SPECTROSCOPY ON *SINGLE* BI NANOWIRES

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Bismuth is a semimetal with unique electronic properties. Bulk material exhibits a very small band overlap ($E_0 \sim 98$ meV at 300 K) and two direct band gaps E_{G1} and E_{G2} at the L- and T-point of the Brillouin zone where electrons and holes are located, respectively (Fig. 1) [1, 2]. For nanowires whose diameter d is in the same range as the Fermi-wavelength λ (in the case of Bi: $\lambda \sim 40$ nm), the energy bands shift against each other and split into subbands [3, 4]. The energy separation between consecutive subbands as well as the energy shift of the bands are inversely proportional to the effective mass of the charge carriers which is very small in the case of Bi ($0.001 - 0.26\ m_e$). Since the electrons have a smaller mass than the holes, the energy shift is larger at the L- than at the T-point.

By means of infrared (IR) and electron energy loss spectroscopy (EELS), we investigated *single* Bi nanowires. Arrays of Bi wires were deposited electrochemically in etched ion-track membranes [5]. The IR spectra show an absorption onset shifting to higher energies for smaller wire diameter (Fig. 2). Furthermore, measurements using linearly polarized light showed that there are at least two transitions. The transition excited by light, whose electric wave vector oscillates normal to the wire axis, exhibits a stronger energy shift than that induced by parallel polarized light. We ascribe them to direct transitions in the vicinity of the L-point and indirect transitions from the L- to the T-point valence band, respectively.

The EELS measurements (see Fig. 3) show a resonance at about 15 eV corresponding to the bulk plasmon of Bi. Additionally, the absorption of the $O_{4,5}$ transition occurs at 24 eV as expected. In relation to this signal, the absorption due to plasmonic excitations decreases with diminishing wire diameter. In the energy range between 26 and 30 eV, the slightly higher signal for thicker wires is probably caused by double plasmon excitations which are the likelier the thicker the specimen is.

References:

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Figures:

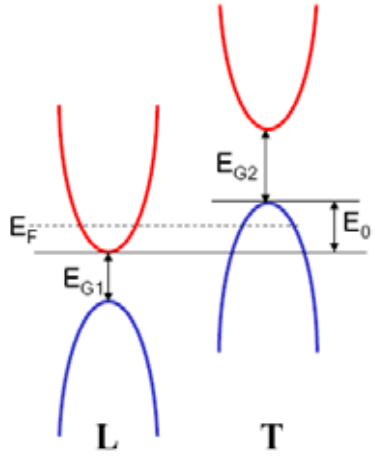

Figure 1: Band structure of bulk bismuth.

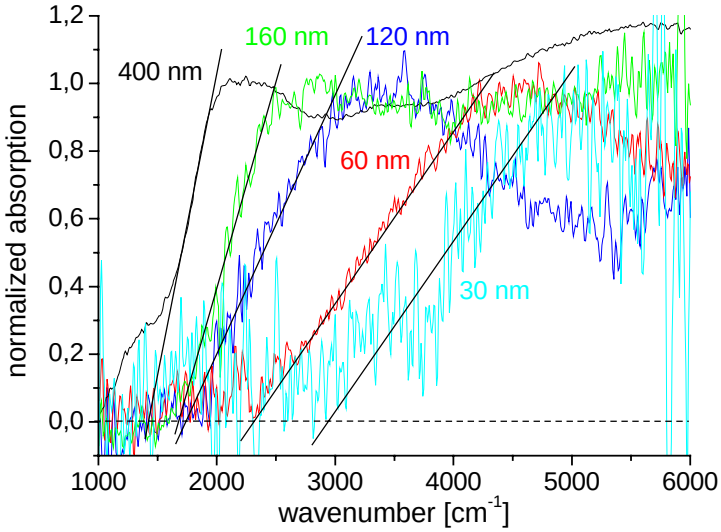

Figure 2: IR absorption spectra at room temperature of Bi nanowires with different diameters.

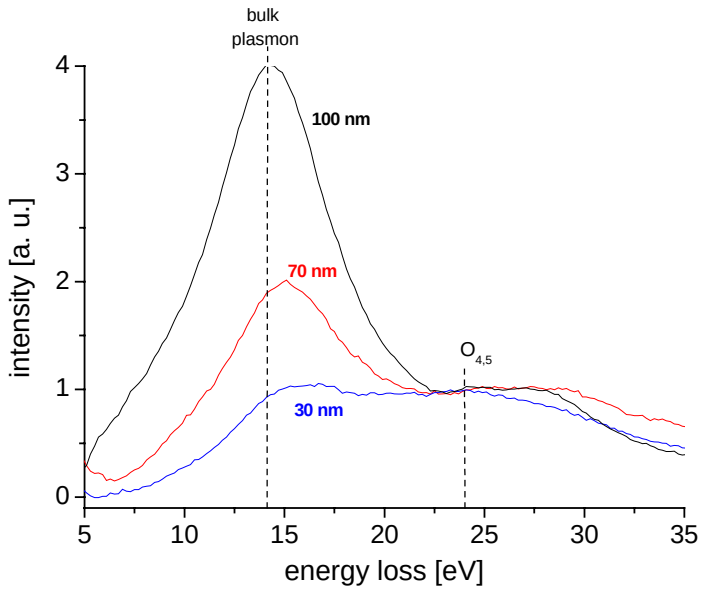

Figure 3: EEL spectra of Bi nanowires of diverse diameters.