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Raman identification of olivine grains in fine grained mineral assemblages fired into aerogel

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Abstract

NASA's Stardust mission returned from the comet 81P/Wild2 in 2006 and has yielded a plethora of research looking into the composition and attributes of the comet. The mission itself collected thousands of cometary dust particles as it flew through the coma of the comet at a relative speed of 6.1 km s^{-1}. This work focuses on one of the most abundant minerals in the solar system – olivine. Previous work has shown capture affects on this mineral in similar impacts to that experienced during the Stardust mission. However, the past work looked into effects on isolated mineral grains which would be a rare occurrence in the Solar System. A more accurate representation of this would be to investigate the capture effects on olivine as a constituent of an assemblage of minerals. Accordingly, here we used samples from the NWA 10256 CR2 carbonaceous chondrite meteorite. This natural sample contains fine grains of olivine, and brings additional issues when analysing the olivine due to limited homogeneity. Shifts in the Raman spectra for olivine, enstatite and hematite were observed after capture due to shock effects. However, this work suggests that olivine may well experience a different shock effect during capture when part of a mineral assemblage as distinct from that experienced by single grains.

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Keywords: comets; shock; aerogel; olivine; stardust

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1. Introduction

NASA's Stardust mission [1] was a sample return mission to collect material from the coma of the Jupiter-Family Comet 81P/Wild2. The mission returned successfully in 2006, and it is estimated that it collected thousands of cometary dust particles, approximately 1 – 300 µm in size and totaling approximately 3 $x10^{-4}$ g in mass [1][2]. The dust particles were collected using aluminum foils and SiO_2 aerogel blocks as Stardust was passing the comet with a relative speed of 6.1 km s^{-1} [3]. Aerogel is a low density, highly porous medium which can capture small impacting grains relatively intact [2]. The aerogel used for the Stardust mission was transparent and had a density gradient of 5 mg cc^{-1} at the front face rising to 50 mg cc^{-1} at the rear. Aerogel is very useful as a capture material as it results in a low pressure impact spread along the length of a track formed as the projectile decelerates in the aerogel. The resulting captured grain at the end of the track is known as the terminal grain (see [4] for a review of the use of aerogel in dust capture in space). The process of capture in aerogel is thought to involve a low shock pressure of ≤300 MPa [5], but it can heat the samples to over 1,000 ^{o}C for a brief period of a microsecond (see [6][7]). Furthermore, [7] has shown that 10 µm sized terminal grain particles remain unmelted and relatively unaltered after capture.

The mineral olivine $((Mg^{+2}, Fe^{+2})_2SiO_4)$, is a very abundant material found in the Solar System, including asteroids and comets. Its Raman spectra is easily recognised by a doublet at around 820 and 850 cm^{-1}, referred to as P1 and P2 respectively (Fig. 1). This doublet represents the internal stretching vibrational modes of the SiO_4 ionic group. The height of P1 and P2 are a function of the crystal orientation [8]. Additionally, it has been observed that the exact position of these peaks systematically varies with the olivine composition [9][10]. Olivine has two end-members forsterite (magnesium rich) and fayalite (iron rich). Therefore, the Fo content refers to the percentage of magnesium found in the olivine, i.e. Fo_{90} has a ratio of 90:10 of magnesisum:iron.

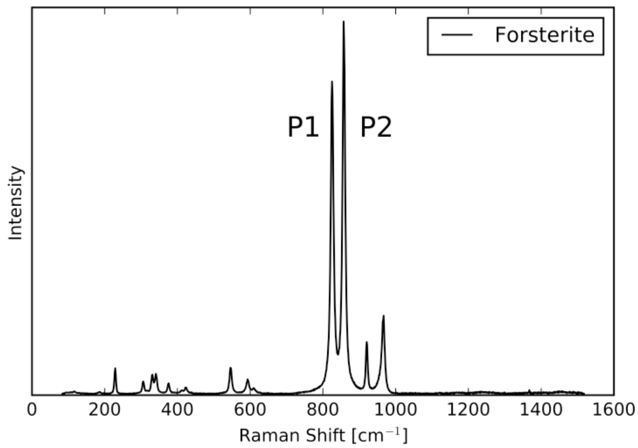

Fig. 1. Characteristic olivine spectra with doublet peaks P1 (~820 cm^{-1}) and P2 (~850 cm^{-1}). Sample from the RRUFF spectral database..

Studies investigating the shock effects on olivine do exist. A permanent shift of the olivine doublet peaks for single grains fired onto both aluminium foil and aerogel at 6.1 km s^{-1} on comparison to the original un-shocked samples has been shown [11]. This effect was thought to be as a result of the strain on the olivine crystal lattice caused by the effect of the impact [11]. Furthermore, natural, homogeneous San Carlos olivine has been fired onto aluminium foils at a range of speeds (1 – 6 km s^{-1}) [12]. This latter work showed that shifts in P1 and P2 only occurred at higher impact speeds (> ~5 km s^{-1}) [12]. Furthermore, the direction of the shift was found to be twice the magnitude of previous work [11].

Singular grains of olivine would be a rare occurrence in space, so this paper investigates the shock effects on mineral assemblages being captured in aerogel. The work focuses particularly on the olivine content of the samples, but the capture effects on other minerals (enstatite and hematite) in the assemblages are also observed.