Low noise magnetic tunnel junctions for field sensors application

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PhD may follow: Yes

Summary :

Magnetic field sensors are currently widely developed in particular for low-consumption miniaturized devices. For such applications, magnetic tunnel junctions may become highly competitive compared to other technologies such as Hall effect sensors for example. Magnetic tunnel junctions are composed of two ferromagnetic electrodes spaced by a tunnel barrier. Their resistance varies as a function of the relative orientation of the electrode magnetizations. These devices are already used as hard-disk read-heads and could be used as low magnetic field sensors for many other applications. The crucial issue for low frequency applications is to lower the junction noise, in particular 1/f noise. Therefore the start-up Crocus-Technology just launched collaboration with our lab for getting a better insight into the physical origin of noise and finding ways to reduce it. Noise measurements will be performed at various voltage biases and for different applied fields. A special care will be devoted to the data quality and to the physical interpretation of the results.

Full description :

Magnetic field sensors are currently widely developed in particular for low-consumption miniaturized devices. For such applications, magnetic tunnel junctions may become highly competitive compared to other technologies such as Hall effect sensors for example. Magnetic tunnel junctions are composed of two ferromagnetic electrodes spaced by a tunnel barrier. Their resistance varies as a function of the relative orientation of the electrode magnetizations. These devices are already used as hard-disk read-heads and could be used as low magnetic field sensors for many other applications. The crucial issue for low frequency applications is to lower the junction noise, in particular 1/f noise. Therefore the start-up Crocus-Technology just launched collaboration with our lab for getting a better insight into the physical origin of noise and finding ways to reduce it.

In magnetic tunnel junction, noise has different physical origins:

- Johnson noise, due to thermal agitation of electrons, which power spectral density is proportional to the electrical resistance.
- Shot-noise, which is related to electron statistical crossing of the tunnel barrier and is independent of temperature; depending on the bias voltage, a crossover between Johnson noise and shot noise is observed.
- 1/f noise from magnetic origin: any magnetization fluctuation (either by coherent rotation or by any change of the micromagnetic structure) influences the device resistance and thus produces resistance noise.
- 1/f noise from electric origin: charge/discharge mechanism in the tunnel barrier induces also resistance noise.

At Spintec laboratory, we showed that this charge/discharge mechanism contributes to the tunnel barrier ageing and finally induce oxide breakdown [1]. In particular, we demonstrated that the more reliable junctions are also the less noisy ones [2]. However, we have no means to foresee what will be the noise level of a given junction. The influence of materials, thicknesses, microfabrication processes and annealing is mostly unknown. Our aim is to answer some of these questions thanks to systematic noise measurements and a thorough physical analysis.

[1] Appl. Phys. Lett. 99, 083501 (2011) ; J. Phys. D: Appl. Phys. 45, 295002 (2012).
[2] Appl. Phys. Lett. 102, 052404 (2013)

Requested skills :

Instrumentation and measurement, notions of statistical physics