GROWTH AND CHARACTERIZATION OF Be-CODOPED GaMnAs

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III-V ferromagnetic semiconductor has attracted great attention as a potential application for spintronics due to a successful demonstration of spin injection from ferromagnetic GaMnAs into semiconductor. A conclusion so far in the GaMnAs system is the maximum incorporation of Mn up to ~ 5% with ferromagnetism below ~110 K. Higher Mn incorporation produces MnAs precipitates, and which has rather decreased the Curie temperature. In the meantime, the authors have shown that another III-V system of GaMnN reveals room temperature ferromagnetism in structures grown by MBE using a single GaN precursor.[1] In the subsequent attempt to further enhance the carrier concentration in the matrix of GaMnN solid solution by codoping nonmagnetic doping element of Mg [2,3], however, the saturation magnetization has dramatically enhanced even with a very small Mn concentration, but magnetotransport could not be observed due to relatively high resistivity or the semiconducting behavior of the layers. In this study, we present a study on Be-codoped GaMnAs including ferromagnetism and magnetotransport at room temperature.

GaAs and GaMnAs films were grown by solid-source MBE on semi-insulating GaAs (100) substrates. The base structure of the series of the samples is GaAs:Be layers grown under a very high Be flux at T_{Be}=1250 ^oC for metallic resistivity of GaAs. The Hall carrier concentration was 3.9×10^{20} cm^{-3}. The Mn cell temperature was then varied in the range of 850-910 ^oC, which covers the flux transition from homogeneous GaMnAs to precipitated GaMnAs if without Be doping. The Hall carrier concentration was 1.1×10^{20} cm^{-3} for T_{Mn}=890 ^oC. The atomic concentration of Mn was measured by electron probe x-ray microanalysis (EPMA), and the structural, electrical, and magnetic properties of the grown layers were investigated by double crystal x-ray diffraction (DCXRD) using Cu K_α radiation, temperature dependent resistivity measurement on van der Pauw geometry, and superconducting quantum interference device (SQUID).

All the grown layers revealed metallic behavior, but the resistivity increases with higher Mn flux. Clear competition between Be and Mn for incorporation was observed. Ferromagnetism in the layers can be clearly confirmed from the M-H curves in Fig. 1(a) measured at room temperature. Anomalous Hall effect is a direct proof of magnetotransport and ferromagnetism in a structure. The anomalous Hall resistances measured by SQUID on van der Pauw geometry is shown in Fig. 1(b). The anomalous Hall effect was visible only for high Mn flux, or at T_{Mn}=890 and 910 ^oC (Fig. 2). While the result obviously suggests a possibility of increasing M_S of the magnetic semiconductors by codoping of highly efficient dopants, it again evidences the importance of the carrier concentration in the carrier-mediated ferromagnetism as was also observed in the Mg-codoped GaMnN films. The conductivity of the layers was also analyzed. The film conductivity was dominated by Be conduction till T_{Mn}=890 ^oC, but by Mn conduction at T_{Mn}=910 ^oC. At least, the ferromagnetism for T_{Mn}=910 ^oC originates from MnAs precipitates. The observation of magnetotransport in the film indicates that the ferromagnetism of MnAs is conveyed through the surrounding highly conductive GaMnAs region. Discussion for the ferromagnetism for T_{Mn}<890 ^oC will be also made.

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References:

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Figures:

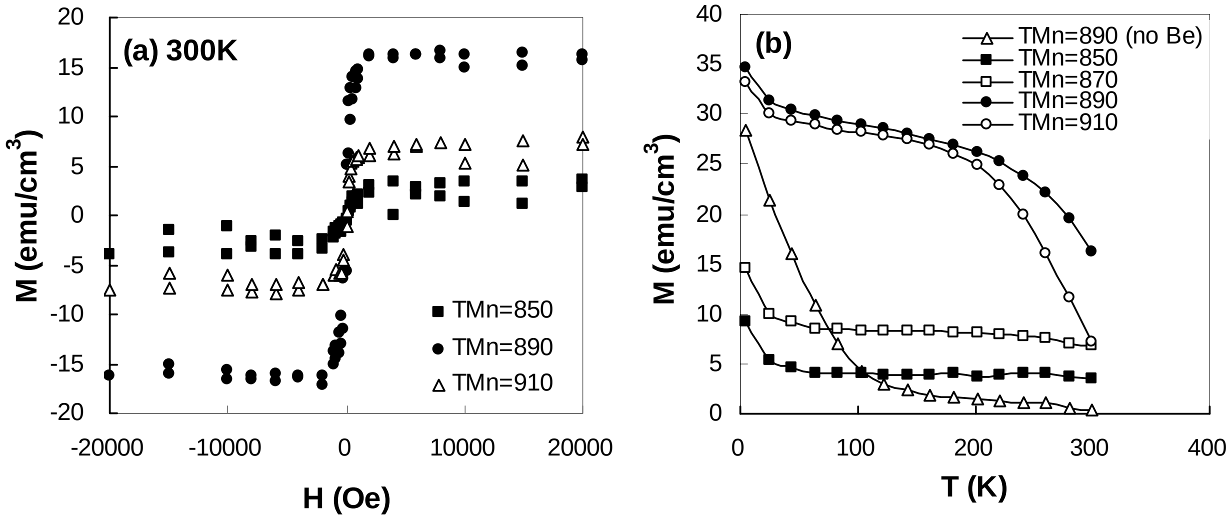

Fig. 1. M-H and M-T curves of the grown Be-codoped GaMnAs layers.

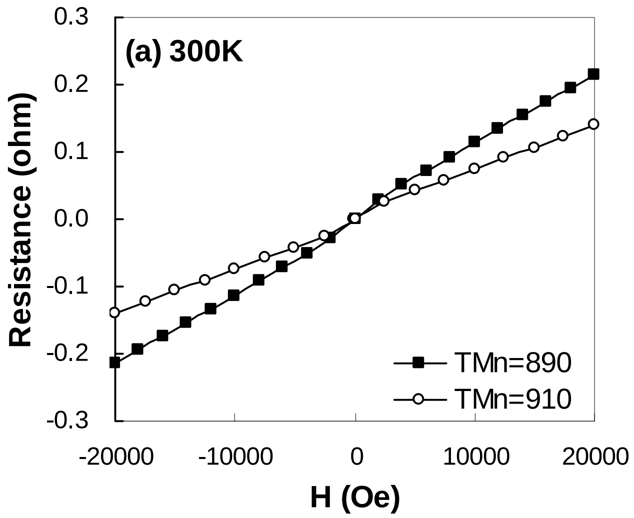

Fig. 2. Anomalous Hall effect measurements of the Be-codoped GaMnAs layers.