Spin Injection Properties in MoS_2 Lateral Spin Valves

전병선[1*], 황찬용[1]
[1]한국표준과학연구원 나노측정센터

1. 서론

2D-layered transition metal dichalcogenides semiconductor molybdenum disulfide (MoS_2) has received significant attentions. The bulk MoS_2 is an indirect-gap semiconductor with a band gap of 1.29eV consisting of weak van der Waals bonded S-Mo-S units. With decreasing thickness, whereas, shift in the indirect gap from the bulk value to the direct gap with a band gap of 1.9eV at monolayer due to the quantum confinement. Because monolayer MoS_2 has a band gap completely block the current in the FET's off-state with carrier mobility of 200 cm^2/Vs at roomtemperature.

Monolayer MoS_2 has strong spin orbit coupling originated from the d orbitals of the heavy metal atoms but induces large spin splitting of up to 456meV at the valance band due to a broken structure inversion symmetry of the bulk compounds in the monolayer case. This spin splitting suppresses the Dyakanov-Perel spin relaxation time and results, long spin diffusion length is expected regardless of the strong spin orbit coupling. On account of broken structure inversion symmetry,MoS_2 is a fascinating material for spintronics application.

2. 실험방법

Mo thin film samples were prepared on 1x1 cm MgO (100) single crystalline substrates by molecular beam epitaxy (MBE). MoS_2 thin films were prepared by sulfurization of molybdenum layers based on a vapor phase growth technique. The Raman measurements with a 532nm laser wave length were performed using a Witecalpha 300R confocal Raman system. Device fabrication was carried out using e-beam lithography employing a negative-tone ma-N2403 resist and Ar^+ ion etching. Subsequently, after removal of the resist, UV lithography patterning was performed to fabricate the macroscopic metal contacts. The magnetoresistance and I-V curves of MoS_2/CoFe lateral spin valve structure were characterized using a physical property measurement system (PPMS) by Quantum Design.

3. 실험결과

A schematic illustration of the device structure and a scanning electron microscopy (SEM) image are shown in Figure. A standard local geometry was used to measure the spin signal of the lateral spin valve (SV) structure. As shown in this figure, our lateral local SV structure is composed of ferromagnetic (FM) CoFe electrodes separated by a non-magnetic semiconductor MoS_2 layer. By applying a current between the two electrodes, spin polarized carriers are injected into a MoS_2 from a first CoFe electrode then detected by a second CoFe electrode that is placed within the spin diffusion length associated with the semiconductor materials. The local resistance is measured as the applied magnetic field swept from a positive to a negative value followed by an pposite sweep back to positive value both the field direction along in-plane and perpendicular to the sample axis. The difference in the CoFe electrodes shape is proposed to facilitate a magnetic configuration due to the shape anisotropy at which the magnetization in the pads switches so that a variation of coercivity can be obtained. In order to analogize the spin diffusion length in the MoS_2,we fabricated different gap size between the CoFe electrodes from 240 nm to 680 nm.

The magnetoresistance (MR) ratio was measured to detect spin injection and transport in MoS_2 lateral SV by applying both in-plane and perpendicular magnetic field to the easy axis of sample from 300 K to 10 K. No measurable MR was observed for MoS_2 lateral SV above 120 K but clear MR is observed at below 120 K. This indicates electrical spin injection from CoFe then transport to MoS_2 layer. The magneto-transport curves show magnetization switching characteristics consistent with the coercivity(H_c) difference between the spin injector and spin detector CoFe electrodes due to the different shape anisotropy.