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Epitaxial Growth and Characterization of *n*-type Magnetic Semiconductor (In,Co)As

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Although Mn-doped III-V based magnetic semiconductors (MSs) such as (In,Mn)As and (Ga,Mn)As are intensively studied, the maximum Curie temperature T_C of (Ga,Mn)As and (In,Mn)As are 200 K and 90 K, respectively, which are still much lower than room temperature despite their high hole densities (10^{20}-10^{21} cm^{-3}).[1,2] Furthermore, those materials are always *p*-type. Recently, a new Fe-based *n*-type III-V MS (In,Fe)As has been successfully grown by low-temperature molecular-beam epitaxy and exhibited surprisingly large *s-d* exchange interaction.[3] However, since Fe atoms doped in InAs do not supply carriers, other donors such as Be or Si need to be co-doped to increase the carrier concentration and T_C. At present, co-doping of Be or Si to obtain high carrier concentrations up to 10^{20}cm^{-3} is technically difficult. Thus, realizing high T_C in (In,Fe)As is still a challenge.

In order to explore other possibilities of narrow-gap MSs and to give a more general picture of InAs-based MSs, we report here a new *n*-type magnetic semiconductor ($In_{1-x}Co_x$)As (x = 3–18%) with electron concentrations in the range of $1.9 \times 10^{18} – 2.4 \times 10^{19}$ cm^{-3}. The metal-insulator transition of ($In_{1-x}Co_x$)As is observed at x = 5%. Furthermore, large negative magnetoresistance (up to -17.5% at 0.95 Tesla) is observed at low temperature and can be attributed to spin-disorder scattering in the (In,Co)As matrix, as shown in Fig. 1(a). From the MCD analysis as shown in Fig. 1(b), (In,Co)As is paramagnetic and has the bands tructure of zinc-blende type semiconductors. The absence of ferromagnetism in (In,Co)As indicates that the *s-d* exchange interaction is very weak. This is contrasting to the strong *s-d* exchange and *p-d* exchange interactions observed in (In,Fe)As and (In,Mn)As, respectively. We suggest that the relative position of the *d* level in the host band structure is important to determine the properties of narrow-gap magnetic semiconductors.

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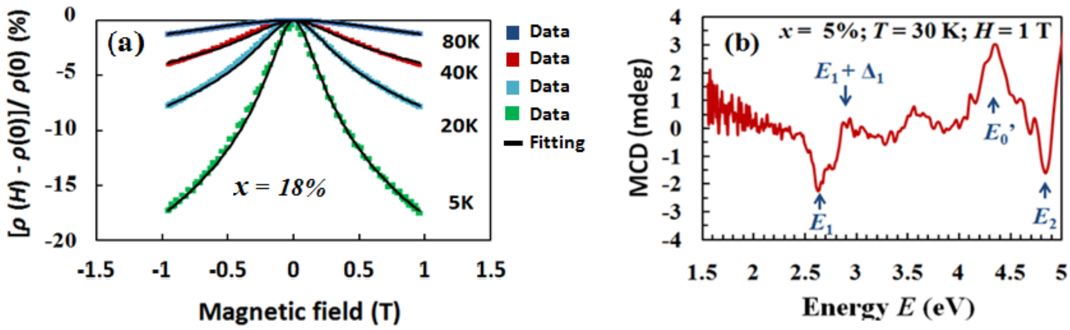

Fig. 1(a) Magnetoresistance as a function of applied magnetic field for (In_{1-x},Co_x)As with x = 18%.
(b) Magnetic circular dichroism (MCD) spectrum measured at 30 K under a magnetic field of 1 Tesla.

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