Preparation of topological semimetal CoSi thin films for spin-orbit torque devices

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Spin-orbit torque (SOT) induced by electrical currents via spin-orbit coupling provides a promising method to manipulate the magnetization direction for energy-efficient spintronic devices, such as magnetoresistive random-access memories (MRAMs). Spin Hall effect (SHE), as one of the origins of SOT, has been intensively studied. In order to realize the practical application of SOT devices, it's important to find materials with large spin Hall effect. Very recently, CoSi was predicted as a kind of new topological semimetal possessing Weyl points [1] near the Fermi energy in its electronic band structure, which may generate significantly intrinsic contribution to spin Hall effect [2]. To date, the spin Hall effect in the CoSi has not been studied. In this work, we aim to prepare CoSi thin films by magnetron sputtering and evaluate the efficiency of spin Hall effect (θ_{SHE}) of the CoSi films.

CoSi films were deposited on different substrates by magnetron sputtering typically with an annealing temperature 480 ℃. The films were characterized by reflection high-energy electron diffraction (RHEED), atomic force microscopy (AFM) and X-ray diffractometry (XRD). Furthermore, the samples were microfabricated into Hall bar structures by UV lithography. The spin Hall magnetoresistance and transport properties of the films were measured by a physical property measurement system (PPMS).

Polycrystalline CoSi films were successfully fabricated on several substrates, including MgO(001), MgO(110), MgO(111), GaAs(001), thermally oxidized silicon, sapphire A plane and sapphire C plane. By comparing the crystallinity and roughness, it is found that the sapphire C-plane substrate is the best for the growth of CoSi films. The RHEED and XRD patterns indicate all the CoSi films are polycrystalline. A relatively flat surface with the average roughness (R_a) of 0.77 nm was achieved for a 47-nm-thick CoSi film deposited on the sapphire C-plane. The resistivity of the CoSi film at room temperature is about 600 μΩ cm, which is 5 times higher than the reported value of bulk single crystalline CoSi [3]. The enhanced resistivity could be attributed to the carrier scatterings at the interfaces of thin films and grain boundaries of the polycrystalline film. The θ_{SHE} of CoSi was evaluated by measuring the spin Hall magnetoresistance in a CoSi(0-11 nm)/CoFeB(1 nm)/MgO(2 nm)/Ta(1 nm) structure. A sizable θ_{SHE} of ~3.5% was achieved in the polycrystalline CoSi film, which is large for material systems without heavy metals. In comparison with the spin Hall angles in pure Co (~1%) [4] and Si (0.01%) [5], the enhancement of θ_{SHE} in the CoSi films suggests that the topological electronic structures of CoSi may play a significant role on the spin Hall effect.

Reference

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