Making Light-weight Mg-Metal Laminated Nanocomposites

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Introduction

Magnesium is the lightest engineering metal [1]. Replacing steel with Mg-based materials in automotive applications would lead to more than 40% weight reduction which significantly boost fuel efficiency [2]. However, conventional Mg alloys typically suffer from low strength and poor deformability due to very few slip systems and easy twinning [3].

Alloying Mg with other materials and microstructural engineering are promising approaches to increase ductility and strength of Mg. According to Wang et al. [4], interfaces with low energy and high coherency may effectively constrict the nucleation of twins in Mg.

Methods

- ❑ Mg-Al nanolaminated composites with 33 wt.% Al were produced by melt spinning and analyzed by X-Ray Diffraction to validate presence of the desired phases.
- ❑ *Characterization*
- ✓ Micropillars made in dual-beam FEI Helios Nano-lab 660 equipped with Ga FIB
- ✓ In-situ compression test using PI 85L SEM Picoindenter
- ✓ Nano-indentation test performed at Hysitron TI 950 Triboindenter applying 8000 μN force
- ✓ Transmission Electron Microscopy (TEM) lift-out samples prepared by (FIB)
- ✓ Conventional BF TEM, HRTEM, STEM mapping and HAADF conducted in FEI Tecnai Osiris

Nanoindentation

Nanoindentation of Mg-Al composites (Fig. 1) demonstrated an increase in Young's modulus from 38 GPa to 68 GPa and from 0.61 to 4.55 GPa in nanohardness compared to pure Mg.

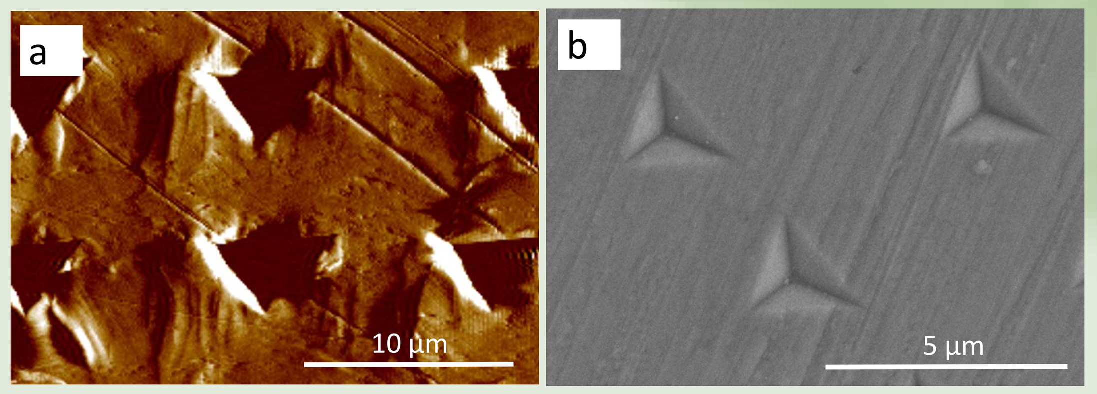

Figure 1. Nanoindentation test Pure Mg (a) and Mg-33 wt. % Al Composite.

In-situ Compression Test

The deformation morphology of Mg-Al composites and pure Mg micropillars during the in-situ compression test is shown at Fig. 2. Buckling is the main event occurred in the case of pure Mg whereas formation of shear bands is evident in MgAl composites. The representative engineering stress-strain curves are illustrated in Fig 3 which clearly indicate the increase in Young's modulus, yield stress and yield strain of the Mg-Al composites compared with pure Mg confirming the results from nanoindentation test.

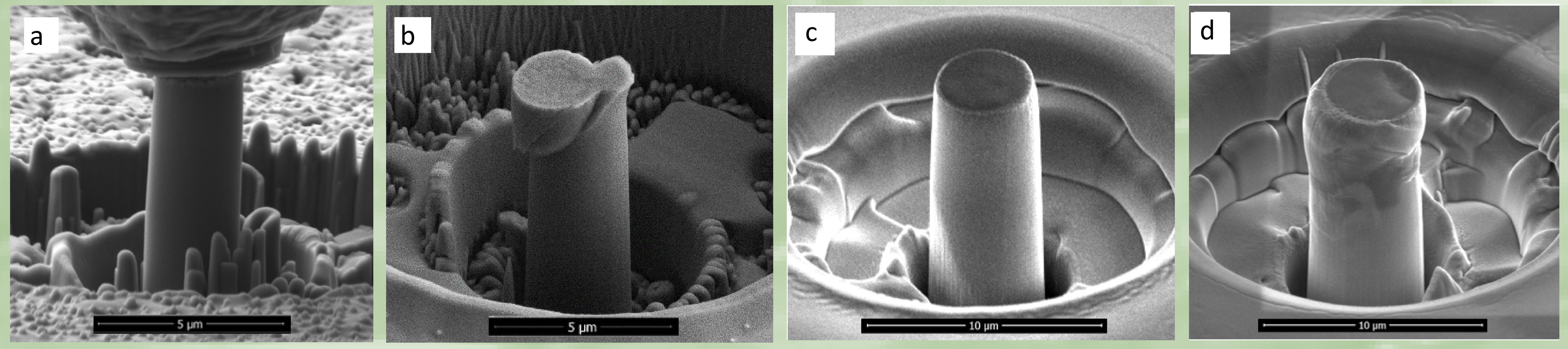

Figure 2. SEM micrographs of Mg-33%Al and Pure Mg micropillars before (a,c) and after (b,d) in-situ compression test, respectively.

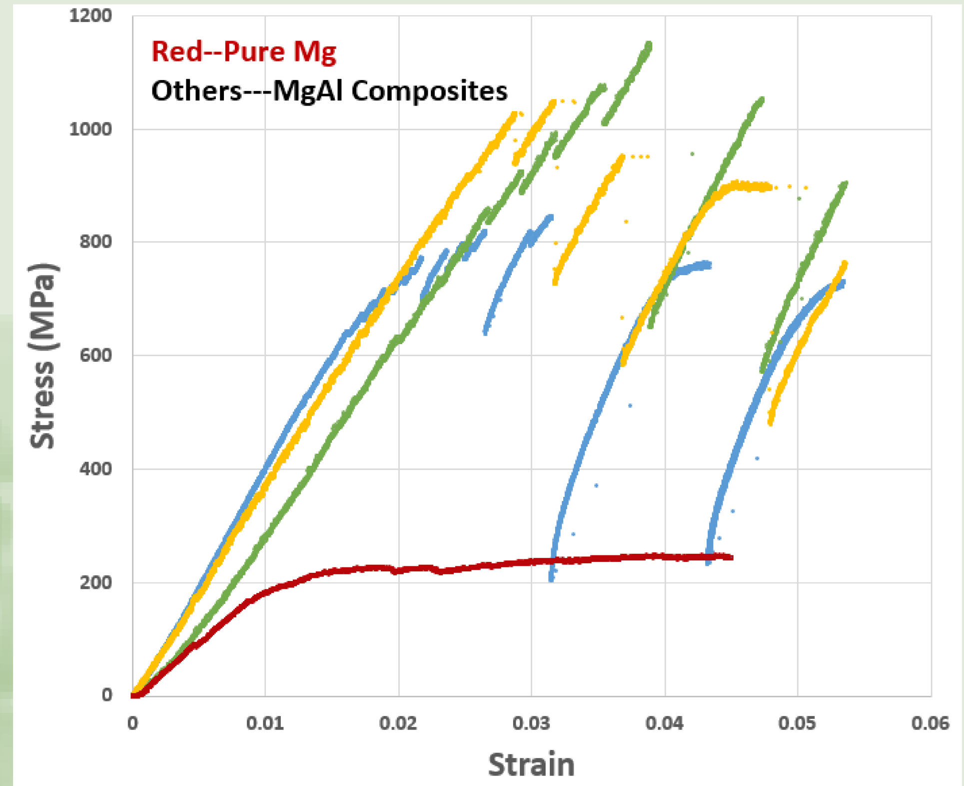

Figure 3. Stress vs Strain curves of pure Mg (red curve) and MgAl composites deformed micropillars.

Microstructural Characterization:

The laminated composites behavior during compression testing was evaluated using TEM imaging (Fig. 4), high angle annular dark field (HAADF) and elemental mapping (Fig. 6). As can be seen, nano-layers of Mg which are nicely arranged in the as-solidified microstructure break up into short strips with slightly increased thickness. High resolution TEM (HRTEM) of the deformed layers (Fig. 5) indicates creation of nano-twins in some layers.

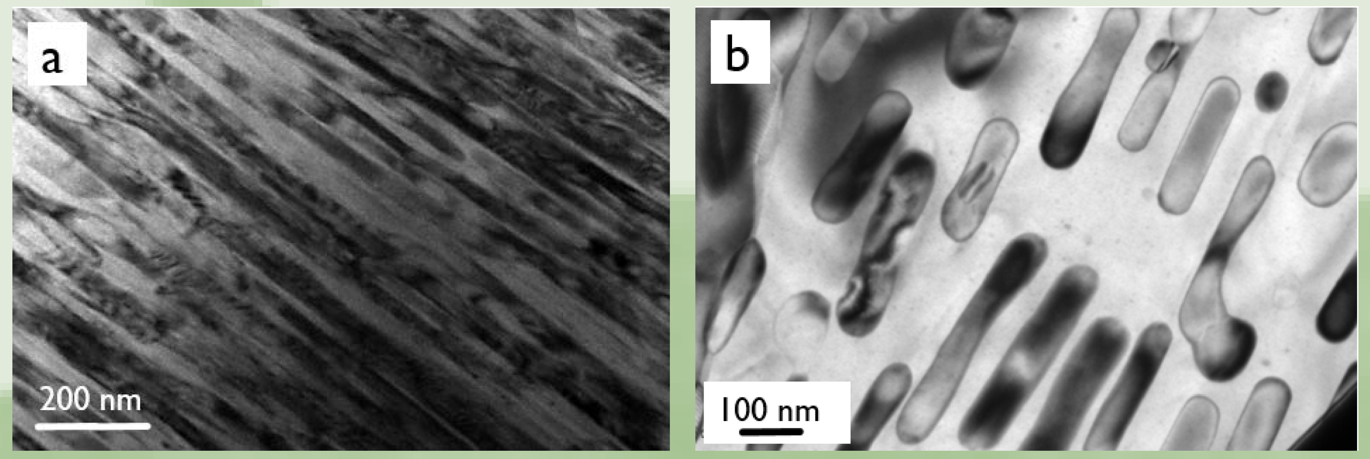

Figure 4. BF TEM micrographs of nanolaminated composites before (a) and after (b) compression test.

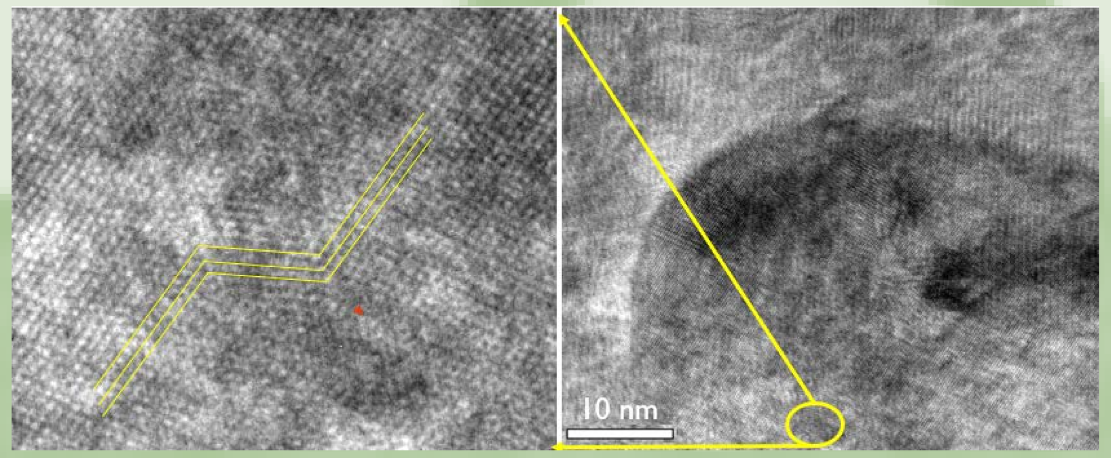

Figure 5. HRTEM image of a single Mg layer after deformation (right) and the deformation twin (left)

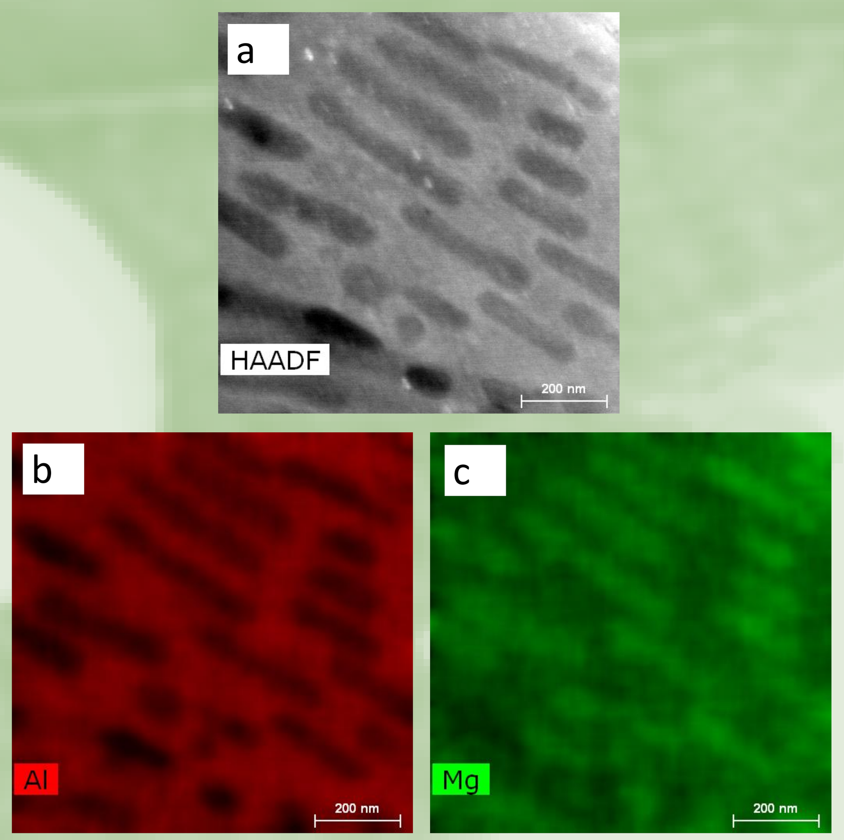

Figure 6. HAADF-STEM image (a) and STEM mapping (b,c) of the deformed micropillar demonstrating Mg-rich short strips.

Conclusion

MgAl nano-laminated composites demonstrated improved mechanical properties vs. pure Mg and the activity of the deformation twins were decreased at nano-scale Mg layers. Evaluation of orientation relationship between the Mg and MgAl layers is under research to correlate the arrangement of the crystallographic planes at the phase boundaries to observed mechanical properties.

Acknowledgement

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