The influence of the residual thermal stresses on the hysteretic processes in the nanowires arrays

I. Astefanoaei, I. Dumitru, A.Stancu,

I. INTRODUCTION

The magnetic nanowires arrays have important potential technological applications as magnetic recording media, nanosensors and magnetodielectrics for microwave devices [1, 2, 3]. The study of hysteretic processes in nanowires arrays is receiving a considerable experimental and theoretical attention, due to the necessity of understanding the magnetization processes of these magnetic systems [4].

II. PURPOSE

In this paper it is analyzed the influence of the thermal stresses on the hysteretic processes of Co, Ni and FeBSi nanowires, prepared by electrodeposition technique on alumina membranes. It was evaluated both the magnetostatic interactions induced in the nanowires hexagonally arrays and the thermal stresses (radial, azimuthal and axial stresses) that appear in the system (nanowire and alumina template) at different temperatures. The analysis of thermal induced stresses provides useful informations concerning the magnetic anisotropy in the nanowires. It was studied the temperature dependence of the remanent magnetization and coercitive field as an effect of the induced thermal stresses and magnetostatic interactions between nanowires. The following important tasks are considered: (i) The thermal stresses that appear in the system at the different temperatures. It was calculated the thermal stresses which appear both because of the thermal gradients and to constraints produced on the nanowire by the alumina template as a result of the difference between the thermal expansion coefficients of the two materials in contact. Using the distribution of internal stresses, it is determined the magnetoelastic anisotropy field of nanowires in alumina template. (ii) It is studied the effect of thermal stresses on the magnetic hysteresis loop for the hexagonal nanowires arrays. The hysteresis loop of the nanowire system was computed using an Ising-type model in which the nanowires magnetization vector has two preferred directions along nanowires axis. For a given temperature, the switch between these states is determined by the energy barrier [5] defined by the applied field, the magnetostatic interaction field and by the magnetoelastic anisotropy field. The magnetocristaline anisotropy field is considered along the nanowire axis. (iii) Discussions about the influence of the thermal stresses on the reduced remanence and coercitivity field of the hexagonally nanowires arrays.

III. RESULTS

The shape of hysteresis loop is significant influenced by the thermal stresses induced into the nanowires at the different temperatures. The remanence magnetization depends on size parameters of the nanowires and temperature. In the case when the magnetoelastic energy is not considered, a decrease of the reduced remanent magnetization (M_r / M_s) was observed for all nanowires. When the magnetoelastic anisotropy due to the thermal stresses is considered an increase of the reduced remanent magnetization is determined. This behavior was experimentally observed for a Co nanowire system embedded into an alumina template [4]. More, a small increase of the coercitive field with temperature was observed in the presence of thermal stresses. Therefore, the thermal stresses from the nanowires and magnetostatic interactions have an essential role in defining the shape of the hysteresis loop of the nanowire arrays. The results show that the thermal stresses that appear in a nanowire at different temperatures, influence the temperature dependence of the major hysteresis loop of the hexagonally nanowires arrays. By the calculation of the magnetostatic interactions induced in the hexagonally nanowires arrays and thermal stresses that appear in nanowires at the different temperatures, information about magnetic behavior of these nanostructures can be obtained directly. The increase of the reduced remanent magnetization with the temperature was determined by numerical computation considering the effect of the magnetoelastic energy in the nanowire system.

Acknowledgement: The authors wish to thank PNII 12-093 HIFI Romanian CNMP Grant for the financial support of this research.

REFERENCES

[1] M. Ciureanu, F. Beron, L. Clime, P. Ciureanu, A. Yelon, T.A. Ovari, R.W. Cochrane, F. Normandin, T. Veres, Electrochimica acta 50 (22) 4487, 2005.

[2] [2] E. D. Boerner, H. N. Bertram, IEEE Trans. Magn. 33, 3052 (1997), "Dynamics of thermally activated reversal in nonuniformly magnetized single particles".

[3] L. Sun, Y. Hao, C.-L. Chien, P. C. Searson, IBM J. RES. & DEV. 49, 1,79-84, 2005.

[4] E. L. Silva, W. C. Nunes, M. Knobel, J. C. Denardin, D. Zanchet, K. Pirota, D. Navas, M. Vázquez, Physica B, 384, 1-2, 22-24, 2006.

[5] Alexandru Stancu, Magnetization Processes in Particulate Ferromagnetic Media, Iasi, Romania.