Institute of Materials Physics

Structural and Thermal Evolution of Ultra-Fine Grained Al (1050) upon Heating and Liquid Ga Penetration

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ABSTRACT

Manipulating microstructure and thermodynamic characteristic of materials in order to obtain desired properties is in the focus of many researches in the field of material science and engineering. A metal’s microstructure depends on two factors: its composition and the thermal and mechanical conditions to which it was exposed during manufacturing. Sever plastic deformation (SPD) as a powerful top-down manipulating technique has attracted great interest since the invention of high pressure torsion (HPT) by P.W. Bridgman at Harvard University in the 1930s that led to the award of the Nobel Prize in Physics in 1946 [1].

Ultrafine-grained (UFG) materials synthesized by SPD represent unusual mechanical, electrical, optical and magnetic properties. In the present study mechanical and thermal properties of UFG-Al (1050) deformed by HPT has been investigated and compared to its coarse grain (CG) counterpart. The effect of post-deformation heat treatment on volumetric and microstructural changes was investigated by Dilatometry, hardness testing, and transmission electron microscopy (TEM).

Fast liquid penetration into the grain boundary (GB) network of a polycrystalline solid is leading to embrittlement, which is observed for different metallic or ceramic couples. A well-known example is the catastrophic embrittlement of Al upon penetration of initially liquid Ga along Al grain boundaries. This effect occurs even at room temperature; below the melting point of Ga. On the other hand, sever plastic deformation (SPD) of Al is known to refine the grain structure, introducing a high density of grain boundaries of different type. The penetration of liquid Ga along grain boundaries of UFG-Al produced by HPT is analyzed. The penetration process was studied using dilatometry, atomic force microscopy (AFM) and scanning electron microscopy (SEM) including electron-backscatter diffraction (EBSD). A two-stage process was observed in the dilatometer. The developments of the grain boundary decoration by Ga and the surface evolution have been examined by SEM and AFM. The microstructure changes induced by the Ga penetration are characterized by EBSD, to monitor the evolution of the grain size, orientation and the grain boundary misorientations. The results are discussed with respect to previous works to gain information on the underlying mechanisms that control the Ga penetration.

Thermal properties of Al and AlGa system was investigated by Differential scanning calorimetry (DSC) in high temperature regime and heat capacity option of physical property measurement system (PPMS) in low temperature regime. No significant DSC signal was observed during continuous heating experiment. Electronic and lattice contributions to the specific heat are reported for Al and AlGa system that obtained from low temperature heat capacity measurement.

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