

Enhancement of spin-orbit torque in W/CoFeB/MgO by controlling W resistivity

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Spin-orbit torques (SOT) allows an electrical control of a magnetization orientation in magnetic heterostructures^[1-3]. SOT has two components with different symmetries: the Slonczewski-like (SL) and field-like (FL) torques, whose magnitudes are characterized as spin-orbit torque efficiency parameters (ζ_{SL} , ζ_{FL})^[4], where ζ_{SL} is equivalent to the effective spin Hall angle. To achieve the efficient control of the magnetization orientation, a material system that exhibits large ζ_{SL} is desirable. W is a promising material exhibiting large ζ_{SL} ^[5-8] and a recent study showed a variation of ζ_{SL} by a factor of 2-3 with W resistivity ρ_W in the range of 100-240 $\mu\Omega\text{cm}$ ^[7]. Here we study the SOT of the W/CoFeB/MgO heterostructures by controlling ρ_W over a wide range (180-730 $\mu\Omega\text{cm}$) and discuss the mechanism for SOT generation in the heterostructures.

All stacks, consisting of W(5)/CoFeB(t_{CoFeB})/MgO(1.3)/Ta(1) (thickness in nm), are deposited on Si substrates by sputtering. Here t_{CoFeB} is the thickness of the CoFeB layer. Ar gas pressure to deposit W is controlled to change ρ_W . As shown in Fig. 1(a), ρ_W increases with Ar gas pressure by a factor of 4. SOT effective fields are evaluated using microfabricated devices by an extended harmonic Hall measurement^[9,10]. Figure 2 shows the obtained ρ_W dependence of ζ_{SL} in the W/CoFeB/MgO structures, together with the reported values^[5-7]. The results before and after annealing at 300°C are shown. Our results show that ζ_{SL} increases with the increasing ρ_W , following the trend of previous studies^[5,7,8]. The highest ζ_{SL} of -1.2 is the largest magnitude which has ever been reported. It is also found that $\zeta_{SL(FL)}$ decreases (increases) by annealing. From a relation between transverse and longitudinal resistivity, we will discuss the mechanism accounting for the generation of SOT in this system.

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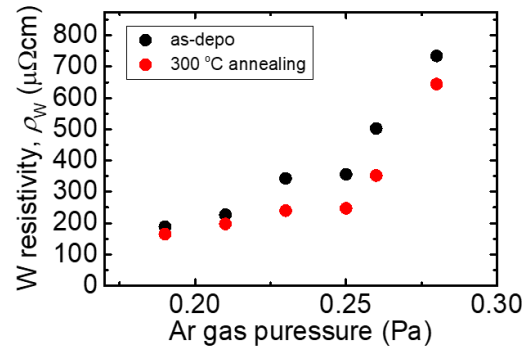


Fig. 1. ρ_W vs Ar gas pressure.

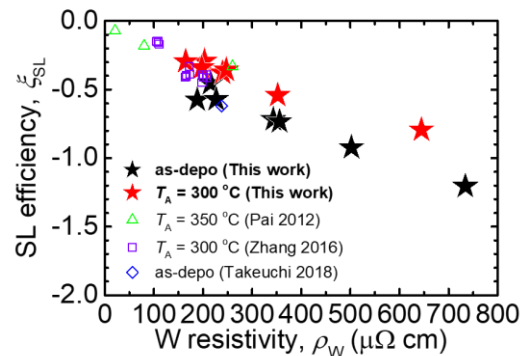


Fig. 2. ρ_W dependence of ζ_{SL} .

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