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The stress effect on electrical resistivity sensitivity of FeBSiC amorphous ribbon

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ABSTRACT

In this paper it was identified and determined the correlation between the stress intensity and electrical resistivity sensitivity coefficient k_σ of the amorphous $Fe_{81}B_{13}Si_4C_2$ ribbon. Crystallization process in this alloy occurs in the temperature range from 500 °C to 540 °C. Therefore, efficient relaxation of amorphous structure was performed by annealing at 400 °C for 30 min. The annealed alloy has stable structure in temperature range from room temperature to 300 °C, exhibiting low temperature resistivity coefficient and linear dependence of resistivity upon stress.

Based on experimentally obtained dependence of termoelectromotive force upon temperature and stress, we have proved that electron state density at Fermi level decreases with stress increase. This causes an increase in resistivity of the ribbon sample, and consequently results in the improvement of sensitivity coefficient k_σ.

1. Introduction

The amorphous metallic alloys represent a class of materials that have specific properties, which are interesting not only for fundamental solid state physics, but also for application in electronics, metallurgy and technology [1–3]. Research of amorphous materials lead to new discoveries in physics via investigations of metals and alloys in disordered state, performed in a low temperature region ($T < \Theta_D$, where Θ_D is Debye temperature).

The amorphous state of matter is structurally and thermodynamically unstable and very susceptible to partial or complete crystallization during thermal treatment or non isothermal compacting [4]. Achieving the optimum amorphous state of a final product requires investigation and understanding of the numerous characteristics of these complex materials, such as thermal, mechanical, electrical and magnetic properties [5].

There are several methods used to form amorphous metal structure. Nowadays, special attention is paid to the development of methods for creation of metals in an amorphous state from various complex metallic compounds, in the presence of metalloids or transition metals added in order to improve glass forming ability [6].

Amorphous metallic ribbons feature high tensile strength and may exhibit substantial changes in electrical resistance as a result of mechanical deformations. Two kinds of soft magnetic materials are successfully used for strain sensing applications: stress annealed cobalt based CoFeCrSiB amorphous ribbons with small negative magnetostriction [7] as well as annealed iron based FeCoNiZrNbSiB ribbons [8] with good magnetoelastic coupling.

The aim of this paper is to investigate possibilities of using annealed $Fe_{81}B_{13}Si_4C_2$ amorphous ribbons as stress sensors and measure electrical resistivity sensitivity coefficient. We conducted experimental investigation on the thermocouple copper wire – amorphous ribbon to study the changes of electron state density at Fermi level.

2. Experimental setup

Amorphous ribbons of $Fe_{81}B_{13}Si_4C_2$ nominal composition were prepared by rapidly quenching of the melt on a rotating disc (melt spinning technique). Ribbon samples of 180 mm long, 2 mm wide and 30 μm thick were used for experiments. Before the actual testing, the samples were annealed in argon at 400 °C for 30 min.

Strain of the ribbon, at stress of 50 MPa, 100 MPa, 150 MPa and 200 MPa, was measured by strain gauge of 5×10^{-3} mm sensitivity. Electrical resistance at the same stresses was measured by Thomson bridge with sensitivity of 5×10^{-4} Ω.

The crystallization process was investigated by the differential scanning calorimetry (DSC) in a nitrogen atmosphere at a heating rate of 10 °C/min using SHIMADZU DSC-50 analyzer.

Four-point method was used to measure electrical resistance of the ribbon sample in the temperature range from 25 °C to 400 °C. During the measurement, the ribbons were in protected argon atmosphere. The measurement sensitivity was 10^{-5} Ω.

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