

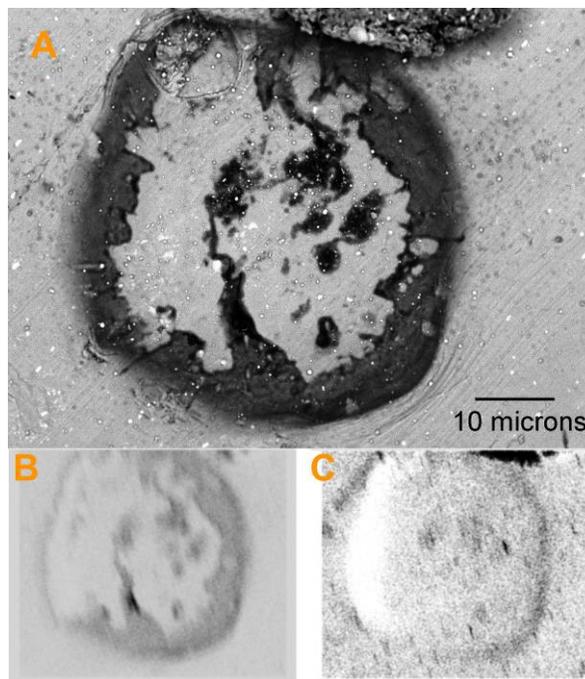
**ALTERATION AND FORMATION OF ORGANIC MOLECULES VIA HYPERVELOCITY IMPACTS.**

M. C. Price<sup>1,2</sup>, M. J. Burchell<sup>1</sup>, A. T. Kearsley<sup>3</sup> and M. J. Cole<sup>1</sup>. <sup>1</sup>School of Physical Sciences, Uni. of Kent, Canterbury, Kent, CT2 7NH, UK ([mcp2@star.kent.ac.uk](mailto:mcp2@star.kent.ac.uk)). <sup>3</sup>Dept. of Mineralogy, The Natural History Museum, London, SW7 5BD, UK.

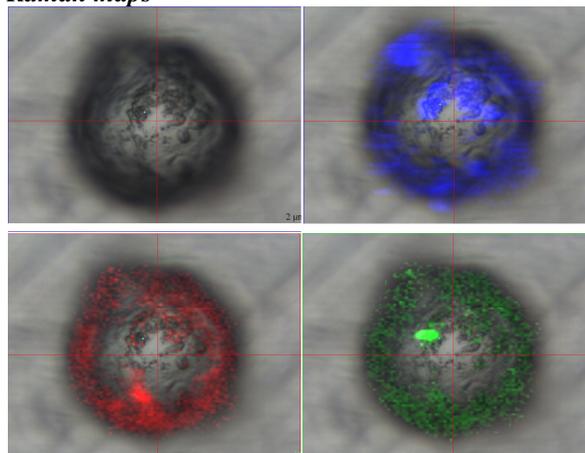
**Introduction:** With the recent launch of the Mars Science Lander, the proposed mission to the Jovian icy moons (JUICE) and the upcoming encounter of *Rosetta* (and Philae lander) with comet 67P/Churyumov-Gerasimenko in 2014, there is significant interest in the possible source, and distribution, of organic species throughout the solar system. The discovery of glycine in the *Stardust* collector [1, 2] signifies that complex, biologically significant, organic molecules exist throughout the solar system. As part of the ongoing work at the University of Kent exploring the creation, destruction and modification of organic species during hypervelocity impact events [3, 4], we have used our light gas gun [5] to fire 40 micron diameter polystyrene monodisperse spheres onto a range of metals targets at speeds of  $\sim 1.5$  and  $\sim 6$  km s<sup>-1</sup>. The resulting impact craters were then imaged using a scanning electron microscope and a mapping micro-raman system. Although hydrocode modelling (Price, unpublished data) indicates pressures of the order of GPa and shocked induced temperatures of several hundred degrees centigrade, polystyrene raman signatures were still observed in the majority of craters. Additionally, distinct raman spectra were observed which are believed to be from the transformation of the polystyrene molecules to a different, possibly more complex, organic molecule.

**Experimental methodology:** The polystyrene projectiles were loaded into a hollow sabot and fired onto four metal foil targets (aluminium, copper, gold and tantalum) mounted on a 1.5 mm thick aluminium backing plate. After firing, the foils were removed and imaged with a low power optical microscope to determine the relative position of craters on the foil. Craters were then mapped using a micro-raman system (a *XploRa* from Horiba). Mapping was carried out using a laser wavelength of 735 nm with a power of  $\sim 10$  mW. Map sizes were 60 micrometres x 60 micrometres, corresponding to an image size of 150 x 150 pixels (22500 spectra in total). The craters were thus oversampled, as the effective beam size of the raman system was ca. 1 micrometer in diameter.

**Results:** Here we present the results of analyses of a single polystyrene impact crater into Al made at a speed of  $\sim 1.5$  km s<sup>-1</sup>. Backscatter electron imagery of the crater (Fig. 1A) crater shows distinct impactor residue, but not the distinctive textures of organic impactors seen at higher speeds [6]. The EDX (Fig. 1B and 1C) maps show that carbon corresponds to the location of the impactor residue, but interestingly there are above background levels of oxygen present.

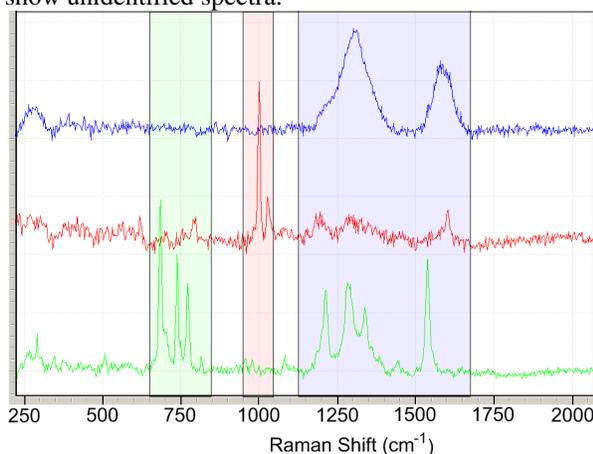


**Fig. 1A:** Backscatter electron image (5 kV) of a polystyrene impact crater in aluminium-1100 foil. The impact speed was 1.5 km s<sup>-1</sup>. Note the dark regions which are indicative of low density (compared to the target aluminium) impactor residue. **B:** EDX map showing the distribution of carbon. **C:** oxygen EDX map. In the EDX maps, darker shades indicate a higher X-ray count.

**Raman maps**

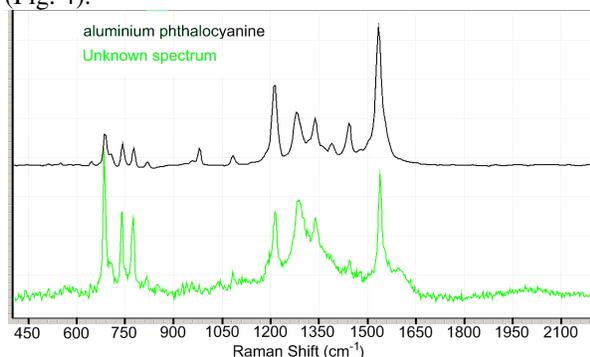
**Fig. 2:** Raman maps of impact crater. Colours indicates the relative strength of the Raman signal in a selected wavelength range (see text).

Raman maps (Fig. 2) show the definite existence of polystyrene within the crater, as traced by the aromatic ring vibration at  $\sim 1000\text{ cm}^{-1}$ . Significant amounts of carbon were also detected (via the 'd' and 'g' vibration bands between  $1128 - 1635\text{ cm}^{-1}$ ) demonstrating the reduction of the polystyrene to elemental (probably pyrolytic) carbon. Additionally, a third distinct spectral signature was also detected (Fig. 3, bottom). Subsequent measurements of unshot projectile material show no indication of this compound, demonstrating it was created during the impact. To date five Al craters from  $1.5\text{ km s}^{-1}$  impacts have been mapped, and four of them show unidentified spectra.



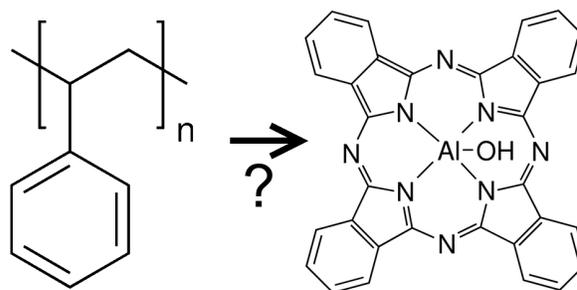
**Fig. 3:** Raman spectra showing the bands corresponding to the colours in Fig. 2. The  $968 - 1050\text{ cm}^{-1}$  (red) region corresponds to the aromatic ring vibration indicative of polystyrene. The  $1128 - 1635\text{ cm}^{-1}$  (blue) region is where the distinctive 'd' and 'g' bands are present for elemental carbon. The  $645 - 840\text{ cm}^{-1}$  (green) region corresponds to C-H vibrations which are observed in the unknown spectrum.

A search through a raman spectral library (part of the Horiba software suite) revealed that the metal complex aluminium phthalocyanine hydroxide has a very similar raman spectrum to the unknown compound (Fig. 4).



**Fig. 4:** Possible identification of unknown Raman spectrum (bottom) observed in the  $1.5\text{ km s}^{-1}$  impact crater as a metal-complex phthalate. The top spectrum is library data of aluminium phthalocyanine hydroxide.

**Discussion:** The presence of elemental carbon within the impact crater shows that the energies present during an impact event are sufficient to totally disrupt the aromatic ring structure. However complementary work by Henkel et al. [7] demonstrate that polystyrene impactors are not completely decomposed to carbon, and it is possible to only break the weaker C-H polymer chain bonds, leaving intact aromatic rings. We speculate that these rings could then recombine to create a phthalate complex (Fig. 5). If aluminium phthalocyanine has been formed from polystyrene during the impact, the question arises where did the oxygen and nitrogen come from to form the molecule? A possible answer is from atmospheric nitrogen and oxygen present in the light gas gun during the impact. The gun is typically evacuated to a pressure of  $0.5\text{ mPa}$  a low, but non-zero pressure. Additionally, oxygen would also be present on the surface of the aluminium foil in the form of aluminium oxide.



**Fig. 5:** Possible structure transition from (poly-) styrene to aluminium phthalocyanine hydroxide.

**Conclusions:** These data add to the growing body of work demonstrating the shock modification of organic compounds [8, 9] at impact velocities relevant to the solar system. Very recent work (Price, unpublished data) has shown that organic molecules are also formed from higher speed impacts ( $6\text{ km s}^{-1}$ ) of polystyrene and urea ( $5\text{ km s}^{-1}$ ) onto gold and aluminium foils and the analyses of these compounds is ongoing and will be reported shortly. These analyses will be greatly enhanced by the imminent delivery to Kent of a state-of-the art mapping Raman system (*LabRam* from Horiba) incorporating three lasers, a concurrent FTIR unit and a temperature controlled ( $77 - 1000\text{ K}$ ) stage.

**Acknowledgements:** We thank Dr. Adrian Knowles of Horiba (UK) for use of the *XploRa* and STFC for funding this work.

**References:** [1] Elsila J. E. et al. (2009). *MAPS*, 44, 1323. [2] Glavin D. P. et al. (2008). *MAPS*, 43, 399. [3] M. C. Price et al. (2010). *LPSC XXXI*, abstract #1830. [4] M. J. Burchell et al. (2011). *MAPS (in press)*. [5] M. J. Burchell et al., (1999). *Meas. Sci. & Tech.*, 10, 41. [6] A. T. Kearsley et al. (2011). *LPSC XXXII*, abstract #1435. [7] Henkel et al. (2012). *LPSC XXXIII*, these proceedings. [8] Furukawa Y. et al. (2008) *Nature Geoscience*, 2, 62. [9] Goldman N. et al. (2010). *Nature Chemistry*, 2, 949.