Cu-Mo and Cr alloys synthesized by mechanical alloying

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Abstract – Cu-Cr and Cu-Mo alloys have been prepared by mechanical alloying using a SPEX mill. Grain sizes about 10 nm were obtained at 50 h milling, stacking fault energy and probability decreased until 20 mJ/m^2 and increased until 10^{-2}, respectively as a function of milling time. The change of solubility of both systems was thermodynamically modeled considering crystallite defects and the presence of external field due to the rotation of vial. The presence of crystalline defects increases the free energy, and the curves of free energy are moved upwards, therefore the solubility limit change.

Technologically, it is interesting to pursue the development of novel high performance materials obtained using a non-equilibrium process, such as mechanical alloying (MA), Today, attention has been concentrated on synthesis of high performance materials such as intermetallics, amorphous metallic alloys and nanocrystalline materials (NCM) [1]

The alloys were synthesized using Cu-5 and 8 wt.% Cr and Cu- 5 and 8 % Mo. The mixtures were placed in a stainless steel container with a 25 ml capacity and milled in a SPEX 8000D mill under an argon atmosphere between 0.5 and 50 h. The alloys were characterized by scanning and transmission electron microscopy- SEM and TEM, x-ray diffraction- XRD, Vickers microhardness- HV and differential scanning calorimetry- DSC. X-ray profile analysis was made using the modified Warren–Averbach and Williamson-Hall methods [2].

The grain size decreased as the milling time increased to values around 10 nm, the dislocation density increased until values of 1×10^{12} m/m^3. Stacking fault energy decreased in the Cu-Cr system until 20 mJ/m^2 and in the Cu-Cr until 10 mJ/m^2 and stacking fault probability increased to 10^{-2} and 10^{-3}, for both systems respectively. The higher HV values were measured for Cu-Mo alloys for all milling times. The typical values at 50 h of milling were around 280 HV. All alloys presented anisotropic strain, which was better interpreted applying modified Warren-Averbach and Williamson-Hall methods. These results show that anisotropic strain is caused by presence of dislocations in both systems. Due to the disappearance of peaks of Cr and Mo, decrease and increase of lattice parameter of Cu-Cr and Cu-Mo, respectively, and decrease of stacking fault energy, confirm the formation of solid solution in both systems, which are immiscible with a positive enthalpy mixing.

The extension of solid solution was modeled using a regular solution model. The increment of free energy due to the presence of crystalline defects was estimated, for the crystalline defects increasing the free energy, and free curves are moved upwards, hence the solubility limit changes. For Cu-Cr system it was that free energy increase until reach values around 8 kJ/mol and for Cu-Mo system until 10 kJ/mol when milling time increase. These values are higher than the mixing free energy of the solution determined using a regular solution model. These results confirm the formation of solid solution of both systems.
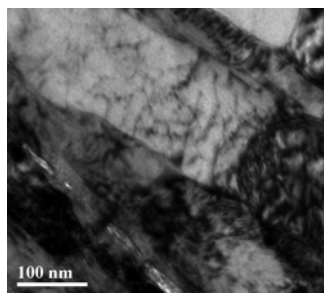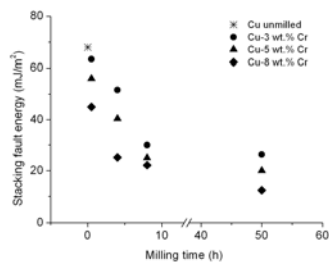
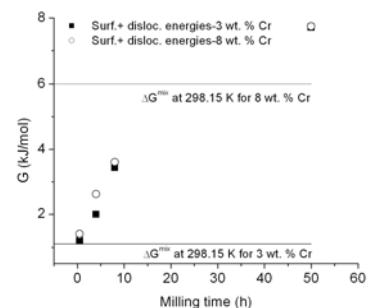**Figure 1:** (a) TEM image shows crystallite of Cu-3%Cr alloy milled at 50 h, (b) crystallite size as a function of the Cu-Cr alloy milling time.

Figure 2: Evolution of free energy of Cu-Cr alloys as function of milling time.

References
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