Ultrafast MRAM concepts for cache applications

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Magnetic memories based on magnetic tunnel junctions, called Spin-Transfer-Torque Random Access Memories (STT-MRAM), are stimulating a considerable interest in microelectronics thanks to their combination of assets: non-volatility, density, speed, endurance. In this work, new flavors of these memories were developed allowing ultrafast (sub-ns) writing suitable for cache SRAM-type of applications. A problem encountered in conventional STT-MRAM upon writing is that the STT is proportional to MSto^MRef. As a result, departing from an equilibrium state P or AP, the STT is initially zero and one has to wait for a sufficiently strong thermal fluctuations for the STT to become large enough to trigger the magnetization reversal. This slows down the writing process due to the stochasticity of the magnetization switching. To circumvent this issue, we proposed [1] to sandwich the in-plane magnetized storage layer between two polarizing layers of orthogonal magnetizations, one magnetized in-plane as in conventional STT-MRAM, the other magnetized out-of-plane. Thanks to the STT created by the perpendicular polarizer, the STT is non zero from the very onset of the write current pulse. This triggers the magnetization reversal without having to rely on thermal fluctuations. However, the STT from the perpendicular polarizer tends to induce a processional dynamics of the storage layer magnetization and therefore an oscillatory probability of switching versus pulse duration. Controlling the final written state requires to control the pulse duration with a high accuracy of ±50ps which is very difficult to achieve at chip level. Therefore, the relative STT contributions from the two polarizers must be properly tuned to achieve an accurate control of the written final state. We demonstrated that this can be achieved by properly adjusting the MTJ cell aspect ratio [2]. Finally, other high speed strategies, based on the use of second order anisotropies or spin will be also described. Second order anisotropy resulting from spatial fluctuations of 1st order anisotropy can namely help increasing the switching speed and reduce stochasticity of the switching.

[1] O. Redon et al, patent US 6.532.164B2.

[2] B. Lacoste et al, Phys. Rev. B 90, 224404 (2014).