Electron-spin dynamics in GaAs quantum wells coupled with II-VI diluted magnetic semiconductors

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1. Introduction

Spin manipulation in quantum structures of III-V compound semiconductors, which are widely used for photonic devices, is a crucial subject in future semiconductor technology. For this subject, spin injection and subsequent spin relaxation of electrons need to be studied. First, an efficient source of spins, a spin generator, is required for spin transportation into the non-magnetic semiconductors. This can be realized, for example, in GaAs/AlGaAs/ZnMnSe hetero-valent structures comprising GaAs quantum wells (QWs) [1]. Spin-polarized electrons are first generated in the II-VI diluted magnetic semiconductor (DMS) of ZnMnSe and then transferred into the non-magnetic GaAs QW via tunnelling with conserving the spin states. We show the electron-spin dynamics in these hybrid quantum structures.

2. Experimental Approach and Results

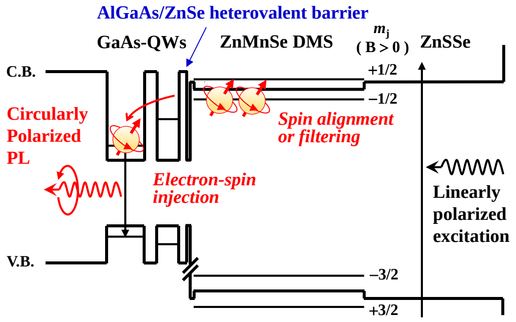

Fig. 1 *Band line-up and electron-spin dynamics in the GaAs/AlGaAs/ZnMnSe/ZnSSe heterostructures at low temperatures and high magnetic fields*

We prepared a double QW comprising 10-nm- and 5-nm-thick GaAs QWs separated by a 3-nm-thick barrier of AlGaAs, as shown in Fig. 1 [2]. The top thinner QW was capped by the heterovalent 0.6 nm-AlGaAs/35nm-ZnMnSe DMS barrier. Finally, a ZnSSe capping layer was deposited. The dynamics of the spin-injection and spin relaxation of electrons in the wider non-magnetic GaAs QW was observed at 2 K and magnetic fields up to 5 T, by circularly polarized transient magneto-photoluminescence (PL).

We observe circularly polarized PL from the wider GaAs QW, when photo-excitation for the ZnMnSe barrier and ZnSSe capping layers is performed by linearly polarized light pulses (Fig. 2 (a)). This circular polarization disappears when we excite selectively the GaAs QW. Therefore, the circularly polarized PL in the GaAs QW is concluded to be indicative of the electron-spin injection from the DMS-ZnMnSe spin generator. The rise of the circular polarization within 200 ps after the pulsed excitation directly indicates the injection dynamics (Fig. 2 (b)), depending on the structural parameters such as a thickness of the ZnMnSe layer. The decay of the circular polarization reflects spin relaxation in the GaAs QW after the injection, which is affected by potential fluctuations originating from the hetero-valent interface between the III-V and II-VI materials.

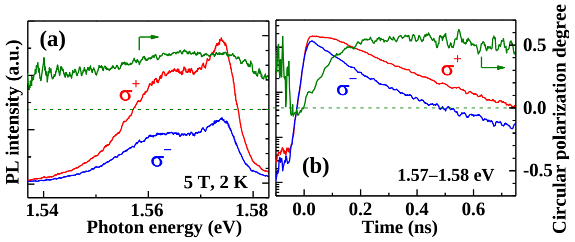

Fig. 2 *Circularly polarized PL spectra (a) and the time profile (b) in the GaAs QW at 2 K and 5 T.*

3. Conclusions

In summary, we observe the electron-spin dynamics in the hetero-valent quantum structures of GaAs QWs coupled with the DMS-ZnMnSe. The electron-spin injection, with highly conserving the spin states, takes place in a picosecond -time region depending on the heterostructures. Better understanding of the electron-spin dynamics enables one to explore efficient spin manipulation in III-V semiconductor quantum structures including self-assembled quantum dots.

4. Open Questions

- Can we prepare a spin generator, which is capable of operating at room temperature and epitaxially grown on the III-V quantum structures?
- Can we inject electron spins efficiently into III-V self-assembled quantum dots?
- How are the detailed defect structures at the III-V/II-VI hetero-valent interface?

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