DENSITY OF METHANE AND NITROGEN AT DIFFERENT TEMPERATURES

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Abstract

In this work the densities of frozen methane and nitrogen molecules are obtained at the laboratory. They are given for different deposition temperatures between 10 K and the sublimation temperature of these molecules in our experimental set up ($\leq 10^{-7}$mbar). As a collateral result the real part of the index of refraction at 632.8 nm is given in all cases.

Keywords: Ice, density, nitrogen, methane.

1. Introduction

Methane and nitrogen are present in different astrophysical scenarios as the interstellar medium (ISM) [1][2][3] or in the Solar System [4][5]. In some cases both could be the dominant specie in a particular terrain. Nitrogen has been identified as the major component on Triton and Pluto icy surfaces [6]. Methane has been identified in both objects [7][5] and it is thought that at the surface of Pluto CH_4 could be segregated [8]. In those scenarios, where these ices are present as the major components, density could be an important parameter because its relation with the porosity and consequently with the capability of trapping molecules.

2. Experimental

A quartz crystal microbalance (QCMB) is put in thermal contact with a closed-cycle helium refrigerator. It is inside a high vacuum chamber that operates at $10^{-8} - 10^{-7}$ mbar. The cooling system is a double-stage cold head that cools the balance to 10 K. A controlled intensity passing trough a resistor, lets choose the temperature from 10 K till room temperature within 0.5 K.

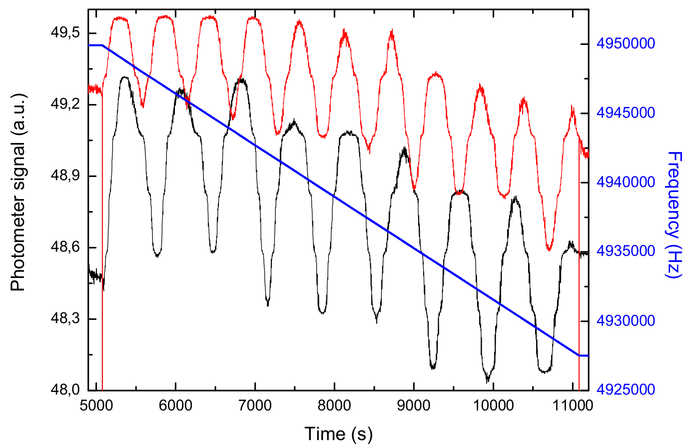

Figure 1. Ice film deposit. Blue line, velocity of deposition. Red interference pattern incidence 27 degrees. Black interference pattern incidence 63 degrees.

When the desired temperature is achieved gas molecules coming from a "pre-chamber" trough out a regulable needle valve, fill the chamber. This kind of deposition is called "background", where the molecules could come from all directions.

The mass deposited is obtained from the variation of frequency of the QCMB, -Δf=1 Hz is equivalent to 15.4 ng cm^{-2}. The total mass deposited per square centimeter, see Figure 1 (right Y axis), is determined for a desired film thickness with an error lower than 0.2%.

During the deposition the interferograms of two polarized (perpendicular to the plane of incidence) He-Ne lasers are obtained. Those allow to measure, from the periods ratio, the real part of the refraction index of the ice film[9]. This result is specially important when no bibliographic data are available for the conditions of the experiment or when the sample is a mixture of different molecules. From the Bragg refraction equation it is apparent that the change in thickness between two adjacent peaks, $\Delta\tau$, is given by

$$\Delta\tau = \Delta q\lambda/2n(1 - sin^2\beta_i/n^2)^{(1/2)}, \quad (1)$$

where $\Delta q = 1$, n is the index of refraction and λ is the wavelength of the incident light.

Dividing mass deposited (g cm^{-2}) by thickness (cm) the density is obtained.

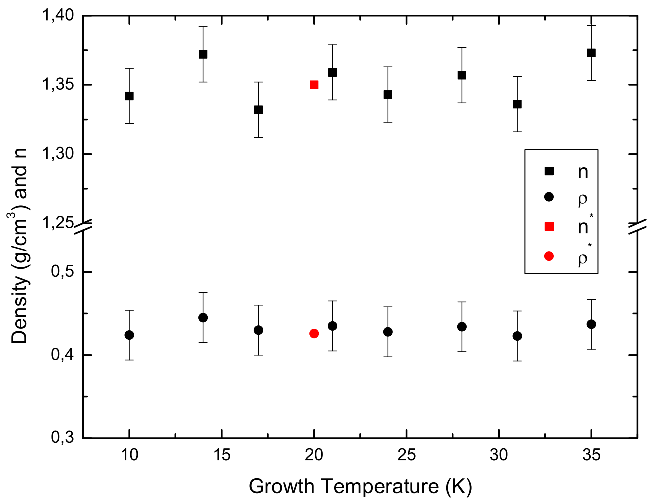

Figure 2. Density and real part of the index of refraction for methane as a function of the growth temperature

Reagents used and their purities are as follows: CH_4 (gas), PRAXAIR 99.9995% purity, N_2 (gas), CARBUROS METALICOS 99.999% purity.

3. Results

The results presented are shown in Figures 2 and 3 where the upper Y axis represents the real part of the index of refraction, and density, in g cm^{-3}, in the bottom Y axis is represented against the temperature of deposition, varying from 10 K until their sublimation temperature at our working pressures. Each point represents one experiment in which the temperature is fixed, and then the molecule is deposited at a certain velocity. In a separate series of experiments it was verified that different velocities of deposition (from 0.3 Hz s^{-1} until 30 Hz s^{-1}) did not affect these results, then we can conclude the density for nitrogen and methane does not vary with the velocity of deposition. In all of those experiments contamination was below 0.1%. The error bars in Y axis are due to lightly variations in the constancy of the periods.

The graphs include points without error bars corresponding to previous results for a certain temperature appeared in the bibliography[11]. We have not found other results in the bibliography for different temperatures of deposition.

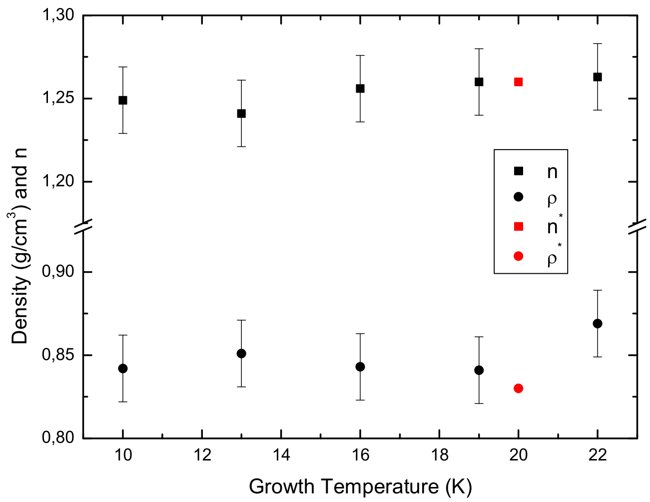

Figure 3. Density and real part of the index of refraction for nitrogen as a function of the growth temperature

As can be seen in Figures 2 and 3 both the real part of the index of refraction and the density remain constant for all the temperatures of deposition from 10 K until their sublimation temperature, 22 K for N_2 and 35 K for CH_4. This behaviour is different in water ice where the density depends on the temperature of deposition[10].

4. Conclusions

We have found no differences in our results for different deposition velocities. Respect Methane ice its real part of the index of refraction is 1.35, and the density 0.43 g cm^{-3}. On the other hand the real part of the index of refraction of nitrogen is lower than methane 1.25, but its density is higher than methane 0.85 g cm^{-3}. For both molecules the density and the real part of the index of refraction remain constant within the range of temperature of deposition from 10 K till the sublimation temperature in our experimental set up.

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