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# Domain Wall Velocity and Magnetic Characterization in Bistable Glass Coated Wires

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***Abstract* – A method for simultaneous measurement of domain wall velocity and hysteresis loop in long bistable magnetic wires is presented. The measurement's results have shown that recorded hysteresis loop present different coercivities depending on the position of the pickup coil along the wire. The observed behaviour was explained by taking into account the mechanism of magnetization reversal in these specific materials.**

***Keywords* – *Magnetic Hysteresis, Domain Wall Velocity, Bistable wire, Microwire, Large Barkhousen jump***

## I. INTRODUCTION

The amorphous glass coated wires with diameters of the metallic core ranging from few microns to several tens of microns and glass thicknesses in the same range represent a class of materials with great potential for applications based on various operating principles [1-3]. One of the important operating principles is based on magnetic bistability i.e the switching of the magnetization in a single step, called large Barkhausen jump, at an applied field above a certain threshold value, called switching field [4]. The magnetization switching mechanism consists, essentially, in generation of a domain wall at an imperfection of the wire, usually at one end, and displacement of this domain wall along the wire length. The magnetic field at which the magnetization reversal occurs and the domain wall velocity along the wire is dependent on both the characteristics of the magnetic material (composition, structure, diameter) and on the glass coating, whose thickness can tailor these characteristics [5].

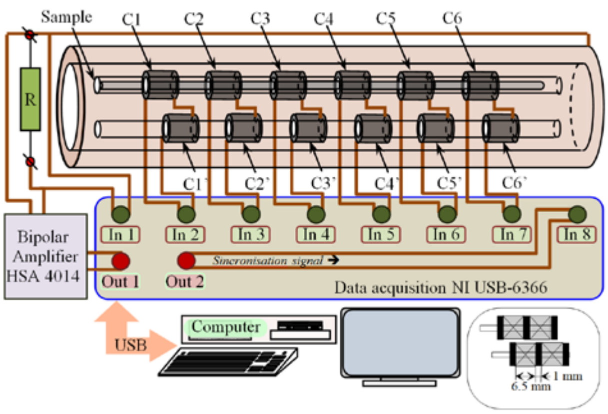
## II. DESCRIPTION OF THE METHOD

In the present study we report on the influence of the finite speed of the domain wall on the hysteresis loop measurement in bistable glass coated wires.

For this purpose we designed and built a system able to record simultaneously the hysteresis loop and velocity of the domain wall. The system combines the Sixtus-Tonks principle [6] for domain wall velocity and the inductive technique [7] for hysteresis loop measurements.

The system consist in a long solenoid, powered through a high power bipolar amplifier, for alternating field generation, a compensated system of six coils placed within the solenoid for sample signal pick-up, an acquisition board to generate the excitation signal and to digitize the acquired signals, and a personal computer for data processing and control of the measuring process (Fig. 1).

A special designed software was used for the acquired signal computing.




*Fig, 1. Schematic of the experimental system employed for the simultaneous recording of domain wall velocity and local hysteresis loop*

## III. RESULTS AND DISCUSSIONS

An amorphous glass coated wire, with nominal composition $Fe_{77.5}Si_{7.5}B_{15}$, having diameter of the metallic core of 10 µm, glass thickness of 30 µm and length of 85 mm, was used as sample for the performed test. The composition and dimensions where chosen to obtain stabile magnetic switching by propagation of a single magnetic domain from one end to the other of the sample and to avoid secondary domain walls nucleation along the wire length.

For a single compensated pick-up coil the hysteresis loop is drawn by connecting the successive points with the coordinate given by the normalized drop voltage on the resistor R (excitation field H) and the normalized integrated signal induced in the pick-up coil (sample polarization $\mu_0 M$) on the X and respectively Y axes for one period of the alternating excitation signal (Fig. 2).

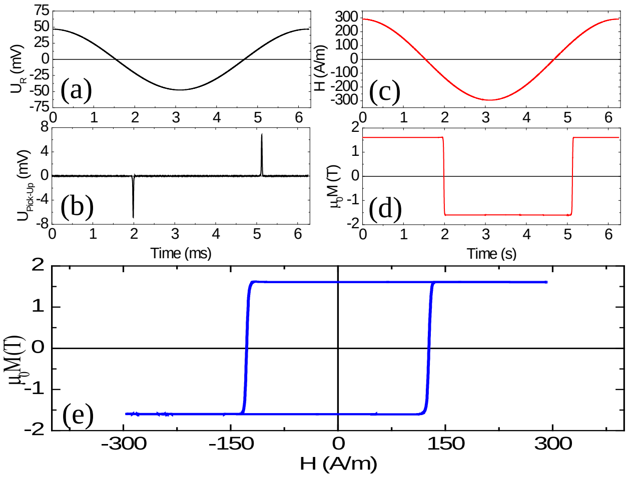



*Fig. 2. Recording diagram for a single hysteresis loop: a) resistor voltage droop; b) pickup coil signal, c) normalized resistor voltage drop; d) normalized integrated pickup coil signal; e) resulting hysteresis loop*

The successive pick-up coils allow to read the time difference between induced peaks when the coils are traversed by a domain wall (Fig. 3). The domain wall speed is calculated as ratio between the coil distance and time difference between successive peaks. For the analysed sample, the recorded domain wall velocity was around 320 m/s for a maximum, sinusoidal, applied field of 290 A/m.

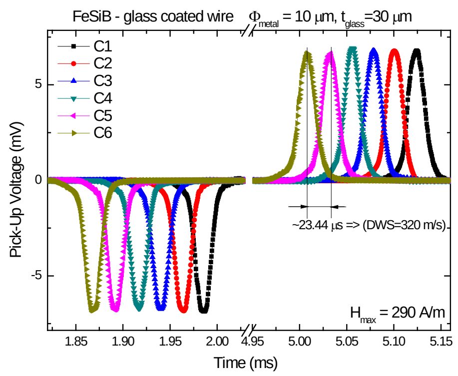



*Fig. 3. Successive peaks induced in the compensated pick-up coils due to domain wall passing*

By integrating the signals on each pair of pick-up coils, the hysteresis loop of the analyzed area of the wire should be obtained. However, the results show that recorded coercivity is slightly different from one pick-up coil to another, being smaller for the coil which is first traversed by the domain wall and progressively increasing up to the last one (Fig. 4). This behaviour can be explained by the fact that the magnetization reversal in the wire takes place not instantaneously but in a certain period of time which is necessary for the domain wall to travel along the wire length.

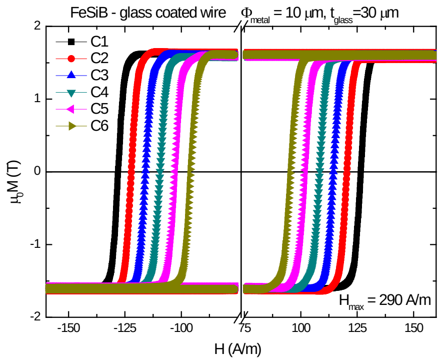



*Fig. 4. Local hysteresis loop measured on successive pick-up coils*

For all samples showing single step magnetization process, with domain wall propagation along the sample length, the measured value of the coercivity is strongly affected by the position of the sample relative to the detection coil, by the domain wall nucleation point on the wire length, by domain wall velocity, and by the value of the coercive field relative to the maximum applied field (the slope of the field at coercivity value).

In the case of sinusoidal excitation the most accurate point of the recorded coercive field is when the maximum field is equal to or very close to the switching field due to the very small slope of the excitation curve at fields nearby the reversal area. For single domain wall propagation, with constant speed, along a homogeneous wire the coercive field ($H_x$) at a given position on the wire (x) can be estimated by measuring the coercive field values $H_{c1}$ and $H_{c2}$ in two points $X_{c1}$ and $X_{c2}$ using the formula:

$$H_x = H_{max} * sin\left[arcsin\frac{H_{c1}}{H_{max}} + \frac{x - x_{c1}}{x_{c2} - x_{c1}}\left(arcsin\frac{H_{c2}}{H_{max}} - arcsin\frac{H_{c1}}{H_{max}}\right)\right] \quad (1)$$

The estimated results using the formula above are in good agreement with the measured values as it can be observed from the Table 1.

*Table 1. Estimated results and measured values.*

| Position X (mm) | Hc (A/m) Measured | Hc (A/m) Estimated |
|---|---|---|
| 0 | - | 144.9 |
| 22.5 | 127.3 | 127.3 |
| 30 | 121.3 | 121.3 |
| 37.5 | 115.1 | 115.2 |
| 45 | 109 | 109.1 |
| 52.5 | 102.4 | 102.9 |
| 60 | 96.3 | 96.7 |
| 85 | - | 75.6 |

## IV. CONCLUSIONS

A particular behaviour of magnetic measurements in bistable amorphous wires, showing different measured coercivities depending on detection coil position, has been highlighted and explained bay taking into account the finite speed of the domain wall which propagate along the wire, when the magnetization is switching from one longitudinal direction to the opposite one.

The obtained results show the importance of the magnetic behaviour understanding for accurate magnetic characterization of bistable magnetic wires.

## V. ACKNOWLEDGMENT

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