

Magnetic Properties and Metastable States of Co–Ir Films

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Abstract—The phase composition, crystal structure, and magnetic properties of $\text{Co}_{1-x}\text{Ir}_x$ alloy films with $x = 0.35\text{--}0.8$ and fabricated by chemical deposition are studied. Saturation magnetization vs. composition and temperature, coercivity, and magnetization reversal of the films are investigated experimentally. It is shown that in the region of equiatomic composition, Co–Ir films have a two-phase hexagonal close-packed structure that alternates with disordered regions, producing halos in electron diffraction patterns.

DOI: 10.3103/S1062873814020063

INTRODUCTION

Contradictory data on the state diagram of the Co–Ir system have been reported in different studies. According to the results of some works, in cobalt–iridium compounds near equiatomic composition there is a broad region of solid solutions based on hexagonal close-packed (hcp) crystal modifications of cobalt; according to other data, there is a region of solid solutions based on iridium face centered cubic (fcc) lattices. There are few literature data on the magnetic characteristics of this film system [1–3]. The aim of this work was to investigate the structure and magnetic properties of Co–Ir solid solution films.

EXPERIMENTAL

Films of a Co–Ir system in the composition range of $\text{Co}_{20}\text{Ir}_{80}$ to $\text{Co}_{65}\text{Ir}_{35}$ were fabricated by chemical deposition onto cover glass substrates. The compositions and thicknesses of the films were determined by X-ray fluorescence.

RESULTS AND DISCUSSION

The film thickness varied within 400–1000 Å. X-ray diffraction revealed the presence of a large fraction of the X-ray amorphous crystal state; in the diffraction patterns of the investigated films, the position of the main phase peak also changed from $2\Theta = 40.833^\circ$ for $\text{Co}_{25}\text{Ir}_{75}$ to $2\Theta = 42.431^\circ$ for $\text{Co}_{65}\text{Ir}_{35}$. The X-ray diffraction data on the film state can be interpreted as reflecting a mixture of solid solutions based on two close-packed crystal modifications, hcp and fcc, but processing the X-ray diffraction patterns using the full-profile technique within a one-dimensionally disordered crystal model (S.V. Cherepanova, Institute of Catalysis, Russian Academy of Sciences, Siberian Branch, Novosibirsk) did not yield the required

results. Since our interpretation of the final results was ambiguous, the crystal structure and elemental composition of local parts of the films were studied on a JEM-2100 high-resolution electron microscope (Figs. 1 and 2). Analysis of the electron microphotographs shows there are neighboring areas with hcp and fcc structures up to 4–4.5 nm in size. In addition, we can see there are vast disordered areas and numerous stacking faults, due obviously to the hcp and fcc structures consisting of close-packed layers and differing only by the type of layer stacking. The fcc structure could be formed by the consecutive deposition of lay-

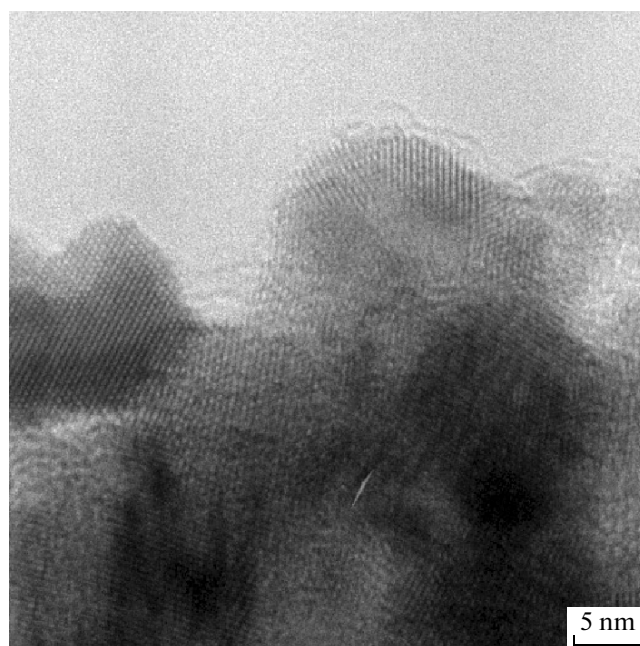


Fig. 1. Electron microphotograph of $\text{Co}_{52}\text{Ir}_{48}$ film structure.

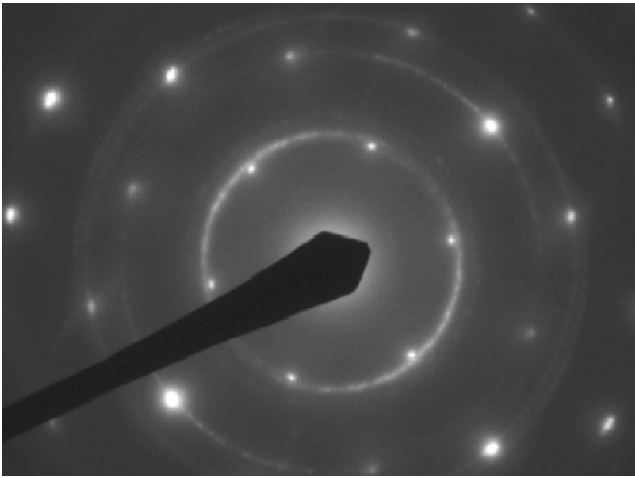


Fig. 2. Electron diffraction pattern of part of a $\text{Co}_{54}\text{Ir}_{46}$ film.

ers ABC, ABC, ABC, and so on; i.e., by consecutive shifting of the AB layer, if taken as a stacking element, by a vector $(1/3, 2/3)$. The hcp structure could be formed by the consecutive deposition of layers AB, AB, AB, and so on; i.e., by shifting by the vector $(0, 0)$. In these close-packed structures, the energy of the formation of stacking faults is obviously very low, resulting in disordered areas that alternate with the fcc and hcp structures. We measured the magnetic characteristics of films with these compositions. Saturation magnetization M_s in the range of compositions from $\text{Co}_{25}\text{Ir}_{75}$ to $\text{Co}_{60}\text{Ir}_{40}$ changes from 260 to 450 G at room temperature. As is well known, pure cobalt exists in two modifications in film samples at room temperature: hcp with $a = 0.251$ nm and $c = 0.410$ nm and fcc with $a = 0.355$ nm and saturation magnetizations of 1420 and 1370 G, respectively at 20°C . As the temperature falls to 4.2 K, the saturation magnetizations drop to 1390 and 1420 G, respectively, i.e., by merely 2%. The measured values for the saturation magnetization of Co–Ir solid solution films in the investigated range of compositions are much lower, clearly demonstrat-

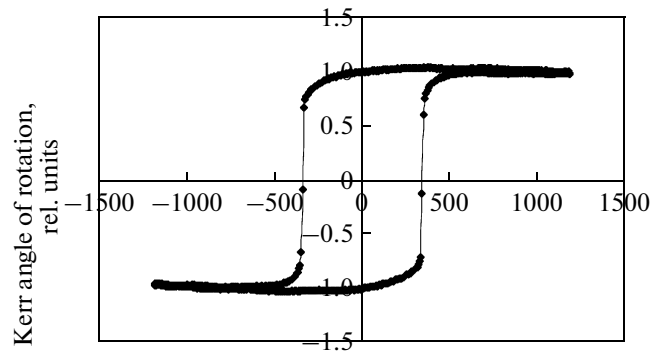


Fig. 3. Hysteresis loop for a $\text{Co}_{56}\text{Ir}_{44}$ film with a thickness of 460 \AA at $T = 300 \text{ K}$.

ing the strong effect of Ir atoms on the magnetization of the alloy [3]. Coercivity H_c of Co–Ir films of the investigated compositions varied from 220 to 370 Oe. This variation depended weakly on the composition and can be observed in films with close compositions. The hysteresis loops were rectangular with on–off time ratios S close to 1 (Fig. 3). We measured the temperature dependence of saturation magnetization M_s for Co–Ir films in the range of 3 to 300 K. The variation in magnetization was 17–31% for compositions $\text{Co}_{65}\text{Ir}_{35}$ – $\text{Co}_{25}\text{Ir}_{75}$; i.e., the relative change in saturation magnetization grew with the iridium content in solid solutions.

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Translated by E. Bondareva