Influence of stress and size over the magnetic response of nickel nanowires

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Nickel nanowires were prepared using electrochemical methods. Porous alumina membrane is used as a template to grow nanowires [Fig. 1]. Different synthesis parameters, such as anodization voltage, anodization time, plating time or temperature determine the morphology and size of our nanowires. This enables us to independently control the size and aspect ratio of the nanowires [Fig. 2].

The magnetic response does not show any evidence of a superparamagnetic blocking, which confers to the material an important application in data storage devices [1]. At room temperature, hysteresis is determined by shape anisotropy [2]. Room temperature coercive field values lower than the predicted in the Stoner-Wohlfarth “in unison” model were measured. The magnetic response of wires with varying aspect ratios shows evidences from particle-to-wire crossover above an aspect ratio Length/Diameter ≈ 4.6. The coercive field for nanowires shows an agreement with “nucleation and propagation” fanning reversal mode for diameters lower than 43 nm (a mode usually neglected) [3]. For larger diameters, the “curling” reversal mode is in qualitatively agreement with our experimental data [Fig. 3].

Below room temperature, a thermally-induced magnetoelastic anisotropy competes with the shape anisotropy. Compression stress due to different thermal expansion coefficients of aluminium [4] and nickel gives rise to a thermally-induced magnetoelastic effect that reduces the coercivity. The latter behavior is shown only if aluminium is not removed from the samples. Otherwise, we obtain the monotonic decrease of coercive field with increasing temperatute that is expected for a thermally activated magnetization switching process. Our work, therefore, puts a end to the controversial question [5] about the origin of this effect. The influence of the stress on the coercive field depends on the aspect ratio of the samples.

Above room temperature, in a range of temperatures not covered until now, the aluminium expansion produces a tensile stress that is the responsible of a coercive field maximum at room temperature. The Curie temperature T_C progressively decreases with decreasing wire diameter [6] [Fig. 4]. In agreement with models, this reduction of the T_C is due to finite-size effects. The T_C extrapolated to infnite diameter shows a decrease of about 3 K with respect the bulk value [7]. This suggest that stresses, whose presence and influence on the magnetic properties have been put into evidence by hysteresis experiments, also modify T_C. This effect is not present for nickel nanowires embedded in mica, where stresses are very weak [8].

References:

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Figures:

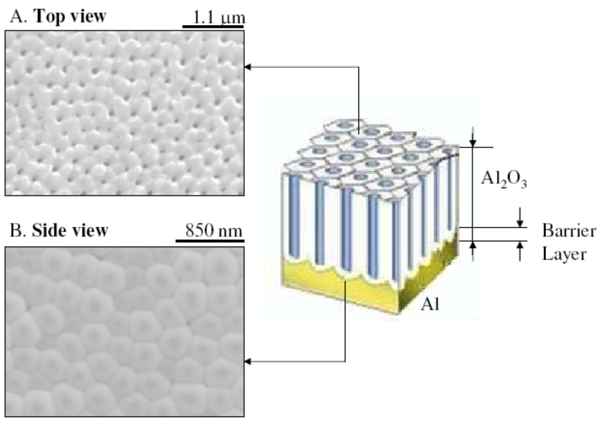

Fig. 1. Schematic drawing of the nanoporous alumina structure as obtained as a result of anodic oxidation. Example of the top view (A) and the side view after aluminium removal (B) of a sample synthesized at 160 V during 2 hours in H_3PO_4 1%.

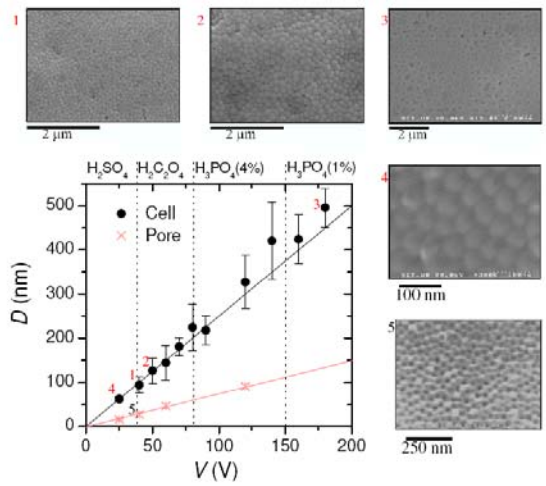

Fig. 2.. Voltage influence on cell and pore diameter. Temperatures and electrolytes used are described in table 2.2 and marked in superior scale. For all samples: t_1 =30 min and t_2 =120 min. Black and red lines are linear fits for cell and pore diameters respectively.

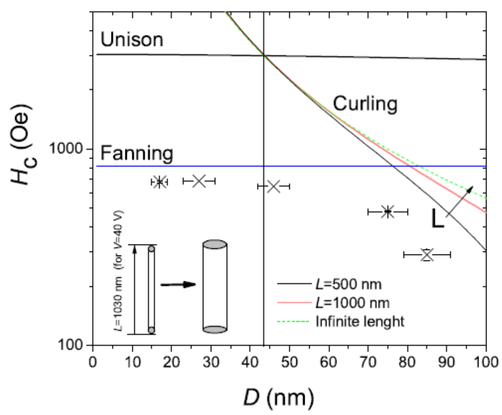

Fig. 3. Coercivity evolution for samples with different diameter. Nucleation field predictions for the diverse reversal modes in samples with a finite length of 1000 nm (length that correspond with sample prepared at 40 V and filled during 10 min) are shown. The vertical line signals the critical diameter D_{cr}. The different curves for curling correspond to wires with various lengths.

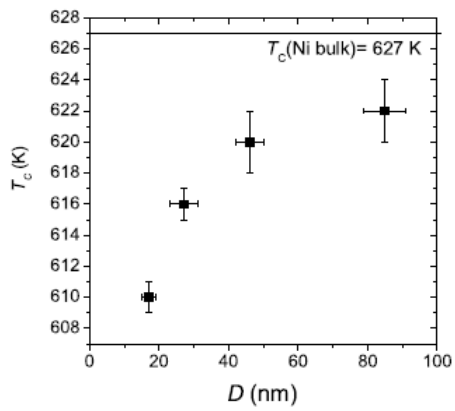

Fig. 4. Curie temperature evolution for samples with different nanowire diameters.