

Grain Boundaries in Severely Deformed Metallic Materials

Gerhard Wilde

Institute of Materials Physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany;

Severe plastic deformation (SPD) has often been applied for refining the microstructure of polycrystalline materials down to the ultrafine grained - or even the nanocrystalline range, yielding bulk materials that are mostly free from porosity or contaminations of the internal interfaces. Materials that were processed by SPD have been shown to possess properties that are modified from their coarse-grained counterparts beyond the expectations given by mere scaling laws. Models for describing the property modifications after SPD processing, mostly with respect to the mechanical properties, are based on assuming modifications of the local atomic grain boundary structures in addition to the drastic increase of the volume fraction of grain boundaries. Yet, along with the enhancement of mechanical properties, several important questions arise e.g. concerning the accommodation of external stresses if dislocation-based processes are not longer dominant at small grain sizes. One question, which has raised continued discussions, concerns the extent of structural modifications of grain boundaries during SPD, since the formation of a specific deformation-induced "state" of high excess free energy density has been postulated. Such "deformation-modified" grain boundaries should possess enhanced excess free energy densities, enhanced residual microstrain and enhanced atomic mobility along the boundary plane and are supposed to present the microstructure element that underlies the property enhancement.

As described above, grain boundaries and particularly grain boundaries with structures that are modified by the interaction with large number densities of lattice dislocations as well as triple junctions of several grain boundaries are important elements of fine-scaled microstructures. Their presence, their structure and particularly their strain state is of importance for the stability, the mechanical performance and also the grain-boundary diffusion and grain-boundary-diffusion-related properties of ultrafine grained or nanocrystalline materials obtained through severe deformation processing. Thus, this contribution focuses on the experimental determination of both, grain boundary diffusion rates and local strain fields with high spatial resolution in severely deformed metallic materials and on their relationship with macroscopic properties. As an outlook, the possible importance of rotational defects for the stability of fine-grained microstructures will also be discussed.