Spin-valve magnetoresistance in ferromagnetic semiconductor (Ga,Fe)Sb heterostructures with high Curie temperature

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Ferromagnetic semiconductors (FMSs), which show both ferromagnetic and semiconducting characteristics, are promising materials for future low-power spintronics devices. Among various FMSs, Fe-doped III-V FMSs are promising, because both p-type and n-type materials are available and the highest Curie temperature ($T_C$) exceeds room temperature. In this work, we demonstrate clear magnetoresistance due to the spin valve effect in ferromagnetic heterostructures containing high-$T_C$ (Ga,Fe)Sb. The samples examined here consist of (Ga$_{0.75}$,Fe$_{0.25}$)Sb (40 nm, $T_C > 320$ K) / InAs (thickness $t = 0, 3, 6, 9$ nm) / (Ga$_{0.8}$,Fe$_{0.2}$)Sb (40 nm, $T_C > 320$ K) grown by low-temperature molecular-beam epitaxy. Clear MR of ~2% with an open minor loop is observed at 3.7 K when $t = 3$ nm, whose peaks ($\pm$0.1 T) are consistent with the coercive forces of the (Ga,Fe)Sb layers obtained with superconducting quantum interference device (SQUID) magnetometry. We found that the GMR ratio increases (from 0.03 to 1.28%) with decreasing $t$ (from 9 to 3 nm), which is caused by the enhancement of spin-dependent scattering at the InAs/(Ga,Fe)Sb interfaces. This is the first demonstration of the spin-valve effect in Fe-doped FMS heterostructures, paving the way for device applications of high-$T_C$ FMSs.