PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. 3 No 1, 01NTF08(2pp) (2014)

Influence of Magnetic Field on Thermal Coefficient of Resistance of the Granular Film Alloys

L.V. Odnodvorets*

Sumy State University, 2, Rymsky Korsakov Str., 40007 Sumy, Ukraine

(Received 01 June 2014; published online 29 August 2014)

The elementary theory about the effects of external magnetic field on the value of the thermal coefficient of resistance (β) granular alloy film was proposed. The obtained value allows calculating the difference between the value β for the sample and solid solution, which based on the granular alloy was formed.

Keywords: Granular alloy, Thermal coefficient of resistance, Solid solution, Granule, Magnetic field.

PACS numbers: 68.60. – p, 73.61. – r

1. INTRODUCTION

Discovery of giant magnetoresistance in multilayers stimulated the search and observation of this phenomenon in other film systems, particularly in the so-called granular alloys (g.a.). This led to the study of other physical properties of g.a. and in electrophysical properties (see, forexample, [1, 2]). In work [1] film system based on non-magnetic and magnetic components are modeled as a layered structure based on the film of granular solid solution (s.s.). In this approach, the sample is a parallel connection of individual layers. In turn, this layer is modeled as a parallel connection of n carried tubes, each of which is represented as a series connection of fragments including (average value – Δl_{ss}) and magnetic metal granules (average radius – r_0). Based on the phenomenological model proposed by authors [1] obtained for the ratio of the resistivity (ρ) and thermal coefficient of resistance (β) g.a.

In the most general form of ratio for β granular alloy is as follows:

$$\beta = \beta_{ss} - \frac{4\beta_g\rho_g}{4\rho_g + \alpha\rho_{ss}} - \frac{\alpha\beta_{ss}\rho_{ss}}{4\rho_g + \alpha\rho_{ss}} + \frac{\beta_g\rho_g + \alpha\beta_{ss}\rho_{ss}}{\rho_g + \alpha\rho_{ss}}, \quad (1)$$

where parameter $\alpha = \Delta l_{ss} / r_0$ authors called the degree of granularity of the sample; ρ_g and ρ_{ss} – resistivity material granules (which may be Co, Fe or Ni) and s.s.; β_g and β_{ss} – thermal coefficient of resistance of the material granules and TR, respectively.

In work [2], the value for β in the limit when the coefficient α satisfies the conditions: $\alpha >> 1$, $\alpha \cong 1$ and $\alpha << 1$:

$$\beta \cong \beta_{ss} - \frac{4\beta_g\rho_g}{\alpha\rho_{ss}}, \alpha >> 1; \quad (2)$$

$$\beta = \beta_{ss} - \frac{\alpha\beta_{ss}\rho_{ss}}{4\rho_g}, \alpha << 1; \quad (3)$$

$$\beta = \beta_{ss} - \frac{4\beta_g\rho_g + \beta_{ss}\rho_{ss}}{4\rho_g + \rho_{ss}} + \frac{\beta_g\rho_g + \beta_{ss}\rho_{ss}}{\rho_g + \rho_{ss}}, \alpha \cong 1. \quad (4)$$

Note that in case (3) can only talk about the theoretical possibility of research as experimental to form a layer system in which the elements of the tube current will satisfy the inequality $\Delta l_{ss} << r_0$, is almost impossible.

Testing of the model was made in work [2] as an example of two-component systems (Ag + Co) / S (simultaneous condensation) and Ag / Co / S (layered condensation), where S – substrate. The authors note that the experimental and calculated data agree to within 12 %.

2. ELEMENTARY THEORY

The aim of this work is to develop a phenomenological theory that describes qualitatively the dependence of the sensitivity of β to the magnetic field (i.e., value $S_B = \partial\beta / \partial B$) and allows to calculate numerically the dependence $\Delta\beta_B = (d\ln\beta / dB - d\ln\beta_{ss} / dB) = \beta_B - \beta_{ssB}$ of the value Δl_{ss} (or coefficient α). Analyzed the above three limiting cases.

In the case $\alpha >> 1$ (formula 2) the ratio for value ΔS_B has the form:

$$\begin{aligned} S_{\beta B} - S_{\beta_{ss}B} &= \frac{\partial\beta}{\partial B} - \frac{\partial\beta_{ss}}{\partial B} \cong \\ &\cong \frac{4}{\alpha}\frac{\rho_g}{\rho_{ss}} \cdot \left[\beta_g\beta_{ssB} - \frac{\partial\beta_g}{\partial B}\right] - \frac{4}{\alpha}\frac{\partial\rho_g}{\partial B} \cdot \frac{\beta_g}{\rho_{ss}}. \end{aligned} \quad (5)$$

From (5) it is possible to access the value $\Delta\beta_B$ assuming that $\beta \cong \beta_{ss}$ (note that this situation is possible because β and β_{ss} are one order of magnitude, which differ only factor at 10^{-3} K^{-1}):

$$\begin{aligned} \Delta\beta_B = \beta_B - \beta_{ssB} &\cong \frac{4\rho_g}{\alpha\rho_{ss}\beta} \cdot \left[\beta_g\frac{\partial\rho_{ss}}{\partial B} - \frac{\partial\beta}{\partial B}\right] - \\ &- \frac{4}{\alpha \cdot \beta} \cdot \frac{\partial\rho_g}{\partial B} \cdot \frac{\beta_g}{\beta_{ss}} \end{aligned} . \quad (6)$$

In the case $\alpha << 1$ of the ratio (3) we obtain:

$$S_{\beta B} - S_{\beta_{ss}B} \cong \frac{\alpha}{4\beta} \cdot \frac{\left(\frac{\partial\beta_{ss}}{\partial B} \cdot \rho_{ss} + \frac{\partial\rho_{ss}}{\partial B} \cdot \beta_{ss}\right)\rho_g - \frac{\partial\rho_g}{\partial B} \cdot \rho_{ss}\beta_{ss}}{\rho_g^2} \quad (7)$$

* larysa.odnodvorets@gmail.com

and

$$\Delta\beta_B = \beta_B - \beta_{ssB} \cong -\frac{\alpha}{4\beta}\cdot\frac{\left(\frac{\partial\beta_{ss}}{\partial B}\cdot\rho_{ss}+\frac{\partial\rho_{ss}}{\partial B}\cdot\beta_{ss}\right)\rho_g-\frac{\partial\rho_{ss}}{\partial B}\cdot\rho_{ss}\beta_{ss}}{\rho_g^2}. \tag{8}$$

Note that the value for ΔS_B if $\alpha \cong 1$ similar to (5), and the ratio for $\Delta\beta_B$ (9):

$$\Delta\beta_B \cong -\frac{\left(4\frac{\partial\beta_g}{\partial B}\cdot\rho_g+4\frac{\partial\rho_g}{\partial B}\cdot\beta_g+\frac{\partial\beta_{ss}}{\partial B}\cdot\rho_{ss}+\frac{\partial\rho_{ss}}{\partial B}\cdot\beta_{ss}\right)\cdot\left(4\rho_g+\rho_{ss}\right)-\left(4\frac{\partial\rho_g}{\partial B}+4\frac{\partial\rho_{ss}}{\partial B}\right)\cdot\left(4\beta_g\rho_g+\beta_{ss}\rho_{ss}\right)}{\beta\cdot\left(4\rho_g+\rho_{ss}\right)^2}+$$
$$+\frac{\left(\frac{\partial\beta_g}{\partial B}\cdot\rho_g+\frac{\partial\rho_g}{\partial B}\cdot\beta_g+\frac{\partial\beta_{ss}}{\partial B}\cdot\rho_{ss}+\frac{\partial\rho_{ss}}{\partial B}\right)\cdot\left(\rho_g+\rho_{ss}\right)-\left(\frac{\partial\rho_g}{\partial B}+\frac{\partial\rho_{ss}}{\partial B}\right)\cdot\left(\beta_g\rho_g+\beta_{ss}\rho_{ss}\right)}{\beta\cdot\left(\rho_g+\rho_{ss}\right)^2}. \tag{9}$$

3. RESULTS OF CALCULATIONS

Based on correlations and experimental data , some of which are given in [2, Table 5] were calculated dependence of $\Delta\beta_B$ that in all three cases is negative, from Δl_{ss} for different values of α (on Fig. 1 the value $\Delta\beta_B$, for convenience, are specified on the module). In the calculations we asked real granules size (see, for example, the data of the work [3] for granular alloy based on Ag and Co): $r_0 = 2$, 5, 10 nm. Size of Δl_{ss} selected so that $\alpha \cong$ 8-16 (at the $\alpha >> 1$); $\alpha \cong$ 0,1-0,4 (at the $\alpha << 1$) and $\alpha \cong 1$ (in the case $\alpha \cong 1$).

As follows from these data, the dependence $\Delta\beta_B$ versus Δl_{ss} (and in fact – on the α value) has a different character for the three limiting cases. In particular, when $\alpha >> 1$ the value $|\Delta\beta_B|$ monotonically decreases from 0,1 to 0.02 T^{-1} (Fig. 1a), while $\alpha << 1$ – changes in the-opposite direction (Fig. 1b) in the same range (accentuate again note that the value $\Delta\beta_B < 0$). In the case $\alpha \cong 1$ (Fig. 1c) the value of $|\Delta\beta_B|$ is 0,1 T^{-1}.

4. CONCLUSIONS

The obtained results denote on the principal possibility to control the magnetic field magnitude of the thermal coefficient of resistance. The difference of the dependence in Fig. 1 we explained different effect on the resistivity of the sample film spin-dependent electron scattering on magnetic metal granules. Specifically, in the first case ($\alpha >> 1$), the low concentration of granules, the electrical properties of g.a. to a large extent determined by the resistivity Including that, most likely, not shunted low-spin channel, while in the second case, the high concentration of granules ($\alpha << 1$) can realize high-resistance system and low-spin channels and ρ_{ss} role in thermal coefficient of resistance is negligible. In the case $\alpha \cong 1$ the value $\Delta\beta_B$ a constant value due to the competing character of these two mechanisms.

The author expresses gratitude to Prof. Protsenko I.Yu. for a discussion of the results and post-graduate Hrychanovs'ka O.A. for their help on figuration of the manuscript.

Work performed under state budget themes No 0112U001381 (2012-2014 years).

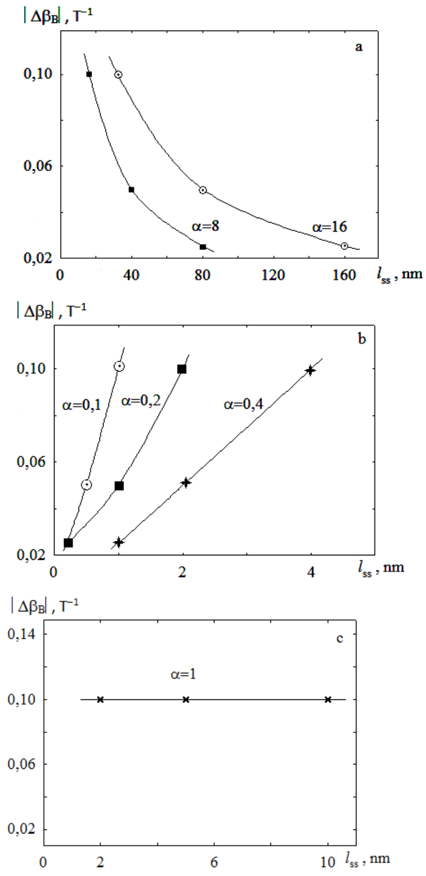

Fig. 1 – The calculate dependences $|\Delta\beta_B|$ versus Δl_{ss} for the limited case: $\alpha >> 1$ (a); $\alpha << 1$ (b) and $\alpha \cong 1$ (c)

REFERENCES

1. S.I. Protsenko, L.V. Odnodvorets, I.V. Cheshko, *Visnyk SymDU. Seriya "Phisyka, matematyka, mekhanika"* № 1, 22 (2008) [In Ukrainian].
2. D.M. Kondrakhova, Yu.M. Shabelnyk, O.V. Synashenko, I.Yu. Protsenko, *Usp. Phys. Met.* **13** № 3, 241 (2012) [In Ukraine].
3. J. Du, B. Zhang, R.K. Zheng et al., *Phys. Rev. B* **75**, 014415 (2007).