

Titan's Beaches: an examination of what is possible and what is chemically feasible. Robert Hodyss¹, Mathieu Choukroun¹, Patricia Beauchamp¹ and Christophe Sotin¹, **Morgan Cable**¹ Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109.

Introduction

Cassini's investigation of Titan continually surprises us with exciting new results. Lakes were discovered in polar areas [1], and spectral features observed by the Cassini VIMS instrument around some of these lakes have been interpreted as putative evaporitic materials [2]. Although thermodynamic models [3] give some clues on the composition of lakes and potential evaporites, we are sadly lacking in interpreting some of these results because of the dearth of experimental data. This presentation provides some of our initial thoughts on how to interpret the notion of 'beaches' around the Titan mares. Are these beaches just deposited organics from the atmosphere, materials precipitated out from the ethane/methane lakes or both? Are crystalline or co-crystalline (such as the 1:1 acetylene-benzene co-crystal observed by [4]) complexes formed from the interaction of dissolved materials? Experiments we have initiated begin to shed light on this conundrum. We have slowly evaporated large volumes (10 mL) of saturated solutions of benzene and acetylene in pure ethane and mixtures of ethane/methane and other possible solvents. Macroscopic quantities of crystals have been generated for analysis of morphology and size distribution and the crystals analyzed with Raman spectroscopy, infrared spectroscopy and optical microscopy. To maintain the integrity of the sample and determine how these materials mix, the Raman microscopy is performed in a cryostage. We will later compare the spectroscopy of some of these simulated 'beaches' with data obtained from VIMS on Cassini.

Experimental methods

Organic evaporates are produced in a custom-built liquid nitrogen cryostat shown in Figure 1. Approximately 10 mL of liquid ethane or methane saturated with the solute or solutes of interest is held at 94 K in a nitrogen-purged glovebag using a Lakeshore 315 temperature controller, while a stream of nitrogen is blown across the surface to hasten evaporation. Evaporation rates can be controlled by varying the temperature and/or nitrogen flow rate. Another method used is the deposition of a few droplets of solution directly inside the cryostage and evaporation therein. The samples after evaporation are deposited in a Linkam LTS 350 liquid nitrogen – cooled cryostage, also held at 94 K, for microscopic observation using a binocular microscope. Another method used is the deposition of a few droplets of solution directly inside the cryostage and evaporation therein. The cryostage is located on a cart

equipped with a UPS to allow transportation to a Horiba Jobin Yvon LabRam HR confocal dispersive Raman spectrometer, equipped with both a He-Ne, 632.8 nm wavelength, 23 mW power laser and an external frequency-doubled Nd-YAG 532 nm laser. A 600 grating is used to acquire spectra over the range 50-3600 cm^{-1} , with a resolution of $\sim 1 \text{ cm}^{-1}$.

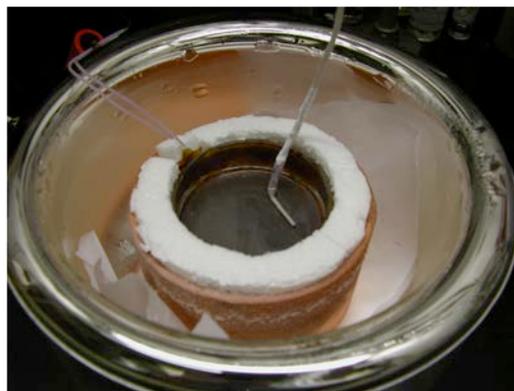


Figure 1. Close-up photograph of the cryostat. Gas lines and a magnetic stir bar are not shown.

Results

To date, several runs have been completed. First, pure benzene and pure acetylene have been deposited in the cryostage and cooled to 94 K, and Raman spectra have been acquired for reference [5]. Figure 2 shows the morphology of a benzene crystal obtained by freezing. The green spot shows laser spot size.

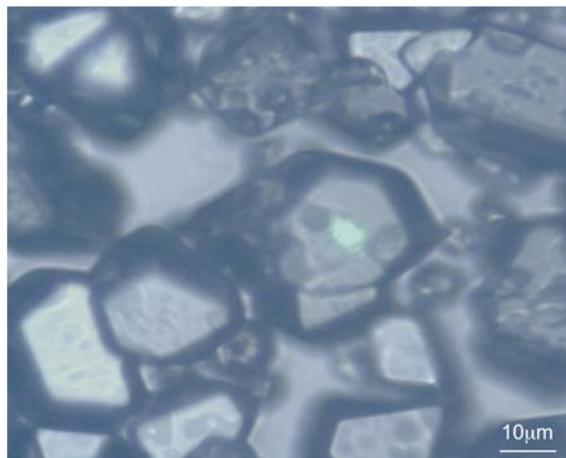


Figure 2. Photograph of benzene crystals formed by cooling of a benzene liquid drop to 94 K in the cryostage, using a 50x objective.

Second, experiments have been conducted using benzene or acetylene dissolved in liquid ethane then evaporated on a glass slide within the cryostat or directly within the cryostage. The first striking observation is, as one would expect, the difference in morphology of the crystals formed by precipitation instead of freezing or deposition. On one hand, benzene crystals formed by freezing (Figure 2) are 20-50 μm large and exhibit sub-automorphic shapes, while vapor-deposited acetylene crystals are sub-mm to mm size range and only exhibit a frost-like appearance. On the other hand, benzene precipitation resulted in either angular crystals in the 20-30 μm size range, or dendritic crystals $\sim 5 \mu\text{m}$ wide and 100 μm to mm long.

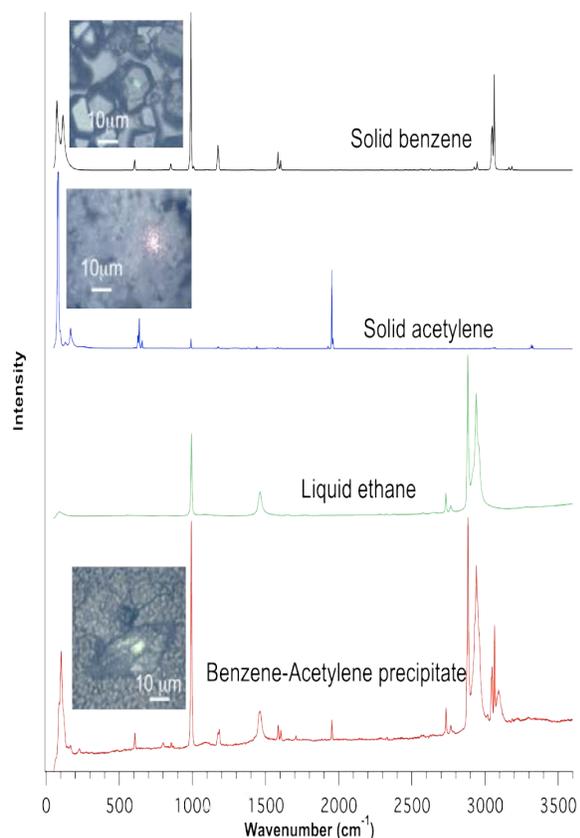


Figure 3. Raman spectra of solid benzene, solid acetylene, and liquid ethane, obtained for reference, and a spectrum obtained on a precipitate crystal while liquid ethane was still present.

A third set of experiments has been conducted, where both benzene and acetylene have been dissolved simultaneously in liquid ethane in an attempt to determine if 1:1 cocrystals could form upon precipitation at Titan conditions. In these experiments, a drop of solution was deposited in a well of the glass slide within the cryostage at 94 K, and slowly evaporated within

the cryostage. Figure 3 summarizes all the Raman signatures observed in our experiments. A few angular, 10-30 μm size crystals formed at 94 K within minutes and were sparsely scattered across the glass slide. Complete evaporation of the ethane solution did not occur at this temperature over the duration of the experiment, thus an ethane signature is visible in all acquired spectra. Nevertheless, the Raman signature of all three relevant compounds are distinct enough that the precipitates can be identified without any ambiguity as mixed benzene-acetylene crystals. Kirchner et al. reported variations in Raman peak positions in the cocrystals in their high-pressure high-temperature experiments. Raman peak positions measured in the precipitates in our experiments are identical to those of pure benzene and acetylene crystals. This suggests that the precipitates consist of an intimate mixture of acetylene and benzene rather than cocrystals, or that the Raman signature of the cocrystals depends significantly on pressure and temperature. Further experiments are needed to better address the potential of cocrystal formation under Titan conditions.

Summary and future research

We have developed an experimental setup and a set of analyses to investigate the composition and morphology of putative Titan “beaches” materials. Initial experiments on benzene, acetylene, and mixtures of the two have allowed us to determine that benzene and acetylene precipitates usually exhibit an angular shape and may also form dendritic crystals. Further experiments are needed to determine whether acetylene-benzene cocrystals actually form upon evaporation. In future experiments, we will also analyze the precipitates using an infrared spectrometer in order to compare the laboratory data with VIMS observations.

Acknowledgements

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References

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