Institut für Physik

Physikalisches Kolloquium

Mittwoch, 22.06.2022, um 11:15 Uhr

HS 013, Hörsaalgebäude, Reichenhainer Str. 90 und online via ZOOM

Dr. Tiffany S. Santos

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

Biography

Tiffany S. Santos received her S.B. and Ph.D. degrees in Materials Science and Engineering from MIT. Her Ph.D. thesis was on thin-film magnetism and spin-polarized tunneling in magnetic tunnel junctions under the supervision of Jagadeesh Moodera at the Francis Bitter Magnet Laboratory, MIT. She is the Director of Non-Volatile Memory Materials Research in the research division of Western Digital Corporation in San Jose, California where she leads a team working on materials for magnetic random access memory technology and other exploratory projects. She first joined the company in 2011, when it was previously known as Hitachi Global Storage Technologies, to work on research of granular FePt media for heat-assisted magnetic recording. Prior to working in industry, she was a Distinguished Post-Doctoral Fellow, and later an Assistant Scientist, at the Center for Nanoscale Materials in Argonne National Laboratory, where she studied emergent phenomena at the interfaces of complex oxide heterostuctures. Dr. Santos has an active role in professional societies in the magnetism community. She is a 2022 Distinguished Lecturer of the IEEE Magnetics Society. She was the Program Co-Chair of the 2020 INTERMAG Conference, and she will be the General Chair of the 2025 Magnetism and Magnetic Materials (MMM) Conference in Palm Beach, Florida. In 2009, she was awarded the prestigious L'Oréal USA Fellowship for Women in Science.

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

Tiffany S. Santos, PhD
Western Digital Corporation
2022 IEEE Magnetics Society Distinguished Lecturer

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 magneto-resistance (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 material 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]. In addition, I will describe an innovative nanofabrication process for achieving dense arrays of MRAM bits with 50 nm full pitch [5].

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[2] J. S. Moodera, G.-X. Miao, T. S. Santos, Physics Today 63, 46-51 (2010).

[3] T. S. Santos, G. Mihajlović, N. Smith, J.-L. Li, M. Carey, J. A. Katine, B. D. Terris, J. Appl. Phys. 128, 113904 (2020).

[4] G. Mihajlović, N. Smith, T. Santos, J. Li, B. D. Terris, J. A. Katine, Appl. Phys. Lett. 117, 242404 (2020).

[5] L. Wan, T.-W. Wu, N. Smith, T. Santos, G. Mihajlović, J.-L. Li, K. Patel, N.D. Melendez, B. Terris, J.A. Katine, IEEE Trans. Magn. 58(5), 3400406 (2022).