FABRICATION OPTIMIZED SUB-40NM PLANAR PATTERNING PROCESS FOR A FULLY SPIN-POLARIZED MAGNETIC MEMORY

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Due to their large spin polarisation, ferromagnetic oxides, such as $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), Fe_3O_4 and CrO_2, are promising materials for spin-electronics and can be used as injectors of spin-polarised electrons in magnetic memories. Also, their peculiar transport properties across interfaces, like tunnel junctions [1] and domain walls [2] allow an enhancement of the magneto-resistive (MR) response at low fields. We have recently proposed a new concept of a planar magnetic memory element, in which nanokinks are introduced at a nanometer scale using 30 keV electron beam lithography (EBL) and ion beam etching (IBE). Constrained domain walls are shown to be pinned by the nanokinks producing large and sharp resistance switches under magnetic field. The challenge is thus to pattern and to etch these highly polarized half-metallic oxides in a sub-50 nm range [3-4].

This paper focuses on two different planar processes, that allow to generate nano-kinks in 40 nm-thick LSMO oxide films. The first process is based on the high resolution positive (polymethacrylate) PMMA resist followed by an Al lift-off, and the second one is based on the negative HSQ FOX resist, that will act as the mask during IBE.
For the first process, it will be demonstrated that sub-40 nm wide nanokinks can be patterned in routine in the LSMO film taking advantages of the proximity effects. These proximity effects in PMMA were studied as a function of the geometry of the kink, as described in the figure 1. The best geometry for the nanokink corresponds to both triangular and rectangular-shape patterns. After development, the kink has the appearance of a small resist bridge in suspension over the LSMO surface and this fragile nanobridge will act as a mask during the Al evaporation. The optimized geometry (Fig.1a) produces the strongest nanobridge that sticks on the LSMO surface. The strength of such sticking 40nm-wide nanobridge has been confirmed during the Al lift-off, since the lateral width of the transferred in Al kink approaches the measured value after development (Fig.1b).
A second process based on the negative HSQ FOX e-beam resist has been developed for two reasons. First, if Al has an advantage of being an hard mask for the manganite LSMO etch, its removal uses basic solutions that always damage the LSMO surface and alter the magnetic properties. Secondly, Al bubbles are more often present, producing non-smooth surfaces after etching (see Fig. 1b). Because the FOX cannot be easily removed, we have performed tests on FOX (500nm)/PMMA(50nm) bi-layers for studying both proximity effects and high resolution (Figure 2). The importance of both prebake annealings (at 150 °C and at 220 °C) and development parameters will be discussed.

References:

[1] J. Sun et al, Appl. Phys. Lett. 69, 3266 (1996), Y. Lu et al, Phys. Rev. B 54, R8357 (1996)
[2] N. Matthur et al, J. Appl. Phys. 86, 6287 (1999)
[3] A.M. Haghiri-Gosnet et J-P. Renard, J. Phys. D: Appl. Phys. **36** (2003) R127
[4] J. Wolfman, A.M. Haghiri-Gosnet et al, J. Appl. Phys. 89 , 6955 (2001)

Figures:

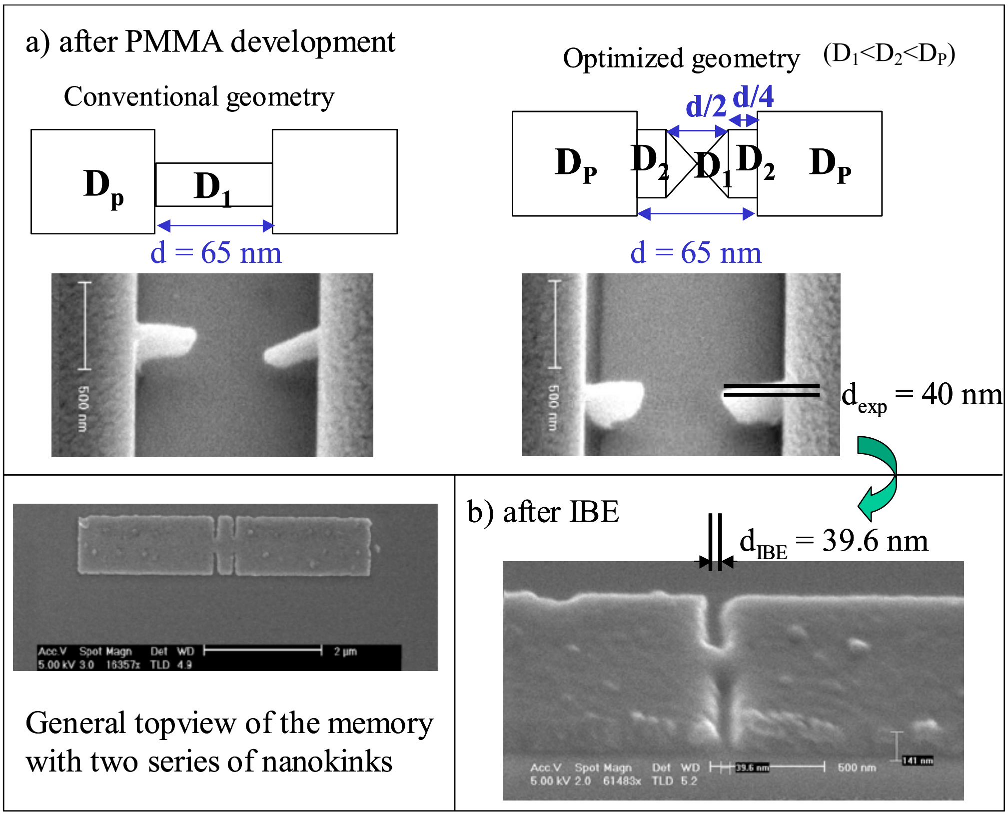

Figure 1 : SEM tilted images of PMMA 40nm-nanokinks (a) after development and for two different geometries, (b) after both Al lift-off and Ar IBE steps (a top view of the general magnetic nano-memory is also presented). Note that Al has not been removed and some bubbles remain on the top surface.

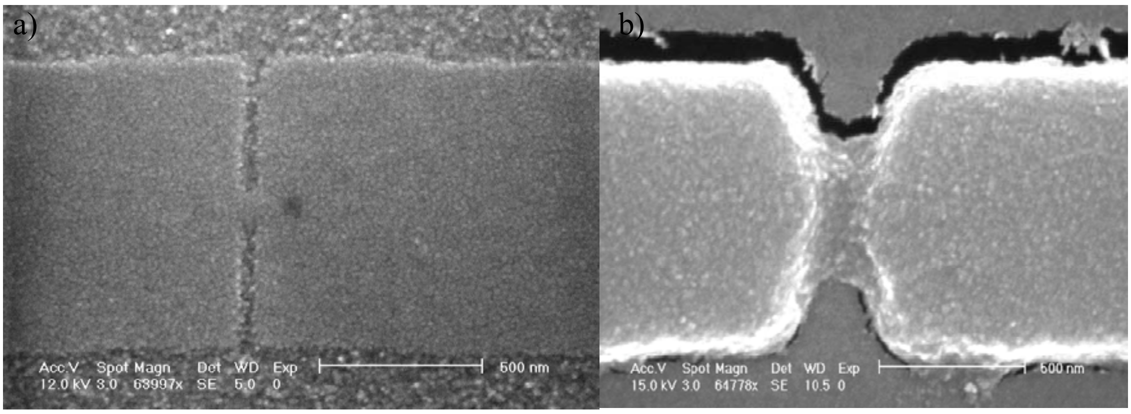

Figure 2 : (a) SEM top view of a 50nm-wide nanokink obtained in the bilayer FOX/PMMA after development of the FOX resist using the conventional geometry, (b) SEM image of a second type structure for the study of proximity effects on large distances (the distance between the two insulated regions is about 250nm).