Available online at www.sciencedirect.com
ScienceDirect
Journal of Magnetism and Magnetic Materials 311 (2007) 555–559
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Mössbauer spectroscopy studies of spin reorientations in amorphous and crystalline $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ glass coated micro-wires

I. Nowik[a,*], I. Felner[a], H. Garcia-Miquel[a,b]

[a]*The Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel*
[b]*Department of Electronic Engineering, Polytechnic University of Valencia, Valencia 46022, Spain*

Received 4 January 2006; received in revised form 12 June 2006
Available online 14 September 2006

Abstract

Thermo-gravimetric, differential scanning calorimetry and comprehensive ^{57}Fe Mössbauer spectroscopy studies of amorphous and crystalline ferromagnetic glass coated $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ micro-wires have been recorded. The Curie temperature of the amorphous phase is T_C(amorp) ~730 K. The analysis of the Mössbauer spectra reveals that below 623 K the easy axis of the magnetization is axial-along the wires, and that a tangential or/and radial orientation occurs at higher temperatures. At 770 K, in the first 4 hours the Mössbauer spectrum exhibits a pure paramagnetic doublet. Crystallization and decomposition to predominantly α-Fe(Si) and Fe_2B occurs either by raising the temperature above 835 K or isothermally in time at lower temperatures. Annealing for a day at 770 K, leads to crystallization. In the crystalline material the magnetic moments have a complete random orientation. After cooling back to ambient temperature, both α-Fe(Si) and Fe_2B in the glass coated wire show pure axial magnetic orientation like in the original amorphous state. The observed spin reorientations are associated with changes in the stress induced by the glass coating.
© 2006 Elsevier B.V. All rights reserved.

PACS: 78.70.Gq; 75.80.+q; 77.84.Lf; 76.80.+y

Keywords: Magnetic micro-wires; Mössbauer spectroscopy; Spin reorientations

1. Introduction

Several recent publications [1–3] discuss the magnetic properties of soft magnetic glass-covered amorphous Co-rich and Co–Fe micro-wires, because of their outstanding magnetic properties and reduced diameter. These materials were proposed in applications as sensing elements in sensor devices, as active elements in magnetic shielding or making use of their absorption characteristics [4]. Therefore, particular interest was focused on their properties such as magneto-impedance and microwave behavior. The wires are prepared in such a way that the insulating glass coating covers the metallic nucleus. The coating induces additional internal stress due to the difference between the thermal expansion coefficient of the glass coating and the metallic nucleus [2]. By using different thickness of glass coating, it was shown that this stress affects the process of magnetization reversal and surface domain structure. The magnetic Fe-based wires are basically axially magnetized (along the wire), with a small fraction tangential (on the circumference). Amorphous wires are non-equilibrium metallic solids, formed by very rapid solidification from the molten to the amorphous state. Since the amorphous state is essentially metastable, it can easily transform into a more stable crystalline state. However, the most promising properties of the wires discussed above, have been found to deteriorate drastically upon crystallization.

Mössbauer spectroscopy studies (MS) of ^{57}Fe have been proved to be a powerful tool in the determination of the magnetic nature of Fe in its various locations. The analysis of the MS spectra also yields the orientation of the magnetization in the sample to be studied. Here we report MS, up to 800 K, of amorphous glass coated micro-wires of $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ which are ferromagnetic (FM) at room temperature, their Curie temperature

*Corresponding author. Tel.: +972 2 6584347; fax: +972 2 6586347.
E-mail address: nowik@vms.huji.ac.il (I. Nowik).

0304-8853/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2006.07.039

being T_C(amorp) ~730 K. The purpose of this study was to reveal possible changes in the orientation of the magnetization in these glass-coated micro-wires as a function of temperature, in both the amorphous and crystalline phases.

2. Experimental details

Glass-coated amorphous micro-wires of $(Co_x Fe_{1-x})_{72.5}Si_{12.5}B_{15}$ have been obtained by quenching and drawing the molten alloy (Taylor-Ulitovskue technique), having a metallic nucleus of around 4 μm in diameter and a thickness for the Pyrex-loke coating of around 3 μm, Fig. 1. The analysis and the characterization of the wires were described in Ref. [4].

^{57}Fe Mössbauer studies of magnetic micro-wires of $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ were performed using a conventional constant acceleration drive in the transmission mode, in conjunction with a 30 mCi ^{57}Co:Rh source. The velocity calibration and zero velocity reference are those obtained from an iron foil spectrum at room temperature. The experimental spectra were least square fitted with theoretical spectra, in which the magnetic hyperfine field distribution and the angle between the magnetization axis and the Mössbauer γ ray were adjusted. The micro-wires were packed in the absorber holder so that the γ rays were perpendicular to the wires.

Thermo-gravimetric study (TGA) of the sample with and without external magnetic field was carried out at a heating rate of 10 °C/min under nitrogen flow by using a Mettler TGA/STDA 851 equipped with a small permanent magnet. Differential scanning calorimetry (DSC) measurements were carried out in nitrogen atmosphere on a Mettler DSC-30 instrument (Mettler TC11 TA processor).

3. Experimental results

The thermo-gravimetric (TGA) measurement with a small magnetic field directed opposite to the gravitation force for $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ is displayed in Fig. 2. The strong exothermic peak, which appears at around 835 K, in the DSC curve (Fig. 2, inset) is due to the crystallization process. This implies that the as prepared wires are in the amorphous state. This result is consistent with the sharp drop in the TGA curve exhibited in Fig. 2 (main panel).

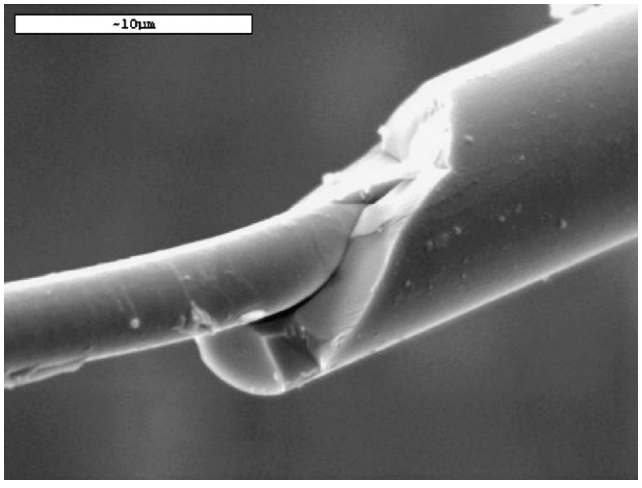

Fig. 1. Scanning electron microscope picture of a glass coated Fe-based micro-wire.

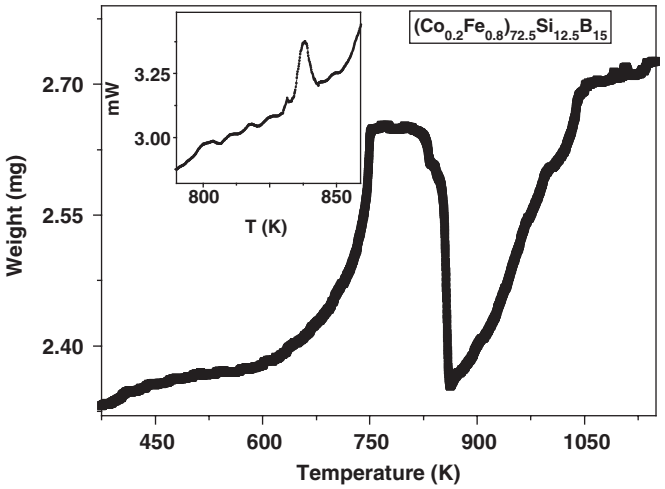

Fig. 2. Thermo-gravimetric measurement of $(Co_{0.2}Fe_{0.8})_{72.5}Si_{12.5}B_{15}$ with a small magnetic field directed opposite to the gravitation force. The DCS curve, shown in the insert, exhibits a strong exothermic peak around 835 K.

The key points to be noted in understanding the observations shown in Fig. 2 are as follows. (1) Crystallization of the amorphous wires takes place at temperatures above 770 K. The crystallization is completed by formation of the predominantly two FM, α-(Fe, Si) and Fe_2B, materials [5,6]. (2) The Curie temperature of the amorphous wires, T_C(amorp) is lower than those for the crystalline materials, which are around 1000 K. As a result, the hyperfine magnetic parameters (see below) for crystalline materials are higher than those for the amorphous phase. (3) The atomic magnetic moment in the PM state is lower than the moments in the two ordered phases. Therefore the sample weight in the PM state is higher than those in the FM state. (4) The crystallization process is irreversible, upon cooling the formed FM crystalline phases remain stable. Bearing these points in mind, the interpretation of the TGA curve is straightforward.

Upon increasing the temperature from room temperature (RT), the TGA curve exhibits a typical FM behavior with T_C(amorp) ~730 K. Any increase of the temperature should yield the paramagnetic amorphous state with almost a constant high sample weight. At higher temperatures, the crystallization rate is accelerated and the growth of the two FM α-(Fe, Si) and Fe_2B phases dominates the TGA curve features. This is most apparent at ~835 K, where the magnetic moment increases, and as a result the weight is sharply decreased. At further fast warming, the crystallization process ends (~855 K) and the magnetization reaches a new maximum, and then drops toward the Curie temperatures of the crystalline phases, ~980–1020 K.

Download English Version:

https://daneshyari.com/en/article/1804275

Download Persian Version:

https://daneshyari.com/article/1804275

Daneshyari.com