ESRF	**Experiment title: Magnetism and lattice dynamics of the divalent (0001)Sm surface**	**Experiment number**: HC-1092
Beamline: ID18	**Date of experiment**: from: 19/08/13 to: 6/09/13	**Date of report**: 10/08/13
Shifts: 18	Local contact(s)**:** Daniel Merkel, Rudolf Rüffer	*Received at ESRF:* *10/08/13*

Names and affiliations of applicants (* indicates experimentalists):

*Dr. S. Stankov, Institute for Photon Science and Synchrotron Radiation, KIT Karlsruhe, Germany

*O. Bauder, Laboratory for applications of synchrotron radiation, KIT Karlsruhe, Germany

*A. Seiler, Laboratory for applications of synchrotron radiation, KIT Karlsruhe, Germany

*Dr. S. Ibrahimkutty, Institute for Photon Science and Synchrotron Radiation, KIT Karlsruhe, Germany

*Dr. P. Piekarz, Polish Academy of Sciences, Krakow, Poland

Report:

The original aim of this experiment was to investigate the lattice dynamics of the native Sm(0001) surface, that is expected to exist in a divalent state instead of the trivalent valence state characteristic for the bulk Sm. However, during the preparation of this experiment in the UHV system at ID18 it turned out that the Sm metal contains an unacceptably high level of hydrogen that resulted in a base pressure of $7x10^{-9}$ mbar or higher. With this pressure the epitaxial growth of high-quality Sm(0001) films was not possible which made the originally proposed lattice dynamics studies of the Sm surface impossible. In order to use the valuable experimental time at the ESRF in the most efficient way we have performed a systematic investigation of the lattice dynamics in exotic Eu nanostructures. In our home lab at ANKA we have established the growth conditions for stabilizing nanowire-like epitaxial Eu structures with high aspect ratio. The growth of these nanowires is facilitated by the native formation of nanowires of Nb (Fig. 1) oriented along [1120] by depositing this metal on (11-20)Al_2O_3 applying elaborated growth procedure.

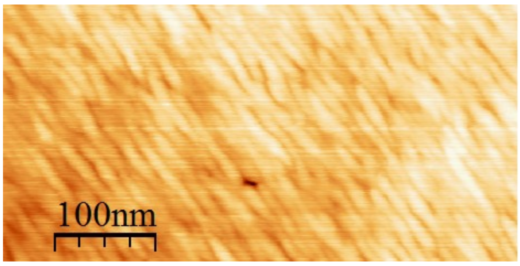

***Fig.1** AFM image of the low temperature grown Nb buffer layer on (11-20)Al_2O_3. The formation of wire-like structures oriented along [1120] direction is clearly visible.*

The experiment was performed at ID18 of the ESRF using the ultrahigh vacuum facility [1] installed in the second experimental hutch. We point out that this is the only place worldwide where *in-situ* nuclear inelastic experiments on ultrathin films and nanostructures can be performed. We used the 16-bunch filling mode of the ESRF storage ring. The final energy bandwidth of 1.0 meV (at the resonance energy of 21.5 keV) was obtained using a dedicated high-resolution monochromator. The vertical beam size was reduced to 12 μm using Kirkpatrick-Baez focussing mirror.

Metallic Eu (enriched to 96% in ^{151}Eu) was sublimated from an effusion cell equipped with Ta crucible on the Nb(110) buffer layer epitaxially grown in two steps on the A-plane Al_2O_3 substrate. Deposited at 150°C on this buffer layer Eu grows in hexagonal structures with the directions [1120]Eu||[001]Nb and [1100]Eu||[110]Nb adopting the wire-like surface morphology of the buffer (Fig. 1). Samples with a nominal Eu coverage of 2, 3 and 5ML (1ML=0.325 nm) were grown and their lattice dynamics was investigated. The inset of Fig. 2 shows an AFM image of the wire-like structure of the sample with 2ML coverage of Eu. The samples were characterized by reflection high energy electron diffraction (RHEED) before the inelastic experiment. The energy dependencies of nuclear inelastic absorption were measured parallel (along [1100]Eu) and perpendicular (along [1120]Eu) to the wire-like nanostructures. Due to the significant multiphonon excitations at room temperature all samples were measured at 100 K.

Fig.2 shows the phonon density of states (DOS) of the wire-like structures for the samples with nominal Eu coverage of 2,3 and 5ML a) along [1120] and b) along [1100] directions. The phonon DOS of the bcc Eu is shown with a grey dashed line for comparison.

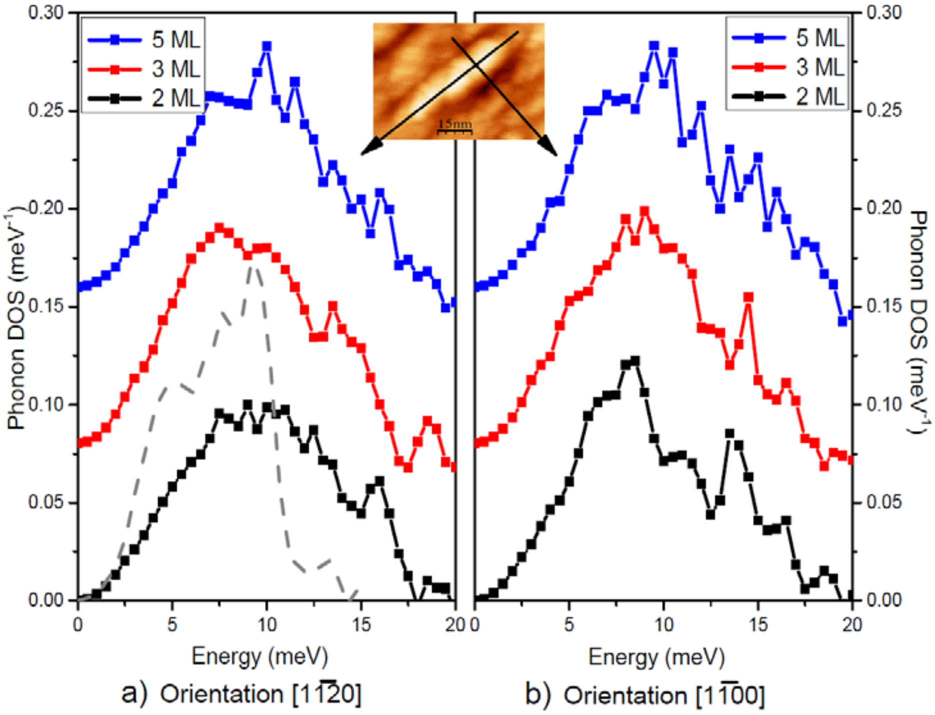

Fig.2 *Phonon DOS of the wire-like structures for the samples with Eu coverage of 2ML (black points/ line), 3ML (red points / line) and 5ML (blue points/line). Additionally the Eu phonon DOS of the native bcc structure is shown for comparison. The AFM image of the sample with a nominal Eu coverage of 2 ML is shown as inset.*

The experimental data reveal the presence of a pronounced vibrational anisotropy for the sample with coverage of 2ML. By increasing the Eu coverage this anisotropy is gradually vanishing and for the 5ML coverage it is not visible any longer. The thickness dependence of this anisotropy could be explained by a careful RHEED and AFM investigation performed in our home lab. The 2ML sample consists of epitaxial structures with a hexagonal symmetry. In addition, the phonon DOS is shifted to higher energies in comparison to that of the bcc Eu (Fig.2 a). This shift might originate from the expected semimetal state predicted for Eu with an expanded nearest neighbours distance in comparison to that in the bulk bcc Eu [2]. In order to get a comprehensive understanding of the observed phenomenon the experimental results will be compared with the results from the ab initio calculations that are in progress.

References:

[1] S. Stankov et al., Rev. Scientific Instr. 79, 045108 (2008)
[2] H.L. Skriver Phys. Rev. B 31, 1909 (1985)