Spin Relaxation Dynamics of an Individual Co^{2+} Ion in a CdTe/ZnTe Quantum Dot

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Studies of single dopants in semiconductors constitute one of the research areas of the dynamically developing field of solotronics [1]. The progress of the field is driven by the perspectives of the ultimate miniaturization of information storage and processing devices, as well as by the possibility to investigate interactions between impurities and the host crystal in a single-atom scale. From scientific point of view quantum dots (QDs) containing single magnetic dopants seem to be as a model system to study those interactions. Until recently, only QDs with single manganese ions have been investigated, since other magnetic impurities were believed to quench any photoluminescence (PL) of the dots. However, this turned out not to be true in the case of a single impurity embedded in the dot, as a few new systems of single magnetic ions in semiconductor QDs were presented [2]. Systematic investigations on spin dynamics in those systems are important in the context of future optoelectronic devices.

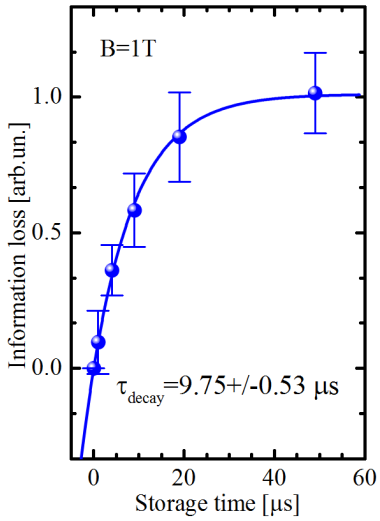

Fig.1 Spin-relaxation time of the single Co^{2+} ion in CdTe/ZnTe QD determined by time-resolved PL under modulated excitation.

In this work we present studies of spin dynamics of a single Co^{2+} ion embedded in a CdTe/ZnTe QD. The sample used in the experiment contains a single layer of MBE-grown, self-assembled dots. The presence of a single Co^{2+} ion in selected dots was confirmed by observation of characteristic patterns in the excitonic PL spectrum with and without magnetic field [2]. In order to determine spin-relaxation time of the single Co^{2+} ion we performed time-resolved measurements of the QD PL under quasi-resonant, modulated excitation (see Fig. 1). It is experimentally simpler than the method previously used for the Mn^{2+} ion [3]. The measurements were carried out at various magnetic fields. The obtained values of relaxation time stay in an agreement with the values determined previously under non-resonant excitation [2] and are much shorter than those reported for the Mn^{2+} ion [3].

We discuss the impact of the local strain on the spin relaxation. The Co^{2+} ion has non-zero orbital momentum, thus it is more sensitive to the local anisotropy of surrounding lattice than the Mn^{2+} ion. Analyzing different dots, we show that local distortion has minor influence on the cobalt relaxation time. This new observation can help to determine the spin-lattice relaxation mechanism of a single magnetic ion in a QD.

We also show that similarly to the case of the QDs with Mn^{2+} ions [3], qusi-resonant injection of spin polarized excitons leads to the orientation of the Co^{2+} spin. The time resolved measurements of this effect reveals that the spin orientation efficiency per one exciton for a Co^{2+} ion in a CdTe dot is much larger than for Mn^{2+} ion in a similar dot.

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[2] J. Kobak, T. Smoleński, et al., Nat. Commun., 5, 3191, (2014)
[3] M. Goryca, T. Kazimierczuk, et al., Phys. Rev. Lett. 103, 087401, (2009)