ESRF	**Experiment title:** Vibrational density of states in "*Sm-type*" and *dhcp* Sm epitaxial single crystalline films by nuclear inelastic scattering	**Experiment number**: HS-3174
Beamline: ID18	**Date of experiment**: from: 26/01/07 to: 05/02/07	**Date of report**: 28/02/07
Shifts: 18	Local contact(s)**:** Ilya Sergueev	*Received at ESRF:* *28/02/07*

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Report:

In this experiment we have studied the density of phonon states (DOS) of single crystalline epitaxial Sm films exhibiting the native for this metal "*Sm-type*" crystal structure and characteristic for the light rare-earth metals (La-Pm) double hexagonal close-packed (*dhcp*) crystal lattice (Ce is an exception with its face-centred cubic *fcc* lattice).

The studied Sm films with thickness 5000 Å were prepared by molecular beam epitaxy, following the procedure described by C. Dufour et al. [1] in an ultrahigh vacuum (UHV) system located ad ID18 of the ESRF. The NIS experiment was performed at the beamline ID22N of the ESRF, using a transportable UHV chamber, dedicated to nuclear resonance scattering experiments, in which the inelastic spectra were measured *in-situ*. The vacuum in the chamber during transport and measurements was maintained below 5.0×10^{-10} mbar.

The experiment was performed during 16-bunch filling mode of the ESRF storage ring. The final energy bandwidth of 1.0 meV (at the resonance energy of 22.5 keV) was obtained using a dedicated high-resolution monochromator. The vertical beamsize was reduced down to 28μm using Kirkpatrick-Baez focussing mirror.

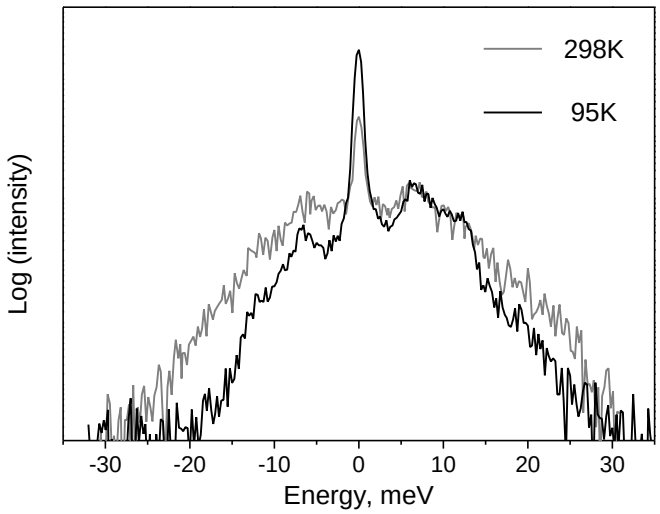

Fig. 1 Nuclear inelastic spectra measured on the "*Sm-type*" sample at room temperature and at 95K.

Fig. 1 shows NIS spectra of the "*Sm-type*" structured film, measured at room temperature and at 95K. Comparing both spectra one can see that due to the multiphonon excitations, the peaks related to the van Hove singularities of transverse and longitudinal phonon modes ca be hardly observed at room temperature. Therefore all NIS scans for both samples were performed at 95 K, which is the lowest achievable temperature on the sample-holder in the UHV chamber using liquid nitrogen as a coolant.

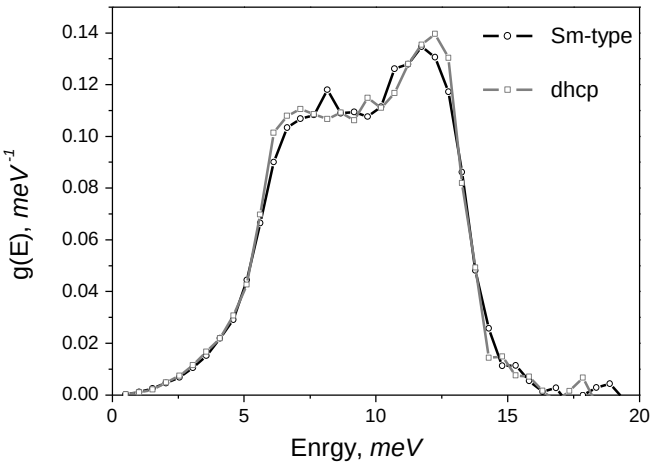

Fig. 2 DOS of the Sm films with *dhcp* and "*Sm-type*" crystalline structure obtained at 95K

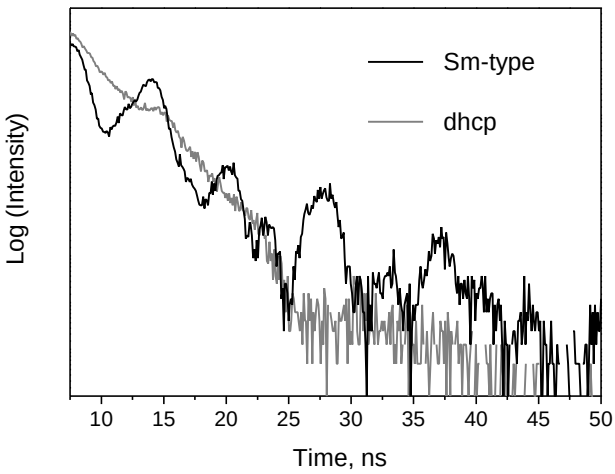

Fig. 3 Nuclear forward scattering spectra of "*Sm-type*" and *dhcp* films obtained at 95 K.

Fig 2 shows the density of phonon states for "*Sm-type*" sample (black) and *dhcp* sample (grey) obtained from the single-phonon events, after subtraction of the elastic peak and correction for multiphonon contribution [2]. One can see that the main difference between the phonon spectra of both structures appears in the vicinity of the transverse and longitudinal phonon modes, since the low and high energy tails coincide within the experimental error bars for both samples. This result is rather expected due to the very close co-ordination of the Sm atoms in both crystal lattices. More details will be gained from comparison with the phonon spectra obtained by the on-going *ab-initio* calculations.

The first hint about the crystal structures can be obtained from the nuclear forward scattering (NFS) spectra, shown in Fig 3, which are measured during the inelastic scans. These spectra clearly show that the "*Sm-type*" film is in magnetically ordered state at 95 K, as it is expected for Sm metal (Neel transition for the hexagonal sites T_{Nh}=106K and for cubic sites T_{Nc}=14K [3]). The Sm films with *dhcp* structure are reported to order magnetically bellow $T_{Nh} = T_{Nc}$ =25 K [4]. The NFS spectrum of that sample at 95K, shown in Fig. 3 with grey line, strongly suggests that Sm is in paramagnetic state, as expected for this structure. More details about the crystal structure of both samples will be obtained by on-going *ex-situ* X-ray diffraction studies (on the same films covered by 3nm thick Nb layer in order to prevent oxidation).

In conclusion:

- *The density of phonon states of 500 nm thick Sm films with "Sm-type" and dhcp crystal structures are obtained from the experimentally measured NIS spectra in-situ, under ultra-high vacuum conditions and at 95K.*
- *From the DOS a number of thermodynamic parameters are calculated for both crystal lattices.*
- *The performed experiment opened-up the possibility for further in-situ studies of both - the vibrational and magnetic properties of Sm-based thin films and nanostructures by nuclear inelastic and nuclear forward scattering of synchrotron radiation under UHV conditions.*

References:

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[4] C. Dufour et al., Phys. Rev. B **66** 94428 (2002)