Experiment number: SI-2364
Beamline: ID18

Density of phonon states of ultrathin Europium metallic films from in-situ ^{151}Eu nuclear inelastic scattering

Determination of the lattice dynamics of pure rare-earth metals has been a great challenge for both experimentalists and theoreticians. Until now, reliable information on the lattice dynamics of the lanthanides could only be scarcely found in the literature. The availability of the ultrahigh vacuum system [1] for samples growth and characterization at ID18 of the ESRF, as well as, the access to three rare-earth isotopes (^{149}Sm, ^{151}Eu, ^{161}Dy) opened up the possibility to grow high quality single-crystalline films and to investigate their vibrational properties *in-situ*, thus avoiding oxidation of these very reactive metals. The density of phonon states has recently been determined for samarium and europium bulk-like metallic films by nuclear inelastic scattering on ^{149}Sm [2] and ^{151}Eu [3]. While the experimental data for *bcc* Eu are in perfect agreement with the results from *ab initio* calculations, a detectable disagreement is observed in case of Sm.

To further investigate the source of discrepancy, we have measured the phonon density of states of 11 Å thick Eu film exhibiting *hcp* crystal lattice. Fig. 1 reveals a tremendous difference between the phonon DOS of *bcc* and *hcp* europium. It is expected that the comparison with the results from the first principles calculations will shed more light on the influence of tiny effects, such as the spin-orbit coupling, for example, on the lattice dynamics of the lanthanides with hexagonal lattices. While the spin-orbital coupling in europium metal is negligible, samarium exhibits the largest spin-orbital interaction among the lanthanides. The theoretical treatment of such tiny interactions is not straightforward, which could be one of the reasons for the observed disagreement between theory and experiment in case of samarium.

In addition, the obtained data demonstrate that ultrathin rare-earth films even with mono- and sub-monolayer coverage could be investigated in a reasonable timescale by nuclear inelastic scattering at the ESRF. This opens new scientific directions, which will be explored in the near future.

[1] S. Stankov et al., Rev. Scientific Instr. **79**, 045108 (2008).
[2] Experimental report HS-3174.
[3] S. Stankov et al., Phys. Rev. B **78** 180301(R) (2008).

Data acquired during experiment SI-2364, August 2011 at ID18
S. Stankov, O. Bauder, M. Zajac, M. Kaufholz

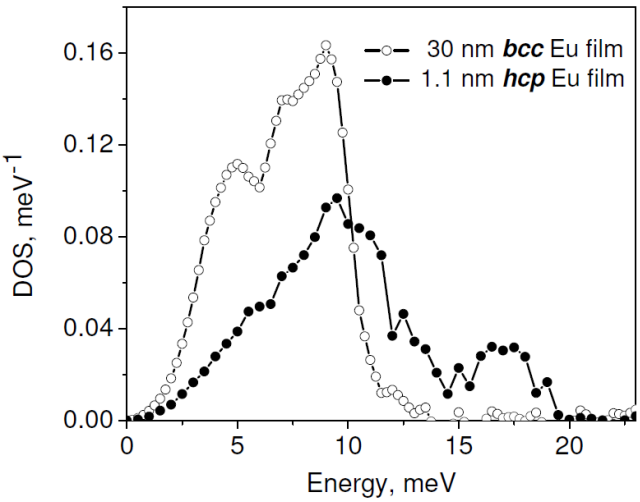

Fig. 1. Phonon DOS of ^{151}Eu epitaxial films exhibiting either the native for europium *bcc* lattice (open circles), or the characteristic for the heavy lanthanides *hcp* structure (filled circles).