Ultimate scalability of STT-MRAMs with perpendicular shape anisotropy

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PhD may follow: Yes

Summary :

Most of the STT-MRAM development effort is nowadays focused on out-of-plane magnetized MTJ taking advantage of the perpendicular magnetic anisotropy (PMA) arising at magnetic metal/oxide interface, a phenomenon discovered at Spintec in 2002. This interfacial anisotropy allows to conciliate large anisotropy required to insure a sufficient retention of the memory together with low switching current density thanks to weak spin-orbit coupling. However it is difficult to achieve 10 year retention up to 100Â°C using only this interfacial perpendicular anisotropy in sub-20nm devices. This imposes to use very thin CoFeB magnetic layers (sub 1.4nm) which exhibit enhanced Gilbert damping and reduced TMR. For deeply sub-20nm nodes, new materials with large bulk PMA and low damping still have to be found such as Heusler alloys. Furthermore, because this PMA is an interfacial effect, it is very sensitive to the structural and chemical properties of the magnetic metal/MgO interfaces. With conventional patterning technique, these interfaces can be affected during etching leading to additional dot to dot variability.

Full description :

To solve these problems in very small feature size STT-MRAM, we propose to use MTJ stacks in which the storage layer anisotropy is uniquely controlled by its out-of-plane shape anisotropy i.e. by giving the storage layer a cylindrical shape with large enough aspect ratio (thickness/diameter typically >1) so that for a purely magnetostatic reason, the storage layer magnetization will point out-of-plane. This innovative approach has several advantages: i) It provides a very robust source of PMA, much less sensitive to defects than the interfacial PMA; ii) it makes possible the use of well-known easy to grow materials with low damping such as Permalloy (Ni80Fe20 in combination with CoFeB next to MgO) iii) it provides a scalable approach since the same material could be used at all sub-20nm nodes thus removing the need to find new material with higher anisotropy at each node. To develop these PSA-MRAM (Perpendicular Shape Anisotropy-MRAM), the student will: i) conduct micromagnetic simulations to investigate the micromagnetic state of these thick out-of-plane magnetized storage layers, adjust their aspect ratio to insure the specified retention and investigate their switching behaviour under STT; ii) evaluate the dependency of the damping coefficient as a function of the thickness of the magnetic storage layer. The student will measure first thin films with various thicknesses either CoFeB or CoFeB/Ta/CoFe adapted at MgO based magnetic tunnel junctions stacks iii) Evaluate the feasibility of the proposed concept as a function of the expected variability of the fabrication process (lateral size, ellipticity, thickness). This study will be first performed by micromagnetic simulations and will be compared afterwards to experimental results on patterned pillars.

This study can be continued by a PhD.

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Requested skills :

solid state physics, magnetism