Stage N° : 4

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Title

Magnetic memory with reduced write current thanks to microwave assistance

Keywords

Spin-electronics; Magnetic memory ; MRAM ; magnetic tunnel junctions; spin transfer torque

Summary

There is an increase interest in microelectronics industry for a new type of magnetic non-volatile memory which have been developed in our lab for more than 10 years called STT-MRAM. In these memories, the storage elements are nanopatterned magnetic tunnel junctions which consist of two ferromagnetic layers separated by a thin tunnel oxide barrier (MgO). The information (0 or 1) is encoded in the relative orientation of the magnetization of the two magnetic layers (Parallel=0; Antiparallel=1), the magnetization of one being pinned in a fixed direction (reference layer) while the magnetization of the other is switchable (storage layer) to reach the P or AP states. These memories are about to be introduced in products for consumer electronics.

Lot of applications (wearable applications such as smartphones, interconnected objects of Internet of Things, etc) require to minimize the electrical consumption, in particular of the memories, to extend the battery lifetime. In this internship, we propose to investigate a novel approach for reducing the energy conception for writing in the memory by assisting the switching of the magnetization of the storage layer thanks to a microwave produced by spin transfer torque. This spintronics phenomenon occurs when an electrical current traverses the magnetic tunnel junction and gets spin-polarized while flowing through the reference layer. It results in magnetic torques exerted on various layers of the magnetic tunnel junction stack yielding the switching of the storage layer magnetization with an energy cost of only a few tens of fJ. The internship will comprise simulations and experiments.

Details of subject

MRAM are non-volatile memories based on magnetic tunnel junctions (MTJ). MTJ consist of two ferromagnetic layers separated by a very thin MgO tunnel barrier (1nm thick). The information is encoded in the magnetic orientation of one of the layer (called storage layer) while the magnetization of the other layer remains fixed. When a current flows through the junction, the resistance depends of the relative orientation of the magnetization of the two magnetic layers (Parallel="0"=low resistance state; antiparallel="1"=high resistance state). This allows to electrically read out the magnetic state of the junction. During write, the magnetic state of the storage layer is switched by a phenomenon called spin transfer torque which results from the exchange interaction between the spin of the tunneling electrons and those responsible for the magnetization of the storage layer. SPINTEC played a leading role in the development of magnetic memories based on these structures which are now about to be widely adopted by the microelectronic industry. This interest is due to the unique combination of assets that no other types of memory gathers: non-volatility (i.e. ability to keep the information when the memory is powered off), relatively low power consumption, high density and almost unlimited write endurance (in contrast for instance to FLASH memories which can only be written 100 000 times). These memories are expected to be launched in volume production in 2018 for embedded memory applications used in consumer electronics.

For wearable applications (smartphones, interconnected objects of IoT, etc) but also for servers, high performance computing (HPC), reducing the power consumption of electronic circuits remains a major goal. We propose here to

investigate a novel write approach in magnetic MRAM which uses the phenomenon of spin transfer torque assisted by microwave. Spin transfer torque (STT) occurs when a spin polarized current is injected in a magnetic nanostructure. Due to the exchange interaction between the injected electrons and those responsible for the magnetization of the nanostructure, a torque is exerted on this magnetization which can have to effects: 1) a switching of the magnetization of the nanostructure, phenomenon already used as write scheme in STT-MRAM but leading to a relatively large power consumption during write , or 2) excitation of a steady precession of magnetization which can be used in spin transfer microwave oscillators.
The idea that we want to explore here consists in combining the two above mentioned effects to reduce the power consumption during write in MRAM. The principle consists in using magnetic tunnel junction stacks in which the switching of the storage layer by STT is assisted by the microwave produced by another layer whose magnetization is driven into precession by the same current flowing through the stack.

This internship which covers both fundamental and applied aspects, will comprise numerical simulations and experiments.
Based on the laboratory expertise in the field, we propose to first evaluate the proposed concept by numerical simulations. We will then grow the corresponding stacks by sputtering, characterize their magnetic and electrical properties at wafer level. We will then pattern the stacks in the form of nanometric pillars in our clean room and characterize their switching by spin transfer torque. The results will be benchmarked with the properties of the existing structures.
We hope that the internship will be pursued in a thesis. This would allow a thorough optimization of the stacks to minimize the write energy in views of wearable applications but also of fast switching memories such as non-volatile SRAM used as CACHE memories.

Requested skills
Basics in programming and magnetism

Possibility to follow with a PhD Yes