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Coupling of dislocations and precipitates: impact on the mechanical behavior of Al 7xxx alloys at the submicron length scale

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ABSTRACT

Reducing length scale on precipitation strengthened aluminum alloys leads to improved strength but reduced ductility and nonuniform elongation. Underlying mechanisms are attributed to the interaction between grain boundaries, dislocations, and precipitates. Recent studies revealed that a high volume fraction of grain boundaries provided sinks for structural defects, i.e., vacancies and dislocations, in ultra-fine grained (UFG) Al 7075, and thus the density of defects is relatively low in grain interiors. As a consequence, the precipitate nucleation mechanism is altered. In an effort to investigate how coupling of dislocations and precipitates affects the mechanical behavior of Al 7xxx alloys at a submicron length scale, it is important to develop and sustain a high density of dislocations in the grain interior via deformation. In this study, nanostructured Al 709x alloy powder was fabricated by cryomilling and was subsequently consolidated to form UFG bulk materials through two different processing routes: one with elevated temperature slow strain rate deformation and the other with room temperature high strain rate (HSR) deformation. The latter provides the opportunity to sustain a high density of dislocations in the grain interiors of UFGs. For comparison purposes, coarse grained (CG) counterparts were fabricated via the same consolidation and deformation processes but using gas-atomized CG powder. Results reveal that the coupling effects between dislocations and precipitates in the HSR deformed UFG lead to extreme high strength (UTS 878 MPa) with uniform elongation. Interestingly, T6 temper decreases the strength of the UFG–HSR sample while it improves the ductility. Detailed microstructural characterization is performed to provide insight into the interaction between structural defect evolution and precipitation phenomenon.