Antiferromagnetic anisotropy determination by spin Hall magnetoresistance

We propose an electric method for the antiferromagnetic anisotropy determination through spin Hall magnetoresistance (SMR) measurement in normal metal (NM)/antiferromagnetic insulator (AFI) bilayers. This work elaborates a new method for the antiferromagnetic anisotropy determination in both AFI bulk material and thin films.

Antiferromagnetic spintronics is an emerging research field since antiferromagnetic (AFM) materials have great potential for the spintronics applications, which has been demonstrated by recent experimental and theoretical progress [1,2]. At the same time, however, very limited effort has been made to utilize spintronics phenomena to characterize the magnetic property of AFM. In this work, we propose that the spin Hall magnetoresistance (SMR) in a normal metal (NM)/antiferromagnetic insulator (AFI) bilayer can be utilized to determine the antiferromagnetic anisotropy in the AFI.

In this paper, we simulated the SMR in realistic NM/AFI bilayer systems, such as Pt/Cr_2O_3, Pt/NiO and Pt/CoO. Our work shows that the SMR in a NM/AFI bilayer provides a new electric method for the antiferromagnetic anisotropy determination in both bulk material and thin films. Besides, the simulated SMR results in realistic system with uniaxial Cr_2O_3 and biaxial NiO, CoO yield a concrete reference for the experimental observation of the SMR in NM/AFI bilayers.

Figure 1(a) and (b) show the illustrations of the SMR in NM (NM=Pt)/AFI (AFI=Cr_2O_3, CoO, NiO) bilayer with AFI Néel vector $\mathbf{\Delta} = \mathbf{M}_A/M_A - \mathbf{M}_B/M_B$ parallel and perpendicular to the direction of the interface electron spin accumulation. In analogy to the SMR in NM/ferromagnetic insulator(FI) [3], in NM/AFI bilayers, when electron spin polarization $\boldsymbol{\sigma}$ and Néel vector $\mathbf{\Delta}$ are not parallel, spin-flip scattering is activated. Figure 1(b) shows when $\boldsymbol{\sigma} \perp \mathbf{\Delta}$, the spin-transfer torque induced absorption at the NM/AFI interface will be maximized, which gives a higher resistance than the state $\boldsymbol{\sigma} \parallel \mathbf{\Delta}$.

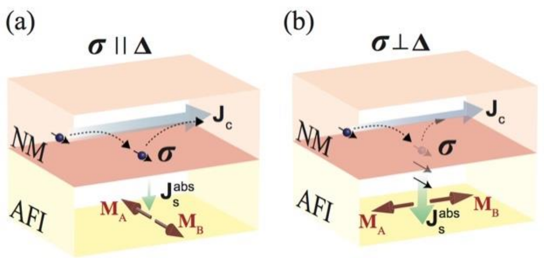

Fig. 1 (a), (b) Illustrations of the SMR in NM (NM=Pt)/AFI (AFI=Cr_2O_3, CoO, NiO) bilayer with AFI Néel vector parallel and perpendicular to the direction of the interface electron spin accumulation. $\mathbf{J}_C$ and $\mathbf{J}_S^{abs}$ represent the injected charge current and the spin current absorption in AFI respectively. $\mathbf{M}_A$ and $\mathbf{M}_B$ are the AFI sublattices.

In an AFM material, the Néel vector $\mathbf{\Delta}$ will stay along the easy axis below the Néel temperature due to the anisotropy. When applying magnetic field $\mathbf{H}$ parallel to the easy axis with magnitude larger than the critical field H_C, the Néel vector will suddenly changes its direction perpendicular to $\mathbf{H}$, this first-order transition is called spin-flop transition. Since in general cases, the Néel vector in AFM is determined by both the external magnetic field and the magnetic anisotropy [4]. Combining the angular dependence of the Néel vector with the SMR in NM/AFI, we simulated the angular dependence of the SMR in Pt/ Cr_2O_3 (110) bilayers with different magnetic fields, as shown in Fig. 2.

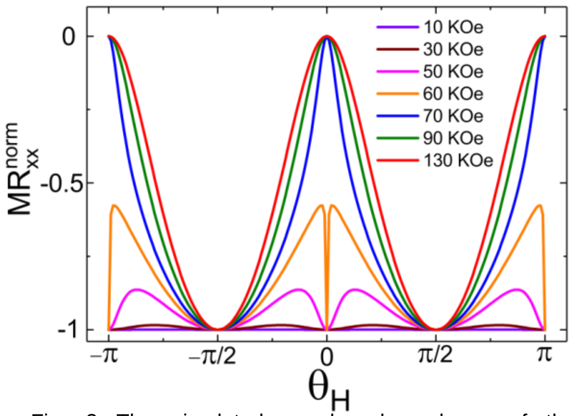

Fig. 2 The simulated angular dependence of the normalized SMR resistivity in Pt/ Cr_2O_3 (110) with different magnetic fields. θ_H is the angle between the magnetic field **H** and easy aixs.

In conclusion, we propose a new method for the antiferromagnetic anisotropy determination in both AFI bulk material and thin films through SMR measurement in NM/AFI bilayers.

References

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