# High performance spintronic devices for microwave technology and computing

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In this talk, I will present recent advances achieved in the development of spintronic microwave detectors, oscillators and amplifiers based on magnetic tunnel junctions (MTJs). I will review the main applications of those devices for computing including the realization of Ising machines based on probabilistic computing with p-bits.
The spintronic technology takes advantage of the manipulation of the electron spin together with its charge. This technology potentially combines important characteristics such as ultralow power needs, compactness (nanoscale size) and it is CMOS-compatible. Spintronics has different success stories such as the head read for magnetic hard drive and the recent spin-transfer-torque magnetic random access memories. The latter are realized with MTJs which are devices composed by two ferromagnets separated by a ultrathin isolating material. The resistance of this device depends on the relative orientation of the magnetization of the two ferromagnets and in particular the configuration where the magnetization are parallel or antiparallel can code the binary information. Together with memory developments, which are already in the market and integrated within the CMOS processes by main foundries (INTEL, SAMSUNG, GlobalFoundries), MTJs can be used for the development of auto-oscillators and very high efficient detectors. In detail, I will show the applications of spintronic diodes based on MTJs for energy harvesting, sensors and RF detectors and what it is expected to achieve in the next three years for integration with CMOS-technology. I will also present, theoretical predictions on how voltage controlled magnetocrystalline anisotropy (VCMA) can be used to excite linear and parametric resonant modes in easy-axis antiferromagnetic materials AFMs with perpendicular anisotropy, thus opening the way for an efficient electrical control of the Néel vector, and for electrical detection of THz dynamics. In particular, I will focus on two key results: (i) VCMA parametric pumping experiences the so-called “exchange enhancement” of the coupling efficiency and, thus, is 1-2 orders of magnitude more efficient than microwave magnetic fields or spin-orbit-torques, and (ii) zero-field parametric resonance, which cannot be achieved by other parametric pumping mechanisms in AFMs with out-of-plane easy axis.
The latter part of the talk will focus on probabilistic computing which is one direction to implement Ising Machines. Probabilistic computing is a computational paradigm using probabilistic bits (p-bits), unit in the middle between standard bit and q-bits. I will show how to map hard combinatorial optimization problems (Max-Sat, Max-Cut, etc) into Ising machine and how to implement those in spintronic technology.

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**Biography of Invited Speaker**

Giovanni Finocchio received the Ph.D. degree in advanced technologies in optoelectronic, photonic and micromagnetic modeling from the University of Messina, Italy, in 2005. Since 2010, he has been an Assistant Professor first and Associate professor now with the Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences at the University of Messina. He is director of the laboratory PETASPIN (Petascale computing and Spintronics) at Messina. His research interests include spintronics, skyrmions, and computing (https://scholar.google.co.uk/citations?user=eKDbn-oAAAAJ&hl=en). In the last 10 years, he served on many technical program committees of international conferences and organized more than 10 international conferences and workshops as Chair, Program Committee Member, or in other positions. He is regularly invited at conferences in Magnetism and Spintronics. He is also president of Petaspin association (www.petaspin.com), AdCOM member of the IEEE Magnetics society, chair of the TC-16 on Quantum, neuromorphic and unconventional computing of the IEEE Nanotechnology council and past-chair of the IEEE Magnetics Italy chapter (2019-2022). Since 2022, he is also associate editor of Physical Review Applied (APS).