Heat Treatment on Magnesium Aluminum Zinc Alloy AZ91D

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Overview

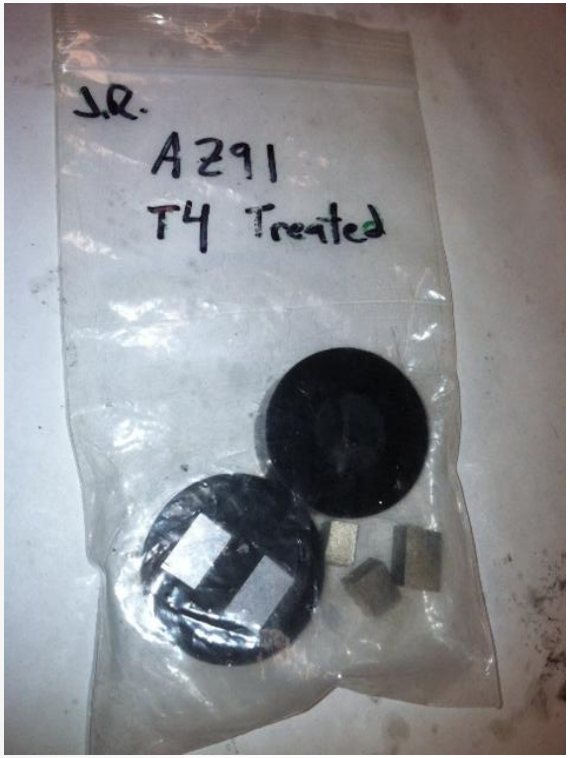
- Introduction to Composites and AZ91D
- Practical applications of Magnesium alloys and impetus for further exploration
- Experimental Tools
- Experimental procedure
- Results
- Conclusion

Composite Materials

- A composite material is a material comprised of more than one element, wherein they retain their physical and chemical identity.
    - Ex. Plywood, chocolate chip cookie
- Alloy is the specific term classifying metal composite materials
    - Ex. AZ91D

Composite Materials Lab

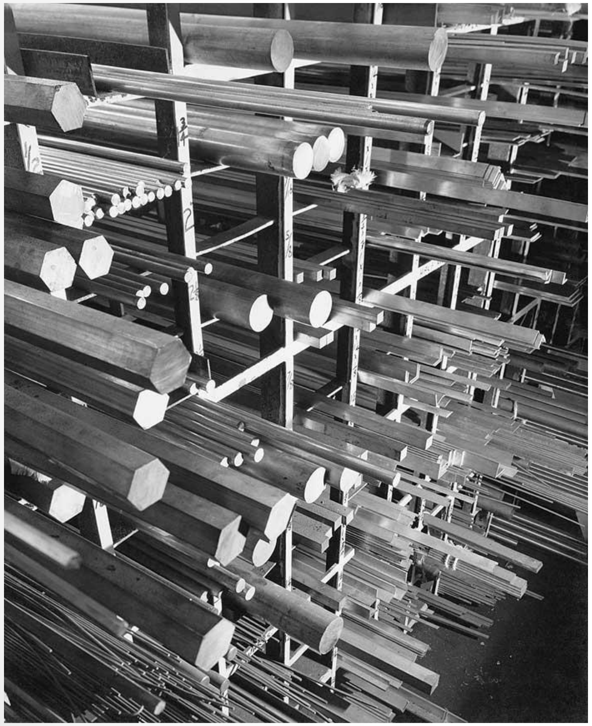
- Studying Forged Alloys



- Creating your own composites

Alloy Material Examples

- Steel



- Magnesium Alloy

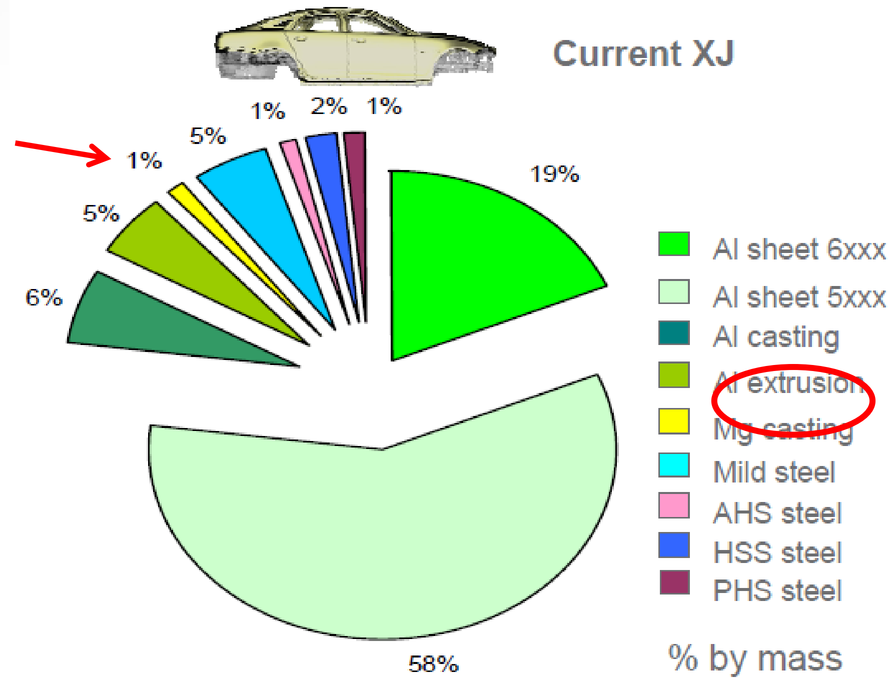
Precision Machined Products Association

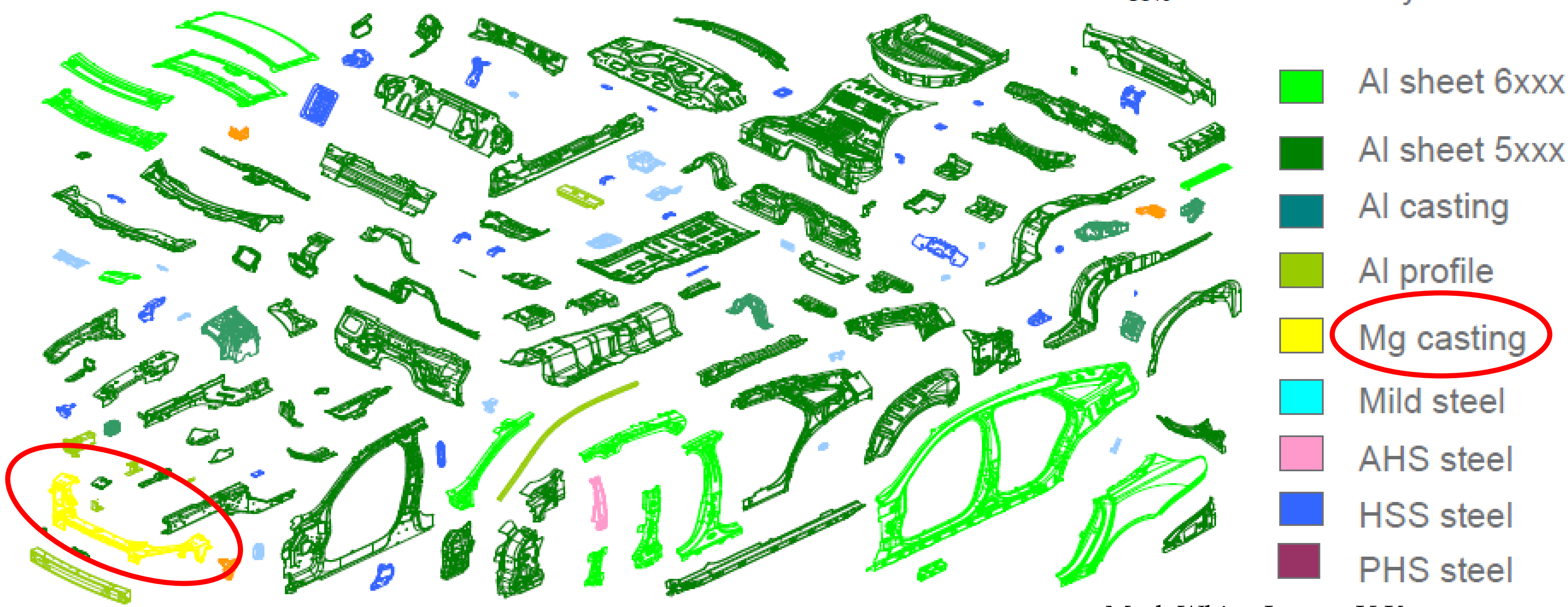
The metallurgy's blog for beginners

Why study Magnesium Alloy?

- Magnesium is one of the most abundant elements on Earth.
- Harvested from the crust of the Earth and seawater.
- 20% as dense as steel
- High workability

Automotive application of Magnesium





Mark White, Jaguar, U.K.

Military application of Magnesium Alloy

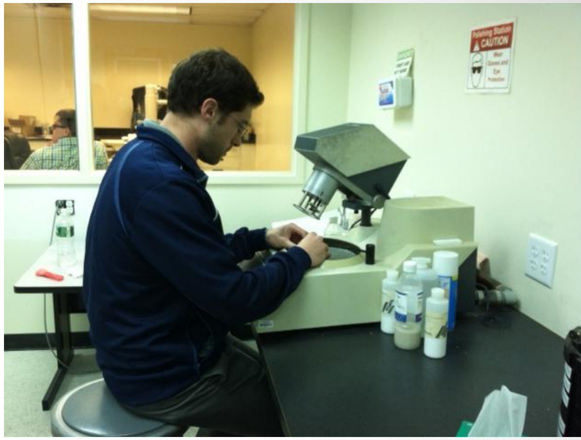
Drive train on Boeing engine for Apache attack helicopter

Gear Box on General Electric F110 engine for F-16 fighter jet.

Bruce Gwynne, Paul Lyon, Magnesium Elektron

Experimental Tools

- Optical Microscope
  - Nikon Epiphot 200
- Scanning Electron Microscope
  - Hitatchi S-3400N
- Vickers Hardness Tester
  - Future-Tech Microhardness Tester FM



Experimental Procedure

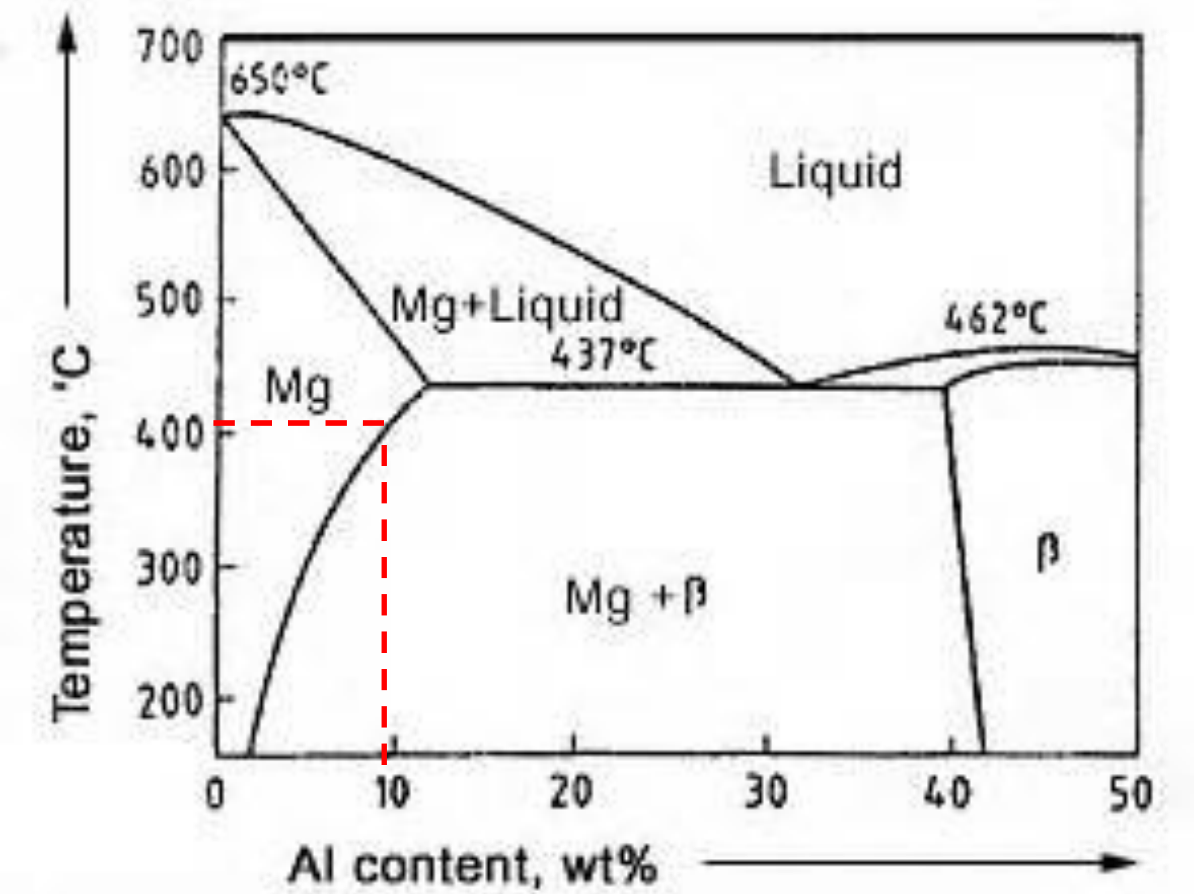
- Metallurgical sample preparation: Embedded all specimens in a polymer to aid handling
  - Steel, Aluminum, AZ91D control, AZ91D T4 treated, AZ91D T6 treated.

1. Polished all specimens with a grit of 6 micron
2. Performed T4 and T6 heat treatment on select specimens of AZ91D
3. Performed Optical microscopy
4. Performed Electron microscopy
5. Calculated Vickers Hardness Value

T4 and T6 treatments

- T4 treatment heats the specimen to a temperature based on the phase diagram for a period of 16-24 hours.
- T6 heats the specimen to an aging temperature for 16 to 24 hours. (Pre-requisite: T4 treatment).

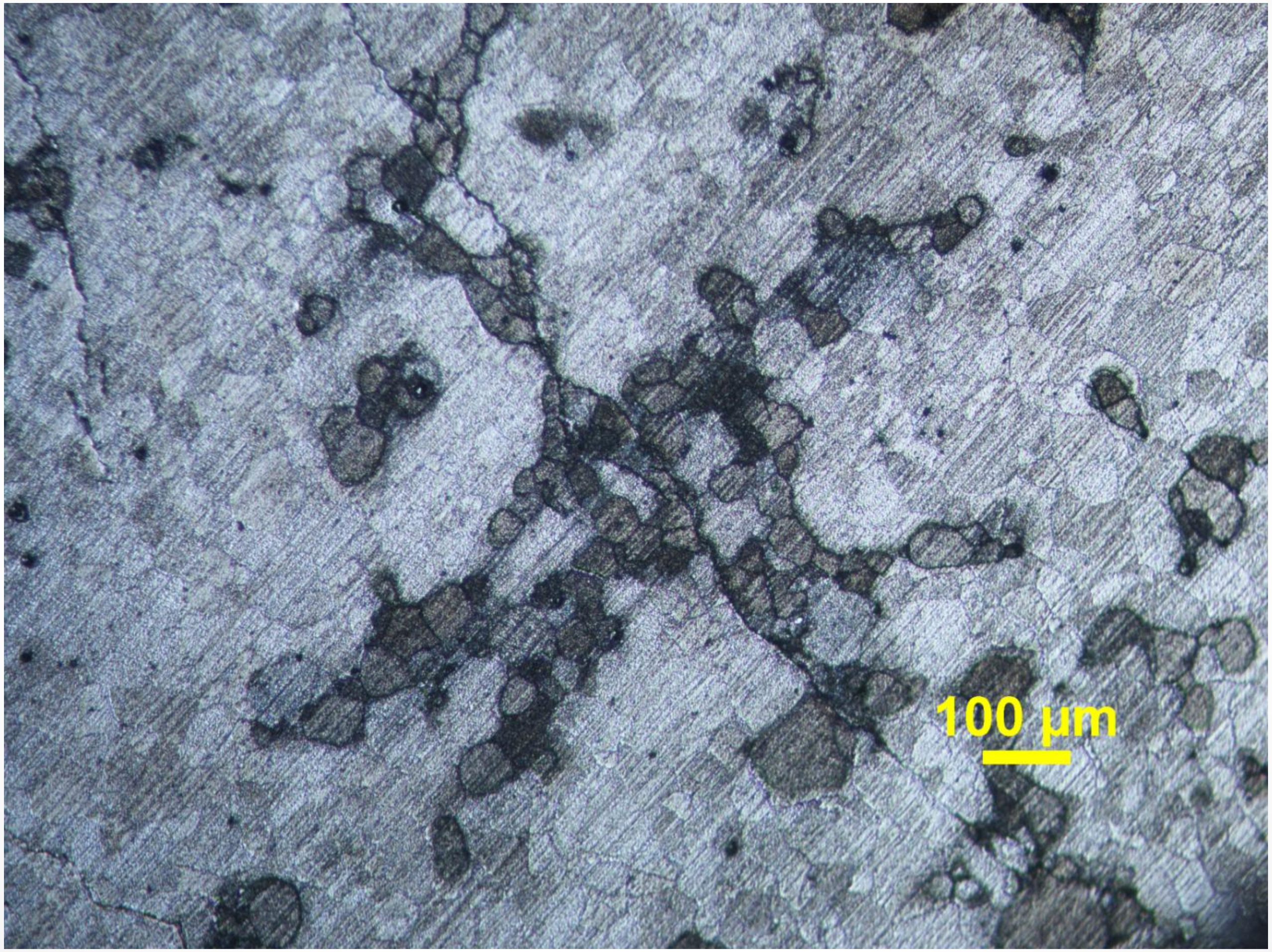
Magnesium-Aluminum Alloy Phase Diagram



Phase diagram for the binary system Mg-Al

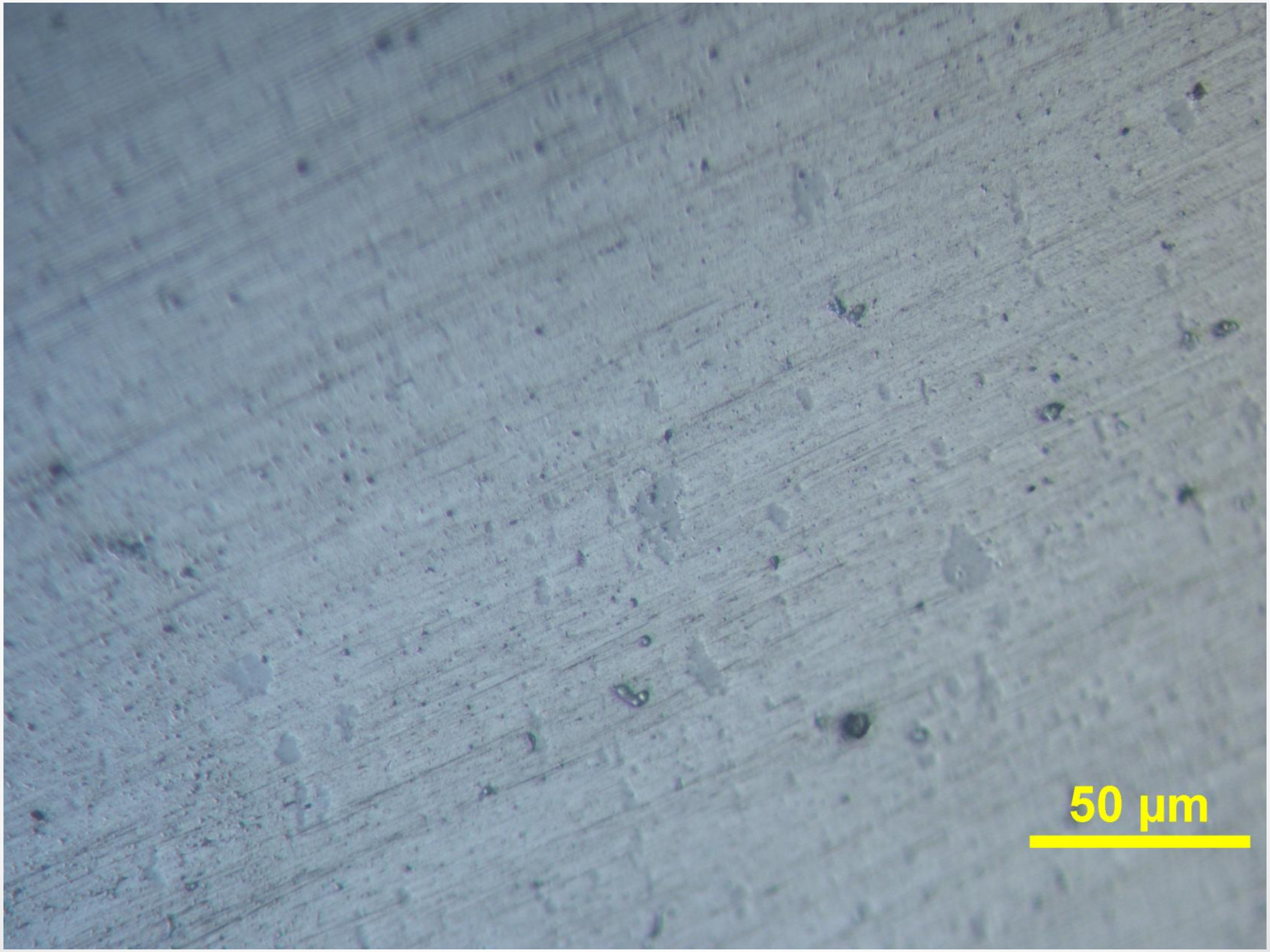
Results – Control specimens

Steel



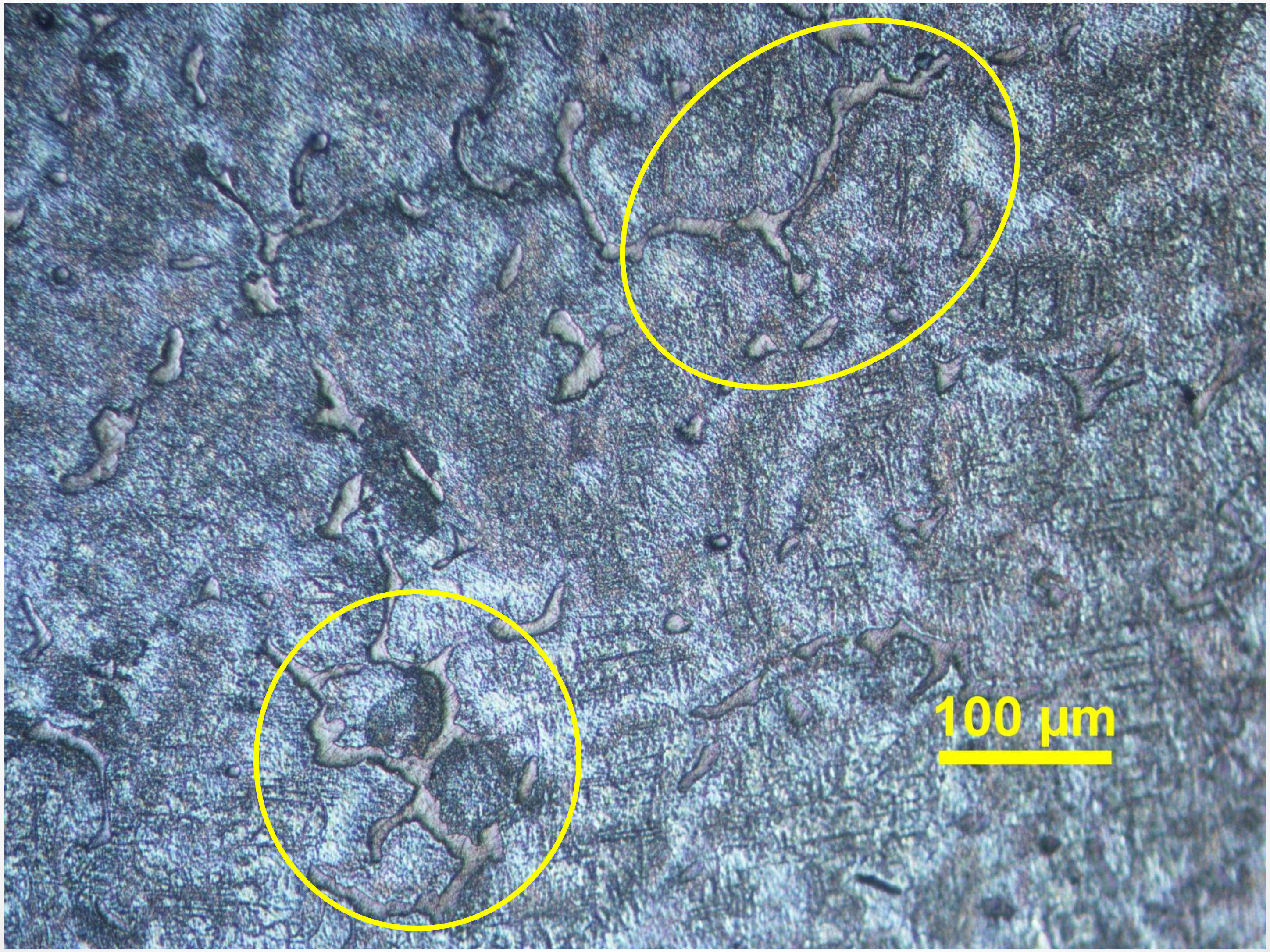
Results - Control Specimens

Aluminum



Results – Control Specimens

AZ91D



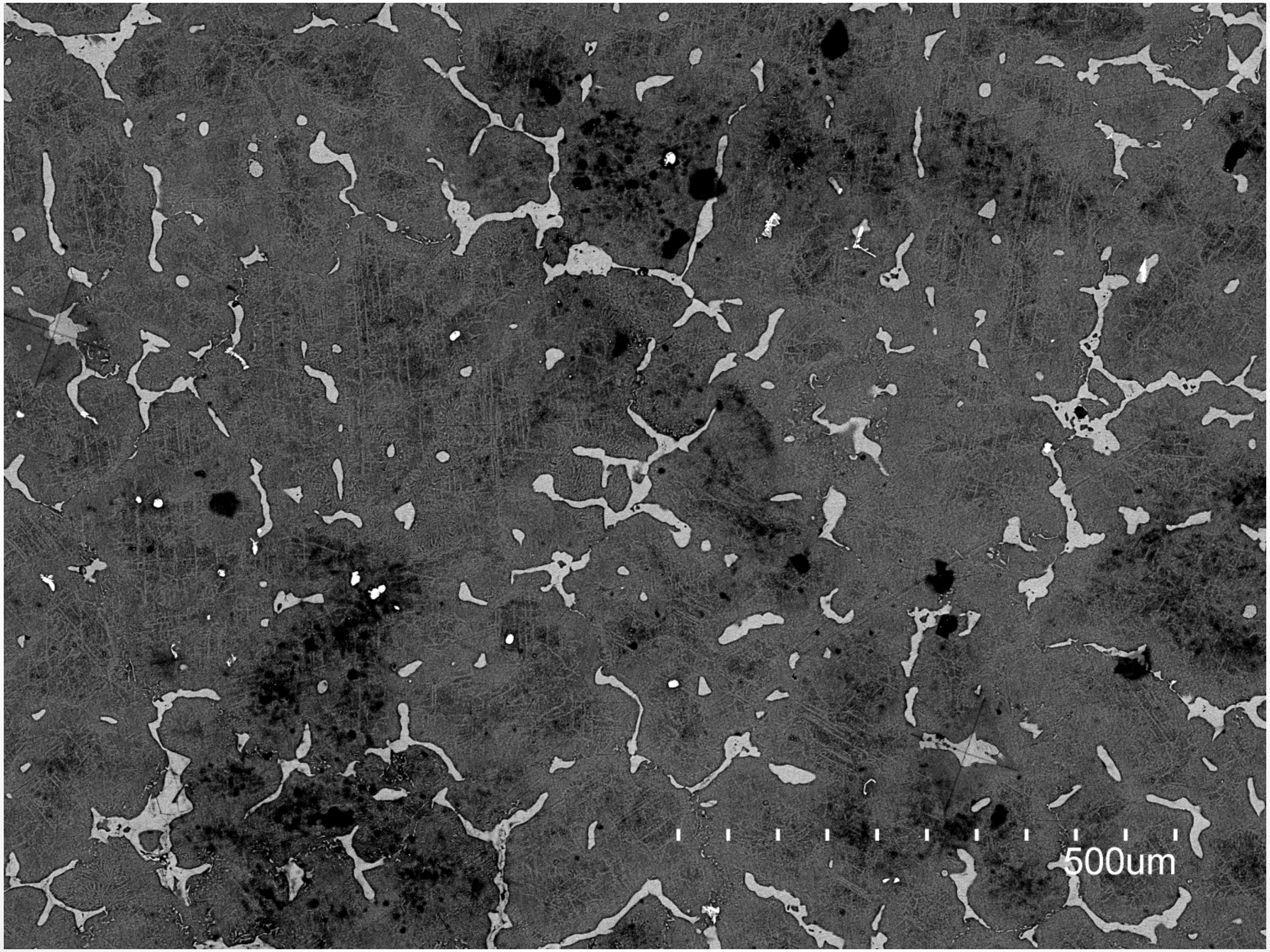
Results – Evolution of AZ91D through Optical Microscopy

T4 Treatment

T6 Treatment

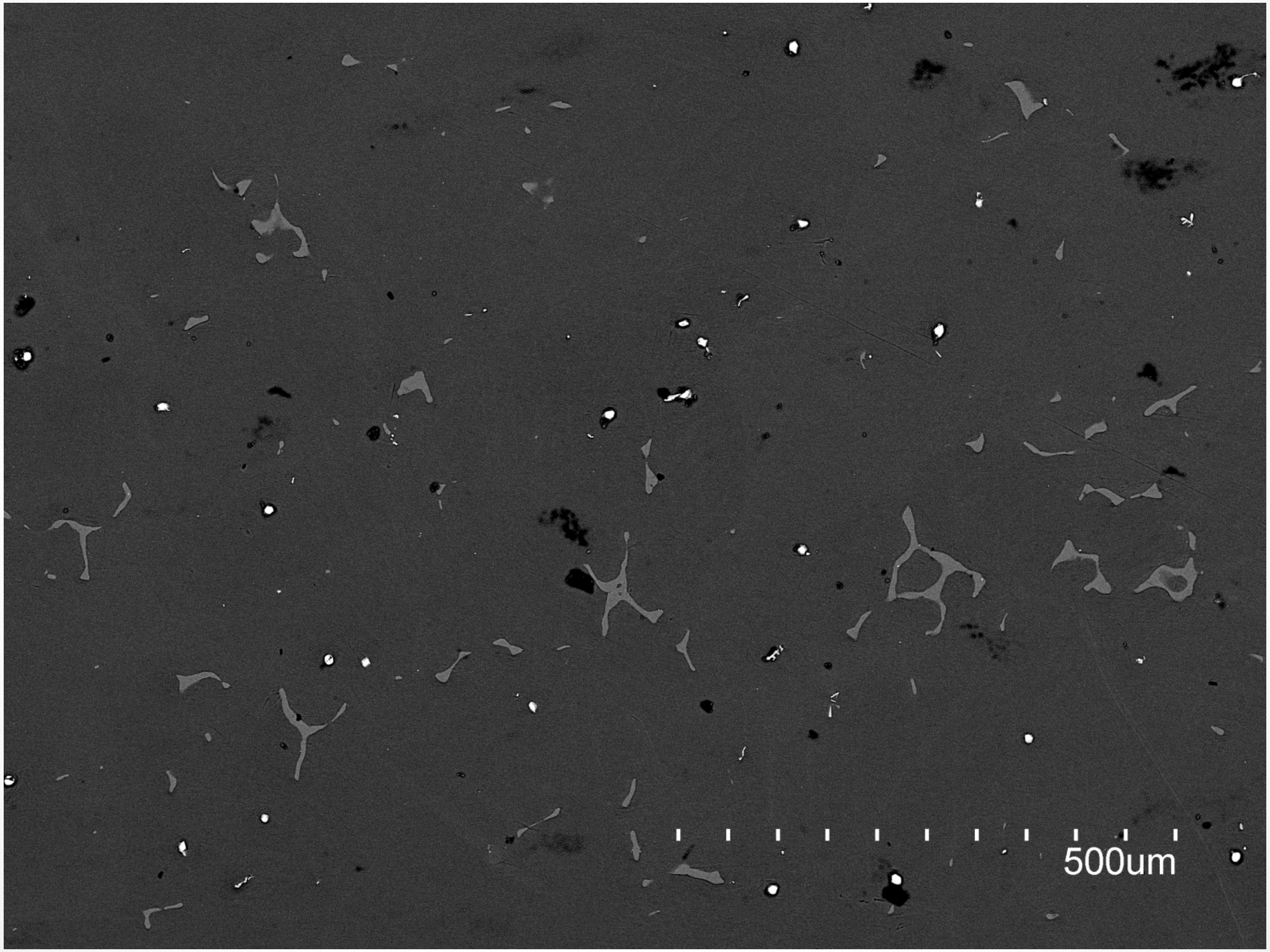
Results – Evolution of AZ91D through Electron Microscopy

AZ91D control



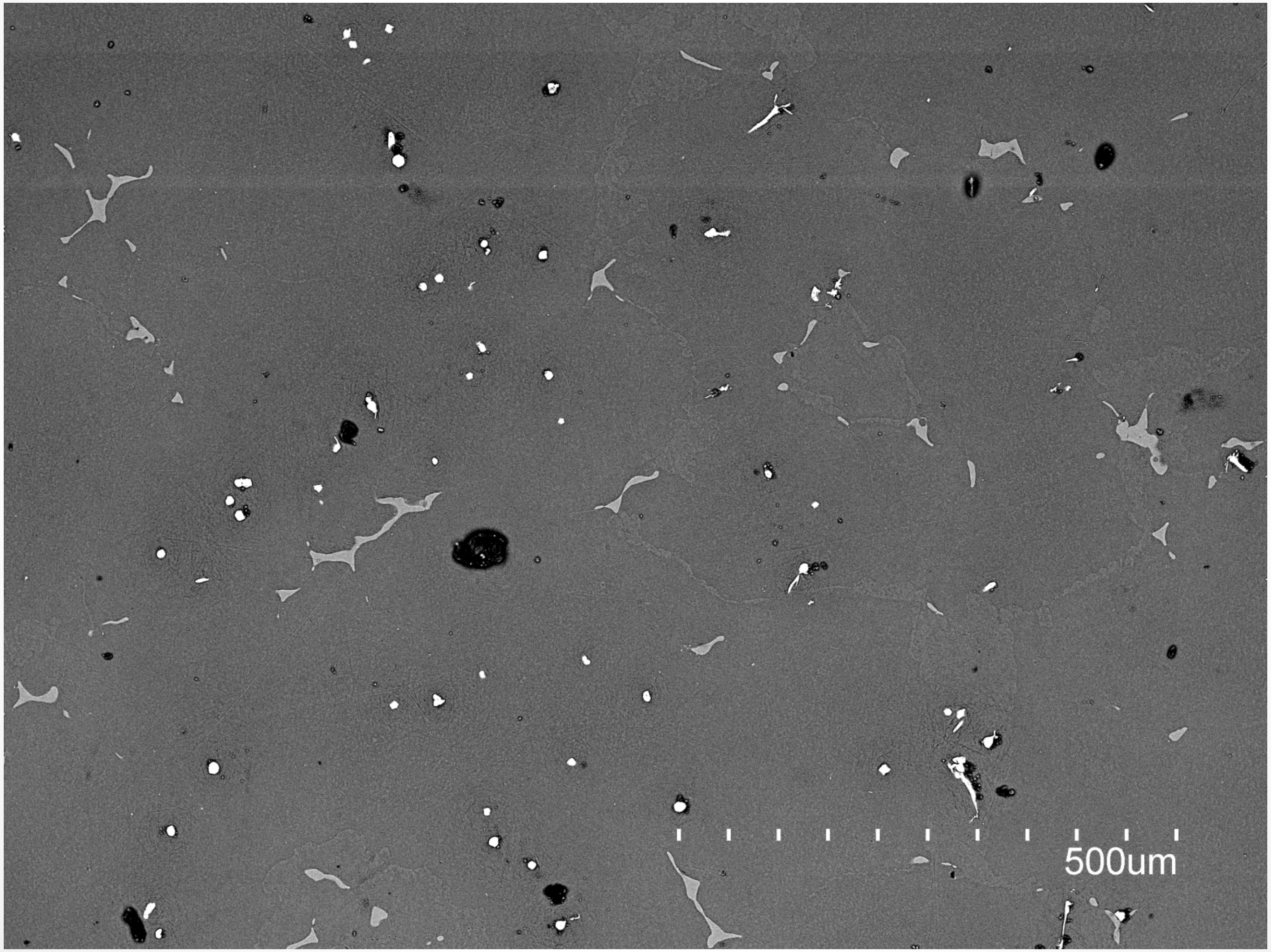
Results – Evolution of AZ91D through Electron Microscopy

T4 Treatment



Results – Evolution of AZ91D through Electron Microscopy

- T6 Treatment



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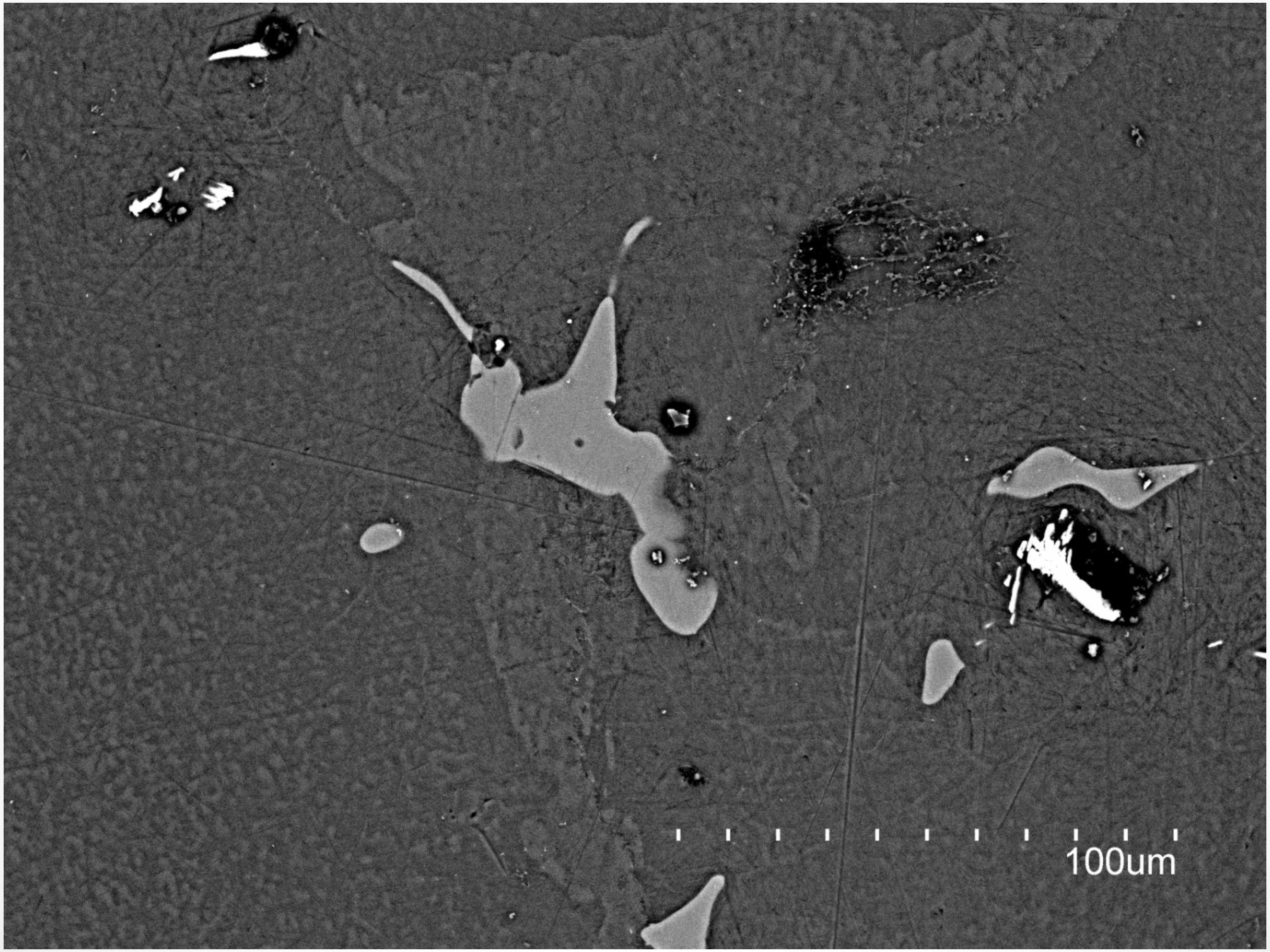
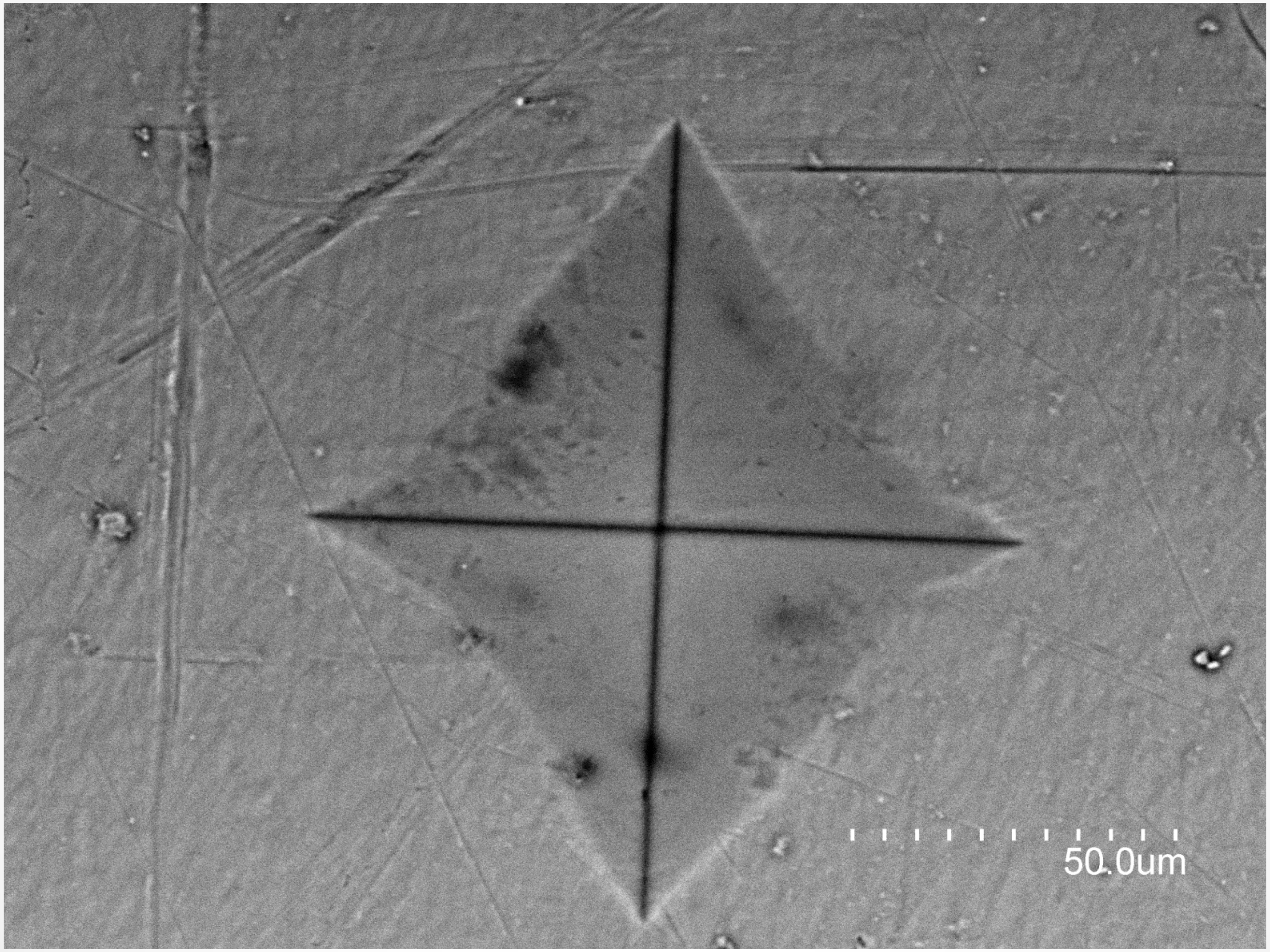
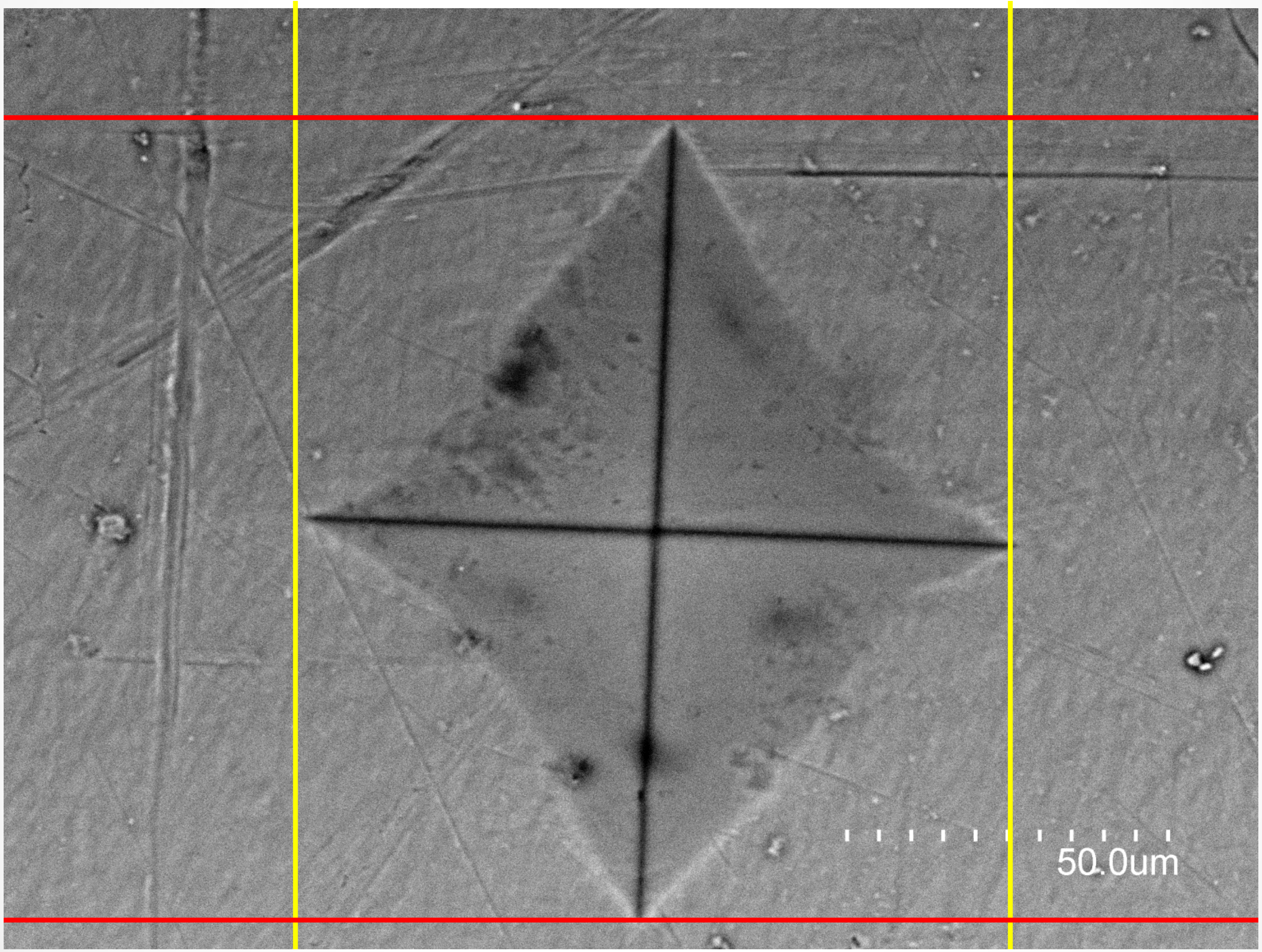


Vickers Hardness



Vickers Hardness



Vickers Hardness Data

SPECIMEN	Test Load	Sample Size Matrix	Hardness Matrix	Standard Deviation Matrix
	Dwell Time	Sample Size Precipitate	Hardness Precipitate	Standard Deviation Precipitate
Steel	1961 mN	18	95.7	9.4
	56s	22	100.7	10.9
Aluminum	4903 mN	30	152.3	4.4
	56s	-----------------------	------------------------	------------------------
AZ91 Control	4903 mN	20	62.0	6.7
	56s	20	79.6	8.9
AZ91 T4 treated	4903 mN	20	61.7	9.1
	56s	20	70.1	7.8
AZ91 T6 treated	4903 mN	20	62.0	6.6
	56s	20	87.2	12.5

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Conclusion

- The heat treatment process expedited the natural rate of precipitate reconfiguration. The strength of the material INCREASED after the T4 treatment and DECREASED after the T6 treatment
- The decrease in precipitates from control to T4 treated AZ91 as well as the decrease in the difference between hardness values indicates the material increase in strength.
- The increase in the difference between hardness values between the T4 specimen and the T6 specimen indicate an decrease in strength

Conclusion Continued

- As the AZ91 ages (naturally or through an expedited heating process) the specimen will first see an increase in strength until it reaches its maximum point of strength at an undetermined time after creation. From that point, instead of plateauing, the strength will then begin to decrease as the specimen ages.
- Engineers can use this data to tailor a material to best fit a project.
    - Ex. Making a sample weaker to be placed in the crumple zone in an automobile
    - Ex. Making a sample stronger to be used as a load bearing member in a structure.

Potential for Further Investigation

- The relationship between heat treatment aging rate and natural aging rate is still unknown
- An investigation into the compression strength, elasticity modulus and tensile strength will yield more data on the effect of heat treatments.
- More applications in the production world (commercial, industrial, or militaristic)

Acknowledgements

- This work was supported by the National Science Foundation under grant EEC-1132482, "RET Site: Science and Mechatronics Aided Research for Teachers with an Entrepreneurship expeRience (SMARTER)."
- I would like to thank my colleagues in the Composites Materials and Mechanics lab for helping me in accomplishing the research work.

The Effect of Microballoon Density and Strain Rate on the Properties of Syntactic Foam Composites

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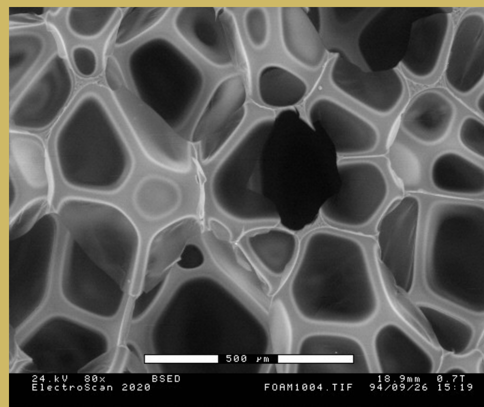
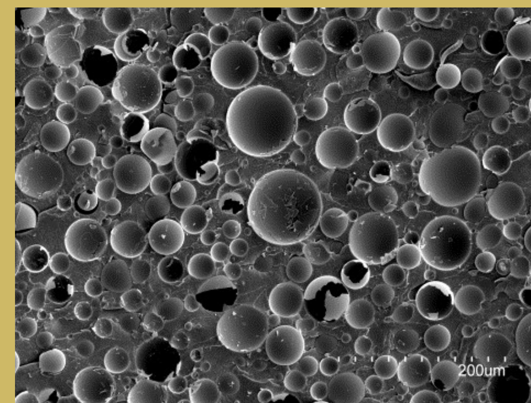
NATIONAL SCIENCE FOUNDATION

Composite Materials

- When 2 or more materials are combined in hopes of maximizing the materials strengths while minimizing their weaknesses. The two entities retain their physical and chemical structure.
  - Plywood
  - Concrete
  - Syntactic Foams

Composite Foams

<table>
<tr><th>Open Cell Foams</th><th>Closed Cell Foams</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">A matrix which can consist a wide range of resins and hardeners that are combined with microballoons.</td></tr>
<tr><td>Open cell foam: This gives no control over the type or the amount of porosity to be embedded in the foam.</td><td>Closed cell foam: Control the porosity content in the foam.</td></tr>
</table>

Microballoons

Wall thickness

The density of microballoons can be changed by changing the wall thickness of the spheres.

Syntactic Foam Applications

Underwater vehicles

- Locating a lost hydrogen bomb in the Mediterranean Sea in 1966
- Exploring the first known hydrothermal vent sites in the 1970s
- Surveying the wreck of RMS Titanic in 1986

Syntactic Foam Applications

USS Zumwalt class destroyer with syntactic foams modulus for buoyancy and radar transparency

Syntactic Foams/Density

Microballoon Type	Foam Type	Theoretical Foam Density (kg/m3)	Average Experimental Density
S22	SF220-40	784	812.4
S22	SF220-50	690	608.5
S22	SF220-60	596	706.3
K46	SF460-40	880	870.4
K46	SF460-50	810	793.1
K46	SF460-60	740	698.5

Specimen Preparation

Glass microballoon

Mechanical stirrer

Epoxy resin

Hardener

Aluminum molds

Mechanical stirrer

Specimen Preparation

The cast syntactic foam slabs (compression test specimens have been drilled out of them)

Experimentation

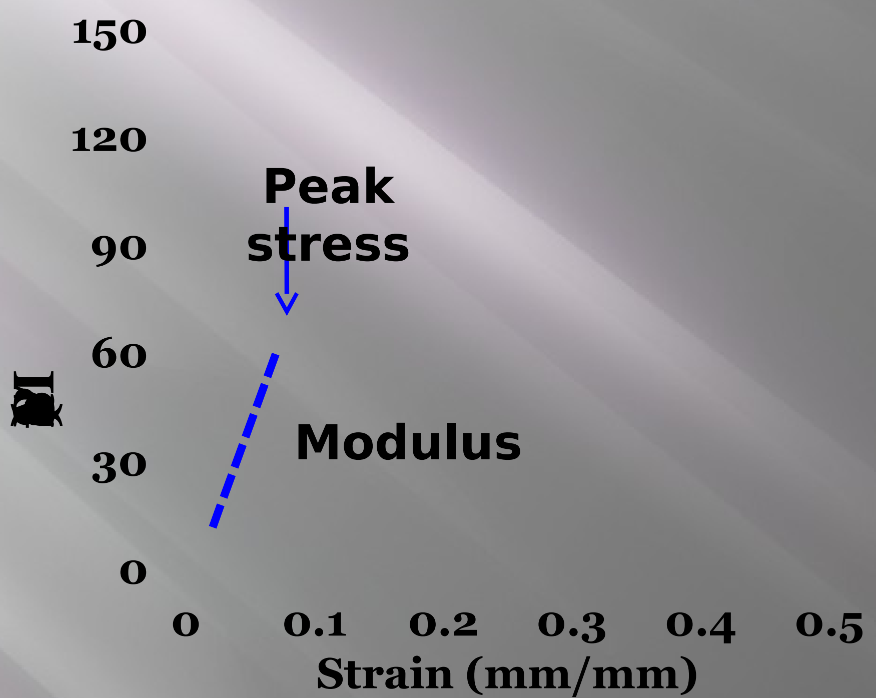
- **<u>Strain:</u> the ratio of change in the length to the original length of the sample**
- **<u>Strain Rate:</u> the rate of change of strain with respect to time, *t***
- **<u>Static Testing:</u> compression which occurs at slow rates over time**
- **<u>Stress</u>: the average force per unit area**
- **<u>Modulus of Elasticity:</u> slope of the initial linear elastic region**

Quasi-Static Compression Tester

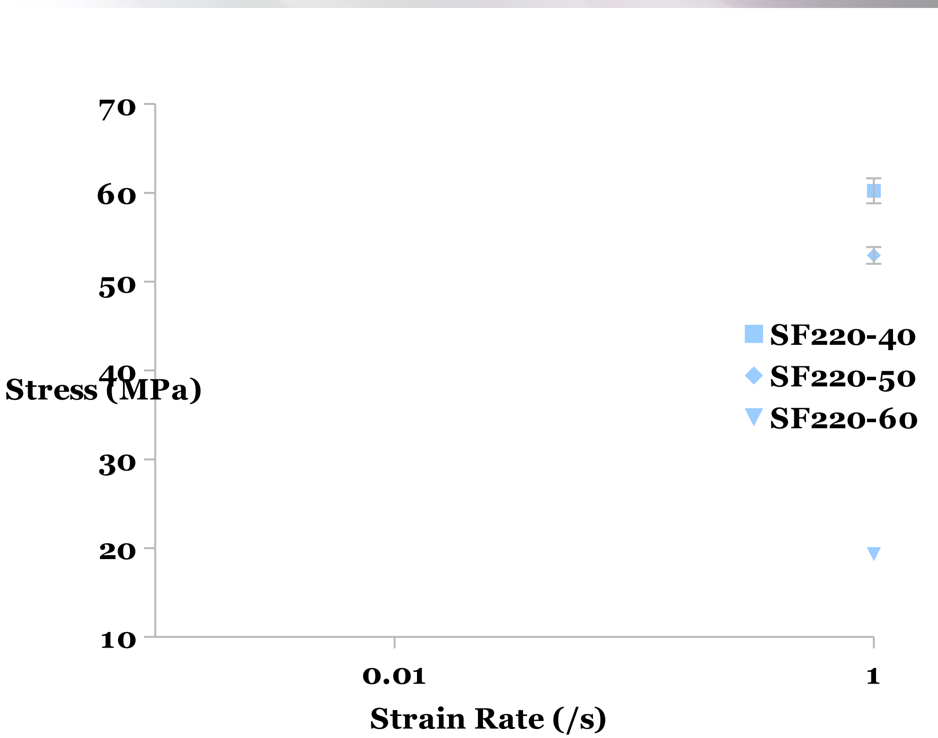
Syntactic Foam sample during and after compression

Stress-Strain Diagram

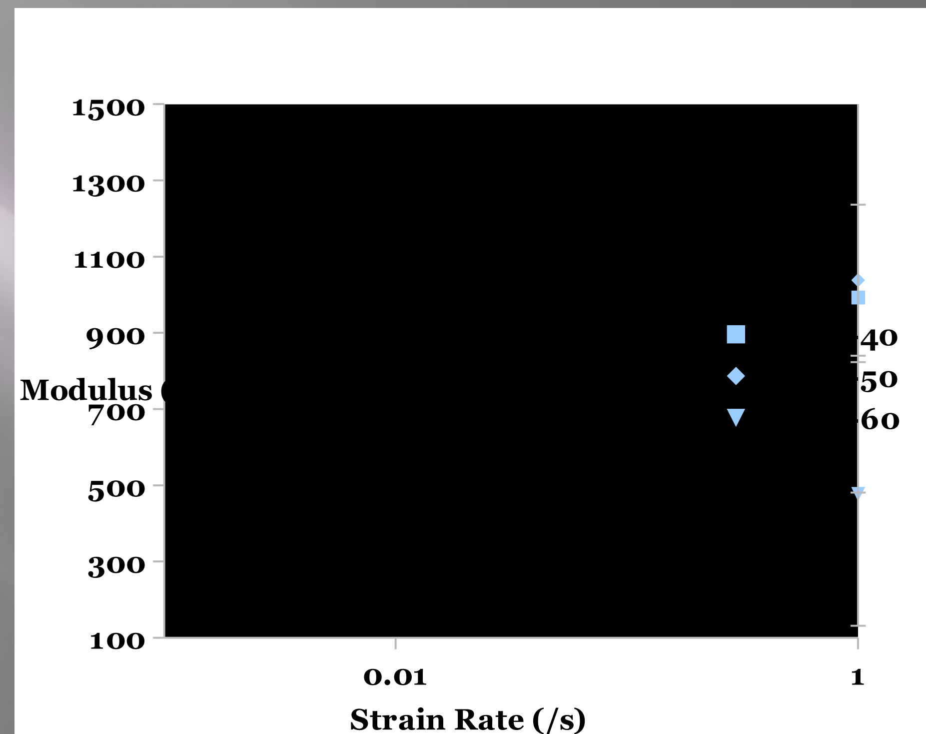
Representative stress strain curve of SF 220-40 at 0.001 /s



ress and Modulus Averages of SF-220

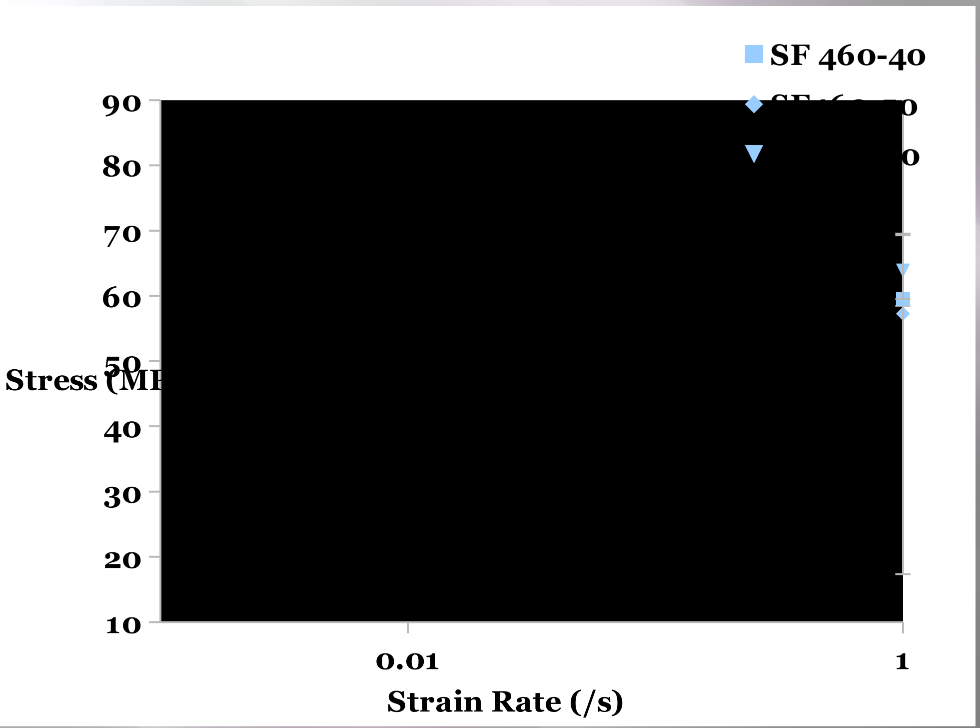


Strength of 220 foams at various strain rates

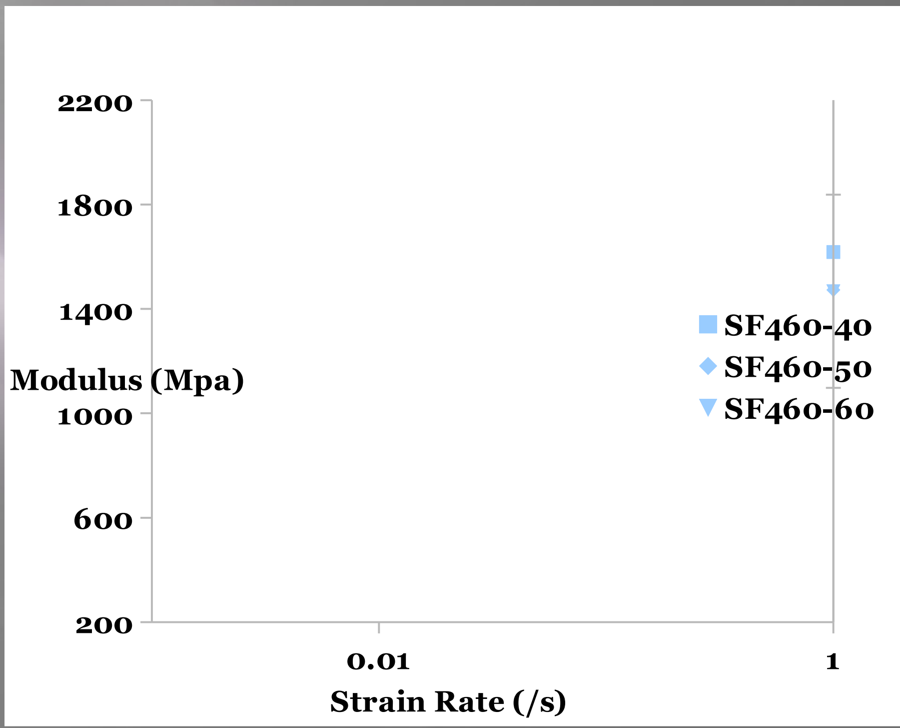


Modulus of 220 foams at various strain rates

ress and Modulus Averages of SF-460



Strength of 460 foams at various strain rates



Modulus of 460 foams at various strain rates

Conclusion

- The two syntactic foams of varying densities were studied at different strain rates from 0.001 to 0.1 /s.

  The Stress was observed to increase with the strain rate for 460 type.

- The modulus values showed an increase with the strain rates for the 220 and 460 type syntactic foams.

Acknowledgements

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Steven Labella

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