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Observation of spin diffusion length and relaxation time in InAs quantum well

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1. Introduction

One of the major challenges in contemporary spintronics is the development of an efficient injection and detection of spin polarized current in semiconductors. In particular, purely electrical spin injection and detection are necessary to realize spin field effect transistors (spin-FET), of which a model device structure was proposed by Datta and Das in 1990 [1]. The spin polarized current injected from a ferromagnetic electrode (source) transmits through a semiconductor channel to reach the other ferromagnetic electrode (drain) in a spin-FET. In this research spin injection and relaxation in a ferromagnet-semiconductor system is systematically studied.

2. Experiments

In this work, two-dimensional electron gas structure with InAs channel is used for spin transport channel and NiFe is used for spin injector and detector. In order to observe the spin diffusion lenth and relaxation tim nonlocal geometry is utilized. In this measurement geometry, two voltage terminals do not measure the section where charge current flows. Only the chemical potential sensitive to spin accumulation is measured by a ferromagnetic detector.

3. Results and Discussions

Non-local signal as a function of channel length is shown in Fig. 1. By fitting the obtained data in Fig.1, spin diffusion length (λ_s) and injected polarization (η) are estimated to be 1.8 mm and 1.9%, respectively, at 20 K. A similar fitting has been performed for other temperatures. We estimate that $\lambda_s \approx 1.9$ mm, $\eta \approx 1.7\%$ at 50 K, $\lambda_s \approx 1.5$ mm, $\eta \approx 1.7\%$ at 100 K, and $\lambda_s \approx 1.3$ mm, $\eta \approx 1.4\%$ at 295 K, respectively. The injected spin polarization into InAs 2DEG and spin diffusion length show very weak dependence of temperature. The spin relaxation time can be estimated by $\tau_s = \lambda_s^2/D$. The diffusion constant is given by $D = 1/N(E_F)e^2R_s$, where $N(E_F)$, R_s, and e is the density of state at the Fermi level, sheet resistance of channel and the electron charge, respectively. The temperature dependence of τ_s in InAs 2DEG is shown in Fig. 2. The plot shows rather weak temperature dependence. The temperature dependence of spin relaxation is also consistent with predictions of the D'yakonov-Kachorovski [2] and D'yakonov-Perel [3] mechanisms. They predict that the spin relaxation rate $1/\tau_s$ scales as $TE_1^2\tau_p$ in a narrow quantum well. Here E_l is the confinement energy of the quantum well, and τ_p is the momentum scattering time. In the temperature range of our experiment, τ_p shows roughly T^{-1} dependence above 50 K as shown in Fig. 2. Therefore τ_s of the narrow quantum well as our InAs HEMT is expected to be independent of T.

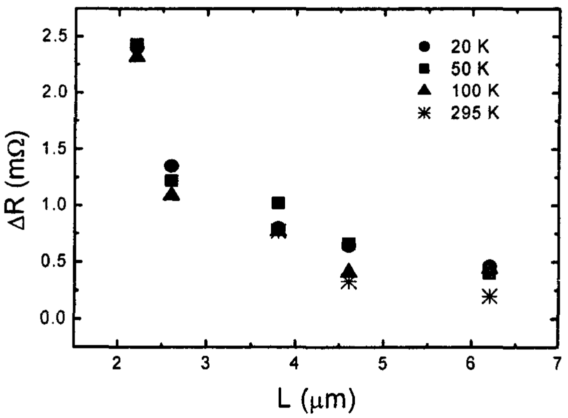

Fig. 1 Non-local signal as a function of channel length.

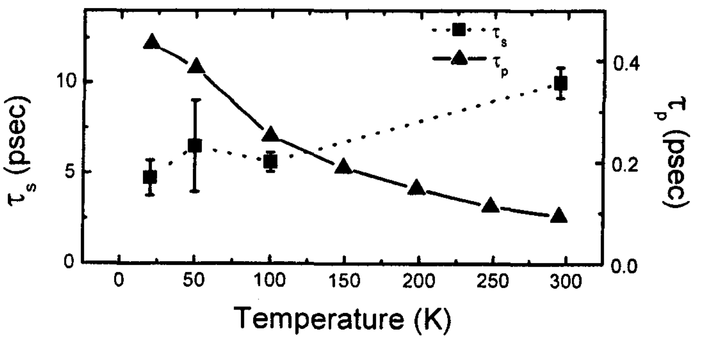

Fig. 2 Spin relaxation time (t_s) and momentum scattering time (t_p).

4. References

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