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Epitaxial growth of ferromagnetic semiconductor $Ga_{1-x}Mn_xAs$ films on Ge(001) substrate

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Fabrication of heteroepitaxial structures between $Ga_{1-x}Mn_xAs$ and group IV semiconductors should be an important technology for developing III-V/VI hybrid spintronic devices. Zhao *et al*. and Uchitomi *et al*. have achieved the epitaxial growth of $Ga_{1-x}Mn_xAs$ on Si(001) substrates [1,2]. However, due to a rather large lattice mismatch (Δa) between GaAs and Si (4.1 %), a thick GaAs buffer layer of several hundred nm was necessary to grow the epitaxial $Ga_{1-x}Mn_xAs$ layer. The use of such a thick buffer layer would be detrimental to spin injection from $Ga_{1-x}Mn_xAs$ into Si. Here, we report the magnetic properties of epitaxial $Ga_{1-x}Mn_xAs$ film directly grown on Ge(001), where Ge has a very small Δa with GaAs (0.12 %).

$Ga_{1-x}Mn_xAs$ films were directly grown on Ge(001) substrate at 250°C by molecular beam epitaxy method. Figure 1 shows the reflection high-energy electron diffraction (RHEED) image of a 65-nm thick $Ga_{1-x}Mn_xAs$ (x = 0.06). The image revealed clear streak patterns, showing that an epitaxial $Ga_{1-x}Mn_xAs$ layer was successfully grown. The lattice constant of the $Ga_{1-x}Mn_xAs$ layer was estimated from X-ray diffraction (XRD) peaks to be 0.5660 nm which is larger than that of Ge (0.5646 nm). This indicates that the $Ga_{1-x}Mn_xAs$ layer is under compressive strain.

The magnetization curves of the $Ga_{1-x}Mn_xAs$ (x = 0.06) sample at 5 K is given in Fig. 2, with the magnetic fields applied parallel ($H_{//}$) and perpendicular ($H_{\perp}$) to the film plane, respectively. Clear hysteresis with a square shape was observed only for applying $H_{//}$, indicating that the easy axis of magnetization of the $Ga_{1-x}Mn_xAs$ lies in the plane of the film. This is consistent with a compressive strain in the $Ga_{1-x}Mn_xAs$ layer as proven by the XRD measurements. Curie temperature of the $Ga_{1-x}Mn_xAs$ is 66 K which is an almost the same as a reference $Ga_{1-x}Mn_xAs$ film grown on GaAs(001) (65 K). These demonstrate that $Ga_{1-x}Mn_xAs$/Ge is a promising structure for III-V/IV hybrid spintronics devices.

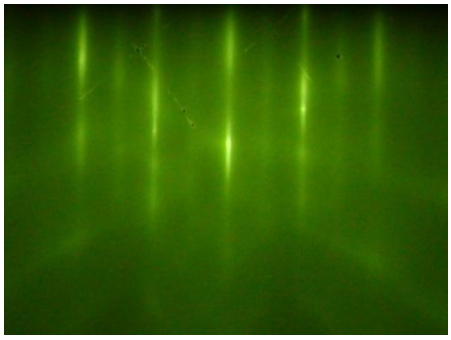

Fig. 1 RHEED pattern of $Ga_{1-x}Mn_xAs$ (x = 0.06) film on Ge(001)

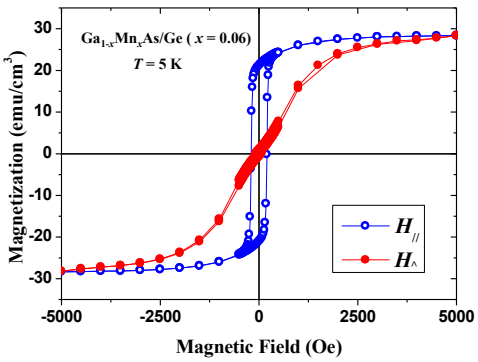

Fig. 2 Magnetization curves of $Ga_{1-x}Mn_xAs$ (x = 0.06) film grown on Ge(001) substrate.

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