THE TITAN AEROSOL SIMULANTS PRODUCED AT LOW TEMPERATURE IN THE TITAN HAZE SIMULATION EXPERIMENT AT NASA AMES: A CLOSER ANALOG OF TITAN’S AEROSOLS?
E. M. Sciamma-O’Brien1,2, K. T. Upton3, J. L. Beauchamp2, F. Salama1, NASA Ames Research Center, Moffett Field, CA (ella.m.sciammaobrien@nasa.gov); 2Bay Area Environmental Research Institute, Sonoma, CA; 3Noyes Laboratory of Chemical Physics and the Beckman Institute, California Institute of Technology, Pasadena, CA.

Introduction: Titan, Saturn’s largest moon, is the only solid body in the outer solar system with a dense atmosphere. Because Titan’s atmosphere is mostly composed of nitrogen and methane, it is often considered as a cold primordial Earth analog. Titan’s atmosphere is the siege of a complex organic chemistry that occurs at temperatures lower than 200 K and leads to the production of heavy molecules and subsequently solid aerosols that form the orange haze surrounding Titan. Because the reactive carbon and nitrogen species present in Titan’s aerosols could meet the functionality requirements for precursors to prebiotics (the ingredients for the building blocks of life), the study of Titan’s aerosol has become a topic of extensive research in the fields of astrobiology and astrochemistry. Experiments have been developed in several laboratories in the past 30 years in order to understand the production processes and composition of these atmospheric aerosols.

The Titan Haze Simulation (THS): The THS experimental setup was developed at the NASA Ames Cosmic simulation facility (COSmIC) to produce simulated aerosols in a pulsed, supersonic jet-cooled plasma expansion. The unique characteristic of the THS is that it cools down the gas to Titan-like temperature (150 K) before inducing the chemistry by pulsed plasma1, and that the pulsed nature of the plasma allows for a truncated chemistry that can be used to study the early stages of aerosol production, which has not been readily accomplished so far using other production methods. The study of the early stages of the chemical evolution of these simulated aerosols is critical to be able to predict the chemical functionalities present on Titan, for the development of the instruments needed for future lander missions. In addition, because the THS uses a plasma jet expansion, the gas and solid phase products of the chemistry are accelerated to supersonic speeds before being detected and/or deposited for future analyses, which is the closest laboratory simulation of a probe descent in Titan’s atmosphere. The THS can therefore be used to help define which substrate and diagnostic methods are most appropriate for future missions.

Both the gas and solid phases can be monitored and analyzed. A previous in situ study of the gas phase has demonstrated the unique advantage of the THS to look at the first and intermediate steps of the N2-CH4 chemistry2. Due to the short residence time of the gas in the pulsed plasma discharge, only the first steps of the chemistry have time to occur in a N2-CH4 discharge. However by adding heavier hydrocarbon trace elements to the initial N2-CH4 mixture, we can observe a chemical growth evolution and study the intermediate steps of Titan’s atmospheric chemistry.

Solid Phase Analyses: An extensive study of the solid phase products is presented here, and confirms the results of the gas phase analysis. In this study, THS Titan aerosol simulants were deposited on a variety of substrates for further ex situ analyses. The analogs were analyzed using complementary analytical techniques: infrared (IR) spectroscopy, scanning electron microscopy (SEM), nuclear magnetic resonance (NMR) spectroscopy, Direct Analysis in Real Time (DART) and Electron Spray Ionization (ESI) mass spectrometry, and visible reflectance spectroscopy for the determination of the simulants’ optical constants. IR spectra of N2-CH4 THS simulants show the typical spectral features observed with other Titan aerosol analogs. Both DART and ESI spectra of THS simulants produced in a N2-CH4 mixture show, in agreement with the gas phase, that the THS aerosols are made of less complex molecules than other Titan simulants. SEM images show that grains are produced in volume in the expansion and then jet deposited onto the substrate. The grains produced in N2-CH4-C6H6 mixtures are much larger than those produced in N2-CH4 mixtures, consistent with a more complex chemistry when adding heavier precursors. The NMR results also support a growth evolution of the chemistry when adding heavier species to the initial N2-CH4 mixture. Finally, reflectance measurements in the visible led to optical constants for THS simulants that are closer to the Titan aerosol optical constants obtained from observational data by Rannou et al (2010) than any previously reported optical constants of Titan simulants produced in other experimental setups.


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