Mechanisms of magnetization reversal in magnetic wires. Magneto-optical study.

A. Chizhik[1]**,** A. Zhukov[1,2], J. Gonzalez[1]

[1]Departamento de Física de Materiales, Facultad de Química, Universidad del País Vasco, UPV/EHU, San Sebastián, Spain
[2]IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain
oleksandr.chyzhyk@ehu.es

Sensors based on magnetic microwires have reached the competitive level in the area of micro-sensors [1]. Application of GMI effect in these sensors – the most promising effect discovered in glass covered microwires, is related mainly to the transformation of surface magnetic domain structure. Although the magnetic microwires have been studied widely during the last years the elucidation of the mechanisms of magnetization reversal is the actual task. The present work is devoted to the recent results on magneto-optical Kerr effect (MOKE) study of the surface magnetization reversal and surface domain structure in glass covered amorphous microwires.
Experiments have been performed in Co-rich microwires (metallic nucleus radius 50 µm, glass coating thickness 20 µm, and a ratio of metallic nucleus diameter to total microwire diameter ρ = 0.7). Magnetic domain imaging in the surface of microwires has been performed by means of optical polarizing microscopy in the longitudinal magneto-optical Kerr effect (L-MOKE) configuration [2]. The magnetic contrast of the domain structure was improved by standard image processing. The surface magnetic domains could be observed basically because of different in-plane (circular) components of the surface magnetization that transforms to black-white contrast when the polarized light reflects from the top of the cylindrically shaped surface of the microwire. The incidence plane was perpendicular to the wire axis.

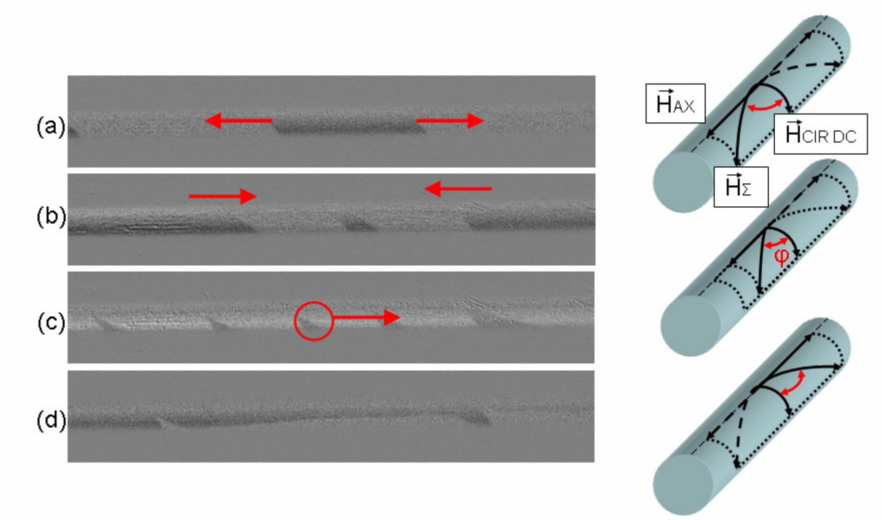

Fig. 1. Kerr image obtained for different configurations of external magnetic field. (a) H_{CIRC} DC = 0; (b) H_{CIRC} DC = 0.5 Oe; (c) H_{CIRC} DC = 0.65 Oe; H_{CIRC} DC = 1 Oe.

In the present study we put our attention mainly on the transformation of the surface domain structure. The experiments have been performed in crossed magnetic fields. The external magnetic field H_{Σ} was a sum of an axial *(H_{AX})* and a circular *(H_{CIRC})* fields (Fig. 1). In order to produce the circular magnetic field H_{CIRC}, an electric current flowing *I* through the wire has been used.
It was found 4 different mechanisms of the magnetization reversal depending on the configuration of external magnetic field (Fig. 1). The increase of the DC circular magnetic field causes the change of the mechanism.
First, the magnetization reversal has been studied for the case of $H_{CIRC} = 0$. The sample of Kerr image obtained for the magnetic field applied parallel to the wire is presented in Fig. 1 (a). This observation corresponds well to the found earlier long distance quick motion of the solitary circular domain walls (DW) related to giant Barkhausen jump.
It was found that the increase of the circular magnetic field causes the successive changes of the mechanism of the magnetization reversal. Here we present 3 different types of this mechanism as a dependence of the value of H_{CIRC} DC.
The first change of the mechanism of the surface magnetization reversal takes place for the value of the H_{CIRC} DC of 0.5 Oe: the effect of domain suppression is observed (Fig. 1(b)) - the advantageous dark

domain placed in the centre of the frame, disappears under the pressure of two moved domain walls marked by the red arrows in the figure. The specific feature which we consider as a key one is the periodical difference in the angle of the inclination of the domain walls: the left DW of the bright domains is more inclined toward the axial direction then the right DW. This difference results into a formation of wedge shaped domain with the tendency to instability and disappearance.

Subsequent growth of the H_{CIRC} DC (up to 0.65 Oe) leads to a new modification of the magnetization reversal - the drift of the surface domains is observed (Fig. 1(c)). The magnetization reversal occurs basically as the nucleation of multiple domains followed by the directed motion of the wedged domains as whole objects along the microwire. The moved domains reduce during the drift process up to the complete disappearance.

The last type of the mechanism of the magnetization reversal observed here is the formation and transformation of the vortex domain structure (Fig. 1(d)). The increase of the DC circular magnetic field (up to 1 Oe) causes the formation of the compact structure which could be qualified as a non-planar vortex-type structure. The domain structure observed under the present configuration of two magnetic fields is very unusual and never has been fixed earlier in magnetic microwires. At the first stage of the magnetization reversal this surface structure is characterized by the extended domain walls parallel to the wire axis.

The analysis of the obtained results has been performed based on our theoretical model supposed four magnetization states with different chirality [3]. Helical magnetic field induces the co-existence of stable and metastable helical magnetic states in the surface of the microwire. The variation of DC circular magnetic field causes the formation of complex magnetic multi-domain structure. When the circular field is high enough four different helical states co-exist forming the vortex structure. In turn, the axial magnetic field induces the transformation and re-arrangement of the vortex structure.

References

[1] V. Zhukova, M. Ipatov and A. Zhukov, Sensors **9** (2009) 9216.

[2] J. Gonzalez, A. Chizhik, A. Zhukov and J. M. Blanco, Journal of Physics: A **208** (2011) 502.

[3] A. Chizhik, V. Zablotskii, A. Stupakiewicz, C. Gómez-Polo, A. Maziewski, A. Zhukov, J. Gonzalez, and J. M. Blanco, Phys. Rev. B **82** (2010) 212401.