Scalable Synchronization of Spin Hall Nano-Oscillators

Proposers

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Introduction

Spin Transfer driven Nano-Oscillators have been attracting for some years the attention of the Spintronics community. This research topic combines a wealth of fundamental physics questions together with extreme challenges concerning materials optimization and device nano-fabrication. Furthermore, the potential for real world applications is very large and includes novel modulation/demodulation schemes with nanoscale devices, possible use for 5G communications, low power IoT communications and even more disruptive ideas such as true random number generation for hardware based cryptography and neuromorphic computation. In recent years, pure spin currents dissociated from electrical currents have been used to excite dynamics in ferromagnetic layers incorporated in magnetic tunnel junction stacks. This is an important step towards solving some of the standing issues that keep eluding researchers such as the demonstration of a scalable synchronization scheme that seems to be the only viable way of reducing the phase noise of these devices down to a level that truly enables practical applications. Addressing this issue is the objective of this PhD proposal.

Project outline/goal

Up to the present, there are only a couple of publications demonstrating MTJ based spin hall nano-oscillators. It was possible to demonstrate so far that pure spin currents can enable auto-oscillations and that the spin transfer torque associated with these pure spin currents can be combined with the torque from spin tunneling currents to enhance the auto-oscillations. Still, the output of spin hall nano-oscillators is still lower than that obtained from homogeneous nano-oscillators or vortex nano-oscillators and a lot of the progress accomplished in recent years on these more conventional oscillators still lacks demonstration on spin hall nano-oscillators. Despite all the challenges concerning fabrication, spin hall nano-oscillators are promising in what concerns the synchronization of a large number of oscillators because due to their particular geometry, it is possible to connect a very large number of oscillators in parallel and since the spin currents are not associated with tunneling currents, it is still possible to keep the impedance of the ensamble close to 50 Ohm by using large RxA tunnel barriers. The main objective of this PhD proposal is to make such a demonstration. To this end, the PhD candidate will develop his PhD work across two partner labs.

Partner 1 – INESC-MN

During 2019, INESC-MN will install a new deposition module in the Nordiko 3600 cluster tool which will enable the in-situ deposition of complex MgO stacks incorporating up to 14 different targets. The first task within this PhD proposal is to optimize the deposition conditions in the new tool aiming the production of high quality MgO MTJs with ultra-thin MgO barriers, meaning that they should approach the limit of RxA~1 Ohm um^2 while keeping a TMR>100% and approach a TMR of 200% for RxA>5 Ohm μm^2. Furthermore, in order to use these MTJ stacks as spin hall nano-oscillators, the stack should be inverted (free layer on bottom and pinned layer on top), with a high spin hall angle material such as Pt or β-Ta, in contact with the free layer. All this should be accomplished together with a strongly pinned reference layer keeping the reference direction under fields of up to 2000 Oe.

Partner 2 – INL

For the past years, INL has been producing spin hall nano-oscillators and has successfully demonstrated the ability to excite auto-oscillations with pure spin hall currents as well as the ability to combine spin hall currents together with tunnel currents to enhance auto-oscillations. The stacks optimized at INESC-MN will be nanofabricated at INL and characterized in the Radio-Frequency Laboratory. The masks used for the nano-fabrication process will enable the characterization of a large range of geometrical configurations and interconnection possibilities. The nano-pillar target size will range from 30nm (homogeneous spin hall nano-oscillator) up to 600nm (in an attempt to demonstrate that spin hall vortex nano-oscillators can also be produced).

System Integration – INL and INESC-MN

Once the wafer level functionalities of the synchronized arrays of nano-oscillators are demonstrated, a system level integration of the devices will be performed. The type of system to be used will depend on the particular advantages demonstrated by the ensembles of nano-oscillators. But at the very least, a low power frequency modulator/demodulator communication circuit using the spin hall nano-oscillators as DC->RF and RF->DC transductors should be performed. The performance of such system will have to be benchmarked with respect to state of the art IoT like communication modules.

Student profile

Profile sought: hard working and persistent student with an Engineering Physics background and experience in cleanroom Micro/Nanofabrication, programming and data acquisition circuit design.