# THIN FILMS AND MULTILAYERS FOR SPINTRONICS DEPOSITED BY HYBRID CVD-ALD PROCESS

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Spin-based electronics (spintronics) is receiving significative interest, as it offers possible attractive solutions for the future information technology market [1]. Among the most competitive options for replacing and/or integrating the currently used non-volatile memories, the magnetoresistive random access memory (MRAM) is very promising. The core element in MRAMs is the magnetic tunnel junction (MTJ) [1]. Typically a MTJ consists of two ferromagnetic (FM) layers acting as electrodes separated by an oxide tunnel barrier: the magnetization of the soft electrode consitutes the storage information. Reading process is achieved through the sensing of two different perpendicular-to-plane resistances in the MTJ stack, depending on the relative orientation of the electrodes magnetization, parallel or anti-parallel configurations (tunnel magnetoresistance effect). The interest that major companies are manifesting in MRAMs motivates the development and optimization of thin films deposition methods capable of growing smooth, uniform and conformal FM layers and oxides for their inclusion into functional spintronic devices. We show our recent research efforts towards the use of hybrid atomic layer- and chemical vapour- deposition (ALD/CVD) methods for the fabrication of MTJs. We developed a simple, efficient, and cost effective deposition chamber for the growth of the FM films such as Co and magnetite ($Fe_3O_4$), by employing $Co_2(CO)_8$ and $Fe_3(CO)_{12}$ carbonyls precursors, while a conventional ALD reactor was used for the deposition of thin MgO films, in such a way that the fabrication of $Fe_3O_4$/MgO/Co stacks was achieved. We investigated the structure, microstructure, morphology, chemical profiling, contaminations and magnetic behaviour of selected Co, $Fe_3O_4$ films and $Fe_3O_4$/MgO/Co structures, by means of time of flight secondary ion mass spectroscopy (ToF SIMS), X-ray diffraction (XRD), X-ray reflectivity (XRR), conversion electron Mössbauer spectroscopy (CEMS), and superconducting quantum interference device (SQUID) magnetometry. X-rays measurements evidenced that our films have low surface and interface roughness, within few nanometers, and are in $Fe_3O_4$ poly-crystalline phase. ToF-SIMS profiled homogeneous and uniform $Fe_3O_4$ and Co films with negligible carbon contaminations. CEMS measurements focused on the structural and magnetic properties of the magnetite films at the atomic scale, evidencing the presence of two characteristic magnetically-split sextets related to the tetrahedral A site and the octahedral B site, characteristic of bulk magnetite. The theoretically predicted half-metallicity of magnetite, the notable difference in the coercivity values of the Co and $Fe_3O_4$ FM electrodes and the overall good quality of the as deposited films and multilayer, suggest that the $Fe_3O_4$/MgO/Co stack, as produced by the ALD/CVD method, is promising for the fabrication of well-performing MTJs. We also explored the magnetotransport properties of selected magnetite films in an applied field up to 1.1 T using conventional two probe setup, showing magnetoresistance values up to 2.4 % at the maximum field.

[1] C. Chappert, A. Fert, and F.N. Van Dau, Nature **6**, 813 (2007).