# High-temperature ferromagnetism in heavily Fe-doped ferromagnetic semiconductor (Ga,Fe)Sb

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Although Mn-doped III-V FMSs have been intensively studied, the best Curie temperature ($T_C$) of (Ga,Mn)As (200 K) and (In,Mn)As (90 K) are still much lower than room temperature.[1, 2)] Recently, we have successfully grown a new p-type Fe-doped FMS ($Ga_{1-x}$,$Fe_x$)Sb ($x$ = 3.9 – 20%) thin films by low-temperature molecular beam epitaxy (LT-MBE). ($Ga_{1-x}$,$Fe_x$)Sb ($x$ = 3.9 – 20%) is an intrinsic FMS and has zinc-blende-type crystal structure with spin-split band structure. Notably, $T_C$ (230 K) of ($Ga_{1-x}$,$Fe_x$)Sb at $x$ = 20% is the highest in III-V FMSs, indicating that (Ga,Fe)Sb is promising for high-$T_C$ FMS.[3,4)] In this paper, we report the magnetic properties of heavily Fe-doped ($Ga_{1-x}$,$Fe_x$)Sb with $x$ = 23% and 25% grown by LT-MBE. Figure 1(a) shows the MCD spectra of our (Ga,Fe)Sb samples at 5 K with a magnetic field of 1 T applied perpendicular to the film plane. For a reference, we also show the MCD spectrum of an undoped GaSb, in which the MCD intensity is very small. In contrast, the MCD spectra of ($Ga_{1-x}$,$Fe_x$)Sb ($x$ = 23% and 25%) show strongly enhanced peak at $E_1$ (~2.2 eV), corresponding to the optical critical point energy of the GaSb band structure.[5)] Furthermore, we see no broad background which would be observed if metallic Fe-related nanoclusters existed. This result indicates that heavily Fe-doped ($Ga_{1-x}$,$Fe_x$)Sb ($x$ = 23% and 25%) still preserves the zinc-blende crystal and band structure with large spin-splitting due to the *s,p-d* exchange interaction. Figures 1(b) and (c) show the MCD-$H$ characteristics of those samples at various temperatures. $T_C$ estimated by Arrott plots are 300 K and 340 K for the sample with $x$ = 23% and $x$ = 25%, respectively, which are the highest values reported in III-V FMSs so far. Our results show that (Ga,Fe)Sb is promising for room-temperature operation of semiconductor spintronic devices.

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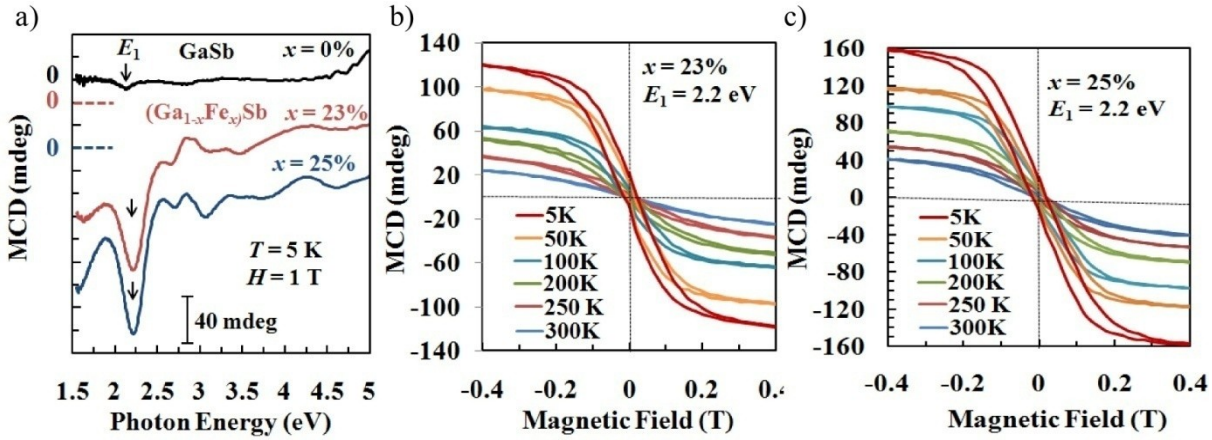


Fig. 1. (a) Reflection MCD spectra measured at 5 K under a magnetic field of 1 T applied perpendicular to the film plane for ($Ga_{1-x}$,$Fe_x$)Sb with $x$ = 23% and 25%. MCD spectrum of a reference undoped GaSb sample is also shown. (b) and (c) MCD-$H$ characteristics of the ($Ga_{1-x}$,$Fe_x$)Sb samples with $x$ = 23% and 25% at various temperatures.

**References**

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