14th Czech and Slovak Conference on Magnetism, Košice, Slovakia, July 6–9, 2010

The Study of Magnetization Process in Amorphous FeNiSiB Microwires

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We have studied the magnetization process in amorphous $Fe_{49.6}Ni_{27.9}Si_{7.5}B_{15}$ microwire. It was found that the hysteresis mechanism consists of two contributions: magnetoelastic and structural relaxation. It was shown that at low frequencies, the magnetization process is controlled mainly by the structural relaxation. At higher frequencies (above 50 Hz), the relaxation effect disappears and switching field is determined mainly by the magnetoelastic contribution. Moreover, the effect of thermal treatment at temperature 300 °C has been studied. As-cast microwire is almost unsensible to the applied tensile stress since the applied stresses are lower than that induced during production. After annealing, the stresses relax and stress sensibility of microwires increases.

PACS numbers: 75.50.Kj, 75.60.Ej, 75.60.Jk

1. Introduction

Amorphous glass-coated microwires are attracting a great interest due to their large potential for technical application [1]. They are composite materials that consist of metallic nucleus (1–40 μm), which is covered by pyrex glass-coating of thickness 1–2 μm. Due to their amorphous nature and small dimensions, their magnetic properties are mainly driven by magnetoelastic and shape anisotropy [2]. Hence, the positive magnetostriction microwires are characterized by a monodomain structure. Such monodomain structure is characterized by so-called magnetic bistability (e.g. their magnetization can achieve only two values: M_s and $-M_s$). Magnetic bistability is very useful in technical applications for coding or sensing [3]. Magnetization process in such microwires runs through the depinning and subsequent propagation of the closure domain wall. This happens when the applied field is equal or greater than the so-called switching field (H_{sw}).

The aim of the present contribution is to show the effect of thermal treatment on the switching field and its stress dependence.

2. Experimental

Amorphous glass-coated microwire of composition $Fe_{49.6}Ni_{27.9}Si_{7.5}B_{15}$ with internal diameter 15 μm and total diameter 33 μm were produced by the Taylor–Ulitovski method. The length of all samples was 7 cm. The amorphous microwire was studied in as-cast state and annealed for 1 h at temperature 300 °C in argon atmosphere. Dynamic switching field was measured at room temperature by the induction method using triangular shaped exciting magnetic field in the frequency range 10–5000 Hz and under applied stress up to 100 MPa. More details can be found elsewhere [4].

3. Result and discussion

As it was shown earlier [4], the switching field of amorphous glass-coated microwires consists of two contributions: magnetoelastic one and pinnng of the domain wall on the defects introduced into the microwire during production. These two contributions can be recognized by measuring the frequency dependence of the switching field [5] (Fig. 1). The pinning of the domain wall on the defects (and specially their relaxation) leads to a decrease of the switching field at low frequencies (below 100 Hz). On the other hand, magnetoelastic contribution is responsible for an increase of the switching field at higher frequencies (above 100 Hz).

In contrary to the observations in [5], the effect of applied tensile stress on as-cast microwire is minimal (Fig. 1). Stresses up to 47 MPa increase a little bit the total switching field, however, the slope of the frequency dependence of the switching field remains the same. Such a fact can be understood in terms of internal stresses introduced into the microwire during production. Either it is the stress from quenching, drawing or the stresses that arise from a different thermal expansion coefficient of the glass coating and metallic nucleus. When these stresses are higher than the applied tensile stress, no effect on

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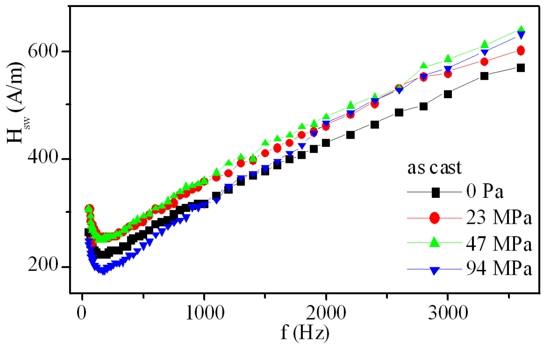

Fig. 1. Frequency dependence of the switching field in as-cast amorphous FeNiSiB microwire. Applied tensile stress as a parameter.

the switching field appears. Slight increase of the slope is observed only in the frequency range 100–2000 Hz for highest applied tensile stress of 94 MPa.

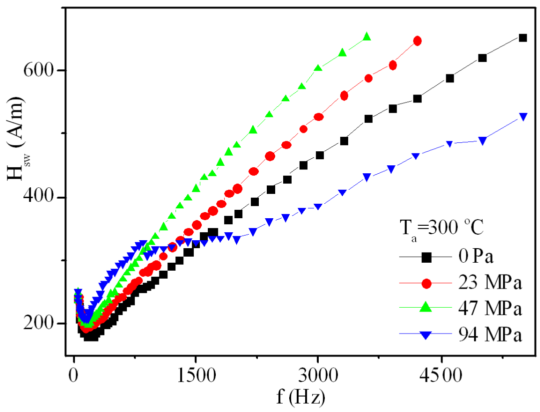

Fig. 2. Frequency dependence of the switching field in amorphous FeNiSiB microwire annealed at 300 ℃. Applied tensile stress as a parameter.

Different behaviour can be found in the case of heat-treated microwire (Fig. 2). The slope of the frequency dependence of the switching field gradually increases with the applied tensile stress. The reason of such behaviour is that annealing at 300 ℃ for 1 h causes the stress relaxation. Finally, the internal stresses (introduced during microwire's production) decrease and strong influence of the switching field on applied stresses appears. Such thermal treatment allows us to tune the stress dependence of the switching field according to desired applications. Moreover, it is clear that by tuning the measuring frequency, the stress dependence of the switching field can even be enhanced (at higher frequencies).

Finally, the tensile stress of 94 MPa results in the change of the frequency dependence of the switching field at the frequency of about 750 Hz. Such a change of the slope has already been observed in [6] and it was ascribed to the change of the domain wall structure from transversal to vortex one. The vortex wall is less sensitive to the frequency of the domain wall and therefore the slope of the frequency dependence of the switching field decreases above 750 Hz.

4. Conclusions

We have studied the effect of applied tensile stress on the switching field and its frequency dependence in amorphous FeNiSiB microwire. In the as-cast state, the switching field has very weak response to the applied tensile stress, because of the high internal stress introduced during the microwire's production. Annealing the microwire at 300 ℃ results in the internal stress relaxation and the switching field sensitivity on the tensile stress increases. By tuning the frequency of exciting field, the stress dependence can even be enhanced and can be fitted according to required applications.

Acknowledgments

J.G. acknowledges the program SPP Hlavicka. This work was supported by the project NanoCEXmat No. ITMS 26220120019, Slovak VEGA grant No. 1/0076/09, MVTS 6RP/Manunet/UPJS/08 and project VVGS UPJS No. 30/09-10.

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