ESRF

Experiment title: Vibrational properties of Fe Clusters studied by Inelastic Nuclear Resonant Scattering	Experiment number: SI383
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Report:

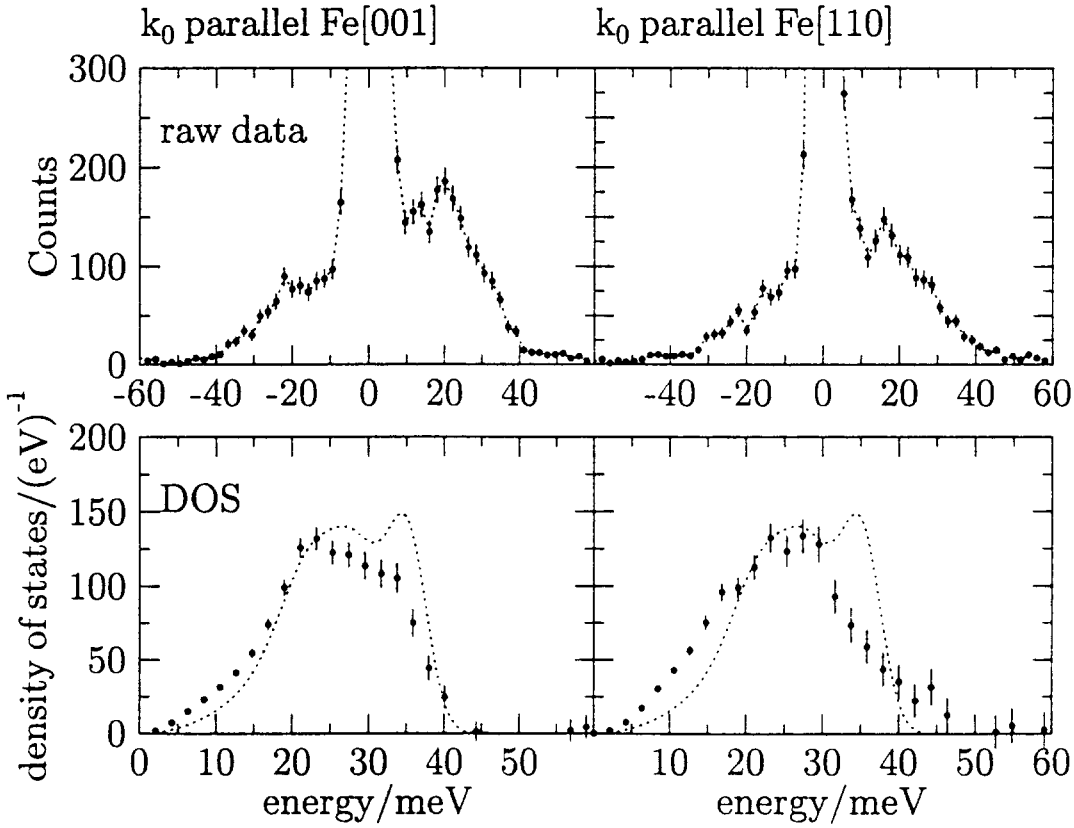
In this experiment we have measured the phonon density of states (DOS) of ^{57}Fe clusters by inelastic nuclear resonant scattering. In an experiment performed recently at the ESRF [1], we have measured a phonon spectrum of a 12 nm thick layer of $FeBO_3$, with 4×10^{14} ^{57}Fe atoms involved [2]. This number is in the order of a monolayer surface coverage with ^{57}Fe. Therefore we could expect similar vibrational studies on ^{57}Fe cluster layers with a comparable effective surface coverage to be feasible.

The Fe islands were prepared by thermal evaporation of ^{57}Fe (95% enriched) from a crucible under ultra-high vacuum conditions onto a clean single crystal of W(110). After deposition the crystals were heated to about 1000 K. At these temperatures Fe forms separated and well ordered 3D islands with the lattice constant of bulk iron on a pseudomorphically ordered Fe monolayer. The islands are of rectangular shape with the long axis pointing along the W[001] direction. Finally, the sample was capped with a carbon film of about 10 nm in order to prevent oxidation of the Fe islands ex-situ.

To achieve maximum countrates, the sample was illuminated at a grazing angle of 5.2 mrad, i.e. the critical angle of total reflection of the W substrate at 14.4 keV. The energy resolution in the experiment was 5.6 meV.

The idea in this experiment was to study the phonon DOS dependent on the direction of the incident radiation relative to the crystal lattice. A similar study has been performed recently on a single crystal of $^{57}FeBO_3$, where a pronounced anisotropy in the vibrational properties was observed [3]. This could be expected due to the anisotropic crystal lattice in case of $FeBO_3$. In pure α-Fe, however, due to its cubic lattice, the vibrational properties should be isotropic. The question is, if this is still the case for small particles like islands or clusters of Fe.

X-ray diffraction and elastic nuclear resonant scattering revealed that the Fe islands indeed exhibit magnetic and structural properties like bulk bcc Fe. Our inelastic measurements (see figure below), however, indicate an anisotropy in the vibrational properties. Phonon spectra were measured with the incident radiation parallel to the Fe[001] and to the Fe[1$\bar{1}$0] direction, respectively. The average countrate in the phonon wings was about 0.7 Hz, so that phonon spectra with reasonable statistics could be obtained in 5 - 6 hours. The DOS was derived from the data via the procedure as described in [4]. Comparison with the DOS of bulk Fe (dashed line) reveals significant differences in both cases, in particular a damping of the longitudinal phonon branches around 35 meV and a considerable excess of low-energy phonons.



References

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[3] A. I. Chumakov et al., Phys. Rev. B 56 10758 (1997)
[4] W. Sturhahn et al., Phys. Rev. Lett. 74, 3832 (1995)