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Simulating Atmospheric Alteration of Micrometeorites using a Two Stage Light Gas Gun.

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1. Introduction

An estimated 20-30,000 tonnes of extra-terrestrial dust arrives at the Earth each year [1] with up to 90% of this mass burning up during atmospheric entry [2]. These particles are largely thought to sample asteroids and comets. Analysis of those particles that survive atmospheric entry to arrive at the Earth's surface (micrometeorites, MMs) suggest they sample a larger number of parent bodies than meteorites. MMs therefore have the potential to provide us with a more complete picture of the contents of the Solar System. Many MMs have, however, experienced both morphological and chemical changes as a result of intense heating during atmospheric entry. These melted particles are referred to as cosmic spherules (CSs) and are amongst the most abundant source of extra-terrestrial matter on the Earth's surface [3]. Understanding the alteration processes which particles have experienced during atmospheric entry, such as melting and vaporization, will enable us to better understand the contribution these particles make to the Earth (both it's atmosphere and surface). It will also allow us to gain greater insight into the precursor MM's mineralogy, providing a better understanding of the parent bodies from which the particles originate. Previous experimental attempts to understand the heating effects of atmospheric entry on micrometeorites have subjected a variety of MM analogues to pulse heating [4,5]. In these experiments, the particles have been heated uniformly. Due to the non-symmetrical shape of many of the grains entering the Earth's atmosphere they will likely experience tumbling during entry, resulting in non-uniform heating and the differentiation of molten elements of different densities [6], both of which would not be replicated during such stationary heating. This may explain why magnetite rims and the loss of non-volatile materials (e.g. iron-nickel beads) are not observed in these experiments [5]. Some groups have also attempted to use computer simulations to model the ablation of atoms from heated particles [7]. These models have provided interesting results that suggest that cometary materials can survive entry through Earth's atmosphere, but largely rely on the use of theoretically rather than empirically derived parameters. Some groups are also investigating the possible use of Reddy Shock Tubes [8].

2. Method

Here we report the results of our attempts to use the two stage light gas gun (LGG) at the University of Kent to replicate the interactions of a MM analogue travelling at hypervelocity through an atmosphere. The LGG is capable of firing single solid projectiles up to 3 mm in diameter at velocities up to 7.5 km/s [9], however, during shots the gun and LGG's target chamber must be evacuated down to 0.5 mBar. We have therefore designed an environment chamber (Figure 1) to fit within the target chamber that is capable of containing a sealed atmosphere up to a pressure of 2 atm. The environment chamber consists of a Plexiglas tube, with a solid aluminum breech and uses an aluminised Mylar film to seal the front end. The projectile enters

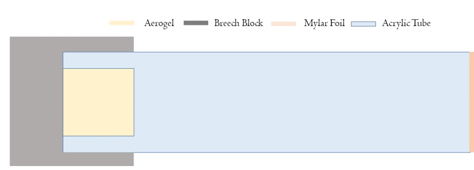

Figure 1: Schematic of the environment chamber.

the chamber by penetrating the Mylar foil and travels through the atmosphere before being captured by an aerogel block. The effects of aerogel on hypervelocity projectiles is well studied, having been used to capture dust particles by a number of missions (e.g. orbital debris collector on MIR [10], Stardust [11] and Tanpopo on the International Space Station[12]). For each investigation we fire 2 shots: one with the atmosphere tube evacuated and one with atmosphere present. By comparing the samples in each case we aim to identify and differentiate those effects caused by atmospheric ablation and those which are caused by the effects of capture. Our initial testing of the environment chamber used 1 mm stainless steel projectiles accelerated to 3 km/s. We have now begun to study 3 mm olivine (Fo90) crystals as a more realistic micrometeorite analogue. The projectiles are characterized before and after shooting optically, by Raman Spectroscopy and SEM EDX.

3. Results

In our initial studies with 3 mm stainless steel projectiles, we demonstrated the survivability and reusability of the chamber. We were also able to film the projectile's passage through the atmosphere and subsequent interactions using low specification high speed cinematography (Figure 2). Initial results using the olivine projectiles showed that using the current set up a maximum projectile velocity of $1\ \mathrm{km\,s^{-1}}$ was obtainable before the Mylar foil seal resulted in the catastrophic disruption of the olivine.

Figure 2: Showing the light flash recorded by the Panasonic HX-WA30 high speed camera during the test shot of the environment tube. The projectile is travelling from right to left.

4. Summary

Preliminary results show the environment tube permits the simulation of high speed atmospheric entry, with work ongoing to enable hypervelocity entry by modifying the Mylar seal.

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