Mechanisms of plastic deformation of magnesium matrix nanocomposites

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Abstract: Magnesium is the lightest of all structural metals, which gives it a huge potential to be used in applications that require lightweighting. However, its strength needs to be increased in order to compete with other light metals such as aluminum and titanium. A solution is the reinforcement of magnesium and its alloys with the addition of oxide nanoparticles. The hexagonal close packed crystalline structure is responsible for the complex plasticity of magnesium, which is characterized by a very strong plastic anisotropy as well as a complex twinning activity. Understanding these deformation mechanisms is crucial for the development of more performant nanocomposites, allowing widespread industrial application. The present work focuses on the processing and characterization of magnesium based nanocomposites reinforced with oxide particles. Two different processing techniques have been compared: friction stir processing and ultrasound assisted casting. The homogeneity of the dispersion of the reinforcement particles has been verified in 2 and 3 dimensions using electron microscopy and X-ray tomography, respectively. Friction stir processing produces nanocomposites with a more homogeneous dispersion of particles, while reducing their size. Tensile tests have shown strengthening of magnesium with the addition of a volume fraction of only 0.3 % of reinforcement. An annealing heat treatment has then been performed in order to promote abnormal grain growth and single crystalline microcolumns for microcompression testing have been machined by focused ion beam (FIB). The purpose is to isolate the role of particles. The orientation dependent mechanism of deformation and the size effects have been studied in order to understand the influence of the reinforcement particles on the plasticity for orientations favorable for basal slip or tensile twinning. Differently from the strengthening observed macroscopically, no clear strengthening effect is observed on microcolumns when dislocation glide operates. The reason is the higher density of potentially mobile dislocations that is generated due to stress concentrations around the reinforcement particles. In addition, the size effects usually observed on pure magnesium have also been suppressed with the addition of particles. The reinforcement particles seem to affect the twin nucleation stress and twin morphology: particles induce the nucleation of multiple twins inside a microcolumn, whereas in pure magnesium, only one or two twins have been observed. These results provide relevant insights on the role of nanoparticles on the onset of plastic deformation, as well as size effect, in single crystalline magnesium nanocomposites.