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_R), 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