Session 36: Nano Device Technology - Spintronic Devices and Applications
Wednesday, December 5, 1:30 PM
Continental Ballroom 1-3
Co-Chairs: Z. Chen, Purdue University
H. Fukutome, Samsung

1:35 PM - 2:00 PM
36.1 First experimental demonstration of a scalable linear majority gate based on spin waves, *F. Ciubotaru, G. Talmelli, T. Devolder*, O. Zografos, M. Heyns, C. Adelmann, and I. P. Radu, imec, *Univ. Paris-Sud*

We report on the first experimental demonstration of majority logic operation using spin waves in a scaled device with an in-line input and output layout. The device operation is based on the interference of spin waves generated and detected by inductive antennas in an all-electrical microwave circuit. We demonstrate the full truth table of a majority logic function with the ability to distinguish between strong and weak majority, as well as an inverted majority function by adjusting the operation frequency. Circuit performance projections predict low energy consumption compared to CMOS for large arithmetic circuits.

2:00 PM - 2:25 PM
36.2 Spintronic devices for low energy dissipation (Invited), *K. L. Wang, H. Wu, S. A. Razavi, and Q. Shao, University of California, Los Angeles*

Spintronic devices are considered as one of the best candidates for next-generation electronics to complement CMOS technology. First, we will briefly show the recent progresses on spintronic devices based on spin-transfer torque, spin-orbit torque and voltage-controlled magnetic anisotropy in reference to energy efficient applications. We will then discuss the recent progresses using antiferromagnets and topological insulators for applications in memory, logic and circuits. Finally, the new prospective of 2D materials for spintronic devices will be addressed.

2:25 PM - 2:50 PM
36.3 Room Temperature Highly Efficient Topological Insulator/Mo/CoFeB Spin-Orbit Torque Memory with Perpendicular Magnetic Anisotropy, *Q. Shao, H. Wu, Q. Pan, P. Zhang, L. Pan, K. Wong, X. Che and K. L. Wang, University of California, Los Angeles*

Spin-orbit torque (SOT)-MRAM is a promising candidate for future nonvolatile memory technology. Finding materials that have large SOT efficiency (ξ_{DL}) is critical for developing the SOT-MRAM. Topological insulators (TIs) have been shown to exhibit giant ξ_{DL} (>1) at room temperature. However, integration of high ξ_{DL} TIs with CoFeB with perpendicular magnetic anisotropy (PMA) at room temperature (RT) has not been achieved. In this work, we demonstrate a record-high ξ_{DL} (~2.66) in the (BiSb)2Te3 with PMA CoFeB and achieve magnetization switching with TI current density as low as $3x10^9 A/m^2$ at RT. For the first time, we propose to insert a light metal spacer between TI and CoFeB to achieve resistance matching and thus reduce write energy. We show that without insertion, TI/CoFeB show in-plane magnetic anisotropy but TIs show high ξ_{DL}, consistent with previous reports. We then insert a Mo spacer to achieve PMA at RT. We accurately determine the ξ_{DL} using both second harmonic method and MOKE for the first time. We investigate the SOT-driven switching and discover a memristor-like behavior in the TI/Mo/CoFeB.

2:50 PM - 3:15 PM
36.4 Scaled spintronic logic device based on domain wall motion in magnetically interconnected tunnel junctions, *E. Raymenants, D. Wan, S.Couet, O. Zografos,V.D. Nguyen, A.Vaysset, L. Souriau, A.*

Thiam, M. Manfrini, S. Brus, M. Heyns, D. Mocuta, D.E. Nikonov, S. Manipatruni*, I. A. Young*, T. Devolder** and I. P. Radu, imec, *Intel Corporation, **Univ. Paris-Sud, Univ. Paris-Saclay*

We present a scaled device based on magnetic domain wall (DW) transport for logic applications. The device consists of multiple magnetic tunnel junctions (MTJs) connected by the same magnetic free layer (FL). Magnetic domain walls are injected by spin-transfer torque (STT) at the input MTJs and are sensed by tunneling magnetoresistance (TMR) at the output MTJ after propagation through the FL. Logic functions can be built by merging several domain walls. By enabling real-time detection of long range DW transport, we demonstrate a spintronic component which can be used for either Boolean or non-Boolean logic.

3:15 PM - 3:40 PM

36.5 Binary and Ternary True Random Number Generators based on Spin Orbit Torque, *H. Chen, S. Zhang, N. Xu*, M. Song**, X. Li, R. Li, Y. Zeng, J. Hong, L. You, Huazhong University of Science and Technology, *University of California, Berkeley, ** Hubei University*

In this work, we have experimentally demonstrated the binary- and ternary- True Random Number Generators (B-TRNG and T-TRNG) based on the stochastic switching characteristics of the nano-scale Ta/CoFeB/MgO heterostructures with perpendicular magnetization anisotropy. For the first time, the random code generation utilizes the spin orbit torque (SOT) induced by current flowing in the heavy metal underneath the CoFeB layer. The 3-XOR post-processed binary random codes pass the NIST SP800-22 test. Furthermore, the T-TRNG provides a much higher security level as compared to the B-TRNG counterpart.