Proceedings of the 15th Czech and Slovak Conference on Magnetism, Košice, Slovakia, June 17–21 2013

Effect of Temperature on Magnetization Processes in Amorphous Rapidly Solidified FeSiB/CoSiB Bilayer Ribbons

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Amorphous bilayers consisting of Fe-Si-B and Co-Si-B layers have been prepared by planar flow casting from a single crucible using a double-nozzle technique. Temperature dependencies of magnetization and hysteresis loops have been investigated in a wide temperature range. At room temperature, the effects of interlayer stresses, induced in material due to different thermal expansion coefficients of two mechanically interconnected soft magnetic layers, resulted in rounded hysteresis loops with flattened central part, indicating a dominant role of magnetization rotational processes. With an increase of measurement temperature, the interlayer stresses are relieved and the hysteresis loops became more squared.

DOI: 10.12693/APhysPolA.126.120

PACS: 75.50.Kj, 75.60.Ej, 75.80.+q

1. Introduction

Rapidly solidified amorphous and/or nanocrystalline bilayer ribbons, consisting of ferromagnetic phases with different magnetic and/or magnetoelastic properties, are subject of continuing interest for both physicists and technologists, due to their potential utilization in sensors and actuators [1]. In order to optimize the magnetic performance of these systems it is important to deepen the knowledge about the influence of composition and processing techniques, that can be used to tailor their properties.

The aim of this work is focused on the high temperature magnetic behavior of $Fe_{77.5}Si_{7.5}B_{15}/Co_{72.5}Si_{12.5}B_{15}$ amorphous bilayer. This bilayer system is composed of two ferromagnetic layers with markedly different thermal expansion coefficients and magnetostriction values [2].

2. Experimental

Rapidly quenched bilayer ribbon consisting of layers of $Fe_{77.5}Si_{7.5}B_{15}$ (air side) and $Co_{72.5}Si_{12.5}B_{15}$ (wheel side) have been prepared by planar flow casting from a single crucible using the double-nozzle technique [3]. Ribbons with typical thickness of 45-50 microns and a width of 6 mm exhibited coiling along longitudinal direction. The amorphous structure of both layers in as-quenched state was confirmed by X-ray diffraction (XRD) and transmission electron microscopy (TEM) [4]. For the sake of comparison, we have prepared the individual monolayer ribbons with the same composition as the constituent alloys in bilayer by using single-nozzle casting.

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Magnetic properties of prepared amorphous ribbons were characterized by a home-made low field vibrating sample magnetometer and by commercial VSM magnetometer (EV9, MicroSense). The $M(T)$ dependencies of magnetization were measured in temperature range 293-1073 K under applied field of 80 kA/m, by using a constant heating rate of 10 K/min. The hysteresis loops were measured between 300 and 700 K with a step of $T = 50$ K.

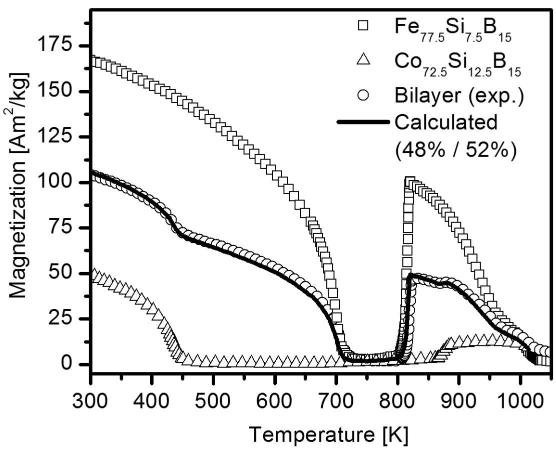

Fig. 1. Experimental $M(T)$ curves for the bilayer and the mono-layer samples as well as the calculated magnetization of the model bilayer sample obtained using the proportions 0.48/0.52 of the individual Fe-Si-B and Co-Si-B monolayers, respectively.

3. Results and discussion

Figure 1 shows the temperature dependences of magnetization for the bilayer and monolayer ribbons. We can see that the values of Curie temperature (T_c) and crystallization temperature (T_x) of constituting alloys in bilayer composite are practically the same as compared to their monolayer counterparts. The T_c values of the Co-Si-B and Fe-Si-B layers were determined to be 435 and 702 K, while their T_x values were estimated to be 861 and 808 K, respectively. The good agreement between the experimental $M(T)$ curve for bilayer ribbon and the model magnetization curve, calculated using the weighted magnetizations (the optimum ratio of the individual Fe-Si-B and Co-Si-B monolayers was 0.48/0.52), clearly shows that the overall magnetization of bilayer composite can be approximated as a simple linear combination of the two constituent alloys.

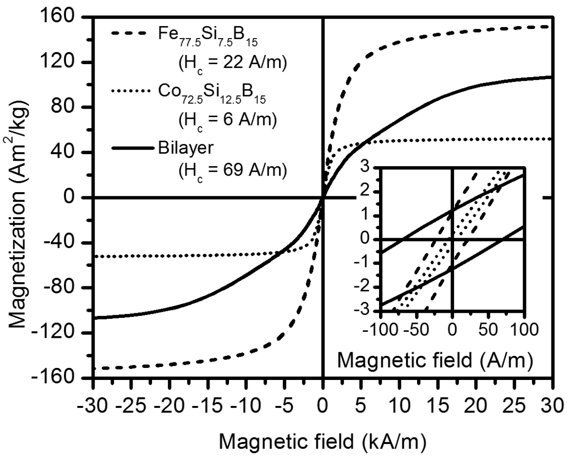

Fig. 2. Hysteresis loops for the bilayer and monolayer samples taken at room temperature.

Figure 2 shows that the hysteresis loop of bilayer ribbon at room temperature is no longer a weighted average of the two individual alloys, indicating that the magnetization process of the bilayer composite is markedly different from its monolayer counterparts. The observed difference is attributed to the presence of strong interlayer stresses, which are induced in material due to different thermal expansion of two mechanically solid connected individual layers. The measurements of thermal variation of dilatation for monolayer ribbons revealed that amorphous Co-Si-B exhibits stronger dilatation with temperature as compared to Fe-Si-B [2]. Thus upon the cooling of the prepared bilayer ribbon from high temperatures, the Co-based layer will have a tendency to shrink more, as compared to the Fe-based layer. As a consequence, the Co-Si-B layer will impose a compressive stress on the Fe-Si-B layer, and vice versa, the Fe-Si-B layer (with smaller thermal expansion coefficient) will impose a tensile stresses on its Co-Si-B counterpart. Therefore, the preferred orientation of magnetic moments in the tensile stressed Co-Si-B layer with negative magnetostriction ($\lambda_s \sim -2.6 \times 10^{-6}$) and also in the compressed Fe-Si-B layer with positive magnetostriction ($\lambda_s \sim 32 \times 10^{-6}$) will be in transverse direction to the ribbon length. Hence, the dominant magnetization process in $Fe_{77.5}Si_{7.5}B_{15}/Co_{72.5}Si_{12.5}B_{15}$ amorphous bilayer is magnetization rotation, which makes the reaching of saturation magnetization more difficult as compared to unstrained monolayers. This scenario is supported by the measurements of hysteresis loop at high temperatures, which are depicted in Fig. 3. Here, the interlayer stresses relieve with the increase of measurement temperature and the hysteresis loops become more squared, indicating that predominant magnetization processes are connected with the domain wall movement.

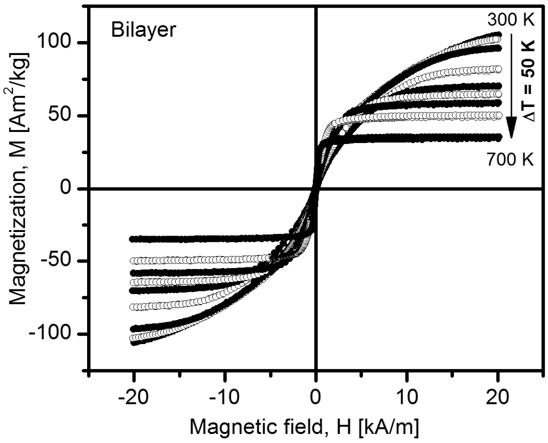

Fig. 3. Hysteresis loops of bilayer ribbon measured at different temperatures.

4. Conclusions

The magnetization and magnetic reversal processes in the Fe-Si-B/Co-Si-B bilayer system were investigated in a wide temperature range. We have shown that magnetic reversal process in such bilayer is strongly influenced by interlayer stresses, which are induced in material due to different thermal expansion of two mechanically solid connected individual layers.

Acknowledgments

This work was supported by the projects APVV 0492-11, APVV 0266-10, MNT-ERA.NET II STREAM, VEGA 2/0192/13, Cex CFNT-MVEP and NanoCEXmat ITMS 26220120019.

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