Identification of Mineral Impactors in Hypervelocity Impact Craters in Stardust Grade Aluminium foils by Raman Spectroscopy of Residues. N. J. Foster[1,2], M.J. Burchell[1], A.T. Kearsley[3], J.A. Creighton[1] and M.J. Cole[1]. Centre for Astrophysics and Planetary Sciences, School of Physical Sciences, Ingram Building, University of Kent, Canterbury, Kent, CT2 7NH, United Kingdom. [2]Authors email address: nf40@kent.ac.uk. [3]Impact and Astromaterials Research Centre, Department of Mineralogy, The Natural History Museum, London, SW7 5BD, United Kingdom.

Introduction: The use of Raman spectroscopy techniques to identify mineral particle fragments after their impact at 6.1 km s^{-1} into aluminium foil is demonstrated. Samples of six minerals (olivine, rhodonite, enstatite, diopside, wollastonite and lizardite) were fired into aluminium foil and the resulting impact craters studied with a HeNe laser connected to a Raman spectrometer. This technique has also been successfully demonstrated on NASA Stardust foil crater C2086N1. The survival of identifiable projectile fragments after impact at 6.1 km s^{-1} is thus established in general, but may not apply to all minerals.

Method: The impacts were generated using a two stage light gas gun at the Univ. of Kent [1] using powdered samples of the aforementioned minerals, giving several craters to analyse from each shot. Targets were sheets of flight spare Stardust aluminium foil. This was type Al 1100; thickness 0.1 mm and surface area of 1 cm^2. Although most shots had only one mineral type per shot, one shot included a mixture of rhodonite and olivine as a blind test of the analysis. Craters sizes ranged from ≈60 – 300μm, and were analysed using Raman spectroscopy. These craters are large compared to the majority of craters on the Stardust spacecraft; however, 63 Stardust craters >20 μm diameter have been identified so far, 7 of which (sizes 44 – 142 μm) have been studied in detail [2]. The Raman system used a Jobin-Yvon HR640 microRaman module using an Olympus BX40 microscope. The spectrometer has a 1200 gr/mm grating and a LN_2 cooled CCD. Illumination was from a HeNe (632.8 nm) laser delivering 10 maw. Collection times for raw grains were typically 4x30 s and 8x30 s for craters.

Results: After each shot the target foils were examined and impact craters found. The impactors were estimated as ≈ 12 to 60 μm in diameter, using ≈ x5 projectile diameter to crater diameter ratio [2] for the minerals in our experiments. Raw Raman spectra were obtained from each mineral sample before firing. After a shot the craters were then examined with the Raman system. For the olivine, rhodonite and diopside shots, identifiable Raman spectra of the residue material were readily obtained. In the shot which fired both rhodonite and olivine, all craters studied gave spectra. It was possible to take spectra from several distinct sites inside individual craters. Raman spectra showing rhodonite were obtained from both the bottom & walls of the crater, indicating a wide dispersion of the residue in the crater. For the enstatite shot, initially no Raman signals were obtained, but longer integrations resulted in a spectrum. It may be that for some materials, longer integration times combined with selectivity in the site to be illuminated are needed to obtain signals above the noise level. By contrast, the wollastonite impact craters that were studied only gave good Raman spectra from 1 out of 6 craters. In the lizardite shots, no Raman spectra were found. Raw grains of lizardite did however readily give Raman spectra. On Stardust crater C2086N1 spectra were readily available from 5 different locations inside the 50 μm crater corresponding to an olivine signal of Fo_{98} based on calibration work by [3].

Conclusion: For 5 minerals (olivine, diopside, rhodonite, wollastonite and enstatite), Raman spectra may be obtained after a projectile impacts an Al target at 6.1 km s^{-1}. For some minerals all of the craters studied readily gave recognizable Raman spectra. In others, longer integration times were needed. This suggests that either the survival of crystalline fragments is not uniform or that they may be buried in the impact melt below a layer of Al. The smallest craters so far studied which gave Raman signals were 25 μm dia., corresponding to ≈ 5 μm dia. grains of olivine. For lizardite, no Raman spectra were obtained from the impact craters. These results suggest that whilst in general projectile fragments may survive the impact, this may not be true for all materials, also confirmed by [4] using transmission electron microscopy. This novel result both changes the view as to the degree of melt and alteration in impacts at these speeds and also introduces a new analysis technique for studying impact crater residues

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