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Characterization of Beam Sensitive Materials Using Low Loss EELS: Application to III-V (InP, InAs and alloys) Nanowires

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Abstract –Subnanometer Energy Dispersed X-Ray Spectroscopy (EDS) is currently possible in TEM work, but radiation damage challenges the application to beam sensitive materials. In these cases, low loss EELS is an alternative. Here, we describe the use of volume plasmons to characterize InAs/InP semiconductor nanowires. In our Shottky gun STEM, the compromise between damage and signal limits our EDS sensitivity to 5-10% for 10 s exposure time with a ~1 nm probe. Preliminary measurements indicate that a significant improvement can be achieved using plasmon shift in 20-50 nm wide nanowires (~1-2% sensitivity for ~1 s exposure).

Semiconductor nanowires are promising objects for the implementation of novel devices due to their new chemical and electronic properties. Future applications require precise characterization of these properties at the nanometer and subnanometer scales.
Modern TEM/STEM microscopes allow the formation of subnanometer probes with high currents. This renders subnanometer Energy Dispersed X-Ray Spectroscopy (EDS) analysis attainable in many commercial instruments. However, its application toin beam sensitive materials, such as III-V semiconductors nanostructures, represents a serious challenge beacause the quick material decomposition limits acquisition time and statistics. As an example, in our JEOL 2100F URP equipped with a Schottky gun, the 0.7 nm probe drills holes in InP nanowire (20-50 nm in diameter) in about 10 seconds.
As an alternative to EDS measurements, we propose the use low loss EELS to chemically characterize these nanomaterials. As an example, we measured the chemical shift of the plasmon peak across an InAs/InP/InAsP interfaces in heterostructured NWs grown by CBE. The observed plasmon peaks are 14.07 eV (InAs) and 14.53 eV (InP) for single phase wires, which will be used as standards. Peak position was quantified from each spectrum by fitting the low loss region with two lorentzians (for the volume plasmon and oxide plasmon peaks) and a straight line to take into account the background. Preliminary measurements indicate that our sensitivity should be ~1-2% for optimized acquisition conditions (approximately 1 second exposure per pixel). This represents an improvement in sensitivity when compared to EDS (5-10%) with a 10 times decrease in acquisition times, what greatly diminishes radiation damage.

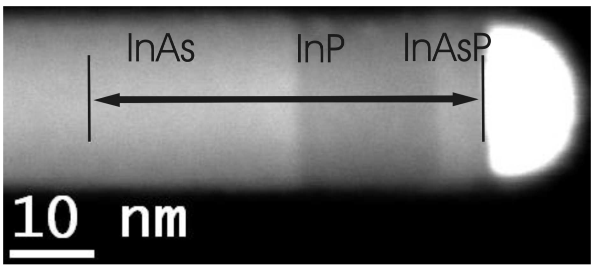

Figure 1: ADF (Annular Dark Field) image of the InAs/InP/InAsP segment of a nanowire. The region marked by the arrow shows where the plasmon chemical shift was measured.

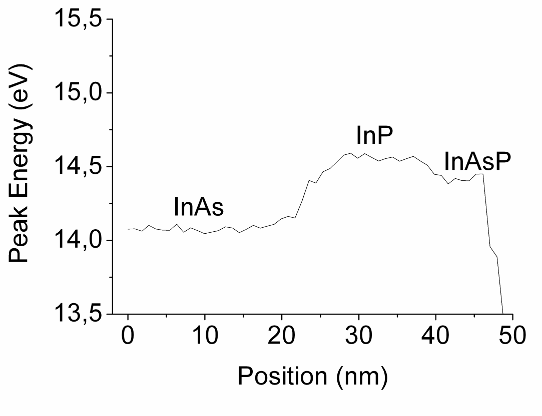

Figure 2: Profile of the plasmon peak energy along an InAs/InP/InAsP segment of a nanowire, showing chemical shift. From these shifts, local composition can be quantified.