Spin Hall angle in W/CoFeB/Pt trilayers

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Thin films made of heavy metals (HM) exhibiting significant spin-orbit coupling are promising materials for spintronics, where the charge current (J_c) may be converted into spin current (J_s), which in turn may exert a torque on the magnetization in the adjacent ferromagnet (FM) due to spin Hall effect. In HM/FM/HM trilayers, the additional Oersted fields induced by the charge current flow in both HM layers may cancel each other out, which leads to pure spin-Hall-induced dynamics in FM.

In the presented paper, bilayers of CoFeB/W, CoFeBPt and trilayers of W/CoFeB/Pt are investigated because W and Pt are characterized by an opposite sign of spin Hall angle [1]. First the magnetron-sputtering process of W were optimized for highly-resistive β-phase in the W thicknesses up to 8 nm [2,3]. Afterwards, using spin-torque ferromagnetic resonance technique (ST-FMR) [4] in W(t_W)/CoFeB(5) bilayers, with t_W ranging from 0 up to 10 nm, patterned into microstripes, we measured DC-voltage as function of excitation microwave frequency and in-plane magnetic field. By fitting the sum of symmetric and anti-symmetric Lorentzian-like lineshape we calculated the spin Hall angle from W layer of $J_s/J_c = 0.27$. Similar approach applied to CoFeB/Pt bilayers with t_{Pt} ranging from 0 up to 10 nm, lead to the conclusion that field-like term cannot be completely neglected for such system [5].

Finally, we investigated W/CoFeB/Pt using the same technique. The total RF Oersted field in CoFeB layer was analyzed numerically and fitted using equation $H_{rf} = (a+b*t_{Pt})/(1+c*t_{Pt})*J_c$ and thereafter used to normalized symmetric part of Lorentz signal. We found that for $t_{Pt} = 1.1$ nm, the signal is almost completely symmetric, which is caused by the absence of the H_{rf}, which coincides with equalization of J_c in W and Pt layers. Using the developed model we calculated the total spin Hall angle from W and Pt layers of up to $J_s/J_c = 0.4$ for $t_{Pt} = 5$ nm.

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