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PARTICLE EMISSION FROM ARTIFICIAL COMETARY MATERIALS

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ABSTRACT

During KOSI (comet simulation) experiments mineral-ice mixtures are observed in simulated space conditions. Emission of ice-/dust particles from the sample surface is observed by means of different devices. The particle trajectories are recorded with a video system. In the following analysis we extracted the parameters: particle count rate, spatial distribution of starting points on the sample surface and elevation angle and particle velocity at distances up to 5 cm from the sample surface. Different kinds of detectors are mounted on a frame in front of the sample to register the emitted particles and to collect their dust residues. By means of these instruments the particle count rates, the particle sizes and the composition of the particles can be correlated. The results are related to the gas flux density and the temperature on the sample surface during the insolation period. The particle emission is interpreted in terms of phenomena on the sample surface, e. g. formation of a dust mantle.

INTRODUCTION

In the comet simulation (KOSI) project the behaviour of mineral-ice mixtures under simulated space conditions is studied. The experiments take place in the space simulation chamber at DLR in Köln (Kochan et al. (1988)).

This paper refers to the KOSI 5 experiment performed in November 1989. The sample composition was 70 % H_2O, 9 % minerals (olivine : montmorillonite = 9:1), 4 % CH_3OH, and 17 % CO_2 by weight. The mixture of minerals and volatiles was produced by spraying a suspension of water, minerals and methanol into liquid nitrogen. The resulting ice is then mixed with carbondioxide ice. During the experiment the sample container was tilted by an angle of 40^0 with respect to the horizontal plane. It was irradiated for about 12 hours with an intensity of 1.16 solar constants on the sample surface. During the irradiation phase the particle emission which is described in this paper, the thermal behaviour of the sample (Benkhoff and Spohn (1991) and Grün et al. (1991)) and the gas release (Hesselbarth et al. (1991)) is monitored.

PARTICLE DIAGNOSTICS

In front of the sample about 77 cm below and approximately 20 cm away from the surface center a frame is placed on which different kinds of particle collectors and detectors are mounted (Thiel et al. (1991)). Special ice particle detectors have been developed (Mauersberger et al. (1991)) to measure the volatile component of the emitted particles by ion gauges and to collect the dust residues in ten different cups. The size range of particles which can be registered is 7 - 220 μm equivalent radius. It has been found that there occur two kinds of signals which strongly differ in the rise time and the decay time of the ice sublimation rate. They are interpreted as two different types of particles. The particles with low ice sublimation rate presumably contain the volatiles inside a porous mineral cover while the high ice sublimation rate of the other type of particle indicates a pure ice composition (Mauersberger et al. (1991)).

In a distance of approximately 105 cm from the sample 10 piezoceramic acoustic detectors are attached to the frame. These detectors register particles greater than 250 μm with a time resolution of 100 sec (Kohl (1989)).

The time development of the particle emission during the insolation period shows the following characteristics (Mauersberger et al. (1991), Michel (1990) and Kölzer et al. (1990)): Pure ice particles are only emitted in the beginning of irradiation. The emission of mineral-ice particles starts about 15 minutes after beginning of insolation. The count rate has its maximum after about 0.5 hours of irradiation. The count rate shows a steep increase and a slow decrease. The signals of the impact detectors indicate an superposition of pure ice and mineral-ice particles (Kölzer et al (1990)). The largest amount of dust residues in the collectors coincide with the highest activity of mineral-ice particle emission. While the count rate of ice and mineral-ice particles is negligible after two hours of insolation there is still emission of pure dust particles.

The dust residues which are collected on the frame in front of the sample are investigated by an optical microscope in transmitted light and the particle sizes measured by means of an image processing system. The lower threshold of the size measurements is 5000 μm^2 ($\cong$ 40 μm equivalent radius). It turns out that the size distribution of the dust residues which are collected in the ice particle detectors does not change over hours (Kölzer (1991)). The exponents which are found for the best fit power laws have values between 1.8 and 1.9. These results are in fair agreement with the theoretical models developed by Brin and Mendis (1979), Fanale and Salvail (1984), Podolak and Herman (1985), and others. As long as there are no in situ measurements of the sizes of the dust particles on the sample surface during the experiment it is assumed that this exponent also characterizes the size distribution in the dust mantle, which is considered as a constant parameter during the evolution of the mantle.

DYNAMICAL PARAMETERS OF THE EMITTED PARTICLES

The emission of ice-/dust particles from the sample surface is observed by different devices. The particle trajectories are recorded with a video system (Kochan et al. (1991)). The video tapes are evaluated with an image processing system.

To establish the time dependence of the emission process nine definite time intervals covering the total insolation period were evaluated. Each time interval was defined by the total number of at least 400 emission events. The single event is characterized by the recorded particle trajectory. The average count rate is established by the recorded particles per time interval. In Figure 1 the particle count rate is plotted versus the time of irradiation. The highest count rate is observed at about half an hour after irradiation has started. Then the emission activity decreases exponentially with a time constant of about 143 min.

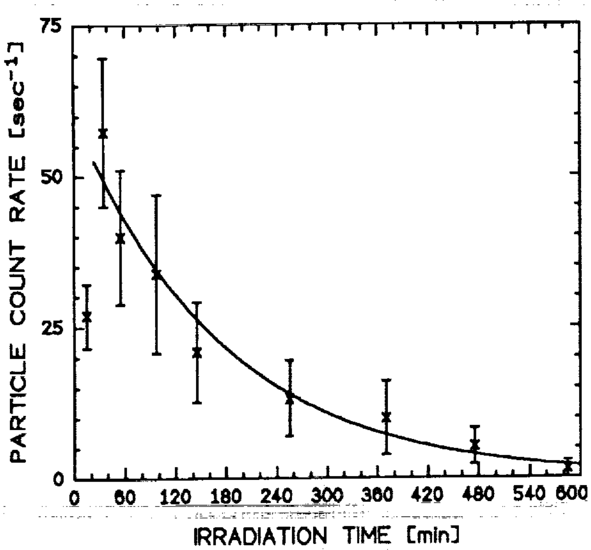

Figure 1 Count rate of emitted particles versus irradiation time. The decay of the emission activity is fitted by the function $y(t) = N \cdot exp\left(-\frac{t}{t_0}\right)$ with the parameters: $N = 800000 \frac{1}{sec}$ and $t_0 \approx 143\, min$.

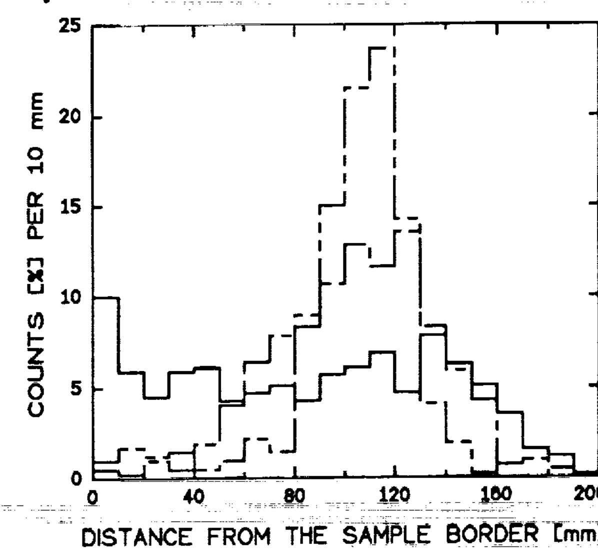

Figure 2 Distribution of starting points of the emitted particles on the sample surface 35 min (——), 370 min (— - —) and 585 min (— - - —) after beginning of irradiation.

The particle velocity is calculated from the first two recorded points of the trajectory. The elevation angle is given by the connecting line of the first two points of the particle trajectory and the sample surface.

Both parameters are then attributed to the intermediate trajectory point. By the foot of the surface normal intersecting this intermediate point a reference point on the sample surface is defined. The distance of this foot point from the lower rim of the sample container is called 'starting point' in the following text.

In Figure 2 the distribution of the starting points on the sample surface is shown for three different times. The abscissa presents the distance to the lower rim of the sample. The number of particles starting in a 10 mm interval is counted and normalized to the number of starting particles in the respective time interval. During the first 2.5 hours of insolation the distribution of starting points is rather flat. In the next seven hours the lower part of the sample surface becomes inactive with increasing time.

The particle velocity ranges from 0.4 to 2.4 m/sec with a mean of 1.1 m/sec. This mean is constant in time. The elevation angle ranges from 0^0 to 80^0. The mean elevation angle decreases with time from 36^0 to 22^0 during 450 minutes.

DISCUSSION

The results of the observation of particle emission and the measurements of the gas flux density (Hesselbarth et al. (1991) and Lämmerzahl (1991)) and the temperature (Heidrich (1990)) on the sample surface which are summarized in Figure 3 lead to the following scenario on the sample surface during the insolation period in the KOSI 5 experiment: At the beginning of irradiation the sample surface is covered by a thin layer of frozen H_2O vapour. Only emission of pure ice particles is observed at this time. After the ice cover is removed the emission of mineral-ice particles starts (Michel (1990)). The highest activity of this type of particle appears after about half an hour of insolation. After about two hours of irradiation the emission of ice containing particles has leveled off. The sample surface is covered by dry dust residues which are still emitted. It also happens that these dust particles roll downward on the tilted sample surface. After a while the particle emission and probably the gas flux are suppressed in the lower parts of the sample surface. The inactive region extends upward to about 8 cm measured from the lower rim. Investigations of the sample in a glove box after the experiment (Roessler (1991)) show that a dust mantle of 2 - 4 mm thickness has formed on a 2 - 4 cm thick mineral-ice crust. This modification of the sample may also influence the gas flux. The angle of the sample surface with respect to the horizontal plane is 35^0 while it was 40^0 at the beginning of the experiment. From the experimental results one may deduce that: (1) Successive emission of three different particle species (ice, ice-dust, dust) from mineral-ice mixtures, (2) quenching of particle emission by dust layers exceeding 5 mm in thickness, and (3) nearly constant emission velocity for a given particle size range at constant insolation intensity should also be relevant surface phenomena on a comet nucleus.

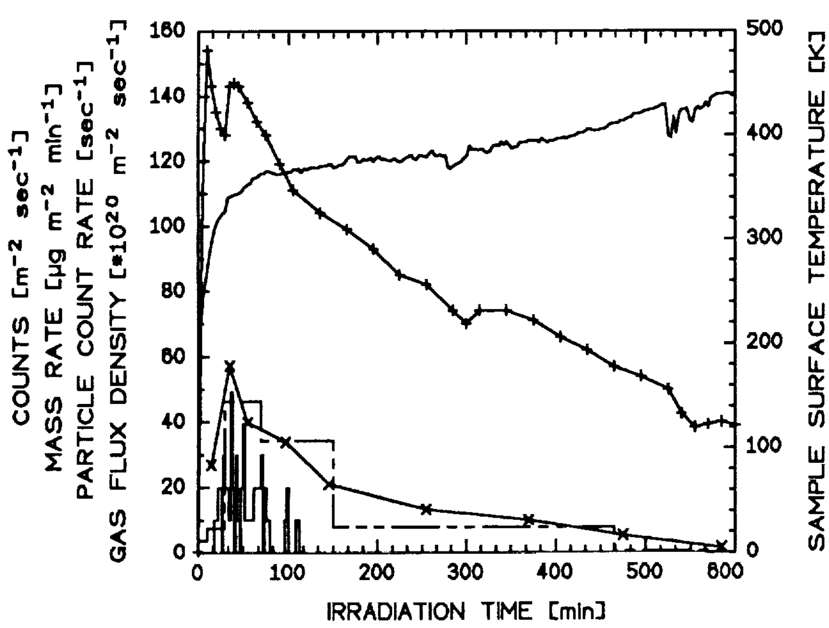

Figure 3 Temperature (——, curve, right y-axis) and gas flux density (—+—+—, left y-axis) on the sample surface and count rate of particles recorded by the video system (—×—×—, left y-axis), total masses of dust residues per collector in the ice particle detector in a distance of about 500 mm from the center of the sample surface (— - - - —, left y-axis) and counts of mineral-/ice particles (———, step function, left y-axis) (see Michel (1990)) of the same detector during the insolation period in the KOSI 5 experiment.

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