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Switching, sensing, and coupling nanomagnets enabled by spin-orbit coupling

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The spintronics landscape has changed dramatically over the last ten years. Much of this change is due to a deeper understanding of the charge-spin conversion processes and magnetic interactions mediated by spin-orbit coupling in different classes of materials [1]. In this talk, I will discuss new opportunities to control and manipulate the magnetization of metallic and insulating nanomagnets. Illustrative examples will focus on the electrical switching of magnetic tunnel junctions [2,3] and iron garnets [4], as well as on the emergence of chiral coupling phenomena, which enable the realization of synthetic antiferromagnets and skyrmions [5] as well as of domain wall logic circuits [6].

[1] Current-induced spin-orbit torques in ferromagnetic and antiferromagnetic systems, A. Manchon et al., Rev. Mod. Phys. **91**, 035004 (2019).
[2] Single-shot dynamics of spin-orbit torque and spin transfer torque switching in 3-terminal magnetic tunnel junctions, E. Grimaldi et al., Nat. Nanotech. **15**, 111 (2020).
[3] Field-free switching of magnetic tunnel junctions driven by spin–orbit torques at sub-ns timescales, V. Krizakova et al., Appl. Phys. Lett. **116**, 232406 (2020).
[4] High-speed domain wall racetracks in a magnetic insulator, S. Velez et al., Nat. Comm. **10**, 4750 (2019).
[5] Chirally coupled nanomagnets, Z. Luo et al., Science **363**, 1435 (2019).
[6] Current-driven magnetic domain-wall logic, Z. Luo et al., Nature **579**, 214 (2020).

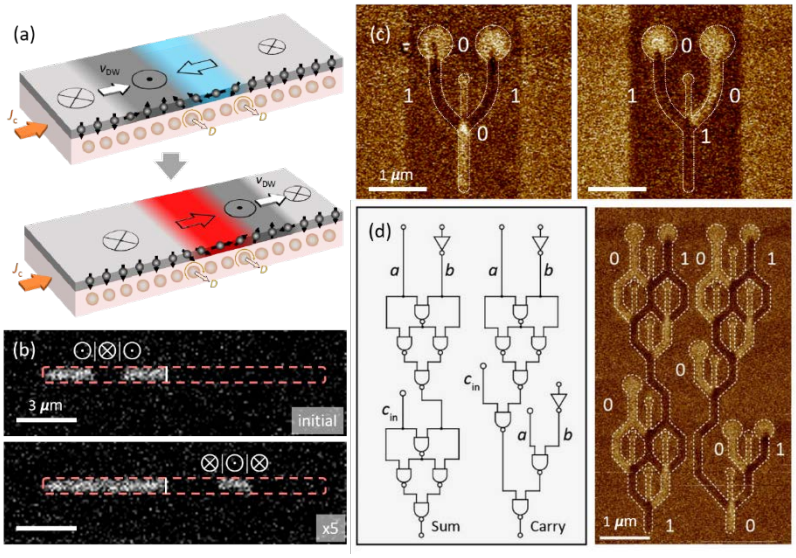

Figure 1. Current-driven magnetic domain-wall logic. (a) Schematics of a domain-wall inverter (NOT gate). (b) Magneto-optical Kerr effect images of a domain-wall inverter (white line) prior and post application of a series of electric pulses. (c) Magnetic force microscopy images of a NAND gate. (d) Left panel: Sketch of a full adder gate. Right panel: realization of the full adder gate with "a=0" and "b=1" inputs resulting in "Sum=1" and "Carry = 0". Reproduced from [6].