# Depth resolved phonon density of states of Fe at an interface with MgO

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This experiment aims at obtaining monolayer resolution measurements of atomic vibrations (phonons) in a metallic Fe film near its interface with a MgO substrate. Since the phonon density of state (PDOS) of MgO shows almost no frequency matching with Fe (in bulk), the interface is a good thermal insulator (no phonon propagation). We want to study how the phonon density of states of the Fe layer evolves when approaching the interface. In particular, we also wanted to correlate the observed phonon spectrum with the thermal properties of the interface by submitting the system to a temperature gradient.

The experiment was carried out at the P01 beamline of Petra III. The samples were placed in a home build chamber that allowed electrical current heating of the metallic layer. The technique of nuclear inelastic scattering was used to obtain depth resolved phonon density of states of the Fe layer in contact to the MgO. For that purpose, a series of samples were measured, which all embed a 0.4 nm $^{57}$Fe layer (the rest of the Fe layer is made of $^{56}$Fe) placed at different distance from the interface. In Figure 1, one can compare the PDOS of a 10 nm and a 0.2 nm $^{57}$Fe layer. The general shape of the 10 nm film PDOS is comparable to bulk Fe, although the peak at 38 meV is reduced in intensity. The 0.2 nm interface layer shows a completely different spectrum with little or no features of metallic Fe. Such structureless PDOS is characteristic from disordered interface structures [1].

The application of a temperature gradient across the interface leads to a different behavior for the two layers. The interface layer remains unchanged while the thick layer shows a pronounced softening with an excess of phonon modes between 15 and 25 meV. This behavior is not clearly understood yet. In order to have a clear idea of the process, new experiments should be carried out, with different thickness ranges. Indeed it is surprising to see that that a layer as thick as 10 nm can be influenced by the heat gradient. New experiments are foreseen to challenge these questions. They should bring a definitive view on how phonon mediated heat transfer can occur at such meta/oxide interface.

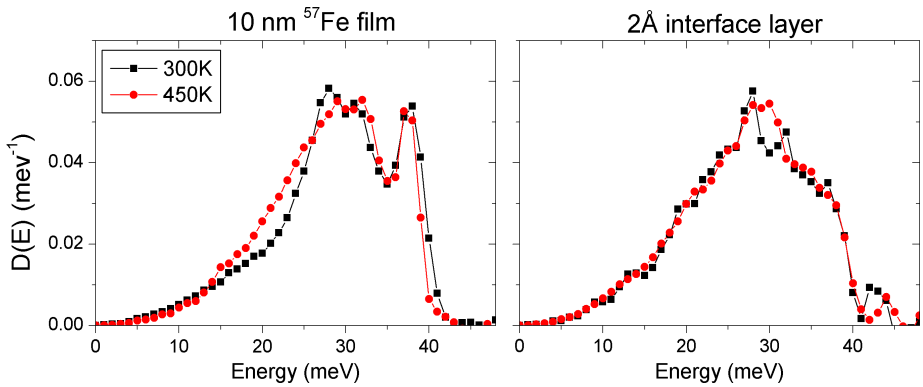


Figure 1: Phonon density of states recorded by NIS on two samples with a 10 nm and 0.2 nm $^{57}$Fe layer deposited on MgO. The application of a temperature gradient leads to a drastic change of the spectrum of the 10 nm layer.

## References

[1] S. Stankov, Y.Z. Yue, M. Miglierini, B. Sepiol, I. Sergueev, A.I. Chumakov, L. Hu, P. Svec and R. Rüffer, Phys. Rev. Lett. **100**, 235503 (2008)