Magneto-optical properties of DMS QWs in hybrid ferromagnet/semiconductor structures

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The influence of external magnetic fields on diluted magnetic semiconductor (DMS) quantum structures has been a subject of very intensive research over the past years. However, almost all experimental and theoretical studies were concentrated on cases with the magnetic field uniform over the area of examined objects. On the other hand, interesting effects are expected to occur in DMS structures subject to a highly inhomogeneous, local in nature, magnetic fields. Such local magnetic fields can be produced in a quantum structure, as calculated and shown experimentally [1], by deposition of thin ferromagnetic layers on a structure surface. These overlayers are to be magnetized in the plane of structure and, thus, act through their fringing fields as micromagnets.

We have fabricated ferromagnetic/semiconductor hybrid device based on MBE-grown semiconductor structure containing 61ML-wide $Cd_{0.96}Mn_{0.04}Te$ DMS quantum well (QW) embedded in $Cd_{0.91}Mg_{0.09}Te$ barriers 300 Å bellow the surface. Matrices of ~ 0.2 μm thick rectangular Fe stripes with lateral dimensions 6x10 micrometers were deposited on the surface of semiconductor structure. The pattern had been first defined be an e-beam writer in the electron sensitive resist and, then, by use of the low temperature sputtering of Fe, and of the lift-off technique, the small Fe rectangles were obtained. Hybrid structures, produced in this way, were examined first by atomic and magnetic force microscopy.

We measured spatially resolved micro magneto-photoluminescence (μ-PL) excited by the 476 nm line of the Argon laser. The laser beam was focused on the hybrid sample surface into the spot of ~2 μm in diameter by an optical microscope. The emitted light was collected by the same microscope and dispersed by a 1 m double monochromator. A constant magnetic field, of approximately 1.2 T, applied in the plane of the structure (Voigt configuration), was produced in the narrow slit between pole shoes attached to the permanent neodymium-iron-boron.

By placing the hybrid sample inside the magnet slit and by magnetizing the ferromagnetic stripes along their longer axis we have expected to produce sub-micron regions with locally strong fringe magnetic fields having nonvanishing component also along to the growth axis of QW. This local magnetic field component should induce, in turn, a local giant splitting of the band edges in the buried DMS QW and, thus, it should result in a local energy minimum for some excitonic states. We could expect, then, to observe in spatially resolved PL experiments an appearance of additional low energy line(s) originating from magnetically induced objects of lower dimensionality. These objects could be, e. g., of the nature of quantum wires, if the corresponding μ-PL lines would appear near the shorter edges of an Fe rectangle. Our low temperature, spatially resolved μ-PL experiments in fact revealed the presence of an additional low energy peak in the spectra provided that the measurements were carried out in the close vicinity of the Fe stripe edge. No additional signal was seen when the exciting laser was focused away from the stripe. We have performed also temperature dependent studies of this additional feature in μ-PL. The observed dependence is at small variance to that of PL from a normal DMS QW temperature behavior. We can not decisively prove at present that the additional peak is related to the fringing fields or rather it is due to the thermal strain exerted by the iron mesa. However, the temperature dependence exerted in the latter case is predicted to be much smaller indicating that the former is more probable.

[1] see, e. g., Reijniers J, Peeters FM. *Appl. Phys. Lett.*, 73, 357, (1998)