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Recent progress of ferromagnetic semiconductors: N-type electron-induced ferromagnetic semiconductor (In, Fe) As

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Abstract

Ferromagnetic semiconductors (FMSs) have been intensively studied for decades as they have novel functionalities that cannot be achieved with conventional metallic materials, such as the ability to control magnetism by electrical gating or light irradiation. Prototype FMSs such as (Ga, Mn) As, however, are always p-type, making it difficult to be used in real spin devices. Here, by introducing Fe into InAs, we have successfully grown a new n-type electron-induced FMS with the ability to control ferromagnetism by both Fe and independent carrier doping. The studied (In_{1-x}, Fe_x) As layers were grown by low-temperature molecular beam epitaxy on semi-insulating GaAs substrates. Electron carriers are generated by independent chemical doping of donors. The electron-induced ferromagnetism was evidenced by magnetic circular dichroism (MCD), superconducting quantum interference device, and anomalous Hall effect measurements. MCD spectra and their magnetic field dependence indicate that the band structure of (In, Fe) As is spin-split due to the *sp-d* exchange interaction. The electron effective mass is estimated to be 0.03-0.175m_0. These results reveal that the electrons are in the InAs conduction band rather than in the impurity band, making it easy to understand (In, Fe) As by conventional Zener-model of ferromagnetism. This band picture isdifferent from that of GaMnAs. Our results open the way to implement novel spin-devices as well as help understand the mechanism of carrier-mediated ferromagnetism in FMSs.

Biography

Masaaki Tanaka received his Ph.D. degree in electronic engineering from the University of Tokyo, in 1989. He is currently a professor of electrical and electronic engineering at the University of Tokyo. His current research covers various materials and nanostructures, spin-related phenomena, and devices, including magnetic semiconductors, ferromagnet/semiconductor heterostructures and nanostructures, magnetic tunnel junctions, and spin transistors. He has authored and coauthored over 200 scientific publications, and presented over 80 invited talks at international conferences and meetings. Dr. Tanaka is an executive editor of AIP Advances, and on the board of directors of the Japan Society of Applied Physics.