KIST Spintronics 발표 3

Electrical Spin Injection and Detection in Semiconductors: Progress toward a Spin Field Effect Transistor

Jonghwa Eom[1,2]*, Hyun Cheol Koo[1], Hyunjung Yi[1], Jae-Beom Ko[1], Seon-Gu Huh[1,2],
Joonyeon Chang[1] and Suk-Hee Han[1]
[1]Nano Device Research Center, Korea Institute of Science and Technology
[2]Department of Physics, Sejong University

1. Introduction

Spintronics is a fascinating new paradigm with the potential to overcome some of the physical limitations of conventional electronics. An essential ingredient of spintronic devices is the presence of a spin-polarized current, which is often generated by current injection from ferromagnetic metals. However, contemporary spintronics faces the challenge of developing efficient injection and detection methods for spin-polarized currents in semiconductors. In particular, fully electrical spin injection and detection are the primary prerequisites for realizing a spin field-effect transistor (spin-FET), for which a seminal model device structure was proposed by Datta and Das in 1990 [1]. In a spin-FET, the spin-polarized current injected from a ferromagnetic electrode (source) transmits through a semiconductor channel to reach the other ferromagnetic electrode (drain).

2. Experiments

In this work, two-dimensional electron gas (2DEG) structure with InAs channel is used for spin transport channel and NiFe is used for spin injector and detector. The carrier density and mobility of 2DEG are $n = 4.6 \times 10^{12}$ cm^{-2} and $\mu = 34{,}700$ cm^{2}V^{-1}s^{-1}. The shape of each ferromagnetic electrode has different aspect ratio so that the switching field of the magnetization is distinctive from each other. A desired configuration of the magnetization orientations can be made by the external magnetic field along the easy axis of the ferromagnetic patterns. In order to observe the spin diffusion length and relaxation time the measurement was performed by using nonlocal geometry. The nonlocal geometry, which is important to obtain the spin diffusion length in a metal or a semiconductor. 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. The chemical potential in the parallel (antiparallel) magnetization makes an additive (subtractive) contribution to the nonlocal voltage

3. Results and Discussions

The spin diffusion length and the injected spin polarization were estimated from an analysis of the space correlation of the nonlocal spin signal. Figure 1 shows the spatial dependence of the magnitude of the nonlocal spin signal. The spatial dependence of the nonlocal spin signal

ΔR is known to follow the exponential-decay formula . $\Delta R = (\eta^2 R_S \lambda_S / w)\ \exp(-L/\lambda_S)$, where η is the injected spin polarization of the current crossing the NiFe/InAs interface, R_S is the sheet resistance of the InAs 2DEG, w is the width of the InAs 2DEG and λ_S is the spin diffusion length of the InAs 2DEG. Fitting the obtained data to the formula yields estimates of λ_S= 1.8 μm and η = 1.9% at 20 K. We estimate that λ_S= 1.9 μm and η = 1.7% at 50 K, λ_S= 1.5 μm and η = 1.7% at 100 K, and λ_S= 1.3 μm and η = 1.4% at 295 K. These data represent the first determination of SUB>S</SUB> is the spin diffusion length of the InAs 2DEG. Fitting the obtained data to the formula yields estimates of λ_S= 1.8 μm and η = 1.9% at 20 K. We estimate that λ_S= 1.9 μm and η = 1.7% at 50 K, λ_S= 1.5 μm and η = 1.7% at 100 K, and λ_S= 1.3 μm and η = 1.4% at 295 K. These data rep

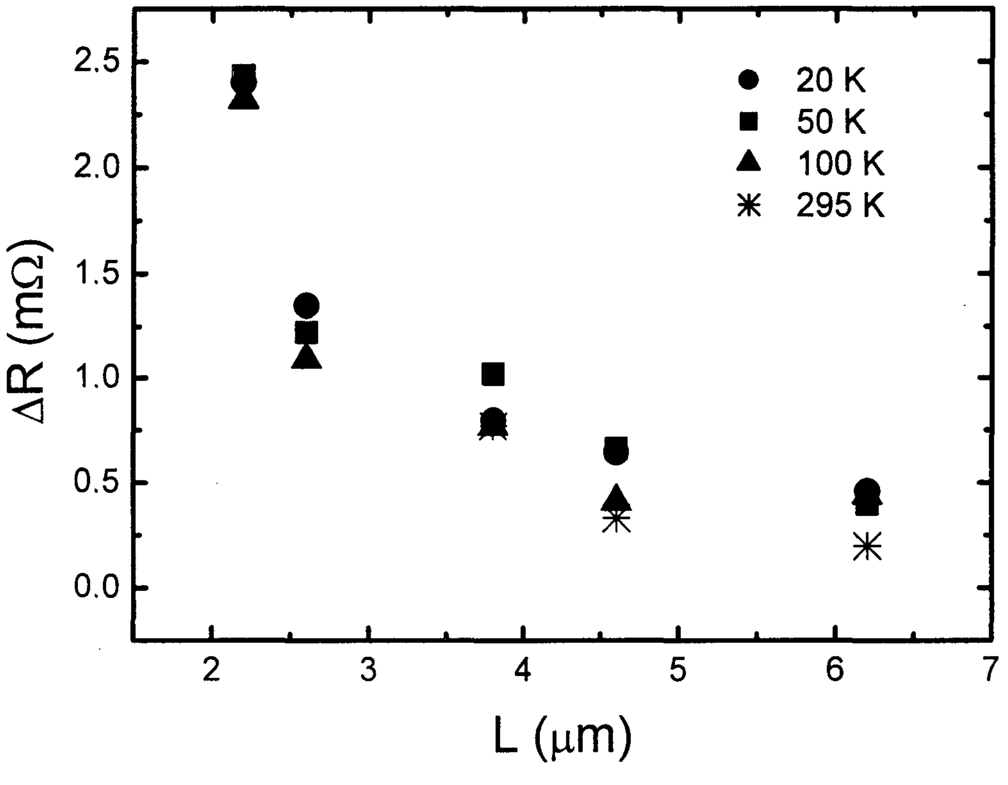

Fig. 1 Non-local signal as a function of channel length.

4. References

[1] S. Datta and B. Das, Appl. Phys. Lett. 56, 665 (1990).

[2] A. T. Hanbicki, B. T. Jonker, G. Itskos, G. Kioseoglou, and A. Petrou, Appl. Phys. Lett. 80, 1240 (2002).