Experimental report

19/05/2017

Proposal: 7-01-423 **Council:** 4/2015

Title: Investigation of anisotropic vibrational properties of iron nanowiresembeded in an alumina matrix

Research area: Physics

This proposal is a resubmission of 7-01-419

Main proposer: Daniel PEREZ LOZANO

Experimental team: Eva-Maria ANTON
Daniel PEREZ LOZANO

Local contacts: Stephane ROLS

Samples: Fe nanowires embeded in a Al2O3 matrix

Instrument	Requested days	Allocated days	From	To
IN4	7	4	03/06/2016	09/06/2016

Abstract:

The vibrational dynamics of solid-state matter, known as phonon density of state (PDOS), govern many thermodynamic and elastic properties which are usually well known for bulk material. However the effect of reduced dimensionality on the PDOS of a material is not clear. It is fundamental to know how the thermodynamic and elastic properties change in nanostructures since nowadays they play a crucial role in applications, such as microelectronics. Using the isotope sensitive technique of nuclear resonant inelastic x-ray scattering (NRIXS), we have investigated the anisotropy in the phonon density of states of 57Fe nanowires embedded in an Al2O3 matrix. However, the isotope selectivity of the technique prevents understanding the effects of the matrix on the vibrational dynamics of the nanowires. We therefore need a technique to probe the vibration of the complete system (nanowires + matrix). The goal of the experiment is to investigate the effects of a matrix on the atomic vibrations of the confined iron nanowires and compare it to what is obtained by NRIXS.

Local contact: Stéphane Rols

User: Daniel Pérez

Summary of the experiment: Investigation of anisotropic vibrational properties of iron nanowires embedded in an alumina matrix

The aim of the experiment was to study the effect of a host matrix on the atomic vibrations of iron nanowires with diameters of 18 nm and 100 nm. More specifically, the goal was to resolve the generalized phonon density of states (GDOS) when the momentum transfer vector was parallel and perpendicular to the nanowires axis using time of flight spectroscopy (TOF) and compared these results with the ones previously obtained in the same system using the isotope selective technique nuclear inelastic X-ray scattering

We investigated Fe nanowire arrays embedded in Al_2O_3 matrices with two different pore diameters: 18 and 100 nm. Using these two diameters we expected to see pronounce differences between the vibrational properties of the two samples and respect to bulk Fe. The experiment was carried out at two different temperatures and wavelengths: T=320 K and λ=2.41 Å, and T=2 K and λ=1.3 Å. We placed twelve samples of identical pore diameter in three stacks of 4 samples each along a Cd sample holder. Cadmium was used as a sample holder since it is a neutron absorber, therefore it does not contribute to the signal measured. The samples were placed forming a 45º with respect to the incident beam. In order to have the transfer vector parallel to the nanowires axis we just use the data collected in the detectors situated between 80º and 100º so the average scattered vector makes 90º with respect to the incident vector. To make the transfer vector perpendicular to the nanowire axis we just rotated the sample 90º.

The experiment began with the measurement of the 100 nm samples. The temperature was set to 320 K and the wavelength to 2.41 Å. The settings selected allowed us to record data up to transfer energies of 120 meV. The anti-Stockes line was used to derive the GDOS. In the second part, the sample was cooled down to 2 K and the wavelength was changed to 1.3 Å. In this case the Stockes

part of the spectrum was used to retrieve the GDOS and due to the limited resolution the scans taken up to transfer energies of 40 meV. The same procedure was repeated for the 18 nm samples, besides the measurement at low temperature.

The application of the incoherent approximation to the TOF spectra allowed us to extract the GDOS of every sample and geometry measured

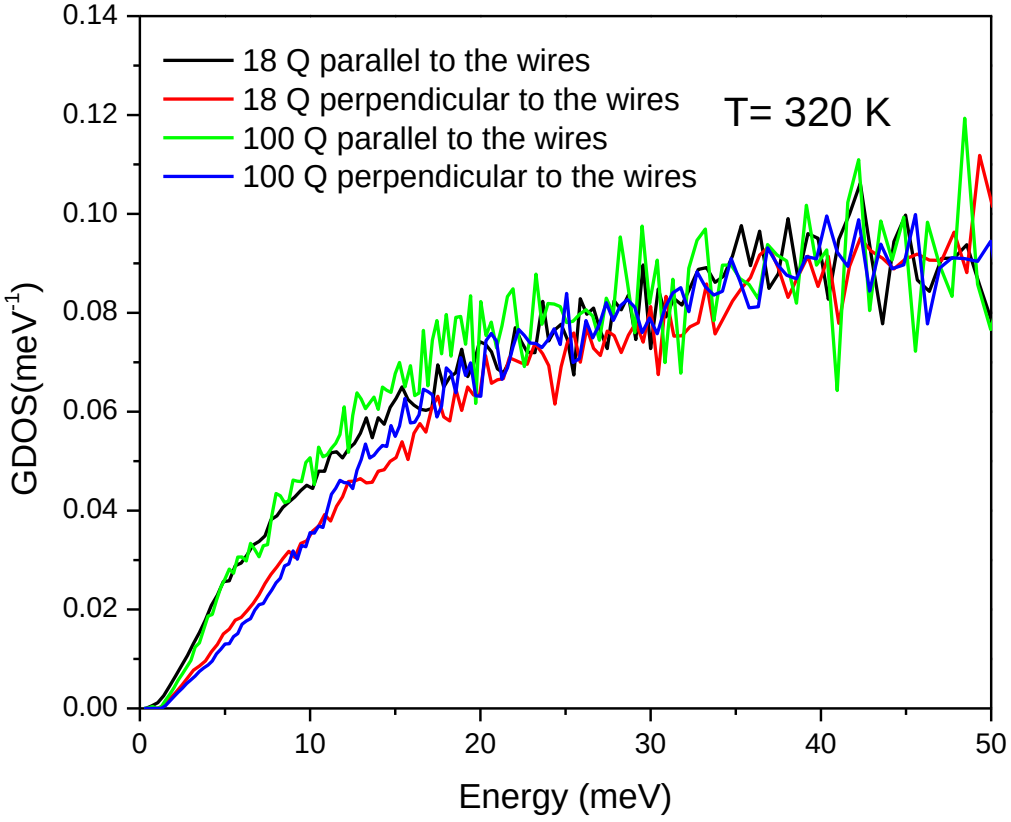

Figure 1. GDOS of the 100 nm and 18 nm samples in the two orientations probed, at temperature of 320 K and a neutron wavelength of 2.4 Å. The anti-Stockes branch of the TOG spectra was used to derived the GDOS.

We observe differences in the low energy part of the spectra when comparing the GDOS of the 18 nm and 100 nm sample. However, there are not significant differences observed between the curves when the Q vector is parallel and perpendicular to the nanowires axis for a fix nanowire diameter. Moreover, no features corresponding to Fe are observed in the data collected. This is due to fact that the pre-factor which is a combination of the nuclear scattering length and the mass of the Al_2O_3 is one order of magnitude higher than the one for Fe, thus

the contribution of the host matrix to the total GPDOS is much more relevant than the one from Fe. Similar results are obtained for the 100 nm sample at 2 K using neutrons with a wavelength of 1.3 Å.