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Magnetic Characterization of Co_2MnSi Heusler Microwires

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We report on the basic magnetic properties of glass-coated Co_2MnSi Heusler microwires. Measurements of hysteresis loops in different directions show that easy magnetization axis coincides with the wire's axis. The frequency dependence of the coercive field has been measured at room temperature in the frequency range from 10 Hz to 10 kHz. The coercivity decreases with the frequency up to 100 Hz and then increases linearly up to 1 kHz.

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1. Introduction

Heusler alloys belong to the group of old materials, known from the beginning of 20th century, that have recently been found very useful for various applications based on magnetocaloric effect [1–4], magnetic shape memory effect. Particularly, Heusler alloys of the chemical composition Co_2MnX (X- Si, Sn...) is a perspective group of materials for spintronics [5], because of their large magnetic moment, high Curie temperature, high spin polarization or small Gilbert damping [1].

Taylor-Ulitovski method is an easy method that allows massive production of very thin wires covered by glass [6]. The wires are prepared by drawing and quenching of molten precursors [7].

In this paper, we performed the first magnetic characterization of Heusler Co_2MnSi magnetic microwires prepared by Taylor–Ulitovski method. We show that they have a well defined easy axis of magnetization. Moreover, the study of AC magnetization process has been performed.

2. Experimental

Magnetic properties were investigated in glass-coated microwires of Co_2MnSi composition, prepared by Taylor-Ulitovsky technique. Metallic nucleus of studied microwires has a diameter of 10.2 μm and is covered by the Pyrex glass with total diameter of 22.4 μm.

Temperature dependence of the saturation magnetization was measured by vibrating sample magnetometer (VSM) in the magnetic field of 0.3 T in the temperature interval from 300 to 1000 K. A bunch of 50 microwires of length of 30 mm was used for AC magnetic measurements.

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DC hysteresis loops were measured in parallel and perpendicular direction with respect to the wire's axis at the temperature of 100 K. A single piece of the wire was used for the DC measurements, having the length of 15 mm for axial and 5 mm for perpendicular direction.

AC hysteresis loops were measured by induction method in parallel direction in the frequency range from 10 Hz to 10 kHz at room temperature. A bunch of 14 microwires of length of 30 mm was used for AC magnetic measurements.

3. Result and discussion

The saturation magnetization decreases with the temperature up to 600 K. Increasing the temperature leads to the stress relief and homogenization of the sample. Above 600 K, the magnetization remains almost constant and becomes more homogenous up to the Curie temperature, when it falls down. The value of Curie temperature (1004 K) fits well to the values observed in bulk Co_2MnSi Heusler alloys [8]. Such high Curie temperature makes the Heusler Co_2MnSi microwire an excellent candidate for spintronic applications.

Figure 1 shows the hysteresis loops of Co_2MnSi microwire measured at 100 K. Hysteresis loop measured in parallel direction shows square shape with the coercive field of 310 A/m (1.6 kA/m, for perpendicular). After the saturation at around 100 kA/m (for perpendicular at 500 kA/m), the magnetization decreases as a result of diamagnetic contribution of the glass-coating. In the perpendicular direction the remanent magnetization is 10 times lower than in the case of parallel direction. The shape of both hysteresis loops points to the fact that easy magnetization axis is well defined and that it is parallel to the wire's axis.

AC hysteresis loops measured at 10 Hz show increased coercive field of 736 A/m (see Fig. 2). The shape of hystereis loop as well as the value of the coercive field remains almost constant up to the value of 1000 Hz. Above this frequency, the coercivity as well as remanent magnetization increase.

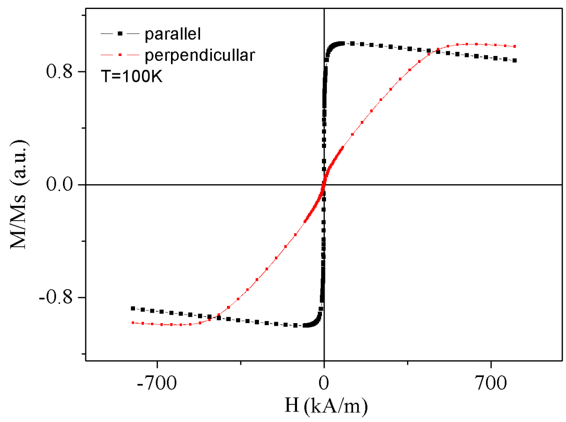

Fig. 1. DC hysteresis loops measured by SQUID at 100 K in parallel direction and perpendicular direction.

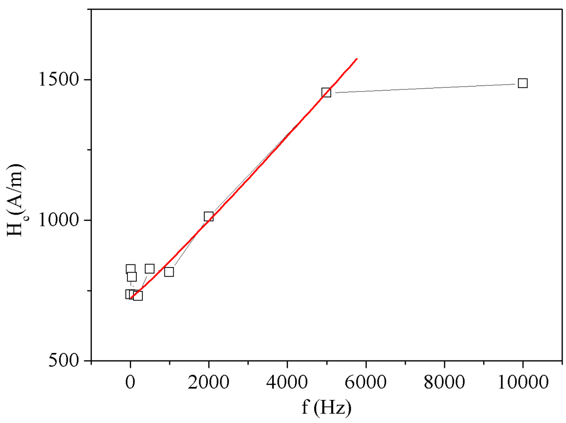

Fig. 1. Dependence of coercivity field on frequency at room temperature. Line represents the fit according to Eq. (1).

Frequency dependence of the coercive field H_c in magnetic materials can be described by the power law [8-9]:

$$H_c = H_{c0} + \text{const.} f^{1/n}, \quad (1)$$

where H_{c0} is the static coercive force and n is in the range from 1 to 4. Figure 2 shows the frequency dependence of the coercive field for Co_2MnSi microwires [10]. The coercive field decreases slightly with frequency, up to the frequency of 100 Hz. Above the frequency of 100 Hz, the coercive field increases linearly with the frequency. This points to the fact that the coercivity in Heusler Co_2MnSi microwire can be described in terms of pinned domain walls in high-frequency limits of no-negligible restoring force and sufficient domain wall mass [10].

4. Conclusions

In conclusion, we report on fabrication and magnetic characterization of a new Heusler-type glass-coated Co_2MnSi microwires prepared by Taylor-Ulitovsky method. The Curie temperature has been found to be as high as 1004 K, which classifies the Co_2MnSi microwires into the group of materials very suitable for applications. DC hysteresis loops confirmed a well defined easy magnetization axis, which is identical with the wire's axis. AC magnetic measurements show that the coercive field decreases slightly at low frequencies. Above the 100 Hz, the coercivity linearly increases.

Acknowledgments

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