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MECHANISMS OF PLASTIC DEFORMATION OF MAGNESIUM MATRIX NANOCOMPOSITES ELABORATED BY FRICTION STIR PROCESSING

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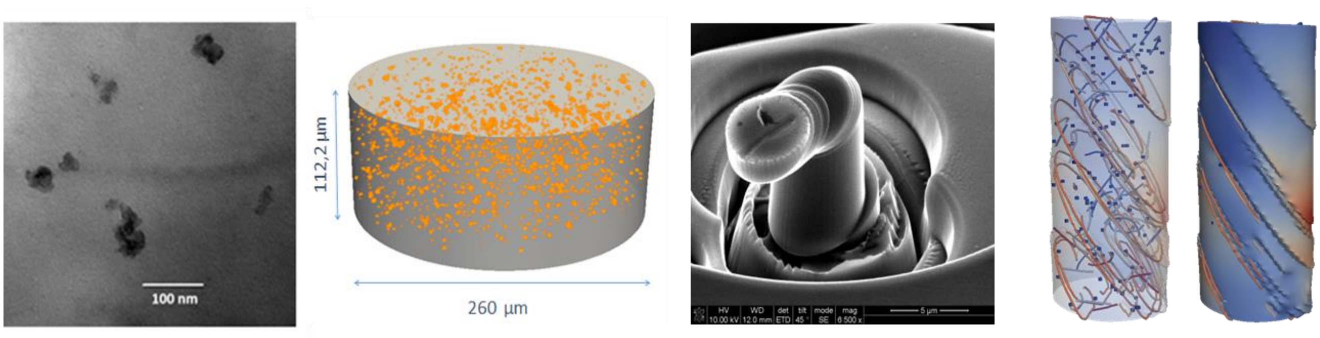
Magnesium based composites have attracted much attention over the past few years as a promising solution to lightweighting, energy saving and emission reduction, especially for automotive and aerospace applications. With a specific weight as low as 1.74 g.cm-3, magnesium is the lightest of all structural metals. However, the strength of Mg needs to be improved in order to compete with other light metals such as Al or Ti. The present study focuses on Mg reinforced by Y_2O_3 nanoparticles. The aim of the work is to investigate the single crystalline plastic behavior of Mg strengthened by oxide dispersed particles, in comparison to that of pure Mg.

A major challenge is to elaborate single crystalline samples with a homogeneous distribution of particles. In the present work, yttrium oxide reinforced magnesium matrix nanocomposites were produced using friction stir processing (FSP). FSP is a novel solid-state processing technique based on the same principle of friction stir welding. It proves to be an efficient method to produce metal-based composites. As shown in Fig.1(a), the initial 3 µm particles were fragmented during the process and their size was reduced to less than 100 nm. The three-dimensional dispersion of nanoparticles was confirmed by synchrotron X-ray microtomography, as shown in Fig.1(b). Since the FSP sample presents fine grains (around 10 µm), a subsequent heat treatment was performed to enable abnormal grain growth.

The increased grain size allows the subsequent fabrication of single crystalline micropillars for microcompression testing. The advantage of this method over traditional mechanical testing for studying the mechanisms of deformation is that the entire sample can be investigated post-mortem (Fig. 1(c)), and a variety of grain orientations can be tested for a single processing history. Micropillars were machined inside a single grain with a known orientation using focused ion beam (FIB) machining. Microcompression experiments were then conducted in a nanoindenter equipped with a diamond flat-ended conical indenter. The stress-strain response was measured for different single crystal orientations.

In addition to experimental investigations, three-dimensional discrete dislocation dynamics (3D DDD) simulations (Fig. 1(d)) were carried out for comparison. The results provide relevant insights on the role of nanoparticles on the onset of plastic deformation in single crystals as well as twinning nucleation in Mg nanocomposites.



a b c d

Figure 1 - TEM micrograph showing the Y_2O_3 particles in the FSPed sample (a). Synchrotron X-ray microtomography confirms the homogeneous dispersion of particles (b). Post-compression structure (c). 3D dislocation dynamics simulations of a micropillar (Ø=10 µm and h=25µm) with cubic particles (f_V=0.1% and Ø=250nm) (d).