Large power emission in MTJ based spin torque nano-oscillators using a free layer near the in-plane to out-of plane transition

M. Tarequzzaman, J. D. Costa, J. Borme, M. Gonzalez-Debs, B. Lacoste, E. Paz, S. Serrano-Guisan, R. Ferreira and P. Freitas.
INL-International Iberian Nanotechnology Laboratory, Avenida Mestre Jose Veiga,
4715-330, Braga, Portugal
tareq.zaman@inl.int

Spin torque nano-oscillator (STNO) explore dynamic magnetic effects induced in the free layer of magnetoresistive devices induced by spin polarized currents. Soon after its discovery, STNO draw much attention to the researchers because of its advantages over conventional CMOS oscillators. The advantage of STNO covers, simple structure, smaller footprint (<200nm), high frequency tunability, large frequency (2-20 GHz range oscillations depending on magnetic field), low cost and good compatibility with the standard complementary metal oxide semiconductor (CMOS) technology.[1-3] However several challenges need to be addressed before STNOs are to be used in practical purpose. As it has critical disadvantages in terms of lower output power and relatively large linewidth in comparison with voltage controlled oscillators (VCOs).[4]

The power generation of STNO depends on several factors; resistance change induced by the magnetoresistance (MR) effect in the magnetization oscillations is one of them. Therefore, MgO based magnetic tunnel junctions (MTJs) with higher MR ratio (>50%) deliver larger microwave signals than metallic oscillators with lower MR ratio (<10%).[3] In addition to this, another requirement for a large power emission is the excitation of large-amplitude oscillations. To this end, several configurations for the magnetization of the free and pinned layer have been proposed.

In this work, MTJ stacks (50 Ta/ **X** $CoFe_{40}B_{20}$/MgO [3.0 Ohm-µm^2]/2.2 $CoFe_{40}B_{20}$/0.85 Ru/2.0 $CoFe_{30}$/20 IrMn (Thickness in nanometer) with an MgO barriers have been deposited using a Singulus TIMARIS PVD system. The free layer thickness (**X**) was changed between 2.0nm (free layer magnetization in plane) down to 1.0nm (free layer magnetization perpendicular to plane). These stacks were then patterned into nanopillars with different shapes (circular and elliptical) and dimension (50 nm to 200 nm in diameter) by electron beam lithography and ion milling technique.

The nano-pillars have been measured in a radio frequency transport measurement setup at room temperature. It is found that a large power output with a small linewidth is obtained in nano-pillars with a free layer thickness of 1.4nm which still have an in-plane magnetization but right at the transition to out-of-plane magnetization, i.e., the in-plane free layer experiences a very strong perpendicular anisotropy contribution.

An example of such measurements is shown in Fig. 1.a. for a pillar with circular shape and 150nm diameter. The result, show in Fig. 2, displays microwave signals with maximum power of 300 nW and narrow linewidth as small as 30 MHz. These STNOs operate with frequencies in the range between 2.4-2.8GHz .The large power output and narrow linewidth of these nano-oscillators make them good candidates for integration with CMOS circuits such as new generation Phase-Locked-Loops (PLLs).

References:

[1] Z. Zeng, G. Finocchio, B. Zhang, P. K. Amiri, J. A. Katine, I. N: Krivorotov, Y. Huai, J. Langer, B. Azzerboni, K. L. Wang, and H. Jiang, Sci. Rep. 3, (2013) 1426
[2] S. I. Kiselev, J. C. Sankey, I. N. Krivorotov, N. C. Emley, R. J. Schoelkopf, R. A. Burman, D. C. Ralph, Nature. 425, (2003), 380–383.
[3] Z. Zeng, P. K. Amiri, I. N. Krivorotov, H. Zhao, G. Finocchio, J.-P. Wang, J. A. Katine, Y. Huai, J. Langer, O. K Galatsis, K. L. Wang, and H. Jiang, ACS Nano 6, (2012) 6115–6121
[4] H. S. Choi, S. Y. Kang, S. J. Cho, I. Y. Oh, M. Shin, H. Park, C. Jang, B. C. Min, S. Kim, S.Y. Park, C. S. Park, Sci. Rep. 4, (2014) 5486

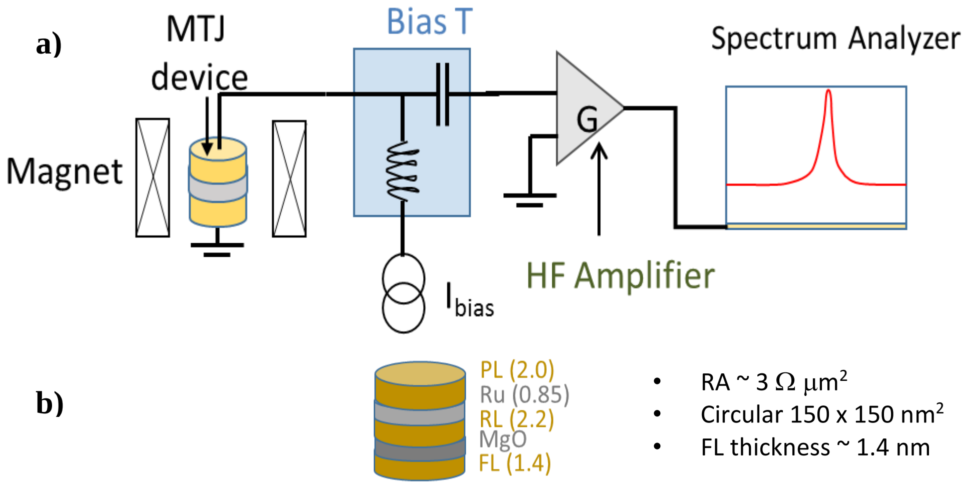

Figure1: a) Illustration of radio frequency (RF) measurement setup. **b)** The measured MTJ stack and nanopillar dimension.

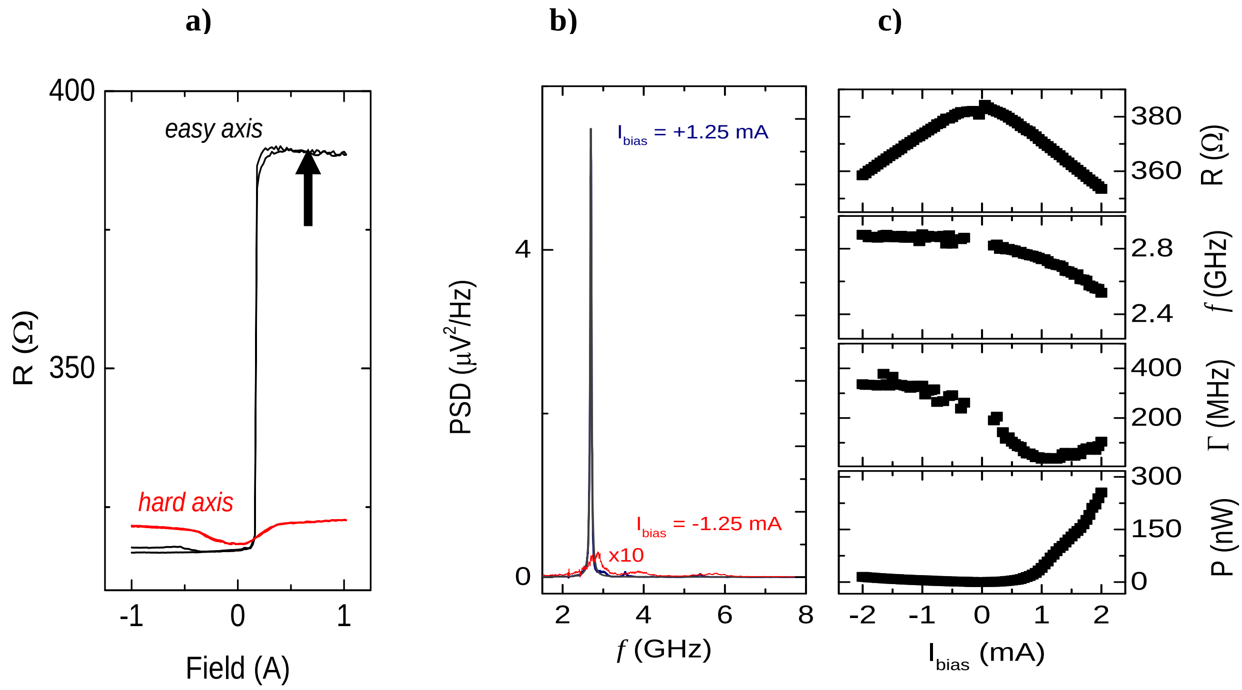

Figure2: a) Transport measurement (two contact measurement) in easy and hard axis. The arrow indicating the RF measurement point b) Microwave emission spectra measured in positive bias currents (Black spectrum) and negative bias currents (Red Spectrum). c) Shows the results, in terms of power emissions, linewidth, frequency tunability and resistance.