Spin transistor using exchange-biased ferromagnetic electrodes in an InAs quantum well

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The spin field effect transistor (spin-FET), proposed by Datta and Das [1], is one of the most popular concepts for next generation devices due to low power consumption, high speed, and nonvolatility. The main operation of spin-FET is that the control of spin-procession angle by a gate electrode in a semiconductor quantum well [2]. In this device, the spin-polarized current is injected from a ferromagnetic source and detected by the other ferromagnetic drain. While travelling spin polarized current from the injector to the detector in a semiconductor quantum well, the angle of spin-procession angle is decided by Rashba field which is controlled by a gate electrode. To be utilized for the logic gate, we should operate spin transistor without external magnetic field and parallel- and antiparallel types of spin-FET (P-ST and AP-ST) which can replaced conventional *n*- and *p*-MOS.

The Rashba field arises along the *y*-axis, so the magnetization direction of source and drain should be along the *x*- or *z*-axis, i.e. perpendicular to the Rashba field (B_{Ry}), to induce spin precession. In this experiment, we choose the ferromagnetic electrodes (FM) with magnetization along the *x*-axis. The lateral sizes of FMs are 0.5 μm × 15 μm and are 0.8 μm × 15 μm, respectively. Since the shape anisotropy would lead to a FM magnetization along the *y*-axis, we employ an exchange bias field along the *x*-axis using $Co_{84}Fe_{16}/Ir_{22}Mn_{78}$ bilayers. During the sputtering of $Co_{84}Fe_{16}$ and $Ir_{22}Mn_{78}$, we applied magnetic fields of +20 mT and −20 mT along the *x*-axis, respectively. Due to interfacial exchange interaction between the $Co_{84}Fe_{16}$ and $Ir_{22}Mn_{78}$, the first interfacial layer of $Ir_{22}Mn_{78}$ has the same magnetization direction as the $Co_{84}Fe_{16}$ layer. The antiferromagnetic order of $Ir_{22}Mn_{78}$ causes subsequent layers to have alternating magnetizations. The antiferromagnetic order is very stable, so that the ferromagnetic $Co_{84}Fe_{16}$ layer retains its magnetization direction even without a magnetic field. The ferromagnet/anti-ferromagnet bilayers have +35.5 mT and −36.3 mT of exchange bias. We also calculated the spin transistor operation using those parallel and antiparallel types spin-FET.

References

[1] S. Datta et al., Appl. Phys. Lett. 56, 665 (1990).

[2] H. C. Koo et al., Science, 325, 1515 (2009).