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Controlling Magnetization using Spin Orbit Torque

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Recently it has been shown that spin orbit coupling (SOC) and/or broken inversion symmetry in vertical heterostructures can generate accumulation of spins when a charge current is flowing through them. In doing so, it can exert a torque on an adjacent magnet [1,2]. Indeed, high Z metals (Ta, Pt, W, *etc.*) with strong SOC have been used to inject spin currents into adjacent ferromagnetic layers and thereby to induce magnetic switching, oscillation, domain wall movement etc. SOC physics promises to significantly reduce the required current for current induced magnetic switching for next generation data-storage applications. In this presentation we shall discuss some of our recent work on SOC induced control of magnets with perpendicular magnetic anisotropy (PMA). A current flowing in-plane presents interesting symmetry problems with respect to a PMA magnet. We shall discuss how these symmetry relations can be utilized for switching of and domain wall movement in the PMA magnets [3]. In addition to storage applications, we shall also discuss possibility of exploiting SOC for spintronic logic applications [4].

[1] Miron, I. M. *et al.* Perpendicular switching of a single ferromagnetic layer induced by in-plane current injection. *Nature* **476,** 189-193 (2011).

[2] Liu, L. Q. *et al.* Spin-torque switching with the giant spin Hall effect of tantalum. *Science* **336**, 555–558 (2012).

[3] D. Bhowmik, et al., Deterministic Domain Wall Motion Orthogonal To Current Flow Due To Spin Orbit Torque, arXiv:1407.6137v1

[4] D. Bhowmik, L. You, S. Salahuddin, Spin Hall effect clocking of nanomagnetic logic without a magnetic field., *Nat. Nanotechnol.* **9**, 59–63 (2014).