Inverse spin Hall effect induced by spin pumping into semiconducting ZnO

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The generation, manipulation, and detection of the spin current are very important and necessary for spintronics devices. The spin Hall effect (SHE) refers to the phenomenon that the spin-up and spin-down transport electrons accumulate transversely on opposite sides of a nonmagnetic conductor due to the spin-orbit coupling (SOC) that occurs without an external magnetic field. Consequently, the SHE can provide a simple physical mechanism to generate the transverse spin current by using the longitudinal charge current [1,2]. However, it is very difficult to observe the spin Hall effect in semiconductors, especially for ones with weak SOC. Group II-VI semiconductor material Zinc Oxide (ZnO) has attracted a lot of attention lately for its prospects in optoelectronics applications owing to its direct wide band gap and large exciton binding energy[3]. In addition, it has a small SOC, implying a large spin coherence length. Therefore, ZnO is also a promising candidate for combining optoelectronics and spintronics applications[4,5]. We have successfully injected the spin current into semiconductor ZnO thin films with weak SOC by utilizing the spin pumping method and observed the Inverse spin Hall effect (ISHE).
FIG. 1. Schematic illustration of the ZnO/Ni$_{80}$Fe$_{20}$ films. H represents an external magnetic field, angle $\theta$ is between the field and microwave propagation direction, Y axis, can be varied.

FIG. 2. (a) Magnetic field H dependence of the electromotive force V of ZnO/Ni$_{80}$Fe$_{20}$ thin film under 50 mW microwave excitation, where $\theta$ are 0$^\circ$ and 180$^\circ$. The solid lines show the fitting results using the Lorentz function. $V_{\text{ISHE}}$ is estimated as the peak height of the resonance shape in the V spectra. (b) Shows the in-plane angle $\theta$ dependence of the electromotive force V for ZnO/Ni$_{80}$Fe$_{20}$. The hollow symbols are the experimental data, and the solid line is a fitting line.
FIG. 3. FMR linewidth as a function of microwave frequency for ZnO/Ni$_{80}$Fe$_{20}$. The inset shows microwave power $P_{MW}$ dependence of $V_{ISH}$ for the ZnO/Ni$_{80}$Fe$_{20}$ bilayer at $\theta = 0^\circ$ and $180^\circ$.

Reference:


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