Spin relaxation and spin dependent energy transfer in II-Mn-VI DMS nanostructures

Vitalii Yu.Ivanov[1], Joerg Debus[2], Dmitri R.Yakovlev[2,3] and Marek Godlewski [1,4]

[1]Institute of Physics Polish Acad. Sci., 02-668 Warsaw, Al. Lotników 32/46, Poland
[2]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany
[3]A. F. Ioffe Physico-Technical Institute, 194017 St. Petersburg, Russia
[4]Dept. Mathematics and Natural Sciences College of Science, Cardinal S. Wyszyński University, Warsaw, Poland

Optical detection of magnetic resonance (ODMR) in semiconductors has been widely used to study the energy and spin structures of excitons and impurity centers. The technique is especially suitable for nanostructures, where a small amount of active materials is not sufficient for application of electron spin resonance (ESR) methods. ODMR has been intensely applied for studying diluted magnetic semiconductors (DMS) from the pioneer's experiments of Ryabchenko et al. [1] up to recent studies of II-VI nanostructures [2,3].

In this communication we summarize the results of comprehensive studies of spin - dependent energy transfer processes between excitons and 3d-shell levels of Mn^{2+} ions in quantum well (QW) structures of $Zn_{1-x}M_xSe/Zn_{1-y}Be_ySe$, with Mn^{2+} content varied from x=0.004 to x=0.12. Dependencies of intensities of excitonic photoluminescence (PL) and intra-shell Mn^{2+} PL on magnetic field, as well as, kinetics of both emission processes have been studied. ODMR spectra were monitored by studying intensity changes and energy shift of excitonic PL and intensity change of Mn^{2+} ions PL.

Strong enhancement of integral excitonic PL of $Zn_{1-x}M_xSe/Zn_{1-y}Be_ySe$ in magnetic field was observed together with quenching of intra-shell Mn^{2+} PL emission. This phenomenon has been reported recently [3,4], but its origin was not clear. Two concurrent mechanisms have been taken into account: i) spin dependent direct resonant excitation transfer between excitonic levels and $3d^5$-shell of Mn^{2+} ions and ii) spin dependent Auger recombination of excitons, mediated by population of excited states of Mn^{2+} ions.

In the ODMR experiments we observed a strong decrease of an integral intensity of excitonic emission against an increase of Mn^{2+}ions intra-shell emission in the ESR condition, i.e., at the magnetic resonance of Mn^{2+} ions in the ground state. At the same time SLR (spin-lattice relaxation) time (measured following time evolution of microwave induced excitonic line shift [3]) decreases resonantly, as well as, a decay time of Mn^{2+}ions intra-shell emission.

Based on comprehensive studies of the above-mentioned effects, including polarization dependencies of the ODMR spectra, we discuss the role of a direct resonance excitation transfer and spin dependent Auger recombination processes. Also, the results of detailed studies of SLR processes in DMS nanostructures in the presence of hot carriers are discussed.

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