Spin transfer RF nano-oscillators for wireless communications and microwave assisted magnetic recording

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Slonczewski[1] and Berger[2] predicted in 1996 that a spin-polarized current flowing through a magnetic nanostructure exerts a torque on its magnetization due to the exchange interaction between the spin of the conduction electrons and the spin of the electrons responsible for the local magnetization. This torque is called spin transfer torque (STT). This effect was first experimentally observed in metallic spin-valve nanopillars and later on in magnetic tunnel junctions. The spin torque acts as a damping or antidamping term and can induce very peculiar magnetization dynamics. Of particular interest is when an applied field and the spin transfer torque (STT) have competing influence on the magnetization of the free layer of a spin-valve or of a magnetic tunnel junction, for instance the field favoring parallel alignment between the magnetization of the free layer magnetization and that of the reference layer whereas the STT favors antiparallel alignment. In such situations, the magnetization of the free layer is driven into steady state oscillations. The magnetization continuously pumps energy into the spin current to compensate the dissipation by Gilbert damping. These steady state oscillations combined with the giant or tunnel magnetoresistance of the stack generate oscillations of the voltage across the stack at GHz frequencies. Moreover the frequency varies as a function of the current density flowing through the stack.
This phenomenon can be used to design frequency tunable RF oscillators which could be quite useful in wireless communications as well as to assist writing by microwave emission in magnetic recording technology.

In this presentation, I will review our work on STT RF oscillators and describe the implementation of such oscillators in magnetic recording technology (Microwave Assisted Magnetic Recording).

At SPINTEC, a significant effort has been focused on a particular configuration of STT RF oscillators in which an out-of-plane magnetized polarizer is used to inject out-of-plane spin polarized electrons into an in-plane magnetized free layer. It was shown that this configuration in particularly interesting since it allows generating large angle precessional motion thereby maximizing the magnetoresistance signal associated with this motion[5]. In this configuration, the frequency varies almost linearly with current up to a maximum value where it saturates because of micromagnetic distorsion of the magnetization.

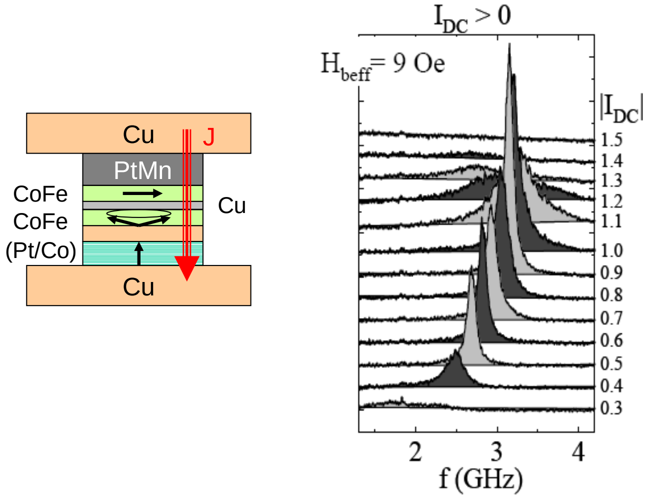

Figure1: STT oscillator with perpendicular polarizer and in-plane free layer. A fixed in-plane magnetized reference layer is added to produce a magnetoresistance between this reference layer and the precessing free layer. Typical spectra obtained when measuring the voltage between top and bottom electrodes.

Two important characteristics must be carefully addressed in such oscillators before being able to use them in RF devices for wireless communications. One is output power, the other is the excitation linewidth and associated phase noise.
By using magnetic tunnel junctions, the output power could be increased by 2 orders of magnitude thanks to the higher impedance of these systems.

By optimizing the structure of the stack and for instance using synthetic antiferromagnetic free layer, the linewidth could be also significantly reduced. I will discuss our work on these two topics.

Another area where these STT oscillators can be quite useful is the one of magnetic recording. The present technology of recording which consists in storing the information on granular media and switching the magnetization of the grains with a write head which is a tiny electromagnet is reaching a physical limit called the magnetic trilemma. This trilemma is caused by the impossibility to satisfy simultaneously i) a sufficient stability of the magnetization against thermal fluctuation, ii) a sufficient media signal to noise ratio and iii) the ability to write on the media with magnetic field which can be produced by the write head (close to 2T).
It was therefore proposed to assist the writing either with a temporary heating of the media (Heat Assisted Magnetic Recording: HAMR) or by microwave (Microwave Assisted Magnetic Recording: MAMR).

In MAMR a spin-transfer oscillator is inserted in the write gap of the head. This oscillator has also a perpendicular to plane polarizer combined with and in-plane magnetized free layer but no reference layer since the purpose is here to generate a RF field outside the pillar and not a RF voltage across the pillar. The precession of the free layer generates a rotating RF field outside the nano-oscillator pillar. This RF field penetrates into the media and transfer energy to the magnetization of the grains. This additional energy combined with the field from the write pole of the head allows the switching of the magnetization of the media.

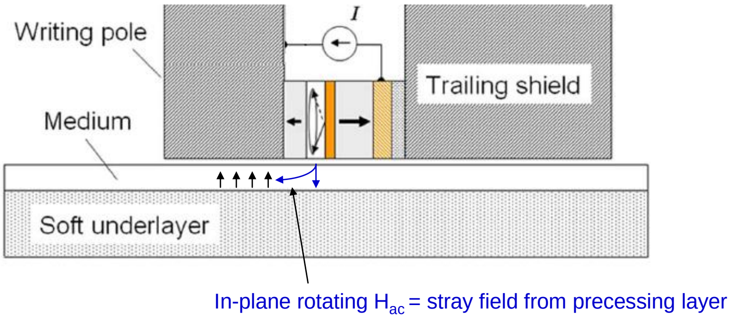

Figure 2: Schematic representation of the operation principle of MAMR.

I will describe the on-going effort around this technology.

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