Wetting of Cu Grain Boundaries in the Cu-Bi System

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Grain boundary (GB) wetting by the liquid phase is as important as the "classical" wetting of surfaces by fluids; however, much less attention was paid in the past to this important phenomenon. In particular, perfect wetting at GBs is of primary interest, as it can produce a catastrophic failure of solid materials. The controversy about the observation of perfect wetting at GBs still persists. Since direct observations of liquid wetting films at GBs cannot be performed at high temperatures, and because these films may dewet during the cooling of the sample, we have developed an experimental protocol which combines grain boundary grooving measurements and post-mortem observations of Bi at GBs. Experiments have been performed in the Cu-Bi system and analyzed using Scanning Electron Microscopy (SEM) and an Atomic Force Microprobe (AFM). GB grooving was measured by AFM after annealing polycrystalline Cu samples under Bi vapor in hydrogen between 750 °C and 1000 °C. As the annealing temperature increases, it is found that the dihedral angle decreases until it reaches a constant value were both the surface energy of the solid and the grain boundary energy reach a minimum value. It is also observed that the grooving rate of Cu grain boundaries accelerates in the presence of Bi in the vapor phase, and that the shape of the groove deviates from the Mullins shape at the highest temperature. After dihedral angle measurements, several samples were fractured and Bi was observed at GBs in the form of large faceted particles at faceted grain boundaries. From these observations, it is demonstrated that perfect wetting of a Bi-Cu liquid takes place at high energy GBs and high temperatures.