Density, porosity and internal structure of interplanetary dust

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Interplanetary dust recovered on Earth in the form of interplanetary dust particles (IDPs) and micrometeorites is, together with larger meteorites, valuable source of primitive extraterrestrial material. Reliable determination of interplanetary dust's bulk and grain density and porosity is an issue of key importance in planetology. Interplanetary dust represents material released from asteroids and comets into interplanetary space. It carries important information about the composition and structure of cometary dust or coma as well as of asteroid surfaces. Thus, knowledge of interplanetary dust's physical properties is essential in the interpretation of ground-based or space-based observations of comets and asteroids. Some interplanetary dust experience significant atmospheric processing during its entry while other survives almost unaffected. Comparison of the physical properties of pristine interplanetary dust to the melted one significantly affected by atmospheric entry can give us insight into changes related to their atmospheric entry.

Physical properties and internal structure of interplanetary dust in the form of ~100-300 µm-sized micrometeorites (including both melted and unmelted prticles), collected in the Novaya Zemlya glacier in Russia was investigated using x-ray microtomography (XMT) at the Department of Physics, University of Helsinki. Due to its high-voltage (20-180 kV) nanofocus x-ray tube, and variable imaging geometry, the XMT equipment allows scans of samples sized from10 cm down to 50 µm, with sub-micron resolution (i.e. voxel size below 1 μm^3).

XMT results indicate predominantly silicate composition of the studied micrometeorites. The internal structure of the unmelted micrometeorites varies from highly porous vesicular structure to more compact one with abundant sulphides. The melted micrometeorites are affected by atmospheric entry and their internal structure varies from glassy to barred or porphyritic olivine with sulphides metamorphosed into metal or iron oxides.

Additionally to internal structure imaging, XMT allows bulk particle shape, volume, density and porosity determination. The porosity of the unmelted micrometeorites varies from ~1% up to over 33 % while the grain density was determined to be in range of 2.5-3.2 g/cm^3. The melted micrometeorites were found to be quite compact with porosity mostly below 3% and increased grain density in range of 3.4-3.5 g/cm^3. One melted micrometeorite was found to have a large metal inclusion amounting almost 5% of its volume. This is also reflected in its higher grain density of 5.7 g/cm^3 similar to stony iron meteorites. Magnetic studies of the melted micrometeorites revealed further ~4 wt% fraction of submicron-sized iron oxides which is too finely grained to be detected in the XMT scans.

Melted micrometeorites have in general lower porosities and higher grain densities compared to unmelted ones and larger, compositionally similar, carbonaceous chondrites. Porosity decrease is most likely a result of meteoroid melting and recrystallization during atmospheric entry. An increase in grain density is most likely due to the loss of volatiles and sulfur evaporation from iron bearing sulphides as troilite or pyrrhotite.

XMT proved to be a capable 3D non-destructive investigation tool suitable for extraterrestrial material studies and for quantitative evaluation of its physical properties and represents a significant improvement over the SEM based methods used in earlier studies.