Laboratory Simulation of Titan's Ionospheric Conditions

Abhina K P [†], Antony Arupara, Malavika S, Shravan Kale, Umesh R Kadhane [†]

Atomic and Molecular Physics Laboratory, Indian Institute of Space Science and Technology, Thiruvananthapuram, Kerala 695547, India

Synopsis RF driven plasma of nitrogen-methane mixture is used to recreate molecular processing in the ionosphere of Titan. While stable molecules produced during this plasma processing were monitored in real-time using mass spectrometry, the resulting Tholin deposition on different substrates were investigated using SEM, and mass spectra were recorded during plasma operation. Further work will focus on experiments with condensation of volatiles produced as well as direct extraction of boh positive an negative ions from the plasma reactor.

Titan, Saturn's largest moon, has a nitrogen-rich atmosphere containing methane. Solar radiation and energetic particles from Saturn's magnetosphere initiate ionization, dissociation, and chemical reactions that lead to the formation of complex organic compounds. These compounds contribute to the formation of aerosols known as *tholins*, which serve as laboratory analogues for investigating the chemistry of Titan's atmosphere[1]. Understanding how these materials form and identifying the chemical species involved are important for studying the evolution of organic matter in planetary atmosphere.

In this study, a nitrogen–methane plasma was generated using a 13.56 MHz radio-frequency inductively coupled plasma (RF-ICP) source to simulate aspects of Titan's atmospheric chemistry. Tholin deposited during plasma operation was collected on three substrates: silicon (Si), fluorine-doped tin oxide (FTO), and quartz. The samples were examined using scanning electron microscopy (SEM), and the images were compared with those of the corresponding uncoated substrates. The SEM images revealed an additional surface layer on the plasma-exposed samples that was absent in the uncoated substrates, providing morphological evidence of deposition. Using three different substrates also allows the deposited material to be examined on different surface types. Further characterization will be carried out to investigate the morphology, composition, and chemical properties of the deposited tholin.

Mass spectra were also recorded during nitrogen–methane plasma operation to investigate the molecular species formed through plasma-induced chemical reactions. Signals were observed at mass-to-charge ratios (m/z) above 50, indicating the presence of species across a broad mass range. These measurements provide an initial basis for investigating the chemical products formed in the plasma and developing a more complete understanding of plasma-driven organic chemistry.

Further experiments are planned using a liquid-nitrogen cold trap to collect condensable reaction products for subsequent analysis. A new plasma reactor model is also being developed to improve the direct sampling of neutral species, positive ions, and negative ions while minimizing disturbances to the plasma. Together, these studies aim to investigate the gas-phase products and deposited organic materials produced during nitrogen–methane plasma reactions.

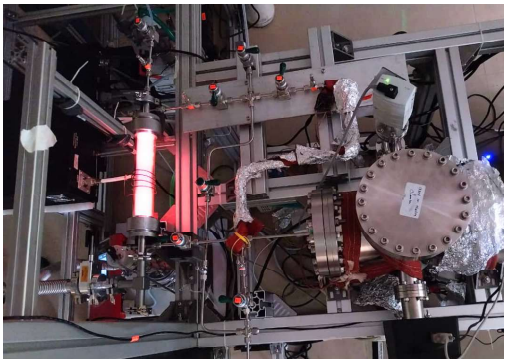


Figure 1. Experimental setup used for the laboratory simulation.

References

[1] Sciamma-O'Brien E *et al.* 2014 *Icarus* **243** 325–336

[†]E-mail: corresponding. abhinakattungal@gmail.com
[†]E-mail: corresponding. umeshk@iist.ac.in