World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:11, No:06, 2017

Grain Growth in Nanocrystalline and Ultra-Fine Grained Materials

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Abstract : Grain growth is an important and consequential phenomenon that generally occurs in the presence of thermal and/or stress/strain fields. Thermally activated grain growth has been extensively studied and similarly, there are numerous experimental and theoretical studies published describing stress-induced grain growth in single-phase materials. However, studies on grain growth during the simultaneous presence of an elevated temperature and an external stress are very limited, and moreover, grain growth phenomena in materials containing second-phase particles and solute segregation at GBs have received limited attention. This lecture reports on a study of grain growth in the presence of second-phase particles and solute/impurity segregation at grain boundaries (GBs) during high-temperature deformation of an ultra-fine grained (UFG) Al alloy synthesized via consolidation of mechanically milled powders. The mechanisms underlying the grain growth were identified as GB migration and grain rotation, which were accompanied by dynamic recovery and geometric dynamic recrystallization, while discontinuous dynamic recrystallization was not operative. A theoretical framework that incorporates the influence of second-phase particles and solute/impurity segregation at GBs on grain growth in presence of both elevated temperature and external stress is formulated and discussed. The effect of second-phase particles and solute/impurity segregation at GBs on GB migration and grain rotation was quantified using the proposed theoretical framework, indicating that both second-phase particles and solutes/impurities segregated GBs reduce the velocities of GB migration and grain rotation as compared to those in commercially pure Al. Our results suggest that grain growth predicted by the proposed theoretical framework is in agreement with experimental results. Hence, the developed theoretical framework can be applied to quantify grain growth in simultaneous presence of external stress, elevated temperature, GB segregation and second-phase particles, or in presence of one or more of the aforementioned factors.

Keywords : nanocrystalline materials, ultra-fine grained materials, grain growth, grain boundary migration, grain rotation
Conference Title : ICNM 2017 : International Conference on Nanostructured Materials
Conference Location : Venice, Italy
Conference Dates : June 21-22, 2017