Date: Feb. 21 (Wed.) 2024 13:15-14:15
Place: Seminar Room 5 (A615), ISSP

New magnetotransport phenomena in Fe-doped ferromagnetic semiconductors and quantum heterostructures

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Ferromagnetic semiconductors (FMS), which inherit properties of both semiconductors and ferromagnetic materials, are realized by doping a certain amount (several %) of magnetic elements in semiconductors. In the past, most of the research has been dedicated to Mn-doped III-V FMSs, which are only P-type and the highest Curie temperature (T_C) is 200 K. Recently, we presented an alternative approach by using Fe instead of Mn as the magnetic dopants in narrow-gap III-V semiconductors like InAs, GaSb, and InSb. Using low-temperature molecular beam epitaxy (MBE), we have successfully grown both P-type FMS [(Ga,Fe)Sb] [1] and N-type FMSs [(In,Fe)As [2,3], (In,Fe)Sb [4]]. Intrinsic room-temperature ferromagnetism has been observed in (Ga_{1-x},Fe_x)Sb with $x > 23\%$ [1] and (In_{1-x},Fe_x)Sb with $x > 16\%$ [4].

In this talk, we present new novel magnetotransport physics in bilayer structures of a nonmagnetic (NM) material and an Fe-doped FMS, where a magnetic proximity effect (MPE) from the FMS is expected to affect the NM channel. The sample structure consists of InAs (thickness t = 15 - 40 nm)/(Ga,Fe)Sb (15 nm, 20% Fe) grown on AlSb buffer/semi-insulating GaAs (100) substrates (Fig. 2a,b). We found that a strong and long-range MPE is induced at the InAs/(Ga,Fe)Sb interface, resulting in a spontaneous spin splitting ΔE, as large as 18 meV, in the InAs channel[5,6]. Furthermore, this spin splitting ΔE can be largely modulated by applying a gate voltage V_g. We observed a giant even-parity magnetoresistance (~80% at 14 T), which we call proximity magnetoresistance (PMR) [5,6], and a large odd-parity linear magnetoresistance (OMR) [7], corresponding to a resistance change of 27% when the perpendicular-to-plane magnetic field B (=10 T) direction is reversed. The unprecedented large OMR was found to occur in the edge transport channels of the InAs thin film, due to simultaneous breaking of both the space inversion symmetry (SIS) and the time reversal symmetry (TRS) (Fig. 1a). These new features realized in the Fe-doped FMSs and their quantum heterostructures are particularly important for the applications of low-power and high-speed spin-based electronics. Furthermore, the gate-controllable spin splitting provides a mechanism to locally access Majorana fermions in InAs-based Josephson junctions [8].

These works were partly supported by Grants-in-Aid for Scientific Research, the CREST and PRESTO Programs of JST, the UTEC-UTokyo FSI program, Murata Science Foundation and Spin-RNJ.

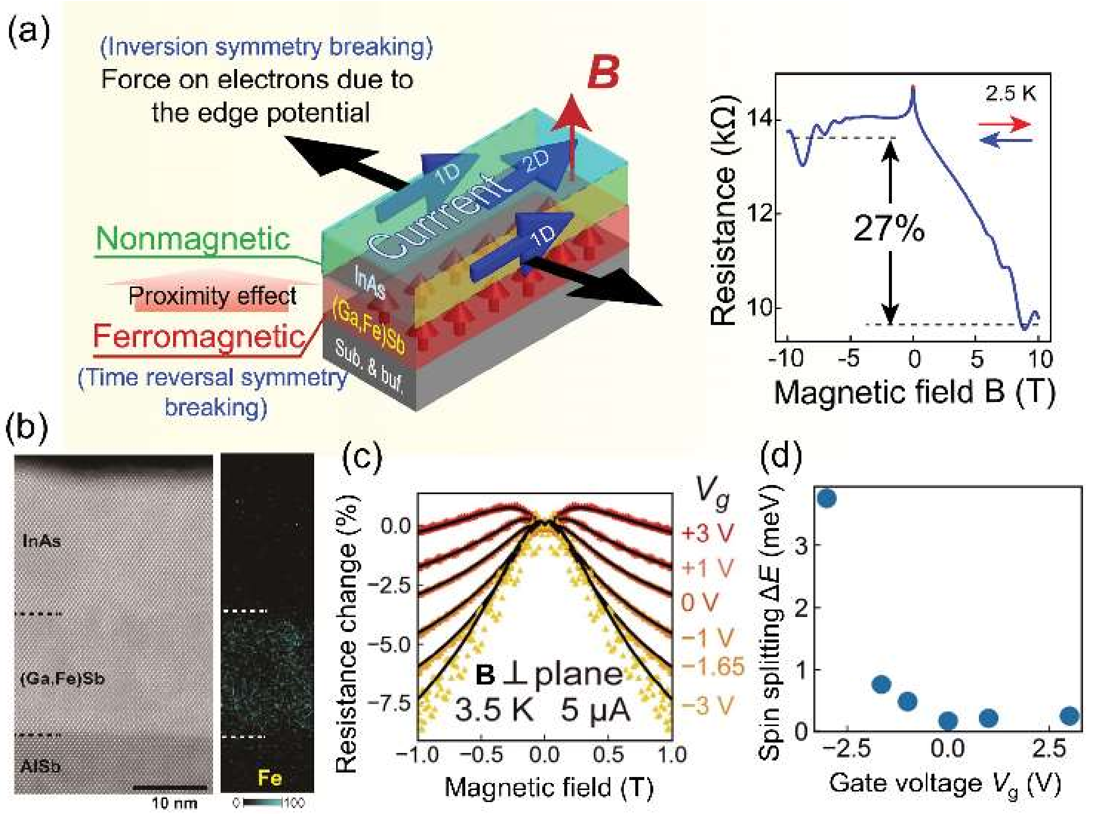

Fig 1. (a) InAs/(Ga,Fe)Sb bilayer structure and magnetoresistance measured at 2.5 K. (b) Lattice image of the bilayer measured by HR-STEM. (c) Electrical gating of the PMR. Black curves are fitting results. (d) Spontaneous spin splitting ΔE is induced in the InAs channel as a function of the gate voltage.

References

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