Researchers develop framework for understanding current-switched magnetic devices

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An international collaboration led by researchers from the NIST Center for Nanoscale Science and Technology (CNST) has made significant progress in modelling how electric currents affect the magnetization in some current-switched magnetic devices. While a number of such devices hold promise as low energy electronics, progress on some of the latest ideas has been impeded because different and contradictory models have been proposed to understand how they work and how to best optimize their performance.

Electronic devices based on magnetic materials have the potential to significantly reduce energy consumption below that of CMOS devices because they retain their state even after current has been removed. However, devices that use magnetic fields to switch their magnetization do not scale well to smaller sizes. An alternate approach which scales well has recently been developed that uses spin currents rather than magnetic fields to transfer information between the electrical current and the magnetization. One promising device is spin-transfer-torque switch magnetic random access memory (STT-MRAM), which is in development in several leading integrated circuit manufacturers. Device designers are searching for ways to reduce the current required to switch the magnetization in order to reduce both device size and energy consumption. One possible mechanism for reducing current is to incorporate materials with strong spin-orbit coupling, where the spin of the particle strongly affects its motion. Several experimental groups have shown remarkable results for switching magnetic bits and for moving domain walls in magnetic nanowires, which have strong spin-orbit coupling.

Common factors in these devices are their reliance on strong spin-orbit coupling and the presence of an interface between different materials. To test the existing theories for explaining their measured behavior, the researchers have taken a variety of approaches with the goals of unifying the disparate models and connecting the models' results to the experimental systems. In one approach, they compute all of the relevant experimental quantities predicted by a widely used theoretical model. They find that this single model cannot consistently explain all of the data, indicating that other important physics is at play in these systems. In a complementary approach, they compute the interfacial spin-orbit coupling and its consequences using first principles techniques. They show that the ability to switch the magnetization by current flow is determined by the extent to which the material with strong spin-orbit coupling induces large spin-orbit splitting, or changes in the electron energy levels, in the ferromagnetic material.

The researchers believe that these analyses form a framework that can help experimentalists select materials to optimize the spin-orbit splitting needed for successful current-switched magnetic devices.

More information: Kyoung-Whan Kim1,2, Hyun-Woo Lee, Kyung-Jin Lee, and M. D. Stiles, "Chirality from Interfacial Spin-Orbit Coupling Effects in Magnetic Bilayers." *Phys. Rev. Lett.* 111, 216601 (2013) [5 pages]. DOI: 10.1103/PhysRevLett.111.216601

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