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Results from Raman analyses of six *Stardust* cometary grains: forsterites, organics and an unknown.

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Abstract

We present initial Raman spectroscopy results from a set of six terminal grains found in tracks C2112,4,170,0,0 ('170'), C2045,2,176,0,0 ('176'), C2045,3,177,0,0 ('177') and C2045,4,178,0,0 ('178') taken from the cometary side of NASA's *Stardust* mission sample collector [1]. Three were identified as olivines, two are (possibly) organic and one is currently unidentified.

1. Introduction

In order to maximise the scientific return from the unique sample set returned by NASA's *Stardust* mission, it is vital that analyses of the samples are undertaken using as many different, non-destructive, techniques as possible - preferably on particles whilst they are still embedded in aerogel [2]. Previous in situ XANES and EXAFS analyses carried out on the terminal grain of track 170 concluded that the grain contained a mixture of Fe-metal and Cr- and Ca-bearing silicate [3]. Raman spectroscopy results supported the initial results of Bridges *et al*, and determined that the mineralogy of the silicate phase was Mg-rich olivine, Fo_{95} [4], after correcting for changes in mineralogy due to impact heating [5, 6]. Given the success of this investigation, further Raman analyses have been performed on three more tracks: 176, 177 and 178.

2. Experimental methodology

We have used a state-of-the-art Raman spectrometer at Kent to study the terminal grains. This spectrometer (a *LabRam-HR*) incorporates three lasers: 785 nm , 633 nm and 473 nm. The maximum laser power at the sample is 30 mW, but here, a 10% neutral density filter was used at all times which limited the power at the sample (through a ×50 objective) to a maximum of ~3 mW, thus avoiding unwanted heating and possible modification of the grain [7]. Upon receipt, the keystones were carefully unwrapped and photographed prior to examination. Track 170 was mounted on a glass slide covered with kapton tape which proved to be highly fluorescent, thus necessitating the use of the 633 nm laser. Tracks 176, 177 and 178 were mounted between thin (thickness unknown) silicon nitride windows which greatly reduced fluorescence permitting a 473 nm excitation wavelength to be used on these grains.

3. Results and Discussion

Track 176: This has a bulbous morphology (Fig. 1) and two distinct terminal grains at the end of two styli. Both grains were investigated and their spectra given in Fig. 2. For both grains elemental carbon was detected (as evidenced by the presence of the carbon 'D' and 'G' bands) as well as several other bands not associated with olivine. Additionally, a weak peak is present at ~2900 cm^{-1} possibly indicating the presence of C-H bonding. It is thus likely that both grains are organic and further analysis is on going.

Track 177: This track is long and carrot-shaped. Several very thin styli are present, each of which has its own terminal grain (to be investigated). The main terminal grain has strong olivine lines at 821 and 854 cm^{-1}, indicative of a Fo_{92} mineralogy (Fig. 3).

Track 178: A bulbous track with several styli, each holding a terminal grain. Two terminal grains have so far been investigated ('TG#1' and 'TG#2'). TG#1 has olivine lines at 821 and 856 cm^{-1} indicating a $>Fo_{92}$ mineralogy. TG#2 has no sign of an olivine signature, but two lines at 215 and 279 cm^{-1}. A positive identification has not yet been made of TG#2, but it is possibly a metal oxide (Fig. 3).

Table 1: *Stardust* track ID, approximate diameter (microns) and estimated mineralogical composition (#s indicate multiple grains within the same track).

Track ID	Average dia. (µm)	Suspected mineralogy
C2112,4,170,0,0	20	Fo_{95}
C2045,2,176,0,0	10	#1: organic(?) #2: organic(?)
C2045,3,177,0,0	8	Fo_{92}
C2045,4,178,0,0	10	#1: $>Fo_{92}$ #2: metal oxide(?)

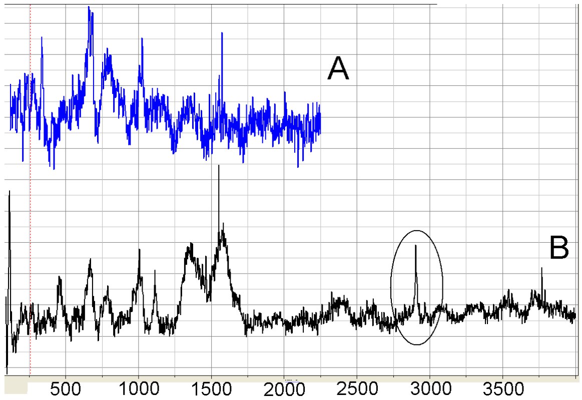

Fig. 2: Raman spectra of terminal grains found in track 176. **A:** Terminal grain #2 (Fig. 1); **B:** Terminal grain #1. Note the possible presence of C-H bonding vibration (circled). The X-axis is Raman shift in wavenumbers. Spectra have been baseline corrected.

Further work is currently on going to identify the organic material in track 176 and to rule out organic contamination within the surrounding aerogel. Additional spectra will be obtained with increased numbers of integrations to improve the signal-to-noise ratio. The results will be presented at EPSC 2013.

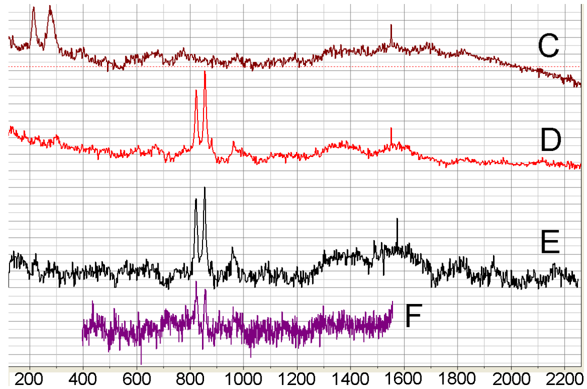

Fig. 3: Raman spectra of terminal grains. **C:** Track 178, terminal grain #1; **D:** Track 178, terminal grain #2; **E:** track 177, terminal grain; **F:** Track 170, terminal grain. The X-axis is Raman shift in wavenumbers and all spectra have been baseline corrected.

References: **[1]** Brownlee D. E. et al. (2006), *Science*, 314, 1711. **[2]** Wopenka B. (2012), *MAPS*, 47.4, 565. **[3]** Bridges J. C. et al (2012), *XXXIII LPSC*, abstract # 2214. **[4]** Price M. C et al (2012), *EPSC*, EPSC2012-333. **[5]** Burchell M. J. et al., (2006) *MAPS*, 41.2, 217. **[6]** Burchell M. J. et al (2012), *GCA* (accepted). **[7]** de Faria D. L. A et al. (1997). *J. Raman Spec.*, 28, 873

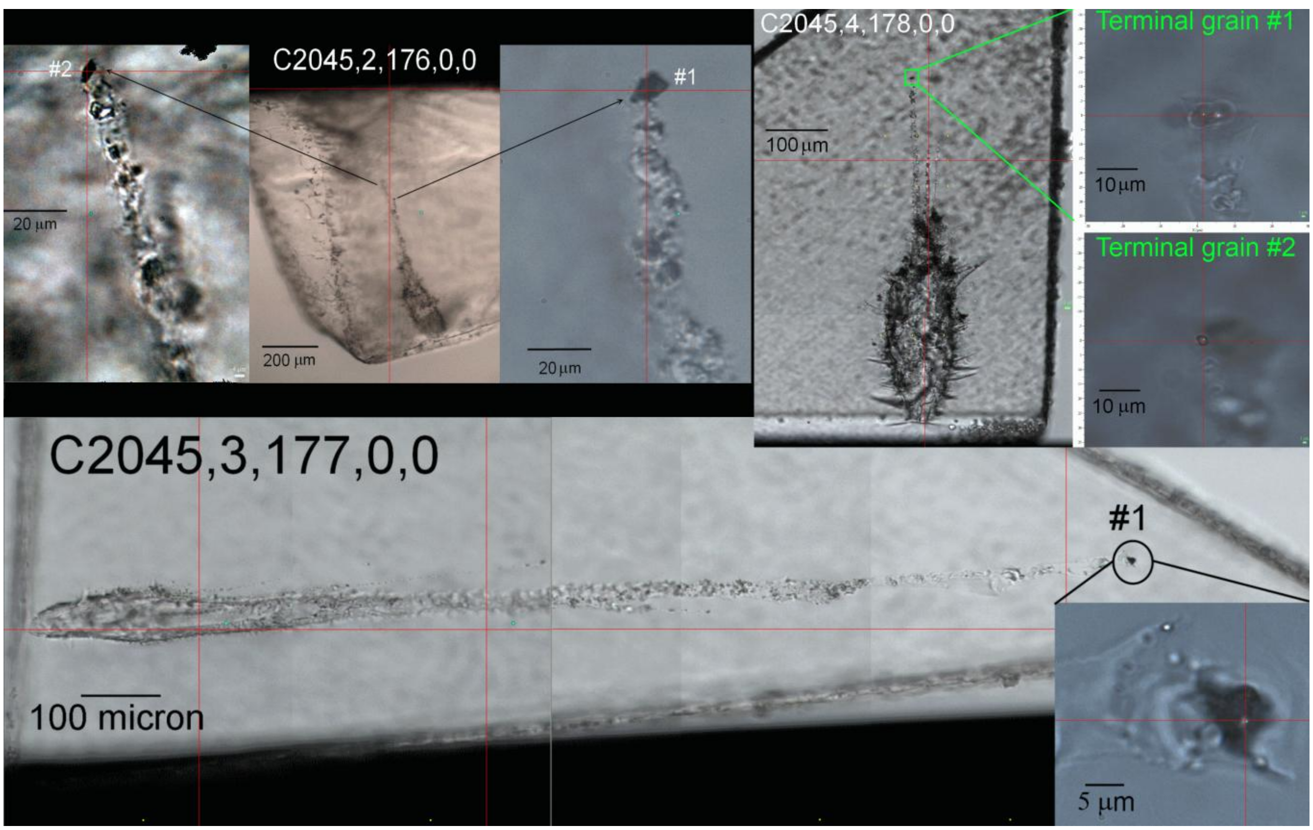

Fig. 1: Optical images of tracks 176 (top left), 177 (bottom) and 178 (top right) and associated terminal grains.