Microstructure and thermal stability of ultrafine-grained CuZn5 processed by HPT

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Background and aims:
High-pressure torsion (HPT) is widely known as an effective method for severe plastic deformation (SPD). This intense shear strain, combined with high pressure, not only results in notable grain refinement but also introduces a substantial density of dislocations, thereby enhancing mechanical strength [1].

Concurrently, ensuring the stability of ultrafine-grained (UFG) microstructures is crucial for their reliable performance in practical applications. Grain growth can compromise the enhanced strength of UFG materials, highlighting the importance of investigating microstructural stability for their commercial feasibility [2].

This concern is particularly notable in certain pure metals with low stacking fault energy such as fcc metals. In order to avoid grain growth, the grain boundary (GB) migration has to be limited. This can be done through the segregation of solute elements, which depends on the GB character. In this work, we use copper (Cu) as bulk material and add different amounts of Zn to examine the impact of varying Zn content on microstructural changes and thermal stability of GBs after HPT processing at room temperature.

Methods:
CuZn5 solid solutions were processed using HPT with a pressure of 4.5 GPa. The thermal behaviors of these materials were studied using differential scanning calorimetry (DSC). Scanning transmission electron microscopy (TEM) in combination with energy dispersive X-ray spectroscopy (EDX) was used to investigate the microstructure and composition of Cu-5at.%Zn (CuZn5), with a focus on GB segregation before and after annealing at different temperatures. Additionally, 4D-STEM (ACOM) was utilized to extract information on grain size distribution, grain orientation, and grain boundary types.

Results:
Annealing of CuZn5 up to 300°C by DSC shows a single exothermic peak at about 275°C. it should be mentioned that no grain growth or changes in the grain orientations occurred up to 200°C. High-angle annular dark-field (HAADF)-STEM imaging helps to understand the effect of Zn on the microstructure and GBs. From the 4D-STEM orientation mapping, the GBs can be classified into low-angle GBs, special coincidence site lattice (CSL) boundaries as well as high-angle general GBs. Together with STEM-EDX, it was found out that low energy boundaries such as Σ3 twin boundary is not enriched by Zn. On the other hand, Zn general GBs are segregated with Zn. This observation agrees well with the theory that solute segregation depends strongly on the GB energy. While special Σ-boundaries have low energy, they are less affected by solute segregation.

Conclusion:
CuZn5 maintains a single-phase structure even after annealing, suggesting that the improved thermal stability of the alloys compared to pure Cu is attributed to the presence of solute content. This is due to the solute-drag effect [3], hindering the diffusion of GBs and contributing to the enhanced thermal stability of the alloys

Keywords:

Cu alloys; HPT; DSC; ACOM

Reference:

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