Inter-dot spin exchange interaction in coupled II-VI semiconductor quantum dots

S. Lee$^1$, M. Dobrowolska$^2$, and J. K. Furdyna$^2$

$^1$Physics Department, Korea University, Seoul, 136-701, KOREA
$^2$Physics Department, University of Notre Dame, Notre Dame, IN 46556 USA

Recently, spin states in quantum dots (QDs) have been proposed as viable candidates for quantum bits in quantum computing. [1] The inter-dot spin exchange interaction in coupled QD structures is then an important phenomenon in order to realize multi-bits gate. We have focused on the double layer QD structures to understand the nature of inter-dot spin exchange interaction. For observing interlayer exchange interaction, we designed coupled asymmetric two-layer QD structures with different bandgap energies. The double layer QD structures were formed by using combination of CdSe and CdZnSe QD layers separated by ZnSe barriers. We observe well-resolved photoluminescence (PL) peaks originating from the two QD layers comprising the double-layer structures, enabling us to identify the PL emissions from each QD family, and to study the influence of one QD layer on the other.

To investigate the spin polarization of carriers in the QDs, we performed polarization-selective magneto-PL experiments by exciting the above structures with unpolarized light, and detecting the PL with either the $\sigma^-$ or the $\sigma^+$ circular polarization. When a magnetic field was applied to the CdSe/CdZnSe double-QD layer, the intensities of the circularly polarized PL peaks corresponding to the CdSe and CdZnSe layers exhibited significant differences, reflecting correspondingly large differences in the degrees of spin polarization of the CdSe and the CdZnSe QDs, in contrast to the PL observed on single-layer CdSe or CdZnSe QD reference structures, both of which showed nearly identical dependence on the field. The behavior observed on the double-layer QD structures was interpreted in terms of anti-parallel spin interaction between carriers localized in coupled QD pairs. Such spin interaction was even more pronounced in double-layer structures in which diluted magnetic semiconductor (DMS) QD layer (either CdMnSe or CdZnMnSe QDs) was used for one of QD layers, reflecting the high potential of magnetic QDs in the context of spin-polarized applications.