Magnetotransport properties of (Ga,Mn)Sb channel in field-effect structures

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Magnetism of hole-induced ferromagnetic semiconductors can be controlled by the application of gate electric fields $E_G$ through the modulation of hole concentration $p$ [1,2]. For (Ga,Mn)As, it was reported that the relationship between $p$ and the Curie temperature $T_C$ is given by $T_C \propto p^\gamma$ with $\gamma \sim 0.2$, where $p$ was changed by the application of $E_G$. The value of $\gamma \sim 0.2$ was shown to be explained by the adapted $p$-$d$ Zener model with nonuniform hole distribution along the growth direction resulted from the presence of the interface depletion layer as well as the application of $E_G$ [3,4].

We have investigated magnetotransport properties of thin (Ga,Mn)Sb layers in field-effect structures. Four 5 nm-thick (Ga,Mn)Sb layers are grown by low-temperature molecular beam epitaxy onto a buffer layer consisting of 5 nm GaSb/300 nm Al$_{0.80}$Ga$_{0.20}$Sb/10 nm AlSb (from the surface side) on a semi-insulating GaAs (001) substrate [5,6]. We fabricate field-effect structures with a Hall-bar geometry with a 40 nm-thick Al$_2$O$_3$ gate insulator formed by atomic layer deposition. We measure Hall and sheet resistances ($R_{\text{sheet}}$ and $R_{\text{Hall}}$) under gate electric fields $|E_G|$ up to 5 MV/cm and magnetic fields up to $|\mu_0 H| = 0.5$ T. We determine $p$ from the $E_G$ dependence of $R_{\text{sheet}}$ and $T_C$ from $R_{\text{Hall}}$ by making the Arrott plots. We obtain $\gamma \sim 1$ for (Ga,Mn)Sb, which is several times larger than that for (Ga,Mn)As. The result can be reproduced by adapted $p$-$d$ Zener model with accumulation of holes at the interface of (Ga,Mn)Sb and gate insulator, opposing to depletion for (Ga,Mn)As. The hole accumulation at the interface is consistent with the Fermi energy pinning position of p-GaSb at the interface [7].

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