

# Experimental formation of low-temperature condensed CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, and C<sub>2</sub>H<sub>6</sub> particles simulating solar-system objects and mid-infrared imaging spectroscopy measurements

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Low-temperature condensed particulates of hydrocarbons are present mainly in solar-system bodies beyond Jupiter, and understanding their phase transitions and crystal growth is important for astrochemistry. The major hydrocarbon present on the Saturnian moon Titan and Pluto is CH<sub>4</sub>, but C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> have also been shown to be present in the form of frost and atmospheric fog. These molecules have been subjected to condensation and annealing experiments and infrared transmission spectra at surface temperatures of 10-60 K in the laboratory. However, infrared transmission spectra have not yet been obtained at higher temperatures (80-110 K). In addition, the process of crystal growth of solid hydrocarbons by solar ultraviolet radiation has not been clarified. This study aims to solve these problems by performing laboratory measurements that reproduce atmospheric and surface frost conditions and to obtain mid-infrared spectra that can be compared with ground-based observations in the future.

In this study, an imaging Fourier transform mid-infrared spectrometer based on the near-common-path wavefront-division phase-shift interferometry was designed to measure the 2D images of transmission and absorption spectra of these molecules with wavelength resolution  $R=100$ , spatial resolution  $12 \mu\text{m}$  and  $3 \text{mm}$   $\phi$  range. We made effective use of a cryostat (Koga et al., 2024), which is connected to the optical system and liquid nitrogen dewar with a small vacuum chamber, and installed a pulse valve to control the gas flow rate. The experiment was then conducted according to the following procedure. (1) reduce the pressure in the chamber to  $\sim 10^{-3}$  Pa, (2) cool the temperature of the IR-transparent ZnSe sample stage to 90 K, (3) stop the pressure reduction and spray pure C<sub>2</sub>H<sub>4</sub> gas onto the ZnSe, and (4) leave the chamber for a while and perform IR measurements every 5 minutes.

As a result, spectra with a single peak at a wavelength of  $11.7 \mu\text{m}$  for C<sub>2</sub>H<sub>6</sub> and a double peak around  $10.4 \mu\text{m}$  for C<sub>2</sub>H<sub>4</sub> were obtained simultaneously in various forms. However, because the ZnSe plate did not cool down to the expected temperature, sublimation occurred, and both spectra were lost within 20 minutes. Therefore, we will improve this experimental apparatus so that it can be cooled efficiently so that frost can be present stably before the presentation. Then, we plan to measure the changes in the vibrational spectra appearing in the mid-infrared region *in-situ* while irradiating ultraviolet light using a D2 lamp with a continuous spectrum up to 200-300 nm as a light source.

Keywords: Infrared spectroscopy, Solar system body