Highly fcc-textured Pt-Al alloy films grown on MgO(001) showing enhanced spin Hall efficiency

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Reducing the power consumption is of paramount importance for increasing the competitiveness of spintronic devices for next-generation computing. The power efficiency of a spin-orbit torque switching device is governed by the figure of merit $\xi_{DL}\sigma_{SH}$ where ξ_{DL} and σ_{SH} are the damping-like spin Hall efficiency and the associated spin Hall conductivity of the material where charge-to-spin conversion via the spin Hall effect (SHE) occurs. When the intrinsic mechanism is the primary source of SHE, alloying is expected to boost up ξ_{DL} while maintaining σ_{SH}, thus the power efficiency can be enhanced. Substantial efforts have been devoted to explore the SHE in Pt-based alloys (by alloying Pt with Al[1], Hf[1], Au[2], Cu[3], MgO[4], etc.) because face-centered cubic (fcc) Pt is the elemental material featuring the highest σ_{SH}. Nevertheless, a general guideline for the choice of successful material combination has been lacking. Here, by revisiting the SHE in $Pt_{100-x}Al_x$ alloys, we reveal the crucial role of highly-ordered fcc texture for efficient charge-to-spin conversion using Pt-based alloys.

We have grown 2 series of $Pt_{100-x}Al_x$(~6nm)/CoFeB(2nm)/AlOx(3nm) heterostructures of varying Al concentration *x* by magnetron sputtering on MgO(001) and SiO_2 substrates. The growth of $Pt_{100-x}Al_x$ layers on MgO was carried out at a substrate temperature of ~300ºC whereas other layers on MgO and the entire stacks on SiO_2 were grown at ambient temperature. X-ray diffraction (XRD) spectra indicate that $Pt_{100-x}Al_x$ alloy films on MgO are highly textured and subsequently crystallize in fcc Pt, fcc-based $L1_2$-ordered Pt_3Al and bcc-based B2-PtAl as *x* is varied from 0 to ~ 48. In contrast, the Pt (x = 0) film grown on SiO_2 is polycrystalline and shows a relatively weak fcc(111) XRD peak. The peak intensity diminishes monotonically with increasing *x* suggesting the disordered alloy films on SiO_2 gradually become amorphous. This is consistent with the limited solubility (~10%) of Al in Pt. The CoFeB layers are in-plane magnetized. We systematically compare the charge-to-spin conversion efficiency of these two series of structures using the in-plane harmonic Hall technique. We surprisingly found that ξ_{DL} and σ_{SH} of highly-textured $Pt_{100-x}Al_x$ alloy films on MgO largely overwhelm those of poorly-textured $Pt_{100-x}Al_x$ alloy films on SiO_2. For $Pt_{78}Al_{22}$ (x = 22), we obtained ξ_{DL} ~ 0.20 for the MgO series and only ξ_{DL} ~ 0.06 for the SiO_2 series which we attribute to the strong correlation between the $Pt_{100-x}Al_x$ crystallinity and the SHE. We will also discuss other factors that will influence the SHE upon alloying.

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