Status of the Swarm Langmuir Probes

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Titanium has low mass density and is strong,

commonly used for Langmuir probes (LP) in space,

but must not oxidice at the surface to 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±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-nitrdes TiN,O_y (63±3 % of the total titanium content). Titanium bonded to fluorine (9±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±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-Pl...

Titanium
Gauge 16g
Inner Diameter: 6mm, 8mm, 10mm, 12mm

18G Gold Titan Klapp Clicker/Nasenring/Septum...

★★★★★ (778)★★★★★ (60 Tsd.)

▶ It cannot be that difficult, go to the experts:
Lennart Åhlen (†) and I went to IABG, Munich, to replace the +Y TiN probes with gold-plated ones,
on August 29, 2013.
Lab discovers titanium-gold alloy that is four times harder than most steels

by Rice University

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.
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 :-)

<table>
<thead>
<tr>
<th>Probe</th>
<th>Gain*</th>
<th>Surface</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>high -2018 low 2019-</td>
<td>TiN</td>
<td>left</td>
</tr>
<tr>
<td>2</td>
<td>low -2018 high 2019-</td>
<td>Au</td>
<td>right</td>
</tr>
</tbody>
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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 (∼StarLink) with simple LPs,
▶ 100-1000 satellites, "big data" for ionosphere research.