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Materials for giant spin hall effect

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Spin-orbit coupling in metastable β-W generates spin-orbit torques (SOT) strong enough to flip the magnetic moment of an adjacent magnetic layer. In a magnetic tunnel junction (MTJ) stack these torques can be used to switch between high and low resistive states. Deposition conditions selective to β-W need to be understood for the large-scale fabrication of SOT-MTJ devices or charge coupled spin-logic devices. We demonstrate two different techniques to grow 5-20nm thick β-W films by introducing either O2 gas or N2 gas during the deposition on SiO2/Si or SiN/Si substrates. The flow rate of these gases had a significant impact upon the crystallinity and formation of β-phase W. X-ray diffraction patterns, resistivities, X-ray photoelectron spectroscopy, and X-ray reflectivity were utilized to determine phase, bonding information, and thickness, respectively. These results demonstrate a reliable technique to fabricate β-W films up to 20nm thick on bare Si and silicon dioxide while providing insights that enable deposition of these films anywhere in the device stack. Recent spin Hall effect studies in the beta phase Ta and W show that transverse spin currents are strong enough to switch an adjacent magnetic layer. Films with perpendicular magnetic anisotropy (PMA) can exhibit uniform magnetizations and higher thermal stability. Inserting a 1nm thick Ta insert-layer between the CoFeB and W induces PMA which is confirmed by vibrating sample magnetometer and anomalous Hall voltage measurements. β-W(5nm)/Ta(1nm) channel and the adjacent CoFeB/MgO/Ta layers are patterned into a 100nm wide Hall bar structures. Effect of in-plane current induced change in coercivity was studied during a sweep of the in-plane magnetic field. An empirical model to quantitatively understand the switching mechanism will be presented.

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