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Changes to meteoroid shape, density, porosity and internal structure during high velocity atmospheric entry

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Abstract

Physical properties and internal structure of both melted and unmelted micrometeorites were investigated using x-ray microtomography (XMT). Melted micrometeorites have in general lower porosities and higher grain densities compared to unmelted ones. Porosity decrease is most likely a result of meteoroid melting during atmospheric entry while an increase in grain density is most likely due to the loss of volatiles and sulfur evaporation from iron bearing sulphides.

1. Introduction

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. Some interplanetary dust experience significant atmospheric processing during its entry while other survives almost unaffected. Comparison of the physical properties of pristine micrometeorites to the melted ones significantly affected by atmospheric entry can give us insight into changes to their meteoroids during high velocity atmospheric entry.

2. Materials and methods

Physical properties and internal structure of interplanetary dust in the form of ~100-300 µm-sized micrometeorites (including both melted and unmelted particles), collected in the Novaya Zemlya glacier in Russia were 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 down to 50 µm, with sub-micron resolution.

3. Micrometeorite properties

XMT results indicate predominantly silicate composition of the studied micrometeorites. The unmelted micrometeorites have irregular shape and their internal structure varies from highly porous vesicular structure (Fig. 1) to more compact one with abundant sulphides. The melted micrometeorites are affected by atmospheric entry. Their shape is spherical with internal structure varying from glassy to barred or porphyritic olivine with sulphides metamorphosed into metal or iron oxides.

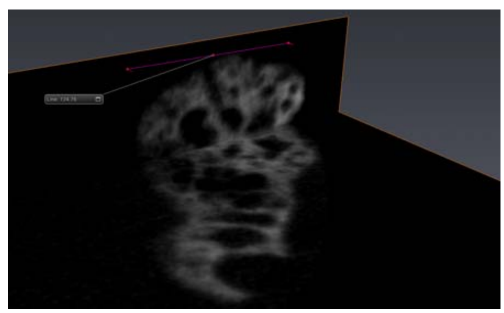

Figure 1: An example of ~200 µm-sized unmelted micrometeorite with highly porous vesicular structure.

The porosity of the unmelted micrometeorites varies from ~1% up to over 33 % while their grain density was determined to be 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 (Fig. 2)was found to have a metal inclusion amounting almost 5% of its volume increasing its grain density to 5.7 g/cm^3, similar to stony iron meteorites. Magnetic and electron microscope 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.

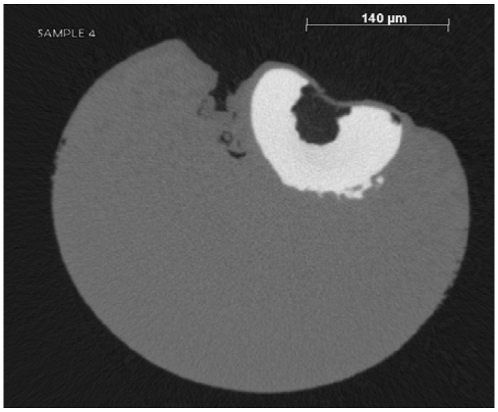

Figure 2: An example of ~300 µm-sized melted micrometeorite with a metal inclusion.

4. Atmospheric entry effects on meteoroids

Comparing melted and unmelted micrometeorites reveal changes in meteoroid physical properties during its high velocity atmospheric entry. Melted micrometeorites have in general lower porosities and higher grain densities compared to unmelted ones (and to larger, compositionally similar, carbonaceous chondrites). Porosity decrease is most likely a result of meteoroid melting and recrystallization during atmospheric entry while 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.