ICE PARTICLE EMISSION FROM COMETARY ANALOGUES

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ABSTRACT. Dust particles originating from comets are an important constituent of the interplanetary dust regime. In order to study the ejection mechanisms from the cometary nucleus surface simulation experiments in the laboratory have been performed. Samples consisting of water ice, carbon dioxide ice and dust grains have been studied when they are irradiated by artificial sunlight within a cooled vacuum system. It has been shown that particle emission is extremely dependent on the initial composition of the samples. For samples with a distinct amount of non-volatile, mineral particles the formation of a dust mantle and, as a consequence, rapid decrease of particle ejection has been observed.

1. Introduction

Comets are an important source for interplanetary dust particles. Heated by solar irradiation the volatile surface material sublimates and consequently emits gas, ice- and dust particles. However, it is not quite clear which proceses cause the release of such particles from the cometary surface in detail. Within classical models only dust particles smaller than a critical radius may leave the comet. Larger pebbles and rocks remain at the surface forming a non-volatile mantle.

To improve our understanding of cometary surface physics, sublimation experiments in the laboratory are performed in the comet simulation (KOSI) project (Grün et al., 1990). KOSI is an interdisciplinary and cooperative project of German, French and Israeli scientists. The scientific aim is to study the physical properties and behaviour of sublimating ice-dust-samples under interplanetary space conditions. Therefore experiments in a few meters large space simulator at Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) in Köln, Germany, and in some other laboratories are performed.

Samples, mainly consisting of water ice, carbon dioxide ice and mineral constituents eject ice and dust particles when they are heated by irradiation of an artificial sun. In order to investigate particle emission from the sample diagnostic instrumentation like video cameras, collectors, impact and laser detectors are installed within the simulation chamber, analyzing physical properties like sizes, speed and emission distribution.

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2. Method

The measurements of ejected particles referred to in this paper are performed by a system of ten piezoceramic impact detectors. These detectors are able to record particles hitting onto a ceramic surface. Particle momentum is transformed to an electric signal by the piezoceramic material. Sensitivity and calibration have been described by Kohl et al. (1990). Although the sensitivity of the detectors is relatively high, only particles larger than 150 to 200 μm can be detected in the KOSI experiments because of the high electric noise level within the space simulator. As the sensitivity threshold is determined both by mass and velocity of the projectiles the lower size limit for the particles is not sharp.

The physical process of momentum transfer at the detctor's surface also determines the detectibility of particles having different physical structure. Calibration experiments showed that only compact projectiles may be recorded by the impact detectors. Fluffy and weakly bound agglomerates like the clay sublimate residues (see chapter 3) are destroyed during the impact process. As a consequence, transferred momentum per unit time is much smaller and the sensitivity of the detector rapidly decreases. This means for the KOSI experiments that only particles may be recorded which contain at least a significant amount of icy components. Even mm-sized iceless agglomerates are not 'seen' by the detectors.

Size and momentum of the projectiles can be directly deduced from the signal form. Because of the time for data processing only four signals of different detectors are stored per 100 sec. Nevertheless every signal during this time exceeding a given threshold may be counted.

The detectors were installed within the vacuum chamber at a distance of 0.98 m from the sample center at different angles from -22.5 to +22.5 degrees in equal steps relative to the irradiation direction (Fig. 1). Because of the geometrical setup only particles with ejection velocities between 1.8 and 3.5 m/s may strike one of the detectors. Evaluation of particle collectors at different positions in the chamber (Thiel et al., 1990) showed that this is just the speed range of most emitted particles.

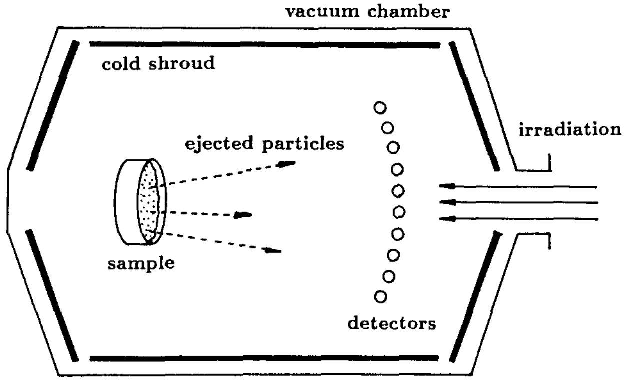

Fig. 1 Experimental setup for investigation of dust particle emission by piezoceramic detectors in the KOSI experiments.

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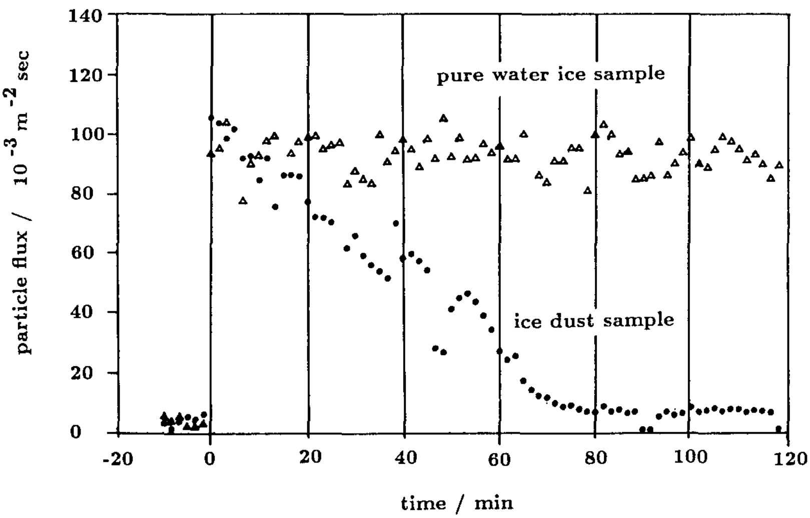

Fig. 2 Particle flux at the detectors as a function of time. At t=0 irradiation with artificial sunlight starts.

3. Simulation Experiments

In this paper we present the results of two experiment. In the first experiment a pure water ice sample was used; the second experiment was performed with a mixture of 41.6 % water ice, 15.0 % carbon dioxide ice, 7.4 % montmorillonite particles, 31.0 % olivine particles and 5.0 % fine grained carbon.

The mineral constituents in the sample show a rather different physical behaviour. Clay particles like montmorillonite which are initially mixed in the suspension with sizes in the order of a few microns tend to clump and form lattice-like agglomerates (Storrs et al., 1988). These agglomerates are already existent in the ice and keep conserved when the volatile material in the pores sublimates and disappears. Therefore sizes and forms of the agglomerates are generally determined by the droplets freezing in the liquid nitrogen. Olivine particles do not have such properties. However, they may adhere to the clay structure to a certain amount.

4. Results and Discussion

Fig. 2 shows the time development of particle flux for the first two hours of irradiation during the two experiments. For both experiments counting rates of particles increase rapidly with the start of irradiation. Particle ejection occurs on a time sclae smaller than the measuring interval of 100 seconds. In the pure water ice experiment the initial counting rate remains almost constant. This is due to free sublimation of water ice at the sample surface. In the water/carbon dioxide/mineral experiment emission activity decreases and reaches the noise level after about 60 to 70 minutes. We assume that a mantle of mineral particles has formed, probably, quenching gas and particle emission.

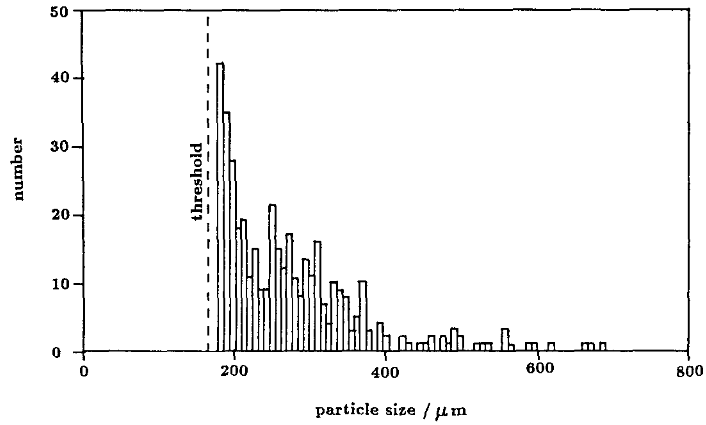

Fig. 3 Size distribution of the recorded particles in the second experiment.

During the second experiment the surface temperature which was measured by the thermal emission (Heidrich, pers. comm.) reaches an equilibrium temperature of 439 K (Höppner, pers. comm.) after about one hour. This proves that a mantle of dust particles almost free of volatile material built up. The mantle causes a thermal shielding against the radiative energy input. As a consequence gas emission and particle ejection decreases.

The histogram in Fig. 3 shows the size distribution of the ejected particles as measured by the impact detectors. Particle frequency distinctly increases with decreasing diameter. This is due to the fact that particles with lower mass may be lifted more easily from the surface than large ones. The largest particles recorded are 600 to 800 μm in diameter. However, still larger ones, up to mm sizes, were found in the collectors after the experiment. An upper limit for the particle sizes, giving an estimation for a possible critical radius of emission, was not found. A significant change in the size distribution of the initial sample and the emitted particles has not been observed, as there is up to now no precise possibility to determine in situ sizes of ice-dust-particles within the sample. Changes of size distribution during the time of irradiation also could not be observed. The reason is the low number of recorded particles not allowing an exact statistical evaluation.

5. References

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