Magneto-photoluminescence Measurements of Self-assembled (Zn,Mn)Se Nanowires

B. J. Cooley, Nitin Samarth (Penn State University, Physics); S.A. Crooker (LANL)

Contemporary interest in semiconductor spintronics provides a strong motivation for studying *sp-d* and *d-d* exchange interactions within magnetic semiconductor nanostructures. Although past studies have explored 2D and 0D nanostructures within this context, experiments aimed at the 1D regime have seen less success: here, we describe attempts to measure magneto-photoluminescence (magneto-PL) in ensembles of quasi-1D magnetic semiconductor NWs.

We grow the NWs via the vapor-liquid-solid mechanism in a molecular beam epitaxy chamber under ultrahigh vacuum conditions, using Si (111) and GaAs (001) substrates coated with gold as the seed particle material. Scanning electron microscopy (SEM) reveals the growth of two broad classes of self-assembled nanostructures (Fig. 1(a)): (a) relatively straight NWs that grow up from the substrate at an angle, with diameters in the range ~10 – ~50 nm and lengths up to ~2 μm; (b) a tangled nanostructured "undergrowth" at the base of the straight NWs. Transmission electron microscopy (TEM) shows that the straight NWs form in the wurtzite (hexagonal) crystal structure. X-ray energy dispersive spectroscopy in scanning TEM mode shows that we have thus far grown (Zn,Mn)Se NWs with Mn concentrations of up to 35%. We do not have any structural data about the undergrowth yet.

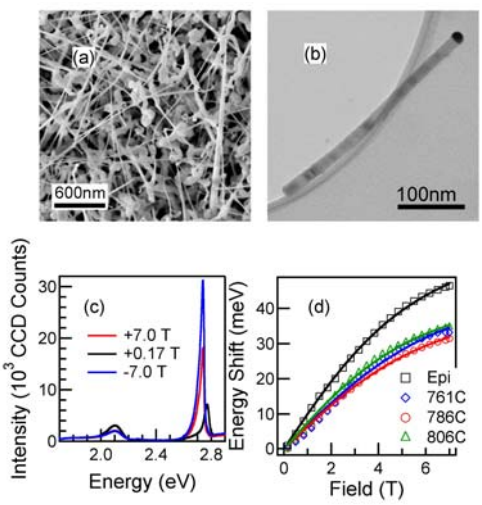

Fig. 1. (a) Plan view SEM of as-grown (Zn,Mn)Se NWs. (b) TEM of a single (Zn,Mn)Se NW. (c) PL spectra from as-grown (Zn,Mn)Se NWs. (d) Zeeman shift of PL from NWs grown at different Mn cell temperatures and from an epilayer with 10% Mn. Solid lines are fits to a modified Brillouin function. All PL data are at T = 5 K.

We use low temperature magneto-PL spectroscopy to look for evidence of *sp-d* exchange-enhanced Zeeman splitting in as-grown, randomly oriented NW ensembles, with the caveat that we cannot definitively separate NW PL from possible PL emanating from the nanostructured undergrowth. Measurements are carried out in the Faraday geometry, wherein the electric dipole allowed transition between Zeeman split ground state excitons is expected to yield circularly polarized PL which red shifts with increasing magnetic field. We collect PL spectra at a fixed setting of a circular analyzer as we sweep the magnetic field (B) between +7 T and -7 T, with positive (negative) fields yielding the σ+ (σ-) components of the emitted light.

The PL from as-grown (Zn,Mn)Se NWs indeed shows a substantial Zeeman shift at low temperatures (Fig. 1 (c)) roughly following a modified Brillouin function (Fig. 1(d)), clearly indicative of an *sp-d* exchange-enhanced Zeeman splitting. However, we find two distinct differences between the magneto-PL in NWs and in a control epilayer. First, the degree of circular polarization in the NWs (maximum value of ~ 30% at 7 T) is much smaller than that in the control sample (100% at B > ~0.1 T). Second, unlike past studies of epilayers, the saturation Zeeman shift in NWs is insensitive to sample composition and is unexpectedly large at the highest Mn compositions studied (where antiferromagnetic Mn-Mn coupling should suppress the Zeeman splitting). The unusual aspects of the magneto-PL from the as-grown NWs may have intrinsic origins related to the reduced dimensionality: e.g. the PL polarization may be modified by dielectric confinement and/or breaking of selection rules, and the large Zeeman shift at high Mn compositions could indicate enhanced paramagnetism in reduced dimensions. However, we cannot rule out the possibility that the PL actually arises from the nanostructured undergrowth, where similar considerations could apply. More definitive experiments are planned at LANL using the single molecule fluorescence facility to measure magneto-PL from isolated NWs.

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References

[1] Cooley, B.J., *et al*., manuscript in preparation.