Comets, Asteroids and Mars: Microfocus Spectroscopy of Planetary Materials

John Bridges

Space Research Centre, Dept. of Physics and Astronomy, University of Leicester LE1 7RH

Planetary materials research has an increasing need for techniques to determine the mineralogy of micron-sized and smaller particles. This is partly driven by sample return missions such as *Stardust* and *Hayabusa* which can provide material vital to further our understanding of the evolution of the Solar System, but in far smaller quantities than traditional mineralogical analyses require. Sample return missions are a priority for the UK and other international space agencies. In particular, Mars Sample Return is a large international endeavour that will involve detailed analysis, over many years, of up to 500 g of rock and soil. Analysis of Martian meteorites is a vital way of preparing for this, in addition to revealing new detail about water-rock interaction on Mars in its own right.

Since grains from the coma of Jupiter Family Comet Wild2 were returned to Earth in 2006, analyses at Beamline I18, Diamond have provided a new picture about the nature and origin of short period comets. For instance, Fe K XANES, EXAFS, XRD analyses have shown the presence of the Fe oxide magnetite.[1,2] In carbonaceous chondrites this is associated with the alteration of ferromagnesian silicates by water. Rather than an unprocessed assemblage of dust and ice it is clear that many comets have captured material that even in the earliest stages of the Solar System experienced a complex series of mineral growth episodes. This new perspective is in turn influencing models for the formation of Solar Systems.[3] Using the same techniques at Diamond, grains of an S class asteroid returned by the Japanese *Hayabusa* mission have been shown to have close affinities to LL chondrite meteorites.[4]

Water-rock interaction is often only visible at the micron scale. Fe K XANES mapping and calibration of Fe^{3+}/Fe^{2+} ratios at Diamond has allowed the first accurate determination of the redox of hydrothermal veins in the nakhlite Martian meteorites. This together with transmission XRD on the veins, and TEM work at Leicester, has led to the first full identification and stoichiometric formulae of Martian phyllosilicates. These are trioctahedral ferric saponite and a ferric serpentine.[5]

Microfocus spectroscopy is now an essential tool for planetary materials analyses of both meteorites and material returned by spacecraft. Building expertise and using new developments at Diamond for submicron characterisation will position the UK to have a leading place in this field.

References

1. Bridges J. C. *et al*. Iron Oxides in Comet 81P/Wild 2 Samples. *Meteorit. Planet. Sci*. **45**, 55 (2010).
2. Hicks L. J. *et al.* XRD Analyses of Terminal Grains in Stardust Tracks **176**, **177**, **178**: Grains From Magnetite-Rich, Chondrite-Like Matrix. *45th Lunar and Planetary Science Conference*, #2051 (2014).
3. Nayakshin S., Cha S-H., and Bridges J. C. The tidal downsizing hypothesis for planet formation and the composition of solar system comets. *Mon. Not. R. Astron. Soc*. **416**, L50 (2011).
4. Noguchi T. *et al.* Mineralogy of four Itokawa particles collected from the first touchdown site. *Earth, Planets and Space* (2014 in rev.).
5. Hicks L. J, Bridges J. C. and Gurman S. J. Ferric Saponite and Serpentine in the Nakhlite Martian Meteorites. *Geochim. Cosmochim Aata*, **136**, 194 (2014).

Email corresponding author: j.bridges@le.ac.uk