A MÖSSBAUER MICROSCOPE FOR MINERALOGY IN THE SYNCHROTRON AGE

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Iron containing phases are common in meteorites, and Mössbauer spectroscopy have been traditionally used to characterize and distinguish between Fe-Ni containing kamacite and taenite (Scorzelli 1993), as well as compounds of iron with sulfur like troilite, and silicates like olivine or enstatite (Malysheva 1979, Jackson 2009). However, so far, there is no good way to obtain the Mossbauer spectrum of each individual grain, located in its natural matrix. We provide Mossbauer microscopic image of iron, using focused sycnhrotron beam, and Mossbauer spectra recorded in time-decay mode to identify several different grains using a technique called nuclear forward scattering (Hastings 1991) or Synchrotron Mossbauer Spectroscopy (Alp 1995).

The spatial resolution in the images shown here is approximately 10 μm, although we have taken 5 μm-resolution images as well. It is expected that the spatial resolution will be at 1 μm level, soon. The image shown in Figure 1(a) was obtained from a thin section of the Estacado meteorite in a few hours, in transmission mode, where only nuclear delayed signal window after each pulse of the synchrotron radiation is used.

The main advantage of Mossbauer microscope can be seen in the time-decay spectra shown in Figure 1 (d-e-f). The time domain nuclear resonant spectra shown here are obtained from each individual grain, as indicated with arrows. With this approach, individual grains can be probed for valence, magnetism, spin state, as well as for composition. Another important advantage will be to use the back-scattered inelastic radiation channel to obtain the isotope fractionation between ^{57}Fe and ^{54}Fe. It is known that this information can be better obtained from the measured phonon density of states by a technique called nuclear resonant inelastic x-ray spectroscopy, NRIXS (Sturhahn, 1995), and we plan to demonstrate the feasibility of quantification of impact of redox reactions on isotope separation, as shown earlier (Polyakov, 2007).

The current spatial resolution needs to improve by an order of magnitude to match well-developed x-ray flourescence microscope. However, the inherent spectroscopic advantages mentioned above makes this approach very unique. The fact that the results shown here are obtained with a standard petrographic thin section provides an alternative approach to meteoric studies.

References:

Alp. E. E., et al, Nucl. Instrum. Methods Phys. Res. B, **97**, (1995) 526–529.
Hastings, J.,et al, Phys. Rev. Lett. **66** (1991) 770
Jackson, J., et al, Eur. J. Mineral. **21**, (2009), 551
Malysheva, T.V., Proc. Lunar Plan. Sci. Conf. 10th (1979) 977.
Polyakov, V. B., et al, Geochimica Et Cosmochimica Acta 71, (2007) 3833.
Scorzelli, R. B., *et al J. Phys. F: Met. Phys.* **17** (1987) 1993.
Sturhahn, W., et al, Phys. Rev. Lett. **74**, 3832 (1995)

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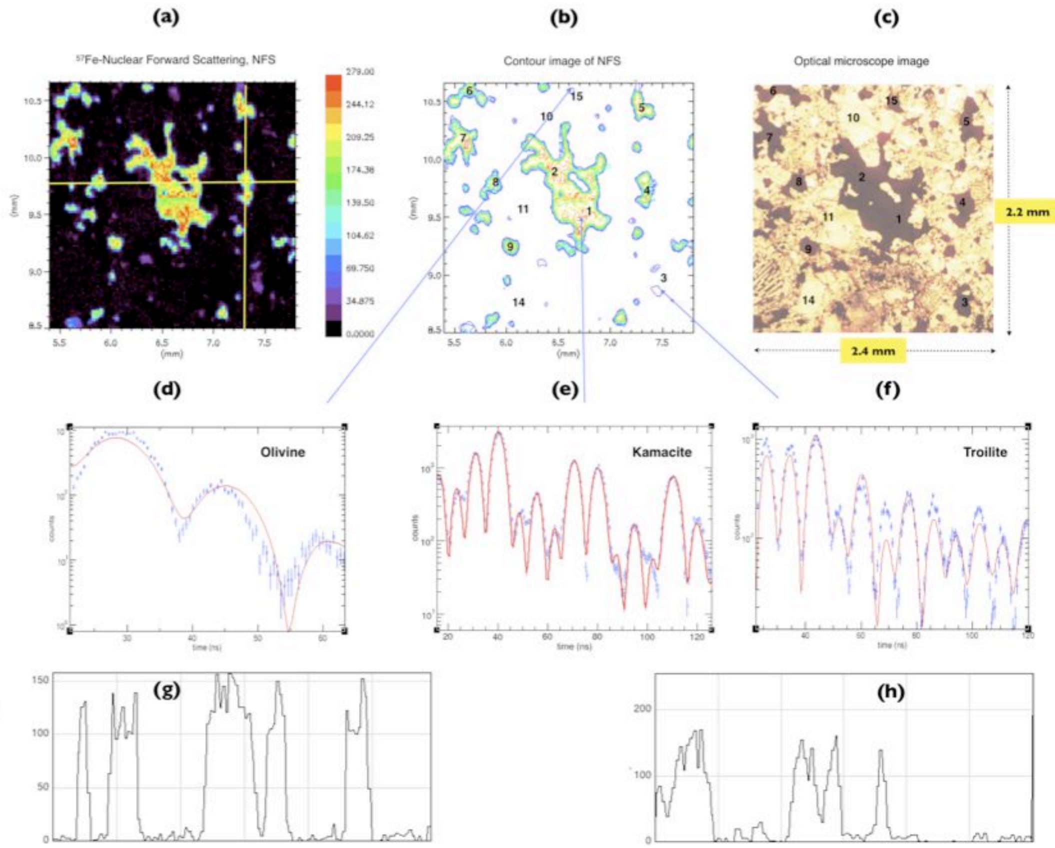

Figure 1. (a) The scanning image of a petrographic section of the Estacado meteorite obtained by a technique called nuclear forward scattering, (b) a contour image of the same section, (c) an optical microscope image of the same area. The data shown in (d) is representative of an olivine grain, (e) an Fe-Ni alloy, and (f) troilite, FeS. The signal given in (g) and (h) are the horizontal and vertical cross-section intensity profiles taken along the lines shown in (a), emphasizing the excellent signal-to-noise ratio observable in the Mossbauer radiation channel