ESRF	**Experiment title:** Determination of the exact shape of the electron-phonon interaction in compact and cluster-assembled superconducting Sn films	**Experiment number:** HE-1660
Beamline: ID18	**Date of experiment:** from:03/09/2014 to:09/03/2014	**Date of report:** 19/10/2015
Shifts: 17	**Local contact(s):** A. Chumakov	*Received at ESRF:*

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Report: The aim of the experiment was to study the effect of reduced dimensionality on the phonon density of states (PDOS) of Nb_3Sn superconducting thin films and to correlate these observations with the modification of the superconducting properties. More specifically, the goal was to resolve the Sn partial PDOS in Nb_3Sn thin films as a function of layer thickness, above and below the superconducting transition temperature T_c and compare it with the Eliashberg function (electron-phonon coupling factor times the PDOS) which was measured via tunnel junctions in our laboratory. It is, in general very difficult to measure the PDOS of such thin flims since traditional techniques to measure vibrational properties, such as inelastic neutron scattering and inelastic x-ray scatering can not probe such small samples.

Five Nb_3Sn thin films with thicknesses ranging from 50 to 2.5 nm, deposited on MgO and Al_2O_3 substrates, were investigated. This thickness range covers the transition from a bulk-like PDOS to a regime where the PDOS shows confinement effects.
The experiment was carried out at 3 different temperatures: room temperature, above and below T_c. The measurements at room temperature were done in air while the measurements above and below T_c were performed in a cryostat with a base temperature of 4.2 K. The samples were placed in grazing incidence geometry with four electrodes attached, to monitor the superconducting transition (drop of resistance to 0 Ω) during the low temperature measurements.
First, all five samples were measured at room temperature. The experimental procedure was to record several nuclear inelastic spectra (NIS) on each same sample and then to sum them up to reach sufficient statistics.

After completing all room temperature measurements the 50nm film was put in the cryostat and cooled down to 20K. At this temperature, NIS spectra were recorded, using the same procedure as for the room temperature measurements. Then the sample was cooled down below T_c (this was verified by measuring the resistance of the sample) and the previous procedure was repeated. Unfortunately it was not possible to measure any other sample at low temperature due to a lack of time.

The analysis of the recorded NIS spectra allowed the extraction of the PDOS for all the measured films. From the measurements at room temperature the evolution of the PDOS with thickness could be seen. The supression of the peak at 25meV, as well as an increase in energy modes between 25 and 30meV was observed, as the thickness was reduced. Furthermore, an enhancement of the low energy modes was found to follow the same trend. This is a confinement effect of the phonons in the direction perpendicular to the sample surface. From the differences in the PDOS for the samples deposited on MgO and Al_2O_3 (5 nm films), it can be seen that in such ultrathin films the surface modes of the substrate influence the PDOS of the film substantially. Finally, the PDOS in the superconducting state (5K) of the 50nm film shows a kink around 4meV that does not apear in the PDOS extracted from the NIS spectra taken above T_c (20K). This is a clear sign of the superconducting gap. These results will be subject of an article which is going to be submitted to the Physical Review B journal very soon.

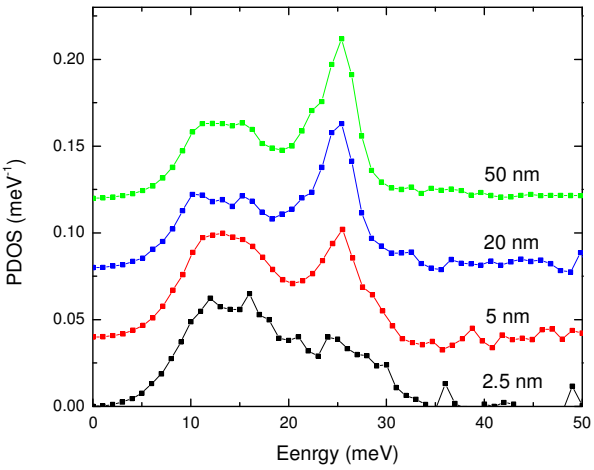

Figure 1. Evolution of the PDOS as a fuction of film thickness

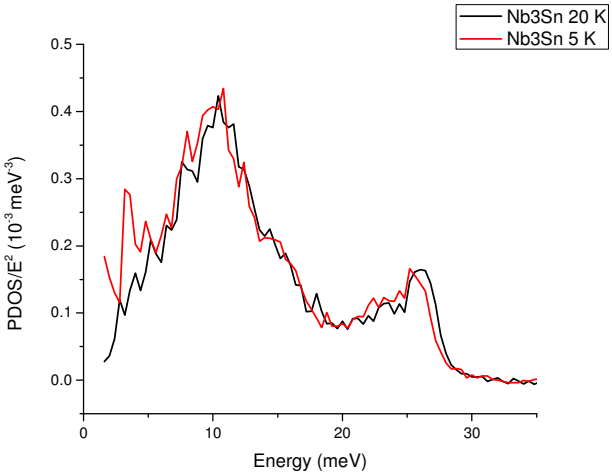

Figure 2. Reduced density of states. The kink around 4meV in th red curve is a sign of the superconducting gap.

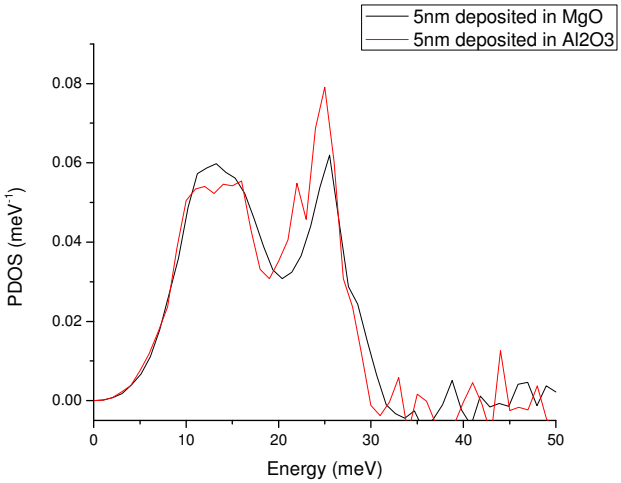

Figure 3. Comparation between thePDOS of the sample deposited in MgO and Al_2O_3. We can observe some differences in the peak positions and magnitudes.