Influence of the evaporation temperature on the structural properties of epitaxial Fe_3O_4 films evaporated on $SrTiO_3$/Si

Iciar Arnay[a,b] (arnayort@esrf.fr), Juan Rubio-Zuazo[a,b], Min-Hsiang Mark Hsu[c,d], Ziyang Liu[c,e] ,Aida Serrano[a,b], Clement Merckling[c], German R. Castro[a,b]

(a) BM25-SpLine, ESRF (European Synchrotron Radiation Facility), 71 Avenue Martyrs, 38000 Grenoble, France
(b) ICMM-CSIC (Instituto de Ciencia de Materiales de Madrid), Ciudad Universitaria de Cantoblanco, 28049 Madrid, Spain
(c) imec, Kapeldreef 75, 3001 Leuven, Belgium
(d) Photonics Research Group, INTEC, Ghent University imec, 9000 Gent, Belgium
(e) Department of Metallurgy and Materials Engineering, KU Leuven, 3001, Leuven, Belgium

Spintronic offers a new range of possibilities for new semiconductor-based data processing and memory applications. The successful application of this technology relies on the efficient injection of spin-polarized electrons into a semiconductor host material, and one of the biggest challenges is to find systems were the spin information is preserved. The large impedance mismatch existent between ferromagnetic materials and semiconductors is one of the limiting factors on the spin injection. It has been proved that the use of a spin-dependent resistive tunnel barrier can circumvent this problem. In addition, the use of half-metal sources as magnetite can also increase the efficiency of the system by increasing the spin polarization on the source. Due to its particular electronic band structure this materials are predicted to present 100% spin polarization. However the functionality and magnetic response of the source is highly related with its structural properties, which can be strongly modified when preparing the material in a thin film form. Because of this, a deep characterization of the structural properties of the heterostructure can be really useful to understand its magnetic behavior and the causes that reduces the efficiency of the system.

Within this context, we have successfully prepared Fe_3O_4/$SrTiO_3$/Si heterostructures. In a first stage, crystalline single oriented $SrTiO_3$ films were evaporated on Si (100) substrates by MBE. Later, epitaxial Fe_3O_4 films were deposited by PLD on the $SrTiO_3$/Si system. Samples were prepared at different evaporation temperature in order to optimized evaporation conditions to get the best compromise between the Fe_3O_4 films quality and the $SrTiO_3$ stability. A wide characterization of the structural properties of the system was performed by synchrotron based techniques: X-ray Absorption Spectroscopy (XAS), X-ray Diffraction (XRD) and X-ray Reflectivity (XRR). Preliminary magnetic measurements were also performed by Magneto-optical Kerr effect (MOKE)

Even though the tunnel barrier is desired to be as thin as possible, during the study the presence of chemical diffusion and modification of the $SrTiO_3$ structure was observed for thickness lower than 10 nm if the evaporation temperature was higher than 350°C. When evaporating at this temperature single phase magnetite films were successfully evaporated keeping flat interfaces and without formation of mixed phases at the interface even for ultrathin $SrTiO_3$ films (5 monolayers). For $SrTiO_3$ films with thickness above 10 nm the evaporation temperature can be increased without compromising the stability of the tunnel barrier but we observed the formation of iron metallic phases on the magnetite films for evaporation temperatures higher than 600°C. In addition, not relevant influence of the temperature on the quality of the magnetite films was observed.

$Fe_3O_4/SrTiO_3/Si$ heterostructures were successfully prepared without intermixing of the layers and achieving high quality interfaces even for ultrathin tunnel barrier thickness. The evaporation temperature must be kept under 350°C in order to work with ultrathin $SrTiO_3$ layers. In the same way, no relevant impact of the evaporation temperature on the magnetite films quality was observed in terms of crystalline orientation and domain size. Magnetite films also present a ferromagnetic behavior at room temperature.

This work has been supported by the Ministerio Español de Economia, Industria y Competitividad (MINECO) through the projects PIE-2010-OE-013-200014 and MAT2012-38045-C04-03. The ESRF, MINECO and CSIC are acknowledged for the provision of synchrotron radiation facilities.