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TEM studies of Discontinuous Precipitation in Cu-Co Alloys

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Over the last decade, much interest has been focused on Cu-Co alloys in virtue of their magnetic properties in the nanoscopic scale. In this system, the giant magneto resistance (GMR) appears as a consequence of the unbalanced electronic scattering of the spin-up and spin-down carriers by the magnetic Co particles. These changes in the magnetic and electronic transport behavior are related to segregation, nucleation and grain growth processes [1-2]. The precipitation behavior of Cu-Co alloys is well-known as a system exhibiting discontinuous precipitation when properly annealed. From the experimental findings, it appears that discontinuous precipitation is the dominant type of heterogeneous precipitation in this system. The present work deals with cooperative discontinuous growth of coherent rod-like Co particles from supersaturated copper-rich Cu-Co solid solutions and subsequent spheroidization of these rods into columnar arrays [1-3].

The alloy composition we are currently investigating ranges from 1 to 4 at% Co, with the balance being Cu. Here, we are focusing on the 3% alloy with a thermo-mechanical history, which resulted in a fully recrystallized microstructure with an average 100 µm grain size. The homogeneous solid solutions were rolled at room temperatures. The amount of rolling was about 70%. Isothermal aging treatments were conducted at temperatures of 400 to 900^{0}C. Sample preparation followed conventional practice of electrolytic polishing down to electron transparency and ion beam surface cleaning. TEM observations were conducted using a Jeol 2010 at 200 kV under diffraction contrast mode.

Figure 1, a dark field TEM image, is representative of the columnar discontinuous precipitation product. The particles in the columns were often so close together that their strain fields overlapped. As shows in figure 2, particles form as chains by coagulation of rods after discontinuous precipitation. The columnar arrays of spheres result from the spheroidization of coherent rods, which form initially from a matrix containing coherent spheres. These spheres are thought to form as a consequence of Rayleigh instability [2, 4]. A copious general precipitate in front of the boundary is observed in some cases, as can be observed in figure 3. Large-scale Co precipitates (obtained by EDS) have been developed at the second stage in virtue of the much larger driving force. Figure 4 is a bright field/ dark field pair of a precipitation product developed upon two stage aging: at 900^{0}C for 1 hour followed by 30 minutes at 500^{0}C. [4]

References

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[4] This work was supported by CNPq.

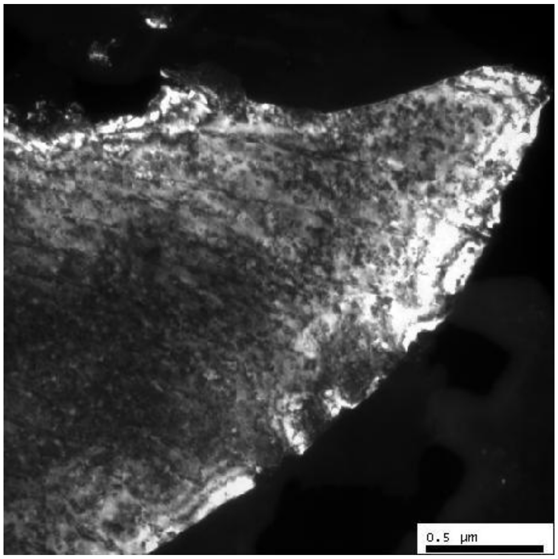

Figure 1. Dark field TEM micrograph showing discontinuous precipitation in a Cu-3%Co alloy aged at 650^0C for 5 min.

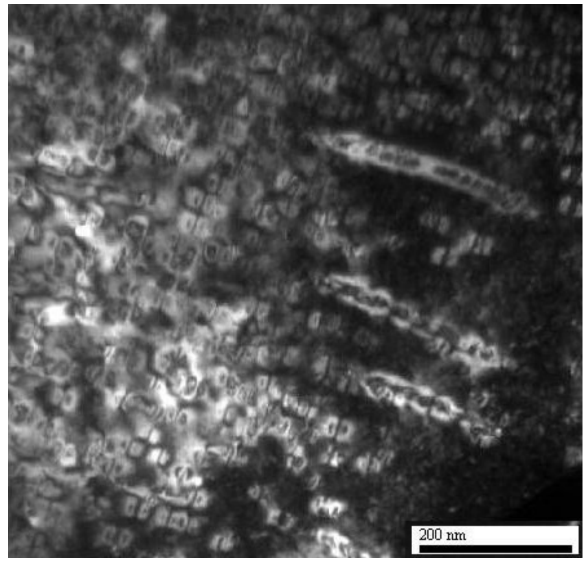

Figure 2. Dark field image. Enlargement of Fig. 1 showing the process of detachment of the Co particles.

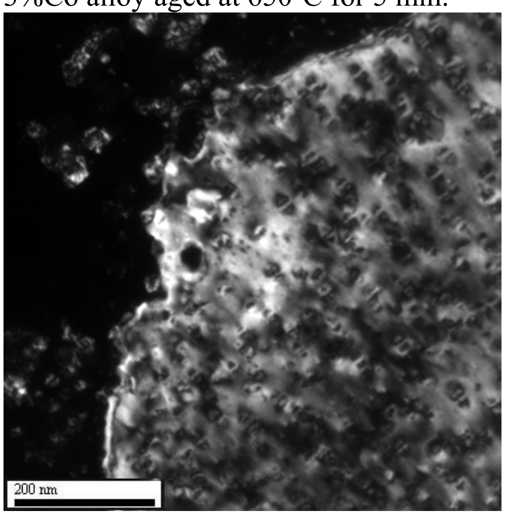

Figure 3. Dark field TEM micrograph showing discontinuous precipitation in a Cu-Co alloy aged at 650^0C for 5 min.

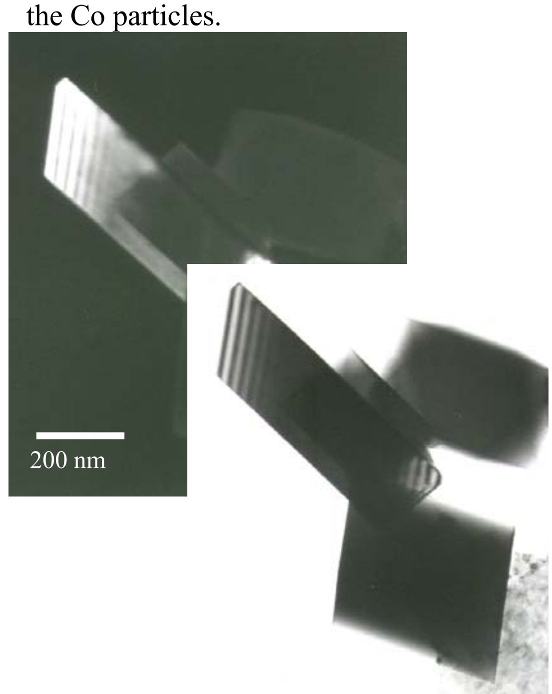

Figure 4. Bright field-dark field pair of larger precipitates developed upon two stage aging at 900^0C for 30min and 500^0C for 30min.

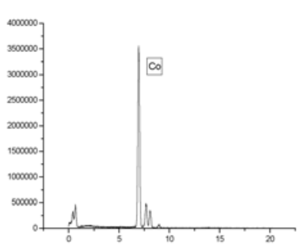

Figure 5. EDS spectra of precipitates in Fig. 4