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THE EFFECT OF TEMPERATURE ON SENSITIVITY COEFFICIENT OF THE AMORPHOUS RIBBON FORCE SENSOR

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ABSTRACT
The dependence of the changes of relative electrical resistance on the relative changes of ribbon length (dR/R)/(dl/l) i.e. sensitivity coefficient on temperature has been experimentally investigated in $Fe_{81}B_{13}Si_4C_2$ *amorphous ribbons.*
Thermo-electrical measuring of interrelations between electrical resistance and temperature resulted in establishing temperature interval of thermal stability of the investigated alloy, from room temperature to 300°C. The study suggests that within this temperature interval coefficient of sensitivity is independent on temperature.
Measuring of the dependence of electrical resistance on temperature has shown that the temperature coefficient of electrical resistance, within the range of room temperature to 300ºC, is rather low. The sample underwent the process of structural relaxation during annealing whereupon the coefficient of sensitivity of the ribbon was increased by some 20%, whereas the temperature interval of thermal stability was expanded up to 400ºC.
Keywords: amorphous ribbons, electrical resistivity, sensitivity coeficient

1. INTRODUCTION
Amorphous metallic alloys objectively present a new class of materials and have specific properties attractive not only from the aspect of fundamental solid state physics but also in electronics, electrical engineering, metallurgy and technology [1-3]. New prospects have been offered in the field of physics owing to research on amorphous materials, as investigations of metals and alloys in a non-ordered state can now be performed at low temperatures ($T < \Theta_D$, Θ_D standing for the Debai temperature).
The amorphous state of a metal is structurally and thermodynamically unstable, prone to stabilization by partial or complete crystallization during thermal treatment or non-isothermal compacting. This requires widening knowledge and investigation of numerous characteristics of these materials, i.e. thermal, electrical and magnetic ones, with the purpose of maintaining the amorphous state of the final product.
Parameters which enable the formation of an amorphous metal structure are not completely known, though several methods for obtaining this state have been developed. However, special attention is paid nowadays to the development of methods for obtaining metals in an amorphous state from various complex metallic compounds, in the presence of nonmetals or transition metals as amorfizers [4].
Amorphous metallic ribbon-shaped alloys exhibit a unique mixture of high solidity and strength. As regards solidity, they are superior to the most solid crystal alloys. Particularly important property of the amorphous metallic alloys is that relatively minor deformities considerably affect electrical resistance.
The paper presents the investigation of application of amorphous metallic alloys $Fe_{81}B_{13}Si_4C_2$ as force sensor.

2. EXPERIMENTAL

The amorphous ribbon-shaped alloy $Fe_{81}B_{13}Si_4C_2$ has been investigated. The samples were 180 mm long, 2 mm wide and 30 mm thick. Absolute straining at various temperatures has been measured by the $5\cdot10^{-3}$ mm sensitivity tensiometre. Measurement of electrical resistance of ribbon was performed by a four-point method in an argon atmosphere.

During the mechanical straining of the ribbon, changes in electrical resistance were measured by the Thomson bridge ($5\cdot10^{-3}$ sensitivity).

3. RESULTS AND DISCUSSION

Fig. 1 presents experimentally obtained dependence of electrical resistivity on temperature.

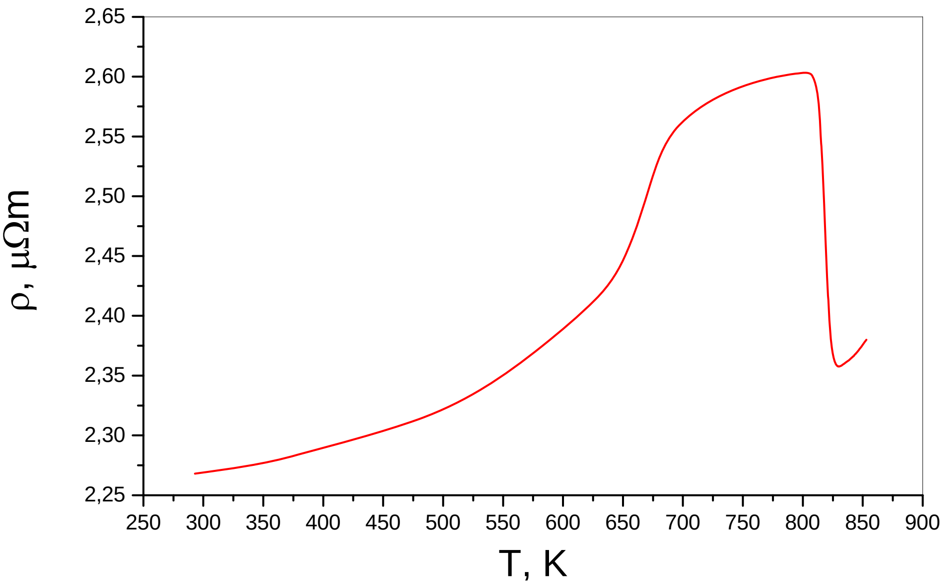

Figure 1. The dependence of the specific electrical resistivity on temperature in the amorphous alloy $Fe_{81}B_{13}Si_4C_2$.

Fig. 1 shows that temperature coefficient of resistance is very low from room temperature to 300ºC (573 K) suggesting that within this temperature interval this amorphous ribbon could be suitable material for force sensor.

In classical electronic theory of metals the electrical resistivity ρ is presented by

$$\rho = \frac{2m\cdot\bar{v}}{ne^2\cdot\bar{\lambda}} \tag{1}$$

m – electron mass, $\bar{v}$ – mean speed of the chaotic electron movement, e – electron beam charge and $\bar{\lambda}$ – electron inelastic mean free path.

Increased deformities induce decline in electron inelastic mean free path, which brings about immediate increase in electrical resistivity.

Sensitivity coefficient of ribbon equals the ratio of the relative change of electrical resistance and relative deformation of the ribbon.

Logarithming and differentiating of the electrical resistance formulation with definitions

$$R = \rho\frac{l}{S} = \rho\frac{l^2}{V}. \tag{2}$$

results in $\log R = \log\rho + 2\log l - \log V$

$$\frac{\Delta R}{R} = \frac{\Delta\rho}{\rho} + 2\frac{\Delta l}{l} - \frac{\Delta V}{V}\,. \tag{3}$$

Further simplification gives:

$$\frac{\Delta R}{R} = \frac{\Delta V}{V} - (C-1) + 2\frac{\Delta l}{l} \quad , \quad C = \frac{\Delta\rho}{\rho} \Big/ \frac{\Delta V}{V} \tag{4}$$

As

$$V = \frac{D^2\pi \cdot l}{4} \quad , \quad \frac{\Delta V}{V} = 2\frac{\Delta D}{D} + \frac{\Delta l}{l} \tag{5}$$

With regard to the known relation

$$\frac{\Delta D}{D} = -\mu \cdot \frac{\Delta l}{l} \tag{6}$$

μ standing for Poison coefficient of the magnitude $\mu = 0.3$ in most metals.

Interchange of (5) in (4) results in:

$$\frac{\Delta R}{R} = (C-1)\cdot\left(2\frac{\Delta D}{D} + \frac{\Delta l}{l}\right) + \frac{2\Delta l}{l}\,. \tag{7}$$

The change of (6) and (7) and division by $\Delta l/l$ results in

$$\frac{\Delta R}{R} \Big/ \frac{\Delta l}{l} = 2 + (C-1)\cdot(1-2\mu),\; K = (C-1)\cdot(1-2\mu) \tag{8}$$

Values C = 0 and $\mu = 0.5$ gives K = 2.

Sensitivity coefficient of the materials used as measure ribbons is expected to be as high as possible.

Experimentally obtained dependance of the change in electrical resistance on the relative deformation in the amorophous alloy $Fe_{81}B_{13}Si_4C_2$ at temperatures 50ºC, 100ºC, 150ºC, 200ºC, 250ºC and 300ºC are presented in Fig. 2

The diagram in Fig. 2 shows linear dependence of relative change of electrical resistance on relative deformation within the entire range of absolutely elastic deformation of the ribbon throughout the temperature interval (from room temperature to 300ºC).

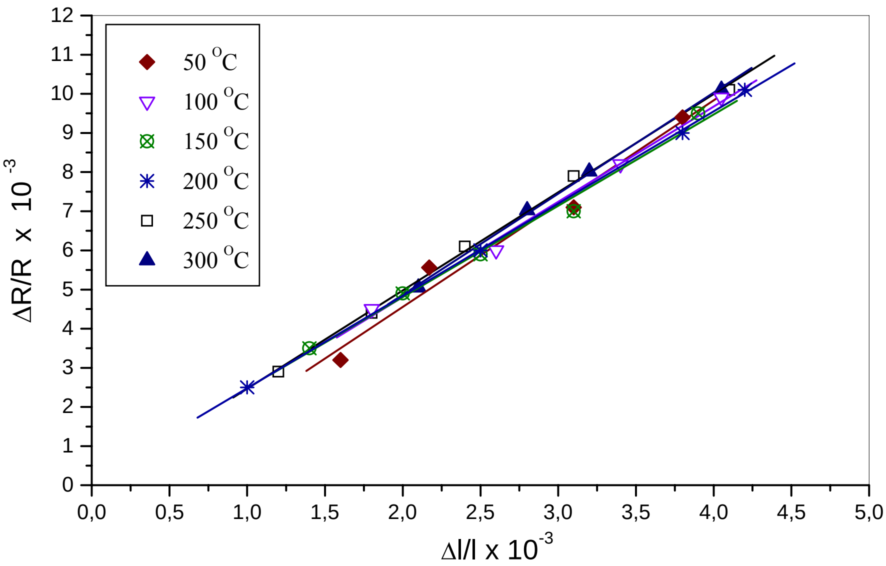

Figure 2. Dependence of relative change in electrical resistance on relative deformation at 50ºC, 100ºC, 150ºC, 200ºC, 250ºC and 300ºC.

Prior to studying dependence of ΔR/R on Δl/l, the ribbon was annealed for 30 min at 400 ºC, which is about 120 ºC lower than the crystallization temperature [5]. The process is accompanied by the annealing of the defects and micro-extension of the initial ribbon sample, which ensures the elimination of the effect of structural relaxation on electrical resistivity during the process of straining at higher temperatures.

The inclination of straight lines in Fig. 2 determines sensitivity coefficients of the ribbon at temperatures t_1 = 50ºC, K_1 = 2.6374 ; t_2 = 100ºC, K_2 = 2.4319 ; t_3 = 150ºC, K_3 = 2.3308 ; t_4 = 200ºC, K_4 = 2.3566 ; t_5 = 250ºC, K_5 = 2.5082 ; t_6 = 300ºC, K_6 = 2.5806 .

The obtained values of sensitivity coefficients of the amorphous ribbon are higher than classical ones by some 20%. Similarly, sensitivity coefficient of the ribbon is independent on temperature within the interval room temperature – 300 ºC.

The above stated material and exceptional anticorrosion properties of the amorphous ribbon $Fe_{81}B_{13}Si_4C_2$ recommend its usage as force sensor.

4. ACKNOWLEDGEMENTS

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