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Impact Ionisation Mass Spectra of Mineral Microparticles

J. K. Hillier (1,2), A. Mocker (3,4), S. F. Green (1), S. Kempf (2,5), F. Postberg (4,6), S. Sestak (7), R. Srama (3,4), Z. Sternovsky (2) and M. Trieloff (6)
(1) PSSRI, The Open University, UK (2) LASP, University of Colorado Boulder, USA (3) Institut für Raumfahrtsysteme, Universität Stuttgart, Germany (4) Max-Planck-Institut für Kernphysik, Heidelberg, Germany (5) Technische Universität Braunschweig, Germany (6) Institut für Geowissenschaften, Universität Heidelberg, Germany (7) CSIRO, Sydney, Australia. (j.k.hillier@open.ac.uk / Fax: +44-1908-858022)

Abstract

We present mass spectra derived from the impact ionisation plasmas generated by the hypervelocity impacts of mineral microparticles over a range of speeds. The mineral microparticles were made from silicates (olivine, pyroxene, anorthite) and pyrrhotite and accelerated to velocities of 1–>30 km s^{-1} using the Van de Graaff electrostatic accelerator at the Max Planck Institut für Kernphysik, Heidelberg [15]. The mass spectra were produced using high resolution reflectron-type instruments (e.g. LAMA etc. [20, 19, 18]) intended for use as space-based dust telescopes. We show that, if spectra are obtained over a range of impact velocities, it is possible to identify species from the bulk mineral material even if there are significant contributions to the spectra from organic or anthropogenic contaminants. In some cases it is also possible to infer the composition of the mineral, based on unique fragment and cluster ions.

1. Introduction

The in situ compositional analysis of cosmic dust particles can reveal a great deal about both its sources and, potentially, its evolution. From the crude mass spectra of interstellar dust returned by Helios [1] and the mass spectra of cometary dust returned from Halley (PIA and PUMA 1 [11, 12]) and Wild 2 [14], to the plethora of discoveries by the Cosmic Dust Analyser on Cassini (e.g. [9, 16, 6, 7, 17]), the properties of some of the smallest denizens of the solar system have informed us about some of the most enigmatic. The next generation of large area dust detectors [20, 19, 18] use a simple arrangement of electric fields (the reflectron) to remove the effects of their initial energy distribution from ions created during hypervelocity dust impacts (as used in CIDA [13]), creating high resolution mass spectra whilst maintaining a large sensitive area. To calibrate these instruments with realistic impacts, cosmic dust analogue mineral grains of sub micron size must be accelerated to velocities in excess of 10 km s^{-1}. A Van de Graaff accelerator is required to produce these impact speeds [2, 15].

2. Method

Successful electrostatic acceleration requires that the dust particles be capable of holding charge. To enable this with mineral grains a conductive coating must be applied. For these particles either a conductive polymer (polypyrrole [3]) or a thin layer of metal (Pt [8]) was applied. The particles were then accelerated and the resulting impact plasma separated by an electric field, accelerating either the positive or negatively charged particles, via a reflecting field, to a charge detector. The spectra were calibrated onto a mass scale and analysed using in-house code [10], co-added in suitable velocity bins where required (e.g. Fig. 1).

3. Results

Using a combination of direct identification based on ion mass, examination of the threshold velocities at which ion species appear and vanish from spectra, and correlation analysis, we identify species within spectra due to the particles' bulk mineral compositions, surface and processing contaminants and impact target materials. Larger molecular fragment and cluster ions are identified and compared with those from laser ionisation methods [4, 21, 5].

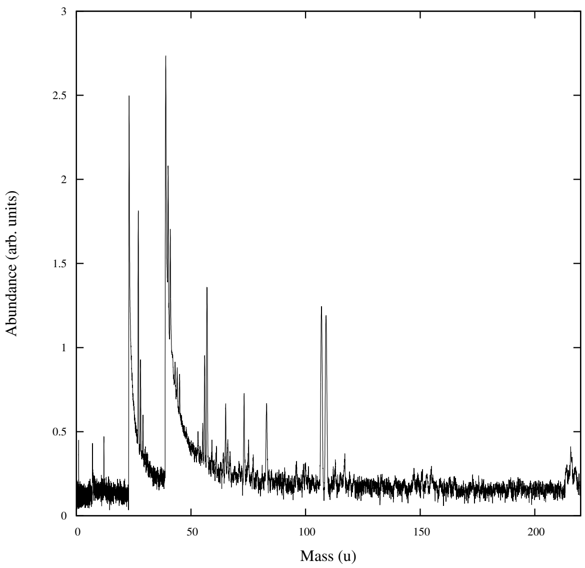

Figure 1: A sum spectrum of 32 impact ionisation mass spectra of anorthite grains which impacted at velocities of between 5 and 6 km s^{-1} onto the LAMA laboratory model.

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