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Magnetic properties of ordered arrays of pseudo-one-dimensional nanostructures with modulated diameters

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Abstract – The magnetization reversal in ordered arrays of pseudo-one-dimensional nanostructures with modulated diameter is investigated theoretically as a function of their geometry. Magnetostatic interactions between the nanostructures are responsible for a decrease in the coercive field in the array. Our calculations are in good agreement with recently reported experimental results.

Magnetic nanoparticles have attracted increasing interest among researchers of various fields due to their promising applications in hard disk drives, magnetic random access memory, and other spintronic devices. To apply nanoparticles in various potential devices and architectures, it is very important to control the size and shape and to keep the thermal and chemical stability of the nanoparticles. The properties of virtually all magnetic materials are controlled by domains. Where two domains meet, a domain wall forms. Measurements on elongated magnetic nanostructures highlighted the importance of nucleation and propagation of a magnetic domain wall between opposing magnetic domains in the magnetization reversal process. For instance, by equating the direction of a domain's magnetizations with a binary 0 or 1, a domain wall also becomes a mobile edge between data bits: the pseudo-one-dimensional structure can thus be thought of as a physical means of transporting information in magnetic form. This is an appealing development because computers currently record information onto their hard disks in magnetic form. [1]

Considerable efforts have been invested in the past years into the development of methods for the preparation of pseudo-one-dimensional nano-objects with well-defined and homogeneous diameter. Indeed, confinement effects (which by nature depend on geometry) are strongly affected by structural irregularities. Conversely, introducing changes in diameter in a controlled manner into nanowires or tubes should give rise to novel physical properties as well as novel possibilities to fine-tune them. In the magnetism realm, diameter modulations should provide a handle over the motion of magnetic domain walls, a phenomenon proposed as a future data storage platform, [2] but the basis physics of which remain to be explored in detail.

We recently reported the synthesis and magnetic characterization of pseudo-one-dimensional nano-objects with the controlled introduction of changes in diameter. [3] In these arrays we demonstrated that the introduction of a single short wide segment in the middle of a long narrow tube causes a drop in coercive field by more than 30%. Thus, this presentation focuses on the investigation of the magnetic switching of pseudo-one-dimensional nanostructures with modulated diameters as a function of their geometry. Besides, we will introduce the effect of the stray field in these systems.

Figure 1: Examples of pseudo-one-dimensional nanostructures with modulated diameters.

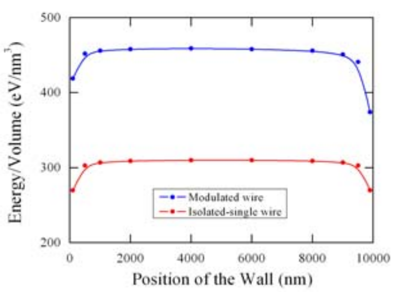

Figure 2: Energy barriers for the transverse reversal mode of an isolated tube and a modulated tube.

[1] R. P. Cowburn, Nature (London) 448 (2007) 544.
[2] S. S. P. Parkin, M. Hayashi, and L. Thomas, Science 320 (2008) 190-194.
[3] K. Pitzschel, J. M. Montero Moreno, J. Escrig, O. Albrecht, K. Nielsch, and J. Bachmann, (submitted).