Magnetic proximity effect in $In_{1-x}Ga_xAs$/(Ga,Fe)Sb bilayers via proximity magnetoresistance

Kosuke Takiguchi[1], Kyosuke Okamura[1], Le Duc Anh[1,2,3] and Massaaki Tanaka[1,4]

[1] *Department of Electrical Engineering and Information Systems, The University of Tokyo.* [2] *Institute of Engineering Innovation, The University of Tokyo.* [3] *PRESTO, Japan Science and Technology Agency.* [4] *Centre for Spintronics Research Network, The University of Tokyo.*

E-mail: takiguchi@cryst.t.u-tokyo.ac.jp

Utilizing a magnetic proximity effect (MPE) in a non-magnetic (NM)/ferromagnetic (FM) bilayer system is a promising way for introducing ferromagnetic coupling into a high-mobility non-magnetic channel. One direct consequence of the MPE is the proximity magnetoresistance (PMR) [1], which was demonstrated recently at an interface between a NM semiconductor InAs and a FM semiconductor (Ga,Fe)Sb [2,3]. In this system, the PMR can be used to probe the spin splitting energy Δ*E* in the NM channel, which can be largely modulated by twenty-fold using a gate voltage [1]. This large modulation of Δ*E* can be explained qualitatively by enhancement of the penetration of the electron wavefunction in the NM channel into the insulating FM side, which enhances MPE. However, the detailed mechanism of MPE at the interface of NM/FM semiconductor bilayer remains unclear and needs thorough investigations.

In this work, we prepare $In_{1-x}Ga_xAs$ (x = 0%, 5%, 7.5%, 10%)/(Ga,Fe)Sb bilayers, on which we formed field-effect-transistor structures, and investigate MPE by measuring the PMRs under various gate voltage V_g. As shown for the case of x = 5% in Fig. 1(a), we are able to largely control the PMR in both sign and magnitude, which reflects the MPE change by V_g application. Our analysis of the PMR using a modified Khosla-Fischer model [1,4] indicates that ΔE in the NM channel is enhanced by two factors, (i) penetration of the carrier wavefunction into the FM layer, and (ii) increasing the carrier concentration n as shown in Fig. 1(b). The carrier-induced ferromagnetism via MPE in (ii) is clearly observed in NM semiconductor. Furthermore, we also observe dependence of ΔE on the carrier relaxation time, which implies that the electron-electron interaction suppresses the enhancement of ΔE. This will be discussed in detail. These results provide insights into the mechanism of MPE at semiconductor-based FM/NM interfaces.

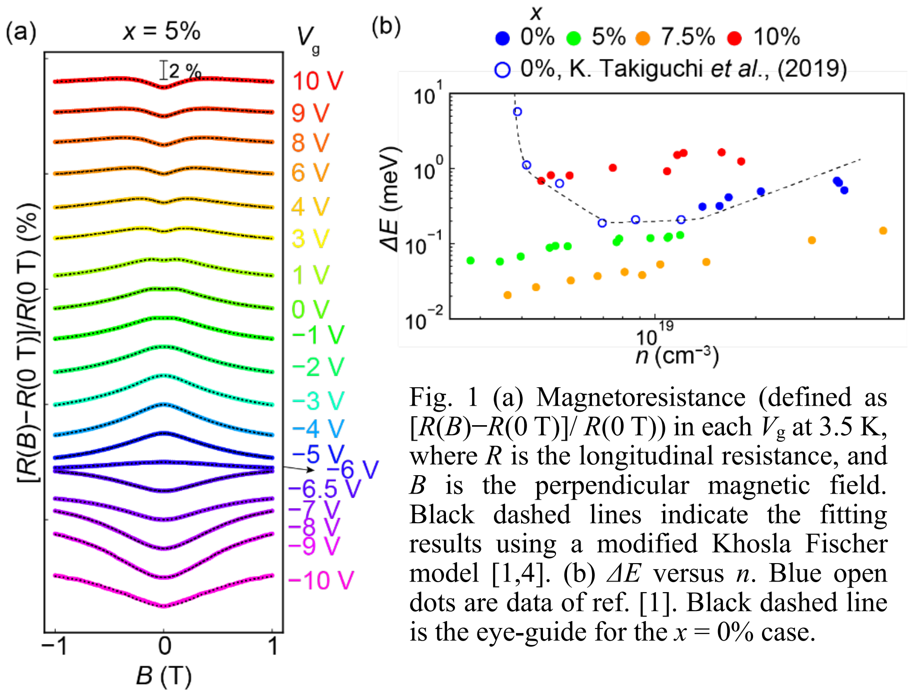

Fig. 1 (a) Magnetoresistance (defined as $[R(B)-R(0\ \mathrm{T})]/R(0\ \mathrm{T})$) in each V_g at 3.5 K, where R is the longitudinal resistance, and B is the perpendicular magnetic field. Black dashed lines indicate the fitting results using a modified Khosla Fischer model [1,4]. (b) ΔE versus n. Blue open dots are data of ref. [1]. Black dashed line is the eye-guide for the x = 0% case.

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