HYBRID MAGNETORESISTIVE/MEMS DEVICE FOR 1/F NOISE REDUCTION

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It was previously shown that it is possible to suppress 1/f noise in spin valve (SV) sensors, by modulating an external DC magnetic field at high frequency through the movement of a MEMS cantilever with an incorporated magnetic flux guide[1]. This shifts the operating frequency and enables the detection of DC magnetic fields in the high frequency thermal noise regime, where the 1/f noise is typically 2 orders of magnitude lower.

In this work we present a hybrid magnetoresistive/MEMS device, where MgO based magnetic tunnel junction (MTJ) and MEMS torsionators are used, allowing a DC field detection limit of 27 $nT/Hz^{1/2}$ and improving the MEMS magnetic field modulation efficiency to 20 %.

MgO based MTJ sensors were deposited in an automated sputtering machine with the following structure: Glass/Ta[50] / Ru [180] / Ta [30] / MnPt [200] / CoFe [20] / Ru [9] / CoFeB [30] / MgO [15] / CoFeB [15.5] / Ru [50] / Ta [50] / TiW(N2) [150], (thickness in Å). The TMR ratio was 30 %. The MTJ sensors were patterned down to a dimension of 1.5x15 μm^2. A 4000 Å thick CoZrNb flux guide concentrator was patterned close to it, to convey and focus the external field to the sensor area. Finally, after passivating the sensor with an oxide layer, a 30x20 μm^2 MEMS torsionator was fabricated with a double layer of a-Si:H (4000 Å)/Al (1000 Å) and an additional 2000 Å thick CoZrNb flux guide. The MEMS torsionator is actuated by a gate electrode at frequency *f*, causing it to oscillate at 2*f*. This oscillation produces a 2*f* AC magnetic field, which is read by the MTJ in a spectrum analyzer. Fig.1 shows a SEM micrograph of the integrated device and a cut view diagram.

Noise measurements in the 2 kHz – 500 kHz range were performed in the MTJ sensor. For a bias a current $I = 10^{-5}$ A and at 500 kHz (close to the thermal noise background) the magnetic field detection limit is $S_B^{SV} = 4\ nT/Hz^{1/2}$

With this MTJ-MEMS hybrid device the minimum detectable DC field is given by:

$$B_{detect} = S_B \,/\, e_{tors} \qquad (1)$$

where S_B is the MTJ noise in $T/Hz^{1/2}$ at the modulation frequency, and e_{tors} the magnetic modulation efficiency of the MEMS torsionator.

Figure 2 shows the MTJ output, when the MEMS gate is actuated by a 20 V_{pp} AC signal at 230 kHz . The MEMS torsionator oscillates at 460 kHz. For a DC external field B_{ext} = 0.36 mT entering the flux guide, the MTJ sensor detects the generated AC field at 460 kHz, showing a magnetic output of 240 μV/Hz$^{1/2}$.

The MEMS torsionator modulation efficiency (e_{tors}) was calculated and found to be 20 %. Putting this together with the noise of the MTJ sensor at this frequency – S_B^{SV} (4.4 nT/Hz$^{1/2}$ at 460 kHz) we can estimate from Eq. (1) the DC detection limit of this hybrid-device, B_{detect} = 27 nT/Hz$^{1/2}$.

Further work is being developed, mainly to reduce the thermal noise in the MTJ sensors, so that its further integration in this hybrid-device would lead to pT DC field detection.

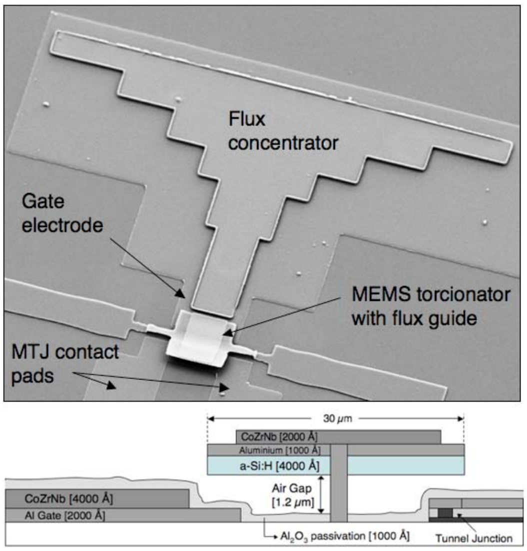

Figure 1

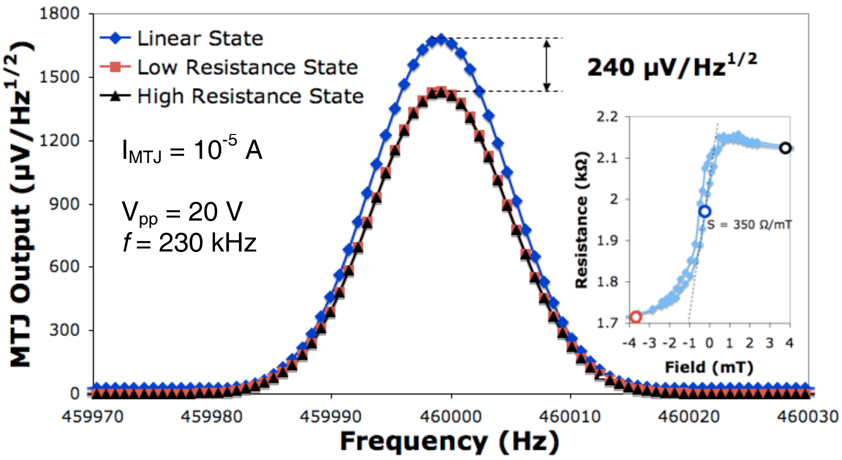

Figure 2

References:

[1] A. Guedes, S.B. Patil, S. Cardoso, V. Chu, J. P. Conde, P. P. Freitas, Jour. Appl. Phys. (*in press*) 2008.