

Advances in Selective Plating: Deposition on Titanium Alloys



Introduction / Utility of Titanium

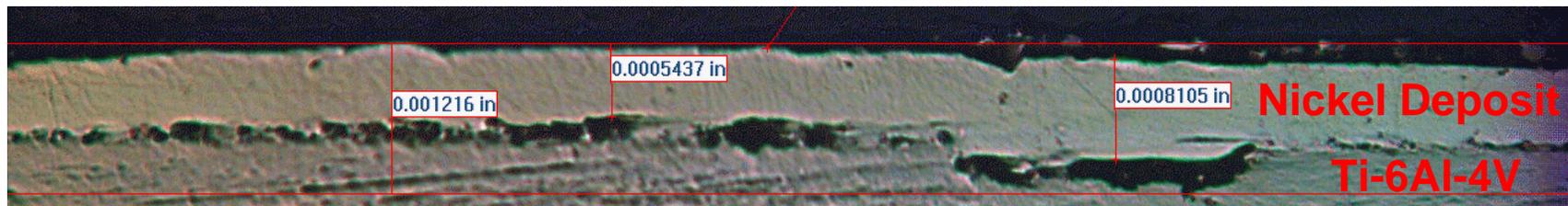
- Titanium and titanium alloys are very attractive materials due to their superior strength-to-weight ratio, good corrosion and erosion resistance, low density, and high temperature capability.
- Ti-6Al-4V and Grade 2 titanium were chosen for coating research because of their widespread use in aerospace and medical, and chemical and marine applications respectively.

Why plate various metals on Ti and Ti Alloys?

- To improve the surface fatigue, anti-galling and fretting characteristics.
- To improve surface properties for
 - Brazing
 - Corrosion resistance in hot acidic environments
 - Conductivity (higher or lower)
 - Lubricity
 - Resizing and Repair
 - Heat reflection
 - Emissivity

Titanium Dioxide

- Titanium is intrinsically quite reactive.
- An oxide film forms immediately upon exposure of the metallic surface to air or any environment containing available oxygen forming a tenacious passive film which protects the underlying substrate.
- Effective bonding of a coating to the titanium substrate is problematic with the oxide present.
- Titanium dioxide is soluble in hydrofluoric acid.

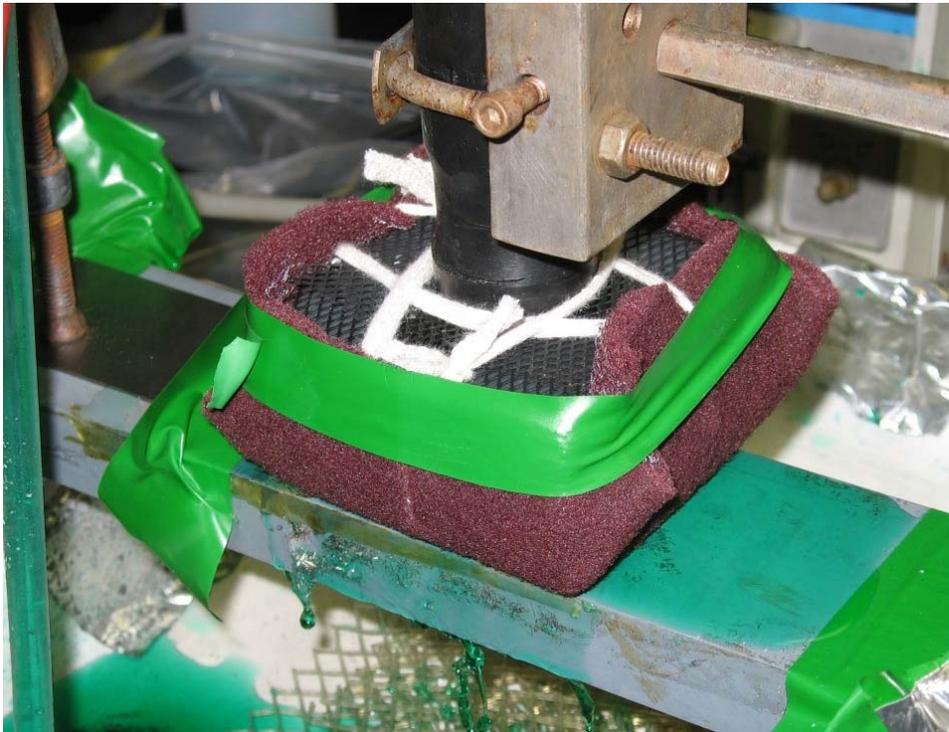


The problem with Titanium Dioxide:
Separation at Interface between Titanium and Nickel Deposit.

Research Goals

- Develop a method of plating on Ti using the SIFCO technology.
- Provide excellent adhesion between deposit and Ti.
- Method must not use hydrofluoric acid.
- Demonstrate robustness of the process.
- Experiments were carried out to remove the native oxide and keep it off during plating.

Titanium Panel Brush Plating Setup

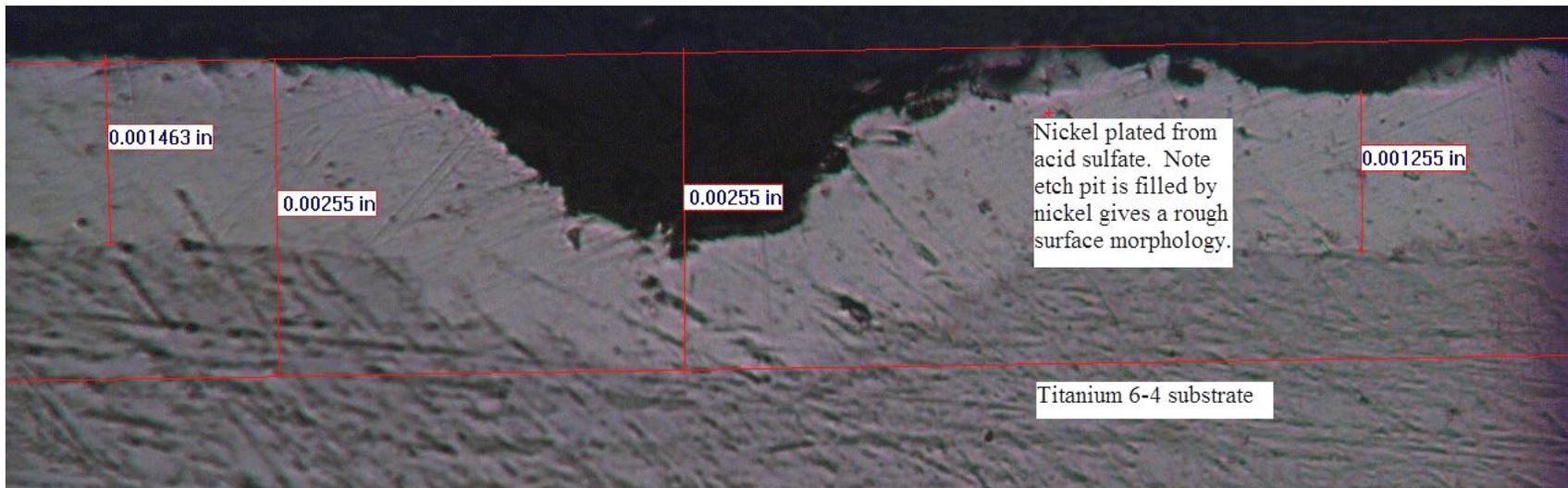


Anode movement from a traversing arm.

Equipment used in testing:

- Peristaltic Pump.
- SPL 75 amp rectifier.
- Model 75 flow system.
- Anodes:
 - Polypropylene block wrapped with Ir/Ti mesh.
 - Graphite.
- Red ScotchBrite™.
- Traversing arm.

Good Adhesion with Excessive Roughening of Ti-6Al-4V



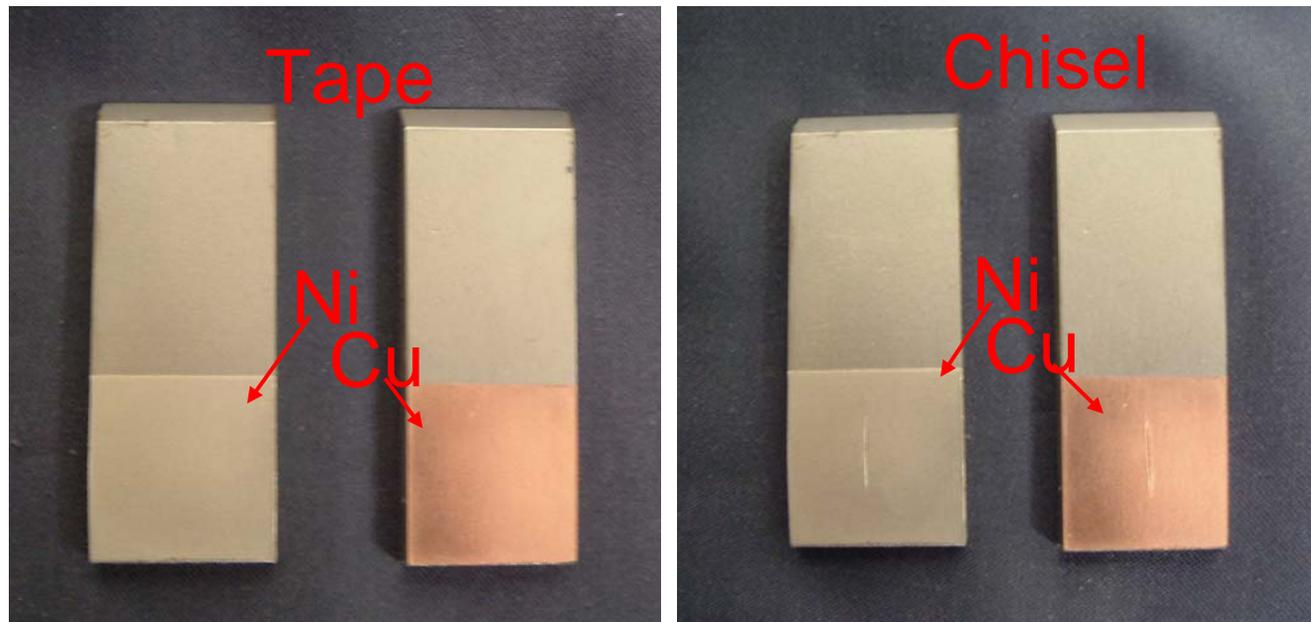
- Oxide film is removed by electrochemical treatment (low acid long time) with good adhesion between nickel and Ti-6Al-4V.
- The Ti surface morphology with etch pits results in a coating with excessive roughness.
- Surface should be microroughened.

Optimum Electrochemical Pretreatment of Ti 6-4



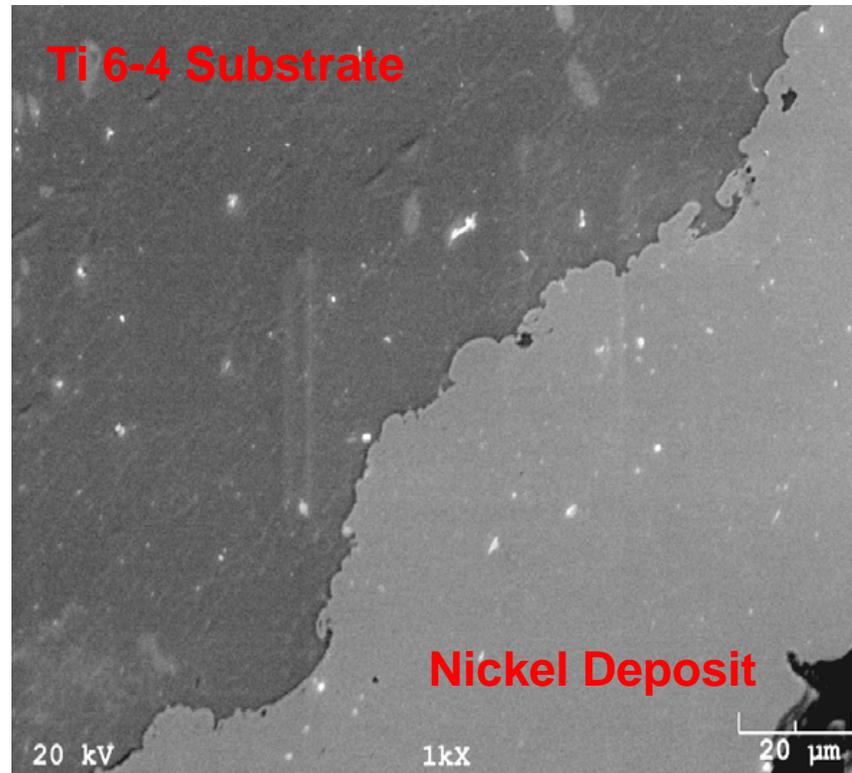
- Optical micrograph of the interface shows a microrough morphology with small re-entrant features which generate a mechanical interlock between deposit and substrate.
- Oxide film is removed by electrochemical treatment (high acid, short time).
- Good adhesion between nickel and Ti-6Al-4V.

Adhesion Tests



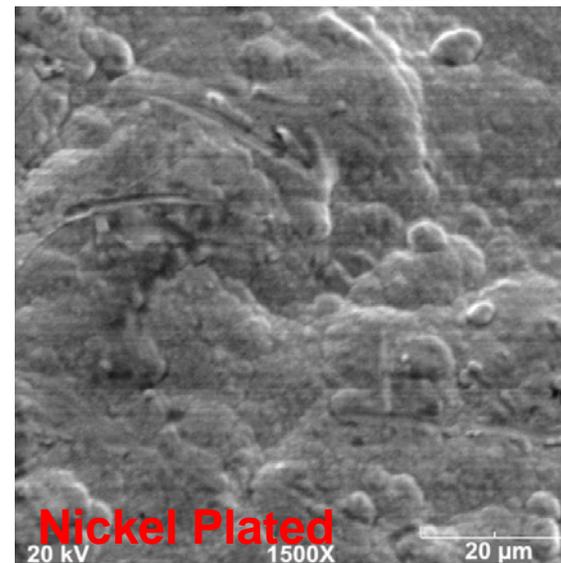
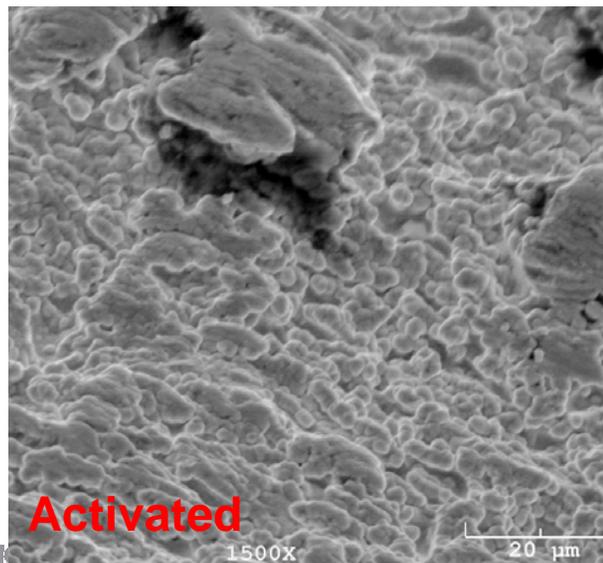
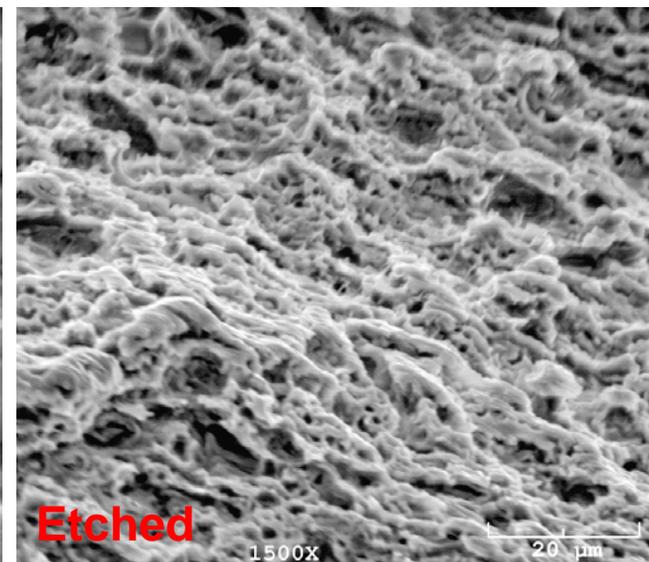
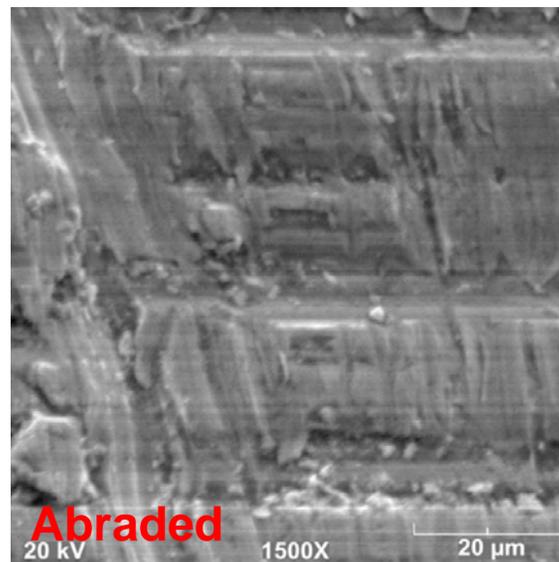
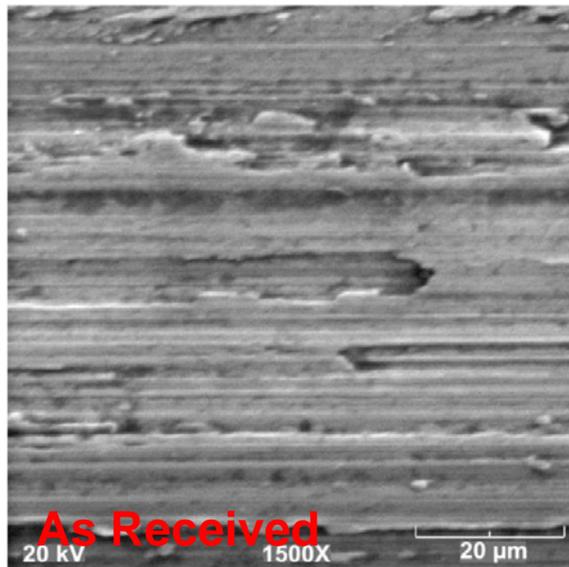
- Ti-6Al-4V coupons nickel and copper plated. Passes tape and chisel tests, AMS 2451A.
- Bend test: Ti-6-4 breaks before adhesion fails, ASTM B571.
- Passes quench test, 250°C into RT water, and scribe test.
- >6,000 psi Ni to Ti-6Al-4V Tensile Adhesion, ASTM C633.

SEM Micrograph at the Interface Between Ti-6Al-4V and Nickel Plate



Microroughened Interface

SEM Micrograph of Treated Ti-6Al-4V Surfaces



Electrochemical Pretreatment Process

Step	Operation	Material	Conditions
1	Abrade	Red ScotchBrite™	Wet with T2 Electrolyte
2	Etch	T2 electrolyte	14 V Anodic, 10 seconds
3	Activate	T2 electrolyte	4 – 8 V Cathodic, 1 minute
4	Plate	Nickel Plate	8 - 18 V Cathodic, 0.078 A*hr/cm ²

No rinsing is done between steps until plating is complete

- Titanium electrode always under potential control, 100% coverage.
- Etch-to-activate transition occurs by reversing power supply polarity.
- Activate-to-plate transition occurs by replacing T2 electrolyte with plating solution without interrupting current.

Effect of Surface Treatments on Ti-6Al-4V: Surface Roughness

	Average Roughness, R_a (μm)	
	Machine Direction	Cross-Machine Direction
As received	0.7	0.8
Abraded	0.5	0.4
Anodic Etched	5.8	5.0
Activated	6.6	3.7
Plated	1.4	2.1

- Etching and activating microroughen the Ti surface.
- Mechanical abrasion and plating reduced roughness.
- Anodic etch removes 0.0089 g/cm^2 (0.0008 in.) of Ti.

Hydrogen Embrittlement Test Ti-6Al-4V



Coupon predrilled with a 0.25" diameter hole for a stress riser. Nickel plated after the T2 activation

Ti-6Al-4V coupon under cantilever load at 85% of yield for 24 hours

- No failure or cracking observed on samples stressed with no heat treatment or after heat treat of 375° F for 24 hours.
- All samples were satisfactory for hydrogen embrittlement to specification GM3661P.

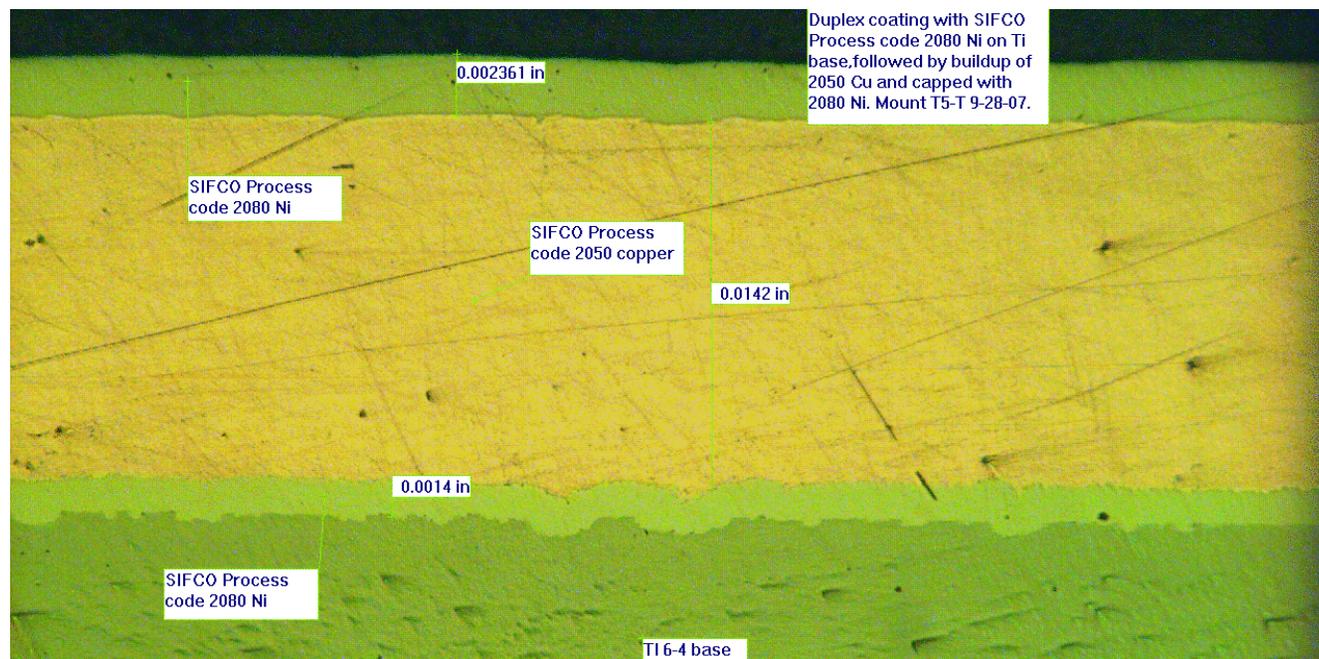
Hydrogen in Titanium Alloy

- Hydrogen in Ti-6Al-4V was measured by LECO per ASTM E1447 at various process steps.

T2 Process Step	H concentration wt. % (avg. 2)
Anodic Etch	0.014
Etch + Activate	0.015
Etch + Activate + Nickel Plate	0.029
Etch + Activate + Nickel Plate + Etch Nickel	0.035

Duplex Coating Ni/Cu/Ni on Ti 6-4

Acid nickel used for the final deposit or as a base coat for other metals.



60 μm Nickel Cap
360 μm Copper
36 μm Nickel
Titanium 6-4 base



Conclusions

- Adherent brush plated coatings on Ti alloys Ti-6Al-4V and Ti-6Al-6V-2Sn can be deposited using a special brush plating process.
- The anodic etch microroughens the surface and increases surface area.
- Cathodic activation further roughens the surface and reduces oxides formed during the anodic cycle.
- The etch and activate steps performed in the same acid chloride electrolyte keeping the surface under potential control at all times.
- The process does not use hydrofluoric acid.
- Robustness demonstrated by >100 articles plated with good adhesion.

Future Work

- Evaluate performance with other Ti alloys.
- Apply other deposits to nickel coated surface (Zn-Ni, Cr_3C_2 /Co metal matrix composite)
- Research a method to provide adhesion to Grade 2 titanium.
- Test effect of heat treatment on adhesion.

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