Conductivity of the crystalline Boron nanowires measured in TEM.

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In this experiment we report on using in-situ STM-TEM system and EELS to characterize the electronic properties of the boron nanowires. We use low loss EELS approach to study the band structure and the dielectric response of these nanostructures. The STM-TEM system is used for a contact measurement of the conductivity of the individual Boron nanowire imaged in Transmission Electron Microscope (TEM). The in-situ EELS analysis has been completed with the structural information provided with HRTEM.

Recently synthesized crystalline boron nanowires [1] are predicted to have unique combination of electronic and mechanical properties compare to other popular nanostructures such as carbon and BN nanotubes. Boron fibers have been successfully used in high performance composites, where high strength, stiffness, and temperature resistance are required. Boron nanowires are expected to have similar mechanical properties. Based on the recent preliminary studies [1], their electronic properties have been reported to be close to those of the semiconductor [2].

The Boron nanowires have been synthesized using simple CVD method [1]. The reactive precursor gas was passed over the catalyst NiB powder in a hot furnace at 1100 C. After the reaction, the catalyst powder with grown nanostructures has been removed from the alumina substrate and transferred onto the gold wire used as a substrate.

The EELS study of the Boron nanowires has been done with GIF Tridiem (Gatan Inc.) installed on JEOL 2010 FasTEM microscope. Typically, a STEM probe of 3nm of effective size has been used to image and excite the EELS spectrum. The EELS spectrometer was utilized in STEM SI mode with dispersion 0.1eV/channel to acquire 1D spectrum image. The analysis and processing of acquired data have been performed with AutoFilter package software (Gatan Inc.). The software includes the Kramers-Kronig analysis of the low loss EELS data. It has been used to obtain the dielectric function of the analyzed nanostructure. The conductivity measurements have been done using STM-TEM system from Nanofactory AB.

Fig. 1(a) shows typical Boron nanostructure studied in the experiment. HRTEM has been used in conjunction with STEM (Fig. 2(a)) to add nanowires structural details into the analysis. Using Kramers- Kronig analysis of the spectra we have been able to evaluate the refractive index, band gap, inelastic mean free path and dielectric constant for both type of the nanostructures. The energies of the bulk plasmon excitations are also provided. In particular, we found the band gap of 3eV and the refractive index of 2.5 for Boron nanowires. The conductivity measurement is shown in Fig. 1(b)-2(b). Further EFTEM analysis of the Boron data revealed that the nanowires might have a thin oxidation layer on the surface, which possibly contributes into the measured constants. The effect and possible contribution from the amorphous carbon as a result of surface contamination are discussed further in detail.

References:

[1] Jones Otten C., Lourie O.R., Yu M-F., Cowley J. M., Dyer M.J., Ruoff R.S., Buhro W.E., "Crystalline Boron nanowires", J. Am. Chem. Society 124, 464-4565, (2002)
[2] Wang, D.; Lu, J.G.; Otten, C.J.; Buhro, W.E. *Appl. Phys. Lett.* 2003 , *83* , 5280-5282

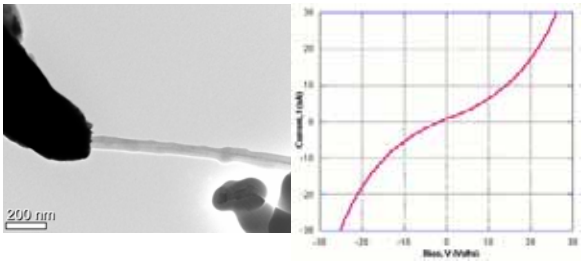

Fig. 1(left) STM tip in contact with Boron nanowire; (right) acquired I-V curve;

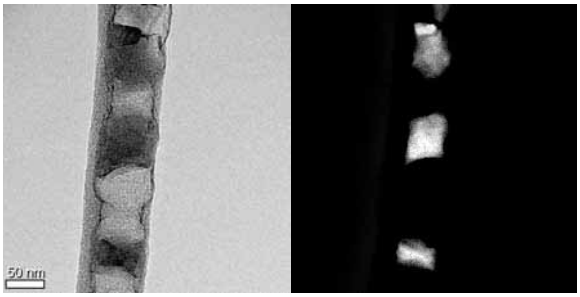

Fig. 2(left) TEM image of melted nanowire; (right) Energy filtered Boron map