ESRF

Experiment title: Phonon confinement and anisotropy in Te bearing thermoelectric nanowires	**Experiment number:** HE-3329

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Report:

During experiment HE3329 we carried out nuclear inelastic scattering (NIS) studies on ^{125}Te bearing thermoelectric materials at 35.493 keV. The studies were carried out using a sapphire Bragg backscattering monochromator [1] using the $(9\ 1\ \overline{10}\ 68)$ reflection in Al_2O_3. The energy resolution in this experiments has been drastically improved from 6.6 meV obtained in the first experiment[1] to currently 1.2 meV [2]. After configuring the spectrometer using a sample of elemental ^{125}Te, we collected the Te element specific phonon spectra of $Bi_2^{125}Te_3$ bulk material and of $Bi_x^{125}Te_y$ nanowires by NIS. The polycristalline nanowire sample was prepared by electrochemistry and grown in an alumina matrix, with approximately 50 nm wire diameter and 2 μm; the stoichiometry was however not exactly controlled; the overgrow, see Fig. 1, was removed mechanically prior to the measurements. The use of the alumina template assured strict orientation of the wires. The phonon spectra of the nanowires were acquired in two different orientations: parallel and perpendicular to the impinging x-ray beam respectively, as indicated in Fig. 1. The spectra of the nuclear forward scattered (NFS) and the nuclear inelastic scattered intensity of the Bi_2Te_3 nanowires oriented parallel and perpendicular to the incoming beam respectively are shown in Fig. 2. From the NIS spectra we extracted the vibrational density of states (see Fig.3) and the speed of sound projected for the phonons with the polarization parallel and perpendicular to the nanowires. The speed of the sound for the phonons polarized parallel to the nanowires is found to be 8% smaller than for the perpendicular polarization. Further measurements are currently carried out in order to characterize the crystallinity and composition of the sample in order to compare the data with the data obtained on bulk $Bi_2^{125}Te_3$ (not shown).

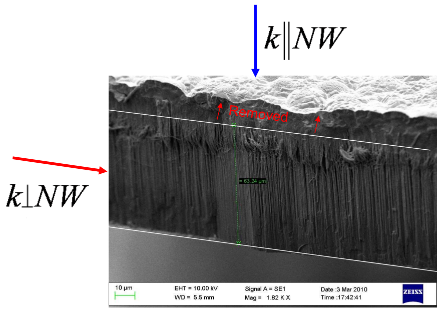

Fig. 1: SEM view of the nanowire template (courtesy W. Töllner, U Hamburg)

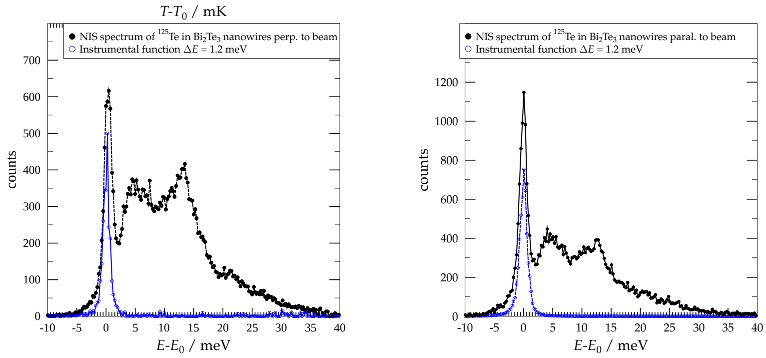

Fig. 2: NIS spectra Bi_2Te_3 nanowires oriented parallel and perpendicular to the incoming beam respectively, and the intrumental resolution function from the NFS signal. The sample temperature is ∼25 K.

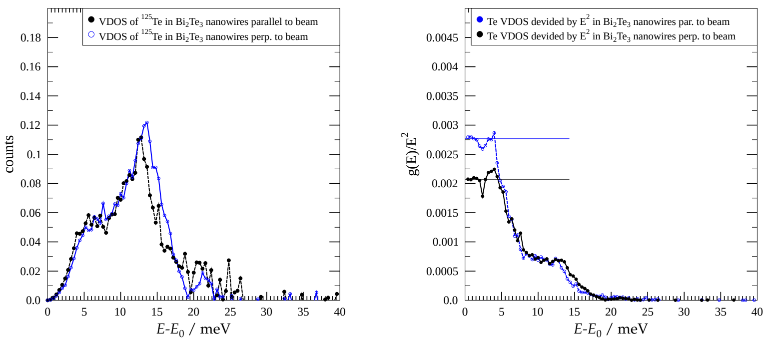

Fig. 3: Left: The vibrational density of states (VDOS) of Bi_2Te_3 nanowires oriented parallel and perpendicular to the incoming beam respectively. Note the different energy dependance at low energies. Right: The reduced VDOS $g(E)/E^2$ emphasizes the difference in the Debye level. The lines are guides to the eye.

References

[1] H.-C. Wille et al., Europhys. Lett. 91 (2010) 62001
[2] I. Sergueev et al., submitted to J. Synch. Radiation (July 2010)