Mg-based metal matrix nanocomposites (MMNCs) with mechanical properties, superior to those of coarse-grained composites, are promising structural materials for applications in the automotive and aerospace industries. The research in this area was primarily focused earlier on either micro-scaled reinforcements or nano-scaled reinforcements with very low volume fractions. MMNCs with high volume fractions have not been explored yet. In this research, we study the processing, microstructures and properties of MMNCs containing ceramic nanoparticles up to 30 vol.%. 

We first investigated the mechanical alloying of Al2O3 nanoparticles and pure Mg under high-energy ball milling conditions. The phase evolution and their distribution were evaluated as a function of milling time. Then, the thermal stability of the formed nanocomposites was investigated by annealing it at high temperatures. It indicated that an exchange reaction had occurred to a large extent between Mg and Al2O3 resulting in the formation of Al and MgO phases. Additionally, the reaction between Al and un-reacted Mg led to the formation of Mg-Al intermetallics. 

Due to the reaction between Mg and Al2O3 during the milling and annealing process, we attempted to synthesize Mg/SiC nanocomposites. The mixed powders containing 0, 5, 10 and 15 vol.% SiC were produced by high energy ball milling and then the powders were consolidated via spark plasma sintering. The phase constitutions and microstructures of the Mg/SiC nanocomposites were characterized. SiC nanoparticles (average particle size ~14 nm) appear to be homogeneously dispersed within the matrix, and the average inter-particle spacings of all the Mg/SiC nanocomposites were smaller than 50 nm. Microscopic methods, even at high magnifications did not reveal any significant porosity in the as-processed MMNCs.

Mechanical characterization of the Mg/SiC nanocomposites was conducted using the microindentation test. Besides the microhardness test, different intermediate pause times and loading rates were used to evaluate the stiffness and loading rate sensitivity of our samples. The abnormal microhardness and loading rate sensitivity were showed for the Mg-15 vol.% SiC samples. At the same time, the monotonical increase of stiffness with volume fraction was exhibited in the Mg/SiC nanocomposites.

Finally, we investigated the quasi-static and dynamic response of Mg/SiC nanocomposites and microcomposites, and discussed the underlying mechanisms. Strain softening was noticed in the milled Mg sample under quasi-static compression. Similarly, the strengthening effect leveling off was also observed in the Mg-15 vol.% SiC samples under either quasi-static or high-strain rate uniaxial compression conditions. No significant plastic deformation was observed in the Mg/SiC nanocomposites. The estimated strain rate sensitivity of all the Mg/SiC nanocomposites in this work was around 0.03, which is much smaller than 0.3 and 0.6, observed for 100 nm and 45 nm grain size pure Mg individually. In particular, the existing models fail in predicting the inverse volume fraction effect, and other mechanisms are yet to be explored. The presence of SiC nanoparticles may play an important role that leads to this difference.
Approved for distribution by Linan An, Committee Chair, on April 9, 2013.

The public is welcome to attend.