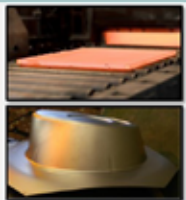
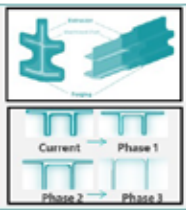
steel welded tubes for heat exchangers, headquartered in Boulogne Billancourt, France, estimated that global titanium industrial demand, which includes oil and gas, automotive, power generation, chemical processing, and desalination, will climb to 31,000 metric tons by the year 2021, compared with a demand level of about 28,000 metric tons this year.

Bruneau identified a slowdown in the lucrative desalination market, but described opportunities to develop the consumption of titanium in process industries, many of which involve displacing copper alloys in refineries and waste flows for district cooling systems. He noted "promising perspective for titanium," such as increasing demand in chemical processing and a steady climb in oil prices. Bruneau also forecasted demand from an increase in the number of nuclear power plants, especially in China, which he sees as the "key driver of nuclear (power generation) titanium consumption."

World Titanium Supply Trends

The Amsterdam conference's World Titanium Industry Supply Trends speaker panel featured Sylvain Gehler, the chairman of Ust-Kamenogorsk Titanium and Magnesium Plant (UKTMP); Nick Corby, ELG Utica Alloys Inc.; Rocco Vincent, sales manager, AMETEK Reading Alloys; and Thomas Hohne-Sparborth, Roskill Information Services Ltd.

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Jeremy Halford, President - Arconic Titanium and Engineered Products

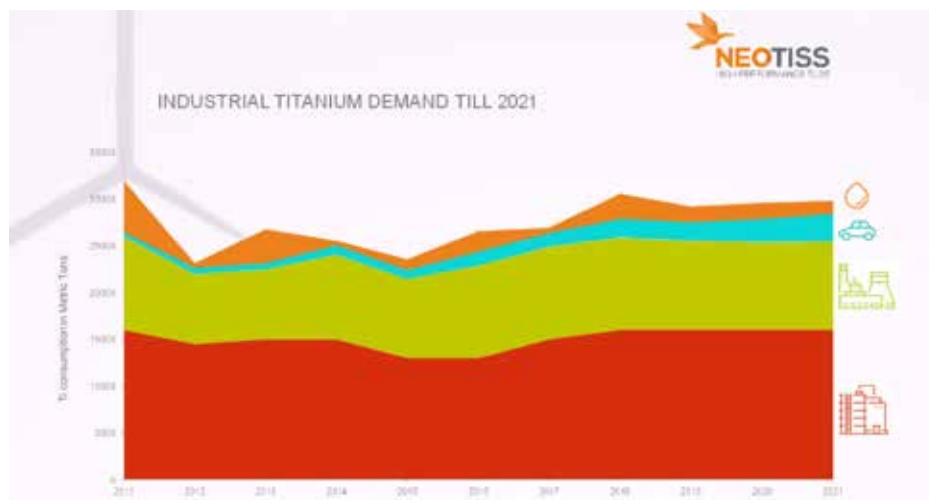
tons for SMW.

The talk by Jeremy Halford, president of Arconic Titanium and Engineered Products, focused on "Driving Growth Through Innovation – World Demand Trends in Airframes." Halford began by reviewing the "era of design," saying that, for commercial aerospace, the thrust for last 10 years has been on development and the introduction of new designs and technology. "As a result, there were an unprecedented number of recently or soon-to-be introduced models," he said, mentioning planes such as the A320neo and A330neo; the 777X, 787 and the 350-XWB.

However, Halford suggested that aerospace has now moved into an "era of delivery. Today's top two questions: how will we manage the transition to new airframe and engine platforms?; and how can we profitably deliver the backlog?" The answer, he said, is innovation in

high-temperature alloys, near-net extrusions, titanium aluminides and additive manufacturing technology.

Albert Bruneau of Neotiss High Per-



Albert Bruneau, Executive Vice President - Neotiss High Performance Tube

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Gehler's presentation tracked the "World

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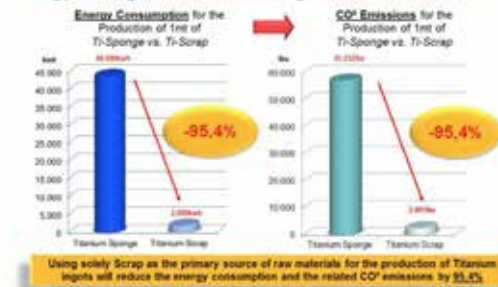
Titanium Sponge Supply Situation.” He estimated that global sponge production this year would be just above 180,000 metric tons this year, compared with over 184,000 metric tons in 2016. China, Japan and Russia are the three largest producers of sponge, followed by the United States, Kazakhstan and Ukraine. North American sponge production is estimated to be 10,700 metric tons this year, compared with 12,000 metric tons in 2016.

According to Gehler, there is a global overcapacity of sponge. Inventory levels are going down, but at a small pace. Sponge production has to be adjusted to the actual demand, while taking into account current inventory levels, he said. “Titanium demand from the aerospace industry is still strong, but not at the level expected by the industry five years ago. (Original equipment manufacturers) should know that the capacity is still there for new projects.”

Nicholas D. Corby III presented “Titanium Scrap Trends; Impacts for a Dynamic Market.” His company, ELG Utica Alloys, with facilities throughout North America as well as in Mexico, Europe, South Africa and Asia, is a major processor of titanium and superalloy turnings

and solids scrap. Corby said that most of the melting capacity for titanium scrap is concentrated in North America, with new projects coming on line in Europe and Asia. “Scrap has to be sourced globally

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Nicholas D. Corby III, Titanium Scrap Trends
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Nicholas Corby III, Titanium Product Manager - ELG Utica Alloys

but supplied locally,” Corby pointed out. “Sophisticated logistics solutions are needed to secure scrap volumes generated in emerging manufacturing clusters.”

He also reviewed recent developments in the scrap market. In France, a joint venture between Aubert & Duval, UKAD, ADEME and CACF will begin qualification this year, with industrial scrap processing slated to start in 2018. In Germany, the VDM melting facility in Essen has been permanently shuttered. In Japan, a

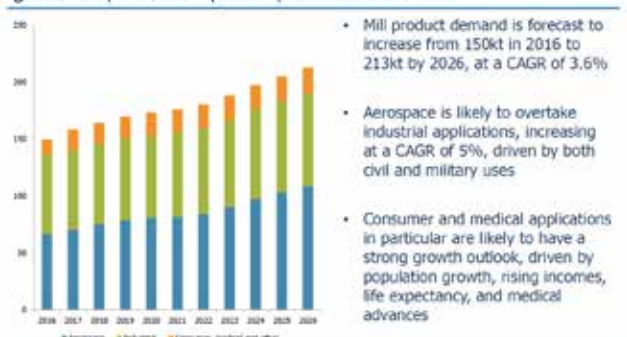
joint venture between Nippon Steel and Sumitomo Metal Corp. recently signed a supply agreement with SAFRAN. In Russia, the utilization of skull furnaces will enable VSMPO to recycle scrap.

The outlook for titanium demand remains healthy, with demand growth expected to speed up in the mid-2020s, according to forecast presented by Thomas Hohne-Sparborth of Roskill Information Services, London. He said mill product demand is expected to reach 213,000 metric tons by 2026, compared with 150,000 metric tons in 2016. The aerospace market will remain a source of strong demand during that same period, reaching about 100,000 metric tons in 2026. Consumer and medical applications have a strong outlook for titanium demand, “driven by population growth, rising incomes, life expectancy and medical advances,” he said.

Last year China (34 percent), the United States (26 percent) and Russia (20 percent) had the largest output of mill products by country. Hohne-Sparborth attributed this to vertical integration, where producers in these countries have achieved upstream integration to sponge, while other producers in Europe, Ukraine and India “only have melt capacity.”

Rocco Vincent, Ametek Reading Alloys, in his talk titled “Master Alloys and Titanium Raw Materials – The Dog Wagging the Tail,” described vanadium master alloys as the “most important class of master alloy products” for the

The outlook for demand for titanium remains healthy, with growth expected to speed-up in the mid-2020s



- Mill product demand is forecast to increase from 150kt in 2016 to 213kt by 2026, at a CAGR of 3.6%
- Aerospace is likely to overtake industrial applications, increasing at a CAGR of 5%, driven by both civil and military uses
- Consumer and medical applications in particular are likely to have a strong growth outlook, driven by population growth, rising incomes, life expectancy, and medical advances

Thomas Hohne-Sparborth, Senior Analyst - Roskill



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titanium industry, citing the wide use of the workhorse Ti6Al4V alloy throughout aerospace and industrial business sectors. Titanium accounts for 4 percent of annual

effect of Centrifugal Casting Parameters on Shaped Castings Quality of New High-Temperature Gamma-TiAl Alloys.” Kochetkov is research group leader of the

titanium alloys department at All-Russian Scientific Research Institute of Aviation Materials (VIAM). He stated that gamma titanium alloy castings containing gadolinium (Gd, number 64 on the Periodic Table of Elements)

exhibit enhanced ductility compared with Gd-free alloys. According to comparative analysis, Kochetkov surmised that this

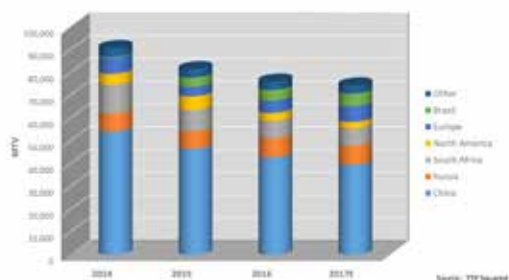
Sergejs Spitans, a process engineer in the research and development department of ALD Vacuum Technologies GmbH, discussed a “New Method for Large-Scale Levitation Melting and Casting of Titanium Alloys.” Spitans said the new concept, known as “FastCast,” is a levitation melting process for titanium alloys. It employs a simple, low-cost, single-part mold that’s well defined and provides a reproducible quality of casting.

Spitans said 3D numerical model for prediction of the turbulent-free surface flow of molten metal in an electro-magnetic (EM) field has been developed and verified. Using numerical simulation, Spitans said it has been proven that by means of horizontal and orthogonal EM fields of different frequencies it is possible to increase the mass of the levitated liquid

metal. “The novel levitation melting furnace has been designed and the prototype has been successfully validated by experiments with aluminum samples up to 500 g.

Levitation melting and single-shot casting simulations with Ti-6Al-4V samples

World Vanadium Production



Source: ITT Inco

Vincent Rocco, Sales Manager - AMETEK – Reading Alloys

vanadium consumption, compared with 93 percent for steel.

He estimated that world vanadium production this year would reach 80,000 metric tons, compared with about 95,000 metric tons in 2014. World consumption of vanadium in 2017 is forecasted to exceed 80,000 metric tons. Vincent provided some analysis of the current world market, saying that vanadium demand is expected to rise (this year) by about 12 percent, compared with consumption demand in 2016. due to increased production of vanadium steels for infrastructure and construction projects. “Most of the increase can be attributed to expected growth in China,” he said. Vincent added that “it appears excess vanadium inventory has been worked out the system,” but warned that supply disruptions could cause high-purity V205 prices to spike.

In his summary remarks, Vincent said that master alloy growth and demand for titanium would “mirror aerospace demand.” And while global raw material production has stabilized this year, “raw material market conditions may be out of sync with the trajectory of titanium demand. The fate of key raw materials (like vanadium and molybdenum) for titanium (master alloys) is determined by the performance of the (global) steel industry.”

Castings

Aleksei Kochetkov discussed the “Ef-

Why gadolinium?

Advantages:

- 1) High chemical affinity to oxygen:
 - effective reducing agent (deoxidant);
 - internal oxidation effect;
- 2) Gd lattice types are isomorphic to those of Ti;
- 3) Low oxidation rate at 20°C, high oxidation rate at 100°C.

64 Gadolinium

Gd 157.25

4f⁷ 5d¹ 6s²

1) Melting point = 1555K (1312°C);

2) Density = 7.395 g/cm³;

3) Lattice parameters:

- α-Gd (P6₃/mmc) – below 1260°C
- a = 0.3606 nm, c = 0.5783 nm, c/a = 1.59;
- β-Gd (Im3m) – higher than 1260°C
- a = 0.495 nm;

4) Cost: ~190...200 \$/kg.

Aleksei Kochetkov, Effect of centrifugal casting parameters on shaped castings quality of a new high-temperature gamma-TiAl based alloy

May 17-19, 2017 • Grand Hotel Krasnopol'skiy • Amsterdam, The Netherlands

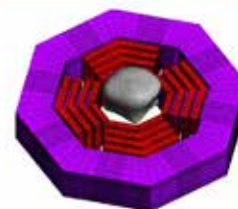
Aleksei Kochetkov PhD, Research group leader of “Titanium alloys” Department - FSUE ‘VIAM’

is due to a more favorable morphology formation and chemical homogeneity of the castings.

“A technology of cast (aircraft engine) blade production using a patented Gd-doped gamma alloy has been developed through the use of cold crucible melting and casting,” he said. The process makes use of an ALD Leicomelt 5 cold crucible induction double-chamber furnace, with mold heating capabilities of up to 1100 C (2010 F).

Gadolinium, a rare-earth metal, has a melting point of 1312 C (2394 F) and is described as having a high chemical affinity to oxygen.

“Simulation-aided” design of the furnace



Sergejs Spitans, R&D Engineer, Process Simulation - ALD Vacuum Technologies GmbH



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(500g) confirm applicability of the FastCast concept for titanium alloys. The build-up of the pilot FastCast setup for titanium alloys forms further plans of research.

Rüdiger Tiefers addressed “Optimization of Multidisciplinary Design Process Gamma-TiAl Low-Pressure Turbine Blades.” Tiefers is the head of casting processes at Access e.V. research institute, Aachen, Germany. He cited a lack of effective networking between turbine and component manufacturers as a reason behind the need to optimize the design process. “Aero-thermodynamic and structural dynamic engineering of turbine blades, especially in γ -TiAl, currently are not integrated into the production (casting) process.” The objective, he said, was to “provide a network design tool for full integration of the manufacturability of

test at DLR Institute of Propulsion Technology, Göttingen, and performed successfully in a structural test, with a test bench on aerodynamic verification in progress. “Eventually this autonomous tool will be available to all OEMs and turbine blade manufacturers.”

Manufacturing Technology

Bertrand Flipo, senior project leader of TWI Ltd., spoke on “Linear Friction Welding – An Alternative Production Route for Titanium Components” and outlined the technology development at his company. He gave a bullet point,



What is Linear Friction Welding?

Time based

High quality

Repeatable

Automated

Self cleaning

Forging process



not Linear Friction ~~Stir~~ Welding

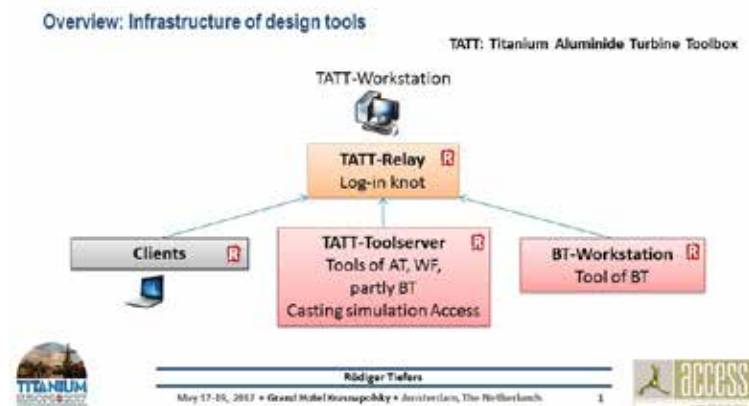


Mr. Bertrand Flipo, Linear Friction Welding Lead - TWI Ltd.

by TWI and an aircraft OEM evaluated over 170 parts. “All components show a minimum of 30-percent cost reduction. In addition to titanium, LFW also shows promise for aluminium-lithium aerospace components.

“bottom line” description of linear friction welding (LFW): high integrity as welded forged joints; parent material is recovered with a heat treatment; can be

Thomas Christiansen of DTU Mechanical Engineering presented a paper on “Surface Hardening of Titanium and Titanium Alloys.” He mentioned research on a new method for “gaseous surface hardening with oxygen—chemically controlled oxygen partial pressure. Christiansen offered slides that showed the formation of a deep “diffusion zone, with no formation of oxides. He also discussed possibilities for surface hardening that involves mixed interstitial compounds in a titanium-based system—titanium oxides, nitrides and carbides. Current test results indicate the potential to obtain “intrigu



Rüdiger Tiefers, Dipl. -Ing., Project engineer - Access e.V.

low pressure turbine components in the high-performance material γ -TiAl.” The aim was to optimizing blade geometry as well achieve efficient aerodynamics, cost-effective production, material-adapted engineering and long service life.

Tiefers tracked the various iterations of design work and offered these a conclusion and outlook on a technology he called the “Titanium Aluminide Turbine Toolbox (TATT).” He declared the casting simulation is validated and that design decisions on castable can be made on the basis of the simulation. “Early application of the tool reduces the number of iterations between engineering and production.” Application of the TATT Toolbox on an engine HPT rotor for experimental validation in the turbine

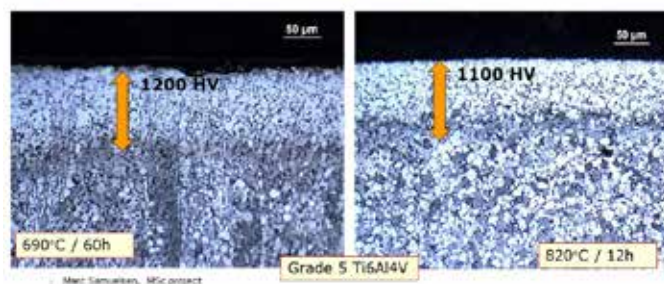
applied without shielding for titanium alloys; a time-dependant process, not volume-dependant; while providing near-net-shape solutions for part-cost reduction.

Flipo offered test results of a Ti-6Al-4V LFW joint performance, reporting that the technology reduced raw material usage, delivery times and cost, while achieving a forged microstructure. As an “economically viable technology,” Flipo said testing conducted

New method for gaseous surface hardening with oxygen; **chemically** controlled oxygen partial pressure



- Formation of a deep “diffusion zone”
- No formation of oxides
- Metallic surfaces can be obtained



Dr. Thomas Christiansen PhD, Senior Scientist, Department of Mechanical Engineering – Technical University of Denmark

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ing new material properties. Dr. Olaf Böhme of POLIGRAT GmbH also discussed techniques for the surface

bilities of a Schuler hot forming press for titanium sheet metal, which has a built-in furnace capable of heating parts and tools up to 950 C (1750 F). A single-action press can handle SPF, diffusion bonding and hot forming. Schuler also has developed a double action press for faster cycle times.

technologies. The company also has additive manufacturing capabilities in laser-wire deposition.

Bosman said GKN Hoeganaes, a powder manufacturer based in Cinnaminson, NJ, and a key part of the company's vertical integration, recently completed a multi-million dollar investment for the development of a new generation of advances metal powder for additive manufacturing, and installed a new gas atomization system.

Pedrum Sodouri of Norsk Titanium AS, Hønefoss, Norway, gave an overview of the company's "Rapid Plasma Depo-



pharmaceutical production vessel electropolished

Dr. O. Böhme, Chemical and electrochemical Surface treatment of Titanium and Ti alloys
May 13-18, 2017 • Grand Hotel Krasnapolsky • Amsterdam, The Netherlands

Dr. Olaf Böhme, Head of R&D - POLIGRAT GmbH

treatment of titanium in a presentation titled "Chemical and Electrochemical Surface Treatment of Titanium and Titanium Alloys"). Founded in 1952, Böhme said POLIGRAT has operations in Europe and North America, delivering turn-key pickling, electro-polishing and anodizing surface treatment solutions for customers, as well as all necessary chemicals and equipment. He said POLIGRAT can offer processes as a subcontracting operation in own factories or for use at the customers site.

Werner Beck of Form Tech GmbH discussed the benefits of the hot-forming process for titanium alloy sheet metal part production. Beck talked about work to improve the manufacturing techniques of the superplastic forming (SPF) and hot deep drawing. He then outlined the capa-

chief technologies of additive manufacturing at Fokker GKN Aerospace, delivered an overview of additive manufacturing at his company. He described GKN as a global engineering group and a Tier 1 aerospace supplier. Regarding its activities in additive manufacturing, Bosman underlined the advantages of GKN's vertical integration. "We operate across the whole value chain, from powder to parts and systems." This includes GKN's addi-

Additive Manufacturing

Marko Bosman,



Marko Bosman, Manufacturing Technology Manager - Fokker-GKN Aerospace

sition" (RPD) process technology for additive manufacturing. Norsk has three facilities—two in Plattsburgh, NY and one Hønefoss—that have a combined fleet of 39 RPD machines.

Norsk's process development work involves a concentration on "Key Process Parameters" (KPP) within a process envelope, according to Sodouri. The KPPs are validated through industry-standard statistical analysis, which provides a basis for understanding and tracking KPP influence on material quality of additive manufactured parts.

A talk by Filomeno Martina of Cranfield University, UK, examined "WAAM, the State of the Art and Ti-6Al-4V Mechanical Properties." Martina, a lecturer at

SCHULER Hot Forming Presses

SPF, DB, Hot Forming and Hot Deep Drawing

The sheet metal hot forming press has a built-in furnace capable of heating tools and parts up to 950°C (1750°F).

Single action presses are used for:

- Super Plastic Forming (SPF)
- Diffusion Bonding (DB)
- Hot Forming (HF)

Schuler has developed a double action press for faster cycle time, constant wall thickness and reduced forming temperature, thus reducing alpha-case build-up. A drawing cushion is installed in the table to supply the blankholder force:

- Hot Deep Drawing (HDD)



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Werner Beck, Benefit of hot forming processes for Ti-alloy sheet metal part production

May 27-28, 2017 • Grand Hotel Krasnapolsky • Amsterdam, The Netherlands

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Mr. Werner Beck, President - FormTech GmbH

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The following chart provides a quick overview of the features and advantages of TFC's coating processes:

Titanium Anodizing

substrates

Titanium
Titanium Alloys

advantages

Stable base for other coatings & adhesive bonding; appearance; color coding

benefits

Prevents fretting & galling
Natural, reproducible colors

Ion Vapor Deposition of Aluminum

Aluminum
Steel
Alloys
Titanium

Non-toxic;
Non-hazardous;
Nonpolluting

Corrosion-resistance
No hydrogen embrittlement
High operating temperature (1100°F)

Hardcoat Anodizing of Aluminum

Aluminum
Aluminum Alloys

Hardness; eliminates burning & dissolution of parts

Allows aluminum application where wear, corrosion or other factors would otherwise exclude its use

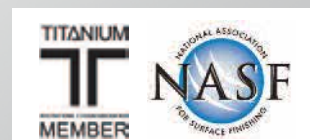
Solid Film Lubricants

Virtually all metals

Automatic & manual application; TFC processes comply with a variety of mil specs; combines with other coatings

Provides excellent lubricity
Improves corrosion resistance

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Process Envelope Development

Objective:

- Demonstrate that material built with different combinations of Key Process Parameters (KPPs) are within the process envelope and have acceptable material properties.

Method:

- Determine Key Process Parameters and Range
- Validate through industry recognized statistical analysis

Value:

- Basis for understanding KPP influence on Material Quality
- Contributes to evaluation of part acceptability if KPP set values are exceeded during manufacture



Pedrum Sodouri, Vice President - Customer Liaison & Production Engineering - Norsk Titanium

Cranfield University's Welding Engineering and Laser Processing Centre, is involved in the development of "Wire plus Arc Additive Manufacturing" (WAAM) technology. He manages a consortium that funds a large research program for the industrial implementation of the WAAM process.

According to Martina, WAAM manufacturing technology can provide a significant reduction in lead time and cost compared with traditional forging and secondary machining. Looking to the future, the WAAM process continues to evolve with higher deposition rates (12 kg/hour), and includes laser-based variants WLAM and WLAAM. In addition, a spin-off company is developing software automation packages to manage the process. Other new WAAM developments

involve "promising high-fidelity/high build rates and robotic cold-work solutions, Martina said. "WAAM is progressing to the qualification phase, and commercial systems with intelligent software will be available in 2018."

Industrial

Jan Palan of Comtes FHT (Complete Technological Service – Forming, Heat Treatment) shared thoughts on the "Development of Pure

Titanium-Based, High-Strength Wires; Possibilities for the Medical Industry." Palan began the talk first by stating the importance of the topic, noting

that pure titanium is considered the most biocompatible metal for medical implants (resistance to corrosion from bodily fluids, bio-inertness, capacity for osseointegration, and high fatigue limit).

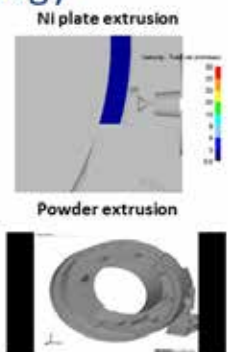
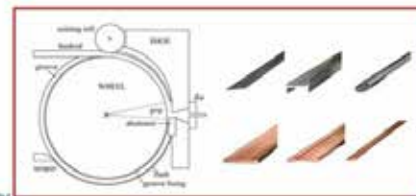
However, for some applications, he pointed out that commercially pure (CP) titanium doesn't have sufficient mechanical properties. "One way how to improve mechanical properties is an alloying, but this could negatively affect biocompatibility. Another way how to increase the mechanical properties is to refine the structure to the level of nanometers using Severe Plastic Deformation (SPD)."

Utilizing SPD is a method to "refine the structure to the level of nanometers, thus improve mechanical properties."

Comtes FHT's "Conform SPD" technology, typically used for continuous

CONFORM technology

- The CONFORM is usually used for continuous extrusion of various profiles from non-ferrous alloys
- Various profiles are processed from a wire feedstock with diameter from 5 to 13 mm. Another way is to use the powder or scrap as a feedstock (development scale).

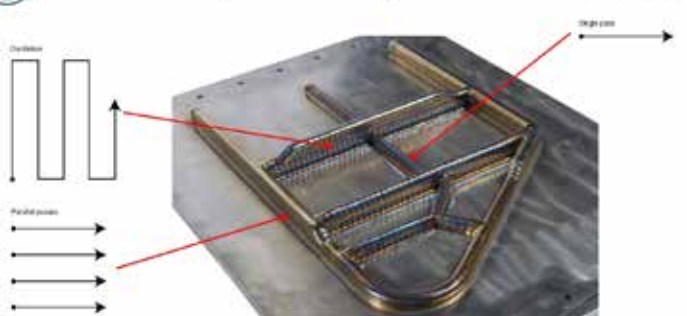


May 17-19, 2017 • Grand Hotel Kronenpolsky • Amsterdam, The Netherlands

Jan Palán, R and D Engineer, Metallurgical Technologies - COMTES FHT

extrusions of various profiles from non-ferrous alloys, is used for the production of nanostructured, high-strength wires. Palan said the company has developed a system for combining Conform SPD with equal-channel angular pressing (ECAP), which provides a process for the cold extrusion of titanium. As a result, the nanostructured CP titanium retains its biocompatibility combined with even higher strength than a Ti6Al4V alloy.

Achieving improved mechanical properties, combined with titanium's inherent biocompatibility, enables designers to create smaller, stronger medical implants,



Dr. Filomeno Martina PhD MSc, Lecturer in Additive Manufacturing, WAAMMat programme manager - Welding Engineering and Laser Processing Centre



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according to Palan. “This is a product with high added value, where the use of nanostructured (CP) titanium delivers improved properties, and therefore increases the price,” he said. “The effect of the higher material prices on manufacturing costs will be minimal.”

Established in December 2000, Comtes FHT is located in Dobruška, Czech Republic, and specializes in the development of forming and heat treatment processes.

renewable power generating sources.

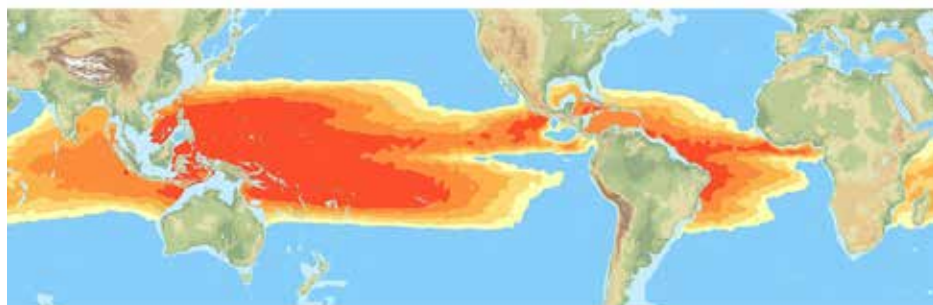
Offering a current snapshot of the market, Blokker said more than 100 countries, throughout tropical regions of Latin America and Asia, have a potential access to use OTEC as an energy resource. The total available market for OTEC energy production is over 100 GW. According to Blokker, OTEC currently is a cost competitive energy system (compared with

cooling, electricity generation, aquaculture benefits and fresh water.

According to recent articles in “Titanium Today,” the magazine published by the ITA, OTEC have been under review for several decades. OTEC uses the ocean’s warm surface water with a temperature of around 25°C (77°F) to vaporize a working fluid that has a low-boiling point, such as liquefied ammonia. The vapor expands and spins a turbine coupled to a generator to produce electricity. The vapor is then cooled by seawater that has been pumped from the deeper ocean layer, where the temperature is about 5°C (41°F). This condenses the working fluid back into a liquid, so it can be reused, creating a continuous electricity generating cycle. The efficiency of the cycle is determined by the temperature differential; the bigger the temperature difference, the higher the efficiency. The technology is viable primarily in equatorial areas where the year-round temperature differential is at least 20°C or 36°F.



Oceans: largest solar collector and energy storage



Ocean Thermal Energy: highest potential when comparing all ocean energy technologies

Remi Blokker, CEO - Bluerise BV

A presentation by Remi Blokker, founder and chief executive officer of Bluerise BV, Delft, the Netherlands, described a “sea of opportunity” for the use of titanium for ocean thermal energy conversion (OTEC). The OTEC technology has been developed on a small scale for a number of years, but is recently gaining attention as a potential source of renewable energy. Given its well-documented resistance to seawater corrosion, titanium would be a strong contender as a material of choice for OTEC systems, especially for heat exchanger components.

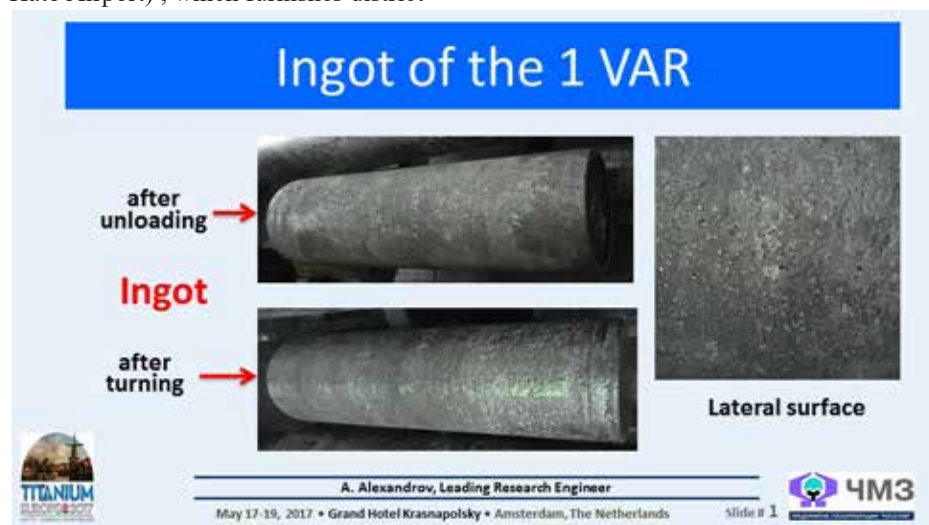
Blokker describe oceans as the earth largest natural solar collector for energy storage, especially in tropical regions. “OTEC is a constant energy source,” Blokker said, adding that ocean temperatures are very stable. An OTEC offers easy grid integration, and a rotating generator (3000-3600 rpm) provides a good power factor. He also indicated that OTEC is highly competitive when compared with solar and wind as “green,”

oil-burning plants) on many Small Island Development States.

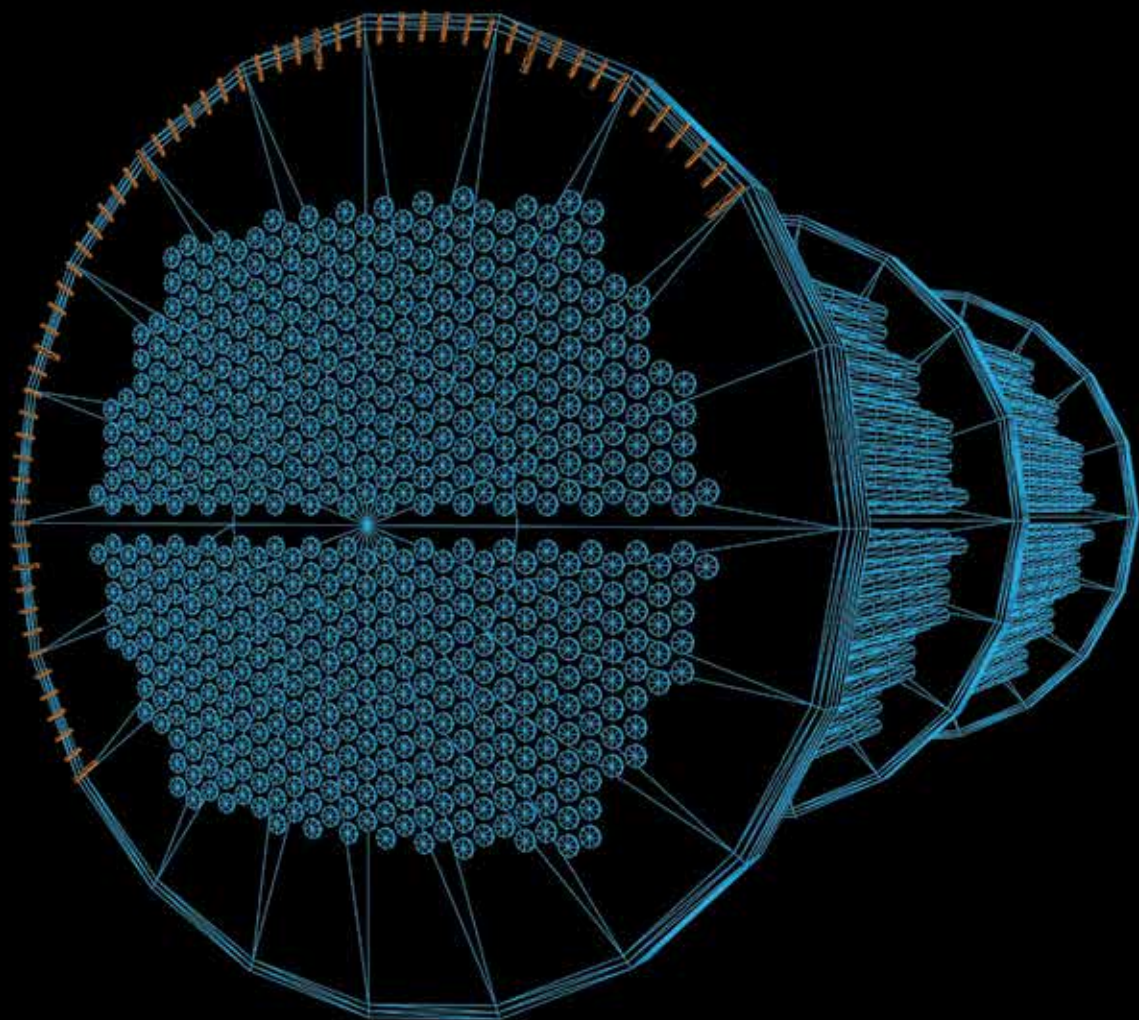
Bluerise’s business portfolio includes OTEC project and technology development, along with software design tools. Blokker pointed to one OTEC system in Ocean Ecopark, Curacao (adjacent to Hato Airport), which furnishes district

Remelt

For the conference’s remelt panel, A.V. Alexandrov of the Central Scientific Research Laboratory (CSRL), presented information on the “Fabrication of Enlarged, Intermetallic Titanium VIT1 Alloy Ingots.” According to online information, a VIT1 alloy contains titanium, zirconium, copper, nickel, and beryllium.



Dr. Alexander V. Alexandrov, Research Engineer - Central Scientific Research Laboratory (CSRL) in JSC



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Alexandrov said the research work at CSRL involved two ingots—one weighing 910 kg (2,006 pounds), the other 1480 kg (3,262 pounds). Both ingots had a diameter of 450 mm (18 inches) and a vacuum arc remelting (VAR) furnace was used for the production of the ingots. The chemical composition of the ingots corresponded to the established requirements and had a high uniformity of the alloying elements distribution along the height. “The ingots successfully passed the ultrasonic control,” Alexandrov said. “From two enlarged ingots six ingots were produced by cutting into dimensional parts according to the specification of the customer. Smelting of the enlarged ingots allows to reduce metal losses on the intermediate operations and labor costs on performance of the work and also to decrease the cycle time of fabrication of small-weight ingots.”

Rob Haun director of new product development at Retech Systems LLC, Ukiah, CA, discussed “Advances in the

turbochargers. The thrust for developing this materials for industrial and aerospace applications is to replace nickel-based superalloys, provide greater engine fuel efficiency (because of the well-documented higher heat resistance of the aluminides), and provide options to develop higher-performance titanium alloys.

During the last five years, development efforts at Retech have been centered on ingots and powder, with hybrid systems using plasma-arc and cold-wall induction. Moving forward, Haun said Retech will continue seeking out alliances with partners and using Induction melt electrode drip gas atomization (REGA) and non-contact nozzle gas atomization.

Production technologies employed by Retech include a patented plasma-arc based melting system (γ -PAM). The company’s production capabilities also include a TIGA (titanium inert gas atomization) and REGA (rotating electrode gas

atomization) for converting ingot to powder and developing new, advanced titanium aluminide alloys

Upcoming TITANIUM conferences TITANIUM USA 2017 will be held October 8-11, 2017 at the Diplomat Resort and Spa in Hollywood, Florida just outside of Miami. A new conference sponsored and organized by the ITA, TITANIUM ASIA 2018 will be held February 4-6, 2018 in Singapore at the Grand Hyatt Hotel, the same week as the Singapore Air Show. The Melia Sevilla Hotel in Seville, Spain will be the site of TITANIUM EUROPE 2018, May 14-16, 2018 which includes an industry tour of the Airbus M400 Assembly Line. Contact the ITA at 1-303-404-2221 to register for these gatherings, or visit the ITA website (www.titanium.org) for more information.

The ITA is a membership-based international trade association dedicated to the titanium metal industry. Established in 1984, the ITA’s mission is to connect the public interested in using titanium with specialists from across the globe who may offer sales and technical assistance. Current ITA membership is comprised of more than 200 organizations and over 1,500 individual members worldwide.

New development: γ -PAM

Effective, low price melting of γ -TiAl-alloys

- Patented Plasma arc based melting system
- Water cooled copper melting vessels
 - 50mm, 100mm, 250mm dia. molds
- Water cooled, vacuum sealed melting chamber



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Mr. Robert Haun, Director, New Product Development - Retech Systems LLC

Systems and Processes for the Production of Gamma Titanium Aluminide Bars and Powder.” Applications for gamma titanium aluminides include low-pressure turbine blades in aerospace engines and precision components for automotive

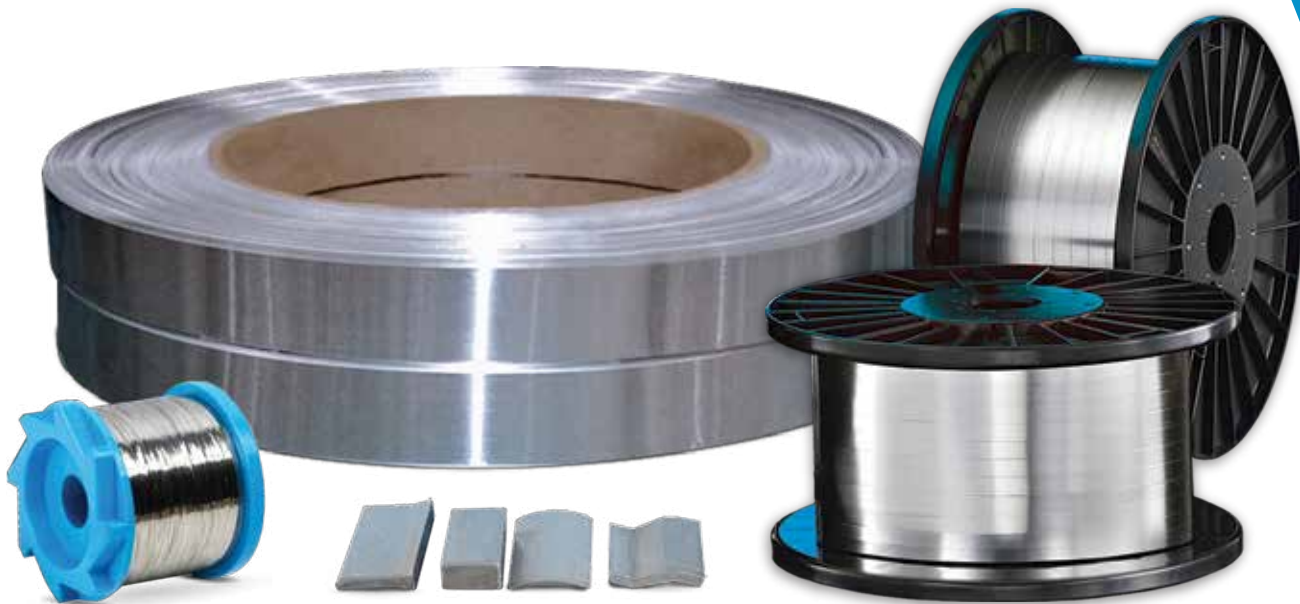
atomization) systems.

For this year and beyond, Haun said Retech would continue to make research and development investments in atomization systems to develop process optimi-

This report was developed by Michael C. Gabriele, independent freelance writer on behalf of the International Titanium Association (ITA) and is intended to provide a broad overview of the TITANIUM EUROPE 2017 conference. The summary provided is based on the presentations interpreted, but is not intended to be either exhaustive or inclusive of all presentations.



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QuesTek's 'Materials by Design' Approach Creates Alloys Tailored For Medical Implants

By Michael C. Gabriele

QuesTek Innovations LLC, Evanston, IL, utilizing its trademarked "Materials by Design®" methodology, has developed a new generation of titanium alloys for Additive Manufacturing (AM) of medical implants. In casting trials and initial wire-based AM trials, QuesTek said these alloys demonstrated 20 percent higher strength at equivalent ductility compared with Ti-6-4, which currently is a titanium alloy of choice used in medical 3D printing. QuesTek is coordinating additional AM trials in powder bed, powder blown, Norsk wire and Sciaky wire builds this year and if all goes according to schedule, the company expects to roll out the first set of commercially available titanium alloys in 2018.

According to information on the company's website (www.questek.com), QuesTek underlines its expertise in the field of Integrated Computational Materials Engineering (ICME). QuesTek has employed this design method for various aerospace applications, and is now applying the technology to design alloys for medical components. QuesTek says ICME "has proven that high performance alloys and other materials can be developed much faster and at lower cost than via traditional (trial and error) methods."

The company's Materials by Design methodology involves a systems-based approach to materials design that utilizes CALPHAD (CALculation of PHase Diagrams)-based tools in combination with proprietary databases, property models, and software to design materials tailored to meet specific performance targets defined by an end user or for specific manufacturing processes such as AM.

ICME and Accelerated Insertion of Materials (AIM) are the design tools that allowed QuesTek to create the company's "QuesTalloys SMA," a nanodispersion-strengthened, high-performance, shape-memory alloy that the company is

marketing as an improved material for use in stents and catheter wires.

In layman's terms, the molecular structure of a shape-memory alloy is designed to have an inherent temperature "trigger," which causes the metal component to change shape, allowing devices made of these alloys to expand or contract when exposed to certain temperatures. Once inserted into an artery at body temperature, such a trigger would cause a shape-memory alloy stent to open up, providing improved blood flow.

Jeff Grabowski, QuesTek's manager of business development, explained that ICME provides an efficient way to produce an alloy with the properties needed for a given design, while AIM greatly minimizes the risk, time and costs associated with the materials qualification process.

Many existing alloy powders and materials used in additive manufacturing typically are not optimized for the 3D additive manufacturing process, according to QuesTek. "The range of alloys to which additive manufacturing can be applied is limited and often accompanied by significant property sacrifices relative to the baseline (wrought or cast) alloys," Grabowski said. "We have been funded on 18 different projects to resolve materials issues observed in AM, across titanium, aluminum, nickel, iron and tungsten systems. This demands the design of material compositions and microstructures specifically tailored for the additive manufacturing processes." He added that QuesTek also is developing concepts to make its high-performance SMA and other shape-memory alloys printable.

Dana Frankel, a materials design engineer at QuesTek, speaking at the Steel Research Group conference held earlier this year, said the company's approach to develop alloys with im-

proved fatigue life involves improved inclusion control along with an increase in yield strength achieved by precipitate strengthening from a nanoscale Heusler phase. Low-nickel and nickel-free Heusler-strengthened shape-memory alloys have been designed using ICME-based models for precipitation, transformation temperature, and yield strength, Frankel said. "Process scale-up of patent-pending alloy designs will investigate both conventional melting/drawing methods and rapid solidification/surface modification techniques to refine inclusion structure."

Rather than relying on a trial-and-error process for alloy development, ICME uses physics-based computational models that draw upon density functional theory, material thermodynamics, and mechanistic property models to develop process-structure-property relationships. The process begins with databases of thermodynamic and kinetic properties of the elements, and crunches the information with predictive models and their respective software platforms to quickly go through thousands of iterations of chemistries and thousands of subsequent virtual heat treatments to optimally target a set of defined performance requirements.

Once the results are in, QuesTek selects two or three "targeted chemistries," which are melted in coin-sized samples in its laboratory and tested to determine the alloy's microstructure and physical/functional properties.

The AIM methodology uses ICME models and predictive tools to forecast minimum material properties based on the possible variations in chemistry and processing parameters that can occur within the full production pathway. Further, these models are calibrated to a minimal set of data points, allowing for both risk and cost mitigation through providing a high degree of confidence with only a few production runs of material.

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QuesTek has shown the efficacy of this approach through the development of two aerospace steels, accurately predicting the minimum properties of ten full-scale heats with data from only the first three heats. Incorporating these models early in the development process will allow for any necessary modifications to be made to the material or processing specifications prior to investing in the full alloy development.

Frankel said QuesTek focuses on the near-equiatomic nickel/titanium system, commercially known as Nitinol. "Our low-nickel compositions use palladium (Pd) as a substitute for nickel to help improve biocompatibility. A little bit of aluminum is added to help form the strengthening precipitates. We are focusing on single alloy compositions of our low-nickel and nickel-free alloy designs for optimization and scale-up, but these alloys could be expanded into alloy families with varying chemistries to target specific transformation properties depending on the application."

As for a commercial rollout, QuesTek will make its shape-memory alloy and additive alloys available as cast bar, wires and powders and will likely be licensed to one or more alloy producers, original equipment manufacturers and end-users. The company is exploring most of the major AM processes: powder bed, powder blown and wire. ICME methods can be tweaked to tailor the alloys depending on the AM processing specifics. In addition to shape-memory alloy stents and catheter wires, QuesTek is considering possible opportunities for its alloys in cast titanium orthopedic implants or fixture devices.

Regarding the company's aim to engage with the titanium industry and become part of the medical industry's supply chain, Grabowski pointed out that QuesTek has had major success in using ICME to design a family of Ferrium steels that are commercially available from Philadelphia-based Carpenter Technology Corp. (a producer and distributor of specialty alloys) and are being used and qualified in demanding applications

such as U.S. Air Force and Navy landing gear, flight critical components on SpaceX Falcon and Dragon programs, and next generation helicopter transmissions. ICME tools also can be used across various alloy systems as evident with its new line of shape-memory and cast titanium alloys. QuesTek has demonstrated success in improving upon legacy Nitinol and Ti-6-4, which is relevant to titanium alloy producers, end-users and the medical industry.

A privately held, limited liability company, QuesTek was established in 1996 by individuals affiliated with Northwestern University (of Evanston, IL) to commercialize the academic work of Professor Gregory B. Olson in the field of computational materials design. QuesTek contributed to the AIM program spearheaded by the U.S. Defense Advanced Research Projects Agency and the Office of Naval Research.

Utilizing additive manufacturing technology, company markets novel titanium hearing aids *By Michael C. Gabriele*

Sonova, Stäfa, Switzerland, a provider of innovative hearing care solutions, earlier this year introduced its Phonak Virto B-Titanium hearing aid, a medical device produced via 3D additive manufacturing.

According recent news reports and information posted on the company's website (<http://www.sonova.com/en>), the process to design the titanium hearing aid begins with an impression of a patient's ear canal, which is made by hand using silicone. This mold is 3D scanned and then turned into a digital model using software from Materialise, a software

solutions company, headquartered in Belgium. Fried Vancraen, the chief executive officer of Materialise, said the company's product development mission is bolstered by an "in-depth knowledge" of additive manufacturing software.

The Phonak Virto B-Titanium hearing aid is produced through a powder-bed fusion method of metal 3D printing, which makes the hearing aid casing that is 15 times stronger than the shell of an average acrylic device and highly resistant to moisture and wear. Sonova officials describe the titanium hearing aid as "no bigger than a fingertip." Scott Witt, director of product management at Phonak, quoted in the trade press, said the Virto B-Titanium is "the most discrete hearing aid ever produced" by the company.

Company officials say titanium "allows for a shell that's half as thin as traditional custom shells, resulting in a deep, comfortable fit that sets new standards for discretion. The overall size is reduced significantly, thus increasing invisible-in-the-canal fit rate by 64 percent." Virto B-Titanium runs on the AutoSense OS™ system that analyzes sounds every 400 milliseconds.

An online innovation feature posted by the Sonova news room reported that the 3D process enables the company to design products tailored for the wearer's individual ear canal and degree of hearing loss. Prior to the use of 3D printing, production of hearing aids had been "the sole preserve of modelers who finished each unique piece by hand in a time-consuming and costly process," according to the company. As such, the use of 3D technology represents a technological breakthrough as well as a competitive advantage in the international medical market.

Sonova's subsidiary brand Phonak produces and markets thousands of custom-made hearing aids for patients around the globe. The company estimates that 1 billion people throughout the world have hearing problems, which significantly affects a person's overall quality of life.

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An Overview of Titanium Medical and Dental Applications

By Dr. Francis H (Sam) Froes, Consultant to the Titanium Industry

Introduction

Titanium is a material of choice in medical and dental applications as more than 1000 metric tons (2.2 million pounds) of titanium devices of every description and function are implanted in patients worldwide every year. Requirements for joint replacement continue to grow as people live longer or damage themselves when playing sports, or are seriously injured in road traffic and other accidents. Light, strong and totally biocompatible, titanium is one of few materials that naturally match the requirements for implantation in the human body.

The list of titanium benefits is lengthy. This makes it incredibly useful for a number of different industries, including the automotive, aerospace and architectural worlds. But because titanium resists corrosion, is biocompatible and has an innate ability to join with human bone, it has become a staple of the medical field, as well. From surgical titanium instruments to orthopedic titanium rods, pins and plates, medical and dental titanium has become the fundamental material used in medicine.

The first use of titanium in medical orthopedic applications (orthopedics is the branch of surgery concerned with conditions involving the musculoskeletal system occurred in the 1950's. Orthopedic surgeons use both surgical and nonsurgical means to treat musculoskeletal trauma, spine diseases, sports injuries, degenerative diseases, infections, tumors, and congenital disorders). Titanium alloys also are the standard material of choice for orthopedic devices such as hip joints, bone screws, knee joints, spinal fusion cages, shoulder and elbow joints, bone plates and scaffolds (Figure 1)1-4.

Titanium also sees use in cardiovascular applications relating to the circulatory system, which comprises the heart and

blood vessels and carries nutrients and oxygen to the tissues of the body and removes carbon dioxide and other wastes from them. Cardiovascular diseases are conditions that affect the heart and blood vessels and include arteriosclerosis, coronary artery disease, heart valve disease, arrhythmia, heart failure, hypertension, orthostatic hypotension, shock, endocarditis, diseases of the aorta and its branches, disorders of the peripheral vascular system, and congenital heart disease.

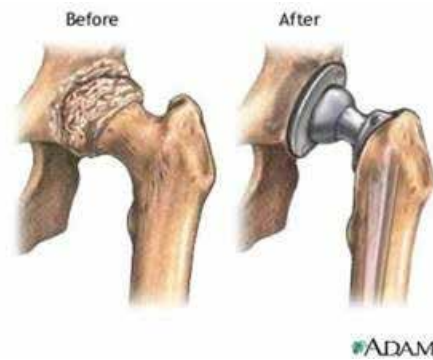


Figure 1. Orthopedic Use of Titanium in Repair of a Joint



Figure 2. General Characteristics of Titanium, which make it attractive for use in the Human Body.

Dental applications for titanium have also increased dramatically in the past 20 years. The replacement of missing teeth with implant-supported prostheses has become a widely accepted treatment modality in dentistry for the rehabilitation of fully and partially edentulous patients.

This breakthrough in oral rehabilitation is based on the concept of osseointegration. This biologic phenomenon is described as direct bone deposition upon a titanium implant surface. Today, commercially pure (CP) titanium has become the material of choice in implant dentistry, since titanium is characterized by excellent biologic and biomechanical properties.

The human body readily accepts titanium as it has proven to be more biocompatible than stainless steel or cobalt chrome. In addition, titanium has attractive mechanical properties (Table 1), including a higher fatigue strength than many other metals. Compatibility with MRI (magnetic resonance imaging) and CT (computed technology) also contribute to the selection of titanium as the material of choice in orthopedic applications. The grades of titanium used in body implants include the commercially pure and Ti-6Al-4V grades listed below3 and a number of other alloy grades such as Ti-6Al-7Nb. This latter alloy is vanadium free, which eliminates the cytotoxic outcomes caused by this element.

- Grade 1 is the most ductile and softest titanium alloy. It is a good solution for cold forming and corrosive environments. ASTM/ASME SB-265 provides the standards for commercially pure titanium sheet and plate.
- Grade 2 Unalloyed titanium, standard oxygen.
- Grade 2H Unalloyed titanium (Grade 2 with 58 ksi minimum UTS).
- Grade 3 Unalloyed titanium, medium oxygen.

Grades 1-4 are unalloyed and considered commercially pure (CP). The tensile and yield strength typically goes up with grade number for these pure grades. The difference in their physical properties is primarily due to the quantity of intersti-



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Property	ASTM Grade				
	1	2	3	4	5
Yield Strength (MPa)	170	275	380	483	795
Ultimate Tensile Strength (MPa)	240	345	450	550	860
Elongation (%)	24	20	18	15	10
Elastic Modulus (GPa)	103–107	103–107	103–107	103–107	114–120

*Adapted from ASTM F67 (Grade 1 to 4) and F136 (Grade 5).

Table 1. Selected Mechanical Property Requirements for Titanium Implants.

tial elements particularly oxygen. They are used for corrosion resistance applications where cost, ease of fabrication, and welding are important.

Grade 5, also known as Ti6Al4V, Ti-6Al-4V or Ti6-4, is the most commonly used alloy. It has a chemical composition of 6 percent aluminum, 4 percent vanadium, 0.25 percent (maximum) iron, 0.2 percent (maximum) oxygen, and the remainder titanium. It's significantly stronger than commercially pure titanium while having the same stiffness and thermal properties (excluding thermal conductivity, which is about 60 percent lower in Grade 5 than in CP titanium), and it's heat treatable. This grade is an excellent combination of strength, corrosion resistance, and is relatively easy to weld and fabricate. Selected mechanical properties of titanium implant materials are shown in Table 1.

Titanium implants

"Permanent" implants are an essential requirement where equipment in critical applications, once installed, cannot readily be maintained or replaced. There is no more challenging use in this respect than implants in the human body. Here, the effectiveness and reliability of implants, and medical and surgical instruments and devices is an essential factor in saving lives and in the long term relief of suffering and pain. Implantation represents a potential assault on the chemical, physiological and mechanical structure of the human body. There is nothing comparable to a metallic implant in living tissue. Most metals in body fluids and tissue are found in stable organic complexes.

Corrosion of implanted metal by body fluids, results in the release of unwanted metallic ions, with likely interference in the processes of life. Corrosion resistance is not sufficient of itself to suppress the body's reaction to cell toxic metals or allergenic elements such as nickel, and even in very small concentrations from a minimum level of corrosion, these may initiate rejection reactions. Titanium is judged to be completely inert and immune to corrosion by all body fluids and tissue, and is thus wholly biocompatible.

The natural selection of titanium for implantation is determined by a combination of most favorable characteristics including immunity to corrosion, bio-compatibility, strength, low modulus and density and the capacity for joining with bone and other tissue, a process known as osseointegration. The mechanical and physical properties of titanium alloys combine to provide implants which are highly damage tolerant. The human anatomy naturally limits the shape and allowable volume of implants. The lower modulus of titanium alloys compared to steel is a positive factor in reducing bone resorption.

Two further parameters define the usefulness of the implantable alloy, the notch sensitivity, - the ratio of tensile strength in the notched vs un-notched condition, and the resistance to crack propagation, or fracture toughness. Titanium scores well in both cases. Typical NS/TS ratios for titanium and its alloys are 1.4 - 1.7 (1.1 is a minimum for an acceptable im-

plant material). Fracture toughness of all high strength implantable alloys is above 50MPa.m^{-1/2} with critical crack lengths well above the minimum for detection by standard methods of non-destructive testing. Examples of Titanium use in body implants are shown in Figure 3.



Figure 3a. Examples of Titanium Implants in the Human Body



Figure 3b. A Titanium Skull Implant, black area

Dental applications

Surgery to repair facial damage using the patient's own tissue cannot always obtain the desired results. Artificial parts may be required to restore the ability to speak or

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Figure 3c. a full knee replacement

eat as well as for cosmetic appearance, to replace facial features lost through damage or disease. Osseointegrated titanium implants meeting all the requirements of biocompatibility and strength have made possible unprecedented advances in surgery, for the successful treatment of patients with large defects and hitherto highly problematic conditions.

A major change in restorative dental practice worldwide has been possible through the use of titanium implants. A titanium 'root' is introduced into the jaw bone with time subsequently allowed for osseointegration. The superstructure of the tooth is then built onto the implant to give an effective replacement Figure 4.



Figure 4. Titanium Dental Implants (top) and their insertion into the mouth (bottom).

Additional information on implants

A comprehensive article on "Understanding Implants in Knee and Hip Replacement" appeared in Titanium Today, 2nd Quarter, 2016 Medical Edition, Figures 5 and 6, published by the International Titanium Association. The titanium knee

replacements are tailored to the patients size, weight and gender (a woman has a narrower bone structure especially on the femur). A companion Article 7 discusses the influence of processing, in particular etched versus unetched conditions, on the performance of titanium middle ear prostheses, with the etched condition exhibiting superior performance. Porous titanium for dental implant applications are presented with additive manufacturing being favored for fabrication of these structures, with further studies required to define the optimum size and geometry.



Figure 5. An Artificial Titanium Knee



Figure 6. A Traditional Total Hip Replacement Implant.

A further article presents details on a 3D printed titanium hip implant with a fully porous cup (Figure 7) allowing in-growth of bone and tissue, resulting in superior performance. A 3-D additive manufactured rib cage and sternum implant is shown in Figure 8. Figure 9 illustrates a Fecal Continence Restoration System consisting of a series of titanium beads with magnetic cores that are connected by titanium wires to form a ring shape.

Titanium surgical instruments

A wide range of surgical instruments are made in titanium (see Figure 10). The metal's light weight is a positive aid to reducing any fatigue of the surgeon. Instruments are frequently anodized to provide a non-reflecting surface, essential



Figure 7. Smith and Nephew Revised Acetabular Fully Porous Cup with Concelloc Technology.



Figure 8. A 3-D Additive Manufactured Rib Cage and Sternum Implant.



Figure 9. Titanium Fecal Continence Restoration System.

in microsurgical operations, for example in eye surgery. Titanium instruments withstand repeat sterilization without compromise to edge or surface quality, corrosion resistance or strength. Titanium is non-magnetic and there is therefore no threat of damage to small and sensitive implanted electronic devices.



Figure 10. A wide range of surgical instruments are made from titanium including Scissor, Forceps and Needle Holders.

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Figure 10. A wide range of surgical instruments are made from titanium including Scissor, Forceps and Needle Holders.

Titanium in wheel chairs

The same characteristics that make Titanium a preferred choice for Implants and Instruments make it a good choice, particularly in Tubular form (Figure 11a & b) for Wheel Chairs (Figure 12), Walkers (Figure 13) and walking sticks/canes (Figure 14). The tubular products are generally fabricated as either seamless or welded components from commercially pure or the Ti-3Al-2.5V alloy.



Figure 11a. Titanium Tubes fabricated in either Seamless or Welded forms.



Figure 11b. Titanium Tubing ready for use in Wheel Chair Applications.



Figure 12a and b. Titanium is a popular choice for Wheel Chairs.



Figure 13. A Titanium Walker.



Figure 14. Titanium Walking stick.

Specifications for titanium in medical and dental applications

Forms and material specifications are detailed in a number of international and domestic specifications, including ASTM and BS7252/ISO 5832 shown in Table 2.

Other titanium based alloys

Nickel titanium, also known as nitinol (also known as a shape memory alloy), is a metal alloy of nickel and titanium, where the two elements are present in roughly equal atomic percentages e.g. Nitinol 55, Nitinol 60. Nitinol alloys exhibit two closely related and unique properties: shape memory effect and super elasticity (SE; also called pseudo elasticity, PE). Shape memory is the ability of nitinol to undergo deformation at one temperature, then recover its original, undeformed shape upon heating above its “transformation temperature” (Figure 15). Super elasticity occurs at a narrow temperature range just above its transformation temperature; in this case, no heating is necessary to cause the undeformed shape to recover, and the material exhibits enormous elasticity, some 10-30 times that of ordinary metal. Nitinol is highly biocompatible and has



Figure 15. Mechanism of Shape Memory. Nitinol undergoes deformation at one temperature, then recover its original, undeformed shape upon heating above its “transformation temperature.”

properties suitable for use in orthopaedic implants. Due to Nitinol’s unique properties it has seen a large demand for use in less invasive medical devices. Nitinol tubing is commonly used in catheters, stents, and super elastic needles. In colorectal surgery, the material is used in devices for reconnecting the intestine after removing the pathology. Nitinol is used for devices developed by Franz Freu-



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ASTM	BS/ISO	ALLOY(S) DESIGNATION
F67	Part 2	Unalloyed titanium – CP grades 1-4 (ASTM F1341 specifies wire)
F136	Part 3	Ti6Al4V ELI wrought (ASTM F620 specifies ELI forgings)
F1472	Part 3	Ti6Al4V standard grade (SG) wrought (F1108 specifies SG castings)
F1295	Part 11	Ti6Al7Nb wrought
-	Part 10	Ti5Al2.5Fe wrought
F1580	-	CP and Ti6Al4V SG powders for coating implants
F1713	-	Ti13Nb13Zr wrought
F1813	-	Ti12Mo6Zr2Fe wrought

Table 2. Specifications for Titanium in Medical and Dental Applications.

dental to treat Patent ductus arteriosus, blocking a blood vessel that bypasses the lungs and has failed to close after birth in an infant. A Medtronic CoreValue Aortic heart valve frame, which must survive 6 x 10⁸ cardiac pulsation cycles, fabricated from Nitinol, is shown in Figure 16.

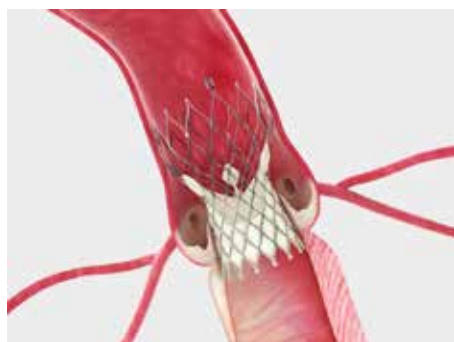


Figure 16. A Medtronic Core Value Aortic heart valve frame which must survive 6x10⁸ cardiac pulsation cycles, fabricated from Nitinol (courtesy of Tom Duerig).

In dentistry, the material is used in orthodontics for brackets and wires connecting the teeth. When the shape memory alloy wire is placed in the mouth, its temperature rises to ambient body temperature, this causes the nitinol to contract back to its original shape, applying a constant force to move the teeth. These shape memory alloy wires do not need to be retightened as often as other wires because they can contract as the teeth move unlike conventional stainless steel wires. Additionally, nitinol can be used in endodontics, where nitinol files are used to clean and shape the root canals during the root canal procedure. Because of the

high fatigue tolerance and flexibility of nitinol, it greatly decreases the possibility of an endodontic file breaking inside the tooth during root canal treatment, thus improving safety for the patient.

Another significant application of nitinol in medicine is in stents: a collapsed stent can be inserted into an artery or vein, where body temperature warms the stent and the stent returns to its original expanded shape following removal of a constraining sheath; the stent then helps support the artery or vein to improve blood flow. It's also used as a replacement for sutures; nitinol wire can be weaved through two structures then allowed to transform into its preformed shape, which should hold the structures in place.

Fabrication techniques

Two developing techniques for the fabrication of medical and dental components are metal injection molding and additive manufacturing. The metal powder injection molding process is similar to the injection molding of plastics, a process developed for long production runs of small (normally below 400 gm) complex shaped parts in a cost-effective manner. By increasing the metal (or ceramic) particle content, the process evolved into a process for production of high density metal, intermetallic or ceramic components (see Figure 17).

There are two basic approaches additive manufacturing: powder bed fusion (PBF); and direct energy deposition (DED), Fig-

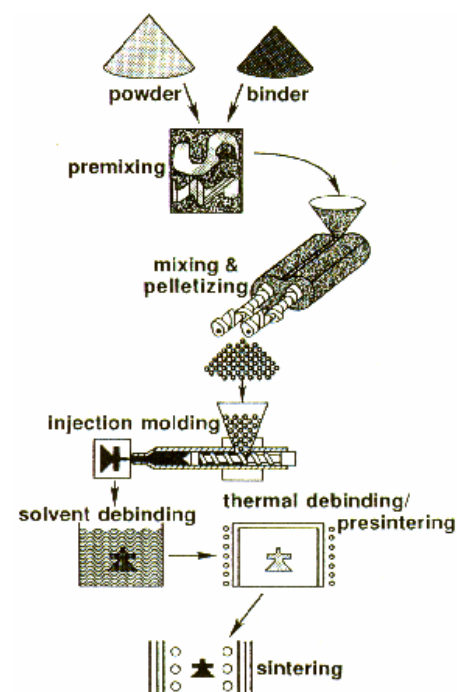


Figure 17. Schematic of the steps involved in powder injection molding, in which a polymer binder and metal powder are mixed to form the feedstock which is molded, debound and sintered. The process relies on the thermoplastic binder for shaping at a moderately elevated temperature of about 150°C.

ures 19 a and b. The PBF technique allows the fabrication of complex features, hollow cooling passages, high precision parts and single metal builds. The DED approach allows large build envelopes, high deposition rates, multiple materials and addition of material to existing components.

The markets for both the metal injec-



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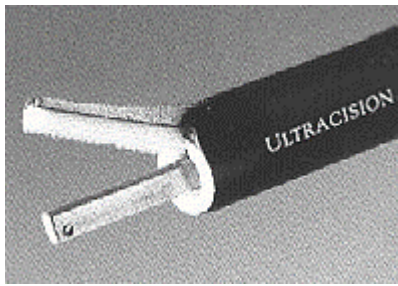


Figure 18 . An ultracision harmonic scalpel which allows surgeons to make incisions with minimal tissue damage , fabricated by the MIM technique (Courtesy Johnson & Johnson)

tion molding and additive techniques are poised for growth. However, what is needed to enhance growth is low cost (less than \$20/lb or \$44/kg) powder of the right size (less than about 40 microns) and good purity (maintained throughout the fabrication process). For non-aerospace applications, the purity level of the Ti-6Al-4V alloy can be less stringent;

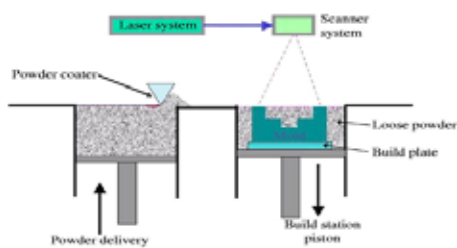


Figure 19a. Schematic showing powder bed fusion technology.

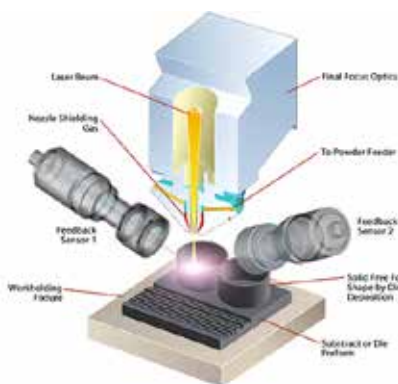


Figure 19b. Schematic showing Direct Metal Deposition (DMD) technology (courtesy: DM3D Technology).

for example, the oxygen level can be up to 0.3 wt percent while still exhibiting acceptable ductility levels (aerospace requires a maximum oxygen level of 0.2 wt percent).

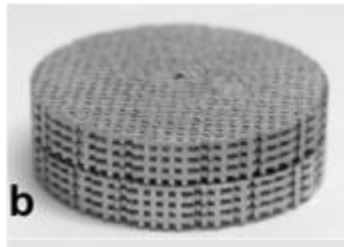


Figure 20a. Ti-6Al-4V scaffold for medical implant applications fabricated using Selective Laser Melting technology.



Figure 20b. An Artificial Hip Replacement fabricated using Additive Manufacturing and Electron Beam Melting.



Figure 20c. A Titanium Jaw fabricated by Additive Manufacturing.

For the CP grades, oxygen levels can be even higher; up to at least 0.4 wt percent (Grade 4 CP titanium has a spec. limit of 0.4 wt percent). In fact, the Grade 4 CP titanium (UTS 550 MPa [80 ksi]) while lower strength than regular Ti-6Al-4V (UTS 930 MPa [135 ksi]) may well be a better choice for the many potential metal injection molded parts where cost is of great a concern. Grade 4 would allow use of a lower cost starting stock and a higher oxygen content in the final part. Further into the future, the beta alloys with their inherent good ductility (bcc structure) and the intermetallics with attractive elevated temperature capability

are potential candidates for fabrication via metal injection molding and additive manufacturing. The science, technology and cost now seem to be in place for the titanium marketplace for both approaches to show significant growth.

Dr. Francis H. (Sam) Froes has been involved in the Titanium field with emphasis on powder metallurgy (PM) for more than 40 years. After receiving a BSc (Liverpool University) and an MSc and PhD (from Sheffield University) he was employed by a primary titanium producer, Crucible Steel Company, where he was the leader of the titanium group and led a major effort on PM titanium under US Air Force (USAF) funding. He then spent time at the USAF Materials Lab, where he was supervisor of the Light Metals group (which included titanium) and again involved an emphasis on PM. While at the USAF Laboratory, he co-organized a landmark TMS-sponsored Conference on Titanium PM (1980) and presented the keynote speech at the first International Titanium Association Conference in 1984. This was followed by 17 years at the University of Idaho, where he was the director and department head of the Materials Science and Engineering Department, again leading a number of programs on titanium PM. During his tenure, he was the chairman of the World Titanium Conference held in San Diego in 1992. He has more than 800 publications, in excess of 60 patents, and has edited almost 30 books – the majority on various aspects of titanium. Recent publications include a comprehensive review of titanium PM and an article on titanium additive manufacturing. Since the early 1980s, he has taught the ASM International course on “Titanium and Its Alloys.” He has organized more than 10 symposia on various of Titanium Science and Technology, including in recent years co-sponsored four TMS Symposia on Cost Effective Titanium (which included a large number of papers on Titanium PM). He is a Fellow of ASM and a member of the Russian Academy of Science, and he was awarded the Service to Powder Metallurgy by the Metal Powder Association.

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Contract Manufacturer Praxis Utilizes ‘Proprietary Process’ to Produce Titanium Metal Injection Molded Implant Parts

By Michael C. Gabriele

In recent years, 3D/additive manufacturing has received considerable attention (and investment dollars) in the titanium industry to establish itself as production technology of choice to create a spectrum of parts—from aerospace components to medical implants. But when it comes to designing and producing medical implants, Praxis Technology, a Tier 1 contract manufacturer, is touting an alternative approach: titanium metal injection molding.

Metal injection molding has been around for decades and is viewed as a mature manufacturing technology. However, Praxis officials say they take pride in the expertise the company has developed in titanium powder processing, which they acknowledge as one of the most difficult materials to handle via metal injection molding.

“Processing titanium requires and in-depth understanding of reactive metals, from a safety perspective through thermal processing,”

Jobe Piemme, vice president, business development, for Queensbury, NY-based Praxis Technology, explained. “The ‘Praxis Proprietary Process’ is a bundle of technical details learned over years of development to provide the most robust titanium metal injection molding process; details range from powder handling through the sintering process. The end benefit of the Praxis Proprietary Process is eliminating risks associated for customers evaluating new

technologies for implantable components, increasing value of existing and new devices, all of which ultimately leads to customer satisfaction.”

Praxis’ titanium metal injection molding works best for long-term medical implants and certain instrumentation—most popular components are within the orthopaedic and extremity sectors, while other applications include dental, vascular access and cardiac

Information posted on the company’s website (www.praxisti.com) states that Praxis Powder Technology is an FDA-registered, ISO-13485-certified manufacturing company that produces titanium components via powder metallurgy for the medical, aerospace and firearms markets. Praxis specializes in porous titanium and titanium metal injection molding and has developed the “only known qualified” titanium metal injection molding process in the world. Re-



rhythm management/neuro-stimulation, according to Piemme. Annual volumes for these applications vary greatly based on the various product types, he pointed out. Last year Praxis submitted a “Device Master File” to the U.S. Food and Drug Administration (FDA) on Praxis’ metal injection molded Ti-6Al-4V material to support regulatory submissions of customers and reduce regulatory entry risks and product launch timelines.

garding this claim, Piemme said Praxis has spent years developing and qualifying the titanium metal injection molding process “to ensure the highest material quality prior to marketing the technology in the medical sector.”

The company says that a critical element that differentiates Praxis’ titanium metal injection molding process is that it’s statistically capable of producing high quality



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Contract Manufacturer Praxis Utilizes 'Proprietary Process' to Produce Titanium Metal Injection Molded Implant Parts *(continued)*

ASTM-compliant material properties. The company states it has developed the Praxis Proprietary Process to provide high performance titanium parts for a variety of demanding applications while satisfying stringent regulatory requirements.

The company outlined the basic steps in the titanium metal injection molding process, saying that fine titanium powder and thermoplastic binders are combined at precise levels. The materials are mixed together and heated to allow the metal powders to disperse within the melted binders. The mixture is then pelletized to form a feedstock suitable for injection molding. Metal injection molding, like plastic injection molding, uses a conventional injection molding machine to form a molded part. Feedstock is fed from a hopper into a heated barrel where the feedstock is melted. Once the feedstock is molten, it's injected into a mold to form the desired part geometry. Once the part is cool, it's ejected and ready for debinding. At this point, the molded part is referred to as a "green part."

The debinding process for the "green" molded component removes a portion of the binder components. The remaining binder will remain in place to hold the part together during the first stage of sintering. Debinding can be carried out in multiple ways; the most common methods are solvent extraction or catalytic decomposition. After debinding, parts are placed on ceramic setters and loaded into a furnace for high-temperature processing. During the early stage of sintering, the remaining binder is thermally decomposed. After this initial stage, the parts are heated to where densification occurs, resulting in significant shrinkage of up to 15 percent.

The resulting solid component is nearly 100-percent dense and identical in chemistry to conventional titanium. To achieve full density and control porosity, the component may be hot isostatically pressed (HIPed). Secondary finishing options can include CNC machining, anodizing, passivation, surface finishing, and laser marking.

As for specifics of the Praxis titanium

sistency. Praxis has two facilities in upstate New York where it houses its production and research and development operations. Moving forward, he said technology licensing of the process "may be an option in the context of the right collaborative effort."

Praxis chose Ti-6Al-4V based on customer needs and high demand, as this workhorse alloy dominates the medical market as the

material of choice for most implant applications, Piemme said. Praxis Ti-6Al-4V material meets the stringent requirements of ASTM F2885 (specification for metal injection molding). Ti-6Al-4V is often evaluated and qualified to replace existing CNC machined components made from Ti-6Al-4V ELI (extra-low interstitials). Praxis officials say titanium metal injection molding can produce parts as thin as 0.04 inch and as thick as 0.5 inch, with weights ranging from 0.02 to 150 grams. The company says titanium metal injection molding provides the flexibility to design complex parts that incorporate features such as ribs, bosses, grooves and threads.

Speaking from the perspective of a contract manufacturer, Piemme observed that original equipment manufacturers in the medical sector face two main challenges: reducing manufacturing costs to maintain profitable growth; and achieving market share expansion into emerging markets. "These challenges require innovative solutions which Praxis' titanium metal injection molding can support

and resolve," he said. "Not only does the technology utilize materials more efficiently, it also offers design enhancements at no additional cost and in some cases can further reduce component costs."



metal injection molding process, Piemme declined to provide details on annual output of medical implants, powder metal suppliers, the thermoplastic binder used, and mold builders. He did note that Praxis does its own in-house compounding of metal and polymer and uses all electric injection molding machines to maximize part con-



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TITANIUM USA 2017 Conference in Florida to Feature “Ti in Medical Technology” Speaker Session

By Michael C. Gabriele

The ever-expanding use of titanium in the medical industry will be a topic among the featured speaker panel sessions at TITANIUM USA 2017, the 33rd annual conference and exhibition sponsored by the International Titanium Association (ITA), based just outside of Denver, Colorado USA. The conference will be held October 8-11th at the Diplomat Resort and Spa in Hollywood, Florida USA, with the medical technology session slated for the afternoon of Monday, October 9th.

“The Global Orthopedic Industry: A High Altitude View,” will be the title of a presentation by Don Urbanowicz, principal at Urbanowicz Consulting LLC, Chatham, NJ. Urbanowicz will examine the global orthopedic industry, including the opportunities and issues expected to be encountered over the next five years. The talk will include an overview of worldwide market growth and competition, along with a discussion of the resultant impact of post-recession, post-reform and the current FDA climate on medical device companies (and each of their key departments, including marketing, product development, regulatory, reimbursement, operations and quality), hospitals, surgeons, patients and payers.

Urbanowicz Consulting (website: <http://urbanowiczconsulting.com>) is a medical device advisory firm with a musculoskeletal focus, seeking to enable prospective clients to achieve their strategic and transaction-related goals by capitalizing on market opportunities. Don Urbanowicz has 30 years of experience in the healthcare industry. He has held senior management/leadership positions at Stryker, Smith & Nephew, Sofamor Danek and Aircast.

Dr. Prabhu Gubbi, research manager, Zimmer Biomet, Warsaw, IN, will discuss “The Role of Titanium in Implant Dentistry.” Titanium implants are used to mimic the functionality of a natural tooth root by acting as an anchor, as well as to provide feature(s) to support for a prosthetic connection. Although various metals have been utilized for

dental implants such as stainless steel, and cobalt alloys, titanium and its alloys are still the most widely used materials in dentistry. While Ti-6Al-4V alloy is considered to be one of the most favored metallic materials for biomedical applications, commercially pure titanium often is preferred over the titanium alloy counterparts for endosseous dental implant applications, according to Gubbi.

The surface characteristics of an endosseous dental implant play a substantial role in the osseointegration phenomenon through contact osteogenesis. In particular, engineered surfaces of specific chemistries, geometries, and topographies have been theorized to influence osteoconduction mechanisms such as protein absorption, clot retention and platelet interactions. Gubbi will explain that by influencing this cascade of events, the rate and extent of bone formation may be accelerated resulting in reduction in the healing time for osseointegration.

Zimmer Biomet (website: www.zimmerbiomet.com) develops implantable devices, components, and associated surgical techniques, and provides expert services in the selection of optimal materials, characterization of materials behavior, failure analysis, formal mechanical testing of materials for medical device and other applications, and biocompatibility assessments.

“Opportunities for Materials Innovation in Orthopedics” is the title of a presentation by Dean Hutchinson, product manager/shoulder arthroplasty team, Arthrex Inc. Hutchinson will point out that there are several ways for materials research to benefit the orthopedic industry. While overall cost of treating patients continues to be a challenge, Hutchinson will explain that there are opportunities for raw material providers to create value by lowering overall patient treatment cost. “Challenges with infections and nickel allergies are real clinical problems that could be solved with innovative materials, and would demand an up charge for the devices,” he states, accord-

ing to an abstract of his presentation. He will discuss the economics of patient care in an attempt to frame market potential for the titanium industry. In addition, research and innovation should continue to push titanium forward for bony in-growth properties.

Based in Naples, Florida, Arthrex (website: www.arthrex.com) is a global medical device company focusing on new product development and medical education in orthopedics. Working with surgeons, Arthrex has pioneered the field of arthroscopy and developed more than 11,000 innovative products and surgical procedures to advance minimally invasive orthopedics worldwide. The company has developed a comprehensive line of products to address the challenges of shoulder arthroplasty.

Gene Kulesha, medical device/additive manufacturing technology leader at Stryker Corp., Kalamazoo, MI, will review “Additive Manufacturing of Medical Implants.” Additive manufacturing/3D printing, in recent years, has emerged as a hot-button topic of interest in all titanium markets. Stryker uses additive manufacturing technology to develop medical devices and tools, and recently announced the expansion of its 3D printing capabilities by developing a new, multi-million-dollar facility. In addition, Stryker has pioneered innovations in spinal surgical implants in fields like orthopedics, neurosurgery and general surgery.

Stryker (website: <http://www.stryker.com/en-us/index.htm>) recently unveiled a 3D printed “Tritanium” posterior lumbar cage spinal implant, which is porous and resembles bone tissue. (Tritanium is the brand name of Stryker’s alloy material, used in their powder bed laser sintering process.)

In addition to the Ti in Medical Technology session, ITA will host a new series of “Tech Talks” in the exhibition hall each afternoon. Fort Wayne Metals, Fort Wayne, IN (website: <http://www.fwmetals.com>), will host one Tech Talk related to medical applications. Shawn Chaney, business

TITANIUM USA 2017 Conference in Florida to Feature “Ti in Medical Technology” Speaker Session

(continued)

development manager, Fort Wayne Metals Research Corp., will share his thoughts on “Nitinol Shape Memory Alloys: Advantages of Utilizing these Unique Alloys and their Applications.”

Nitinol is a binary alloy with approximately equal parts of nickel and titanium, offering mechanical properties like no other metal. It is used in medical devices such as orthopedic implants, orthodontics, and cardiovascular stents. Because of Nitinol’s unique properties such as shape memory, super-elasticity, corrosion resistance, and the ability to be controlled via temperature, it has many advantages in various applications in the medical device, automotive, industrial, and aerospace markets. Chaney’s presentation will discuss the various Nitinol alloys, the unique properties of each and how they compare to other metals, applications for use, and their advantages.

Chaney, who joined Fort Wayne Metals in 2002, is responsible for new product development in the area of nickel-titanium alloys and applications and has authored or co-authored numerous technical papers/articles on metals and metals testing as well as presented at various technical conferences.

The annual TITANIUM conferences offer insights into the current state of the titanium industry, as well as provide high-value networking opportunities for titanium producers, original equipment manufacturers, distributors, fabricators, metallurgists, engineers and designers, and vendors who offer products and services to the global titanium community. To register for TITANIUM 2017, visit the ITA website (www.titanium.org) or contact the ITA at 1-303-404-2221.



Don Urbanowicz
Principal
Urbanowicz Consulting, LLC



Dr. Prabhu Gubbi
Research Manager
Zimmer Biomet



Dean Hutchinson
Product Manager
Shoulder Arthroplasty Team – Arthrex



Gene Kulesha
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Business Development Manager
Fort Wayne Metals Research Corp.

TITANIUM EUROPE 2017 Highlights Medical Content of Featured Academic Poster Sessions

By Michael C. Gabriele

Mohammed Shbeh
Inspired by 'His Mum,' UK Student
Researches Bio-Active Titanium
Foams for Dental Implants. This poster can
be seen on the next page.

A poster session technical paper by Mohammed Menhal Shbeh, University of Sheffield, South Yorkshire, England, presented at the TITANIUM EUROPE 2017 conference and exhibition in Amsterdam, the Netherlands, provided information on his research involving "Surface Modified Titanium Foams for Biomedical Applications."

Prior to his arrival at the University of Sheffield, Shbeh earned his MSc (Master of Science) degree from the University of Newcastle, UK in the field of Materials Design and Engineering, and worked in charge of the particle analysis lab for International Innovative Technologies Ltd. UK. He joined the University of Sheffield to take part in doctoral research under supervision of Dr. Russell Goodall. His research interests cover wide aspects of materials and he is currently working in the field of porous titanium and its use in different areas, including for biomedical applications.

The following is an abstract from a Shbeh's technical paper:

Every year, hundreds of thousands of people in the UK endure tooth loss. This problem is becoming more serious than ever, especially with increased life expectancy and poor nutrition. According to the World health organization, 30 percent of people aged 65–74 have no natural teeth. Titanium dental implants are currently a popular choice for replacing missing teeth.

However, there are several issues associated with titanium dental implants, such as the high cost and the stress shielding phenomenon as well as the bio-inertness of titanium (where bio-active behavior would be preferred). The cost of these implants is still high and they are not universally affordable, and stress shielding (resulting from the non-uniform transfer of load between the

implant and the dental tissue or bone) is one of the main reasons for implant failure.

The inhomogeneity in load transfer occurs due to the large difference between the Young's moduli of the titanium implant and the tissue or the bone. In addition, titanium is bio-inert material which results in poor bone cell adhesion to the implant compared to bio-active materials such as hydroxyapatite.

Solving the aforementioned issues can be approached by developing novel titanium implants using cost effective manufacturing techniques with porous bioinspired structure that replicate the natural structure of the bone for better mechanical fixation and a biologically active surface for improved chemical integration.

The main objective of our study is to produce biologically active novel titanium foams with a structure that mimics the structure of the bone in having a compact outer layer for increased strength and structural integrity with inner spongy layer composed of micro and macro porous channels, which will enable bone ingrowth and nutrient exchange as well as cell migration and attachment.

Interviewed prior to the Amsterdam conference, Shbeh explained that the starting material used in his research is a relatively coarse commercially pure titanium powder. "I decided to use it as a starting material in order to reduce shrinkage and the extent of contamination, as well as lower the cost. This will not only be more economical, but can also result in more intentionally induced micropores. Using Ti-6Al-4V alloy powder ought to work just as well, and would yield foams with better mechanical properties, but we have not tried it yet"

Shbeh said the program utilizes metal injection molding (MIM) as the manufacturing process to produce the bio-active titanium foams for tooth implants. MIM creates the titanium foams, with the incorporation of particles that act as pore formers with

the feedstock; these are removed at a later stage in the manufacturing process using ultrasonic water debinding. "Depending on the amount of porosity needed in the foams and their final application, the size and amount of these pore formers can be adjusted," Shbeh said. "These pore formers dissolve in water leaving behind a network of open pores. The parts are then sintered to generate bonds between the titanium particles and to give mechanical strength to the porous structure. The foams produced have a structure that mimics that of the bone in having a compact outer layer with an inner spongy layer composed of micro and macro porous channels. The advantages of these are that the first gives increased strength and structural integrity, and the latter will enable bone ingrowth, nutrient exchange as well as cell migration and attachment."

The process achieves "bio-active" properties for the dental implants (in contrast to titanium's familiar bio inert characteristics) by modifying the titanium foams via a process called Plasma Electrolytic Oxidation (PEO), according to Shbeh. "This treatment yields a thick, rough, biologically active ceramic surface coating with a thickness of around 55 μm , which extends into the inner structure of the foam through the macropores which are connected to the surface." He said the porous foams help avoiding stress shielding (where the implant carries all of the load and the bone around it degrades) and promotes bone ingrowth inside the macropores, and aids chemical integration at the same time throughout the interconnected network of ceramic coating.

Regarding the status and commercial feasibility of the research, Shbeh said the program aims at understanding these materials from a scientific standpoint, and has not been directly collaborative with implant manufacturers. "While we have thus not looked at commercial feasibility for specific parts in detail, we are currently working on a number of demonstrators with potential company partners."

Biocompatibility Evaluation of Extra Low Modulus Ti-39Nb-6Zr Alloy

Y. J. Hwang, Y. S. Choi and D. G. Lee*

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1. Abstract

- ✓ Titanium and Titanium alloys have excellent biocompatibility, low amount of ion elution in human body and high specific strength
- ✓ Biocompatibility must be met for metals to be used as biomaterials
- ✓ Ti-39Nb-6Zr alloy (TNZ40) consisted of bio-compatible alloying element as Titanium, Niobium and Zirconium
- ✓ in-vitro / in-vivo tests were performed to determine the biocompatibility of Ti-39Nb-6Zr with below 50 GPa elastic modulus
- ✓ Patents (KOREA patent no. : 10-0971649, 10-0959197, JAPAN patent no. : 5204301, European patent no. : 08874499.0)

→ very bio-compatible

2. Experimental Conditions

✓ in-vitro

- degree of proliferation of the cells

By cultured MG-63 cell in incubator (37 °C, 5% CO₂) during 72hr
(used materials : Ti-39Nb-6Zr, Ti-39Nb-6Zr + X (α-stabilizer))

- cell toxicity

By measuring the RGR values, to determined grade
(used materials : Ti-39Nb-6Zr, CP Ti, Ti-6Al-4V)

✓ in-vivo

Insert small specimen into abdominal subcutaneous tissue of ICR-mouse during 4 weeks

(used materials : Ti-39Nb-6Zr, Ti-39Nb-6Zr + X (α-stabilizer))

3. Results I : in-vitro (proliferation)

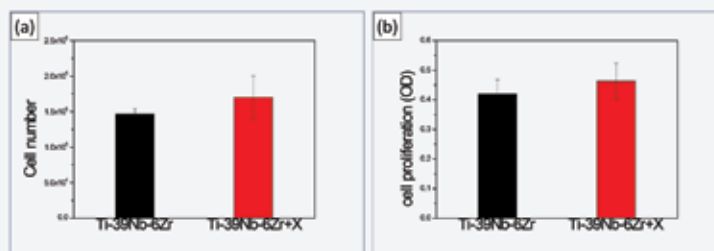


Figure 1. Graph of cell proliferation tests (a) cell number, and (b) cell proliferation after 72 hours

- ✓ The cell proliferation of Ti-39Nb-6Zr is similar to contrast sample
- ✓ According to the reference, the cell proliferation of Ti-39Nb-6Zr is similar to CP Ti (J. Biomater. Tissue Eng., Volume 6, Number 10, October 2016, pp. 798-801(4))

4. Results II : in-vitro (toxicity)

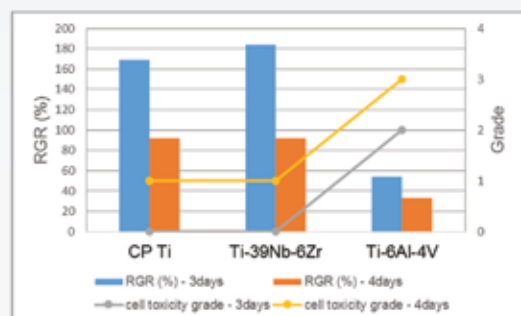


Figure 2. Graph of toxicity for CP Ti, Ti-39Nb-6Zr, Ti-6Al-4V

- ✓ Ti-39Nb-6Zr showed non-toxicity which was better than Ti-6Al-4V and comparable to pure titanium

6. Conclusions

- ✓ Ti-39Nb-6Zr alloy was consisting of bio-compatible alloying element except toxic alloying elements
- ✓ cell proliferation was sound, which was comparable to pure titanium
- ✓ Ti-39Nb-6Zr alloy was non-toxicity
- ✓ Tissue denaturation reaction (hemorrhage, necrosis, discolor etc.) was not observed around inserted Ti-39Nb-6Zr sample
- ✓ Through this study, we found out biocompatibility of Ti-39Nb-6Zr

5. Results III: in-vivo

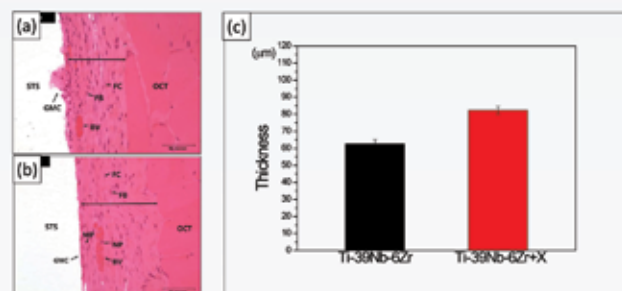


Fig3. Photomicrographs of cells around inserted Titanium specimen (a) Ti-39Nb-6Zr, (b) Ti-39Nb-6Zr+X; BV: blood vessel, FB: fibroblast, FC: fibrocyte, GMC: giant multi nucleated cell, STS: space formerly occupied by the specimen, OCT: old connective tissue, MP: macrophage, NP: neutrophil, and (c) the graph of new fibrous tissue's thickness around inserted Titanium specimen

- ✓ Some of the cells were generated around the specimen
- ✓ New fibrous tissue thickness of Ti-39Nb-6Zr was thinner than contrast sample, but both are similar sound biocompatibility
- ✓ Tissue denaturation reaction (hemorrhage, necrosis, discolor etc.) was not observed

7. Application



(continued)

As for potential applications for the bio-active titanium foam technology other than medical implants, he said it would be possible to use the technology to process different medical implants “as long as they are small to medium sized parts (a limitation in size which comes from the MIM process). Even this can be overcome through the use of additive manufacturing and coating the porous parts.” So far, unpublished research trials of such a method show promising results, he added.

Shbeh revealed that “his mum” is inspiration for his research on titanium for dental implants, “as she has a limited number of teeth to eat on and she gets hurt when she eats something not easy to chew. Dental implants are expensive and still not universally affordable.” He anticipates finishing his doctoral degree at the University of Sheffield in December 2017. “I love doing research and my dream is to find a university research or industrial research and development position on titanium.”

Dr. Goodall focuses on the field of metallurgy research at the University of Sheffield, UK. His main interests are in the processing, properties and applications of open-celled porous metals, the development of new alloys, especially novel alloy types, such as high-entropy Alloys. Another advisor to Shbeh is Dr. Aleksey Yerokhin, a senior research fellow in the School of Materials at the University of Manchester, UK.

Yu Jin Hwang

New Alloy for Biocompatibility. To view this poster, please visit the ITA Website at www.titanium.org under menu item Events >>> Historical Conference Proceedings.

Yu-Jin Hwang, a graduate student at Sunchon National University, South Korea, presented a poster session technical paper at TITANIUM EUROPE 2017 held in Amsterdam, the Netherlands. As spelled out in her poster-session paper, Hwang’s research deals with the biological properties of optimized titanium alloys used for medical implants.

Professor Dong-Geun Lee serves as Hwang’s advisor in this research. According to an abstract provided by Hwang, the

aim of her study is to optimize the micro-structure and mechanical properties of Ti-39Nb-6Zr (TNZ40) for medical implant applications. “TNZ40 was designed to have a low elastic modulus (~40 GPa) and good biocompatibility,” Hwang stated in her abstract. “However, the alloy shows relatively low strength compared to other titanium alloys for bio-implant. In the present study, we tried to obtain the proper combination of elastic modulus and strength by tailoring the direct aging conditions after severe plastic deformation.”

The following text is a condensed, edited version of two technical papers, published in 2016, which reflect Hwang’s research at Sunchon National University.

Titanium and titanium alloys have excellent biocompatibility, a low amount of ion elution in the body, high specific strength and corrosion-resistance, so they take center stage for good biomaterials. In particular, a β -type titanium alloy has low elastic modulus similar to human bone’s elastic modulus (10~30 GPa), and can be improved mechanical, thermal properties by excellent heat treatment characteristics. Hence, the orthopedic application market is increasing for the artificial hip joint, bone fixation devices, which require high strength due to high stress and loading.

Ti-39Nb-6Zr (TNZ40) alloy used in this study consists of only biocompatible elements such as niobium (Nb) and zirconium (Zr). It has low Young’s modulus about 40 GPa and shows non-toxicity. Various in-vitro and in-vivo tests (essential steps in the clinical trial) are performed for biocompatibility to evaluate whether the cells grow well on the surface of the alloy implant and whether this alloy causes any problems when it is inserted in the body.

Consequently, in cell proliferation in-vitro test, the degree of proliferation of the cells was measured by a direct method (cell counting) and an indirect method (optical density measurement). Both results by these methods showed the sound cell proliferation around the implant. When the implant specimens were inserted into the body for in-vivo test, some of the cells that produce such inflammations as giant multi-nucleated cells

and neutrophils (a type of white blood cells) also were generated around the specimen. However, it was not in the range of the level to cause the problems, and tissue denaturation reaction such as hemorrhage, necrosis, and discoloring, were not observed. This means that Ti-39Nb-6Zr alloy is highly biocompatible for the body.

Commercially pure (CP) titanium and Ti-6Al-4V are used widely for biomedical applications owing to their good biocompatibility and high specific strength. Bone implants can be replaced with metal, particularly beta titanium alloys. Titanium alloys are used widely as biomedical materials owing to their corrosion resistance, light weight, and excellent bio-compatibility.

Several elements commonly used in conventional Ti-6Al-4V alloys, such as aluminum and vanadium, are biologically harmful elements to the human body. Conventional titanium alloys have a much higher elastic modulus than human bone. Large modulus mismatch between high modulus implant materials ($E = 110\sim120$ GPa) and low modulus bone causes stress-shielding effects, through which tissue loss and implant failure can occur.

To solve these problems, a new Ti-39Nb-6Zr alloy was developed and bio-activity/corrosion/cell toxicity tests were conducted to evaluate its biological properties. The Ti-39Nb-6Zr alloy exhibited a very low elastic modulus (<60 GPa) compared to conventional biomedical titanium alloys, and can reduce the stress-shielding effects significantly. The bio-compatibility of the developed Ti-39Nb-6Zr alloy was much better than Ti-6Al-4V and comparable to CP Ti.

While this titanium alloy is not yet being sold as a commercial product for medical implant applications, Hwang said that Osstem Implant Co. Ltd. of South Korea—a producer of dental implants—along with other companies, have been actively involved in product development efforts. Hwang is expecting to earn her master’s degree in February 2018, and has hopes to continue her education with a doctoral degree program.



Ulbrich Stainless Steels & Special Metals, Inc. Leads Innovation in Titanium Foil

Ulbrich Stainless Steels & Special Metals, Inc. continues to provide titanium UltraLite Foil® as thin as .0125 mm (.0005") for the most demanding applications.

Since Ulbrich's expansion into UltraLite Foil® in 2006, the company has supplied titanium and titanium alloy foil for critical markets including medical, aerospace, chemical processing and power generation. Ulbrich offers continuous coil up to 300mm wide with exacting tempers ranging from annealed to full hard.

With more than 12,000 sq. ft. of dedicated space for its UltraLite Foil® program, production consists of rolling, tension annealing, slitting and packing. Ulbrich's commitment to continuous improvement has led the quality department to achieve and maintain the following certifications: ISO 9001, ISO 17025, NADCAP, GEAE, Rolls Royce, LCS and A2LA. Thanks to the exceptional

development and supply chain partnership capabilities, coupled with the experienced product managers and metallurgists on staff, Ulbrich is able to meet specific customer requirements.

Ulbrich Stainless Steels & Special Metals, Inc., headquartered in North Haven, Connecticut, is a 4th generation, family-owned precision re-roller and distributor of stainless steel and special metals strip, foil, shaped & fine wire, sheet, plate and bar products for use in the medical, automotive, nuclear and aerospace industries. Ulbrich offers twelve locations in five countries across North America, Europe and Asia, with additional sales representation world-wide.

For more information, please visit Ulbrich.com or contact us at 1-800-243-1676.



The NEW Mid-West Machine™ 6840T

Vulcan's new traveling grinder offers a larger work envelope as well as updated controls and hydraulics systems.

Vulcan Engineering Co. introduces its newest addition to the Mid-West Machine™ line of Metal Conditioning Equipment with the 6840T. This Traveling Grinder incorporates a longer boom, providing a larger work envelope to process material within 68 inches (1725 mm) horizontal, 40 inches (1015 mm) vertical reach.

Mid-West Machine™ Grinders are designed to work effectively in rugged, dirty environments. Engineered for maximum up time with the highest quality components and innovative designs that are assembled and arranged for easy service. The primary purpose of these machines is for conditioning of Steel Alloys and Titanium in a variation of sizes and shapes such as rounds, slabs, blooms, octagons, and squares.

Working with a current owner of Mid-West Machine™ Traveling Grinders, Vulcan was tasked with providing a Traveling Grinder Solution to condition slabs up to 66 inches (1675 mm) wide. Vulcan met the challenge of designing a new machine that handles a larger work envelope while maintaining the long lasting, reliable equipment that Mid-West Machine™ users expect. The customers needed a solution that could meet the new production requirements they obtained as well as process wider material. In order to offer a machine that was comparable to the grinders they have been using for many years, our team created an innovative design similar to the dependable 6040T. Thus, the 6840T was created.

While it is based on a machine that has been built for years, the Mid-West Machine™ 6840T Traveling Grinder also incorporates several updates to further improve safety, commonality of parts with other models, ease of

operation, to provide greater operator comfort, increase productivity, and to lower maintenance costs. Additionally, the new operator cab is much quieter than previous models by integrating thicker insulation. The cab also contains updated intuitive controls.

Optional additions are available such as Load/Unload Tables, Round Rotators, Slab and Square Billet Manipulators, and an updated Swarfbooth System. The newly redesigned Swarfbooth System provides updated controls to synchronize the movement of the swarfbooth with the grinding machine. By updating the hydraulic drives and incorporating a linear transducer, this allows the Swarfbooth to maintain position with the Traveling Grinder. Now, the Swarfbooth mirrors the movements of the traveling grinder allowing for more efficient swarf collection.

The 6840T offers the same long lasting, dependable design that Mid-West Machine™ users are accustomed to, while providing more reach, new controls, updated hydraulics, and increased productivity compared to older machines. Depending on your needs, it is available with either a dead shaft or live shaft spindle. Please visit our website for more information on all Mid-West Machine™ equipment, or contact us today and get more specifications on how the 6840T could benefit your operation.

Vulcan Engineering Co. | Mid-West Machine™
1 Vulcan Drive, Helena, AL 35080 | 205-663-0732
sales@vulcangroup.com | www.vulcangroup.com

Carpenter Technology to Acquire Assets of Puris LLC Provides Immediate Entry into Rapidly Growing Titanium Powders Market Advances Position in Additive Manufacturing Strengthens Core Capabilities as a Solutions Provider

PHILADELPHIA, Feb. 02, 2017 (GLOBE NEWSWIRE) -- Carpenter Technology Corporation (NYSE:CRS) today announced the execution of a definitive asset purchase agreement for the purchase of substantially all of the assets and business of Puris LLC ("Puris"), a producer of titanium powder for additive manufacturing and advanced technology applications, for \$35 million. The assets and business to be acquired include Puris' titanium powder operations and business, additive manufacturing assets, patents and related intellectual property.

"This acquisition will provide Carpenter with immediate entry into the rapidly expanding titanium powder market and is consistent with our strategic focus on strengthening our leadership position in important growth areas," said Tony Thene, Carpenter's President & CEO. "Puris brings industry leading technology and processes for the production of titanium powder, additive manufacturing part production capabilities, a talented team, attractive intellectual property, and established customer relationships. The strengths of Puris, coupled with Carpenter's reputation as an industry leading producer of premium alloys and our global commercial reach, will allow us to further deliver on the growing needs of our customers."

As a result of the transaction, Carpenter will enter the titanium powder market significantly earlier than previously planned and will reduce its planned fiscal year 2017 capital expenditures by approximately \$20 million.

Operations will continue at the existing site which is well positioned for future expansion and will operate as a functional unit of Carpenter Powder Products, complementing Carpenter's existing broad portfolio of well-established powder metallurgy offerings.

Stephen Peskosky, Vice President of Corporate Development at Carpenter stated, "The addition of titanium powder to Carpenter's existing capabilities is significant due to the current and anticipated demand increases from the additive manufacturing industry, which produces mission critical parts supplied to Aerospace and Medical markets, as well as other markets. As we continue to differentiate Carpenter as a solutions provider and market focused company, we believe the expansion of our powder and additive manufacturing capabilities further enhances the value we provide our customers and further expands our long-term growth profile."

Puris is based in Bruceton Mills, WV and is a leading producer of titanium powder for additive manufacturing and other applications. The Puris team includes pioneers in the evolution of spherical titanium powder atomization and utilizes world-leading technology and processes for producing titanium and other pre-alloyed powders of the highest integrity. In addition, the flexibility of Puris' production capacity and process enables fulfillment of both high volume demands, as well as custom lots. Since its founding in 2014, Puris has successfully built leading capabilities, established advanced technology procedures, and earned valuable quality approvals and accreditations.

The transaction is subject to customary closing conditions and closing is expected to occur during the quarter ended March 31, 2017.

About Carpenter Technology

Carpenter Technology Corporation is a leading producer and distributor of premium specialty alloys, including titanium alloys, nickel and cobalt based superalloys, stainless steels, alloy steels and tool steels. Carpenter's high-performance materials and advanced process solutions are an integral part of critical applications used within the aerospace, transportation, medical and energy markets, among other markets. Building on its history of innovation, Carpenter's powder technology capabilities support a range of next-generation products and manufacturing techniques, including additive manufacturing and 3D Printing. Information about Carpenter can be found at www.cartech.com.

Forward-Looking Statements

This presentation contains forward-looking statements within the meaning of the Private Securities Litigation Act of 1995. These forward-looking statements are subject to risks and uncertainties that could cause actual results to differ from those projected, anticipated or implied. The most significant of these uncertainties are described in Carpenter's filings with the Securities and Exchange Commission, including its annual report on Form 10-K for the year ended June 30, 2016, Form 10-Q for the quarter ended September 30, 2016 and the exhibits attached to those filings. They include but are not limited to: (1) the cyclical nature of the specialty materials business and certain end-use markets, including aerospace, defense, industrial, transportation, consumer, medical and energy, or other influences on Carpenter's business such as new competitors, the consolidation of competitors,

Carpenter Technology to Acquire Assets of Puris LLC (Continued)

customers and suppliers, or the transfer of manufacturing capacity from the United States to foreign countries; (2) the ability of Carpenter to achieve cash generation, growth, earnings, profitability, operating income, cost savings and reductions, qualifications, productivity improvements or process changes; (3) the ability to recoup increases in the cost of energy, raw materials, freight or other factors; (4) domestic and foreign excess manufacturing capacity for certain metals; (5) fluctuations in currency exchange rates; (6) the degree of success of government trade actions; (7) the valuation of the assets and liabilities in Carpenter's pension trusts and the accounting for pension plans; (8) possible labor disputes or work stoppages; (9) the potential that our customers may substitute alternate materials or adopt different manufacturing practices that replace or limit the suitability of our products; (10) the ability to successfully acquire and integrate acquisitions; (11) the availability of credit facilities to Carpenter, its customers or other members of the supply chain; (12) the ability to obtain energy or raw materials, especially from suppliers located in countries that may be subject to unstable political or economic

conditions; (13) Carpenter's manufacturing processes are dependent upon highly specialized equipment located primarily in facilities in Reading and Latrobe, Pennsylvania and Athens, Alabama for which there may be limited alternatives if there are significant equipment failures or a catastrophic event; (14) the ability to hire and retain key personnel, including members of the executive management team, management, metallurgists and other skilled personnel; (15) fluctuations in oil and gas prices and production; and (16) the success of actions taken to reduce costs associated with retirement and pension plans. Any of these factors could have an adverse and/or fluctuating effect on Carpenter's results of operations. The forward-looking statements in this document are intended to be subject to the safe harbor protection provided by Section 27A of the Securities Act of 1933, as amended (the "Securities Act"), and Section 21E of the Securities Exchange Act of 1934, as amended. Carpenter undertakes no obligation to update or revise any forward-looking statements.



TITAN Metal Fabricators Closes on Acquisition of Edge International

CAMARILLO, CA, April 3, 2017 / TITAN Metal Fabricators today announced that it has closed on the acquisition of selected assets of Edge International, a leading stocking distributor of medical grade raw materials used in the manufacture of implants and instruments for the orthopedic, spine, and trauma markets.

The addition expands and diversifies TITAN's portfolio with a complementary business model similar to Supra Alloys, a division of TITAN Metal Fabricators, adding a strategic warehouse location in Dayton, Ohio to more effectively support the Midwest and East Coast customer base. Edge International will continue to operate as a separate brand and with its current team of employees under the guidance of its President, Stephen R. Smith.

Steve Muscarella, President of TITAN commented, "Edge International is well-positioned in the medical market

with a strong brand, a loyal customer base, and has a significant opportunity to benefit from taking on some of the additional products and services already being offered by Supra Alloys. We look forward to serving Edge International's customers by bringing them the years of knowledge and expertise of TITAN's operations staff and engineers. We also see the opportunity for Supra to learn from Edge's extensive experience in the distribution of Cobalt Alloys and Stainless Steels in the medical industry."

Stephen Smith added, "We believe this new partnership will strengthen our existing product offerings and enable us to drive improved performance, resulting in greater market share in the distribution of medical grade raw materials. Edge International has always been a successful business,

HAYNES

International

HAYNES INTERNATIONAL, INC. ANNOUNCES ELECTION OF NEW MEMBER OF BOARD OF DIRECTORS

KOKOMO, IN, July 5, 2017 – Haynes International, Inc. (NASDAQ GM: HAYN), a leading developer, manufacturer and marketer of technologically advanced high-performance alloys (the “Company”), announced today that, effective as of July 1, 2017, the Board of Directors of the Company voted to elect Dawne S. Hickton as a new member of the Board of Directors.

Ms. Hickton is President and Founding Partner of Cumberland Highstreet Partners, Inc., a specialty metals consulting firm. She previously served as Vice Chairman, President and Chief Executive Officer of RTI International Metals, Inc. from 2007 until its sale to Alcoa Corporation in 2015. She is also a member of the board of the Federal Reserve Bank of Cleveland, the University of Pittsburgh board of trustees, the board of the International Titanium Association, where she founded Women in Titanium, and the board of the Smithsonian National Air & Space Museum. “Dawne’s leadership experience in specialty metals as well as her knowledge of our key markets will be a great benefit to Haynes, and we are excited to have her joining us,” said Michael L. Shor, Chairman of the Board of Directors of the Company. Ms. Hickton is also a member of the boards of directors of Jacobs Engineering Group (NYSE: JEC), Triumph Group, Inc. (NYSE: TGI) and Norsk Titanium AS.

About Haynes International

Haynes International, Inc. is a leading developer, manufacturer and marketer of technologically advanced, nickel and cobalt-based high-performance alloys, primarily for use in the aerospace, chemical processing and land-based gas turbine industries.

Cautionary Note Regarding Forward-Looking Statements

This press release contains statements that constitute “forward-looking statements” within the meaning of the Private Securities Litigation Reform Act of 1995, Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934. All statements other than statements of historical fact, including statements regarding industry prospects and future results of operations or financial position, made in this press

release are forward-looking. In many cases, you can identify forward-looking statements by terminology, such as “may”, “should”, “expects”, “intends”, “plans”, “anticipates”, “believes”, “estimates”, “predicts”, “potential” or “continue” or the negative of such terms and other comparable terminology. Readers are cautioned that any such forward-looking statements are not guarantees of future performance and involve risks and uncertainties. Actual results may differ materially from those in the forward-looking statements as a result of various factors, many of which are beyond the Company’s control.

The Company has based these forward-looking statements on its current expectations and projections about future events. Although the Company believes that the assumptions on which the forward-looking statements contained herein are based are reasonable, any of those assumptions could prove to be inaccurate. As a result, the forward-looking statements based upon those assumptions also could be incorrect. Risks and uncertainties, some of which are discussed in Item 1A. of Part 1 to the Company’s Annual Report on Form 10-K for the fiscal year ended September 30, 2016, may affect the accuracy of forward-looking statements.

The Company undertakes no obligation to publicly update or revise any forward-looking statements, whether as a result of new information, future events or otherwise.

Retirement Announcement



Susan M. Abkowitz
General Manager
Powder Materials Operations

Susan M. Abkowitz has elected to retire after serving as General Manager of Powder Materials Operations for Arconic Manufacturing since 2015. During her 35-year career in metals, Susan has significantly advanced the use of titanium through research and development, product introduction and follow-on marketing. Her innovations expanded the use of titanium metal matrix composites in medical, industrial and commercial applications.

In recognition of her contributions, Susan has received:

- Distinguished Service to Powder Metallurgy Award in 2013 from the Metal Powder Industries Federation (MPIF)
- Titanium Applications Development Award in 2008 from International Titanium Association (ITA)
- Fellow of ASM International in October 2000 by ASM International

Susan had served as Chief Operating Officer of Dynamet Technology prior to its acquisition by RTI. She then served as Vice President of Technology and Operations prior to her current position. She is a co-holder of several patents related to titanium alloys and metal matrix composites, a member and committee member of several metals industry organizations, and a co-author of numerous technical papers.

She holds bachelor degrees from the University of Pennsylvania School of Engineering and Applied Science and its Wharton School of Business in materials science engineering, and economics and management, respectively.

Job Announcements and Anniversaries

- Kimberly Peko, Business Development Manager – Arconic
- John Barnes, Senior Advisor at 3D Veterans
- Ragesh Asokakumar 3 years at Travancore Titanium Products Ltd.
- Mike Fobar 2 years at Cadence Aerospace
- James Grant 36 years at DuPont
- Dirk Mansfeldt 9 years at Tirus International SA
- Steven D. Rebich 7 years at TIMET
- Jeff Sasek 9 years at Carpenter Technology Corporation
- Daniel Barber 12 years at The Perryman Company
- Vince Rocco 2 years at Ametek Reading Alloys
- Gregory M. Spalding 18 years at Haynes International (Haynes Wire Co.)
- Michael Green 1 year at Kropp Forge
- Michael John Judge 4 years at 5ME, LLC
- Leroy Wang 2 years at Hunan Goldsky Titanium Industry Technology Co., Ltd.
- Greg Davis, Director of Business Development – Vested Metals International, LLC

Women In Titanium Upcoming Events

September 6th

Invest Your Way to Financial Empowerment: What Every Woman Should Know TeleClass

October 8th

Professional Development Sponsored by WiT in conjunction with TITANIUM USA 2017 conference Hollywood, Florida

November 7th

How to Handle Criticism like a Pro TeleClass



Arcam Group provides cost-efficient Additive Manufacturing solutions for production of metal components. Arcam's Electron Beam Melting (EBM®) technology offers design freedom combined with excellent material properties and high productivity. Arcam provides Electron Beam Melting systems through Arcam EBM in Sweden, powder metals through AP&C in Canada and implant contract manufacturing through DiSanto in the U.S.



Busch Vacuum Pumps and Systems is one of the largest manufacturers of vacuum pumps, blowers, and compressors in the world. Our products are at the forefront of vacuum and low pressure technology.

The Busch product range offers the largest selection of industrial vacuum pumps available in the world today. We offer more than 50 years of experience and expertise in vacuum system manufacturing, and can provide customized solutions for a variety of vacuum applications.



Calvi Holding S.p.A. holds equity investments in several manufacturing companies with specific focus on metallurgy and mechanics. Since 2004, Calvi Holding S.p.A. has been committed to creating value based on a network model, which develops synergies to provide its clients with products and solutions that are increasingly innovative and competitive.



CUMBERLAND HIGHSTREET PARTNERS

Formed in London in 2016, Cumberland Highstreet Partners was created in response to the need for executive leaders to have access to a team of proven, experienced professionals who possess a deep domain knowledge of manufacturing. We bring accomplished and creative industry experts to the table who have personally led significant organizations. We are executives with proven track records of successfully navigating the ever-changing needs and requirements of industry.



Manufacturer of titanium exhaust systems. Every CMI header is built to exacting standards that have made them the number one choice for offshore racers and performance-oriented boaters who demand on-water performance. CMI headers are manufactured using state-of-the-art materials, like 316L and 317L stainless steel, offering superior corrosion resistance and durability. A unique, patented bending process assures uniform wall thickness and eliminates any rippling and crazing of the tubing during production. Semi-automated tungsten inert gas welding, plus heat treating of the complete manifold following assembly, significantly reduces internal stresses that commonly cause fatigue, corrosion and premature failure in most high performance applications. To complement its header systems, CMI also manufactures custom tailpipes, exhaust accessories and integral mufflers for virtually any single, dual, triple or quad engine configuration, including small block or big block applications, Chevrolet and Buick V-6s and Ford 460 and SVO's. With CMI, boaters get a combination of performance and reliability unparalleled by any competitive products on the market.



Exova Group plc is a leading provider of laboratory-based testing and related advisory services, operating primarily within the Testing segment of the Testing Inspection and Certification ("TIC") sector. Exova has been hired to do the autoclave work for the NACE MRO175 testing of Gr 12 project by the ITA Industrial committee.

By joining the ITA as a Vendor member Exova would become an active participant in the ITA committee dedicated to industrial applications.

Exova would also benefit from discounted registration at the annual events, would receive a complimentary company description in the membership directory and would be able to take advantage of a variety of other ITA membership benefits.



Baoji JHY Titanium Industry Co., Ltd was founded on 25-09-2002. It is a professional manufacturer for titanium and titanium alloy fasteners and machined products. We can produce them according to different standards, like GB, ISO, DIN, ANSI and JIS etc. They are widely used in petroleum, metallurgy, chemical, pharmacy, marine engineering, racing car, motorcycle, bicycle, yacht, outdoor camping and sports equipment.

Our company insist the "Quality First" strategy rather than "Low priced" one to earn trust from customers, which has been proved correct after 15 years in this industry. Now over 85% our products are exported to Japan, United States, United Kingdom, Germany, Netherlands and other European countries.



Jiangsu Tiangong Technology Company Ltd was founded in 1981, Our company started in 2012 to produce titanium products, including rods, tubes, plates, and wire materials. Products in full compliance with GB/T3621, ASTM B265, ASTM B338, ASTM B348 standard, related technical indicators have reached the advanced level in the industry, meeting the user's application requirement.

Products are widely used in the petrochemical, salt. Offshore industry, energy generation and other related industries, typical applications: Titanium and titanium alloy bar for hot-rolling; Medical devices; Titanium alloy standard parts; Various types of titanium equipment; Ion-exchange membrane, divide slot; Titanium and titanium alloys used in construction board.



K-TIG is a full-penetration welding technology designed to help fabricators to be more productive – by an order of magnitude.

K-TIG is a TIG/GTAW welding system capable of performing a traditional 6-hour TIG weld in 3 minutes, to a quality standard which meets the most demanding requirements of the nuclear, aerospace & defence industries.

洛阳核新钛业有限公司

Luoyang Hexin Titanium Industry Co.,Ltd.

Luoyang Hexin Titanium Industry Co., Ltd was founded in 2014. Our company produces titanium products since 2014, including rods, tubes, plates.

Products are widely used in petrochemical, salt. Offshore industry, energy generation and other industries. Typical applications include: Titanium and titanium alloy bar for hot-rolling; Titanium alloy standard parts; All kinds of corrosive fluid transmission pipeline system; Titanium bicycle tube; automobile exhaust pipe; Offshore aquaculture



Is a low-acid (pH 6.8), far safer etchant for titanium and other metals, with a less toxic waste stream, when compared with hydrofluoric and nitric acids.

Preparing titanium with Multi-Etch enables anodizers to produce brilliant colors and welders to achieve welds that can withstand the rigors of deep space and deep ocean uses.

Multi-Etch is also used to brighten titanium mill products and tumbled titanium parts, and to erase anodizing mistakes. Industries regularly using Multi-Etch include aerospace, medical, dental, marine, architectural, industrial, jewelry and other arts.



NobelClad is the world leader in the field of explosion welding. We have more than half a century of expertise, and we are the one company with the most global resources and infrastructure committed to clad, offering bi-metallic solutions for complex industrial markets, including oil and gas, chemical, and transportation. We work with global partners across the supply chain not only to deliver the highest-quality, most cost efficient clad materials on time, but to inform and help develop project specifications from the onset. Our design ingenuity, technical proficiency, and unparalleled dependability make us an invaluable resource for process architects, engineers, and fabricators alike. That's why our clad materials are the preferred specification for high stakes industrial infrastructure applications all over the world. Specialties: Explosion Welded Clad, Longitudinally Welded Pipe, Pressure Vessels, Heat Exchangers, Structural Transition Joints, Electrical Transition Joints, Cryogenic Transition Joints, Flat Plates & Cylinders, Heads, Tube Sheets.



Oerlikon is a leading global technology group providing market leading technologies and services. Oerlikon has more than 13,800 employees at over 180 locations in 37 countries and sales of CHF 2.331 billion in 2016. The group is structured in three Segments: Surface Solutions, Manmade Fibers and Drive Systems, each operating under their own well-established brands and with their own market-specific strategies. It has a long-standing presence in Asia, particularly in the emerging markets of China and India, a strong foundation in Europe and serves the most important markets in the Americas. In 2016, the group continued to invest over 4 % of its annual total sales in R&D, corresponding to CHF 94 million, and filed 67 patents worldwide.



Materials research conducted by iMatSE students and faculty lead to advances and discoveries that become the building blocks of tomorrow. Through formal coursework in small classes and participation in cutting-edge sponsored research, students in the Intercollege Graduate Degree Program in Materials Science and Engineering enjoy a graduate education that prepares them well for their future careers.

iMatSE students receive full funding (stipend and tuition) in the form of fellowships or research assistantships. Program Highlights:

- Penn State ranked #1 in funded materials research in the US (NSF)
- Thesis-based Ph.D. and M.S. degrees
- Multi-disciplinary research programs and centers
- Over 50 iMatSE and affiliated faculty members
- Approximately 150 current graduate students
- Specialized laboratories and shared facilities

PRECISION THIN METALS

The Precision Thin Metals (PTM) business of Arnold Magnetic Technologies produces thin and ultra-thin alloys that improve the power density of motors, transformers, batteries and many other applications in Aerospace, Industrial, Automotive, and Medical markets. Customers rely on us for thin-rolled titanium in applications that demand high performance and consistent quality. Arnold's Precision Thin Metals business offers titanium products in a number of commercially pure grades and several standard alloy compositions. Our titanium and titanium alloys are available in cold rolled or annealed condition. PTM is Nadcap certified for heat treatment.



Manufacturer of industrial saw blades. The oldest cutting tool manufacturer in North America, Simonds offers one of the broadest and most trusted names found anywhere in the world of cutting tools. Many industries have grown to depend on the quality and innovation of Simonds products and services. We have a continuing tradition of quality, design, and innovation. Simonds has innumerable patents, a global leader in high-performance and high-production sawing. The first bandsaw manufacturer in the world to be ISO certified and we remain certified so today. We set our goals high and our customers have grown to expect it.

Since 1832... The Professionals' Edge.



At Scanacon, our mission is to help stainless, titanium, zirconium and specialty alloy finishers achieve efficient, high quality production at the lowest cost.

With over 30 years' experience as the World's preferred supplier of acid management equipment, our knowledge, experience and equipment offers the producer the ability to achieve productive, efficient and cost effective finishing operation. Our solutions have consistently proven themselves across a wide range of pickling, etching and milling applications for all wrought and cast forms.

Scanacon understands that ease of use, low maintenance requirements and efficiency is key to designing process equipment that delivers value, day after day. No two producers or applications are exactly alike. Delivering value requires a knowledge that can only be gained by experience and is why Scanacon continues to be the chosen supplier for acid management system by all major producers, worldwide.



Structure Medical is a leading manufacturer of medical implant products that are used by orthopedic surgeons to treat disorders of the musculoskeletal system. Orthopedic surgeons use these medical devices to treat trauma, sports injuries, degenerative diseases, tumor and congenital conditions.

Structure Medical was founded in Naples, FL in 2004 and established a second facility in Mooresville, NC two years later. The company uses the most advanced machine tooled available around the world to produce products that meet the highest quality standards.



T-M Vacuum Products has more than 50 years' experience designing and manufacturing various standard and custom size vacuum furnaces and vacuum ovens in both rough and high vacuum configurations with temperatures up to 2,000°C.

We specialize in all metal hot zones and strive to create the best vacuum furnaces and vacuum ovens possible. Our team of experienced engineers and highly skilled technicians build the best systems in the industry. Our systems typically exceed 20 years of life in a full-time 24/7 production environment. This means that each vacuum furnace and vacuum oven, you purchase from us is the most advanced and cost effective on the market.

As an ITA member company, T-M Vacuum is more than happy to assist customers in choosing the right vacuum furnace to meet their needs. Contact us or visit our web site for more information



Verder Scientific Inc., comprised of the Retsch, Carbolite Gero, and ELTRA brands sets the standard in high-tech scientific equipment serving research institutions, analytical laboratories as well as manufacturing companies for decades. The company manufactures and supplies instruments for sample preparation, elemental analysis as well as heat treatment of solid materials.

Producers, Distributors, Fabricators, OEM's, & Vendors to the Industry

5ME

www.5ME.com

5ME is a technology company entirely focused on Manufacturing Efficiency. One of the core components within its solution portfolio is Cryogenic Machining Systems. 5ME has developed a unique, multi-patented solution for routing liquid nitrogen through a machine tool as well as inside the cutting tool to provide the most efficient means of removing heat from the metal cutting process. By taking the cutting tool to -321°F, 5ME's technology is an enabler for processing difficult to machine materials - like Titanium, up to 5 times faster than what is possible with traditional water or oil-based coolants. It also has significant benefits with respect to part quality as white layer, grain boundary distortion, residual stress, and burr formation are all dramatically reduced. Additionally, it offers environmental benefits by eliminating coolants from the metal cutting process.

Able Electropolishing

773-277-1600

www.ableelectropolishing.com

sales@ableep.com

Since 1954, Able Electropolishing has been a metal finishing pioneer and is now the world's largest electropolishing specialist. We provide metal finishing services to companies from a wide variety of industries that use common and specialty metal alloys. Because of our extensive capabilities, thousands of companies rely on our metal finish services as the last step in their metal part production.

Above Material Technology Co., Ltd.

+86-10-82371996

www.amt-alloys.com

Above Material Technology Co., Ltd. is professional in titanium wires since 1997, specialized in R&D and manufacturing. We are proud to be a well-known and top quality brand in China and supplying the world's top quality Titanium wires with competitive price to all over the world, especially Europe, USA, and Japan.

Our top quality Titanium (Welding) Wires have four advantages:

1. Shiny clean - Our wires are clean, shining. The competitors are some dull;
2. Full spool and precise weight - Our wires can be weight control precise;
3. Pretty logo printing - Our wires can be stamped beautiful;
4. Neat end-cut - Our wires are neat end-cut, shiny and homogenous color too.

Our quality titanium fine wires can be from diameter 0.1-5.0mm, level winding without support used for 3D printing, with large single weight and neat convenient package.

Accushape™ Inc.

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accushapeinc@msn.com

Accushape™ has fully integrated facilities for processing Titanium Sponge Granules, with custom screening, particle size and shape modifications, application development, pressing and sintering of parts, machining and metal finishing processes. Accushape™ is a member of the International Titanium Association.

ACNIS® International

+33 (0)4 72 14 55 00

www.acnis-titanium.com

contact@acnis-titanium.com

Since 1991, ACNIS® International is a leading stockholder and distributor of alloyed and non-alloyed Titanium in all forms and sizes. From the beginning ACNIS® International has always focused on the medical industry.

Among our wide product range, we offer bars with tight tolerances, sheets and plates.

We serve our customers from our head office in Lyon-France, but also from our 3 Service Centers located in Paris (AEROMETALS & Alloys®), Brazil (ACNIS® Do Brasil) and China (ACNIS® Asia).

ACNIS® Group distributes high quality Titanium from world renowned producers.

Certified ISO 9001, ISO 13485, EN 9120.

For further information, please visit our website www.acnis-titanium.com

ADMA Products, Inc.

+1-330-650-4000

www.admaproducts.com

ADMA Products Inc. is AS9100 registered fully integrated manufacturer of ADMA Hydrogenated Titanium Powder, ADMATAL® net shape and near net shape powder metallurgy titanium and titanium alloy products. These products, produced by ADMA under its proprietary and patented "solid state" (non-melt) consolidation processes, meet all critical specifications and standards, including Aerospace Materials Specifications (AMS). Components made from ADMA Hydrogenated Titanium Powder are characterized by high purity, refined microstructures, low oxygen content, excellent "weld-ability", low energy input, almost 100% "buy to fly ratios", low cost, and performance that is superior to those of titanium ingot based products. ADMA additionally specializes in stainless steel, nickel, niobium, zirconium and other advanced materials produced by powder metallurgy processes.

Akrapovič Titanium Castings LLC

+386 1 78 19 261

www.akrapovic-foundry.com

Akrapovič is a producer and supplier of Titanium investment casting and carbon-fiber composites products. With many years of experience and constant development in the Titanium processing industry we can offer our customer high quality build to print products out of required certified material, precision and flexible delivery time and full service approach of our high specialized team support.

ALD Vacuum Technologies GmbH

+49 6181 307 0

www.ald-vt.com

info@ald.vt.de

ALD Vacuum Technologies – High Tech is our Business

ALD is a worldwide leading supplier of advanced furnace systems for

melting, casting, coating and heat treatment of metals under vacuum.

ALD furnaces are used for the production of especially pure and specially alloyed metals, materials and parts. Our customers are comprised of the leading manufacturers of materials used in aerospace, energy, semiconductors, medical and commercial markets for a variety of applications that require those super-alloys, reactive and refractory materials as well as rare earth and powder materials.

ALD Vacuum Technologies also is the industry leader in EB PVD Thermal Barrier Coating Systems and our Precision Casting Systems are used for super-alloy, Titanium and Ti Aluminide cast parts. Our expertise in heat treatment furnace technologies and sintering furnace technologies are utilized by leading automotive manufacturing companies as well as the tool manufacturing industries for highly critical parts in gear case and fuel injection systems and specialty tools.

ALD has worldwide representation and services through wholly owned subsidiaries in North America, Japan, Russia, Mexico, India, Thailand, Poland, France and China. With more than 20 representatives across the globe, working together with nearly 400 employees at our corporate headquarters in Hanau, Germany ALD is able to provide timely and knowledgeable services and support.

ALD is part of the AMG, Advanced Metallurgical Group N.V., Netherlands, a public listed technology company with leading market position and interesting growth potential.

Alloy Works, Inc.

704-645-0511 ext. 118
JWoock@Alloyworks.com
Todd.Tomczyk@timet.com

AlloyWorks, a TIMET company, specializes in plasma cold hearth melting titanium aluminides, standard titanium alloys, and cp. AlloyWorks products are used to produce parts in aerospace, industrial, and military applications. AlloyWorks is AS9100, ISO 9001 certified and holds approvals from several leading engine companies.

Alloy Metals Company

562-219-7831
www.alloymetalsco.com
moe@alloymetalscompany.com

Alloy Metals Company is a full line distributor and key supplier of aerospace, defense and industrial grade titanium and other hard alloys.

Ampere Scientific

www.amperescientific.com

Ampere Scientific is the manufacturer and distributor of the VARmetric measurement system, seamlessly integrating existing process measurements and passive sensor technologies to monitor and visualize arc locations during the melting process. VARmetric couples with standard process signals to evaluate process dynamics and correlate this data with product quality measures. Thus, for the first time ever, the VARmetric system allows the user to visualize and act upon deleterious operating conditions, conditions that are not apparent in traditional VAR monitoring systems, during melting, conditions that could lead to safety related operations or defect formation.

American Prosthetic Components

American Prosthetic Components is a manufacturer of prosthetic

components.

American Titanium Works LLC

+1-603-398-3342

American Titanium Works LLC is completing plans to build a new, green-field, integrated, world-class titanium manufacturing facility in the southeast of the United States. ATW is targeting the defense, industrial, commercial, consumer and emerging markets with a range of products and services including alloy and commercially pure titanium plate, bloom, billet, slab, and ingot.

Applications for our products will include defense ballistics and general military equipment construction, chemical processing equipment, oil & gas systems, pulp & paper production facilities, medical implants, and a wide and growing range of consumer goods.

AMETEK - Reading Alloys

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AMETEK - Reading Alloys is a manufacturer of high quality master alloys comprised of Vanadium, Molybdenum, Niobium, Chrome, and Aluminum alloy ingredients. Master alloys are used for rotor grade titanium, aerospace grade and non-aerospace grade titanium, commercial metals, and super alloy metals applications. Reading Alloys also manufactures high purity titanium powders for thermal spray coatings as well as additive manufacturing. In addition, a series of gas atomized specialty powders for hard facing, brazing, and thermal spray further compliment the product offerings. We can offer toll melting, cold isostatic press, hydride/dehydride and other services. Our quality system is certified to ISO 9001:2008 and AS9100C and we have a fully accredited lab that is Nadcap certified. Visit AMETEK - Reading Alloys via our website at www.ametekmetals.com.

Arcam Group

Arcam Group provides cost-efficient Additive Manufacturing solutions for production of metal components. Arcam's Electron Beam Melting (EBM®) technology offers design freedom combined with excellent material properties and high productivity. Arcam provides Electron Beam Melting systems through Arcam EBM in Sweden, powder metals through AP&C in Canada and implant contract manufacturing through DiSanto in the U.S.

Architectural Titanium LLC

+1-785-842-2299

www.architecturaltitanium.com

Architectural Titanium provides the most experienced consultants for worldwide applications in architecture, art and design. We look forward to the opportunity to share our expertise and support your design concepts through the entire process of samples, details, specifications, procurement, fabrication and installation.

Arconic

+1-231-894-7330

www.arconic.com



Arconic (NYSE: ARNC) creates breakthrough products that shape industries. Working in close partnership with our customers, we solve complex engineering challenges to transform the way we fly, drive, build and power. Through the ingenuity of our people and cutting-edge advanced manufacturing techniques, we deliver these products at a quality and efficiency that ensure customer success and shareholder value. For more information: www.arconic.com. Follow @arconic: [Twitter](#), [Instagram](#), [Facebook](#), [LinkedIn](#) and [YouTube](#).

Aries Alloys

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India's leading Stockholder of Titanium, Nickel Alloys & Stainless Steel Mill Finished Products, Re-Usable & Scrap.

ARIES Manufacturing

+1 704-289-8531

www.aries-manufacturing.com

ARIES Manufacturing: ARIES Manufacturing, formerly marketed as The Cyril Bath Company and ACB Company, is part of an International corporation known as the ARIES Alliance. This group of aerospace focused businesses provides innovative metal forming and joining solutions to the aerospace industry. The foundation of its technologies is stretch forming of aluminum alloy sheet for fuselage skins, as well as aluminum and titanium profiles for airframe structure components. The company's stretch presses are equipped with the latest CNC control systems, designed and developed by its in-house software engineers. Our stretch forming customers include the leaders in commercial and business aircraft manufacturing, in addition to their complete supply chain network. ARIES Manufacturing has developed a very innovative Hot Stretch Forming process, or HSF®, to contour titanium profiles for airframe component applications. This high temperature forming process precisely stretch forms titanium extrusions to the exact part design contour. The hot stretch formed part is then machined and finished into a critical airframe component. This valuable forming process saves starting titanium weight by offering a near net profile solution; contoured in a controlled, repeatable process, with minimal residual stress. In addition, under ARIES Manufacturing, we hot form and superplastic form titanium sheets for applications in nacelle and pylon components. Our facility in Nantes, France operates 12 hot forming/Superplastic Forming presses of varying sizes. Additionally, we can laser or machine trim, spot weld, hot brake form, and perform assembly work. All of our hot presses are designed and built within our corporation businesses. Finally, ARIES manufacturing has a facility in Grenoble, France that can perform pocket milling and final trimming on large aluminum alloy fuselage skins. This contract manufacturing work utilizes our internal expertise and design engineering of a very innovative "mirror milling" type CNC machining center.

ATI

+1-412-394-2800

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ATI is one of the largest and most diversified specialty materials and components producers in the world. As a fully integrated supplier from raw material (titanium sponge) and melt (specialty alloy systems) through highly engineered finished components, we use innovative

technologies to offer growing global markets a wide range of specialty material solutions.

Through unsurpassed manufacturing capabilities, industry-leading alloy systems, mill products, and engineered castings and forgings, ATI offers a unique supply chain solution that Creates Value Thru Relentless Innovation®.

Avon Metals Ltd.

+44-1452-874500

www.avonmetals.com

Avon Metals are a primary & secondary aluminum smelter manufacturing high performance aluminum-based master alloys and alloying products for the wrought aluminum, titanium and superalloy industries. We are actively engaged in the strategic sourcing & trading of primary and scrap metals for industry including Titanium CP & 90/6/4 solids & turnings, Titanium sponge, Strontium Metal, Electrolytic Manganese Flake, Silicon Metal, Aluminothermic Chromium Metal, Primary Magnesium, Hafnium Crystal Bar and ingot, Zirconium/Zircalloy, SHG Zinc, Pure Tin ingot, Pure Lead Shot, Rhenium Pellets, Tantalum and Niobium.

BAHCO

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www.snapon.com/industrialbrands

industrialbrands@snapon.com

Bahco's 3860 Multi Chip Carbide bandsaw blade has been developed specifically for cutting Titanium Alloys. The 3860 Multi Chip Carbide blade improves and optimizes Bandsaw operation with a World leader in Cutting Technology. In the 1980's Bahco developed and Patented the first "Set Tooth" Carbide Bandsaw blade to provide fast, efficient cutting of exotic alloys and have led the way in this sector ever since.

Bahco is a registered trade name of Snap-on Incorporated a leading global innovator, manufacturer and marketer of tools, diagnostics, and equipment, software and service solutions for professional users. Products and services are sold through the company's franchisee, company-direct, distributor and Internet channels. Founded in 1920, Snap-on is a \$2.8 billion, S&P 500 Company headquartered in Kenosha, Wisconsin. Our Mission - The most valued productivity solutions in the world. Snap-on Incorporated P.O. Box 1410 Kenosha, WI 53141-1410, U.S.A. 262-656-5200.

Banner Medical

+1-800-323-9732

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Banner Medical is a strategic business unit of Banner Service Corporation. Banner Medical specializes in providing complete single-source cold finished bar and supply chain solutions for the medical, dental, and aerospace industries. We carry over 1 million pounds of raw and finished goods inventory to service our customers quickly. Our complete offering of stainless, titanium, aluminum, alloy, nickel and cannulated products coupled with unique value added services sets Banner Medical apart. Some of these unique value added services include:

- Custom supply chain management solutions
- Complete traceability from melt source to finished product
- In-house non-destructive testing
- Vendor managed inventory (service) and JIT programs
- Line marking
- Niton Gun material analysis
- Near-net shape machining

- Precision saw cutting
- Waterjet cutting

Quality Throughout

Banner Medical has developed and implemented a proprietary Quality Management System that assures we meet or exceed the stringent standards required by the medical and aerospace industries. Each Banner facility is ISO 9001:2008 certified. Medical production facilities are ISO 13485:2003 certified. Our Carol Stream facility is also AS9100C:2009 certified

Baoji JHY Titanium Industry Co., Ltd

+86 917 3372 996
stella@ti-bolts.com



Baoji JHY Titanium Industry Co., Ltd was founded on 25-09-2002. It is a professional manufacturer for titanium and titanium alloy fasteners and machined products. We can produce them according to different standards, like GB, ISO, DIN, ANSI and JIS etc. They are widely used in petroleum, metallurgy, chemical, pharmacy, marine engineering, racing car, motorcycle, bicycle, yacht, outdoor camping and sports equipment.

Our company insist the "Quality First" strategy rather than "Low priced" one to earn trust from customers, which has been proved correct after 15 years in this industry. Now over 85% our products are exported to Japan, United States, United Kingdom, Germany, Netherlands and other European countries.

Baoji Titanium Industry Co., Ltd.

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www.baoti.com
iedept@baoti.com

Baoji Titanium Industry Co., Ltd (Baoti) is the biggest manufacturer of titanium mill products and titanium alloys in China. An integrated production system that includes melting, forging, rolling, drawing and fabricating enables Baoti to manufacture various products such as titanium sponge, ingot, billet, bar, wire, plate, sheet, tubing, forging, casting of all grades of CP titanium and most titanium alloys as well as many down-stream products in accordance with AMS, ASTM, MIL, ASME, ISO, DMS, AWS, JIS specification. These products are widely used in every kind of industry ranging from aerospace and automotive to sports, medical, chemical and petrochemical industries. Baoti is an ISO9001 and NADCAP approved company.

Baosteel Special Metals Co., Ltd.

+86-021-26032903
www.baosteel.com

Baosteel Group is the largest and most advanced integrated steel company in China. Baosteel Special Metals Co., Ltd is a subsidiary company of Baosteel Group. Baosteel Special Metals Co., Ltd grew out of Shanghai No. 5 Steel Works, and started manufacturing of titanium alloys since 1968. The main titanium products include: ingot, slab, billet, bar, plate, coil, stock, isothermal forging and so on.

Beijing Hongda Titanium Science & Trade Co., Ltd

+86-10-82274866
www.chinabti.com.cn

Beijing Hongda Titanium Science & Trade Co., Ltd was established

in 2002, and is located in Beijing, China. We are a professional manufacturer of titanium and titanium alloy. Our products mainly include sheets, plates, bars, strips, rods, wires, forgings, and processing titanium. As a leading corporation of titanium in China, we always stick to "Quality First". We have ISO 9001:2008 quality certificate. We sincerely hope to establish long and friendly business relations with clients from all over the world.

BIBUS METALS

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www.bibusmetals.com
info@bibusmetals.ch

BIBUS METALS Group is 100% Swiss owned and has over 37 years of experience as a leading distributor and stockholder of Titanium (CP and Titanium alloys) as well as Nickel based alloys, Cobalt-Chromium and 316LVM (1.4441) in Europe and Asia. BIBUS METALS Group is a supplier for different applications in medical, chemical, aerospace, automotive, oil & gas, power generation industries and offers:

Sheets/Plates; Wire/Bars; Tubes/Pipes; Strip/Foil; Welding wire; Screw/Nuts; Profiles

The fully integrated Service Centres are located in Switzerland, Germany, Czech Republic, Poland, Hungary and China to ensure reliable and rapid service for customers worldwide.

Where necessary the entities of the Group are certified according ISO 9001, EN/AS 9120 for aerospace and EN ISO 13485 for medical. Quality, flexibility and tailored solutions are of great importance for the whole BIBUS METALS Group.

For further information please email to info@bibusmetals.ch

Blaser Swisslube Inc.

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Blaser Swisslube is an independent and family-owned Swiss company founded in 1936. Blaser Swisslube is represented in about 60 countries, close to its customers. The Company develops and produces high-quality cutting and grinding fluids and its customers produce, with great success, a wide range of products from the tiniest of components to large, critical and structural components in all manufacturing industries.

Blaser Swisslube's goal is to optimize its customers' manufacturing processes with the liquid tool and to improve their economic efficiency, productivity as well as the machining quality. In close cooperation with the customers, Blaser Swisslube presents the possibilities to fully exploit the potential of machines and tools by using the right metalworking fluid which becomes a liquid tool. This promise is backed by excellent products, customized services, competent experts and its long experience in the metalworking industry. For more information please visit www.blaser.com.

Bodycote

+1-310-604-8000
www.bodycote.com

With more than 170 locations in 21 countries, Bodycote is the world's largest provider of thermal processing services. Through heat treatment, metal joining, surface technology and Hot Isostatic Pressing (HIP), Bodycote improves the properties of metals and alloys, extending the life of vital components for a wide range of industries, including aerospace,

defense, automotive, power generation, oil & gas, construction, medical and transportation. Customers in all of these industries have entrusted their products to Bodycote's care for more than 30 years. For more information, visit www.bodycote.com.

Bonatech Metal Research Institute

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www.bonatech.cc

Bonatech Metal Research Institute (BMRI) is a leading research institution in China specializing in research and development, technical transfer and technical service of metal material and automated control equipment. BMRI was jointly established in 2004 by a private enterprise, a prestigious domestic university and a professional research academy. It is supported by a group of top science and technology and expert team in the fields of metal, mechanical and electric control, automated control and mineral dressing. At present, BMRI has 50+ researchers, including eight engineers with senior professional titles, two researchers with PhD degrees, five professionals with master degrees, and others with college or bachelor degrees.

Over the past years, we have been focusing on the industrialization of key technologies in light metal and alloy. Significant achievements have already been made in terms of industrialization of energy-saving light metal (i.e., titanium & aluminum) electrolysis and smelting equipment.

Busch LLC

Busch Vacuum Pumps and Systems is one of the largest manufacturers of vacuum pumps, blowers, and compressors in the world. Our products are at the forefront of vacuum and low pressure technology.



The Busch product range offers the largest selection of industrial vacuum pumps available in the world today. We offer more than 50 years of experience and expertise in vacuum system manufacturing, and can provide customized solutions for a variety of vacuum applications.

Butech Bliss

330-337-0000

www.butechbliss.com

sales@butech.com



Butech Bliss is a designer and manufacturer of capital equipment, repair components and engineering and field services for metals producers and processors that roll, forge, melt, flatten, stretch, shear and extrude metals of all types. Butech Bliss is located in Salem, Ohio and is home to one of the largest manufacturing facilities in the industry. With over 50 engineers on staff, 400,000 sq. feet, 100+ machining centers, full fabrication and assembly departments, 200 ton crane capacity and a dedicated rail spur, Butech Bliss is equipped to handle any project. Butech Bliss product offerings include copper crucibles, liners, molds, hearths, etc. for VAR, ESR, PAM and EBM Re-melting equipment as well as Rolling Mills, Forging and Extrusion Press upgrades and Coil, Plate and Sheet processing equipment for all metals. Butech Bliss is comprised of Butech Inc., E.W. Bliss (Bliss-Salem), Loewy Machinery and Lombard Industries.

Caledonian Alloys

http://www.pccforgedproducts.com/brands/caledonian_alloys/

Caledonian Alloys is the world leader in the management of nickel and cobalt base superalloy and titanium alloy recycling for the aerospace,

land-based turbine, and chemical industries.

The company transforms revert, through rigorous process, into material which can be re-melted, to produce new nickel, cobalt, or titanium alloys. Revert consists of excess alloy material which can arise from high performance component manufacturing, from decommissioned parts, and from the melting process.

Caledonian Alloys provides customers with a range of tailored revert management services designed to enable them to optimize the use and value of their own revert material.

Accredited with all major vacuum and high temperature melters worldwide, Caledonian Alloys supplies fully processed nickel and titanium revert material to the melting industry. We also purchase revert material from a wide range of industrial customers throughout the world.

Calvi Holding S.p.A

www.calviholding.it

Calvi Holding S.p.A. holds equity investments in several manufacturing companies with specific focus on metallurgy and mechanics. Since 2004, Calvi Holding S.p.A. has been committed to creating value based on a network model, which develops synergies to provide its clients with products and solutions that are increasingly innovative and competitive.

CEFIVAL SA - SIDERVAL S.p.A

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www.cefival.fr www.siderval.it

commercial@cefival.fr siderval@siderval.it

CEFIVAL and SIDERVAL manufacture special sections and tubes with hot extrusion process to obtain near net shape Profiles. The shapes are studied and manufactured according to customer's requirements in a wide range of solid and hollow sections. Our manufacturing process improves the buy to fly ratio. Main grades are titanium, inconel, carbon steel alloys, super alloys, stainless steels and other on requirement. Main application fields are aeronautics for aircraft ring engines (CFM56, GE90, GP7000, CF6-80, SM146, Gen X) and structural parts (such as seat tracks, floor and wings stiffeners, door hinges...), Power Generation for nuclear (ia drive rods) and conventional applications, medical and food industry.

Chaoyang Jinda Titanium Co., Ltd.

+86 421 2976177

www.jinda.cc

Chaoyang Jinda Titanium Co., Ltd.(Jinda Titanium)was founded in August, 2006.The main products are Jinda brand titanium sponge(famous brand products in Liaoning Province) and titanium ingot and other processed products. Production ability per year for titanium sponge is 10,000 tons, for ingot is 2000 tons and 40,000 tons for anhydrous magnesium chloride.

Jinda Titanium is the National High-tech Enterprises with unique production technology, advanced inspection instruments and strong technical force. Jinda Titanium passed ISO9001 Quality Management System,ISO14001 Environmental Management System, GB / T28001 Occupational Health and Safety Management System, GJB9001B Military Standard Quality Management System, AS9100C Aerospace Quality Management System Certification and ISO / IEC17025 National Laboratory Accreditation.

The quality of Jinda titanium sponge is stable. Self R & D MHT-90 high-quality titanium sponge and small size titanium sponge have become the

preferred raw materials of aerospace and defense, marine engineering and other high-end usage of titanium industries.

Jinda Titanium is a member of the International Titanium Association, the vice managing director of Chinese non-ferrous metal industry association titanium zirconium Hafnium Branch, the vice managing director of Titanium Industry Progress and the director of Baoji Titanium Association. Jinda Titanium comprehensive ranks forefront in titanium industry.

Chesapeake Industrial Cleaning Products, Inc.

+1-410-340-9052

www.chesapeakeindustrial.com

Chesapeake Industrial formulates and supplies manufacturing chemicals and degreasers to titanium recyclers and processors. Cleaners for removing oil from turnings, dirt and oil from scrap, cutting fluids from formed products and other typical operations are our expertise. Chesapeake provides a wide range of formulated products from general cleaners to high spec materials made at facilities in several US locations. Products specifically designed for individual operations can be formulated for costs often lower than 'off-the shelf' materials. Chesapeake has served customers in the titanium industry for over 10 years. Drums, Totes and Bulk deliveries of materials are all available.

China Huaxia Special Metal Limited

0086-21-58770128

www.nonferrous-metal.com

www.csmhuaxia.com

helen@nonferrous-metal.com csm@nonferrous-metal.com

China Huaxia Special Metal Limited is one of the largest manufacturers of titanium, nickel & nickel alloy, stainless steel/duplex & super duplex with forms at sheet/plate, seamless tube/pipes, bar/rod, wire, welded pipe, seamless & welded fitting, flange, valve, clad material etc. With the logo CSM (China Special Metal), we hope to be the best one of special metal manufacturer in China. CSM always treat the quality as our life, CSM invest the quality and future. CSM material have been widely used in oil & gas industry, chemical industry, construction industry, sports industry etc, many big companies in these field have approved CSM material. CSM took the pride in CSM titanium sheet used in 2012 London Olympic Village decoration, CSM has the mission to be the enterprise to improve the position of Chinese titanium products in the international market.

China Steel Corporation

+886-7-802-1111

http://www.csc.com.tw/csc_e/pd/mlg/mlg.html

China Steel Corporation provides high quality titanium products, including ingot, plate, sheet, bar, wire coil and tube, for a wide range of applications in architecture, chemical industry, heat exchangers, copper foil facilities, fasteners, desalination, electronics, sports industry, leisure and moving forward to biomedical and aerospace application.

The stable and reliable quality of CSC's titanium products have gained the acceptance of Asia industries widely, and CSC has also been selected as the first priority provider to purchase their needed titanium materials owing to CSC's quick and efficient technical services. CSC will continue to improve customer services and the technical technologies both for customers and CSC itself to promote Titanium Alloy products' international competitiveness.

Cogitic Corporation

www.cogitic.net

Cogitic is an engineering and manufacturing company specializing in the machining, assembly and test of complex components and assemblies produced from exotic alloys. Large 5-axis capability with full CMM validation of all products.

Consarc Corporation

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Consarc Corporation, an Inductotherm Group Company, is a manufacturer of vacuum furnaces for the titanium forging and casting industry. Consarc custom designs and manufactures Reactive Vacuum Arc Remelting (RVAR) furnaces for primary electrode melts of compacted sponge titanium and titanium alloys, and secondary melt furnaces for remelting fully dense electrodes. Consarc also designs and manufactures fully customized Induction Skull Melting (ISM) systems for melting titanium in a refractory free environment for casting or ingot withdrawal. Consarc is ISO 9001-2008 certified, and with operations on 5 continents, is well equipped to tackle fully customized furnace projects globally.

Continental Steel and Tube Company

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www.continentalsteel.com/Titanium/default.asp

Continental Steel and Tube Company is one of the world's leading value added volume suppliers of quality metals. With an outstanding global reputation, our team of expert sales associates can source a comprehensive inventory of metals to meet any application requirements.

Continental Steel supplies a wide range of metals including, titanium, stainless steel, nickel, steel, aluminum, hot/cold rolled, galvanized, and stainless and electrical steel in carbon and alloy grades. Our long list of Titanium Grades includes Ti 6AL-4V ELI. Our materials are available in coils, sheets, strips, plates, angles, bars, rounds squares, hexagons, and other custom shapes. Continental also offers tubing or pipes in welded, DOM and seamless.

Cristal Metals Inc.

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Cristal Metals was formed in 1997 as International Titanium Powder (ITP) to develop and commercialize Armstrong Process® patented and proprietary technology for high purity metal and alloy powders with specific emphasis on titanium. Armstrong Process® technology is intended to lower the production cost of powders suitable for direct consolidation, to lower the manufacturing costs of titanium products through powder metallurgy processing, and to reduce the environmental impact of titanium production.

CSIRO High Performance Metal Industries

+61 3 9545 8644

<https://www.csiro.au/en/Research/MF/Areas/Metals>

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The High Performance Metal Industries Program is engaged in applied research across the metal value chain, specialising in novel metal production techniques, interfaces/corrosion, energy systems, metal forming, and additive manufacturing / 3D printing, particularly for

Titanium and its alloys. Strong Multiphysics modelling techniques are combined with practical experimentation to understand and develop advanced solutions for global industry. HPMI partners with industry and other research providers around the world, in applied research or to develop new technologies. HPMI also provides consulting services, use of specialized facilities, additive manufacturing training, and aims to be a global leader in the knowledge and application of fundamental metals technologies. It runs CSIRO's 'Lab22 Innovation Centre' – the largest metallic additive facility in the Southern Hemisphere. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's primary national research body, with over 5,000 researchers active over a wide range of fundamental and applied research challenges.

Cumberland Highstreet Partners

<http://cumberlandhighstreet.com>

Formed in London in 2016, Cumberland Highstreet Partners was created in response to the need for executive leaders to have access to a team of proven, experienced professionals who possess a deep domain knowledge of manufacturing. We bring accomplished and creative industry experts to the table who have personally led significant organizations. We are executives with proven track records of successfully navigating the ever-changing needs and requirements of industry.

Custom Marine

920-450-9939

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Manufacturer of titanium exhaust systems. Every CMI header is built to exacting standards that have made them the number one choice for offshore racers and performance-oriented boaters who demand on-water performance. CMI headers are manufactured using state-of-the-art materials, like Titanium, 316L Stainless, Inconel and duplex alloys offering superior corrosion resistance and durability. A unique, patented bending process assures uniform wall thickness and eliminates any rippling and crazing of the tubing during production. Semi-automated tungsten inert gas welding, plus heat treating (where applicable) of the complete manifold following assembly, significantly reduces internal stresses that commonly cause fatigue, corrosion and premature failure in most high performance applications. To complement its header systems, CMI also manufactures machined components, custom exhaust accessories and integral mufflers for virtually any engine configuration. With CMI, boaters get a combination of performance and reliability unparalleled by any competitive products on the market.

BHN Special Materials Ltd.

+86 411 8924 9999 ext 8088

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Dalian BHN Special Materials Ltd. is one of the state-of-the-art manufacturers and suppliers of high-grade master alloys for applications in the Titanium, steel and Aluminum Industries.

BHN is a customer-oriented company focused on R&D, process and product improvement.

BHN is certified according to EN9100:2009 and ISO 9001:2008.

Danobat S. Coop

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www.danobatgroup.com

Sixty years have gone by since DANOBAT manufactured its first machine. Nowadays, DANOBAT Sawing Division does not simply make saws, but innovates in the field of machine tools.

DANOBAT strategy is to offer custom solutions for highly complex sawing applications on high-tech products offering bandsaws and circular saws. The aerospace, automotive, railway, wind power, oil and gas sectors and outsourcing workshops are the main trading sectors.

The technological leadership of DANOBAT in the development and manufacture of horizontal and vertical saws makes it possible to offer leading-edge and highly effective sawing solutions to our customers. DANOBAT provides solutions for solid bars, pipes and plates with the highest accuracy.

Automatic band saw machines, wagon style or gantry for large dimensions, vertical plate bandsaws and circular saws are the solutions offered by DANOBAT.

DHL Drawback Services

+1-585-328-7130

www.dhldrawback.com

DHL Drawback Services is a licensed Customhouse broker specializing in duty drawback matters. With offices in Houston, Texas and Rochester, New York, we have over 20 years' experience obtaining the maximum in allowable duty drawback refunds and excise tax credits for our clients in a compliant, timely, thorough, and professional manner that imposes the least amount of administrative burden on our client's time and resources.

DKSH Switzerland Ltd.

+41 44 386 72 72

www.dksh.com

ti@dksh.com

Pioneers in sourcing of Titanium bars and plates from Japan and China: DKSH Advanced Metals is part of a Swiss group with 140 years of experience in bridging Asia and the West. For the last 30 years, we have been instrumental in introducing high quality titanium and titanium alloys from top quality Japanese and Chinese producers to European, US and South East Asian customers. We serve stockists as well as end users in the Medical, Aerospace, Automotive, Chemical, Oil & Gas and other high tech industries. Our wide range of services includes access to a comprehensive stock of Ti semi-finished products, advanced supply chain management such as vendor managed inventory and subcontracting for machining and forging, tailor made financing solutions and metallurgical expertise. Our deeply rooted knowledge of sourcing and subcontracting markets coupled with our Swiss sense for premium quality ensures that we remain at the forefront of innovation when it comes to serving your needs.

Duferco SA

+41 91 822 56 00

www.duferco.com

Duferco Participation Holding is the ultimate shareholder of Vanchem Vanadium Products (Pty) Ltd. ("Vanchem"). Vanchem is one of the world's top five vanadium producers and its assets comprise mining activities and various vanadium oxide, ferro-vanadium, and vanadium

chemical production facilities. Production is now idle. Duferco SA is also the exclusive distributor of the vanadium products made by Hesteel Chengde. Visit our website at www.duferco.com.

Duisburg Tubes Production AG

+49 203 6003 315

www.dtp-ag.eu

sales@dtp-ag.eu

The Duisburg Tubes Production AG is a German manufacturer and developer of high quality seamless tubes made of zirconium, titanium and nickel-based alloys with over 50 years of experience.

As a supplier of cladding tubes for fuel rods for the nuclear industry the DTP AG is the reliable partner for all demanding applications. To fulfill all quality requirements is the second nature.

The range of application is as mentioned before the nuclear industry. Moreover the use in all kinds of tubular heat exchangers, in the aviation industry, in the chemical industry, in the oil and gas industry, in the food processing industry and many other demanding environments.

The cold pilger mill seamless tube production is a special form of cold rolling and guarantees high precision and close tolerances. The combination of pilger know-how and the sophisticated annealing knowledge leads to an extraordinary product quality.

The quality management system is conform to ISO 9001, ISO 5001, ISO 14001 and EN 9100.

Edge International

+1(937) 395-7222

www.edgeintl.com

metals@edgeintl.com



Edge International, located in Dayton, Ohio, is an ISO 13485-certified stocking distributor of raw materials, specializing in medical grade Cobalt-alloys, Stainless Steels and Titanium for the manufacture of implants and instruments for the orthopaedic, spine and trauma markets. Edge works with its customers to provide cost-effective solutions and concentrates on the medical market to ensure the highest level of compliance, quality and service. Value-added services include precision grinding to size and tight tolerances, precision sawing, non-standard grades and sizes, and just-in-time inventory programs. Edge conducts business internationally, supplying to customers around the globe.

ELG Utica Alloys, Inc.

+1-315-574-1680

www.elguticalloys.com

EUA is one of the world's largest Titanium, Nickel and Cobalt alloy recycling companies. We operate under the tightest quality standards, utilize the latest equipment, offer unparalleled service, are fed by over 40 sister yards worldwide and have the financial backing of ELG Haniel GmbH.

Evrast Stratcor, Inc.

+1-312-533-3650

www.evraststratcor.com

EVRAZ Stratcor offers titanium producers one-stop shopping for all their master-alloy requirements. Using a state-of-the-art, ISO approved production facility that is focused on meeting the ever-increasing quality needs of the

aerospace industry, we can provide a full range of vanadium and other master alloys, including innovative and customized specialty alloys that are marketed and managed by EVRAZ Stratcor, Inc. based in Chicago, Illinois.

EWI

+1-614-688-5000

www.ewi.org

info@ewi.org

EWI is the leading engineering and technology organization in North America dedicated to developing, testing, and implementing advanced manufacturing technologies for industry. Since 1984, EWI has offered applied research, manufacturing support, and strategic services to leaders in the aerospace, automotive, consumer electronic, medical, energy, government and defense, and heavy manufacturing sectors. By matching our expertise to the needs of forward-thinking manufacturers, our technology team serves as a valuable extension of our clients' innovation and R&D teams to provide premium, game-changing solutions that deliver a competitive advantage in the global marketplace. To learn more, visit www.ewi.org, email info@ewi.org, or call 614.688.5000.

Exova

www.exova.com

Exova Group plc is a leading provider of laboratory-based testing and related advisory services, operating primarily within the Testing segment of the Testing Inspection and Certification ("TIC") sector.

Exova has been hired to do the autoclave work for the NACE MRO175 testing of Gr 12 project by the ITA Industrial committee.

By joining the ITA as a Vendor member Exova would become an active participant in the ITA committee dedicated to industrial applications. Exova would also benefit from discounted registration at the annual events, would receive a complimentary company description in the membership directory and would be able to take advantage of a variety of other ITA membership benefits.

FAE S.A.

54-11-63261493/94/95

www.fae.com.ar

fae@conuarfae.com

FAE is an Argentinean company qualified by Airbus for supplying hydraulic titanium Ti-3Al-2.5 tubing for Family 320. Also is the first Latin-American company in getting a tier one contract with EADS group. One of its main activities, apart from aerospace, is the manufacturing of seamless commercial pure titanium and titanium alloy tubes straight or U bend for heat exchangers which are up to 35 meters long. These tubes are also made in nickel alloys 690 & 800 for steam generators for nuclear power plants. The nuclear business is the origin of the company and the Zirconium cladding tubing for the nuclear fuel elements constitutes the main product of the company. It also produces ingots and bars in titanium alloys and bright annealed finish seamless instrumentation titanium tubes (O.D 1/4" up to 5/8"). FAE is certified according UNE EN 9100: 2009, ISO 9001: 2008, ISO 14001: 2004, OHSAS 18001: 2007, PED 97/23/EC & CSA N285.0 standards. Its products are exported to countries all over the world and they are used in aerospace and corrosion resistant applications. Now also NADCAP certified company for heat treating and non-destructive test.

FE Mottram Ltd.

+44 1142446723

www.femottram.com

UK manufacturer of tailor-made and high grade ferro titanium.

Fine Tubes

+44 (0)1752 876416

www.finetubes.com

sales.finetubes@ametek.com

Fine Tubes is a leading global manufacturer of precision tubing in high performance titanium, stainless steel, nickel and zirconium alloys. The company manufactures tubes in both seamless and welded forms used in mission critical applications across a range of specialty markets including aerospace, oil and gas, nuclear, power generation, chemical process and medical devices.

TITANIUM TUBING EXPERTISE

Seamless titanium tubes from 1 mm (0.040 in) OD to 50 mm (2 in) OD. Straight lengths up to 5.5 metres (18 ft.)

TITANIUM ALLOYS

Fine Tubes offers a comprehensive portfolio of titanium tubing in the following alloys: Ti CP (Grade 1), Ti CP (Grade 2), Ti 6Al/4V (Grade 5), Ti 3Al/2.5V (Grade 9), Ti 5Al/4V and Ti 4Al/2.5V. The tube mill has achieved NADCAP approval for Ultrasonic Testing, Heat Treatment and Fusion Welding.

WORLD CLASS FACILITY

Proudly based in the United Kingdom, Fine Tubes operates several state-of-the-art titanium processing facilities including:

- Pilger Rolling Mills
- Draw Benches
- Vacuum Furnace Heat Treatment
- Chemical Processing
- Conditioning & Degreasing

Our metallurgical and engineering experts are ready to support your teams in developing competitive solutions for your most demanding technical challenges.

Along with its US-based sister mill, Superior Tube, Fine Tubes is a unit of AMETEK Specialty Metal Products, a division of AMETEK, Inc.

Forecreu

World leader in high speed steel hollow bars for drills and coolant fed taps.

World leader in cannulated bars in stainless steel and titanium for surgical tools and implants.

Fort Wayne Metals

+1-260-747-4154

www.fwmetals.com

info@fwmetals.com

Fort Wayne Metals has a long history of producing precision titanium bar, wire and wire-based components for the medical device industry. In fact, most of the materials we produce ultimately end up in the human body.

As a result, we understand the critical importance of quality. After all, our employees have experience producing materials for applications designed to improve or even save lives. We uphold the highest quality

standards throughout our production process – beginning with melting material in our own furnace. We are 9100C and ISO 9001 certified, and maintain a A2LA - ISO/IEC 17025 compliant Materials Testing Laboratory.

Available diameters:

Wire: 0.001" (0.0254mm) to 0.062" (1.5748mm)

Coil: 0.040" (1.016mm) to 0.500" (12.70mm)

Bar: 0.0787" (2.0mm) to 0.500" (12.70mm)

Available grades:

Commercially pure Titanium (ASTM F-67 • ASTM B348 • ASTM B-863 • ISO 5832-2)

Grades 1 – 4

Alloyed Titanium

Ti-6Al-4V ELI (ASTM F-136 • ASTM B-348 • ASTM B-863 • ISO 5832-3)

FRIEDRICH KOCKS GmbH & Co KG / KOCKS PITTSBURGH COMPANY

+49-2103-7900 +1-412-367-4174

www.kocks.de

sales@kocks.de

FRIEDRICH KOCKS GmbH & Co KG was founded in 1946 by Dr.-Ing. Friedrich Kocks. We have been successfully operating worldwide in the field of rolling mills for tube, wire rod and bar as independent, medium sized family owned company.

By a consistent and future-oriented development of our products, our technology has acquired a leading position on a global scale. KOCKS rolling mills are the benchmark for creative application oriented solutions as well as first class competence in engineering and manufacturing. Following its policy, KOCKS will pursue these constant innovations so that KOCKS will provide tomorrow's technologies today.

Friggi N.A.

+1-519-421-9291

www.friggiamerica.com

info@friggiamerica.com

Friggi N. A. Inc., provides premium metal and aluminum cutting solutions to the North American market. With over 70 years manufacturing experience we now offer large vertical plate and block saws, high-speed carbide saws, plasma, and waterjet cutting solutions. Within our product line, we offer specialized equipment to cut challenging materials like Titanium or exotic metals with extreme precision and performance. Our plate saw capacity is over 20 feet and our Gantry models will cut blocks up to 140" with minimal material handling. Machines are available in automatic or semi-automatic version to cover any requirement. We service many key market segments including aerospace, automotive, defense, oil and gas, steel service centers, forging and mold makers. Whether the application is to cut ferrous or non-ferrous metals for ingot, bar, block, or plate we offer the best solution for our clients' production needs.

G&S Titanium, Inc.

+1-330-263-0564

www.gs-titanium.com

G&S Titanium manufactures many grades of titanium in the form of round and hex bars, fastener wire, spring wire, weld wire, precision ground medical bars, and fine wire. This includes the standard grades such as CP Gr. 1-2-3-4, 6Al-4V, 6Al-4V ELI, as well as hard to find alloys such as 3-8-6-4-4, 13-11-3, 6-2-4-2, 8-1-1, Gr. 7, Gr. 9, Gr. 12,

21S, 230, 679, 685, 829, etc.

Gautier Specialty Metals, LLC

814.535.9200

www.gautierspecialty.com

sales@gautiersteel.com

Gautier's premier plate mill provides rolling capacity for advanced high performance metals to a variety of industries.

At its heart is a 58" wide 4 High Mesta Reversing mill, capable of rolling the most difficult of specialty metals. The mill is expandable to 110" wide in the future. Building on Gautier's long legacy of short lead times and excellent customer service, GSM will be able to provide high quality alloy, tool and stainless steel as well as advanced nickel based and titanium alloys.

Large Alloy Selection: Alloy & Tool Steel, Stainless Steel, Nickel Based Super Alloys and Titanium

Built for Conversion on a quick turnaround.

GfE Metalle und Materialien GmbH

+49 911 9315 299

www.gfe.com

alloys@gfe.com

GfE, founded in 1911 and being part of AMG Advanced Metallurgical Group N.V., is a leading manufacturer and global supplier of high performance metals and materials.

We offer a wide range of high-quality master alloys that meet the highest technical requirements for different specialized sectors, mainly aerospace, super alloy industry and ship-building.

Furthermore titanium as high-purity HDH powder is produced by GfE for thermal spray coatings. Its specific characteristics offer an advantageous material for porous layers on medical implants.

Our product spectrum is completed by inter-metallic Titanium Aluminum light weight alloys, known as gamma Titanium Aluminide alloys. Its present applications include low pressure turbine blades (LPT) for civil aircraft engines as well as turbocharger wheels for the automotive industry.

GfE is certificated in accordance to ISO 9001, EN 9100, ISO 14001, ISO 50001 as well as BS OHSAS 18001 and operates an accredited laboratory according to DIN EN ISO/IEC 17025.

Global Titanium Inc.

1-313-366-5300

www.globaltitanium.com

Global Titanium is a leading producer of ferrotitanium, titanium scrap products, and titanium HDH powder. Located in Detroit, Michigan, Global Titanium serves the steel, stainless steel, aluminum, and titanium industries. Global Titanium is an ISO 9001:2008 registered company with a strong commitment to safety, quality, and customer service.

Goldman Titanium, Inc.

716.823.9900

www.goldmanti.com

info@goldmanti.com

Goldman Titanium, Inc. purchases and processes scrap titanium in order to supply the highest quality finished product to our customers. As a pioneer in the titanium industry, our company was first established in 1955, and we have continuously expanded our business over the years. Titanium is the only metal we handle, making us experts in our field.

Goldman Titanium is certified to ISO 9001: 2008 and AS9100:2009, Rev. C, complying with the rigorous requirements of the aerospace and defense industries. Our company's products have been approved by major U.S., European, and Asian melters, as well as by master alloy producers, steel and stainless steel producers, and ferro titanium producers.

Grandis Titanium

+1-949-459-2621

www.grandis.com

titanium@grandis.com

GRANDIS TITANIUM is an ISO 9001:2008 certified worldwide supplier of titanium products like Titanium Bars, Sheets, Plates and Wire for Industrial and Chemical applications. Company maintains warehouses in Los Angeles and Rotterdam, and USA sales offices in California, Ohio and Oregon. We also have sales offices in South Korea, China, Russia, Belgium and Italy.

Haynes International Inc.

+1-765-456-6000

www.haynesintl.com

rburke@haynesintl.com gspalding@haynesintl.com

Haynes International, Inc., headquartered in Kokomo, Indiana, USA, is a leading developer, manufacturer and marketer of high-performance nickel- and cobalt-based alloys used in corrosion and high-temperature applications. Our highly-trained staff and technicians provide superior customer service, worldwide technical support and one-on-one consultation in selecting the proper alloy for the application. In addition to stocking our standard product forms, our global service centers offer value-added services to shorten your cycle time, reduce material waste and increase your operation's efficiency. Haynes International is a partner in your entire material management system and provides value far beyond the alloys themselves. Additionally, Haynes produces HAYNES® Ti-3Al-2.5V alloy which is used for aircraft hydraulic systems. Our seamless Grade 9 titanium tubing is produced to AMS 4943, AMS 4944, AMS 4945, SB 338/B 338Gr9 and UNS R56320.

Hempel Special Metals GmbH

+49208 6204 0

www.hempel-metals.com

Hempel Special Metals in Germany is one of the largest stockists for Titanium, Nickel Alloy and Zirconium in Europe with companies in England, Poland, Switzerland, Italy and various sales representatives. Our main businesses are chemical process industry, flue gas desulfurization, oil & gas, medical and watch industry. Beside all standard titanium grades we stock special grades (Grade 4, 5, 5-ELI, 7, 9) in bars, sheet/plates and tubes. Our services include individual stocking, cutting, sawing, plasma, laser- and water jet cutting, individual bar marking and turning. We supply material tailor made and in packages for special projects.

Hi Tech Alloys

+1-925-937-3836

Hogue Metallography

Services Include:

- Metallographic Services
- Sample Preparation - metals and non-metals
- Documentation - macro and micro
- Interpretation of Microstructures and metallographic
- Failure Analysis
- Industrial Problem Solving
- Litigation
- Laboratory Design
- Equipment selection
- Selection of optimum consumables
- Layout

Consulting may be performed on site, in the field, or at my laboratory.
Training Courses Offered.

HORIE Corporation

+81-256-66-2237

www.horie.co.jp

a-tanabe@horie.co.jp

Horie Corporation is the world leader at surface engineering of Titanium such as precision coloring, etching, grain controlling and the solution provider to complex titanium fabrications. Horie has developed its original titanium technology using Horie's electro-chemical technology and surface treatment technology. Our titanium knowledge provides our customers with unequaled solutions in titanium. Horie will continue to develop many new products and search the unlimited possibilities and beauty of titanium.

Hudson Metals & Alloys, llc Independent Forgings & Alloys Ltd

+44-114-234-3000

www.independentforgings.com

sales@independentforgings.com

Independent Forgings & Alloys Ltd is an open die forge with expertise in titanium, nickel and steel alloys. Processing ingots to billets, rolled/hammer forged rings and flat bars through our onsite capabilities which include a 1600 tonne open die press, 2 x ring rollers, 3 forging hammers, NADCAP approved heat treatment and machining facility.

Inductotherm Corp. - Long Products Division

+609-267-9000

www.inductotherm.com

sales@inductoerm.com

President: Bernard Raffner
General Manager: Bert Armstrong
Director – Sales: Andrew Procopio
National Sales Manager: Kevin Bertermann

PRODUCTS and SERVICES - Inductotherm manufactures a complete line of induction heating and boosting systems for titanium slabs, billets, blooms, bars and rods prior to rolling. Other products include vacuum induction melting, holding, pouring, heating and coating equipment for thermal applications in air or controlled atmospheres for the metals industry. Coreless and channel furnaces with capabilities up to 500 tons; power supplies up to 42,000 kW; automatic pouring systems with vision

control; computer controls and charge handling systems.

Industrial Metals International Ltd.

+1-631-981-2300

www.industrialmetals.com

IML is a supplier of bar, sheet, tube, wire, rings and forgings in aluminum, titanium, nickel stainless steel, alloy and bronze products. In business for over 40 years, IML is approved by companies such as Rolls Royce, Boeing, Airbus, UTAS, GE, and Pratt and Whitney. Located near JFK Airport in NY, IML is able to offer same day shipping to countries worldwide with no minimum order charge for stock items.

Inteco

www.inteco.at

Being a supplier and partner to the steel and general melting industry since 1973, INTECO is proud to be until today the only single source supplier worldwide who offers and has already put into operation all production processes for the liquid treatment of steel, ferroalloys and super alloys such as:

- Melting (EAF, SAF)
- Refining (LF, VD/VOD, AOD, RH & Auxiliaries)
- Casting (CC, IC etc.)
- Special Melting & Remelting (VIM, ESR, Pressure ESR, ESRR, VAR) and Titanium Production Technologies
- Automation & Level 2 Systems (incl. Titanium-Workshops)
- Consulting Services

Invera

+1-610-325-0124

www.invera.com

peterd@invera.com

Invera is the leading supplier of ERP software for the metal distribution industry. Our STRATIX software provides advanced functions for sales, inventory control, production, shipping and outside processing of specialty metals.

Metal Specifications, Mill Test Certs and third party certificates can be controlled within STRATIX and as required emailed to customers upon shipment.

Full product traceability enables companies to have complete control and accountability of all material purchased, processed and shipped to customers.

Invera also provides INVEX for eCommerce and Customer Web Service options over the internet. Coupled with the INVEX-CRM applications companies can optimize the sales process by recording quotes, activities and tasks.

Because STRATIX was designed from the ground up for metal distributors and processors the inventory can be accessed using metal industry nomenclature. A complete solution tailor made for titanium metal companies.

Jiangsu Tiangong Technology Company Ltd.

0511-86319358

www.tggi.cn

rongjun_jiang@tiangong-tools.com

JIANGSU TIANGONG TECHNOLOGY CO., LTD was established

Titanium Buyers Guide (continued)

in 2010, is a wholly owned subsidiary of Tiangong International. The company is located in JuRong City, JiangSu Province. our company is a production, sales strategy based on titanium and titanium alloy new materials, Tiangong has smelting, forging, hot rolling, cold rolling, finishing a series of production process of finished materials, the main products are titanium ingot, titanium bar, titanium tube, titanium plate, titanium coil, hot rolled tape. Titanium wire etc..

K-Tig

1-724-325-5600

www.k-tig.com

belinda.latz@k-tig.com

K-TIG (Keyhole TIG), a variant of GTAW, is a high speed, single pass, full penetration welding technology that welds up to 100 times faster than TIG welding in materials up to 16mm in thickness, and typically operates at twice the speed of plasma welding. K-TIG reduces power and gas consumption by up to 95%, dramatically reduces labor costs and routinely delivers overall savings in excess of 90%.

K-TIG is ideally suited to Titanium, exotic materials and most corrosion resistant materials. K-TIG is a robust process with a board operating window and simple set-up requirements.

K-TIG welding requires no edge bevelling of the materials, and eliminates the need for wire consumables by autogenously welding the parent materials in both pipe and plate.

Save the time, labor, energy and cost of V-prepping your materials and eliminate the need for setting root gaps. Plus, tack welds are simply consumed in the K-TIG process. K-TIG can even be used to perform a sealing pass around the joint prior to welding if airtight purging is required for reactive materials like titanium.

K-TIG is a TIG/GTAW welding system capable of performing a traditional 6-hour TIG weld in 3 minutes, to a superior quality standard but don't take our word for it. We prefer to let our customers do the talking:

"K-TIG has significantly improved our cost position and greatly improved our delivery times. The results speak for themselves – faster welding, less consumables, less prep, cleaner welds, reduced re-work and higher quality. The machines are easy to use, simple to setup and the K-TIG team is great to work with."

Jeff Thomas, Vice President, Operations, TITAN Metal Fabrication

KASTO, Inc.

1-724-325-5600

www.kasto.com

sales@us.kasto.com

KASTO, Inc is the world's only COMPLETE supplier of Metal Cutting Machinery offering all available Metal Sawing methods. These include Band Saws, Plate & Block Saws, Cold Circular Saws & Hacksaws. Customers benefit from un-biased recommendations about which Metal-Cutting Equipment is best for their application. We also offer complete Storage and Retrieval Systems!

Kevin Kreitman, EFO

530-921-1711

klkreitman@gmail.com

Chief Kreitman has 36 years' experience in the fire service beginning his career as a firefighter in Albany, OR. He was Fire Chief with the City

of Albany from 1999 until accepting the Fire Chief's job with the City of Redding, CA in Sept. 2008. Kreitman developed significant experience during his time in Albany dealing with the numerous metal industries handling materials that presented unique fire hazards. Based on those hazards, Kreitman wrote a paper on the proper handling of titanium and zirconium metal fires.

He's a member of National Fire Protection Association (NFPA) Combustible Metals committee and has been active in the standard process with emphasis on the development of the Fire Prevention, Fire Protection and Emergency Response Chapters. He has written articles on dust & combustible metal hazards and conducted presentations at national conferences; he has assisted NFPA and the National Institutes for Occupational Safety and Health on investigations and publications dealing with combustible metal hazards, and was an author of the Combustible Metals chapter in NFPA's recent 9th Edition of the Fire & Life Safety Inspection Manual.

Keywell Metals, LLC

+1-773-572-6173

www.Keywell.com

Keywell Metals, LLC is the industry leader in specialty steel recycling and a worldwide purchaser, processor and seller of titanium scrap metal for ingot formulation, alloy additions and ferro-titanium production. In addition to the complete range of processing capabilities, Keywell Metals, LLC operates the largest and most modern fully equipped on site analytical laboratory in the scrap metal industry. Every product shipped from Keywell Metals, LLC is fully certified and guaranteed to meet Customer Specification.

Kings Mountain International (KMI)

+1-704-739-4227

www.kmiinc.net

sales@kmiinc.net

Kings Mountain International (KMI) is an ISO 9001:2008 / AS9100C certified precision grinding company.

KMI processing includes:

- Flat / Tapered / Contoured precision thickness machining
- Tolerances to +/- .001" (.0005" upon request)
- Sizes up to 110" x 360: larger sizes upon request
- Weight control for Aerospace applications
- Thin sheet grinding to .010"
- Surface Finishes from 250 RMS to 12 RMS and finer
- Polishing of sheet and plate to #3, #4 or #8 mirror. Non-directional also available

Benefits:

- State of the art measurement instrumentations
- Experience with all types of metals
- Plate / Sheets arrive clean, damage free and ready for fabrication

Industries we serve:

- Aerospace / Defense/ Energy / Commercial Aircraft / Architecture
-

KOS Ltd.

www.koswire.com

Has titanium wire drawing, heat treating and special coating facilities.

Kropp Forge

www.kroppforge.com

Kropp Forge opened as a job forging shop in 1901. Output was limited to flat die work produced on three small hammers. Today, Kropp Forge is an industry leader, producing high quality forged materials in over 450,000 sq. ft. of production space using small and large hammers as well as hydraulic presses. The plant produces a wide variety of forgings ranging from 3,000 pounds to parts weighing just a few pounds. Our Markets include: Military and Commercial Aerospace, Power Generation, Oilfield/Petrochemical, Construction Equipment, Heavy Truck and other General Industrial forgings. Materials Forged include: Titanium, Nickel Based Alloys (Inconel), Stainless Steel, Steel and other forgeable grades of material. We furnish product as forged, Heat Treated, Rough Machined and/or Finish Machined and are equipped for Non-Destructive and/or Destructive Testing.

L.C.M.A.

+352 26 55 43-1

www.lcma.lu

Mr Otis Claeys – CEO - claeys@lcma.lu

Mr Thomas Mitidieri – Production Manager - Thomas@lcma.lu

Founded in 1996, LCMA is now a fully integrated producer, processor and distributor of a wide range of semi-finished titanium and titanium alloy products for aerospace, medical, petrochemical and industrial applications.

We work with several manufacturers based in Ukraine and Europe who convert our Grade 1 to 5 ingots in forged and rolled bars, sheets, plates, coils, spools, electrodes, tubes and more. LCMA is ISO 9001:2008 and EN9100:2009/AS9100:2009 aerospace approved and is PED97/23EC certified.

Being part of a vertical structure LCMA controls quality at all production processes and all products are US, EC and HB tested. We deliver to customers all over the world and our Quality, Experience, Flexibility, Short lead time, Large stock and Competitive prices makes us one of the key players on the market.

Please contact us at fax: +352 26 55 13 45 or

Email : lcma@pt.lu

Laboratory Testing Inc.

800-219-9095

www.labtesting.com

sales@labtesting.com

The Materials Testing, Nondestructive Testing and Calibration Services offered by Laboratory Testing Inc. (LTI) help businesses deliver the highest quality and most dependable medical implants and devices. Our test results provide information necessary for product development, material verification, production control and other important business decisions.

The Lab is fully qualified:

- A2LA accreditation
- ISO/IEC 17025 certified and in compliance with ISO 13485
- Over 30 years' in the business providing certified reports
- Offering the full range of services at one convenient location
- Testing performed to industry standards, including ASME and ASTM

Technical experts and a service-focused support team help clients get their jobs done quickly and find the answers they need. With a 104,000 sq. ft. facility, near Philadelphia, PA, Lab Testing is one of the largest

independent testing laboratories in the USA and fully capable of handling and testing materials of all shapes, sizes and quantities. Call or visit www.labtesting.com for a fast quote.

LAI International

+1-518-273-3912

www.laico.com/industrial



LAI International (formerly Zak Incorporated) is a fully integrated design, fabrication, machine, and test facility. We engineer, manufacture, and refurbish crucibles, liners, molds, and accessories for the remelting and production of specialty metals. Our manufacturing and consulting experience has contributed significantly to the VAR, ESR, Plasma, EB, C.C., and EBPVD processing industries. This experience, along with our precision CNC machining capabilities, will extend your product life cycles and improve the reliability of your process. Our ISO 9001-2008 certified services include a full range of dual pallet, multi-axis CNC machining centers with live tooling; MIG, TIG, and stick welding of copper and other dissimilar metals; hydro, helium, X-ray and other available NDT services. For more information about Zak Incorporated, please visit us at www.laico.com/industrial

Laube Technology

(888)-355-2823

www.laubetitanium.com

tisales@laube.com

Laube Titanium Mill Products is a division of Laube Technology. Laube began its long history of quality and service in 1948 as a Chicago based warehouse distributor of steel mill products. Anticipating the growing influence of the Pacific Rim countries in supplying product to the United States, Laube's corporate offices were moved to the west coast in 1961. Strategically poised, Laube became an industry leader, pioneering the importation of metal products from Asia and elsewhere. Today the Laube group consist of three separate divisions. Those are: Titanium Mill Products; Offering titanium forms of sheet, plate, bar, tube, pipe, and coil from both domestic and foreign mills. The Custom Metal Parts division, which specializes in providing the industry with unique metal components usually designed for a specific use; and Electronic Components and Assemblies Division. This department supplies all types of custom control panels and keyboard assemblies. Laube is a privately held, family run company and continues in its proud heritage of providing decades of quality product at competitive costs.

Lord Steel Industry Company Limited

+86-512-62861001

www.lordsteel.com

Lord Steel International Co., Ltd. (LSI SIP), belong to LORDSTEEL, is a global leading solution provider and manufacturer agent in Tube & Pipe of Stainless Steel, Nickel Alloy, Copper Alloy and Titanium. We are specializing in high performance condenser tubes, heat exchanger tubes, high purity stainless steel tubings, Titanium alloy & Cu/Ni Alloy Tubings. We end up many year's control of UNS S44660/UNS S44735 super ferritic stainless steel condenser tubes supplied by US and European Manufacturers.

LSI People not only see our products as normal Industry products, we take them as artwork with high quality value. In every LSI people's heart, Quality is always first. High service level shall be our added value in the products. Competitive price and our promise in the lead time shall Strengthen the mutual Trust relationship between LSI people and our clients.

LOTERIOS S.p.A., a TIMET Company

+39-02-9648281

www.loterios.com

LOTERIOS S.p.A. core business: TIMET Italian Service Center (sheets, plates, bars, forgings, etc.) and leading fabricator of titanium pipe, fittings, shell and tube heat exchangers and vessels as required.

Louyang Hexin Titanium Industry Co., Ltd

Luoyang Hexin Titanium Industry Co., Ltd was founded in 2014. Our company produces titanium products since 2014, including rods, tubes, plates.

Products are widely used in petrochemical, salt. Offshore industry, energy generation and other industries. Typical applications include: Titanium and titanium alloy bar for hot-rolling; Titanium alloy standard parts; All kinds of corrosive fluid transmission pipeline system; Titanium bicycle tube; automobile exhaust pipe; Offshore aquaculture.

Luoyang Titanium Group (LTiG)

Luoyang Titanium Group, Inc. (LTiG) is the exclusive North American Representative of Luoyang Sunrui Wanji Titanium Industry Company Limited (Sunrui Wanji). Sunrui Wanji primarily produces high-quality (pure and near pure) titanium sponge for the domestic (Chinese) and international markets. In our capacity as North American Representative, LTiG is responsible for Sunrui Wanji's entrance into the North American titanium market.

Since its inception, the evolution of the black sand has been a global effort that has inspired scientists, scholars and entrepreneurs alike. We live in a global economy where free-flowing-resources, pursue global opportunities and titanium is arguably one of the best example of a global commodity, fulfilling the growing demands of a multi-nation audience of consumers. Luoyang Titanium Group Inc., along with our global partners, sees our existence and opportunity for growth, as an extension of the global titanium phenomena.

For more information about our products and services; email corporate@LTiGus.com or by calling 707-787-LTiG.

Mair Research S.p.a.

+39 0445 634 444

www.mair-research.com

salesdept@mair-research.com

Since 1977, MAIR Research has offered specialized equipment and services to the steel industry, specifically helping tube and bar producers to create profitable and efficient production processes in a safe environment.

The highest levels regarding innovation and quality are achieved through young and well experienced technical personnel, for the electrical design, software programming and the pre and after sale service.

Single stand-alone equipment or customized complete and integrated finishing lines are developed by an experienced team of technicians and are entirely manufactured in two modern production facilities covering a total surface area of 36000 sqm.

Mair Research has gained significant experience in the field of finishing lines for ERW and Seamless tubes by supplying turnkey solutions to customers in over 45 nations.

Recently a great number of producers of OCTG tubing have chosen Mair Research as supplier of their finishing lines taking the tube from the mill and delivering it in a bundle after having undergone the required finishing and testing operations (e.g. ID beam removal, chamfering, hydro testing, visual and NDT inspections, coating, automatic bundling and strapping). Data management and tube tracking are all features developed by our staff and integrated in the lines.

The range of Mair Research comprises also Bar finishing equipment with the possibility to supply fully integrated lines (e.g. peeling, straightening, multi-cutting, chamfering, automatic bundling and strapping).

Makino

+1-513-573-7200

www.makino.com



A world leader in advanced CNC machining centers, Makino is committed to providing high-performance, leading-edge machining technologies and innovative engineered process solutions that enable manufacturers to focus on making what matters. Makino offers a wide range of high-precision metal-cutting and EDM machinery, including horizontal machining centers, vertical machining centers, 5-axis machining centers, graphite machining centers, and wire and sinker EDMs.

Makino's flexible automation solutions provide reduced labor costs and increased throughput in a variety of production volumes and designs. Makino's engineering services offers industry-leading expertise for even the most challenging applications across all industries. For more information, call 1-800-552-3288 or visit makino.com.

Manufacturing Technology Inc.

Developing customized friction welding solutions utilizing Titanium and other precious metals for customers in many different industries and countries has helped position MTI as a global leader. We have over 800 friction welders on six continents, purchased by satisfied customers who include research centers dedicated to the promotion and development of innovative uses of friction welding. MTI continues to be at the forefront on how to use force and motion for advances in near net shape manufacturing. Please visit our website for full detail examples. We also provide on-site manufacturing welding services from our headquarters in South Bend, Indiana and our location in Kingswinford, England.

We are here to help you with complete technical solutions and manufacturing support by providing everything from Weld Development to Process Design, Manufacturing Services to Next Generation Manufacturing, Machine Specifying to Machine Build, Installation, and Service—a true “one stop” shop. Our approach is about working closely with your team to solve your manufacturing problems. This approach allows us to provide you seamlessly integrated manufacturing cells that meet your production needs.

Materials & Electrochemical Research (MER) Corporation

+1-520-574-1980

www.mercorp.com

The technologies MER pursues includes: Rapid Additive Manufacturing, Titanium Powder and Fabrication by Additive Manufacturing, Metal and Carbon Matrix Composites, Electrochemical Systems, Porous Materials, Coatings, Spinel and Nanotechnology. MER develops processing to produce titanium more economically that includes lower cost than sponge and downstream additive manufacturing processing to produce

low cost titanium components. These technologies include producing titanium powder directly from ore/TiO₂ at a cost substantially lower than that of Kroll sponge, engineering the Kroll process entirely in one reactor at a reduced cost, producing titanium alloy powder from ore/TiO₂ and one-step production processing near net shape alloy components at a cost of under \$10/lb.

Medart, Inc.

+1-724-752-2900

www.medartglobal.com

sales@medartglobal.com

Medart designs and manufactures centerless bar peelers, coil to coil peelers, coil to bar peelers, straighteners, fastener wire pay-off systems, take up systems, plane straighteners and engineered material handling equipment. Purpose built processing equipment for the titanium industry.

METALVALUE

+33680562848

metal@honnart.fr

METALVALUE provides strategic consulting services and invests into selected industrial companies.

Metalwerks PMD, Inc

+1-724-378-9020

www.metalwerks.com

Metalwerks PMD, Inc. produces a wide variety of specialty metals, superalloys and developmental alloys in Iron, Nickel and Cobalt based alloys. We melt current and developmental titanium alloys in ingot form from 400 grams to VAR ingots weighing up to 5000 pounds. We also convert these ingots into mill products for use by our customers.

Metalysis Ltd.

+44 (0) 1709 872 111

www.metalalysis.com

kartik.rao@metalalysis.com

Metalysis is a UK-based technology company, which has developed a proprietary process to produce metal powders at low cost using electrolysis. It is currently focused on the production of tantalum and titanium alloy powders for use in conventional and additive manufacturing, with a variety of applications in industries including aerospace, electronics, bio-medical, petro-chemical and automotive.

MetCon, LLC

+1-724-888-2172

www.MetConLLC.net

MetCon provides conditioning and finishing services for both intermediate and finished products, including bloom, billet, bar, plate, sheet, and machined or fabricated components employing a patented "Green" electrochemical technology. Product yields and costs are dramatically improved when compared to conventional processing. The technology can also provide alpha case removal, precise gauge removal, and ultra-bright micropolishing. MetCon is based in Monaca, PA, 30 miles northwest of Pittsburgh.

Mega Metals, Inc.

+1-602-258-6677

www.megametalsunlimited.com

Mega Metals Inc., is a globally recognized high quality processor of Titanium Turnings and Solids. We are certified by major mills and casting houses for prepared aerospace grade material. Our philosophy is to unite the highest quality in customer service with the highest quality of our materials, in order to serve the expanding international demands of the metals recycling industry.

METRACO NV

+32 56 234400

www.metraco.be

European traders of ferro-alloys and non-ferrous metals. Specialized mainly in ferro-titanium, titanium sponge and manganese metal. Supplying all grades of FeTi 70 % and buyers of titanium scrap and low grade sponge for FeTi production. Supplying steel grade sponge directly to steelmills and masteralloy producers worldwide.

MetSuisse Distribution AG

+41 44 586 02 74

www.metsuisse.com

info@metsuisse.com

MetSuisse reflects the precision and high quality products the industry requires. Being the first metal distribution company specializing in the medical and watch industry, MetSuisse has been able to specialize in sourcing for these industries. The stringent and precise requirements found in the medical & watch industry has given us the experience and abilities required to meet the various requests. Next to our experience we are the first metal distribution company specialized in the medical industry, and operate strictly according to ISO 13485 (Medical) and the GDP standards valid for pharmaceuticals (besides ISO 9001). Currently, we are specialized mainly in the metals titanium, zirconium, CoCrMo, medical stainless and tungsten alloys. However, you can contact us with any of your sourcing requests. We work with dedicated partners worldwide.

MetSuisse has a unique grinding facility allowing:

- precision grinding of titanium foils, sheets and plates
- technology applied for the Swiss medical and watch industry
- no min. quantities for CP Grade 1, 2, 4 and Ti6Al4V Eli
- min. 0.09 +/- 0.015 mm
- (= in inch 0.003543307" +/- 0.000590551")

Mid-West Machine

+1-205-663-0732

www.vulcangroup.com

sales@vulcangroup.com

**MID-WEST
MACHINE™**

Mid-West Machine™ provides metal conditioning equipment and systems for the Steel and Titanium industries. This includes both bonded wheel and coated abrasive belt grinders. We offer Traveling, Stationary, Gantry, Overhead, and Ingot End Grinders as well as material handling equipment for processing slabs, billets and rounds through the grinders.

Monico Alloys

(310) 928-0168

www.monicoalloys.com

info@monicoalloys.com

Monico Alloys specializes in the processing of titanium scrap in the form of solids and turnings. Monico is a Global Mill processor for Titanium

Titanium Buyers Guide *(continued)*

Scrap metal ISO 9001:2008 and approved by every major titanium melter. Monico Alloys prepares bulk-weldable solids, feedstock, cobbles, and turnings to rotor quality specifications. Monico Alloys remains the industry leader by utilizing only the latest scrap processing technology. Monico Alloys offers a wide variety of Titanium Alloy inventory which includes CP, 6-4, 6-2-4-2, 6-6-2, 3-2.5, and others.

MoTiV Metals, LLC

+1-412-200-5832

www.motivmetals.com

MoTiV Metals, LLC is an independent sales and marketing company supplying molybdenum, titanium, vanadium and other products to the global steel, titanium and chemical industries. The company has a vast array of expertise and knowledge in domestic and international sales, logistics and supply chain management.

MoTiV Metals LLC offers Master Alloys to the Titanium industry, through its relationship with BHN Special Materials Ltd, including V-Al, Mo-Al, and other alloys.

Multi-Etch LLC

(928) 634-5307

www.multietch.com

info@multietch.com

Multi-Etch is a low-acid (pH 6.8), far safer etchant for titanium and other metals, with a less toxic waste stream, when compared with hydrofluoric and nitric acids. Preparing titanium with Multi-Etch enables anodizers to produce brilliant colors and welders to achieve welds that can withstand the rigors of deep space and deep ocean uses. Multi-Etch is also used to brighten titanium mill products and tumbled titanium parts, and to erase anodizing mistakes. Industries regularly using Multi-Etch include aerospace, medical, dental, jewelry and other arts, marine, architectural, and industrial.

nanoPrecision Products, Inc.

+1-310-597-4991

www.nanoprecision.com

nanoPrecision Products is a designer, developer & manufacturer of precision products with applications in the telecommunication, data communications, consumer electronics, mil/aero and bio & medical device markets. We employ various metals in our products including titanium. The products we are introducing to the market that utilize titanium are anticipated to consume large volume of material.

Nanoscale Powders LLC

www.nanoscalepowders.com

Nanoscale Powders LLC produces a range of refractory and light metal powders, including titanium and titanium alloy powders.

The company is a startup and deploys patented sodium reduction technology to manufacture commercially pure products.

NEOTISS

+33 1 70 98 30 05

www.neotiss.com

contact.fra@neotiss.com

NEOTISS is leader in the manufacturing of titanium and stainless steel thin welded tubes serving all demanding industry markets from power generation to desalination, process, automotive and more. Our products include not only bare, straight tubes but enhanced surface tubes, such as low fin, helix and corrugated tubes as well as u-bent tubes for special applications. The highest level of quality and safety in the market is guaranteed by stringent control procedures and unchallenged technical experience. The best testimony of product quality is the long list of references, worldwide. Our R&D teams develop ambitious innovation and research programs to enhance the performance of the tubes in the toughest environments. We have high manufacturing capacities, with production mills on three continents, Asia, North America and Europe, (namely in China, France, India, South-Korea, the USA) as well as a secured access to superior quality titanium strip.

NF&M International, Inc., subsidiary of VSMPO-Tirus US, is a producer of premium quality triple melted and standard grade titanium bar and billet products for the aerospace market and manufacturer of small-diameter precision tolerance bar and seam free coil products for aerospace fastener, automotive and medical applications. NF&M also provides a wide range of conversion services, including intermediate grinding and finishing of bar/billet, heat treating, straightening, bar peeling, bar polishing, pickling and inspection. NF&M's Nadcap approved laboratory performs room temperature tensile, hardness, hydrogen analysis and micro/macrostructure evaluation.

NF&M International

www.nfm-titanium.com

NF&M International, Inc., subsidiary of VSMPO-Tirus US, is a producer of premium quality triple melted and standard grade titanium bar and billet products for the aerospace market and manufacturer of small-diameter precision tolerance bar and seam free coil products for aerospace fastener, automotive and medical applications. NF&M also provides a wide range of conversion services, including intermediate grinding and finishing of bar/billet, heat treating, straightening, bar peeling, bar polishing, pickling and inspection. NF&M's Nadcap approved laboratory performs room temperature tensile, hardness, hydrogen analysis and micro/macrostructure evaluation.

NobelClad

www.nobelclad.com

NobelClad is the world leader in the field of explosion welding. We have more than half a century of expertise, and we are the one company with the most global resources and infrastructure committed to clad, offering bi-metallic solutions for complex industrial markets, including oil and gas, chemical, and transportation. We work with global partners across the supply chain not only to deliver the highest-quality, most cost efficient clad materials on time, but to inform and help develop project specifications from the onset. Our design ingenuity, technical proficiency, and unparalleled dependability make us an invaluable resource for process architects, engineers, and fabricators alike. That's why our clad materials are the preferred specification for high stakes industrial infrastructure applications all over the world. Specialties: Explosion Welded Clad, Longitudinally Welded Pipe, Pressure Vessels, Heat Exchangers, Structural Transition Joints, Electrical Transition Joints, Cryogenic Transition Joints, Flat Plates & Cylinders, Heads, Tube Sheets.

Norsk Titanium AS

+47 97 42 22 00

www.norsktitanium.com

info@norsktitanium.com

Norsk Titanium AS is the world's pioneering supplier of aerospace-grade, additive manufactured, structural titanium components. The

company is distinguished in the aviation industry by its patented Rapid Plasma Deposition™ (RPD™) process that transforms titanium wire into complex components suitable for structural and safety-critical applications. The Norsk Titanium research and development team is committed to displacing the age old and inefficient forging process with a precision wire deposition technology embodying substantial savings for aerospace, defense, and commercial applications.
www.norsktitanium.com

North American Alloys

+1-800-985-2250

www.northamericanalloys.com

steve@northamericanalloys.com

Now celebrating our 32nd year in business, North American Alloys processes titanium alloy scrap for recycling and warehouses stocks of new and surplus lots of titanium mill products. North American Alloys warehouse in Kennewick, WA handles titanium sheet, plate, bar, billet and tubing. Please visit our website at www.northamericanalloys.com to view our current inventory of titanium products. North American Alloys is always seeking new sources of excess inventory materials in titanium, cobalt or nickel alloys and specialty metals such as tantalum, columbium, zirconium and beryllium.

Contacts: Michael Shulimson – President, Steve Meredith, Director of Sales and Peter Rockefeller, Warehouse Manager

Nu-Tech Precision Metals

+1-613-623-6544

www.nutechpm.com

shook@nutechpm.com

Nu-Tech Precision Metals manufactures by hot extrusion seamless pipe, tube, fittings, bar, rod and shapes for nuclear, aerospace, military, medical, offshore, mining, chemical, sub-sea and corrosive environments. Extruded shapes, especially those for the aerospace industry in 6Al-4V, fit within a 12" (300 mm) circle size. Our extrusion process creates a near-net shape that reduces material and machining costs overall. Our ability to alpha-beta process results in improved fatigue resistance over beta extrusions...contact us to learn more about how this process will benefit your extrusion requirements. Seamless pipe from 1.5" (40 mm) to 14" (350 mm) plus specialty sizes and wall thickness. In-house finishing options including OD grinding or machining, ID honing or boring, hot straightening, pickling, non-destructive testing and electron beam welding are a few of the services we offer.

Oerlikon

<http://www.oerlikon.com>

Oerlikon is a leading global technology group providing market leading technologies and services. Oerlikon has more than 13,800 employees at over 180 locations in 37 countries and sales of CHF 2.331 billion in 2016. The group is structured in three Segments: Surface Solutions, Manmade Fibers and Drive Systems, each operating under their own well-established brands and with their own market-specific strategies. It has a long-standing presence in Asia, particularly in the emerging markets of China and India, a strong foundation in Europe and serves the most important markets in the Americas. In 2016, the group continued to invest over 4 % of its annual total sales in R&D, corresponding to CHF 94 million, and filed 67 patents worldwide.

"Titanium Valley" Special Economic Zone" OJSC

+7-343-378-45-83

www.titanium-valley.com

welcome@titanium-valley.com

Titanium valley is the special economic zone (SEZ), based in Russia, Sverdlovsk region, where unique conditions for production organization and development are created. The territory of the SEZ is located close to the OJSC "VSMPO-Avisma" Corporation", the world's largest titanium producer, supplier of raw materials, forgings and finished production for Boeing, Airbus, Rolls Royce, Goodrich, Embraer, GE. Thus, the territory is known after the name "Titanium Valley". The companies investing in the SEZ get prepared sites with all the necessary utilities. Moreover, they are exempted from customs duty on import of capital goods, VAT as well as from the corporate profit for the first 10 years. For the moment there are 8 resident companies, organizing their production in different industrial spheres at the SEZ. The key resident is LLC "Vsmo-New Technologies", that will start their production of machined titanium components for aerospace companies, mostly for Boeing, in 2017.

The Olin Research Group

(216) 246-0221

www.olinresearchgroup.com

chrisolin@olinresearchgroup.com

The Olin Research Group is a specialized firm that offers MARKET UPDATE REPORTS for various carbon steel, stainless, specialty materials (titanium & nickel-based alloys), and aerospace company executives. We do this by leveraging our network of industry contacts (distributors, mills, producers, and buyers) and 18-years of experience in the investment world. Together, we can provide unique insights from a "top-down" or "bottoms-up" perspective. Our partners have an edge versus the competition -- for planning and up-to-date market share analysis.

The "value-add" in our research comes from the combination of charting momentum and/or highlighting inflection points. We do this by using data gathered from quarterly surveys. We provide a twist in our reports by incorporating industry models, channel sentiment gauges, and the feedback we are getting from the larger, publicly-traded companies.

Our goal is to provide customers with a different perspective on each metal/aero category, also gauging the relative health of main end-markets. We believe this gives our customers an enhanced ability to navigate through any market challenges and/or opportunities. Our data collection or indexes can also be measured against peers. Track your company's performance versus an anonymous sample group. See where you stand (by region or product category).

Perhaps you are looking for specific market intelligence? Our research team can assemble a survey that fits your needs and answers your questions.

OSAKA Titanium technologies Co., Ltd.

+81 3 5776 3103

www.osaka-ti.co.jp

OSAKA Titanium technologies Co., Ltd. manufactures premium quality titanium sponge mainly for aerospace use, high-purity titanium billet and polycrystalline silicon for semiconductor industry, titanium powder for powder metallurgy and additive manufacturing, and other titanium-silicon related products.

Oscar Production Group Ltd.

+380 56 770 1234

www.oscar-tube.com.ua

mail@oscar-tube.com.ua

Manufacturer of cold and hot formed seamless titanium tubes and rods.

Ospray™ Fire Suppression.

Ospray™ Fire Suppression is the manufacturer of Aquaxera™ Fire Suppression Agent. Aquaxera™ is a dual acting agent that is able to extinguish Titanium fires in seconds, returning the remaining material to ambient temperature. Aquaxera™ also acts as an inerting agent, reducing the ignitability of surrounding material during extinguishment. Ospray™ also does specialty sprinkler system design and system conversion from existing water sprinkler systems.

Overon Group

404-364-1799

www.overongroup.com

mikhailsb2010@gmail.com

The company has been producing valves and equipment details from titanium for more than 50 years.

Usage of high quality rolled, casted and forged blank details as well as most modern machining, welding and heat-treatment equipment provides guaranteed quality of produce. Production process of every detail is being controlled by all necessary destructive and non-destructive methods.

Paris Saint-Denis Aero

<http://www.psd aero.com>

PSD AERO is one of the main suppliers for raw materials products of key players in the aviation sector, like for example AIRBUS, SNECMA, EUROCOPTER, DASSAULT AVIATION, etc. Our Quality Management System meets the IAQG's series requirements.

With our experience and rigor acquired during the last few decades, the company consists of 90 staff members that have enabled them to increase their turnover 10 times over in 10 years.

Pat Mooney, Inc.

www.patmooneysaws.com

Pat Mooney Saws is a 3rd generation family owned and operated business that has been innovative in serving the metal sawing industry since 1949. We specialize in the sales, support, and service of metal sawing machinery and saw blades. We are the exclusive North American Sales and Service center for the following saw manufacturers: Danobat High Production Bandsaws, ishijimax CNC Carbide Cutoff Systems, FMB Precision Miter Gear Driven Bandsaws, PMI Aluminum and Non-ferrous Sawing Systems, and OMP Precision Tube and Bar Sawing Systems. Pat Mooney Saws has over 500 saw installations in North America.

PCC Metals Group

www.precast.com/

The PCC Metals Group joins together PCC's metals companies: TIMET, a vertically integrated titanium supplier; and Special Metals, a leader in nickel alloy development. With over 200 years of collective experience, each organization is an original stronghold and remains a leader in their respective industries by developing and producing specialty alloys to meet customer demands. By uniting the unique capabilities of each company, the PCC Metals Group is able to better serve customers in the specialty metals market and bring successful product solutions to market.

Perryman Company

+1-724-746-9390

www.perrymanco.com



Perryman Company is a vertically integrated producer of specialty titanium products. From melting, forging, and fabrication to finished product, Perryman's quality and technical expertise is unmatched. Our Spectralloy facility is engaged in the recycling of titanium revert raw material for use in various titanium melt processes in the manufacture of titanium ingots. Perryman supplies and services customers in the aerospace, medical, consumer, and recreation markets worldwide. Approvals include ISO9001:2008; AS9100, and NADCAP. Perryman Company is headquartered in Houston, Pennsylvania. Company offices are located in Philadelphia, Warsaw, IN, Los Angeles, London, Zurich, Tokyo, and Xi'an.

Plymouth Engineered Shapes

800-718-7590

www.plymouth.com

jlake@plymouth.com

Plymouth Engineered Shapes is the premiere provider of near-net extruded shapes for a large variety of applications. All customers want to squeeze more cost out of their parts and Plymouth Engineered Shapes offers the solution in Titanium, Stainless steel, Alloy steel, or Nickel-based alloys. Our Engineers are capable and willing to work with your design engineers to develop the most optimum near-net shapes possible to make your finished parts. No other manufacturer in North America offers so much experience in special shape technology, or provides so many value-added options to meet your product specifications.

PMA Engineering / Design Group

253-926-0884

www.pma-engr.com

PMA Engineering/Design Group brings a broad and extensive depth of engineering and operating experience in titanium to work for you. With our expanded resources, and our understanding of the critical requirements of the RG/PG world opens the door for us to benefit your organization. Our experience and ability to assist across all facets of an operation, including sponge, sponge processing, scrap and scrap handling, scrap processing, blending, melting, finishing, flattening, and other operations, allows for integrated, comprehensive solutions.

We can partner with you to Optimize Processes and assist with reviews of your operations in regards to RG/PG standards and expectations. We will utilize our experience to upgrade or replace equipment to improve or increase your production capabilities. We can provide Facility Audits, Feasibility Studies, FEED Studies, and Detailed Engineering for new process and manufacturing facilities, including the integration of your control and data systems for reporting, chronological documentation and MIS reporting. And, we can audit your processes against industry quality standards and provide paths for continuous quality improvement.

We partner to make you better.

PM International Suppliers

(863) 644-6300

www.pmfirfirst.com

info@pmfirfirst.com



We supply pipe and fittings, tubing, valves, flanges, bars, sheet and forgings with numerous worldwide sources for limitless applications.

Titanium Buyers Guide (continued)

PM International Suppliers specializes in providing products in exotic materials such as duplex, super duplex, 6% molybdenum stainless-steels, titanium, copper nickel and nickel alloys.

Industries we serve:

- Offshore Petrochemical
- Geothermal
- Chemical Manufacturing
- Aerospace
- Desalination
- Power Plants
- Water Treatment Facilities
- and more!

PMIS customers are worldwide, and we handle everything from one-off emergency deliveries to complex, long-ranging project installations.

Praxair Surface Technologies



www.praxairsurfacetechologies.com

We engineer gas atomized metal powders in a wide range of standard alloys for all your additive manufacturing techniques and applications. We've also developed a proprietary atomization process specifically designed for titanium. Out cobalt, iron, nickel and titanium metal powders for additive manufacturing flow easily and deposit evenly, resulting in successive layers with consistent density and uniform build rates. Ultimately, this helps products meet the mechanical, performance and final part specifications of 3D printed parts. Out powders are custom-engineered for specific industries – including aerospace, automotive and medical – and our chemistries and particle sizing can be modified to ensure customer's finished products performance and surface finish needs are met.

Precision Thin Metals

<http://www.arnoldmagnetics.com/Precision-Thin-Metals>

The Precision Thin Metals (PTM) business of Arnold Magnetic Technologies produces thin and ultra-thin alloys that improve the power density of motors, transformers, batteries and many other applications in Aerospace, Industrial, Automotive, and Medical markets. Customers rely on us for thin-rolled titanium in applications that demand high performance and consistent quality. Arnold's Precision Thin Metals business offers titanium products in a number of commercially pure grades and several standard alloy compositions. Our titanium and titanium alloys are available in cold rolled or annealed condition. PTM is Nadcap certified for heat treatment.

President Company Ltd.

+886-227411-190

www.presico.com.tw

presico@presico.com.tw

President Co., Ltd., established in Taiwan in 1969, is one of the largest titanium stockists in the Asia. Our business focus on the trading of high quality titanium with diverse stocks. Besides, our product includes titanium slabs, sheets, bars, wires, pipes, fasteners, castings, etc. We commit to supply the most satisfying high quality titanium materials for users with quick lead time and favorable after sales service. Currently, our sales network is well deployed all over China, Taiwan and South-East Asia countries.

President Titanium Co., Inc.

+1-800-225-0304

www.presidenttitanium.com

sales@presidenttitanium.com



President Titanium has the largest inventory of domestic 6Al/4V, 6Al/4V ELI, and Grade 4 titanium bar, sheet & and plate in the country. We have been serving the aerospace, military and medical industries since 1973. Most orders shipped in 1-2 days, call for our free booklet.

Product Evaluation Systems, Inc.

724-834-8848

www.PES-Testing.com

[Mic@PES-Testing.com](mailto:mic@PES-Testing.com)



Product Evaluation Systems, INC. (PES) is an independent testing laboratory, specializing in mechanical, metallurgical, chemical and nondestructive testing and analysis. Since 1979, PES has been proud to offer exceptional personalized response to customer needs. The company includes a team of key personnel with 20-40 years of individual experience in machining, testing and metallurgical evaluation. PES is both NADCAP and ISO 17025 accredited and holds multiple customer accreditations such as GE Aviation, Pratt & Whitney (MCL), Rolls-Royce Aerospace and ATI Nuclear. Accreditation awarded to PES covers mechanical testing, test specimen preparation, metallography, chemical analysis and nondestructive evaluation. Industry sectors include, but are not limited to, Aerospace, Power Generation, Oil & Gas, Mining and Recovery/Reclamation.

Quebec Metallurgy Center

+1-819-376-8707

www.cmqr.qc.ca



The Quebec Metallurgy Center is a technology transfer center located in Trois-Rivieres, Quebec, Canada. Our activities focus on supporting the technological development of manufacturing companies in the metallurgical sector. CMQ has developed a broad expertise on the transformation and development of advanced alloys such as titanium, zirconium, aluminum and nickel. Our semi-industrial metalworking facility is equipped for short series production with controlled atmosphere casting, induction skull melting, plasma arc melting, permanent mold, shell mold and sand mold casting; advanced welding, thermal spraying, heat treating, hot isostatic pressing, additive manufacturing (directed energy deposition, binder jetting and ultrasonic welding) and non-destructive testing.

RathGibson

+1-608-754-2222

www.rathgibson.com

inquiry@pccenergy.com

RathGibson is one of the world's leading manufacturers of precision welded tubing and pipe in both stainless and specialty alloys. From straight lengths to coil, welded and drawn, or seamless tubing and pipe, our products can be made from any of our 40 high-performance alloys so that they will reliably perform no matter how demanding or corrosive the application. At RathGibson, a successful technical process to meet any customer requirements is a priority, so that only the finest and most high quality tubing is delivered. That is why RathGibson invests in unique capabilities to develop customizable products for industries including power generation, renewable, oil and gas, petrochemical, food and dairy, beverage, pharmaceutical, and general commercial.

ReMelt Scientific, Inc.

+1-330-440-0402

www.remeltinc.com

sales@remelt.net

ReMelt Scientific is a global supplier of Titanium Chip Melt Preparation Systems and Weigh and Blend systems. We specialize in titanium and high temperature alloy chip crushing, centrifuging, aqueous wash and solvent cleaning, thermal drying, fines screening, and magnetic and gravimetric separation to prepare chips to for melting. We also specialize in Weigh and Blend systems that weigh and blend titanium chips, sponge, master alloys, aluminum, iron, and TiO₂ to achieve customer specified chemistry requirements.

Renton Coil Spring Company

+1-425-255-1453

www.rentoncoilspring.com

info@rentoncoilspring.com

Renton Coil Spring Co. (RCS) is a world-class spring manufacturer for aerospace and performance markets and has been providing superior quality parts and performance since 1949. Design and material capabilities, along with complete performance solutions has lead RCS to become a top supplier of quality springs, wire forms, assemblies, and flat metal parts with thousands of applications across the world.

Reactive Metals Studio, Inc.

+1-928-634-3434

www.reactivemetals.com

Founded 1981, a supplier of exotic metals to include titanium and niobium to the jewelry and decorative arts market. We consult, teach and supply anodizing equipment. We supply jewelry components, chain and findings in titanium. We are small order specialists catering to the medical, crafts and arts community. RMS distributes MULTI-ETCH, a user friendly titanium etch. Multi Etch prepares titanium jewelry, medical & dental components for bright, smooth anodizing without the dangers of Hydrofluoric acids.

Retech Systems LLC

+1 (707) 462-6522

www.retechsystemsllc.com

sales@rettechsystemsllc.com



Retech is the world's leading supplier of Electron Beam (EB) and Plasma (PAM) Cold Hearth furnaces for melting and refining titanium and titanium alloys. Retech advanced vacuum metallurgical systems also include Vacuum Arc Remelt (VAR), VAR Consumable (Skull) Casting, EB and PAM Consolidation furnaces, Plasma Welders, Vacuum Induction melting (VIM), Precision Investment Casting (DS/SC/EQ), Cold Wall Induction melting and casting, Vacuum Heat Treating, and Gas Atomization for metal powder production. All our furnaces are available in various sizes and configurations, from simple laboratory-scale to large, custom engineered systems. Further, we provide customer access to a wide range of in-house resources, including technology, material and process development. Identifying customer needs, as well as understanding the importance of producing relevant, viable, and cost-effective technologies, is the foundation upon which Retech is built.

Rex Heat Treat

+1-215-855-1131

www.rexht.com

chris.constable@rexht.com

Rex Heat Treat is a family owned and operated business that was founded in 1938. We take pride in our ability to partner with our customers to gain insight regarding their future needs. We are a leader in customer service and quality for the heat treating industry. Our unique furnace design allows us to water quench titanium raw material and formed parts up to 16' long to meet aerospace and medical specifications. We have furnaces capable of annealing up to 30,000 lbs. in one batch and we are approved by almost all major Aerospace companies. We have 3 locations in Eastern United States, Anniston AL., Bedford PA., and Lansdale, PA. Rex Heat Treat has experienced metallurgists on site and we offer testing services. We look forward to exceeding your expectations with timely communication and time performance.

Roll Forming Corporation

+1-502-633-4435

www.rfcorp.com

Roll Forming Corporation's Aerospace division offers Inline custom welding solutions and advanced fabrication applications. RFC's highly skilled and experienced laser welding team is NADCAP approved for a range of aerospace welding and laser welding processes. Additionally RFC offers in house NDT, CWI and NADCAP accredited inspection.

Roll Forming Corporation has taken the initiative in technical development, and collaborating with our customers to find creative solutions to overcome many program hurdles. Our laser welders put us at the forefront of the Aerospace industry in-line laser welded fabrications, RFC continues to lead the way as our inline custom welding solutions, and advanced fabrication applications are RFC's core competencies. For more information call (502) 633-4435 ext. 338.

Rolled Alloys

+1-800-321-0909

www.rolledalloys.com

sales@rolledalloys.com

Rolled Alloys, a global leader in specialty alloys, offers a comprehensive inventory in titanium, stainless steels, nickels alloys and cobalt alloys. We offer extensive processing capabilities, in-depth knowledge of material specifications, supply chain management support, and metallurgical expertise.

Rolled Alloys holds many quality approvals and certifications in the aerospace and medical industries. We are a preferred supplier to companies that are respected around the world for their exceptional quality standards.

Roskill Information Services Ltd.

+44 (0)208 417 0087

www.roskill.com

info@roskill.com

Roskill global market reports include the latest information on supply, demand, end-use applications, trade and prices for a wide range of metals and minerals including titanium, molybdenum and vanadium. Roskill reports also provide informed forecasts of future trends.

Roskill's expert researchers make a thorough and objective analysis of all available data, from sources across the globe. This includes a large and invaluable network of contacts including the key industry players in these markets, making Roskill's research unrivalled in terms of breadth, depth, accuracy and expertise.

To build on this wealth of data, Roskill also offers bespoke consultancy

services that can help to explore and understand any specific scenarios or analysis requirements you may have.

S. Letvin & Son, Inc.

+1-310-327-0590

www.titaniumscrap.com

S. Letvin & Son, Inc., specialists in processing high temperature scrap metals, has been in business since 1947. We prepare a high quality 6/4 titanium feedstock package that meets AMS 4928 Chemistry specifications. We have developed a unique and proprietary process to return mixed 6/4 titanium fasteners to specification 6/4 titanium. The final product is 6/4 titanium "Rotor Grade" feedstock; heavy, dense, clean and extremely consistent in chemistry and gases. Our 6/4 titanium feedstock package is approved and desired by most major US titanium mills, as well as many smaller investment casters worldwide.

S+D Spezialstahl Handelsgesellschaft mbH

+49-211-230999-10

www.s-d-group.com

d.verhoeven@s-d-group.com

The S+D Spezialstahl / S+D Speciality Metals Group is one of Europe's largest stockists for semi-finished high-performance materials like titanium and titanium alloys, special stainless steel for aviation and aerospace or nickel and nickel alloys.

We supply into the following markets:

- Aviation and Aerospace / Motor Sports / Defence Technology / Medical Technology
- Offshore / Petrochemical / Chemical and Process Engineering / Plant and Equipment Manufacturing / Electroplating / Turbine Manufacturing / Marine Engineering / Energy Industry / Automotive Industry / Universities and Research
- Institutes

We deliver just in time any time. At S+D we are able to cut all our materials according to our customer's exact requirements utilising our "state of the art" bar saws and plate saws. We also offer precision water jet cutting. Our just in time service provides our customers with cost savings and security of supply. S+D is aerospace approved according to EN 9120 issued by DNV GL

Sandinox Comercio, Importação e Exportação LTDA

+ 55 15 3335 3565

www.sandinox.com.br

Established in 1986, Sandinox is the largest medical distributor for the Brazilian market, offering a full range of products in titanium, cobalt, and stainless steel alloys for the medical industry. Our goal is the constant search for technologically advanced products and materials that will ensure quality and the desired satisfaction of our customers.

Sandvik Materials Technology Product Unit Special Metals

+46-26-260000

www.smt.sandvik.com



Product Unit Special Metals with two manufacturing locations (Sweden and USA) belongs to Sandvik Materials Technology and is a long term experienced manufacturer of seamless tubes and complementary

products in Titanium, Titanium alloys and Zirconium based materials for a broad range of industrial applications as well as applications within nuclear, aerospace and medical industries.

The full scale commercial manufacture, which started in 1964 is fully integrated from VAR-remelting of Titanium resp. Zirconium sponge up to finished product.

Scanacon, Inc.

330-877-7600

www.scanacon.com

At Scanacon, our mission is to help stainless, titanium, zirconium and specialty alloy finishers achieve efficient, high quality production at the lowest cost.

With over 30 years' experience as the World's preferred supplier of acid management equipment, our knowledge, experience and equipment offers the producer the ability to achieve productive, efficient and cost effective finishing operation. Our solutions have consistently proven themselves across a wide range of pickling, etching and milling applications for all wrought and cast forms.

Scanacon understands that ease of use, low maintenance requirements and efficiency is key to designing process equipment that delivers value, day after day. No two producers or applications are exactly alike. Delivering value requires a knowledge that can only be gained by experience and is why Scanacon continues to be the chosen supplier for acid management system by all major producers, worldwide.

Schaffer Grinding Co., Inc.

+1-323-724-4476

www.schaffergrinding.com

info@schaffergrinding.com

SCHAFFER GRINDING CO. is a toll processor of aerospace alloy materials including: Titanium, high temperature alloys, nickel based alloys, and ferrous materials. Processes include: Precision sheet and plate grinding (90" X 240"), band saw cutting, planer milling, rotary and surface grinding. Schaffer Grinding offers its customers coast to coast service with production facilities in California and Ohio.

Sector3 Appraisals, Inc.

+1-718-268-4376

www.sector3appraisals.com

Sector3 Appraisals, Inc. is a metals and chemicals valuation company offering a complete portfolio of asset valuations and advisory services regarding inventory, machinery and equipment and risk management.

Service Steel Aerospace

+1-800-426-9794

www.ssa-corp.com

sales@ssa-corp.com



Service Steel Aerospace is a customer oriented stocking distributor of high performance stainless steel, titanium, alloy steel, nickel based super alloy, and maraging steel. We are committed to providing quality products to the aerospace industry and other critical application industries throughout the world. SSA performs a wide array of value added processing services designed to meet the specific needs of our customers. Our commitment to the quality and service has made SSA the leader in the industry for over 40 years.

Shaanxi Lasting Titanium Industry Co., Ltd.

00 86 29 89651035 00 86 29 89651082

www.lastingtitanium.com

sales@lastingtitanium.com titanium01@263.net

Shaanxi Lasting Titanium Industry Co., Ltd. is the leading Titanium manufacturer and exporter in China. With more than 20 years' experience, we own two mills in Baoji -The Chinese Titanium City. We are mainly engaged in melting, forging, rolling and machining manufacturing line in titanium and titanium alloy, with an investment of USD 50 million. Exported 3000 mt ingots, 2500 mt forgings and 5000 mt machined parts annually. Our main products include titanium ingots, slabs, bars/rods, plates/sheets, pipes/tubes, forgings, fittings, wire, powder, standard parts, non-standard equipment and other corrosion resistant metals such as zirconium, tantalum, tungsten, molybdenum, niobium.

Sierra Alloys / TSI Titanium PRV Metals Companies

+1-626-969-6711

www.prvmetals.com



Manufacture and supply forged and rolled products in Titanium alloys, nickel-cobalt base alloys, precipitation hardened stainless and high alloy steels from small rectangular and round bar to large section size open die forged bar and stock.

Simonds Saws

www.simondsinternational.com

Manufacturer of industrial saw blades. The oldest cutting tool manufacturer in North America, Simonds offers one of the broadest and most trusted names found anywhere in the world of cutting tools. Many industries have grown to depend on the quality and innovation of Simonds products and services. We have a continuing tradition of quality, design, and innovation. Simonds has innumerable patents, a global leader in high-performance and high-production sawing. The first bandsaw manufacturer in the world to be ISO certified and we remain certified so today. We set our goals high and our customers have grown to expect it.

Since 1832... The Professionals' Edge.

Solar Atmospheres

+1-855-934-3284

www.solaratm.com

info@solaratm.com



Solar Atmospheres provides vacuum thermal processing for titanium material, parts, forgings, and weldments. With the world's largest vacuum furnaces up to 48 feet long, Solar is capable of vacuum processing furnace loads of bar, billet, sheet, and plate up to 150,000 pounds under 1X10⁻⁶ torr vacuum levels. Specific heat treat services provided are: degassing, beta annealing, homogenizing, age hardening, creep forming, hydriding/dehydriding, stress relieving and Fluorescent Penetrant Inspection. Solar is Nadcap, ISO9001:2008 and AS9100C Registered and Boeing approved in heat treating, NDT (Non-destructive testing) services and BASCA (Beta Anneal Slow Cool Age). Solar Atmospheres serves customers with plants located in Pennsylvania, South Carolina, and California.

Solar Manufacturing, Inc.

+1-267-384-5040

www.solarmfg.com

info@solarmfg.com

Solar Manufacturing designs and manufactures high performance, technically advanced and energy efficient vacuum heat treat furnaces. Models range from compact R&D size furnaces to mid-size horizontal production furnaces to huge car-bottom vacuum furnaces for large heavy workloads. Our furnaces feature improved graphite insulation materials, curved graphite heating elements, tapered gas nozzles, high velocity gas quench systems, SolarVac® 4000, and 5000 interactive control systems, and ConserVac energy management system. We design for vacuum heat treat processes such as hardening, brazing, annealing, stress relieving, normalizing, tempering, sintering, low pressure carburizing and vacuum gas nitriding. Solar knows vacuum heat treating inside out. Our engineers and metallurgists bring decades of expertise to the design side of the business and our knowledgeable technicians provide world-class manufacturing keeping Solar in the forefront of vacuum furnace innovations. As an ITA member company, Solar welcomes the opportunity to assist our customers in choosing the right vacuum furnace, replacement hot zone, spare parts and service for your needs.

Specialty Metals Company

+32- 2645-7670

www.uktmp.kz

Sylvain.gehler@specialtymetals.be

Danielle.vanoverschelde@specialtymetals.be

Specialty Metals Co is the major shareholder of UKTMP (Ust Kamenogorsk Ti Mg plant) located in Kazakhstan. UKTMP produces Ti sponge, CP and alloy ingots and slabs.

Specialty Metals Processing, Inc.

+1-330-656-2767

www.specialtymetalspro.com

bwilson@specialtymetalspro.com



Specialty Metals Processing (SMP) is a leading processor of titanium plates, slabs, sheets and coil. Located in northeast Ohio, SMP has one of the largest abrasive belt grinding and polishing operations in the U.S. Our 170,000 sq. ft. facility houses multiple processing lines. We are your reliable source for precision grinding where we can accommodate widths up to 72", material thickness up to 10" and lengths up to 240". We are your reliable source for gantry grind services where we can accommodate widths up to 144", material thickness up to 24" and lengths up to 1200". In addition, we are your reliable source for pinch roll grinding, alpha case removal and reconditioning.

- Precision grinding up to 72" wide and 244" long
- Ability to polish/grind/recondition plate/slabs up to 12' wide by 100' long
- Providing #3, #4, # 6, brushed or matte finishes or custom matched abrasive belt finishes, one or two sides.
- Providing #7 and #8 buff finish on stainless coil
- Offering special inspections, packaging, line marking & PVC options
- ISO 9000 certified since 1996
- Offering one stop shopping on many orders
- Same day quoting on most inquiries
- One sheet or truck load quantities, no order is too big or too small

Please visit our website at www.specialtymetalspro.com

Spectore Corporation

954-481-8422

www.spectore.com

info@spectore.com

Spectore Corporation was founded in 1983 to reinvigorate the 3,000 year-old traditions of the jewelry industry with its introduction of titanium as a new noble element. New technologies were perfected to manipulate this extremely tenacious and non-traditional metal. The company's ambitious designers and R&D team have persistently explored the potential of titanium to create truly unique collections. This resulted in being awarded the 2010 Titanium Development and Advancement Award by the ITA. Today Spectore remains dedicated to the development of new methodologies for the design, engineering and manufacturing of high-end consumer products made of titanium.

Spectore Corporation designs and manufactures for a range of world class brands focusing on consumer products from household, sporting, technology, apparel, corporate gifting and jewelry. Spectore Corporation has also developed their own in house designer brand, Edward Mirell which has won a wide range of national and internationally recognized design awards.

Standard Die

www.standarddie.com

Standard Die is a full-service metal stamping and drawing company. We specialize in small parts made from a wide range of specialty metals ranging from coppers to refractory metals and other exotic materials. Our service, product quality and speed are unmatched in the industries we serve. We cultivate partnerships with our customers and you can work one-on-one with our design engineers and enjoy an active role in the design and manufacturing of your product.

Starrag USA Inc.

+1-859-534-5201

www.starrag.com

ussales@starrag.com

Bumotec develops and manufactures high-precision multi-functional machine tools for complete machining of small work pieces for the medical industry, such as curved bone plates, titanium implants, instruments and devices. The special challenges of the medical industry requirements such as extreme surface quality and precision, as well as economical requirements such as small batch manufacturing and low stock inventory, become feasible with Bumotec equipment. From prototype to unmanned 24/7 manufacturing, Bumotec offers a wide range of economical solutions.

Starrag Group products are marketed under the following strategic brands: Berthiez, Bumotec, Dörries, Droop+Rein, Heckert, Scharmann, SIP, Starrag, TTL, and WMW. Headquartered in Rorschach/Switzerland, the Starrag Group operates manufacturing plants in Switzerland, Germany, France, the UK and India and has established a network of sales and services subsidiaries in numerous other countries. Starrag Group is listed on the SIX Swiss Exchange (Symbol: STGN).

Strohecker Incorporated

+1-330-426-9496

www.strohecker.com

Well-established specialist in the fabrication and repair of copper crucibles, hearths and related equipment used in VAR, ESR, EBM, PAM,

as well as various similar processes. Serving producers of the reactive metals and alloys, nickel alloys, refractory metals, and steel alloys.

Structure Medical, LLC

Structure Medical is a leading manufacturer of medical implant products that are used by orthopedic surgeons to treat disorders of the musculoskeletal system. Orthopedic surgeons use these medical devices to treat trauma, sports injuries, degenerative diseases, tumor and congenital conditions.

Structure Medical was founded in Naples, FL in 2004 and established a second facility in Mooresville, NC two years later. The company uses the most advanced machine tooling available around the world to produce products that meet the highest quality standards.

Sumitomo Corporation Of Americas

+1-847-384-5275

www.sumitomocorp.com

shinya.kuriyama@sumitomocorp.com

Sumitomo Corporation of Americas (SCOA) is a wholly-owned subsidiary of Sumitomo Corporation, which is one of the leading trading companies in Japan. SCOA is an integrated global trading firm with diversified investments in a wide variety of industries, products and services.

Supra Alloys, a division of Titan Metal Fabricators

805-388-2138

www.supraalloys.com

sales@supraalloys.com

Supra Alloys offers a fully-stocked Titanium Service Center with the convenience of extensive in-house processing capabilities. Located in Camarillo, California USA, Supra routinely provides Titanium for applications in the aerospace, chemical processing, medical, metal finishing and sports/recreation industries throughout the world.

T-M Vacuum Products, Inc

856-829-2000

www.tmvacuum.com

eurbanski@tmvacuum.com

T-M Vacuum Products has more than 50 years' experience designing and manufacturing various standard and custom size vacuum furnaces and vacuum ovens in both rough and high vacuum configurations with temperatures up to 2,000°C.

We specialize in all metal hot zones and strive to create the best vacuum furnaces and vacuum ovens possible. Our team of experienced engineers and highly skilled technicians build the best systems in the industry. Our systems typically exceed 20 years of life in a full-time 24/7 production environment. This means that each vacuum furnace and vacuum oven, you purchase from us is the most advanced and cost effective on the market.

As an ITA member company, T-M Vacuum is more than happy to assist customers in choosing the right vacuum furnace to meet their needs. Contact us or visit our web site for more information

TE Wire & Cable

+1-201-845-9400 1-888-4TE-WIRE

www.tewire.com
sales@teewire.com

TE Wire & Cable LLC, a Marmon Wire & Cable/Berkshire Hathaway Company, is a premier thermocouple and specialty wire and cable manufacturer that was formed from the Wire and Cable Division of the Thermo Electric Corporation. Since 1941, the company has been manufacturing high-quality wire and cable solutions for the thermosensing and temperature measurement markets. TE Wire & Cable manufactures a full line of thermocouple wire and cable—from iron and nickel-based alloys to copper instrument and control cable. The company maintains an in-house ISO17025 Accredited laboratory directly certified by the National Institute of Standards and Technology (NIST), allowing it to calibrate its own wire. This results in a higher quality product at a lower cost and with improved performance. TE Wire & Cable is highly regarded as the industry leader and has maintained a reputation for providing high-quality temperature measurement wire and cable products with short lead times and competitive prices. TE Wire's thermocouple wire and thermocouple extension cable solutions can be used for several metallurgy applications, including heat treatment, component testing, furnace surveys and metals production.

Tekna Plasma Systems

www.tekna.com

Tekna offers spherical titanium powders specifically engineered for additive manufacturing applications.

These powders are produced by inductively-coupled plasma, a proprietary technology developed by Tekna which leads to high-purity powders having high density and flowability.

The Council for Scientific and Industrial Research (CSIR)

+27-128412600

www.csir.co.za

The Council for Scientific and Industrial Research (CSIR) is South Africa's leading national research and development organization. The Titanium Centre of Competence (TiCoC) within the CSIR has a mandate to develop technology building blocks needed to establish a new South African titanium industry. The TiCoC is developing a suite of complementary technologies to add value to South Africa's vast resources of titanium. This programme primarily focuses on the development and commercialisation of cost-effective processes for primary titanium metal production and its conversion into finished and semi-finished products. The recently established Titanium Pilot Plant situated on the CSIR campus, is an important milestone in this entire process. Parallel to this the TiCoC is developing and adapting technologies to consolidate "low-cost" titanium powders into products. Formal collaboration agreements have been signed between the CSIR and global companies such as Boeing, Airbus and EADS. These mutually beneficial agreements support South Africa's long-term economic development goals that include the supply of titanium to many industries, including aerospace.

The Pennsylvania State University

Materials research conducted by iMatSE students and faculty lead to advances and discoveries that become the building blocks of tomorrow. Through formal coursework in small classes and participation in cutting-edge sponsored research, students in the Intercollege Graduate

Degree Program in Materials Science and Engineering enjoy a graduate education that prepares them well for their future careers.

iMatSE students receive full funding (stipend and tuition) in the form of fellowships or research assistantships. Program Highlights:

- Penn State ranked #1 in funded materials research in the US (NSF)
- Thesis-based Ph.D. and M.S. degrees
- Multi-disciplinary research programs and centers
- Over 50 MatSE and affiliated faculty members
- Approximately 150 current graduate students
- Specialized laboratories and shared facilities

Thermo Scientific

Thermo Scientific delivers best-in-class handheld and mobile x-ray fluorescence (XRF), near infrared (NIR), Fourier Transform Infrared (FTIR), and Raman-based analytical instruments to meet customers' most demanding applications. Our Niton XRF analyzers serve metal processing, manufacturing and recycling customers in more than 75 countries, with more than 40,000 units installed worldwide. A culture of innovation and a distinguished history of breakthrough achievements have defined our instruments since we released the first handheld XRF analyzer in 1994. Now, with the introduction of the Thermo Scientific Niton XL5, the fastest, most accurate and smallest XRF alloy analyzer has arrived. Part of the Niton family of industry-leading instruments, Niton XL5 offers energy, metal fabrication and automotive industries performance, portability and speed never before seen in a handheld analyzer.

TiFast

+39 0744 736 307

www.tifast.com

info@tifast.com

TiFast is a European producer of titanium ingots, slabs, billets, bars and wires for industrial, medical and aerospace markets worldwide.

TiFast is fully integrated with a melting plant (3 melting furnaces including a VAR), a rolling mill, a bars precision finishing shop, laboratories and R&D facilities.

TiFast can supply bars in a full range of titanium grades with a lot of possibilities of finishing: close tolerances (from h7), surface finishing, straightening...

TiFast is certified ISO 9001, AS 9100, ISO 14001 for environmental, AEROSPACE NADCAP, TUV ADWO and PED for pressure equipment.

Timesavers International B.V.

+31 (0) 113 239910

www.timesaversint.com

timesaversint@timesaversint.com

Manufacturer of wide-belt grinding and brushing machines for stainless steel sheet and coil finishing; lasercut, punched, routed and flame cut deburring and edge radiussing; cast iron, ferrous, non-ferrous and titanium high precision calibration. Timesavers is based in Goes, The Netherlands, with regional offices around the globe in Shanghai (China), Taichung (Taiwan), Kuala Lumpur (Malaysia) and Timesavers Inc, in Minneapolis (USA). Worldwide the company has more than 200 employees supported by a network of local dealers and partners.

TIMET, Titanium Metals Corporation

+1 610-968-1300

www.timet.com



First in Titanium Worldwide

Titanium Metals Corporation (TIMET) is one of the world's largest fully integrated titanium producers. Since 1950, TIMET has been leading the industry in mill and melted products, supplying nearly one-fifth of the world's titanium. We convert rutile ore into sponge; melt and refine ingot and slab; and manufacture mill products. TIMET has a global network of service centers supported by its seven primary melting or mill facilities in Henderson, Nevada; Toronto, Ohio; Morgantown, Pennsylvania; Vallejo, California; Witton, England; Waunarlwydd, Wales; and Ugine, France. With products ranging from sophisticated high temperature alloys used in jet engines, to advanced corrosion resistant alloys used in the chemical industry, TIMET's reach spans the breadth of the titanium applications, and has the technical depth to support developments across a wide range of applications. TIMET's fully integrated supply chain, dedicated research facilities, and decades of experience make us the partner of choice for titanium.

Certified UNI EN ISO9001:2008 and UNI EN 9120:2010, With 20 years of experience, Titanium Consulting and Trading, based in Florence, Italy, with a distribution center in Milan and affiliated offices and distribution centers in both Germany and England, is a privately owned stockist/distributor of titanium mill products.

Being a major supplier in the European market for titanium mill products and its alloys, we can guarantee a prompt delivery for products including ingots, slabs, round bars, hexagonal bars, profiles, welding wire, plates, sheets, coils, tubes and pipes, as well as fasteners, forgings, flanges and fittings. Most ex-stock materials are shipped the next working day with full traceability for all items supplied.

Products supplied are employed in a wide range of applications, including aerospace, medical devices, industrial, chemical.

In 1996, Titanium Consulting & Trading further expanded its operations by setting up dedicated facilities to manufacture finished products on request. Processes available include cutting, welding, forming, turning, heat treatment and finishing.

TIODIZE Company, Inc.

+1-714-898-4377

www.tiodize.com

- Titanium Anodize
- Aluminum Anodize
- Dry film Lubricants
- Corrosion Coatings
- Paints & Primers
- Teflon Coatings
- Manufacturers of Composite Parts (Carbon & Glass)

Titanium Engineers

+1-281-265-2910

www.titaniumengineers.com

TITANIUM ENGINEERS supplies Titanium Bar, Seamless Tubing and Finished Components for oilfield and other industrial markets. Our capabilities include the expertise to process titanium to meet demanding and unique customer specifications. We specialize in bar, seamless titanium tubing and also offer products manufactured by: forging, rolling, and machining using common ASTM grades of titanium including: Titanium Grade 5, Titanium 6-2-4-6, Titanium Beta-C. With our metallurgical background we will support your team from design, through prototyping, and finally into full-scale production of components.

Tipro international co ltd

+86 29 89181603

www.tipro-international.com

terry@tipro-international.com

Tipro produce aerospace titanium bars and wires for many years and signed LTA with some famous aerospace companies.

As a AS9100 and EN 9100 approved company, we can supply titanium products as follow: AMS 4921; AMS 4928 ; AMS 4965; AMS 6931; AMS -T-9047 ; BS TA11 ;

Titanium Fabrication Corporation

+1-973-808-4961

www.tifab.com



A World leader for over 45 years in the application, design and fabrication of quality Titanium and Zirconium process equipment, whether solid or clad construction. Extensive experience in rotating, offshore, marine or ordinance equipment. Most extensive titanium field welding/erection service capability in the world. Mill products available from stock. For more information email bbrownlee@tifab.com.

Titan Engineering Pte Ltd.

(+65) 6853 7424

www.titanium.com.sg

sales@titanium.com.sg

Titan Engineering is a Singapore based distributor of Titanium, High Temperature metal & Specialty alloys. Titan has an extensive stock of prime titanium metal plates, sheets, round bars and welding rods in CP grades and Ti6Al4V grades. Our supply range includes Nickel, Inconel®, Monel®, titanium heat ex-changer seamless & welded tubes and MMO coated anodes. Titan is an approved supplier to Rolls-Royce and other major OEMs. Let Titan be your partner in your titanium procurement

Titanium Finishing Company

+1-215-679-4181

www.titaniumfinishing.com

melinda@titaniumfinishing.com

melanie@titaniumfinishing.com



Metal finishing services include: Titanium Anodize; Hardcoat Anodize of Aluminum; IVD Aluminum Coating; and Application of Solid Film Lubricants. We are a small, women owned business, and have been family owned and operated since 1970.

Titanium Industries, Inc. (T.I.)

+1-973-983-1185

www.titanium.com

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T.I. is the global leader in specialty metals supply for the aerospace, medical, industrial and oil & gas markets. Holding the world's most

TITANIUM Consulting & Trading S.r.l.

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info@tct.it

Titanium Buyers Guide *(continued)*

complete inventory of specialty metals across a global service center network, T.I. delivers supply solutions at all levels of sophistication and complexity. With a globally experienced and technically driven team, T.I. has been providing dependable, quality driven service to our customers since 1972.

Titanium International Group SRL

+39-051-6814893

www.titanium.it

tig@titanium.it

TIG is an European stockist and distributor of Titanium, Nickel alloys and Steels for Aerospace, Medical, Automotive and other high demanding end use markets.

TIG is EN9100 and EN9120 certified and has several customers approvals. TIG provides cut to size services with more than 30 saw cut machines and 3 dynamic waterjet cut machines.

Contact us for a quotation! Your mission is our priority!

Titanium Processing Center

+1-888-771-9449

www.titaniumprocessingcenter.com

AS 9100 and ISO 9001 certified, Titanium Processing Center is your go to source for quality titanium products. Titanium Processing Center is a stocking distributor of a wide range of titanium mill products. Our standard inventory of titanium bar, sheet, plate, tubing and pipe is complimented with specialty fasteners, fittings, forgings and fabrications. In-house capabilities include waterjet & saw cutting, shearing, turning and drilling.

All material is mill certified and fully traceable to the original manufacturer. Our dedicated staff is committed to providing our customers with the courteous and prompt attention that they deserve. Delivering quality products on-time and in compliance with your requirements remains our priority at Titanium Processing Center.

Titanium Products and Consulting, Inc.

+1-412-779-6358

www.titaniumproductsandconsulting.com

The focus of Titanium Products and Consulting, Inc. is primarily in two areas. The first is a consulting role for titanium and titanium alloy products, processes and applications. The second is to provide manufacturing and conversion capability with value added properties to enhance your applications performance and lower the overall cost. The ultimate goal is to provide enhanced customer service and technical assistance to make it easier and cheaper for new applications to be developed.

TMS Titanium

+1-858-748-8510

www.tmstitanium.com

info@tmstitanium.com

TMS Titanium is a leading supplier and stocking distributor of titanium mill products to a variety of industries including, aerospace, medical, racing and commercial. By combining product and industry knowledge, commitment to specialty industries, access to titanium and reliable inventory, TMS is able to consistently provide titanium to its customers in order to keep their production moving forward. TMS works with their trusted network of suppliers, finishers and fabrications to fulfill their

customers' specific titanium needs, while producing the best quality products available.

Toho Titanium Co., Ltd.

+81 467 87 7023

www.toho-titanium.co.jp

Toho Titanium Company, Ltd. manufactures titanium metals such as premium quality titanium sponge for aerospace and other applications, titanium ingot (CP and Alloy), high purity titanium ingot/billet for semiconductor industry and electronic materials including high purity titanium dioxide and ultra-fine nickel powder etc.

Trepanning Specialties, Inc.

+1-562-633-8110

www.trepanningspec.com

Trepanning & machining services. Specializing in hollow bar conversions to pipe, tube, ring and sleeves. Size capacity up to 55" O.D., 21" I.D. yielding a 26" core & can saw cut up to 22". Work with stainless steel to more "exotic" high temperature materials like Titanium, as well as non-metallic materials such as plastic and wood. Full machine shop offering trepanning, gundrilling/BTA, turning, saw-cutting, facing & specialty emergency services. We offer blind shipments. Material can be provided. Family run and Veteran owned since 1973. Contact us via phone (562)633-8110 or email: trepan_spec@yahoo.com.

Tricor Metals

330.264.3299

www.tricormetals.com

info@tricormetals.com



Introduction

We are a woman-owned, small business with facilities in Wooster, OH, Conroe, TX, Plymouth, MI and Oxnard, CA with over 25 years' experience in the supply of titanium mill products, titanium forgings and fabrication of ASME Code equipment for the petrochemical, pharmaceutical, mining, aerospace, and bio-medical served markets.

What we do

We provide quick-ship service center sales and processing of ASTM and AMS grades of titanium mill products and titanium forgings. We also design and build fabricated process equipment built with the most advanced corrosion resistant metals, provide reactive metal and high alloy welding repair services, and supply high performance welding wire.

Where are our facilities

Our fabrication and distribution facilities are in Wooster, Ohio and Conroe, Texas. We also operate technical sales facilities in Plymouth, MI and Oxnard, CA.

Titanium mill products & custom forgings

We maintain one of the world's most complete inventories of titanium mill products in ASTM grades for corrosion including sheet, plate, pipe, fittings, bar, billet, wire, tubing, and fasteners. And we maintain staged billets for custom forgings. We offer advanced processing including water jet cutting, saw cutting, and shearing. We provide custom parts manufacturing and just-in-time inventory for 'blanket' order processing to meet our customer's needs. We stock AMS-grades of titanium sheet, plate, bar and billet for aerospace and bio-medical served markets.

Fabrication of advanced corrosion resistant metal

In our ASME code shops in Ohio and Texas we build custom process equipment including: tanks, towers, pressure vessels, piping spools, shell & tube heat exchangers, plate and frame heat exchangers, and

Titanium Buyers Guide (continued)

custom welded parts. We specialize in advanced metals for solving corrosion such as titanium, tantalum, zirconium, niobium, nickel alloys, duplex stainless and stainless steel.

Field and factory weld repairs

Our repair teams can be mobilized globally for field work. Or we can repair in our facilities. We specialize in welding of advanced corrosion resistant metals like titanium, tantalum, zirconium, niobium, nickel alloys, duplex stainless and stainless steel. Available with 24 hour notice for emergency repairs.

Astrolite® Alloys - Welding wire and titanium for aerospace

We stock, process, clean, process, and package UltraGrade™ high performance welding wires for aerospace, power, and turbine engines.

TZMI, Inc.

+1 281 956 2500

www.tzmi.com

marketing@tzmi.com

TZMI is an independent consulting company that works with a wide range of global clients to provide insight and expert advice on opaque mineral, metal and chemical sectors. Our uniqueness is that TZMI contains technical and operational experience, together with strategic and commercial competency, to provide a full service offering to our clients.

As trusted advisors, our reputation is underpinned by having an experienced cross-section of technical specialists around the globe. TZMI partners with clients from the private and public sectors to provide bespoke solutions across markets and strategic services; and also technical and engineering services. Our clients range from the world's 500 largest companies through to mid-sized companies and small businesses.

TZMI regularly releases market reports and periodicals on relevant subject matters which support the consulting activities and ensure up-to-date, high quality and comprehensive data, analysis and information is provided. TZMI annually hosts the largest titanium and zircon industry conference. Email: marketing@tzmi.com

Ulbrich Stainless Steels & Special Metals, Inc.

+1-203-239-4481

www.ulbrich.com

information@ulbrich.com



Ulbrich Stainless Steels & Special Metals, Inc., is a leading processor of a variety of different alloys including, but not limited to: stainless steels, PH grades, nickel and nickel alloys, cobalt alloys, niobium, zirconium, titanium and titanium alloys. Commercially Pure Titanium: Grade 1, Grade 2, Grade 3, Grade 4, and Titanium Alloys: Grade 9 (Ti 3-2.5), Ti 15.3.3.3 and 21s (Ti Beta21s), as well as the aforementioned metals are available in strip, foil, flat, round and shaped wire. Nitinol, Grade 5 (Ti 6-4) and Ti 6.2.4.2. are available in limited widths at Ulbrich. Please inquire for more detail on all of our product offerings.

United Alloys & Metals, Inc.

+1-562-273-7004

www.uametals.com

United Alloys & Metals is one of the World's leading processors of all grades and forms of Titanium Scrap for all Titanium applications. Both our Santa Fe Springs, CA and Columbus, OH plants have full processing

capabilities and are certified to ISO 9001:2000 standards.

United Performance Metals

888.282.3292

www.upmet.com

sales@upmet.uk



www.upmet.uk

sales@upmet.uk

United Performance Metals (UPM), an O'Neal Industries affiliate company, is a global distributor of high-performance metals serving customers in a variety of industries, including aerospace, fastener, medical, power generation, oil and gas, semiconductor and many others.

UPM offers a comprehensive inventory of products, including stainless steel, duplex stainless steel, Prodec®, nickel alloys, cobalt alloys, cobalt chrome moly, titanium, aluminum, and alloy steel in coil, sheet, strip, plate, bar and near net shapes.

FIRSTCUT+® Processing Services include cut-to-length, leveling, slitting, edging, chamfering & facing, shearing, laser cutting, laser gauge measurement, water jet cutting, plasma cutting, sawing, precision cold saw cutting, precision blanks, first stage machining, heat treating, boring, trepanning and deburring.

Our certifications include AS9100, AS9100 Belfast, ISO 9001, ISO 9001 Belfast, ISO 13485, GE S1000, Pratt & Whitney LCS, And Laser Machining/Cutting Approvals NADCAP AC7116, GE-S422 and Pratt PWA 119.

United Performance Metals is headquartered in Cincinnati, OH and maintains sales and stocking locations in Oakland, CA, Los Angeles, CA, Hartford, CT, Chicago, IL, Greenville, SC, Houston, TX, Belfast, Northern Ireland, Budapest, Hungary and Singapore. For more information, visit www.upmet.com.

O'Neal Industries (ONI), the largest family-owned group of metals service centers in the United States, is the parent company of United Performance Metals. With sales of approximately \$2.1 billion in 2016, ONI is based in Birmingham, Alabama, and has more than 80 specialized facilities throughout North America, Europe and Asia.

Uniti Titanium

+1-412-424-0440

www.uniti-titanium.com

Uniti Titanium brings together two major global titanium producers with complimentary manufacturing and technical capabilities, Allegheny Technologies Incorporated (ATI) of the United States, and VSMPO-Avisma (Verkhnyaya Salda Metallurgical Production Association - Berezniiki Titanium - Magnesium Works) from Russia, to create a joint venture focused on titanium mill products for industrial and other non-aerospace, non-military and non-medical markets. Uniti Titanium integrates the synergistic use of raw material, melting, hot rolling, finishing, research and technology resources of the two companies.

Universal Technical Resource Services, Inc.

+1-856-667-6770

www.utrs.com

Engineering services company, primarily focused on delivering services to the US Government. UTRS maintains a research and development facility working with material science projects, specifically with titanium and titanium alloys.

UTC Aerospace Systems

+1-216-429-4227

www.utcaerospacesystems.com

Provide, Manufacture and Assemble landing gear for the aerospace industry.

Verder Scientific, Inc

+1-267-757-0351

www.Verder-Scientific.com

Info@Verder-Scientific.us

Verder Scientific Inc., comprised of the Retsch, Carbolite Gero, and ELTRA brands sets the standard in high-tech scientific equipment serving research institutions, analytical laboratories as well as manufacturing companies for decades. The company manufactures and supplies instruments for sample preparation, elemental analysis as well as heat treatment of solid materials.

Verichek Technical Services, Inc.

+1-412-854-1800

www.verichek.net

Sales@verichek.net

Verichek Technical Services, Inc. is a third party service supplier to the metals industry. As an ISO/IEC 17025:2005 Accredited Laboratory for PMI Testing and OES Calibration - We sell, service, and calibrate OES Instrumentation. We are also offering rental and refurbished instrumentation for cost-effective solutions to our customers. We are now offering preferred 2017 Service Contract pricing – we offer customized annual calibrations, 24/7 phone and web support, emergency repairs, discounted parts, training, and much more! Visit our site or call us to learn more!

Vested Metals International LLC

904-495-7278

www.vestedmetals.net

info@vestedmetals.net

Vested Metals International is an ISO 9001 and AS9100 certified raw material specialty metals distributor with decades of experience specializing in hard to find alloys, grades, and sizes. We offer various grades of stainless steel, titanium, tool and alloy steels, aluminum, and high temperature nickel and cobalt based alloys. We pride ourselves on helping customers meet and exceed niche requirements.

VSMPO - AVISMA

+7-34345-55764

www.vsmpos.ru



VSMPO-AVISMA, the world's largest producer of titanium, holds more than 300 international quality certifications and approvals at major aerospace OEMs and medical device companies. VSMPO-Tirus operations in the US, the UK, Germany and China provide regional sales, distribution and service center processing.

VSMPO - Tirus, US

+1-720-746-1023

www.vsmpos-tirus.com



VSMPO-Tirus, US is the North American sales and distribution division of VSMPO-AVISMA, the world's largest producer of titanium, holding more than 300 international quality certifications. VSMPO-Tirus US distributes ingot, forgings, slab, sheet, plate, bar, and billet to the aerospace, medical, and consumer products industries. VSMPO-Tirus US also manufactures small diameter bar and coil for medical and aerospace fastener applications.

VSMPO - Tirus China Ltd.

+86 10 8455 4688



VSMPO-Tirus China Ltd. is the Chinese sales and distribution division of VSMPO-AVISMA, the world's largest producer of titanium, holding more than 300 international quality certifications. VSMPO-Tirus China distributes ingot, slab, sheet, plate, bar and billet to the aerospace, medical, and consumer products industries.

VSMPO Tirus GmbH

+0049 69 905477-25

www.vsmpos.de



VSMPO TiRus GmbH is responsible for the sales and distribution of titanium semi-finished products in Europe (except the UK), Brazil and Israel to the aerospace, medical and automotive industries. The company was established in 1999 in Frankfurt/Main. The German affiliate of the largest vertically integrated international titanium producer VSMPO-AVISMA offers optimum service, including custom-made processing of semi-finished products as well as a comprehensive transport service. We offer cut-to-size material (bars, billets, sheets and plates) to meet our customers' individual operational needs. TiRus GmbH also distributes electrodes, ingots, rolled rings and different types of forgings.

VSMPO Tirus UK Ltd.

+(0) 1527 514111



VSMPO Tirus UK Ltd. is the UK's sales and distribution division of VSMPO-AVISMA, the world's largest producer of titanium, holding more than 300 international quality certifications. Tirus UK distributes ingot, forgings, sheet, plate, bar, and billet to the aerospace, medical, and consumer products industries.

VSMPO Titan Ukraine Ltd.

+380 562 313092

www.tw-vsmposavisma.com



VSMPO Titan Ukraine Ltd. is fabricator of seamless tubular products from titanium and its alloys. It is a part of the world's largest producer of semi-products and finished titanium products - JSC Corporation VSMPO-AVISMA (Russia) which supplies billets and bars to the plant. It is guarantee of quality competitiveness of manufactured production for the customers. Annual production capabilities of the enterprise is 700 tons of cold-finished titanium tubes (diameter 3-134 mm and wall thickness 0,2-9 mm), and in cooperation additionally 200 tons of hot-finished titanium tubes (outside diameter 169-325 mm and wall thickness 7-30 mm). Engineers and technical specialists are developing new technologies of titanium tubes production and new types of products. For example, octahedral and ribbed tubes, special kind of thin tubes for silphons, technologies of long-length tubes production, etc. VSMPO Titan Ukraine Ltd. has all equipment necessary for different tests and QA inspections. It allows manufacturing not only according to the international and national standards, but meeting any customer's requirements.

Webco Industries

+1-918-245-2211

www.webcotube.com

titanium@webcotube.com

Webco delivers North America's widest range of tubular products, rapidly fulfilling urgent orders and helping customers avoid costly unscheduled shutdowns and production delays. Customers in the aerospace, automotive, chemical processing, industrial, oil & gas, power generation and other industries, rely on Webco's strength, agility, and innovation to deliver solutions for their most challenging requirements. In fact, Webco manufactures and distributes millions of feet quality tubing made to meet today's most demanding specifications.

Our welded and seamless titanium tube products are available in variety of grades and sizes, standard/off-the-shelf or tailored to meet customers' unique requirements.

Webco maintains a culture for relentlessly pursuing process and product excellence, enabling ever-improving productivity/product quality. For a current list of our ISO, TS, PED, and other certifications as well as ASME, ASTM, and other specifications offered, visit www.webcotube.com

Weber Metals, Inc.

+1-562-602-0260

www.webermetals.com

Weber Metals, Inc. specializes in Aluminum and Titanium open and closed die forgings for the Commercial and Military Airframe, Air and Land Turbine, Nuclear and Semiconductor industries. Our press sizes range in size from 1200 to 33,000 tons. We have capabilities to perform heat treatment, non-destructive and destructive testing in house. Our forgings range in size from 1 pound to 11,000 pounds. Our aluminum stress relieved forgings are some of the most stable products in the industry for machining.

Wellmet International Inc.

+1-909- 594-9639

www.wellmetusa.com

We supply and distribute Titanium Sponge and Titanium Powder. We represent the largest Titanium sponge and powder producers in China. We can also supply other non-ferrous metals which are of Chinese origin with approved quality. The Titanium Sponge producer is ISO9001:2008 certified and sponge quality is approved by world main consumers.

West Penn Testing Group

+1-724-334-1900

www.westpenntesting.com

West Penn Testing Group is a full-service, independent testing laboratory with diverse inspection and testing capabilities since 1952. They provide an extensive array of non-destructive, chemical, metallographic, failure analysis and mechanical evaluation services, serving customers in these industries: aerospace, medical, power generation, commercial, military, raw materials, refractories, oil and gas, and the automotive industry. They have three locations in New Kensington, Pennsylvania and Richburg, South Carolina and perform testing nationally and internationally. Their 79,000 sq. ft. facilities accommodate parts up to 20,000 lbs. www.westpenntesting.com

Western Smelting & Metals, Inc.

+1-503-623-8341

www.westernsmelting.com

Western Smelting & Metals Inc in Dallas, OR is a third generation metal recycling business with almost 60 years of experience in the industry. We are the most preferred locally owned metal recycling service provider with 30 year of experience in titanium processing. Our experts provide valuable information to the clients to help them make a right decision about the formulation of materials. Whether it is blending, sizing or sorting of metals, our experts ensure that we deliver fast and exceed our clients' expectations. Depending upon the clients' needs, we also provide aluminum, cobalt and nickel alloys.

Western Superconducting Technologies Co. Ltd.

+86-29-8651-4505

www.wstitanium.com

dxh@c-wst.com

Western Superconducting Technologies Co., Ltd. (WST), founded in 2003, is headquartered in Xi'an, China. WST is leading supplier of titanium and its alloys material including Ti6Al4V, Ti6Al4V ELI, Ti6242, Ti6246, Ti662, Ti811, Ti38644, Ti1023, Ti6Al7Nb, NbTi in the forms of ingot, billet, forging, slab, bar, rod, wire and profile in the domestic & oversea market. Our products are mainly used in aerospace, medical, automotive industries and other critical industries.

WST possess most advanced 10 tons VAR furnaces and series of high speed forging presses to manufacture 6000 tons ingots and 4000 tons bars per year. We have gotten the certificate of ISO 9001, AS 9100, NADCAP and ISO 14001, strict quality control system make largest assurance for our high quality products. WST's titanium alloy bars hold over 85% domestic aerospace market and also WST has good cooperation with large international aerospace companies like UTAS, Eton etc. and medical companies like Biomet, Smith & Nephew, Medtronic etc.

Westmoreland Mechanical Testing & Research Inc.

+1-724-537-3131

www.wmtr.com

us.sales@wmtr.com



Westmoreland Mechanical Testing & Research is a world leader in materials testing. Founded in 1967, WMT&R serves a broad range of industries including aerospace, automotive, medical, and power generation. We support our customers with our highly-skilled staff and advanced facilities. Our turnaround time is unrivaled, and with over 300,000 square feet of accredited production and testing space, we have the capacity and equipment to handle any materials testing project. WMT&R's testing expertise includes: Mechanical Testing, Composites, Fatigue, Stress/Creep Rupture, Fracture Mechanics, Metallography, Chemical, Heat Treat, Thermal Analysis, and Physical Properties Testing. For more information, please visit www.wmtr.com or email us.sales@wmtr.com.

Wyman Gordon

http://www.pccforgedproducts.com/brands/wyman_gordon/

Wyman Gordon is a worldwide supplier to the aerospace and industrial gas turbine markets. We hold quality accreditations for all of the major airframe and engine manufacturers for both civil and military applications. Wyman Gordon creates rotating closed-die forgings

Titanium Buyers Guide *(continued)*

which are critical for aerospace and land-based gas turbines. Wyman Gordon also manufactures structural forgings for airframe, nuclear, petrochemical, power generation, and space applications.

Xi'an Metals & Minerals Import & Export Co., Ltd.

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www.tiwmo.com

info@tiwmo.com wxd@tiwmo.com hj@tiwmo.com

As a leading manufacturer and distributor of Titanium, Molybdenum and Tungsten products in China, Xi'an Metals and Minerals Import & Export Co. Ltd., has joined into manufacturing, researching and competing in Titanium industry. We supply Titanium and its alloys in various forms as per ASTM, AMS and other main internationally recognized specifications. Our advantage is the most competitive prices as well as guaranteed high quality! Our products are exported worldwide, and gained high reputation because of their excellent performance.

ZIROM S.A.

+40 246 216666

www.zirom.ro

zirom@zirom.ro



ZIROM came into prominence, over the last decades, as one of the largest producers of titanium and titanium alloys in Central and South-Eastern Europe. Ever since the foundation, a permanent emphasis has been laid on its development, through technological optimization and through development of the technology for melting titanium and zirconium scrap by combining EB and VAR technologies, and further, the development of free forging process.

The products manufactured, ingots and forged semi-finished products, are intended both for cutting edge fields (aviation and nuclear areas) and various fields (metallurgy, chemical industry, medical technique and devices).

The ZIROM's integrated management system (quality, environmental, health & safety) and the ZIROM's products are certified by LRQA in accordance with the following standards: ISO:9001:2008, EN 9100:2009, ISO:14001:2005, OHSAS:18001:2008, NORSOK M-650.

Zirom can also provide a series of services like melting the secondary recycle materials, turning/grinding/cutting/milling the surface of products, full chemical and mechanical analyses, LP, US +Eddy testing.



Company	Pg	Company	Pg
AMETEK - Reading Alloys3 www.ametekmetals.com		Retech Systems LLC25 www.retechsystemsllc.com	
Arconic99 www.arconic.com		Sandvik Materials Technology Product Unit27 www.smt.sandvik.com/en/	
Aries Manufacturing21 www.aries-manufacturing.com		Service Steel Aerospace35 www.ssa-corp.com	
Baoji Titanium Industry41 www.baoti.com		Solar Atmospheres37 www.solaratm.com	
Busch USA45 www.buschvacuum.com		TIMET, Titanium Metals Corporation7 www.timet.com	
Edge International17 www.edgeintl.com		Titanium Finishing Company23 www.titaniumfinishing.com	
LAI International19 www.laico.com/industrial		Titanium Industries2 www.titanium.com	
Mid-West Machine33 www.vulcangroup.com		Tricor Metals11 www.tricormetals.com	
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Product Evaluation Systems43 www.PES-Testing.com		Zirom S.A.39 www.zirom.ro	
Quebec Metallurgy Center49 www.cmqtr.qc.ca			



ULTRA-LIGHTWEIGHT,
NEXT-GENERATION
ALUMINUM-LITHIUM
STRUCTURE

ORGANIC
BODY SHAPE

TITANIUM-ALUMINIDE
PROPULSION COMPONENTS

Where the Future Takes Shape

Few people get to witness the course of history being altered. We've had a hand in steering it since the dawn of flight, the birth of highways, and the race to space. When our customers want to develop the next generation of iconic innovations, they look to us for the breakthrough materials and technologies that bring them to life. Because we haven't come this far to only come this far.

Arconic. Where the future takes shape.



ARCONIC

Innovation, engineered.

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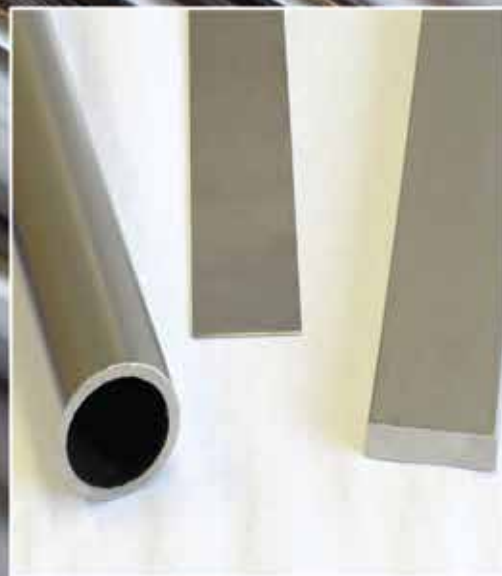
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Wire • Sheet • Plate • Tubes

6Al-4V • 6Al-4V Eli • 6Al-7Nb • CP Grades 1-4

ISO 13485 certified

US, UK, Germany and China sales and distribution locations

Inventory in stock and available today



VSMPO-AVISMA is the World's Largest Producer of Titanium.

Holding more than 300 international quality certifications, VSMPO-Tirus operations provide sales, distribution and service center processing of VSMPO-AVISMA titanium mill products to the medical, aerospace, military, and consumer markets. Our US manufacturing facility produces precision-tolerance bar and wire for medical applications. VSMPO-AVISMA and our US manufacturing and service center locations are ISO 13485 certified.



www.vsm-po.com
sales@vsm-po-tirus.com

 **VSMPO TIRUS**