ELECTROSTATIC FRAGMENTATION OF DUST PARTICLES IN LABORATORY

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ABSTRACT. Experimental laboratory work on simulation of the electrostatic fragmentation was started with loosely bound Al_2O_3 particles of 1 to 10 micrometers size. These particles were suspended in an electrodynamic quadrupole inside a vacuum chamber and electrically charged by ion beams of energies up to 5 keV. The electrostatic fragmentation was observed and derived tensile strengths of the particles range from 10^3 to 10^5 Pa what is compatible with theoretical estimates. A dependence of the tensile strength on the size of particles has been found. This dependence can be well fitted by inverse square power law.

The electrostatic fragmentation of dust particles, i.e., disruption of particles by repulsive electrostatic forces, is one of important destruction mechanisms for cosmic dust particles which leads to conversion of the solid phase of interstellar and interplanetary matter to the gas phase. Many phenomena connected to dust particles within the solar system can be explained by their electric charging with subsequent electrostatic fragmentation - see, e.g., Fechtig et al. (1979), Grün et al. (1984) or Boehnhardt and Fechtig (1987).

Repulsive electrostatic forces within a charged particle produce the electrostatic stress which is proportional to the second power of the particle surface electric field strength. The electrostatic fragmentation should occur when this stress exceeds the tensile strength of the particle material. Measured tensile strengths of materials relevant for cosmic dust particles range from 10^3 Pa for fluffy aggregates to $2x10^9$ Pa in the case of metals. Corresponding critical electric field strengths which should result in electrostatic fragmentation range from $3x10^7$ to $2x10^{10}$ $V.m^{-1}$ (for references see, e.g., Grün et al., 1984).

Cosmic dust particles are probably highly non-spherical, and their surfaces are often not smooth. Any roughness, that is usually much smaller than the grain itself, will be removed, however, due to a local enhancement of the electric field strength, before fragmentation of a particle can occur. Hill and Mendis (1981) calculated electrostatic stress for prolate and oblate spheroids and showed that the stress was increasing with distance towards the centre of prolate spheroids with possible chipping off its ends. As a result, the grain can become more and more spherical during its electric charging.

Tensile strengths of cosmic dust particles are influenced by the size of particles, by the irradiation history, etc. It is known that tensile strengths of carbon whiskers, carbonized organic fibers, or ion microscope tips of many materials including graphite are higher than 10^{10} Pa. It was also found that tensile strength of graphite increased during irradiation from $5x10^7$ to 10^8 Pa (for references see Draine and Salpeter, 1979).

Trying to improve our knowledge about electrostatic fragmentation we started an experimental laboratory work on simulation of this process.

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For test measurements we used loosely bound Al_2O_3 particles of 1 to 10 micrometers size. These particles were suspended in an electrodynamic quadrupole inside a vacuum chamber and electrically charged by ion beams of energies up to 5 keV. The stress at which fragmentation takes place was determined from the charge-to-mass ratio of a particle at the moment of fragmentation and its size. The size was derived from the time during which the amplitude of the particle motion in vertical direction decreased by a certain factor due to particle collisions with atoms of the rest gas at known pressure and temperature. For more details about the suspension system see Svestka et al. (1987) and Pinter et al. (1990).

The derived values of tensile strengths of the Al_2O_3 particles range from 10^3 to 10^5 Pa and there is an obvious dependence of the derived tensile strengths on the size of the agglomerate which can be well fitted by an inverse square power law. In case of such a dependence, the fragmentation condition involves, instead of the electric field strength, the particle electrostatic potential. The electrostatic potential of cosmic particles of sizes within the range we studied is often expected to be practically independent of the size of particles. The same would then apply to the fragmentation condition.

These results are, however, still somewhat uncertain mainly because of probable non-sphericity of the particles. In near future we plan to build a smaller vacuum chamber with a smaller quadrupole inside which much better vacuum will be reached. As a result, instrumental effects on charging processes should then be then minimized. In the present apparatus these effects lead to a substantial reduction of the maximum attainable surface field strength of charged particles to about 10^8 $V.m^{-1}$ (Svestka and Grün, 1991). With the new apparatus we should be able to fragment spherical compact particles, and the comparison of experimental results with theoretical estimates will be extended over a larger range of particle materials and sizes.

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