Geometry effects in spin pumping through thin organic films

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We have investigated spin pumping from yttrium iron garnet (YIG) into Pt through ultrathin organic films (C_{60}, DH_4T) by measuring the damping in ferromagnetic resonance (FMR) by spin pumping and the DC inverse spin-Hall effect (ISHE) in the Pt. With increasing thickness d_0 of the organic the damping drops monotonically from a maximum for zero interlayer thickness to zero for 10 nm or more. The ISHE, however, changes in a non-monotonic way. Maximum ISHE is observed for $d_0=0$. For d_0 of 1 or 2 nm the ISHE drops to less than 50% (Fig. 1). Further increase leads to a reversal of this trend for both organic materials and only after a second maximum is reached a drop to zero is observed which is approx. exponential with interlayer thickness. The origin of this effect can be found in the growth mode of the organic layers. In very thin films the organic molecules grow as islands which can ideally be regarded as half spheres. Magnitude and direction of the ISHE depend on the absolute directions of pumped spins and spin current and their relative orientation. The spin current enters through the bottom of the islands but exits perpendicular to the organic/Pt interface. Only the spin current through the top of the island causes a maximum signal (Fig. 2) while currents flowing almost in plane barely contribute. They either do not cause any ISHE or they cause an ISHE-voltage perpendicular to the measurement direction. With increasing thickness the islands coalesce to a closed layer and all spin currents again pass the interface perpendicular to the layer. The original effect is then restored, except for a decrease by spin flip in the organic film. Simulations and transmission electron microscopy show that this model fully describes our findings. The results are important because they show that especially for spin pumping through very thin films the morphology is extremely important and many different layer thicknesses need to be investigated to get a coherent picture. Due to the purely geometrical origin the effect is universal for all conducting interlayer materials.

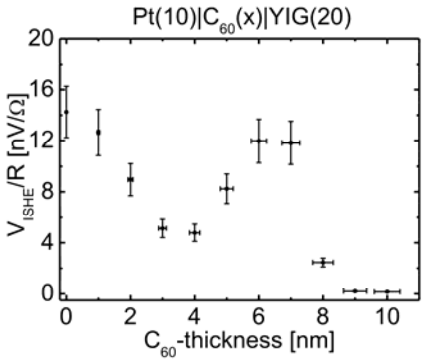

Figure 1: Dependence of ISHE on C60 interlayer thickness d0

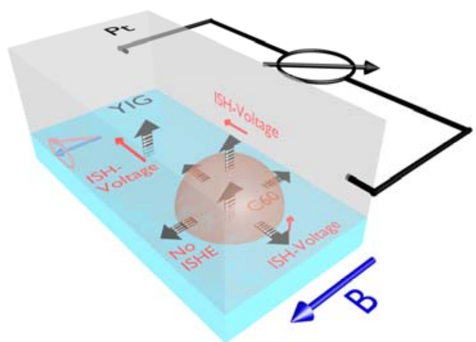

Figure 2: Sketch of the ISHE resulting from spin currents flowing from YIG into Pt through a C_{60} half-sphere

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