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Photoemission Electron Microscopy of Stardust Cometary Foils

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Abstract

The Stardust samples have been studied using a wide variety of techniques. We report preliminary results on a new technique that lends unique insight into the samples of comet Wild2 collected in the Stardust cometary foils: photoemission electron microscopy (PEEM).

Methods

Photoemission electron microscopy (PEEM) images electrons photoemitted from a sample subjected to ionizing radiation, such as x-rays from a synchrotron. An image of the emitted electrons is produced by accelerating them through an electric potential and focusing them with electron optics (magnetic or electrostatic lenses). The image is recorded with an electron-sensitive detector. PEEM is a surface technique, probing a few nm into the sample, as the emitted electrons originating deeper into the sample are absorbed.

The PEEM microscopes used in this study were PEEM-2 [1] and PEEM-3 [2] at the Advanced Light Source. The third generation microscope, PEEM-3, is corrected for spherical and chromatic aberrations whereas PEEM-2 is not aberration-corrected. Because of this, PEEM-3 achieves a spatial resolution several times better than PEEM-2. With an energy resolution $E/\Delta E$ of $\sim$1800 and an energy range of 175–1500 eV, the PEEM2 microscope can obtain x-ray absorption near-edge structure (XANES) spectra of Ca, Mg, C, N, Ti, Fe and many other elements likely to present in cometary dust. PEEM-3 has similar energy resolution and a slightly broader energy range, so it may be able to acquire Si XANES spectra .

Impacts into foils can be analyzed on PEEM with minimal sample manipulation because the foil provides the conducting medium required to replenish photoemitted electrons. An ideal PEEM sample is flat – the surface acts as the first lens in the electron optics setup. The impact crater from a μm-sized impact into Al foil will cause the final image to be somewhat distorted so the microscope cannot be used at its optimal resolution. However, even with this distortion, the two PEEM microscopes at the ALS can achieve sub-μm resolution of material deposited in the bottom of impact craters.

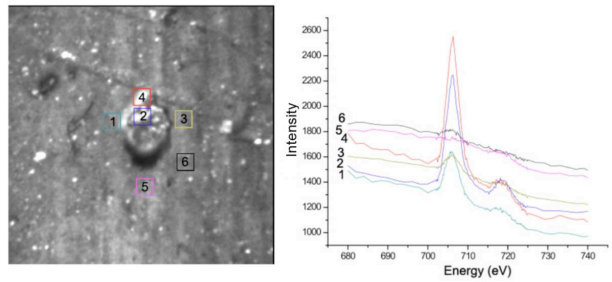

Figure 1: A crater $\sim$5 μm across with associated spectra near the Fe L3 edge. The bump around 718 eV indicates an iron oxide.

We performed an exploratory examination of an aluminum plate shot with basalt on PEEM-2. The plate was peppered with craters of various sizes. Figure 1 shows a crater $\sim$5 μm in diameter and the associated spectra from various spots inside, on the rim, and outside the crater. PEEM analysis on this type of residue can be done without much sacrifice in spatial resolution. For material inside the crater shown in Figure 1 and others of various sizes, we obtained spectra even though the image was blurred. It is possible to mount the sample at an angle so that the emitted electrons from material in the crater's floor can be imaged at higher resolution.

Discussion

PEEM analysis of analog foils shows promise that this technique will be useful in determining properties of minerals in Stardust cometary foils at sub-μm spatial resolution. Additionally, photoemission electron microscopy is nondestructive so these samples can later be analyzed with other methods. Analysis of Stardust cometary foils will commence in June 2009.

References

[1] Doran, A. et al. (2004) *AIP Conf. Proc.*, 705, 1279

[2] MacDowell, A. et al. (2007) *AIP Conf. Proc.*, 879, 1341