D-20

Spin polarization and applications of paramagnetic high g-factor semiconductors

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In semiconductor, spin splitting caused by Zeeman effects is generally inversely proportional to the band gap. For a moderate band-gap semiconductor such as Si and GaAs, electrons in s-like conduction bands have relatively weak spin-orbit (SO) coupling and small Zeeman effect. In narrow-gap semiconductors (NGS), however, the conduction-electron states are strongly mixed with the valence states through the k · p interaction across its narrow band-gap, which leads to strong SO coupling and large Zeeman effect. HgCdTe is one of the most interesting NGS as a spintronic material. It has very large Zeeman effect due to large g-factor; $g* \sim 100$, while that of GaAs is about 0.44. In addition, HgCdTe is featured with remarkably long spin relaxation time. It was reported recently for HgCdTe to have 356 ps and 24 ps at 150K and 300K, respectively (1). These unique spin properties of HgCdTe can be great advantage for spin manipulation in spintronic devices.

For spintronic device, spin states should be manipulated by an externally controllable factor. It is magnetic field for HgCdTe because of the underlining large Zeeman effect. Thus, the strength of the magnetic field needed for spin polarization is an important parameter for this semiconductor, and has been estimated experimentally in this work.

We have studied the spin polarization of bulk $Hg_{1-x}Cd_xTe$ (x=0.21) at 2K by measuring Shubnikov-de Haas oscillations. The magnetic field have been applied in parallel and perpendicular to the current, and the obtained transport properties show the spin-related selection rules near the fully polarized magnetic field regime. The electronic Fermi level is located at 6.5 meV above the conduction band, and the carrier electrons are completely polarized when the applied magnetic field is more than 0.5 Tesla. This magnitude of the magnetic field can be generated and controlled by ferromagnetic materials deposited on the surface of the specimen (2), which means the spin-manipulation such as spin up/down junction (3) can be realized with this material.

We also theoretically investigate the spin polarization of this semiconductor based on the above experimental data. The calculation have been carried out using energy dependent relaxation time approximation in association with spin-flip scattering. As increase the magnitude of the magnetic field, the spin polarization of electron density increase and its sign is not fixed . However, the spin polarization of electric current shows alternative sign. This implies the current polarization can be tuned by the control of magnetic field strength, suggesting the possible application to spintronic device.

References

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