MICROSCOPIC IMAGING OF TITAN SURFACE MATERIALS IN PREPARATION FOR DRAGONFLY.
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Introduction: The *Dragonfly* rotorcraft lander mission will land on Titan in the mid-2030s to investigate the prebiotic chemistry, habitability, and potential chemical biosignatures that may exist on Titan [1-3]. Compounds that *Dragonfly* may come into contact with on the surface include liquids such as methane (CH_4) and ethane (C_2H_6), as well as solid compounds like acetylene (C_2H_2), butane (C_4H_{10}), benzene (C_6H_6), tholins, and water ice, among others [4-9]. However, a detailed understanding of Titan's surface composition remains ill-constrained; *Dragonfly* will reveal what chemical species are present and how they are distributed across the surface, which will in turn inform the geological context of these measurements [10].

Dragonfly's science payload includes a mass spectrometer, a gamma-ray and neutron spectrometer, a geophysics and meteorology package, a camera suite, and a sampling drill [1-3]. This study utilizes specifications from the camera suite (DragonCam), specifically the microscopic cameras, as well as laboratory simulations of Titan surface materials in order to gain a better understanding of the DragonCam-scale morphology differences among large-scale crystal structures of surface-relevant compounds. Cataloging these morphologies may help to contextualize in situ observations from *Dragonfly* in a situation where the surface can be imaged but a sample cannot be collected.

Sample Preparation and Imaging Protocol: A liquid nitrogen-cooled cryostage (LTS 350, Linkham Scientific Instruments, Ltd.) is placed under a high-resolution microscope (Olympus BX51; 20x and 50x objectives) to capture images of the sample. First, the cryostage is purged with N_2 gas to eliminate the risk of contaminants such as water vapor, etc. Next, the cryostage is cooled to a temperature below the freezing point of the associated sample to allow deposition as a solid. A tedlar gas sample bag (Restek, 1L, polypropylene fitting) is pre-filled with the sample (e.g., pure acetylene) and is connected to a gas inlet on one side of the cryostage. A second gas inlet on the other side of the cryostage allows for simultaneous deposition in the case of mixed samples. The sample bag valve is opened to allow sample flow/deposition into the cryostage. After an appropriate amount of the sample has been deposited (~30 seconds or less), the cryostage temperature is decreased to Titan surface temperatures (90 K) for image collection. Liquid ethane is condensed onto the sample at 90 K to simulate "ethane wetting." After images are taken of the sample + ethane at 90 K, the cryostage is warmed to ~120 K to expedite ethane evaporation. Images are collected both before ethane condensation (pure sample), after ethane condensation, and after ethane evaporation to note morphological changes. Table 1 lists the compounds tested so far and their associated morphology descriptors.

Table 1. List of samples imaged, temperature range, and morphology description.

Sample	Temp. (K)	Morphology Description
Acetylene	90	connected, branched, dark
Butane	94	porous, negative relief
Acetylene + ethane	90-128	polygonal cracks
Butane + ethane	90-123	partially dendritic, connected

Imaging results: *Acetylene.* Pure acetylene sample morphology shows a crystalline structure connected in a branching-like pattern (Fig. 1). Parts of the sample appear relatively darker, however this is most likely due to thickness differences with respect to the microscope stage illumination. When liquid ethane was condensed on the sample and allowed to evaporate, significant polygonal "cracking" is observed throughout the sample (Fig. 2), reminiscent of mud cracks or ice wedge polygons that have been observed in terrestrial and Martian environments [e.g., 11]. These cracks could be explained by partial dissolution of acetylene in the liquid ethane prior to evaporation.

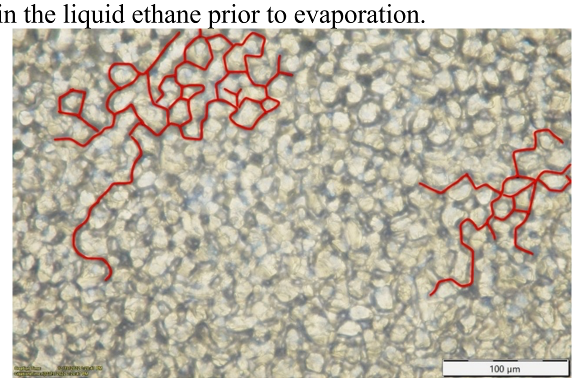

Figure 1. Top-down microscopic image of pure acetylene (90 K; 50× magnification). Notice the connected/branched-like pattern (examples traced in red) and the relatively dark appearance of the crystals.

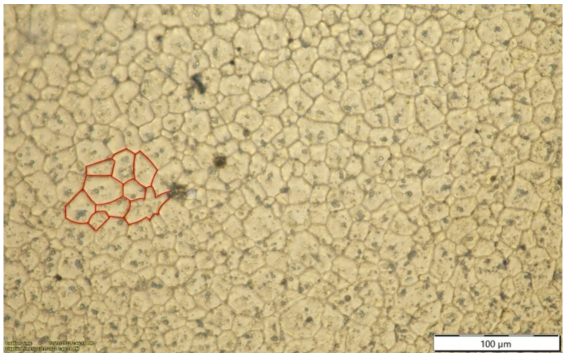

Figure 2. Top-down microscopic image of acetylene after liquid ethane evaporation, same experiment as in Fig. 1 (90 K; 50× magnification). Notice the irregular, polygonal "cracks" throughout the sample (examples outlined in red).

Butane. Pure butane sample morphology shows a more amorphous texture than acetylene. The sample is porous and appears to have negative relief (Fig. 3). When liquid ethane was condensed and allowed to evaporate, we observed a crystalline morphology and dendritic structures (Fig. 4). These changes after liquid ethane addition may be explained by butane's high solubility in ethane [9].

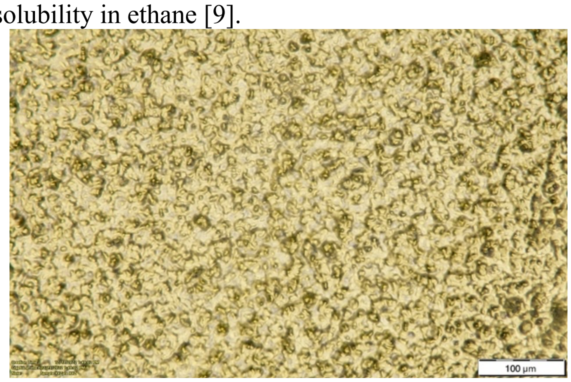

Figure 3. Top-down microscopic image of pure butane (94 K; 50× magnification). Sample morphology exhibits a porous texture, as well as negative relief spots (e.g., bottom right portion of image).

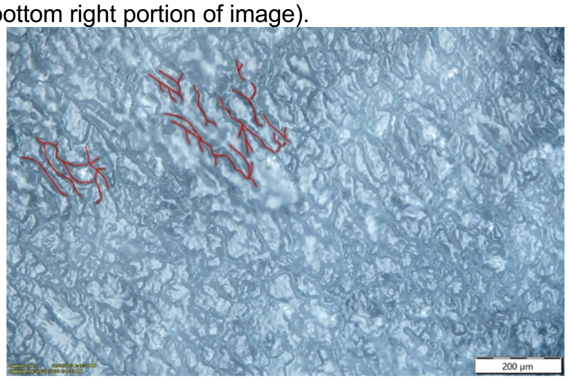

Figure 4. Top-down microscopic image of butane after liquid ethane evaporation, separate experiment from Fig. 3 (90 K; 20× magnification). Notice the partially dendritic morphology on top of the sample (examples traced in red). The grayish color is an artifact of the saturation level when the image was taken.

Next Steps: This project highlights the need to study the microscopic-scale morphology of Titan-relevant surface materials to provide context for DragonCam image collection on Titan. Future experiments and data analysis will include additional mixtures of relevant surface compounds, methane condensation, measuring the size and area of features within the sample, Raman spectroscopy to better correlate morphology with composition, and using a UV source to simulate fluorescent organic detection.

In addition to the microscope images captured in our lab at JPL, the microscopic imager benchtop model with DragonCam wavelengths for *Dragonfly* at the Applied Physics Laboratory [12] will be used in future experiments to compare and contrast the results from the JPL setup, and to provide a closer match to DragonCam instrument specifications.

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