Some talks about Spins, Bits, Flips and Faster, higher, stronger

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Spins, Bits, and Flips: Essentials for High-Density Magnetic Random-Access Memory

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The magnetic tunnel junction (MTJ), a device comprised of two ferromagnetic electrodes with a thin (about 1 nm) insulating tunnel barrier in between, was first proposed in a Ph.D. thesis by Michel Jullière in 1975 [1], and reached widespread commercialization nearly 30 years later as the read sensor in hard disk drives. MTJs became essential for data storage in consumer laptop and desktop computers, early-generation iPods, and now in data centers that store the information in "the Cloud." The application of MTJs has expanded even further, becoming the storage element in non-volatile memory, first in toggle magnetic random-access memory (MRAM) used in automotive applications and outer space, and now in the production of spin-transfer torque MRAM as a replacement for embedded Flash memory. As computing capabilities advance and drive demand for high performance memory, innovation in MTJ continues in order to deliver faster, high-density MRAM that can support last-level cache, in-memory computing, and artificial intelligence.

In this talk, I will describe the seminal discoveries [2] that enabled MTJs for pervasive use in hard disk drives, MRAM, and magnetic sensors, such as the discovery of tunnel magnetoresistance (TMR) at room temperature, the invention of spin transfer torque as the means to flip magnetization without a magnetic field, and the prediction and realization of high TMR using MgO tunnel barriers. As the demand for faster and higher density memory persists, still more breakthroughs are needed for MTJs contained in device pillars (or bits) just tens of nanometers in diameter. These advances require tuning of the materials properties at the atomic scale as well as across arrays of millions of bits in a memory chip. I will describe the magnetic properties of MTJs that are essential for high performance MRAM, including perpendicular magnetic anisotropy, damping parameter, exchange constant, thermal stability factor, and TMR, and how to engineer these properties to deliver high spin-transfer torque efficiency and high data retention in spin-transfer torque MRAM devices [3],[4].

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Three dimensional spintronics: “Faster, higher, stronger”

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The expansion of spintronics to three dimensions provides exciting opportunities to explore new physical phenomena, opening great prospects to create 3D magnetic devices for future technologies [1]. To get full access to the rich phenomenology predicted to emerge when moving to 3D, we have developed a new framework for the “3D nano-printing” of materials using focused electron beam induced deposition [2], which enables the fabrication of complex-shaped 3D magnetic structures with sub-100nm resolution. Making use of this tool, in combination with advanced magneto-optical and X-ray magnetic microscopy methods, we are studying the controlled motion of domain walls along the whole space in 3D magnetic interconnectors, either via external fields [3] or geometrical effects [4]. We are also studying the magnetoelectrical signals generated in these devices, where the non-collinear configuration of magnetic states and electrical currents results in deviations from standard angular dependences normally obtained in planar devices [5]. I will also present our recent work on chiral effects in 3D helical geometries formed by interlaced nanowires, where exchange and dipolar interactions are balanced to result in a very rich phenomenology. The freedom provided to control magnetic effects in this type of geometries has been exploited to form chiral interfaces between domain walls of opposite chirality, allowing us to imprint topological spin defects at localized regions [6]. Furthermore, helical structures may also form strongly coupled domain wall pairs, which result in complex stray magnetic field configurations with topological features [7].

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