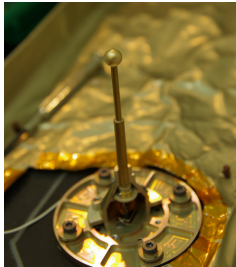


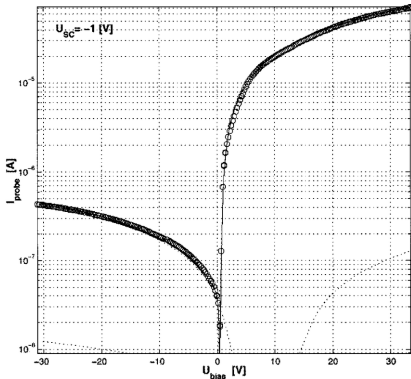
# Status of the Swarm Langmuir Probes

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Swarm 10 Year Anniversary & Science Conference 2024-04-10, Copenhagen

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Bias sweep (scan) of the Cassini  
TiN LP probe

- ▶ Titanium has low mass density and is strong,
- ▶ commonly used for Langmuir probes (LP) in space,
- ▶ but must not oxidize at the surface to  $\text{TiO}_2$ ,
- ▶ which is non-conducting.
- ▶ Therefore pure titanium is sublimed in a Nitrogen atmosphere producing a TiN surface.

- ▶ Swarm with LPs is at IABG Munich, (almost) ready for transport to Plesetsk in August 2013
- ▶ July 2013: "J-P Lebreton (PI LP of the Demeter satellite) observes an hysteresis effect, attributed to an RC time constant on TiN coated LPs"
- ▶ ... likely because of a non-conducting surface layer;
- ▶ possibly from aggressive atomic  $O$  in the Earth's thermosphere?
- ▶ X-ray Photoelectron and Raman Spectroscopy analysis of a (spare) Langmuir probe is done at ESTEC:

#### ABSTRACT

XPS and Raman spectroscopy analyses indicate that titanium nitride coating of the sample contains impurities/defects. High concentration of contaminants (more than 50 atomic%) is registered in the top layer (~5 nm). These contaminants include oxygen-, nitrogen- and fluoro-containing organic compounds, silicon oxides, silicon oxy-carbides, and small amounts calcium, magnesium (likely present in forms of their salts, e.g., in chlorides, carbonates, phosphates). Total  $22.4 \pm 2.0$  atomic% of titanium was measured by XPS in the surface layer of ~5 nm. Pure stoichiometric titanium nitride (TiN) was not registered by XPS in this surface layer. Titanium nitride in the top layer of ~5 nm (XPS data) is present in a partially oxidised state and in oxy-nitrides  $TiN_xO_y$  (63 $\pm$ 3 % of the total titanium content). Titanium bonded to fluorine (9 $\pm$ 2 % of the total titanium content) is also observed in the surface layer. Titanium is also present in forms of its oxides ( $TiO_x$  and  $TiO_2$ , 28 $\pm$ 3 % of the total titanium content) and possibly in titanium oxy-carbides. Copper and zinc are also found and could be present in one of their alloys (e.g. brass).

- ▶ alternative probe material: brass, electroplated with *Au*
- ▶ heavier than Ti! (test shaking etc cannot be done in time);
- ▶ electroplating gold on Ti? From <https://www.sharrettsplating.com/base-materials/titanium>

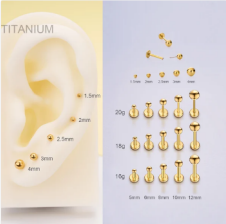
## ISSUES WITH PLATING ON TITANIUM

Plating on titanium has long been considered an extremely difficult, if not impossible, process to master. The biggest issue is that titanium is a highly reactive metal. Specifically, titanium reacts with the oxygen that is produced by many plating processes

# But: Jewelry

Gold titanium (1.000+ relevante Ergebnisse, mit Anzeigen 📄)

Preis (€) ▾ Shops überall ▾ Alle Verkäufer ▾



20G / 18G / 16G Titan Gold Kugel Bolzen Push-Pi...  
★★★★★ (778)



18G Gold Titan Klapp Clicker/Nasering/Septum...  
★★★★★ (60 Tsd.)

► It cannot be that difficult, go to the experts:

# Kugel / IRF

Datum: 16.08.2013 14:50:36

 Applikation: Au\_Ni\_Ti  
 HV: 40 kV Strom: 600  $\mu$ A Zeit: 15 s Koll: 0.300 mm 0

	Nb. (%)	Ti (%)	d ( $\mu$ m)	Ni (%)	d ( $\mu$ m)	Au (%)
1	100,0	0,0	100,0	3,08	100,0	
2	100,0	0,0	100,0	3,13	100,0	
3	100,0	0,0	100,0	2,36	100,0	
4	100,0	0,0	100,0	3,11	100,0	
5	100,0	0,0	100,0	3,25	100,0	
6	100,0	0,0	100,0	3,10	100,0	
7	100,0	0,0	100,0	2,85	100,0	
8	100,0	0,0	100,0	2,78	100,0	

Statistik

	d ( $\mu$ m)	Ti (%)	d ( $\mu$ m)	Ni (%)	d ( $\mu$ m)	Au (%)
<b>Mittelwert</b>	---	100,0	0,0	100,0	2,96	100,0
<b>Std.-Abw.</b>	---	0,0	0,0	0,0	0,28	0,0
<b>Minimum</b>	---	100,0	0,0	100,0	2,36	100,0

- ▶ Lennart Åhlen (†) and I went to IABG, Munich, to replace the +Y TiN probes with gold-plated ones,
- ▶ on August 29, 2013.

# July 20, 2016

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JULY 20, 2016

## Lab discovers titanium-gold alloy that is four times harder than most steels

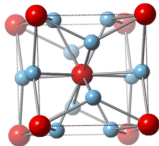
by Rice University

f 1.9K

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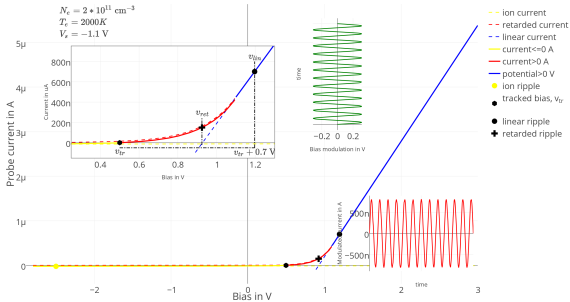
Email



The crystal structure of beta titanium-3 gold. Credit: E. Morosan/Rice University

Titanium is the leading material for artificial knee and hip joints because it's strong, wear-resistant and nontoxic, but an unexpected discovery by Rice University physicists shows that the gold standard for artificial joints can be improved with the addition of some actual gold.

### LP measurements with ripple technique



Probe	Gain <sup>a</sup>	Surface	Position
1	high -2018 low 2019-	TiN	left
2	low -2018 high 2019-	Au	right

- ▶ There is no firm indication that the efforts made any difference,
- ▶ both probes, TiN and gold-plated Ti, work fine;
- ▶ perhaps the "ripple" mode is less sensitive to thin surface contamination?
- ▶ there are no clear sign of LP aging after 10 years in orbit :-)



# Future?

So far unique features of the Swarm LPs:

- ▶ "ripple" mode instead of bias sweeps/scans;
- ▶ the plasma density is derived from the ion admittance (at negative bias),
- ▶ which is independent of the spacecraft potential;
- ▶ the operations do not need any "maintenance";
- ▶ we suggest to equip a constellation ( $\sim$ StarLink) with simple LPs,
- ▶ 100-1000 satellites, "big data" for ionosphere research.