MAGNETIC PROPERTIES OF COBALT NANODEPOSITS CREATED BY FOCUSED ELECTRON BEAM INDUCED DEPOSITION

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The **local deposition of materials using a focused electron beam in the presence of a gas precursor (FEBID)** is a well-known technique used for the mask-less fabrication of structures with nanometer resolution, with a wide range of applications [1]. The possibility of growing nanometric magnetic materials is especially attractive, since it widens the applications to fields such as magnetic storage or magnetic sensing, among others. However, long-standing problems exist for this kind of deposits, associated with the, in general, organo-metallic nature of the precursor gas. The low efficiency of the process for decomposing the precursor molecules gives as a result a predominant C-content composition, with low metallic percentages. As a result, the electrical transport properties show non-metallic behaviour, with resistivities orders of magnitude larger than the bulk value [1].

In this contribution we characterize magnetically **Co nanowires** (NWs) created by FEBID by means of magnetotransport measurements [2], as well as by spatially resolved magneto-optical Kerr effect (MOKE) [3].

By magnetotransport measurements of individual NWs, together with EDX analysis, we have studied the importance of the growth conditions in the quality of the NWs, finding that at high beam currents (figure 1a), the deposits are highly pure (around 95% of atomic cobalt) and their resistivity is about 40 μΩcm at room temperature, with metallic temperature dependence. Magnetoresistance (MR) measurements in different configurations are used to study how the magnetization (M) is aligned in the NWs (see insets figure 1). We find that the shape anisotropy dominates the direction of M. Coherent rotation seems to be the mechanism for reversal when the field is applied perpendicular to the NW axis and the substrate plane, because of the NW dimensions. From the saturation field in this configuration we deduce a saturation magnetization value of 1329±20 emu/cm^3, very close to the bulk value of pure Co. We have studied in detail other aspects of the magnetism of the NWs by measuring the Hall effect and the Planar Hall effect as a function of temperature. Similar magnetotransport properties have been previously observed in polycrystalline Co NWs fabricated by Electron Beam Lithography [4], demonstrating the high quality of these FEBID structures. These high quality properties sharply contrast with NWs grown at lower beam currents (figure 1b), with resistivities 300 times larger at room temperature, semiconducting behaviour, and MR ratios one order of magnitude smaller than those found for the nanowires grown under high currents. We associate the important differences found as a function of the beam with a heating effect process during deposition, a crucial point in FEBID processes [1].

We have also studied the domain wall (DW) conduit properties of FEBID-Co NWs [5], i.e., the possibility to displace DWs at much lower magnetic fields than are needed to nucleate new domains. Controlling the switching of nanometer sized elements is the subject of intense research due to their potential applications in fields such as spintronic logic [5] or DW based memory devices [6]. Most of the work to date in this field has been done on permalloy NWs. We show in this work that FEBID Co is a good alternative for such applications. For this study we have fabricated L-shaped NWs for several aspect ratios (see figure 2a). The component of the magnetization along the x axis was determined by measuring the longitudinal Kerr effect. A typical hysteresis loop is shown in the inset of figure 2a, corresponding to a single-sweep cycle. The sensitivity in this MOKE setup allows a clear observation of the magnetic switching even in a single-shot measurement.By applying different in-plane magnetic field sequences (red dashed lines in figure 2b), the magnetization of the structure (solid black lines in figure 2b) is initialized in a different magnetic configuration. The initial magnetic configuration is achieved by placing (or not) a domain wall at he corner of the L-shape. The initial state determines the magnetization reversal mechanism, which allows the measurement of the domain wall propagation (figure 2b-up) or nucleation (figure 2b-down) field respectively. Significant differences are found for the fields necessary to reverse the magnetization, if a DW is initially present, or not, in the nanostructure. This demonstrates the conduit properties of the Co FEBID nanowires.

References:

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Figures: