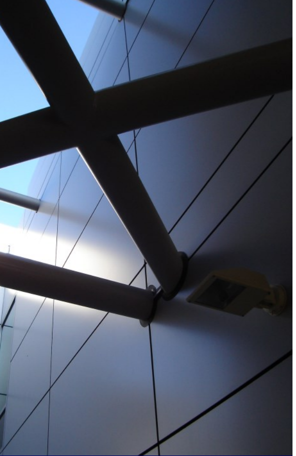

MECHANICAL ENGINEERING
DISSERTATION DEFENSE

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of
Heather Salvador

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Microstructural engineering for strength and stability in magnesium alloy systems

Doctor of Philosophy, Mechanical Engineering
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Dr. Suveen Mathaudhu, Chairperson

In an effort to reduce fuel emissions to meet regulations and improve fuel efficiency, the transport industry is constantly seeking to replace parts made out of aluminum or steel with lighter materials without losing structural integrity. Magnesium has great potential for such applications due to the high specific strength and stiffness, but the low bulk strength and poor formability have prevented magnesium from gaining more widespread use in these industries.

One solution to improving strength is grain refinement, which has allowed magnesium strengths to reach levels not previously seen, however, maintaining the fine grain sizes and resulting strength is difficult as magnesium exhibits poor thermal stability against grain growth at low homologous temperatures. Other mechanisms of strengthening include inclusion of nano-spaced planar defects, the introduction of fine precipitates or particulates, and texture control among others. All of these efforts to strengthen magnesium are typically accompanied by a drop in low-temperature uniform plasticity, which in most magnesium alloys is limited to begin with. For my thesis project, I will examine three different Mg alloy systems whose processing-structure-property combinations seek to minimize the aforementioned trade-offs.

The first study is on the role of textural strengthening in a hot-rolled Mg alloy designed to be strengthened by nano-spaced stacking faults. Pole figures that show the textural evolution and intensity as a function of hot rolling reduction is analyzed, with the results effectively ruling out any significant contribution to strengthening effects from texture, thereby showing that stacking faults can strengthen by interacting with dislocations while also providing alternate dislocation pathways for minimal losses in plasticity.

The second study examines the ability of yttrium-hydride reinforcement to retard grain growth in a magnesium, preventing growth beyond 5μm when sintered at 425°C. The reinforcement phase is shown to reside both within grains and at boundaries further supporting the ability of the reinforcement to reduce the rate and extent of grain growth. Strengthening models for metal-matrix composites are used to approximate yield strength and compared to the experimental results to demonstrate the large disparity that can occur when not accounting for novel deformation mechanisms that change as a function of grain size regimes.

Extending these findings to a Mg-Li-Ca system, I demonstrate excellent thermal stability stemming from the distribution of Mg2Ca precipitates. Adding lithium to magnesium lowers the density even further, but at the cost of decreased thermal stability again grain growth. The system is able to maintain high hardness up to 150°C, whereas other magnesium-lithium systems have demonstrated grain coarsening at room temperature. Further, the partial pinning of grain boundaries, leaving some grains free to rotate plausibly allows for greater plasticity than a fully pinned and fine-grains Mg-Li alloy, but work must be done to verify the elongation capability of the alloy. Overall, my research reveals some novel pathways to avoiding property tradeoffs typical of magnesium alloys. I have unraveled some remaining knowledge on the ability to strengthen Mg alloys via nano-spaced planar defects, and ruled out contributions from enhanced texturing. My research has also successfully strengthened Mg alloys via various processing approaches and resulting strengthening mechanisms while considering emerging understandings on the role of grain size in the micrometer and sub-micrometer regimes, and contributions of particulates to enhanced stability against grain grow and elevated temperature conditions. These finding may contribute to the design of high-strength Mg alloys and processing methods that increase the design space for their use in transportation and other applications.