CHARACTERISATION BY TRANSMISSION ELECTRON MICROSCOPY OF CU ALLOYS STRENGTHENED BY CERAMIC NANOPARTICLES

Rodrigo H. Palma H., Aquiles Sepúlveda O. and Rodrigo Espinoza G., Departamento de Ingeniería Mecánica, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile. Beauchef 850, piso 4, Casilla 2777, Santiago, Chile. e-mail: rhpalma@ing.uchile.cl

Numerous applications require microstructurally stable materials exhibiting high strength at high temperatures in combination with high electrical and /or thermal conductivity. Among the materials to be considered for such purposes are dispersion-strengthened Cu alloys [1,2]. On the other hand, the high-temperature strength of dispersion-strengthened alloys is mainly controlled by two mechanisms: a) dislocation-particle interaction, involving climbing and detachment of the dislocation lines from the particle-matrix interface, with incoherent interfaces being the most effective ones [3], and b) grain boundary-particle interaction, where coherent interfaces are more effective for preventing grain boundary sliding [4].

In this work, the micro and nanostructural characterization of dispersion-strengthened Cu alloys is presented. As the material is intended for high temperature applications, its behavior in hot compression tests was also studied. The following alloys were considered: Cu-5vol.%TiC, Cu-5vol.%Al_2O_2 and Cu-2.5vol.%TiC-2.5vol.%Al_2O_3. These alloys were prepared by reaction milling of elemental metallic Cu powders with Ti and/or Al; O came from the atmosphere and C was added as graphite powders. The attrited flakes were encapsulated at low vacuum and then consolidated by extrusion at 700 ºC, using an extrusion ratio of 10:1.

XRD, SEM, TEM (with EDS) and HRTEM were employed for the structural characterization of the alloys. The mechanical behaviour was evaluated through compression tests performed at 500 and 850ºC, at the true initial strain rates of $0.83x10^{-3}$ and $0.83x10^{-4}$ s^{-1}.

By XRD, the presence of Al_2O_3 or TiC in the attrited flakes was not detected, while that of TiC was detected after extrusion, (see Fig. 1). The matrix consisted in submicrometric size Cu grains (100-250 nm). In the Cu-2.5vol.%TiC-2.5vol.%Al_2O_3 alloy, the presence of Al_2O_2 nanometric particles was shown, by EDS and TEM, and the presence of Guinier-Preston zones rich in Ti and C, by HRTEM and EDS; see Fig. 3.

The obtained strain-stress curves exhibited a shape characteristic of materials presenting dynamic recovery and/or recrystallization, with a stress maximum followed by a plateau associated to steady-state creep prevailing conditions. The Cu-2.5vol.%TiC-2.5vol.% Al_2O_3 alloy showed to be the strongest alloy among the three materials under study, while the Cu-5vol.%Al_2O_3 alloy was the weakest one, see Fig. 2. The value of stress exponent in the classical relationship between strain rate and stress, was found to be higher than those reported for pure metals and metallic solid solutions, and of the same order of magnitude of those reported for materials strengthened with nanoparticles, where particles limit creep mechanisms such as dislocation climbing and grain-boundary sliding.

Refereces.

[1] J. R. Groza, et al., Materials Science and Engineering (1993) A171, 115.
[2] I. Anzel, et al., Metalkd. (1999) 90, 8, 621.
[3] R.H. Palma, et al., Materials Science and Engineering; (2005) A 391, 60.
[4] J. Rösler, et al., Acta Metall. (1990) 38, 671.
[5] E. Arzt, et al., Z. Metallkd. (1996) 87, 874.

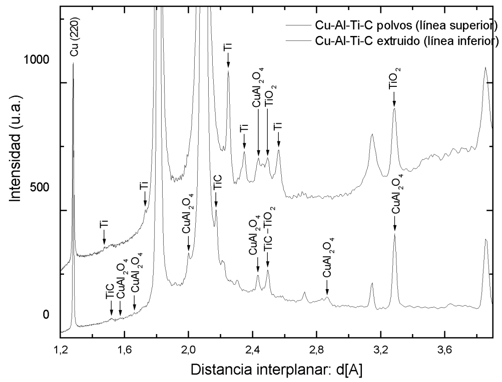

Figure 1. XDR spectra of the Cu-Al-Ti alloy

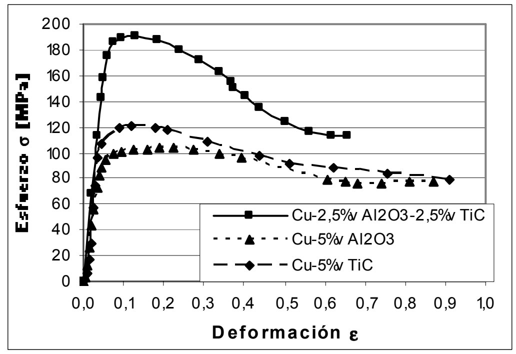

Figure 2. Compression stress-strain curves T = 850 ºC and $\dot{\varepsilon}$ = 0,83x10^{-3} [s^{-1}].

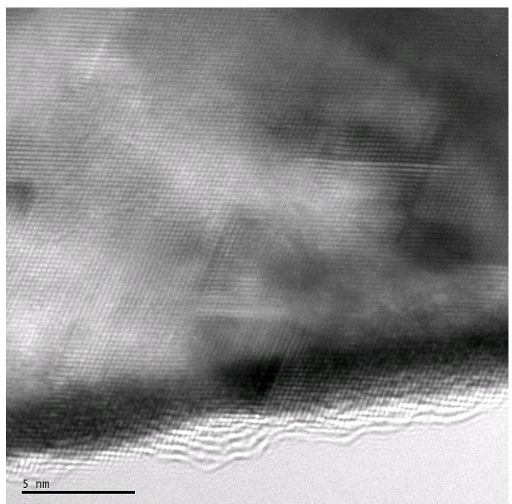

Figure 3. HRTEM image of the Cu-Al-Ti-C extruded alloy. Several zones rich in Ti and C (as detected by EDS) completely coherent with the copper matrix, and aligned along preferred orientations, are observed.