The FFC Process for the production of metals and metal alloys

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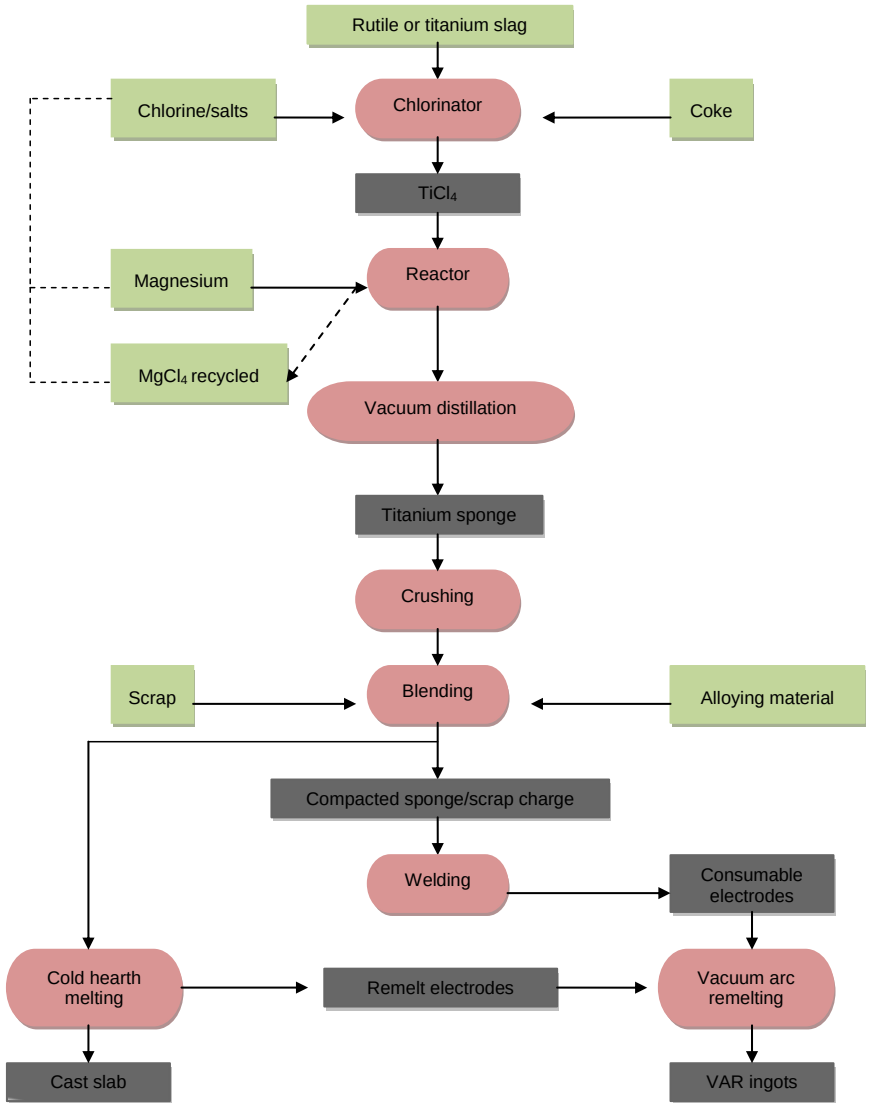
Overview

- The FFC and Kroll processes
- Current operations
- CP-Titanium and alloys
- Product development and powder production
- O2M plant
- Summary

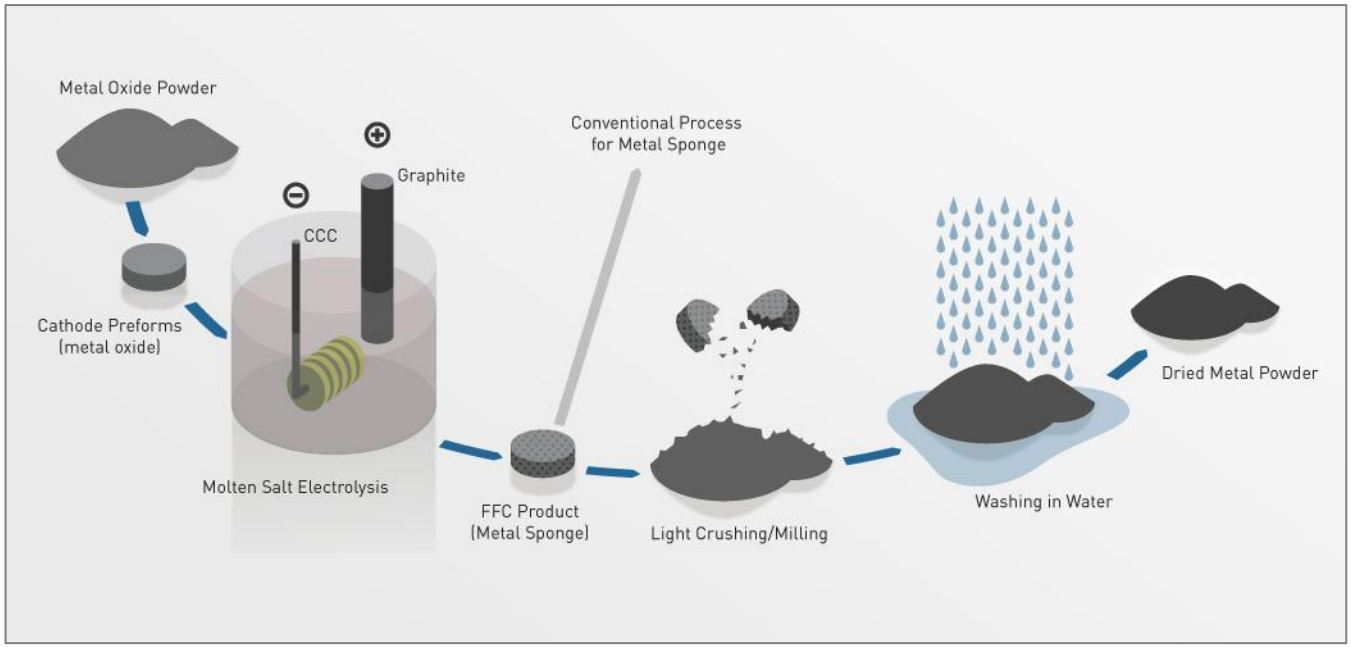
The Kroll process is energy and capital intensive as well as inflexible

- A process that Kroll himself predicted would be replaced by an electrolysis process
- Uses natural and synthetic rutile and titanium slags as feedstock
- Batch process, limited by the ability to cool the reactor
- Product has only one form: sponge cake
- Significant yield losses due to iron and carbon contamination
- Sponge cake is crushed and then sent for either gas atomisation, melting or casting.



Source: Roskill 2010

Simple, green and cost effective oxide to metal process (O2M)



- Metalysis is commercialising the FFC process for production of metals, developed at the University of Cambridge in 1997. Extensively protected via 19 families of patents and trade secrets
- The FFC process reduces metal oxides to metals via electrolysis, using a metal oxide cathode, a graphite anode, and a molten salt. Only by-product is CO/CO_2
- Can produce alloys from their respective metal oxides entirely in the solid-state
- The FFC process can produce a turnkey product for existing processors

Current operations are focused on commissioning

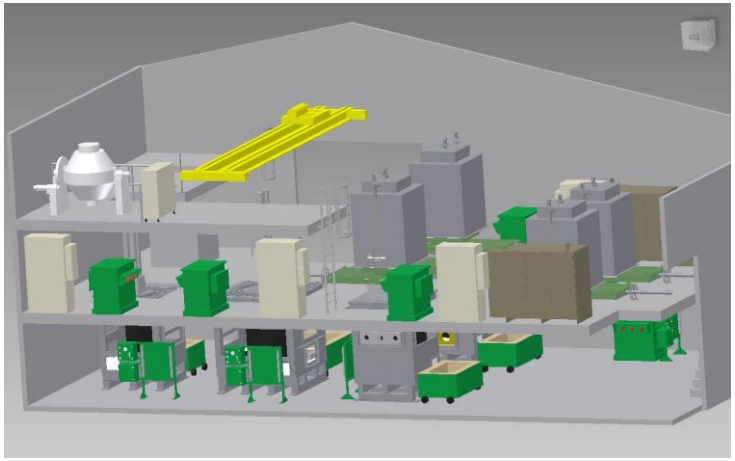
Research Cells
2005 - Present

- 10 g samples
- Up to 1000 g of $CaCl_2$

Development Cells
2008 - Present

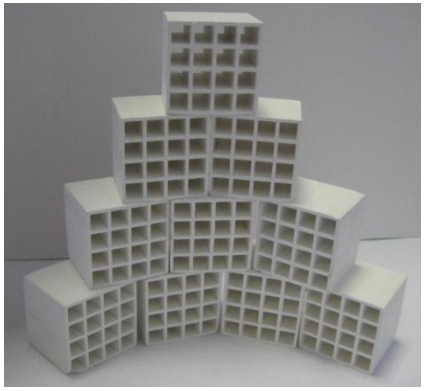
- 2-6 kg samples
- Up to 400 kg of $CaCl_2$

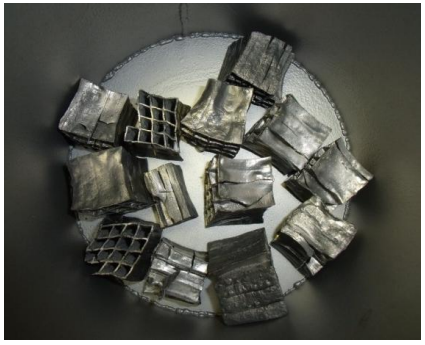
O2M Plant
Commissioning in progress

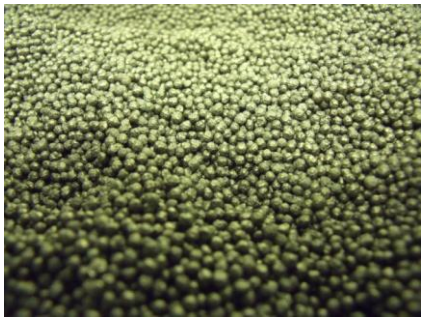


- 100 tonnes per annum
- Salt recycling

Feed shapes can be tailored for specific product streams

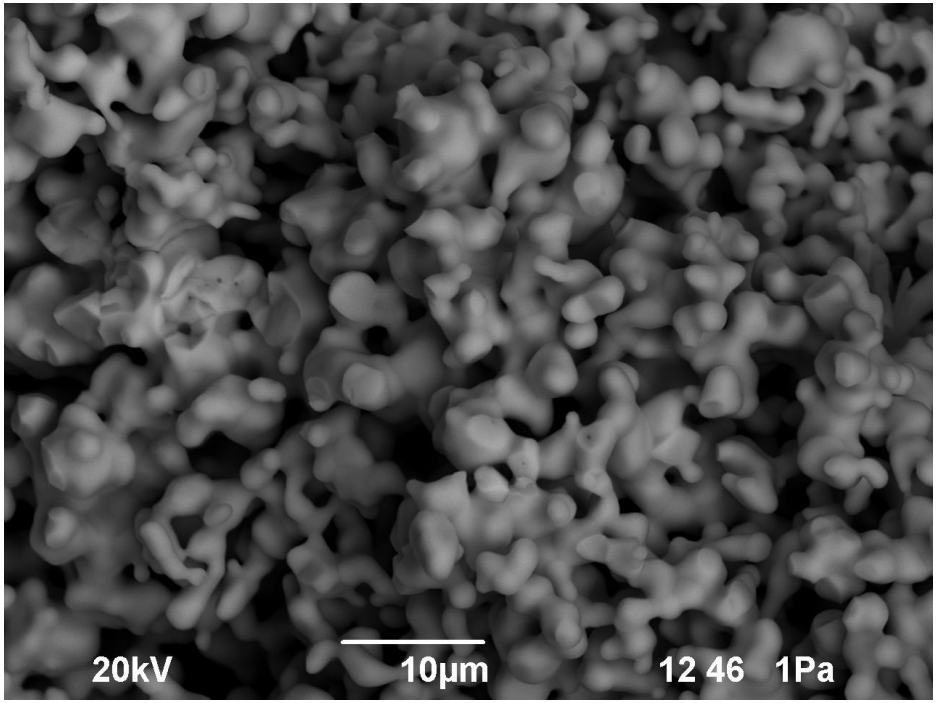


Product is low in oxygen and other interstitial elements

- Chemistry of product direct from development cell
- Produced at kilogram scale
- Using all different feed shapes
- Product not post processed other than light cleaning with water
- Not an optimised product



Oxygen (wt.%)	Carbon (wt.%)	Nitrogen (wt.%)	Hydrogen (wt.%)	Iron (wt.%)
0.14	0.027	<0.01	<0.003	0.10
0.19	0.018	<0.01	<0.003	0.11

Unique and exotic alloys can be formed with new capabilities

- A significant portion of titanium sold is alloyed
- The workhorse alloy is Ti-6Al-4V
- Must be proven by any new process

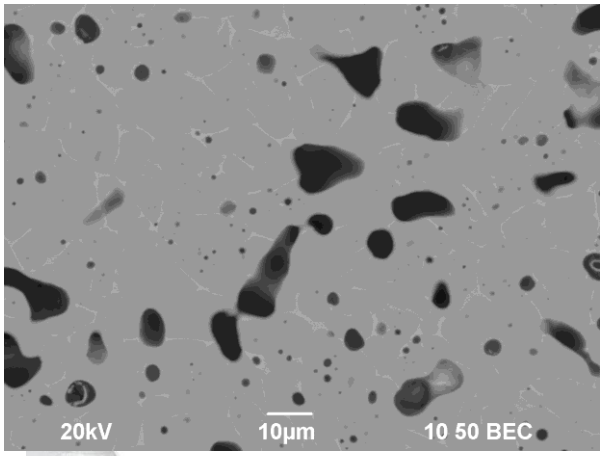
Advantages over Kroll:

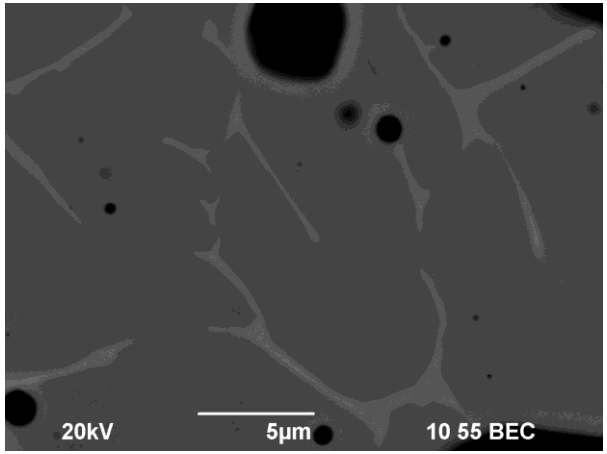
- Can use heavy stabilising elements
- Can produce pre-alloyed material directly from reduction process
- Avoid segregation via melting

Source: US Army

Ti-6Al-4V supersponge can be produced directly from the cell

- Work has focused on preform preparation, reduction parameters and alloying characteristics
- Blend TiO_2, Al_2O_3 and V_2O_5 powders
- Preforms pressed/extruded/cast and sintered
- Similar reduction to CP-Ti
- Many techniques transferred from experience with CP-Ti





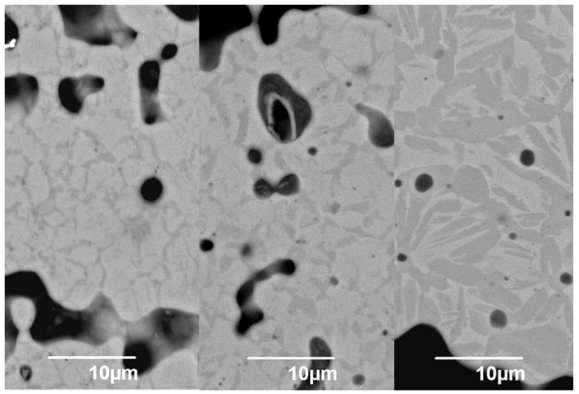
Exotic alloy additions can create master alloys and meltless products

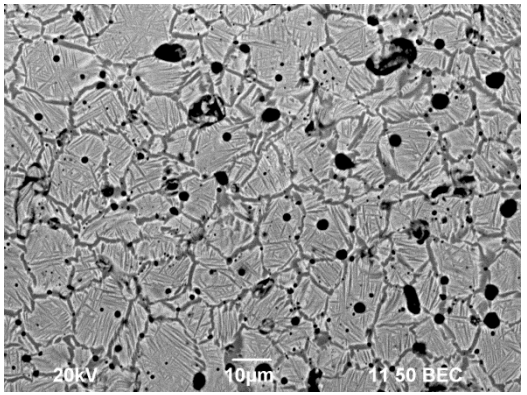
Master alloys

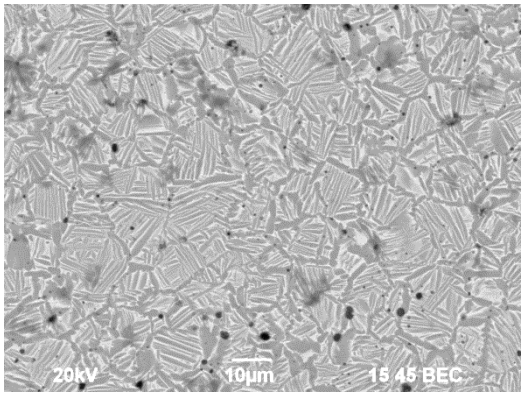
- Have made Ti-Ta and Ti-Mo alloys
- Could reduce the number of melting steps to achieve homogenous alloys

Meltless products

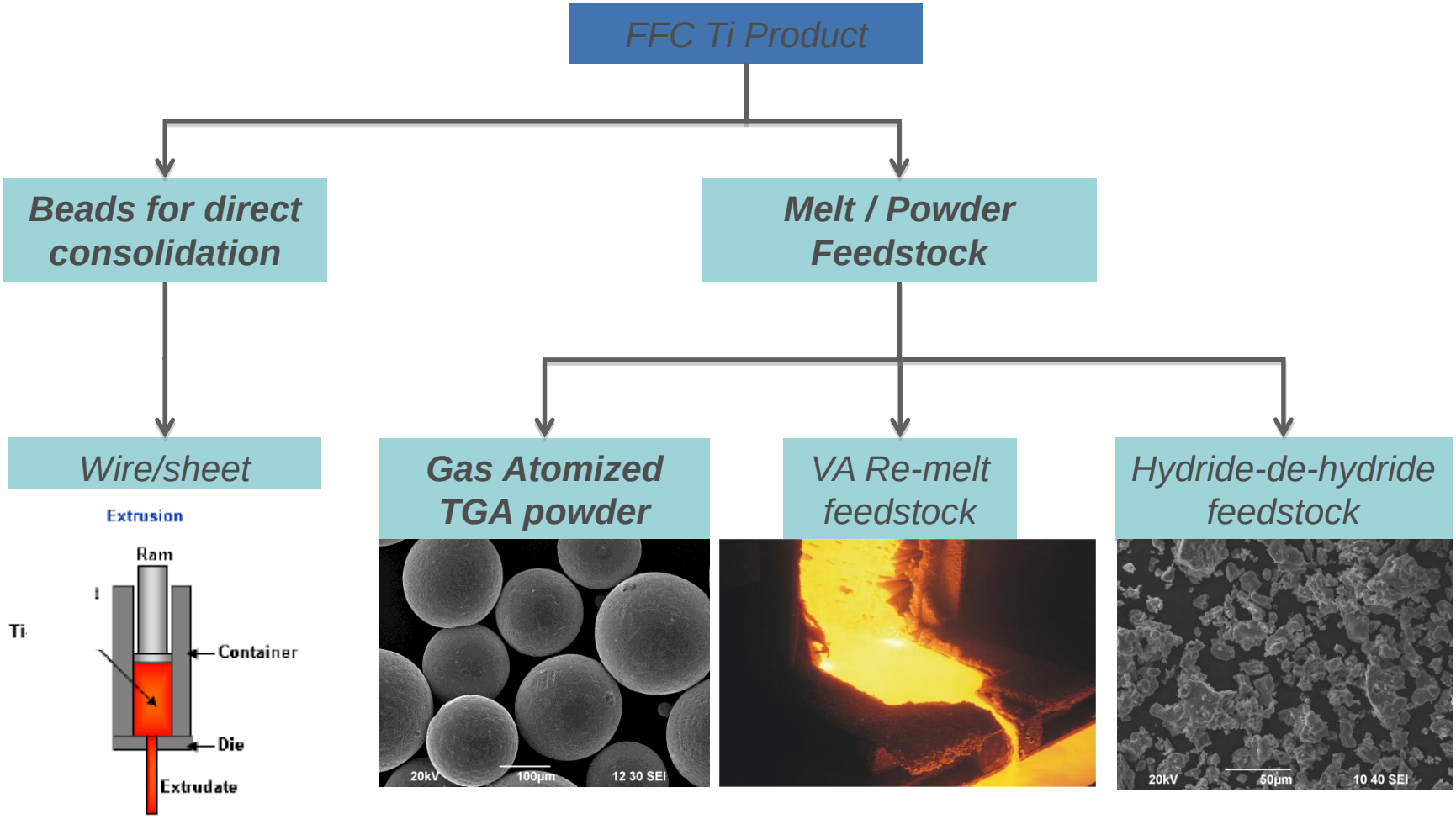
- Experimented with Ti-8V-5Fe-1Al and other difficult alloys
- Other alloys using tungsten have been made







Metalysis proposes some lucrative initial market entry points



A meltless product can create new opportunities for titanium use

- Direct consolidation of FFC-Ti product into mill product (rod, sheet or wire) will by-pass many process steps in the existing value-chain
- Powder metallurgy processes are maturing and can provide methods of direct consolidation
- Such a route would be highly disruptive to the current supply chain
- Development needs to be collaborative and product oriented

Beads for direct consolidation

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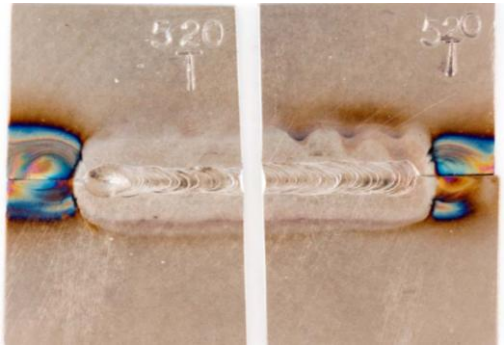
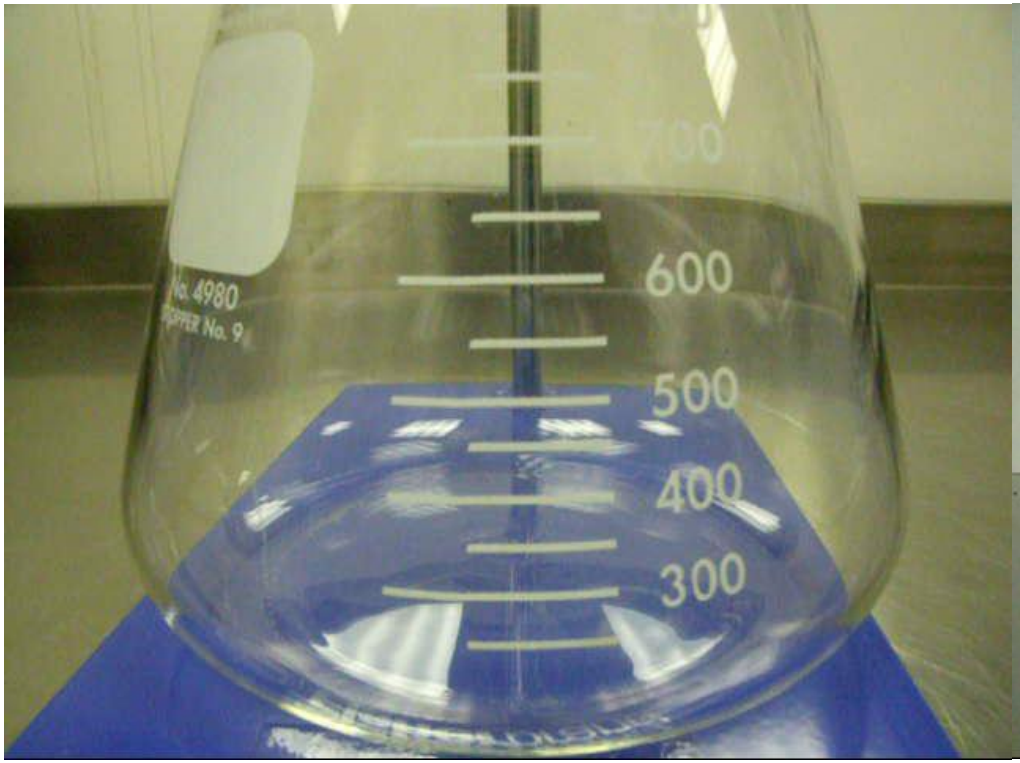
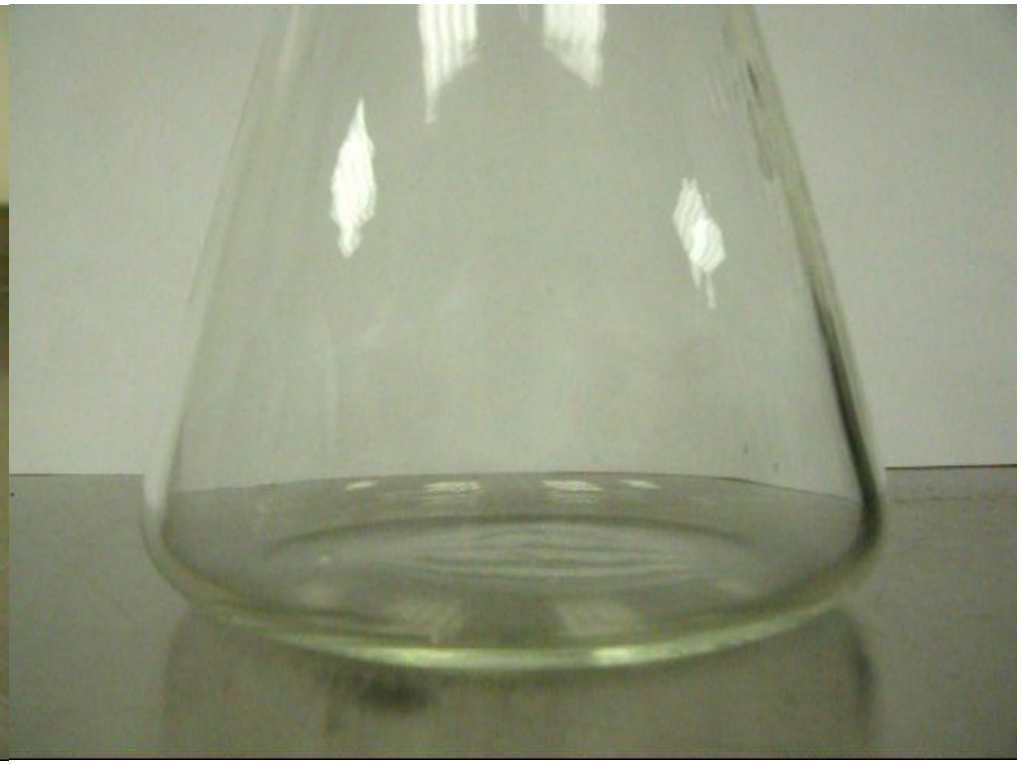
Wire/sheet



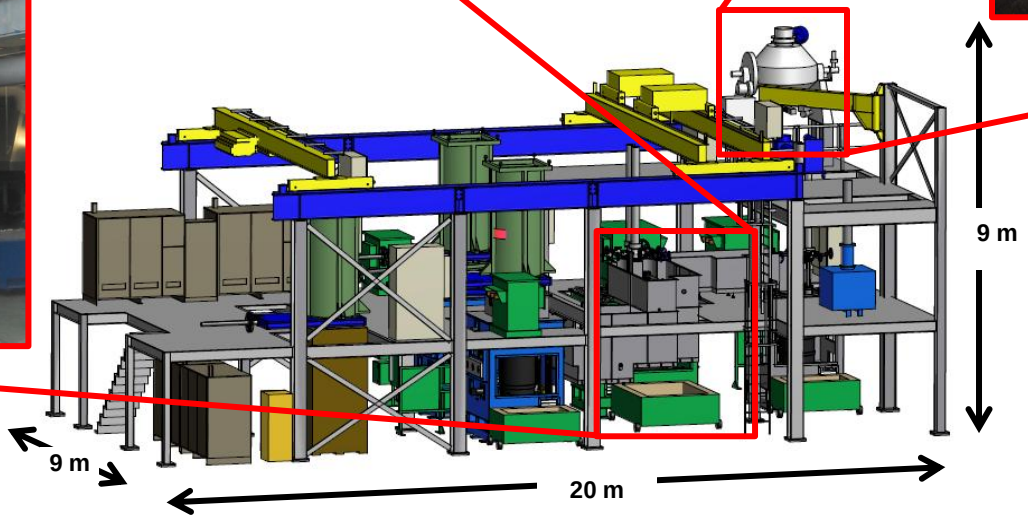
Flowable titanium powder is produced directly from a FFC cell





Oxide to Metal (O2M) plant has been built

- A novel plant, protected by 6 patent families, has been designed and built.
- It is commercially viable scale to produce tantalum metal and demonstrate titanium production.
- The design is modular and scalable, so that capital investment can match market demand.



Summary

- The FFC process is a patented and proven technology capable of producing metal powders.
- Metalysis has built a production plant:
  - Capable of 100 t of tantalum
  - It is capable of producing either tantalum or titanium
- Establish a revenue generating tantalum business
- Continue titanium product development and refine commercialisation strategy