Investigation of Langmuir Probe Coatings In Oxygen-Ritch Space Environment

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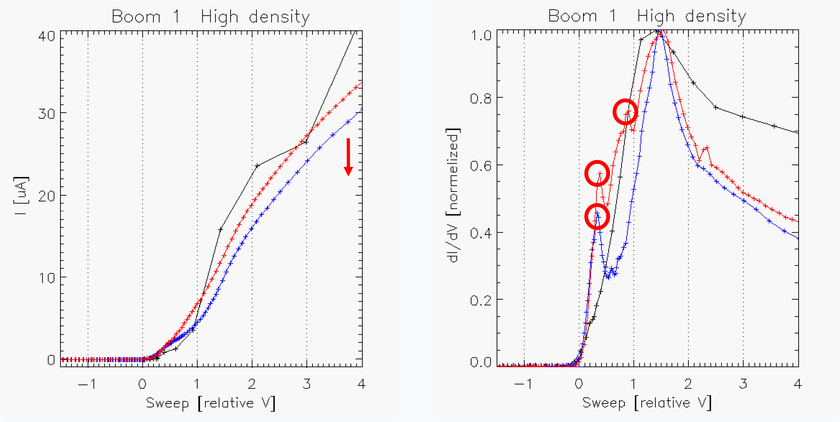
Motivation

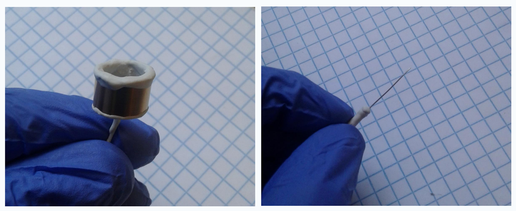
Langmuir Probes, like the one on MAVEN, experience degradation after the probe is exposed to the oxygen rich environment of the upper atmosphere of planets. Current Probes are made from TiN (Titanium Nitride) or DAG (a resin based graphite dispersion), yet both of these coatings create issues when exposed to an oxygen-rich space environment. **TiN showed permanently reduced surface conductivity** while the **DAG layers erode with exposure to oxygen**. Our goals are to find a material or coating that doesn't oxidize and to characterize the effect of oxygen-rich space environments on Langmuir probes .



Data from MAVEN's LPW Boom 1 at similar altitudes, densities, and temperatures: Black, Oct 2014; Blue, March 2015; Red, April 2015.
Current-voltage (IV) curves show the degradation of the probe.

Procedure

TiN and DAG were tested against Copper and Nickel controls, as these metals are known to oxidize easily. Iridium and Rhenium were tested as new coating candidates because of their resistance toward oxidation and their conductive oxidized layer.

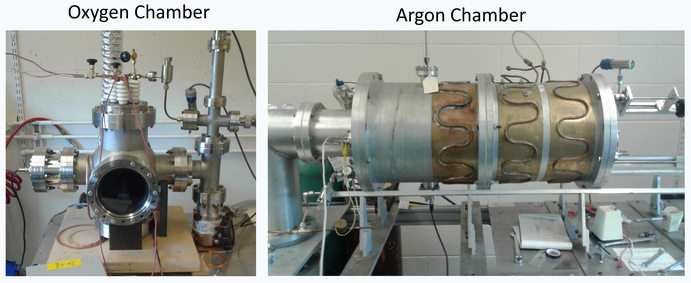


TiN Probe Wire Probes

1. The probes are swept in an argon plasma before oxygen exposure as a control.
2. The probes are then exposed to oxygen plasma for 20 min. This corresponds to several months in Martian orbit.
3. The probes are then re-swept in the same argon plasma to measure the effect of oxidation.
4. The probes were then cleaned via electron bombardment to see if the affected layer could be removed.

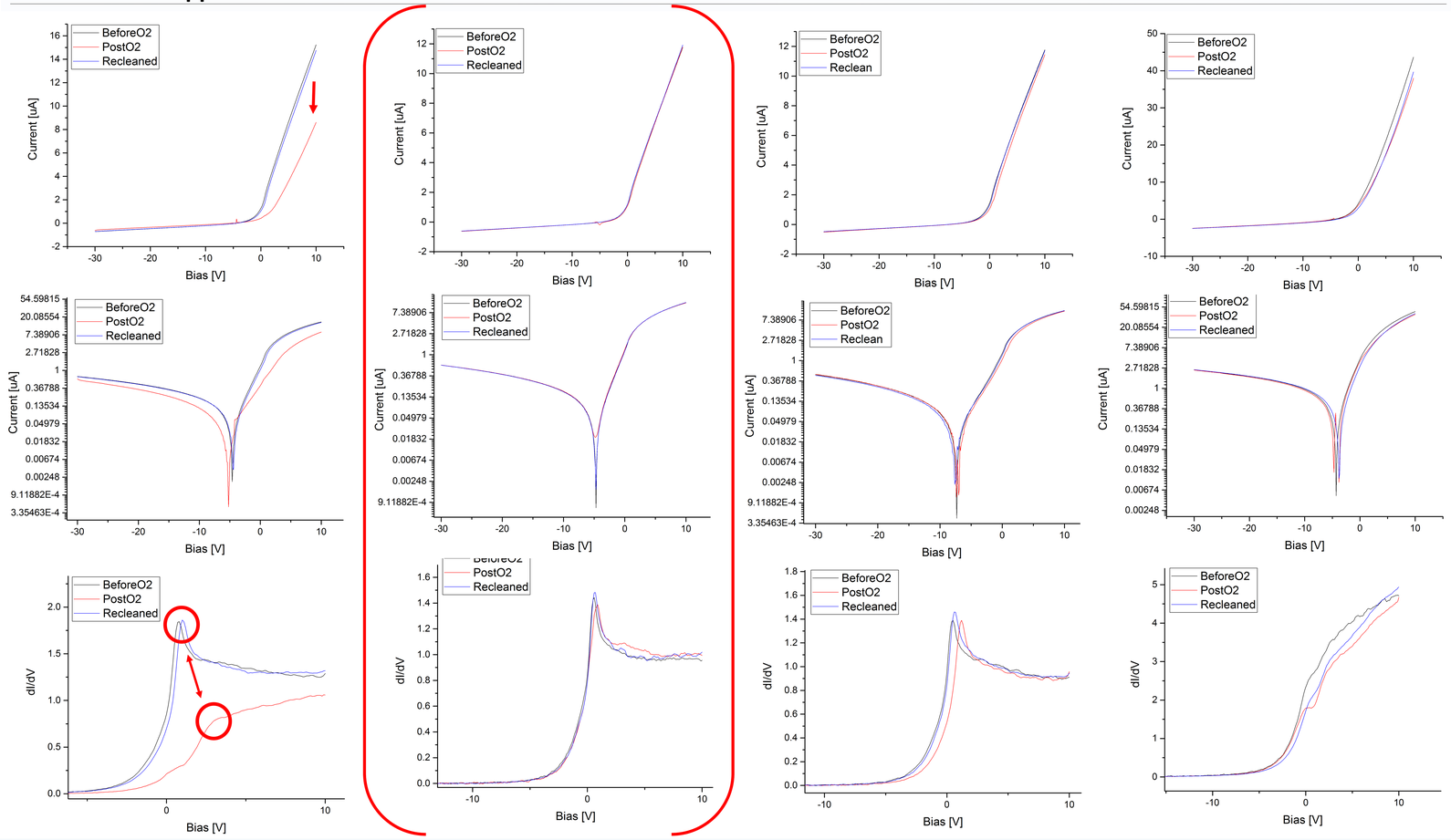
In the oxygen plasma a UV lamp is used to photo-dissociate molecular oxygen into atomic oxygen which is a better analog to the environment of the upper atmospheres of planets.

Oxygen Chamber Argon Chamber

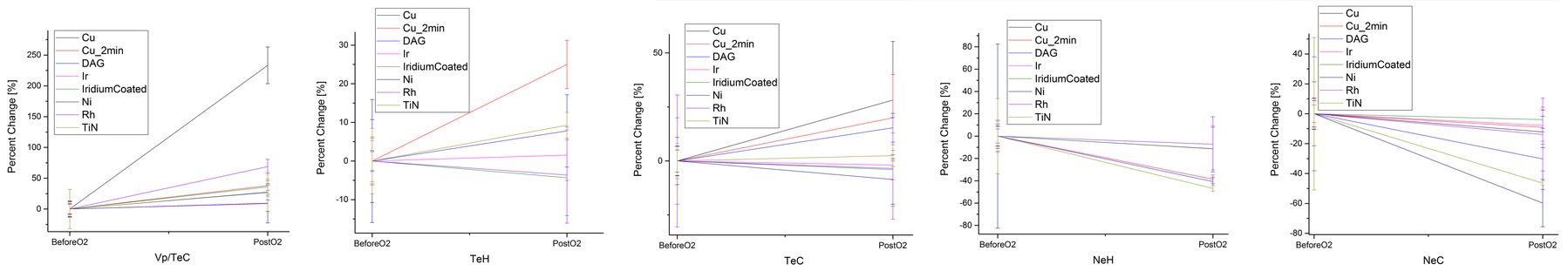


Results

Copper **Iridium** **DAG** **TiN** (Not Wire Probe)



- Copper shows the exaggerated distortion of IV curves after oxygen exposure, such as a shifted and rounded knee, distorted retarding region, and lower current.
- TiN shows permanent degradation after exposure while all other metals returned to their original curves after cleaning, which is in agreement with MAVEN data.
- Iridium out preformed all other materials and showed effectively no change.



General Trends of Plasma Parameters due to Distortion of the IV Curves from Oxidation Effect:

- Plasma potential shifts to the right becoming more positive, and the current decreases.
- Hot electron temperature variation is on the order of the error. The Copper and Nickel hot electron population are suppressed by oxidation.
- Cold electron temperature increases.
- Hot and cold electron densities decrease.

Conclusions

Our results corroborate MAVEN data, specifically the TiN probe trends and its inability to be cleaned. **Iridium was most unaffected by oxygen plasma exposure, suggesting promise as a Langmuir probe material for future probes.** Our results show that Langmuir probes are affected by atomic oxygen causing the derived plasma potential to be over-estimated and density under-estimated. While the electron temperature seems to increase, the trend is inconclusive.

Material	ΔVp/Te [%]	Error [%]	ΔTeH [%]	Error [%]	ΔTeC [%]	Error [%]	ΔNeH [%]	Error [%]	ΔNeH [%]	Error [%]
Cu	233.3	29.8	*	*	28.2	27.1	*	*	-12.1	10.4
Cu 2min	29.8	38.1	25.0	6.3	20.0	20.0	-38.6	3.9	-9.1	11.4
DAG	26.9	12.4	7.8	9.3	15.4	6.6	-40.7	3.6	-30.2	20.5
Ir	8.8	12.3	1.5	6.5	-1.9	6.7	-11.4	20.6	-7.8	10.5
IrCoated	35.9	12.4	-4.3	9.8	-3.9	16.9	-11.1	19.1	-3.9	8.3
Ni	9.5	32.0	*	*	-8.5	11.4	*	*	-59.7	15.8
Rh	68.9	11.8	-3.6	12.4	-3.4	23.5	-7.2	24.7	-13.9	24.3
TiN	27.5	31.9	9.2	3.3	2.5	5.0	-46.9	2.5	-46.4	1.4