Merging from Semiconductor Nanocrystals to Nanowires: Synthetic Procedures and Magneto-optical characterization

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Semiconductor nanocrystals and nanowires show an increasing technological and scientific interest, due to the distinguished physical properties. Colloidal nanocrystals of CdS and PbSe with core-shell structures were recently synthesized in our laboratory (figure 1), offering an effective chemical and electronic passivation, and leading to an increase of the quantum efficiency of the exciton absorption and emission. Likewise, nanowires of PbSe and CdS were prepared by mixing precursors of $PbCl_2$ with dissolved S or Se in an ethylene-diamine solution, under inert conditions and low temperatures. Additional reducing agent, like KBH_4, enhances the formation of the nanowires (figure 2). The ethylene-diamine stays attached to the metal ions at the surface, allowing preferential growth of a certain crystal plane. For example, the 002 plane in CdS hexagonal structure is oriented normal to the growth direction, as indicated by the X-ray analysis.

The electronic and optical properties of the aforementioned nanostructures were examined by size selective spectroscopy, including fluorescence line narrowing (FLN) and photoluminescence excitation (PLE). For example, the non-resonance excited photoluminescence (PL) of 4.0 nm nanocrystals of PbSe exhibit featureless band, centered at 1.41 eV. The FLN spectra were excited at various energies within the PL band, showing a zero-phonon narrow band and its LO replica. The zero-phonon band is Stokes shifted from the corresponding excitation by about 70 meV, which decreased with the decrease in the excitation energy (or the increase of the nanocrystalline's size). In a similar manner, the PLE spectra were blue shifted with the increase in the detection energy. Further investigation of the electronic characteristic and angular momentum of the indicated states were examined, by the use of linear and circular polarized detection of the FLN spectrum in the presence of an external magnetic field. This measurements showed the existence of pronounced linear and circular polarization of the nanowires or alongated nanocrystals. Preliminary analysis of the data indicates that the polarization is induced by the shape anisotropy of the wires. These measurements also supply the g- factor values of electrons and holes in CdS and PbSe nanocrystals and wires. Furthermore, a continuous wave and time resolved optically detected magnetic resonance (ODMR) spectroscopy, currently done in our laboratory, enables the determination of surface defect states in the studied materials. Comparison of the magneto-optical properties of the nanocrystals and nanowires suggest a general trand in the variation of the physical properties when moving from the zero-dimension to one-dimesion materials.

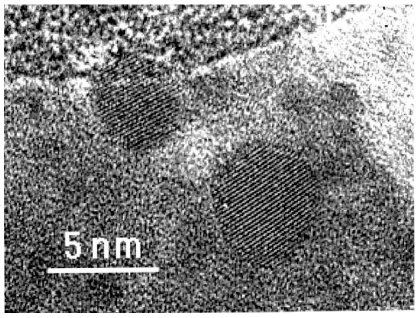

Fig.1. HR-TEM image of PbSe/PbS core-shell

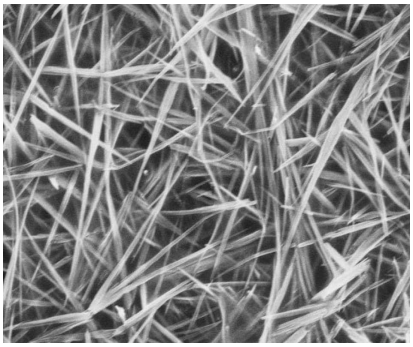

Fig.2. FE-SEM image of PbSe nanowires