EPSC Abstracts
Vol. 11, EPSC2017-272, 2017
European Planetary Science Congress 2017

'Peeling a comet': Layering of comet analogues

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Abstract

Many comet models define the nucleus surface as a strict boundary (e.g. [1]; [2]), others as a dynamic transitional zone (see e.g. [3]). A series of experiments has been performed at the Open University to gain more insight into which of the two is the more realistic approach.

1. Introduction

Our current understanding of the physics of comets is based on data from several space missions (e.g. GIOTTO, Deep Impact and most recently ROSETTA), the predictions of theoretical models and the results of laboratory experiments. Some of the data and images obtained from cometary missions have raised questions that cannot be answered without improving the established theoretical models – a process that should be based on experimental results.

Several series of comet simulation experiments have been done in the past. For example KOSI (KOmeten SImulation, German for comet simulation), the most extended campaign, was performed in the late eighties and early nineties of the last century [4]. Although those experiments provided new insight in the physics and morphology of cometary analogue materials, the set-up was quite complex and made it difficult to analyze the results in a quantitative manner.

To minimize these difficulties we decided to start our series of experiments using samples that only contain two components – H_2O ice and carbon particles (carbon black).
To investigate the influence of subsurface solar light absorption by dust, we added varying quantities of carbon particles to samples of porous ice. The samples are irradiated for several hours, temperature and hardness profile are measured and the change of the surface structure is recorded.

2. Experiments

We investigated mixtures of H_2O ice and carbon black with different initial temperatures, mixing ratios and sample heights under vacuum conditions. The basic set-up for all experiments was the same: a cylindrical container consisting of two Perspex halves fixed on a cooled base plate inside an environmental chamber was filled with the sample material. The sample with an initial height h_0 was cooled down to a given minimum temperature T_0, while the chamber was depressurised. After the temperature gradient inside the sample had stabilised, the samples were irradiated using a solar simulator and the temperature profile inside the sample was measured. Additionally, a time lapse record of the morphology of the sample during the irradiation phase was obtained using a set of commercial off-the-shelf webcams.

2.1 Hardness measurements

After the experiments, the sample was cut in halves and the hardness profile of the sample along the vertical axis was measured using the method described by [5]. The samples were already slightly harder than the original material due to sintering before the irradiation was started. At that time the hardness is constant along the z-axis.

The original sample material was a loose aggregate of particles with a hardness of about 4 -6 kPa. After the samples were cooled in a depressurized surrounding and irradiated for about 18 hours each of the samples got significantly harder with a soft layer including the surface, a harder layer beneath and a more soft one closer to the bottom of the sample.

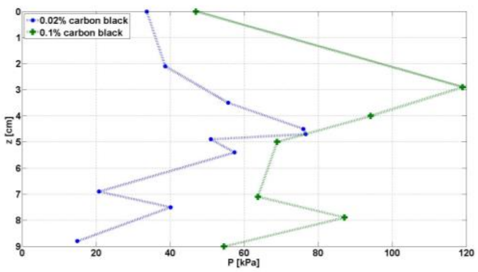

Figure 1: Example of hardness profiles after 18 hours of irradiation for two different H_2O/carbon black mixtures, Surface: z = 0cm, h_0=15cm, T_0 = 173K.

2.2 Surface structure

During the irradiation process the surface has changed significantly. Figure 2 shows the sample surface at the beginning of the irradiation phase (left) and after 18 hours of irradiation (right). Particle emission starts immediately after the light is turned on, a significant change of the surface can already be observed within the first 10 minutes of irradiation.

Figure 2: Change of the surface structure after 18 hours of irradiation. Sample includes 0.2% carbon black. T_0=173K, h_0 = 15cm.

Summary and Conclusions

The results of the experiments carried out so far show that all samples were hardened considerably by exposure to solar light. The higher the amount of light-absorbing carbon particles, the harder the samples became.

The hardest layer can be found 3 - 7cm below the surface where the sample temperature is ~ 203K to 207K.

Changing the base temperature of the sample has less effect on the hardness than chancing the carbon particle percentage.

For low carbon particle content the material close to the base barely changes compared to the original material in terms of hardness.

Particle emission starts immediately after the irradiation starts and conglomerates of carbon black built on the surface.

The dramatic surface hardening by insolation combined with the drastic change in surface structure (even if only a marginal amount of carbon particles are added to the ice sample) suggests that cometary models should treat the nucleus surface as an interactive transitional zone to better represent cometary processes.

Acknowledgements

This project is funded by STFC under grant number ST/L000776/1.

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