DOMAIN WALL PROPAGATION IN BISTABLE AMORPHOUS MICROWIRES

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Introduction

Tendency on miniaturization of the modern magnetic sensors and devices stimulates development of such magnetic materials with reduced dimensionality. Therefore magnetic materials with outstanding magnetic characteristics and reduced dimensionality recently gained much attention. Consequently thin wire with reduced geometrical dimensions (of order of 1-30 μm in diameter) gained importance within last few years [1,2]. These thin wires combine excellent soft magnetic properties (with coercivities till 4 A/m) with and unusual re-magnetization process in positive magnetostriction compositions exhibiting magnetically bistable behaviour and fast domain wall propagation [1-4]. In this paper we'll recent results on domain wall (DW) propagation in these microwires

Experimental

We used experimental set-up based on classical Sixtus-Tonks [3,4] method previously used by us in order to reduce inductivity of magnetizing coil for achieving constant magnetic field when measuring *v(H)* dependence. We also introduce additional pick-up coil in order evaluate defects contribution in domain wall propagation.
The DW propagates along the wire with a velocity:

$$v=S(H-H_0) \quad (1)$$

where S is the DW mobility, H is the axial magnetic field and H_0 is the critical propagation field.
In our experiment we placed one end of the sample outside the magnetization solenoid in order to activate DW propagation always from the other wire end.
Three of pick-up coil are mounted along the length of the wire and propagating DW induces electromotive force (emf) in the coils.
DW velocity is calculated as:

$$v=\frac{l}{\Delta t} \quad (2)$$

where l is the distance between pick-up coils and Δt is the time difference between the maximum in the induced emf.
We achieved steady magnetic field, H, when the DW reaches the first coil p_1.

Results and discussion

One of the main technological interests for utilization of amorphous microwires is related with Large and single Barkhausen Jump (LBJ) observed above some value of applied magnetic field [1]. This Large and single Barkhausen jump takes place under magnetic field above some critical value (denominated as switching field) and also if the sample length is above some critical value denominated also as critical length. Particularly, critical length, l_c, for magnetic bistability in conventional Fe-rich samples (120 μm in diameter) is about 7 cm. Below such critical length hysteresis loop loses its squared shape.
Reduction of the metallic nucleus diameter in the case of glass-coated microwires (almost one order lower) results in drastic reduction of the critical length (till 2 mm), making them quite attractive for micro-sensor applications [1].
The rectangular hysteresis loop could be interpreted in terms of nucleation or depinning of the reversed domains inside the internal single domain and the consequent DW propagation [1,3,4]. Recently great attention has been paid to studies of DW propagation in thin wires with sub-micrometric and micrometric diameter [5,6] related with proposals for prospective logic [5] and memory devices [6]. Essentially non-linear *v(H)* dependences have been observed in a number of microwires compositions (Figs.1,2).

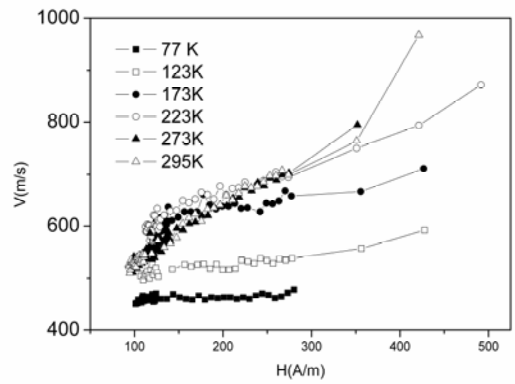

Fig.1. *v(H)* dependence measured for the $Fe_{79}B_{15}Si_{10}C_6$ microwire with d = 14 μm at different temperatures, *T*.

Roughly, *v(H)* dependence of $Fe_{79}B_{15}Si_{10}C_6$ microwire (d=14 μm and D=33 μm) can be described as consisting of 2 linear *v(H)* dependences, increasing DW mobility, *S*, for both regions with increasing the temperature.

Even higher DW velocity (till 18,5 km/s) has been observed in $Co_{68}Mn_7Si_{10}B_{15}$ (d=8 μm, D= 20 μm) which is characterized by the lowest possible magnetoelastic anisotropy (due to its low magnetostriction λ_S) among the microwires with single domain axial structure (see Fig.4).

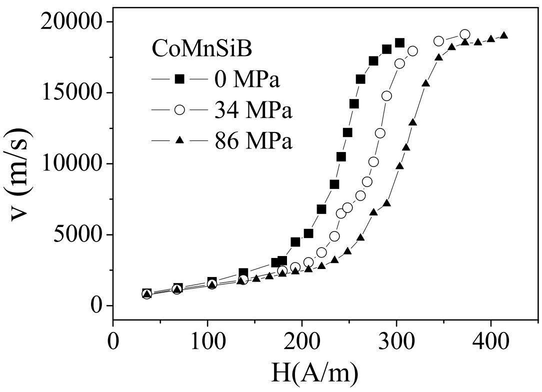

Fig.2 *v(H)* dependence measured for the $Co_{68}Mn_7Si_{10}B_{15}$ microwire with d= 8 μm at different applied stress.

We assume that deviation from linearity and drastic increase of DW velocity at elevated fields are caused by possible nucleation and consequent growing of reversed domain in central part of the sample.

In order to verify this assumption, we compared the *v(H)* dependence with the distribution of the local nucleation fields H_n along the sample length, *x*, as described in ref. [7], i.e. using short magnetizing coil placed far from the samples ends and measuring magnetic field for local magnetization reversal .

The distribution of the $H_n(x)$ for the $Fe_{74}Si_{11}B_{13}C_2$ sample is shown in Fig.3.

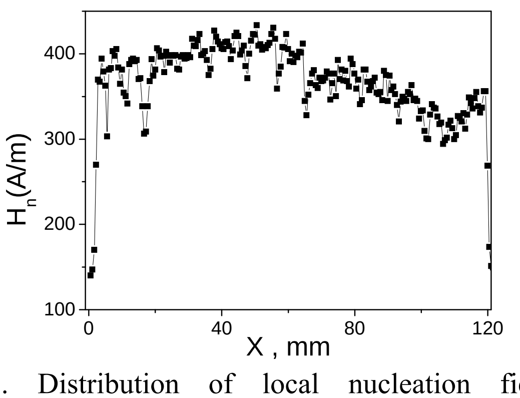

Fig.3. Distribution of local nucleation fields measured in $Fe_{74}Si_{11}B_{13}C_2$ sample.

Below some critical field the *v(H)* dependence is perfectly linear (see Fig.4)

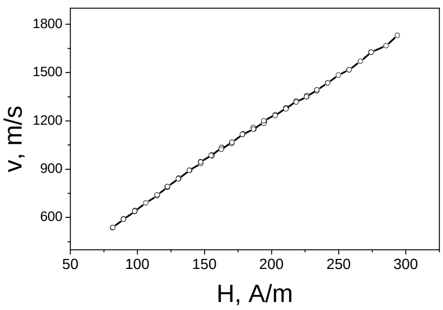

Fig.4. *v(H)* dependence in $Fe_{74}Si_{11}B_{13}C_2$ sample

We observe a number of dip attributed previously to the positions of localized defects existing within the microwire [7]. The overall minimum H_n observed in Fig.3 for studied microwires correlate quite well with the maxima field obtained from DW velocity measurements (compare Figs 3 and 4).

Considering aforementioned we assume that when the applied magnetic field has reached the H_n, the new domain is nucleated and two DW starts to propagate towards the wire's ends.

As it was noted above, in such situation it is not possible to measure correctly single DW velocity.

On the other hand it is worth distinguishing an interesting mechanism of magnetization reversal in magnetically bistable microwires. This mechanism is conditioned by the microwires inhomogeneities. These inhomogeneities can hand lead to considerable acceleration of the sample magnetization switching.

References

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