STRUCTURE AND PHYSICAL PROPERTIES OF MULTICOMPONENT FILMS BASED ON THE Fe-Si-B SYSTEM

Bashev V.F.,[1] Kushnerov O.I.,[2] Kutseva N.A., [2] Ryabtsev S.I. [2]
[1]Dnipro State Technical University, Dniprobudivska, 2, Kamianske, 51918, Dnipropetrovsk region Ukraine.
[2] Oles Honchar Dnipro National University, Gagarin Avenue, 72, Dnipro, 49010, Ukraine.
E-mail: siryabts@gmail.com

Introduction

With the development and improvement of technology, due attention is paid to reducing the size of devices and electronic circuits. The components of the latter are replaced by thin films (objects less than 1 μm thick). Multicomponent films based on the Fe-Si-B system are of particular interest, since there are a few previously unexplored and promising systems. Purpose of the work: to study the effect of three-electrode ion-plasma sputtering on the properties of multicomponent alloys based on the Fe-Si-B system, and their temperature stability.

Materials and Methods

The object of this investigation were multicomponent films of composition (in at.%): $Fe_{73}Si_{15,8}B_{7,2}$-(Cu, Nb)$_4$ (composition 1) and $Fe_{78,5}Si_6B_{14}$-(Ni, Mo)$_{1,5}$ (composition 2)

The films were obtained by the method of modernized three-electrode ion-plasma sputtering (MTIPS). The rate of energy relaxation of the deposited atoms under different modes of sputtering by the MTIPS method, according to theoretical estimates, reaches 10^{12}–10^{14} K/s. The films were deposited on sitall (glass-ceramic) substrates, as well as on a fresh cleavage of a NaCl salt single crystal. Films on sitall substrates were used to study the electrical and magnetic properties. The films on the NaCl substrate after its dissolution were studied by electron microscopy and X-ray diffraction analysis. Measurement of the electrical resistance of the films during heating was carried out in a vacuum of 13.3 mPa by the four-probe method. The coercive force Hc of the films was measured using a vibrating magnetometer in a maximum magnetizing field of 0.3 T, added parallel and perpendicular to the film surface.

Results

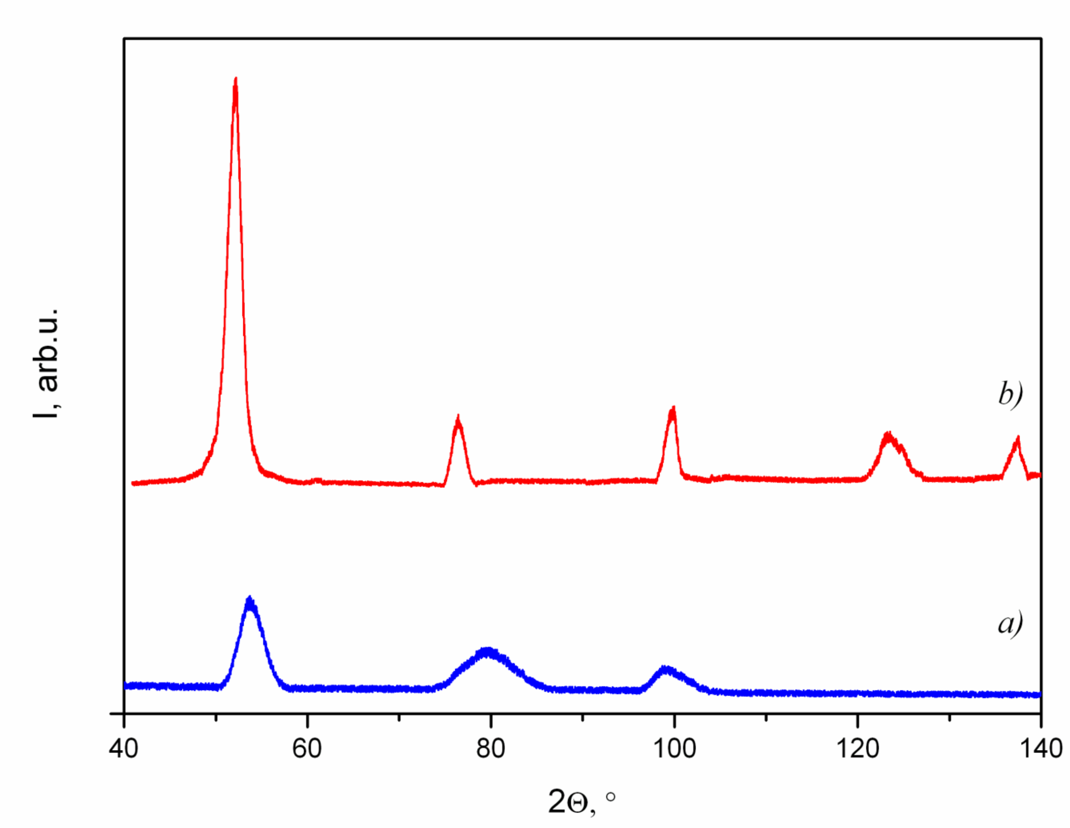

Fig.1 Photometric X-ray diffraction patterns of the films in the initial state (a) and after heating to 893 K (b).

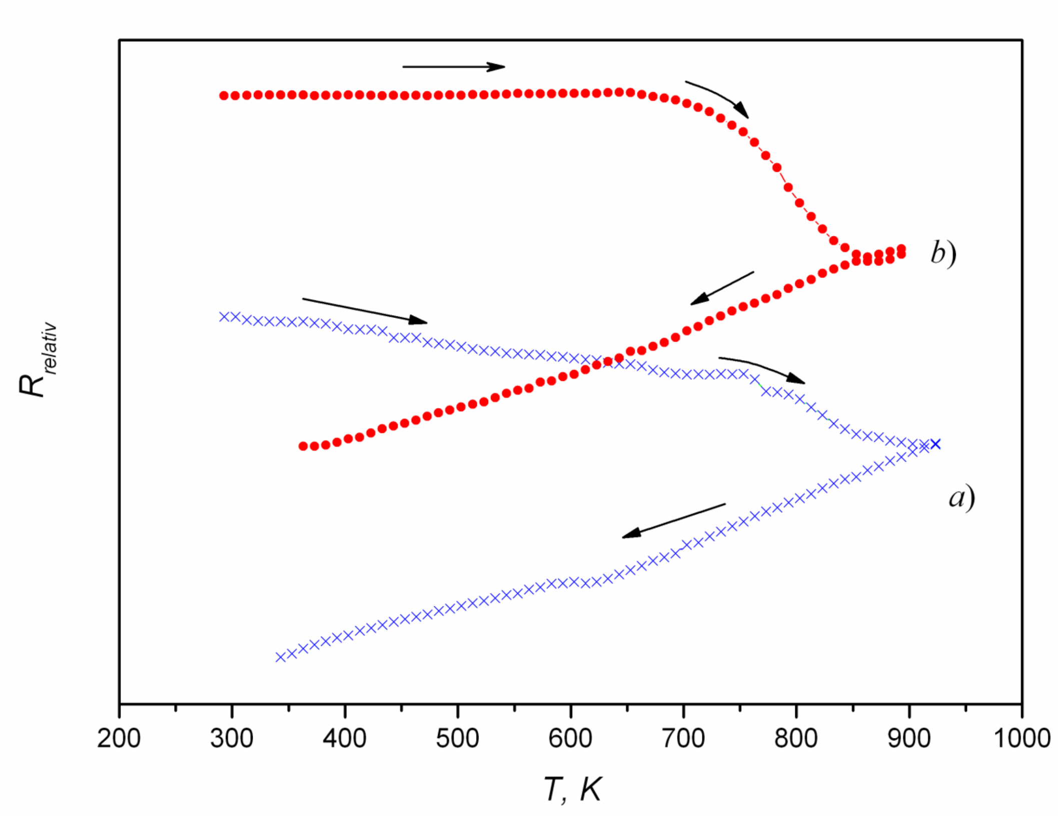

Fig.-2. The temperature dependence of the resistivity of films composition 1 (a) and 2 (b)

In the freshly deposited state, in films (composition 1) $Fe_{73}Si_{15,8}B_{7,2}$-(Cu, Nb)$_4$, an amorphous structure was recorded, characterized by a blurred halo corresponding to the CSR size L≈1.6 nm (Fig. 1). In films $Fe_{78,5}Si_6B_{14}$-(Ni, Mo)$_{1,5}$ (composition 2), a nanocrystalline structure with a CSR size of L≈12 nm is fixed. At 843 K, the beginning of the decay of metastable structures is observed with the appearance of a supersaturated solid solution of α-Fe. The activation energy of the relaxation processes of the initial metastable structures was estimated from the temperature dependence of reaching the maximum value of the relative change in electrical resistance (R/R_0), assuming that the maximum values of R/R_0 for a single-phase interval, achieved at different heating rates, correspond to the same degree of relaxation of the structure. The values of activation energy calculated by the Kissinger method are 10400 ± 1200 K. The obtained value is four times lower than the values of activation energy and the average diffusion coefficient in the $Fe_{40}Ni_{40}P_{14}B_6$ alloy quenched from the liquid state (43000 K), determined kinetic parameters.
This difference is explained by the two-dimensionality of the films under study as compared to quenched from the liquid state foils. The coercive force (H_C) of freshly deposited films of compositions 1 and composition 2 is twice as high as the H_C of pure iron films. After heating films of composition 2 to 893K, H_C decreases by 1.2 times, and in films of composition 2 by 1.5 times, which is explained by the establishment of the optimal ratio between particles of nanocrystalline α-Fe and amorphous phase residues.

Conclusions

It is shown that amorphous and nanocrystalline films are formed during the modernized three-electrode ion-plasma sputtering of $Fe_{73}Si_{15,8}B_{7,2}$-(Cu, Nb)$_4$ and $Fe_{78,5}Si_6B_{14}$-(Ni, Mo)$_{1,5}$ alloys. The beginning of the decay of metastable structures with the appearance of a supersaturated solid solution of ?-Fe is observed at 843K. The values of the activation energy of the onset of structural transformations in films are four times lower than the activation energies in the $Fe_{40}Ni_{40}P_{14}B_6$ alloy quenched from the liquid state. This difference can be explained by the two-dimensionality of the studied films in comparison with foils quenched from the liquid state. The decrease in the coercive force by 1.2-1.5 times of freshly deposited films after heating to 893 K is explained by the establishment of the optimal ratio between the particles of nanocrystalline α-Fe and the remains of the amorphous phase.