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3D laser scanning microscopy of hypervelocity impact features in metal and aerogel targets

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Abstract

We present the results of a study into the mapping of hypervelocity impact features using a Keyence VK-X200 3D laser scanning microscope. The impact features observed are impact craters in a variety of different metal targets (Al, Au and Cu) and impact tracks in aerogel targets, similar to those used in the Stardust mission. Differences in crater morphology between different target materials and impact velocities, as well as differences in track depth and diameter in aerogel, for particles of known constant dimensions, are discussed.

1. Introduction

Impact features, generated by hypervelocity impacts onto surfaces, are often used to investigate the impacting particles. For example, impact features onto Stardust foils (e.g. [1, 2, 3]) and Stardust aerogels (e.g. [4, 5, 6]) represent both serendipitous and planned uses of impact feature analysis. In the case of impact features on metal surfaces (such as foils [1]) or solid targets such as those on LDEF [7], crater sizes, depths and morphologies are analysed to determine projectile size, speed and strength. Aerogel impact tracks undergo similar analyses (e.g. [4, 5, 6]).
Accurate measurement of morphology usually uses SEM imaging and generation of stereo images. This is difficult with aerogel, for which STXM and sample (picokeystone) extraction were until recently required [8, 9] for volume analyses, and scanning electron microscopy for surface analysis.
An alternative, 3D laser scanning microscopy, using pinhole confocal optics at short optical (near UV) wavelengths, allows simultaneous optical imaging and laser morphological measurement. Pre-treatment of samples is usually not required, although this depends on the reflectivity and surface morphology of samples. Additionally, vacuum is not required and the analysis is therefore quick and “gentle" to samples. 3D laser scanning microscopy has recently been successfully used for the analysis of Stardust aerogel picokeystones [6].

1.1. Laboratory simulation

Acceleration of single particles to hypervelocities typically requires the use of a Van de Graaff accelerator, such as that at the Max Planck Institut für Kernphysik [10]. Van de Graaff electrostatic accelerators function by passing a charged dust grain through a large potential (typically ≈MV), with the grain’s kinetic energy increasing according to $\frac{1}{2}mv^2 = qV$ (mass m, velocity v, grain charge q, potential difference V). To simulate the particle types most likely to be encountered in space it is necessary to accelerate analogue mineral particles, which are usually only poor charge carriers. Application of a conductive coating (in this case polypyrrole [11]), enables the analogue particles to be successfully accelerated.
For this work, 500 nm and 1000 nm diameter monodisperse silica particles, coated in polypyrrole, were accelerated to velocities up to 10 km/s and impacted Al, Au and Cu surfaces, as well as aerogel samples.
Measurements were made using a Keyence VK-X200 408 nm violet laser scanning microscope, allowing features to be mapped at a horizontal resolution (XY) of 0.02 μm and a depth (Z) resolution of 0.012 μm (values are standard deviations for repeated measurements).

2. Example Results

Initial testing using iron projectiles impacting a copper target, over a large range of velocities (up to 30 km/s), show that the scanning microscope can successfully image and produce profiles of the generated craters. An example of a field of craters is shown in Fig. 1, with profiles of craters within that image shown in Fig. 2.

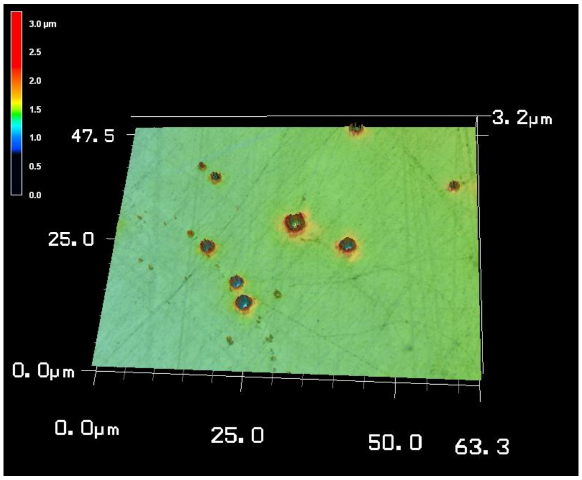

Figure 1: A 3D scanning microscope image of a crater field on a copper target.

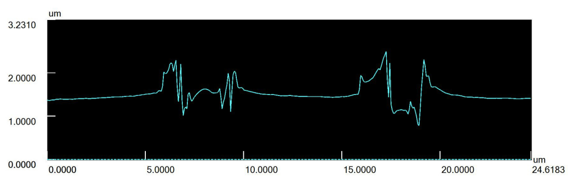

Figure 2: A measured profile across the two largest craters in Fig. 1.

3. Summary

The application of a 3D laser scanning microscope for the characterisation of hypervelocity impact features in metal and aerogel targets is shown. Impact crater morphology on a variety of metal targets, verifying hydrocode modelling, is measured. Track morphology due to mineral particle capture into aerogel is also presented, with applications to the calibration of Stardust flight data discussed. Examples will be presented of comparisons of micron-sized crater profiles measured with the 3D system described herein, and identical craters reconstructed from SEM stereo pairs and MeX software.

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