Giant rectification effect in semiconductor-based non-magnetic InAs / ferromagnetic (Ga,Fe)Sb bilayer heterostructures

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Breaking the space symmetry gives many interesting phenomena such as Rashba and Dresselhaus effects. Recently, unidirectional magnetoresistance (UMR), which shows odd function behavior against an external magnetic field, is observed in a system with a space symmetry breaking under a static electric and magnetic field (**E** and **B**)[1]-[5]. This UMR magnitude is expressed by |**I**·**E**×**B**|, where **I** is an electric current. Although this effect gives us an insight into the symmetry in materials, it is very weak and hard to detect[3][4].

It is experimentally confirmed that the UMR magnitude is proportional to the current density[5]. Therefore, a narrower cross-sectional path of carriers should be effective to increase UMR[1]. Here, we focus on a one-dimensional (1D) edge channel in a semiconductor heterostructure originated from the Fermi level pinning and demonstrate giant UMR observed with DC currents in nonmagnetic semiconductor InAs / ferromagnetic semiconductor (Ga,Fe)Sb bilayers. (Ga,Fe)Sb is a *p*-type ferromagnetic semiconductor with high Curie temperature (> 300 K)[6],[7]. Our InAs/(Ga,Fe)Sb bilayer heterostructures have a small lattice mismatch (< 0.6%) and staggered band diagram. Thus, we can obtain high-quality Rashba system with ferromagnetic coupling in the semiconductor heterostructures.

We have grown InAs (15 nm) / (Ga,Fe)Sb (15 nm, Fe 20%) / AlSb (300 nm) / AlAs (15 nm) / GaAs (100 nm) on semi-insulating GaAs (001) substrates by low temperature molecular beam epitaxy. This sample was patterned into a 100 × 600 μm^2 square bar (Fig. 1(a)). We drove **I** from '1' to '4' terminals and measured the voltage by the standard 4-terminal method with **B** applied normal to the plane. Figure 1(b) shows a magnetic-field dependence of the resistance R(**B**) (voltage measured between terminals "6" and "5") of our InAs/(Ga,Fe)Sb at 2 K with |**I**| = 1 μA. We observe a clear Shubunikov de Haas oscillation and a large odd-functoin component R_{odd} (Fig. 1(b) inset). Also, R data observed with different terminals of '2-3' and '6-5' have completely opposite signs, as shown in Fig. 1(c), which indicates that edge states at the surface play an important role in the transport.

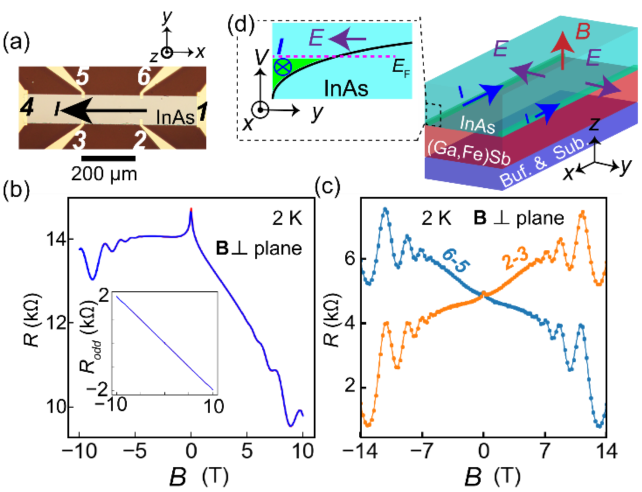

Figure 1 (a) Optical microscope image of the square bar. (b) Magnetoresistance of our InAs/(Ga,Fe)Sb at 2 K with |**I**| = 1 μA. Inset image shows the odd component of the magnetoresistance. (c) Magnetoresistance on '2-3' (orange curve) and '6-5' (blue curves) terminals at 2 K with |**I**| = 1 μA. (d) Schematic structure of our InAs/(Ga,Fe)Sb and conduction band diagram near the surface.

As shown in Fig. 1(d), triangular potentials are formed at the side surface of InAs, leading to **E** parallel to the y direction. When **I** and **B** is applied to the x and z direction, respectively, |**I**·**E**×**B**| is maximized. The UMR magnitude is expressed as UMR = $R(\mathbf{B}) - R(-\mathbf{B}) = 2\gamma R(0)|\mathbf{I}||\mathbf{B}|$, where γ is an index of UMR: We found that γ is estimated to be 1.4×10^4 [$A^{-1}T^{-1}$] in our bilayers and this value is much larger than that reported in other systems by 4 - 7 orders of magnitude[1]-[4]. Our InAs/(Ga,Fe)Sb bilayer heterostructures provide unique opportunities to study such novel MR effects [8].

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