Understanding Characterization Mechanisms of Advanced Magnesium Alloys

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Introduction

Materials are used in our everyday life. They are seen in the form of structures and machines everywhere. However, many commercially available materials have certain limitations, thus material scientists and engineers are constantly trying to discover or create materials that are stronger and lighter. Magnesium is a material of interest, as it is light-weight but lacks strength in its pure form. One method to improve a pure material's strength is alloying, and current research have created advanced magnesium alloys that is stronger and more ductile. By understanding the characterization mechanism of these magnesium alloys, we can figure out the microscopic mechanisms that allowed them to have greater strength. Better understanding may lead to the creation of more effective magnesium alloys, and cause industry to utilize magnesium for strong yet lighter products. Advanced magnesium alloys may improve the performance of many applications in aerospace, automotive, medical, space, energy, and defense industries.

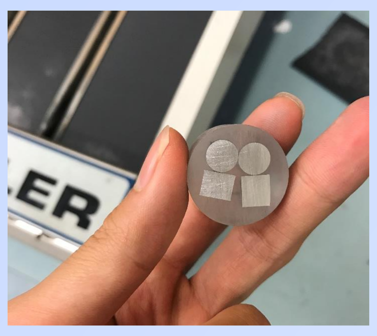
Motives

Magnesium is the seventh most abundant element on Earth. Magnesium is also the lightest structural metal currently available. While being abundant and light-weight makes magnesium a very desirable material, magnesium isn't utilized in industry since it is rather susceptible to fracture and corrosion in its pure form. An example of magnesium being used in industry was the alloy wheels. Around the 1960s magnesium wheels were used on racecars for its lightness. However, people soon found out that these wheels cracked easily and have short lifespans. They are mostly replaced by aluminum alloys nowadays.

Current research have already created advanced magnesium alloys that are far more resistant compared to pure magnesium. One example of such alloy is the AZ series, which fused magnesium with aluminum, zinc, and alumina nanoparticles. There are also different compositions that result in even greater strength. If magnesium's potential can be fully utilized, then we will have a great material that can lead to more efficient machines and structures.

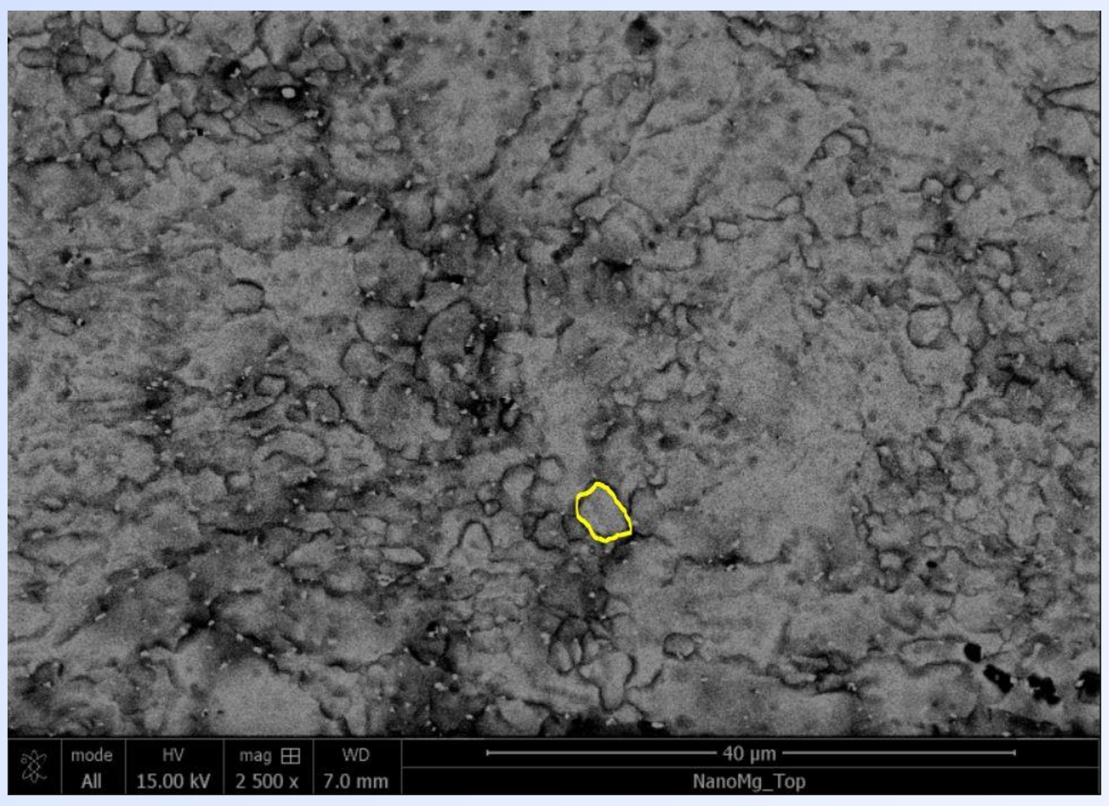
Procedures

The first step is to analyze advanced magnesium alloys is material characterization. Material characterization refers to the general process of preparing a material so that it can be examined under a laboratory setting. For my research this summer, I prepared specimen through cutting (to obtain surfaces for examination), molding (to group smaller specimen for ease of use), polishing (to ensure smooth surface and eliminate variables), and etching (to reveal grain boundaries by soaking acids on surface briefly).

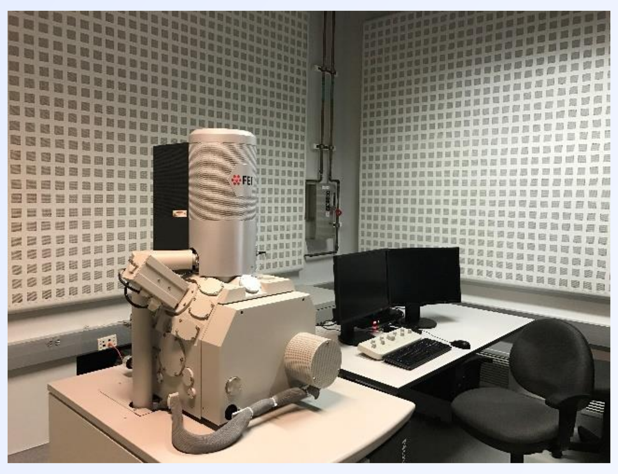


Example of Prepared Specimen

After the specimen is prepared, we can then use scanning electron microscope (SEM) imaging to observe the grain size. Grain size is one of the microscopic property that contribute greatly to a material's strength. The following image is an example of the grains shown through the SEM. Visible grain size will be recorded, and the data can be used to correlate the microscopic properties with the alloy's other mechanism.



On a larger scale, we can observe the structural property of a material through tensile tests. Tensile test machines apply a load onto the specimen tested, and they measure how much deformation occurred under tension/compression. The end result would be a stress-strain curve, which reveals many key properties such as the Young's modulus and the ultimate tensile stress. Stress strain curves are also effective displays of a material's strength and ductility. An example of the stress strain curve is shown in the Results section.



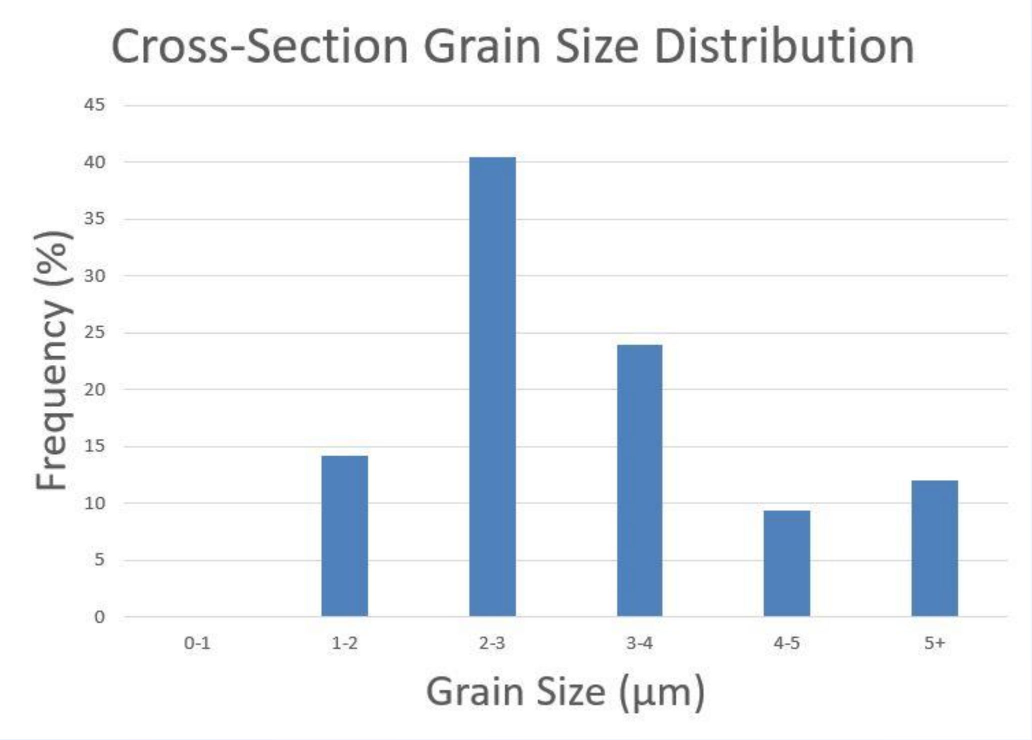
← SEM

Tensile Test Machine →

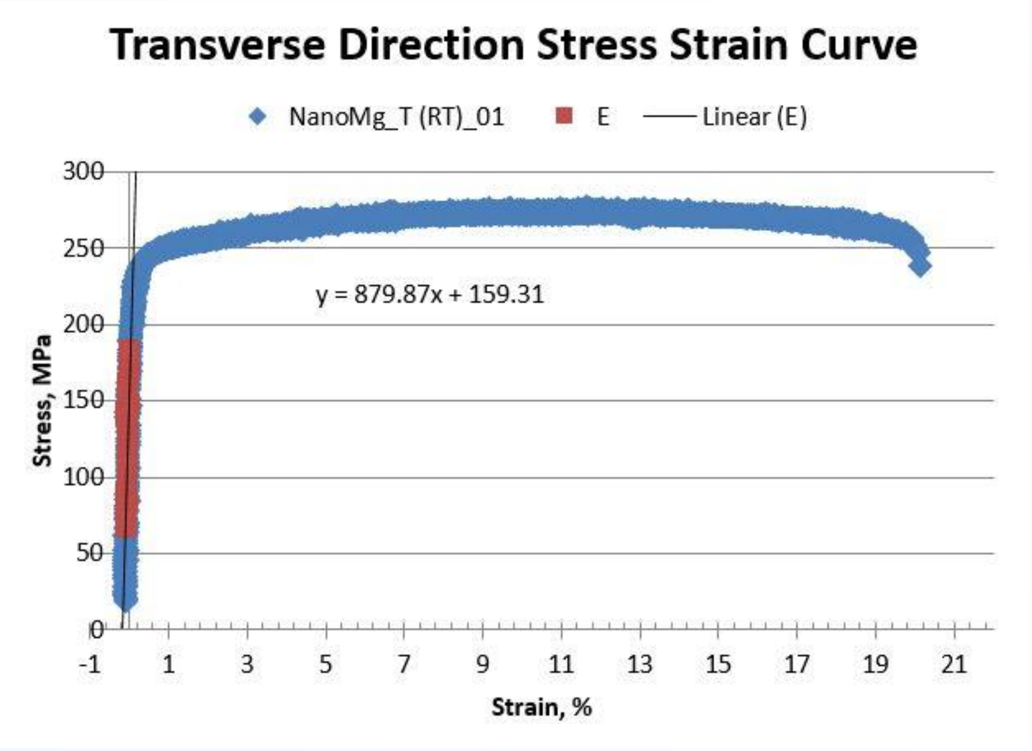
Results

Most microscopic and structural properties of a material are related, and recording as much data as possible can allow us to find connections between the properties, and therefore better understand the material.

The following image is a grain size distribution plot of an example magnesium alloy. Through my research over the summer, I have found that a grain size range from 2 microns to 4 microns to be the most common. Average grain size of the AZ magnesium alloy series ranged from 2.53 to 3.95 microns.



The next image showed the stress strain curve of an example magnesium alloy. Over the summer, I found a wide array of data based on varying testing parameters such as extrusion direction or temperature. Average Young's modulus ranged from around 60 GPa to 80 GPa, which is significantly higher than pure magnesium's 45 GPa, suggesting that these alloys are much stronger.



Conclusion

Through research this summer, I have learned many characterizing tools that allows me to analyze magnesium alloys experimentally. Through material characterization, SEM imaging, and tensile testing, I observed material texture and collected stress strain data. Such practices will prepare me for continued research over the upcoming school year, in which I would use a VPSC code to model the alloy's deformation mechanisms. Data collected this summer may be used to calibrate the VPSC model for particular magnesium alloys.

Acknowledgements

I would like to thank my lab mentor Md Ershadul Alam and professor Irene Beyerlein for their guidance and support throughout this project.

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