ICAM2009

11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Zero field microwave emission in spin torque oscillators

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Abstract – We demonstrate for the first time current-driven microwave emission in nano-oscillators in both the nanocontacts and the nanopillar geometry for *zero* applied field. Zero field emissions are important for applicability of these nanomagnetic devices as miniaturized microwave oscillator in telecommunications where external magnets can typically not be used. Nanocontacts present a narrow sub-GHz dynamic vortex mode for currents above the nucleation threshold. In nanopillar devices processed from a MgO-based magnetic tunnel junction an auto-oscillation mode of the SAF system is found and its threshold under low biases is investigated. A strong and narrow 8 MHz-resonance is detected at 10.7 GHz.

Spin-polarized direct current has been employed efficiently as a high-frequency microwave generator in current confining magnetic devices.[1,2] The underlying effect is the spin-transfer torque, the transference of angular momentum from spin-polarized electrons to the local magnetization, when the threshold current density is exceeded. Spin-transfer torque is broadly applicable in the field of integrated microwave circuitry, such as: reference emitters, tunable oscillators and mixers. Here, we present *zero* field microwave emission in nano-oscillators fabricated in the nanocontact and nanopillar geometries.

In nanocontacts, the extended magnetic region in the bottom pinned exchange biased spin-valve is accessed via a *160 nm* metallic contact etched into a SiO_2 passivation layer. The free layer is a composite of $Co_{90}Fe_{10}$ *(1.5 nm) /* $Ni_{80}Fe_{20}$ *(2 nm)*. The vortex nucleation is induced while applying direct current and magnetic field perpendicularly across the magnetic stack, for values above a certain current-field threshold. At this point, the Oersted-Ampère field provides the necessary attractive potential for a vortex nucleation, whilst its orbital motion is driven by the spin-transfer torque[3]. The vortex dynamics provoke time-varying changes in the magnetization direction underneath the contact leading into voltage oscillations. Subsequent to nucleation, an onset of sub-GHz frequency peaks are observed for varying perpendicular magnetic fields (Fig. 1) under $I = 28$ *mA*. These oscillations are consistent with vortex dynamics since a monotonous blueshift in the oscillation frequency takes place while decreasing the magnetic field. Remarkably now, the excitation mode is resilient even at *zero* field with a total power above $600\ nV^2/Hz$ (bottom curve).

In addition, the nanopillar geometry has been studied. Ion beam etching is used to pattern *100x200 nm* sized nanopillars from low resistance-area product magnetic tunnel junction stack of $0.9\ \Omega.\mu m^2$. Fabrication details, magnetic composition and characterization have been described previously.[4] An estimate of the critical current threshold is $I = 1.5$ *mA*, exciting a resonance peak at *10.59 GHz* at zero field (Fig.2a). A strong non-linear enhancement in total power is observed when further increasing the current, combined with a decrease in linewidth to *8 MHz*. The main peak is believed to be the optical mode of the synthetic antiferromagnet from the current convention. Furthermore, full range field-dependent scans in the easy (Fig. 2b) axis direction qualitatively agree with simulations of eigenmodes in the SAF subsystem excluding a free layer mode.[5] In conclusion, we have demonstrated that zero field auto-oscillations in nanocontacts and nanopillars are possible; however have a very distinct origin.

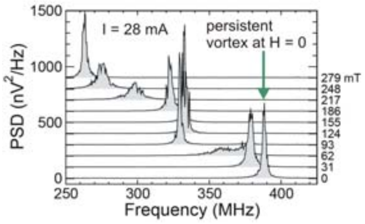

Figure 1: Voltage noise spectra for decreasing H⊥ magnetic field. The hopping frequency behavior is possibly related to changes in the vortex orbit.

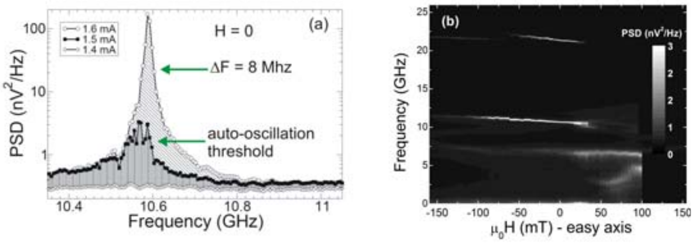

Figure 2: (a) Power spectral density (PSD) evidencing the oscillation threshold at *zero* field. **(b)** Color map of the PSD in function of the magnetic field along the easy axis, showing frequency emission at zero field.

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