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Capture of high-speed interstellar dust analogues in Stardust flight spare aerogel

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Abstract

We present the results of laboratory calibration campaigns designed to determine the effects of particle density and composition on the dimensions of tracks created by hypervelocity dust grains impacting Stardust flight spare aerogel collectors. Tracks created by dust grains from minerals (olivine, orthopyroxene) and latex (poly-[bis(4-vinylthiophenyl)sulfide]) with conductive coatings (platinum or polypyrrole) have been examined and track diameter correlated with impact velocity and particle material. The analogue tracks and terminal particles are compared with the currently identified Stardust ISPE candidates, indicating that only one particle was captured at the expected speed for an interstellar dust particle of the expected size, with the other particles captured at significantly lower speeds.

1. Introduction

In 2000 and 2002 the Stardust Mission exposed aerogel and aluminium foil collectors, for a total duration of about 200 days, to the stream of interstellar grains sweeping through the solar system [1]. The material was returned to Earth in 2006.

1.1 Laboratory simulation

Simulating the impact velocities (10-25 km/s) and sizes (0.1-1 μm) expected for ISD particles encountering the Stardust aerogel collectors [2] requires a Van de Graaff accelerator. These instruments [3] create a large potential difference (typically ≈MV), through which a charged particle passes, gaining kinetic energy. Although conductive materials (mainly metals) can be accelerated without modification, particles which are poor carriers of charge, such as minerals and some plastics, require coating with a conductive layer before use in the accelerator. Two methods were used in this work: coating with a 5-10 nm layer of platinum [4] or 10-20 nm layer of polypyrrole, a conductive polymer (e.g. [5]).

The olivine and poly-[bis(4-vinylthiophenyl)sulfide] latex (hereafter PMPV) were coated with polypyrrole. The orthopyroxene (hereafter OPx) was coated with platinum.

2. Data and Analysis

For each set of parameters (see table), ≈50 particles were accelerated and selected. Square aerogel pieces with a surface area of about 2 cm^2 were mounted into the beam line. Typical tracks in picokeystones (extracted sub-volumes of an aerogel tile that contain a single track, e.g. [6, 7]) were extracted and analysed using Scanning Transmission X-ray Microscopy

Table 1: Materials, speeds and particle size ranges for which particles were accelerated onto flight spare aerogel samples. Olv = olivine, OPx = orthopyroxene, PMPV = poly-[bis(4-vinylthiophenyl)sulfide]. Particle diameters are equivalent spherical diameters for the mineral particles. Brackets indicate that the tracks were too small to be found.

Speed (km/s)	2.5–3.5	5.5–6.5	9-11	14-16	19-21
Diameter (μm)					
0.11-0.13				(OPx)	
0.19-0.24			OPx	OPx	OPx
0.32–0.38			PMPV	PMPV	PMPV
0.36–0.44	Olv	Olv	Olv	OPx	

(STXM). Scanning electron microscopy (SEM) was also used to investigate the track mouths.

3. Results

A typical STXM image of a particle track and terminal particle is shown in Fig. 1. Analyses of these images

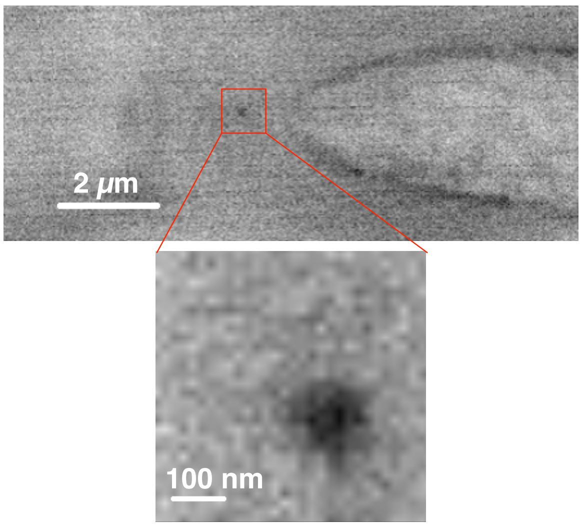

Figure 1: 1304 eV STXM image of a track and terminal particle due to a 15 km/s 0.37 μm OPx particle.

enables the comparison of track diameters as a function of impact velocity with predicted values (Fig. 2).

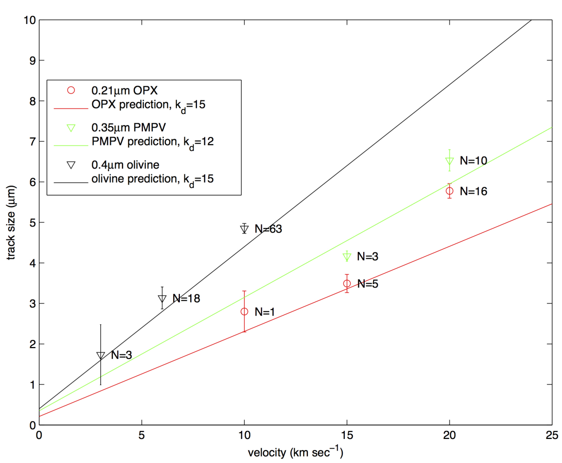

Figure 2: Track diameter as a function of projectile velocity.

4. Summary and Conclusions

Comparison with the three micron-sized ISD candidates currently identified in the Stardust collectors [8] shows that only one was captured at the speed predicted for this size (15–25 km/s). The other two were captured at speeds below 10 km/s, which can only be reconciled with the current understanding of the ISD flux [9] if they were low-density, probably porous, particles. It seems that the compactness of the ISD candidates has governed their fates after capture with, rather counter-intuitively, the compact particle being evaporated, whilst the more fragile particles have remained more or less intact due to their lower capture speed.

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