Magnetization reversal in sub-micrometric Fe-rich glass covered wires

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Following the tendency of the miniaturization of active elements for magnetic sensors the investigation of the magnetization reversal has been performed in Fe-rich sub-micrometric amorphous wires (nominal composition $Fe_{72.75}Co_{2.25}B_{15}Si_{10}$).
The magnetization reversal has been studied using the magneto-optical Kerr effect (MOKE) magnetometer [1].The longitudinal configuration of MOKE was employed. The intensity of the light, reflected from the surface of microwire, was proportional to the magnetization placed in the plane of the light, i.e. to the axial component of the magnetization. A tiny Cu wire was attached to the sample end in order to apply the axial tensile stress. The torsion stress has been applied during the experiments too. The series of the microwires with different values of geometric ration ρ has been studied (ρ is ratio of metallic nucleus diameter, d, to total microwire diameter, D): sample No1 ρ=0.04, metallic nucleus radius r=400 nm, D=19 μm; sample No2 ρ=0.067, r=700 nm, D=21 μm; sample No3 ρ=0.085, r=1000 nm, D=21 μm.

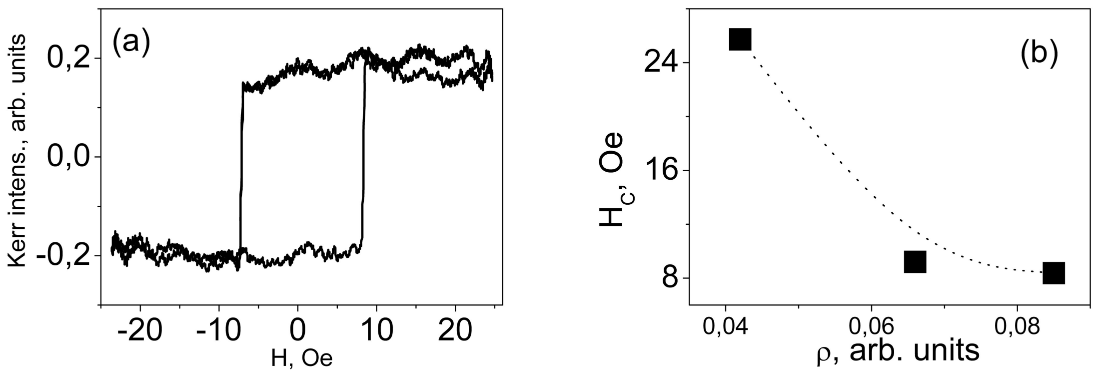

Figure 1. (a) **–** MOKE dependence on axial magnetic field (sample No3); (b) dependence of surface coercive field on geometric ration ρ.

It was found that for the microwires of such thin dimensions surface hysteresis loop has a rectangular shape related to magnetic bistability effect (Fig.1a). It confirms the existence of the Surface Large Barkhausen Jump (SLBJ) in sub-micrometric glass covered wires which is explained by the magnetization reversal in a large single surface domain [2].
Fig.1b demonstrates the coercive field (H_C) growth with decreasing of the geometric ratio ρ. The highest value of the surface coercive field is observed for the extremely small value of the ratio ρ. Such rising of the switching field has been attributed to the increasing of the strength of internal stresses as increasing the glass coating thickness.
The experimental H_C dependence on the tensile stress has been plotted as a function of the square root of applied stress σ (Fig. 2a). Good fitting of the experimental points by the linear dependence takes place. The surface bistability effect is related to formation of surface domain wall. The coercive field in the surface like in the volume of the wire is proportional to the energy required to form the domain wall γ involved in the bistable process.

The surface coercive field is related to the magneto-elastic anisotropy as given by [3]:

$$H_C \sim \gamma \sim [(3/2)\, A\lambda_S(\sigma + \sigma_r)]^{1/2}$$

where A is the exchange energy constant, λ_S is saturation magnetostriction constant, σ is applied tensile stress and σ_r is the internal tensile stress. As it is possible to see, the coercive field must be proportional to $\sigma^{1/2}$ for the applied stress σ larger than the internal stress that is observed in the performed experiments.

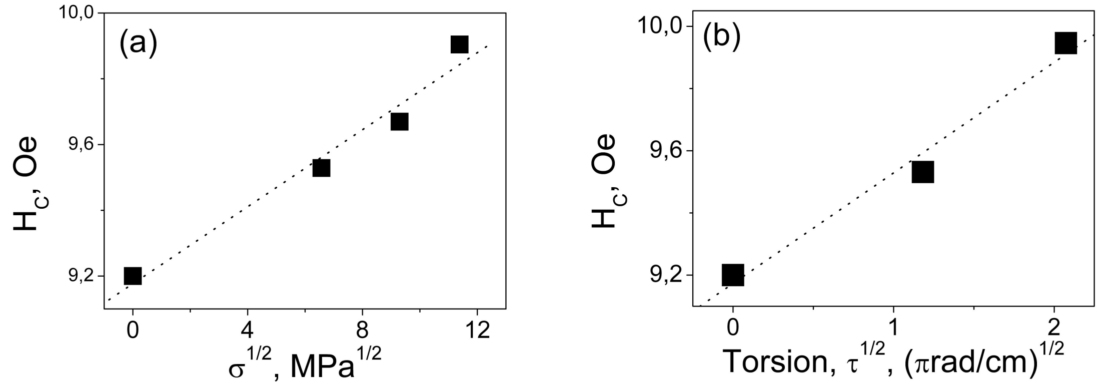

Figure 2. (a) Tensile stress dependence of coercive filed for sample No 2. (b) Torsion stress dependence of coercive field for sample No 2.

The experimental H_C dependence on the torsion stress also has been plotted as a function of the square root of applied stress τ (Fig. 2b). Analysis of the obtained results has been performed following [4] where the appearance of the magneto-elastic anisotropy coming from the applied torsion stress is supposed. In this case the dependence of the coercive field on the torsion stress could be presented as:

$$H_C \sim \gamma \sim [(3/2) A\lambda_S\tau]^{1/2}$$

Good fitting of the experimental points by the linear dependence also observed for the torsion stress that permits us to suppose the existence of the "inner core – outer shell" magnetic configuration with radial and surface closure domains in the surface of the studied nano-wires.
Therefore, we can conclude that in the extremely thin Fe rich glass covered sub-micrometric wires, the magnetic bistable behavior is observed like in the glass covered wires of micro-scale. The performed analysis of the tensile and torsion stresses transformation of surface hysteresis loop demonstrates that about one order decrease of the wire scale does not abolish the basic effects observed earlier in thicker wires. It permits to reduce considerably the size of basic elements of magnetic sensors and make the next step in the way of sensor miniaturization.

References

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