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Microstructure and Magnetic Properties of Cu-Co alloys by Severe Plastic Deformation

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Recent studies have shown that magnets processed by serve plastic deformation could achieve a high coercivity due to the grain refinement [1]. Dilute alloys of Cu-Co system are unique, since small ferromagnetic Co precipitates are formed in non-magnetic Cu matrix during the aging process. The objective of the present investigation is to clarify how one of severe plastic deformation techniques, namely Equal-Channel Angular Pressing (ECAP) [2], can improve the magnetic properties of a Cu-1.8wt.% Co-0.2wt.% Cr containing ferromagnetic precipitates.

Two different aging temperatures of 1073 K and 873 K gave different sizes of precipitates which were expected to show multidomain or single domain structure, respectively, inside the precipitates. Figure 1 shows an octahedral precipitate formed at 1073 K for 259 ks. The average side of the precipitates is measured as 136 nm. The geometrical drawing indicates that the octahedral precipitate is limited by {111} facet planes. Figure 2 shows small superspherical precipitates formed at 873 K for 259 ks whose average sides are 22 nm. The interfaces of precipitates are almost parallel to {100}. For the samples aged at 1073 K, the coercivity was gradually increased after ECAP, as the equivalent strains were increased. The saturation magnetization was increased by almost 1.5 times after 1 pass, due to demagnetizing effect of elongated precipitates. For the samples aged at 873 K, the orientation of the small precipitates was a dominant factor to influence the coercivity, which was increased by 1 pass up to 6 times but slightly reduced by 4 passes. Saturation magnetization did not change through 1 pass of ECAP, but slightly decreased after 4 passes, which implied the dissolution of the precipitates into matrix by ECAP.

The demagnetizing effect of elongated precipitates was evaluated by electron holography [3]. Electron holography is a technique able to provide the phase shift of the electron wave which is sensitive to the electrostatic potential and the in-plane component of magnetic induction in the specimen. The phase shift obtained by electron holography can be expressed as a sum of a mean inner potential φ_{MIP} and a magnetic component φ_{MAG}. A rounded cubic precipitate and an elongated precipitate were investigated to enable each magnetic contribution $B_{\perp}$ to be compared. Figures 3 and 4 include the hologram, φ_{MIP} and φ_{MAG} of the retrieved phases for the rounded and elongated precipitates, respectively. $B_{\perp}$ of the elongated precipitate is calculated as ~0.23 T which is 1.5 times as high as the value for the rounded precipitate.

References

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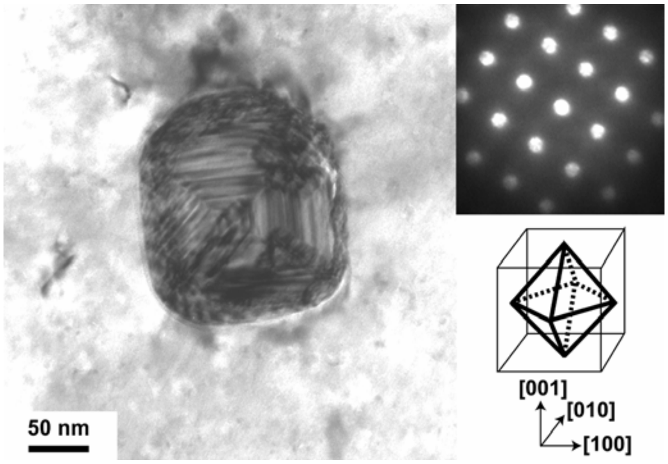

Fig. 1. TEM micrograph of the specimen aged at 1073 K for 259 ks along the [001] zone axis.

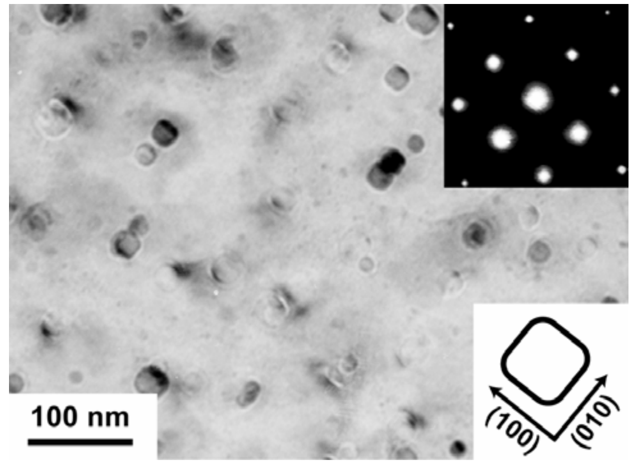

Fig. 2. TEM micrograph of the specimen aged at 873 K for 259 ks along the [001] zone axis.

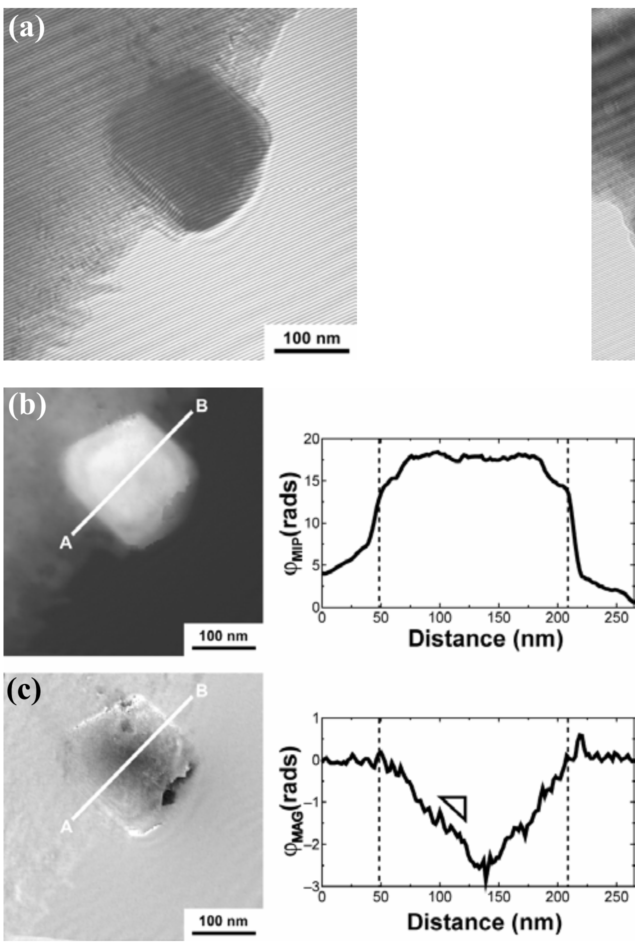

Fig. 3. (a) Experimental hologram of the rounded cubic precipitate; (b) φ_{MIP}; and (c) φ_{MAG}. Both line profiles from A to B across the precipitate are presented.

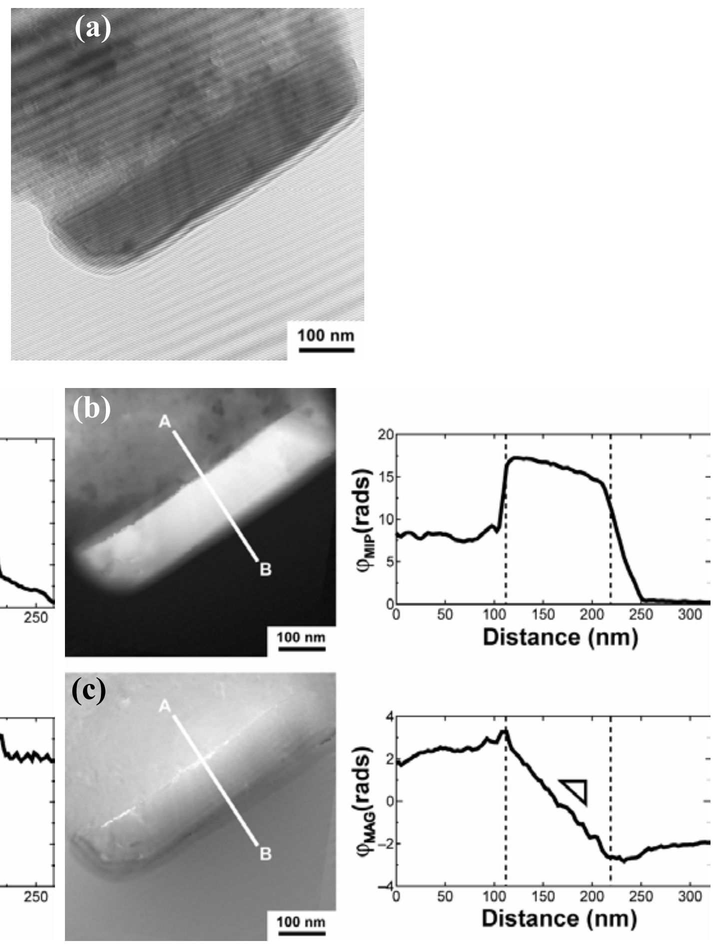

Fig. 4. (a) Experimental hologram of the elongated precipitate; (b) φ_{MIP}; and (c) φ_{MAG}. Both line profiles from A to B across the precipitate are presented.

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