SOME ASPECTS OF THE STRUCTURAL STATE INTERPRETATION OF THE HARD MAGNETIC MATERIAL WITH THE BCC LATTICE

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SOME ASPECTS OF THE STRUCTURAL STATE INTERPRETATION OF THE HARD MAGNETIC MATERIAL WITH THE BCC LATTICE

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Abstract. – Depending on a type of diffractometer used and on its accuracy two different diffraction patterns were received. These results allowed to interpretate the investigated structure as a single-phase or a double-phase one. It seems that it was the reason of different views of the Alnico alloy structure in the literature. With the use of accepted model of mathematical description of single-phase structure can be described.

1. Introduction

Alnico-type permanent magnets alloys containing titanium attain their high magnetic hardness thanks to their structure configuration. In the literature such a structure is interpretated as double-phase one [1-3] (ferromagnetic areas are recognized as α_1 phase particles, weak magnetic or non magnetic areas are recognized as α_2 particles) or single-phase modulated structure with the defined chemical composition wavelength [4-6]. Presented earlier differences in the interpretations of the state structure [1-6] were the inspiration for undertaking of these investigations.

2. Experimental and results

The investigations were carried out on the samples made of the Alnico alloy containing 3.08 % Ti, 32.4 % Co, having the controlled equiaxial macrostructure, received under industrial conditions. Samples were subjected to the full heat treatment anticipated for this kind of alloy. X-ray investigations were carried out with the use of Siemens D500 [7] and Dron 3 [8] diffractometers. In both cases filtered CoK_α radiation was used. Polycrystalline samples were investigated in two positions corresponding to perpendicular and parallel position with regard to external magnetic field used during isothermal annealing.

Due to small number of grains taking part in the diffraction the investigations were made in a changed arrangement (Fig. 1). The measurement of each diffraction profile run in few stages (in the case of D500 diffractometer). Final diffraction patterns received for

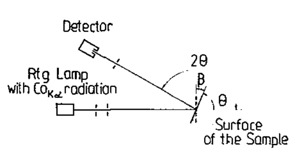

Fig. 1. – Scheme of modificated geometry of the measuring system.

200 and 002 reflexes are presented in figure 2. The diffraction patterns received during investigations carried out with the use of Dron 3 diffractometer are presented in figure 3.

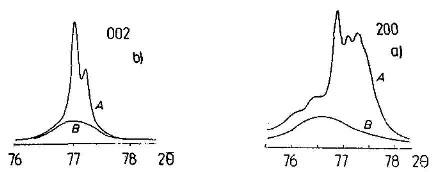

Fig. 2. – Diffraction pattern for a) reference 200, b) reference 002, curve A – sample position in a privilege direction, curve B – sample position out of privilege direction.

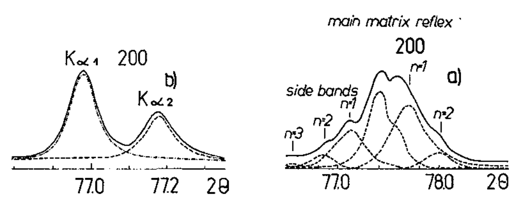

Fig. 3. – Diffraction patterns for a) reference 200, b) refernece 002.

For both reflexes (200 and 002 – see Fig. 2) additional side bands reflexes with different intensity are visible. These reflexes may be connected with the modulated structure occuring in the investigated material. For 200 reflex the K_{α_1,α_2} double with two side band reflexes having low intensities and laying at two opposite sides of maximum peak are visible. For 200 reflex (surface of the sample parallel to the external magnetic field lines) diffraction pattern is more complicated. There are two basic reflexes according to two phases occuring in the investigated material and additional peaks in form of satellites. Complex peak wave form was separated into components with appropriate soft ware. Each component was approximated by a function of form: $y(x) = A[1 + (x-b)^2 / \omega\rho^2]^{-\omega}$ where A and b represent height and centre of peak position respectively, ρ is a width of a peak, ω consider the shape of the peak. A result of such separation is presented in figure 4. The following values of lattice constants were obtained ($\Delta a = 0.0001$ nm) :

$$a_{\alpha_1} = 0.2865 \text{ nm} \; ; \; a_{\alpha_2} = 0.2876 \text{ nm} \; ; \; c = 0.2874 \text{ nm}.$$

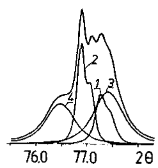

Fig. 4. – Separation of 200 peak into components: 1-phase α_1, 2-phase α_2, 3 and 4-side band reflexes.

Respective ratios are as follows:

$$a_{\alpha_1}/c = 0.997 \; ; a_{\alpha_2}/c = 1.001 \; ; \; a_{\alpha_1}/a_{\alpha_2} = 1.0038.$$

In the result of investigations carried out with the use of Dron 3 diffractometer the diffraction pattern received (see Fig. 3) evidences that a single-dimentional deformation occuring in a plane perpendicular to the external magnetic field lines ([h00]). In this plane none of the left directions ([0h0] and [00h]) over an average Λ distance is privilege on the ground of the external magnetic field symmetry. The above considerations allow to adopt for calculations a single-dimentional deformation model [9, 10]. In accepted model periodical changes of chemical composition of a solid solution in relation to average composition c_0 is postulated. A chemical composition modulation wavelength is:

$$\Lambda = m \cdot a$$

where: $m \gg 1$, a is lattice constant.

The modulation constant Λ determined from the diffraction pattern is $\Lambda \simeq 45.0$ nm. Adopting this value to the further calculations a lattice constant modulation wavelength $\varepsilon \cdot a = 0.0013$ nm was determined what points to two, mutually coherent, regions having an average difference in lattice constants of $\Delta a = 0.0013$ nm and different concentrations of alloy components.

Investigations of the surface perpendicular to the magnetic field lines show that the Bragg reflexes of (h00) type are narrow and spectrally resolved. Investigation of the surface parallel to external magnetic field lines indicate that all reflexes are accompanied by side bands (Fig. 3a). Results received indicate that the investigated material is an ordered solid solution with the bcc lattice constant $a = 0.2873 \pm 0.0003$ nm. The reflexes coming from the superstructure point to an ordered structure of the CsCl type.

3. Discussion and summary

Analysis of the results received during investigations carried out with the use of D500 diffractometer allows to assume the existence in the structure two separate phases α_1 and α_2 with quasi-cubic lattices with the tetragonal deformation. Orientation of both phases is similar within one grain. In the direction parallel to the (001) direction privilege by external magnetic field used during isothermal annealing one, common for both phases, constant c was determinated. In the direction perpendicular to external magnetic field lines lattice constants a_{α_1} and a_{α_2} for two phases α_1 and α_2 respectively were established. "c" value lays between the a_{α_1} and a_{α_2} values. Half-width of 002 reflex for phase α_1 is similar to half-width of 200 reflex but there is a big difference between half-width of 002 reflex for phase α_2 and half-width of 200 reflex. The above interpretation was widely presented [7] and is close to earlier interpretation of other authors [1-3]. Apart from the interpretation given above and basing on the results received during investigations carried out with the use of Dron 3 diffractometer, it can be assumed that the investigated structure is a single-phase one and it is characterized by a fluctuation of interplanar distance d_{hkl} and scattering power F_{hkl}.

The difference between the diffraction profiles' shapes presented above is probably caused by a different accuracy of diffractometers used. Such a difference was the reason of two-ways interpretation of the structural state of the investigated alloy. A difference in accuracy of methods of investigations was the cause of two-ways interpretation by different authors.

[1] de Vos, K. J., Dissert., Univ. Eidhoven (1966).

[2] Pashkov, P. P., Fridman, A., Granowsky, P., *IEEE Trans. Magn.* **MAG-6** (1970) 241.

[3] Lywszyc, B. G., Lineckij, Ja. L., *Fiz. Met. Metallowed.* **22** (1966) 627.

[4] Tiapkin, Ju. D., Jeroszenkowa-Lukanina, I. G., *Dokl. Akad. Nauk SSSR* **160** (1965) 325.

[5] Magat, L. M., *Fiz. Met. Metallowed.* **19** (1965) 521.

[6] Kalichman, W. D., Turow, W. D., *Fiz. Met. Metallowed.* **25** (1968) 1058.

[7] Marciniak, H., Diduszko, R., Kłodas, K., Dymkowski, T., Proc. XIII Conf. Appl. Cryst., Cieszyn (Aug. 23-27, 1988) in press.

[8] Sass, J., Gaca, J., Wojcik, M., Kłodas, K., Dymkowski, T., Proc. XIV Congr. Gener. Assem. Inter. Union Crystal., Perth, (Aug. 12-20, 1987) L. Abstr. 11.

[9] Fontaine, D., Met. Soc. Conf. 36 (New York, Gordon and Breach (1966).

[10] Guinier, A., Théorie et Technique de la Radiocristallographie (Paris-Dunod) 1956.