Model for Pre-Surgical Intracerebral Hemorrhage Planning

DEPARTMENT OF BIOMEDICAL ENGINEERING University of Wisconsin

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Client: Prof. Walter Block Advisor: Dr. Paul Campagnola

BME Design

Abstract

Intracerebral hemorrhaging (ICH) is an extremely dangerous condition that without intervention can ultimately lead to death. Recently, new methods have been developed for evacuating clots formed as a result of ICH. However, the stiffness of the brain clots can be very different from patient to patient, which complicates the decision of what method of evacuation to utilize. Professor Walter Block presented the team with the challenge of designing a brain phantom that will eventually be used to generate a database that allows neurosurgeons to compare MRE phantom images to MRE images of ICH patients. By comparing the patient's scan to the database of phantom images, the surgeon is able to determine the stiffness of the clot prior to surgery, and decide on the best method of evacuation. Other brain phantoms have been created, but none target ICH specifically or include a gel-gel interface. Our solution is to create an alginate phantom with "clots" inside of base gels to prove materials of different stiffness can be differentiated in MRE images.

Problem Definition

- ICH occurs when blood vessels burst in the brain, resulting in blood clots.
- Choosing a treatment for blood clot evacuation can be difficult because it is based on the material properties of the blood clot.
- Surgeons need a control that can be imaged with an MRI to create a standard of measurements that can be used to determine the surgical approach.
- A brain phantom database will be used by neurosurgeons to compare the MRI scans of the phantom with a scan of their patients' brains. The phantoms purpose is to illustrate the stiffness of the patient's clot.
- Our model seeks to create an environment where there are two alginate gels of known, different compositions. The gels will then be imaged by MRI and the difference in stiffnesses between the gels will be distinguishable.

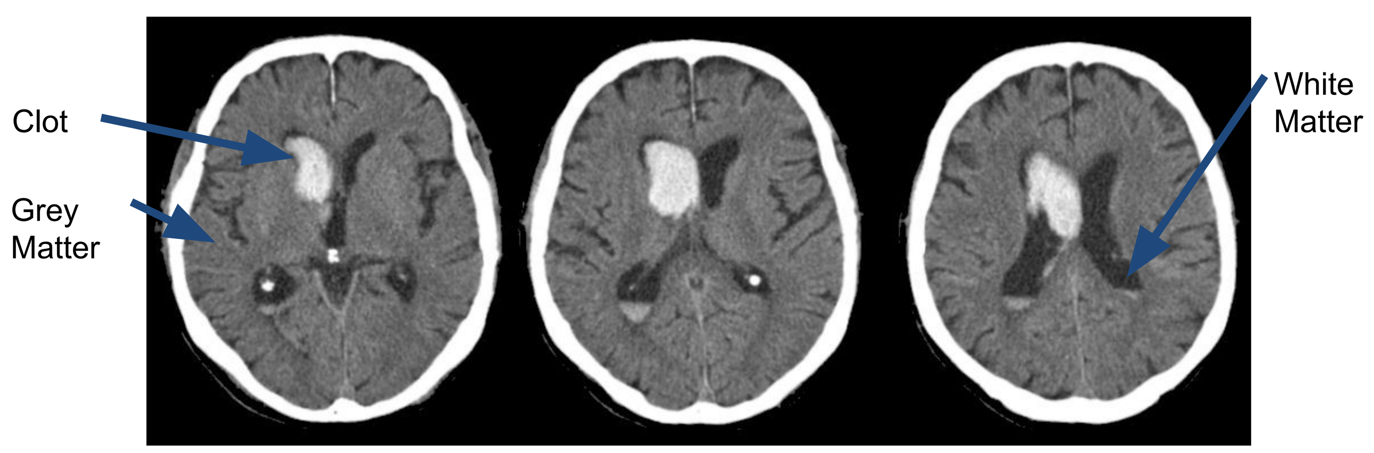

Figure 1.1 Intracerebral Hemorrhage MRI Scan [1]. The white mass in the image indicates a blood clot.

Cranial Sample Holder Design

- Design meant to more closely mimic the cranial structure
- Clot gels suspended in layered base gels to avoid gel-air interface
  - Prevents distortion of MR images
- Clot gels will be formed using clot gel molds and then placed in cranial holder
- Clot gels will be cut to mimic clots found in the brain
- Dimensions: 165 x 177.8 x 130

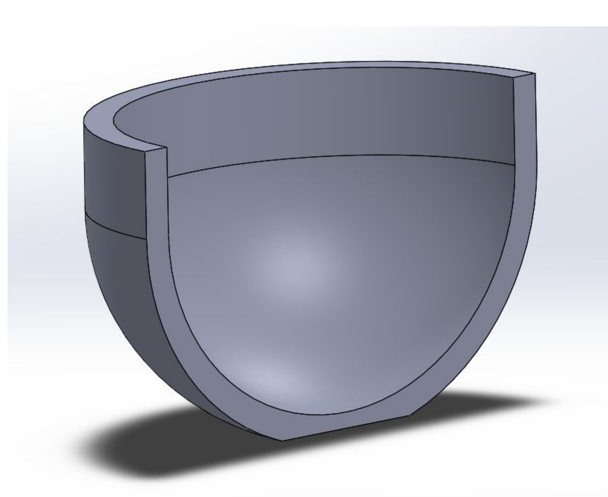

Figure 2.1 Sample holder designed to mimic cranial cavity

Imaging Timeline

1. Create a working phantom with different stiffness gels and make sure a difference can be detected (Complete, see Figure 4)

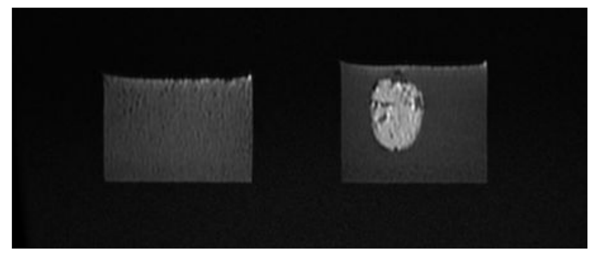

Figure 4.1 T1 Imaging Result

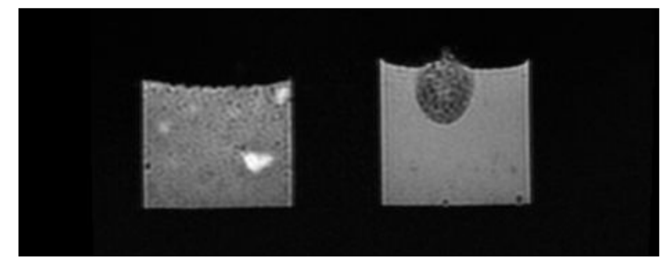

Figure 4.2 T2 Imaging Result

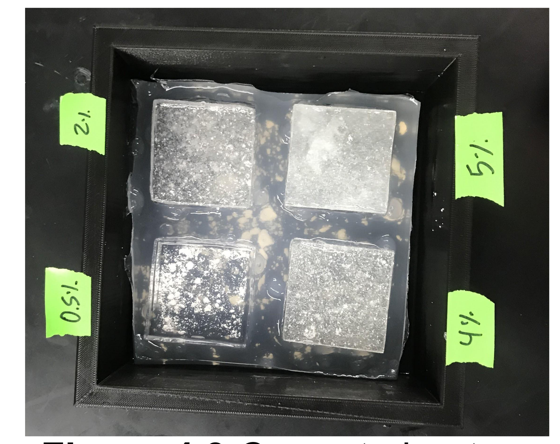

Figure 4.3 Current phantom

2. Update shape of phantom to fit better with MRI surface to minimize wave phase issues (see Figure 5.1)
3. Make phantom anatomically relevant by adding internal ear canal air pocket (see Figure 9.1)
4. Add complexity: fluid pocket, more air pockets, many clots of different sizes and shapes
5. Identify imaging capacity by trying to find smallest detectable size/stiffness differences between clots (see Figure 6.1)

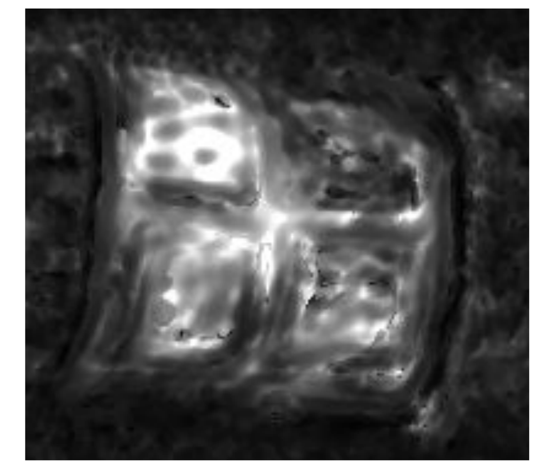

Figure 5.1 Imaged phantom with phase issues

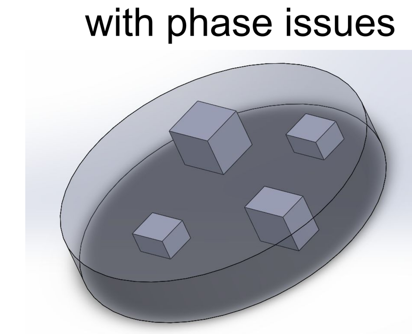

Figure 6.1 Future clot placement model

Mechanical Testing Results

- 1% Gels showed an average Young's Modulus of 253.38 ± 58.89 KPa
- 5% Gels showed an average Young's Modulus of 531.33 ± 53.10 KPa
- Running a one-tailed T-test between the Young's Moduli of the two gel types, at .05 significance we get a t value = -3.50
- We get a p value of .0123 which is significant at the .05 significance level

DMA Stats:

- 5%: storage 54 KPa, loss 2.1 KPa
- 1%: storage 23 KPa, loss 1.8 KPa

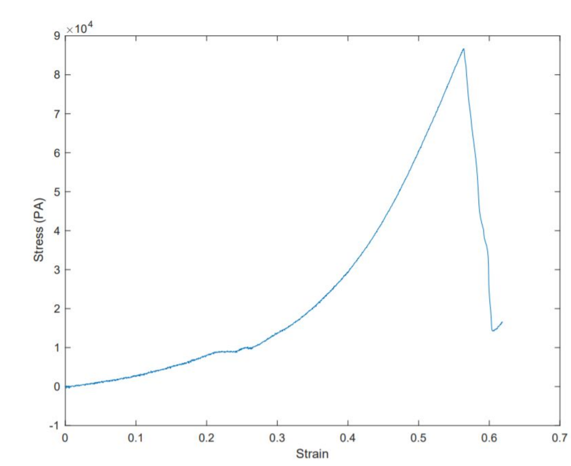

Figure 7.2 Stress vs. Strain results of 1% Alginate Gel. Y-axis = Stress (Mpa), X-axis = Strain

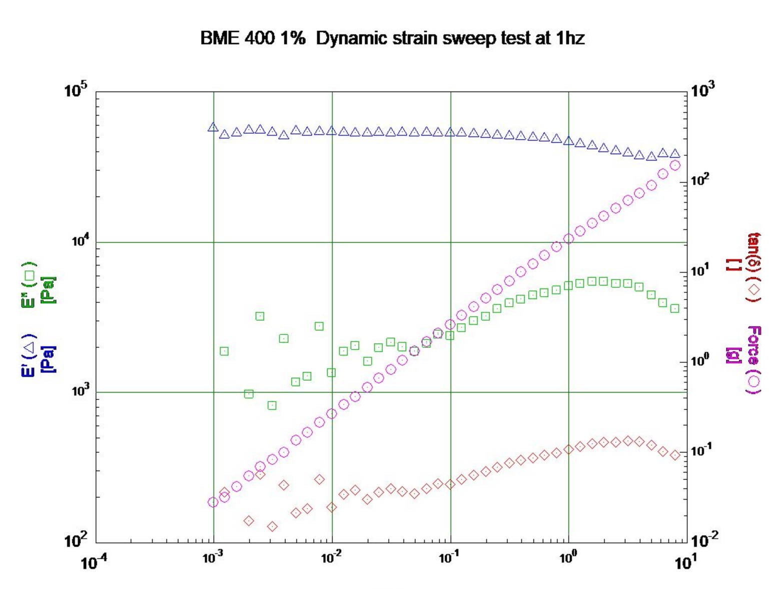

Figure 7.1 DMA testing results for the 1% Alginate gel

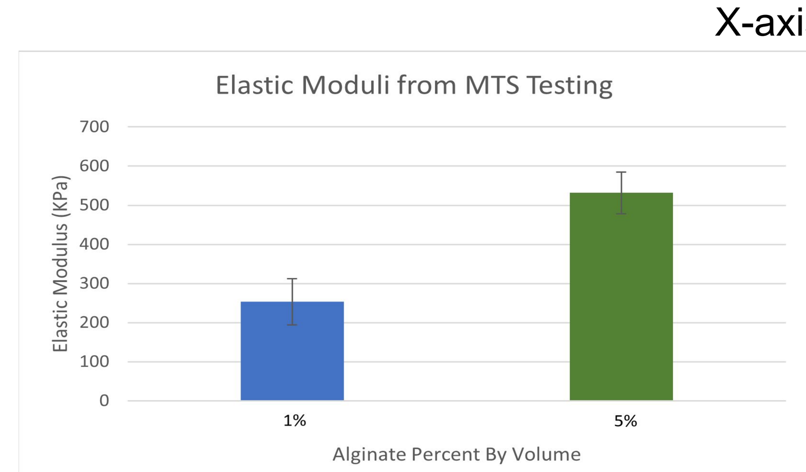

Figure 7.3 Young's Moduli Values Averages for both gel concentrations

References

[1] "Figure 2f from: Irimia R, Gottschling M (2016) Taxonomic revision of Rochefortia Sw. (Ehretiaceae, Boraginales). Biodiversity Data Journal 4: e7720. https://doi.org/10.3897/BDJ.4.e7720."

[2] K. Y. Lee and D. J. Mooney, "Alginate: properties and biomedical applications," *Progress in polymer science*, Jan-2012. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223967/. [Accessed: 04-Dec-20

[3] Figure 1 from L. Q. Wan, J. Jiang, D. E. Arnold, X. E. Guo, H. H. Lu, and V. C. Mow, "Calcium Concentration Effects on the Mechanical and Biochemical Properties of Chondrocyte-Alginate Constructs," *Cellular and Molecular Bioengineering*, vol. 1, no. 1, pp. 93–102, Mar. 2008.

Gel Making Procedure

Protocol [2,3]:

1. Dissolve alginate in water
2. Add $CaCO_3$ and Glucono-δ-lactone
3. Mix gel thoroughly
4. Pour base gel evenly into the holder
5. Place "Clot Holders" into gel before it sets
6. Allow the base gel to set in a fridge
7. Remove "Clot Holders"
8. Repeat steps 1-3 for clot gels
9. Pour clot gels into the holder space
10. Allow clots to set in fridge
11. Repeat steps for a second base gel layer
12. Pour second base layer over top and allow time to set.

Materials & Costs

1. Alginic Acid - $ 46.53
2. Glucono-δ-lactone - From materials lab
3. $CaCO_3$ - From materials lab
4. Sample Box - $28.49

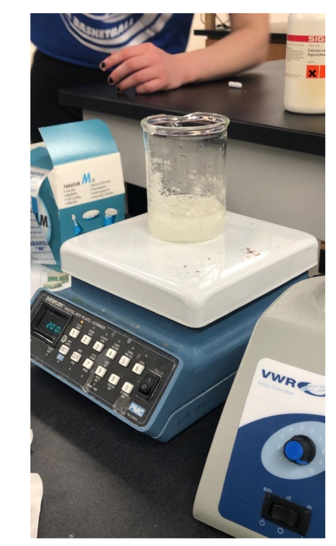

Figure 8.1 Dissolving Alginate

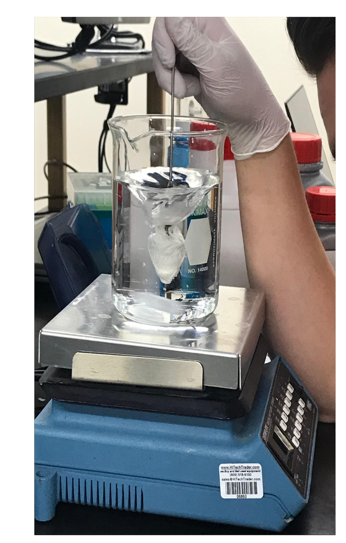

Figure 8.2 Alginate powder being stirred

Figure 8.3 Complete gels, 5% (top left) and 1% (bottom right) alginate

Future Project Development

- Integrate clots into anatomical model
- Integrate air and liquid compartments into model
- Fine tune clot accuracy to white and gray matter of brain

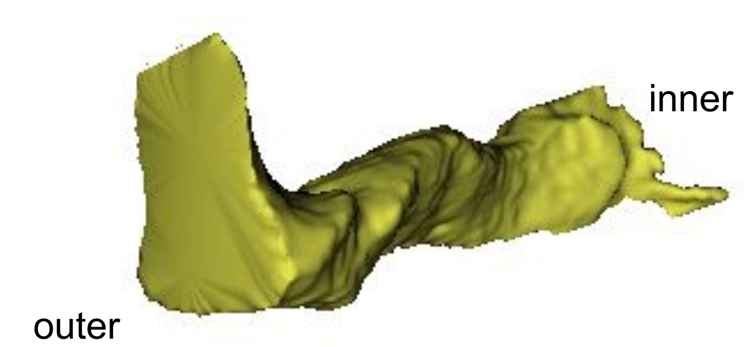

Figure 9.1 Model of the inner ear canal to be placed into the 3D brain phantom.

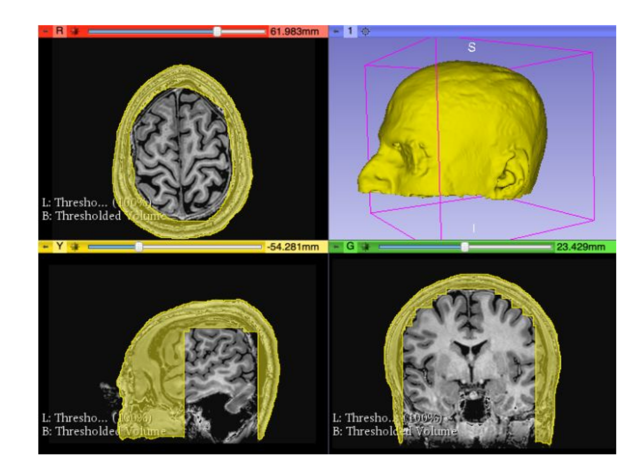

Figure 9.2 3D model of an actual human skull and brain to be used as a phantom

Acknowledgements

- Dr. Aviad Hai
- Dr. Kristyn Masters
- Prof. Walter Block
- Dr. Paul Campagnola
- Anna Kiyanova
- Julie Morasch
- Robert Moskwa
- UW-Madison Makerspace
- Dept. of Biomedical Engineering

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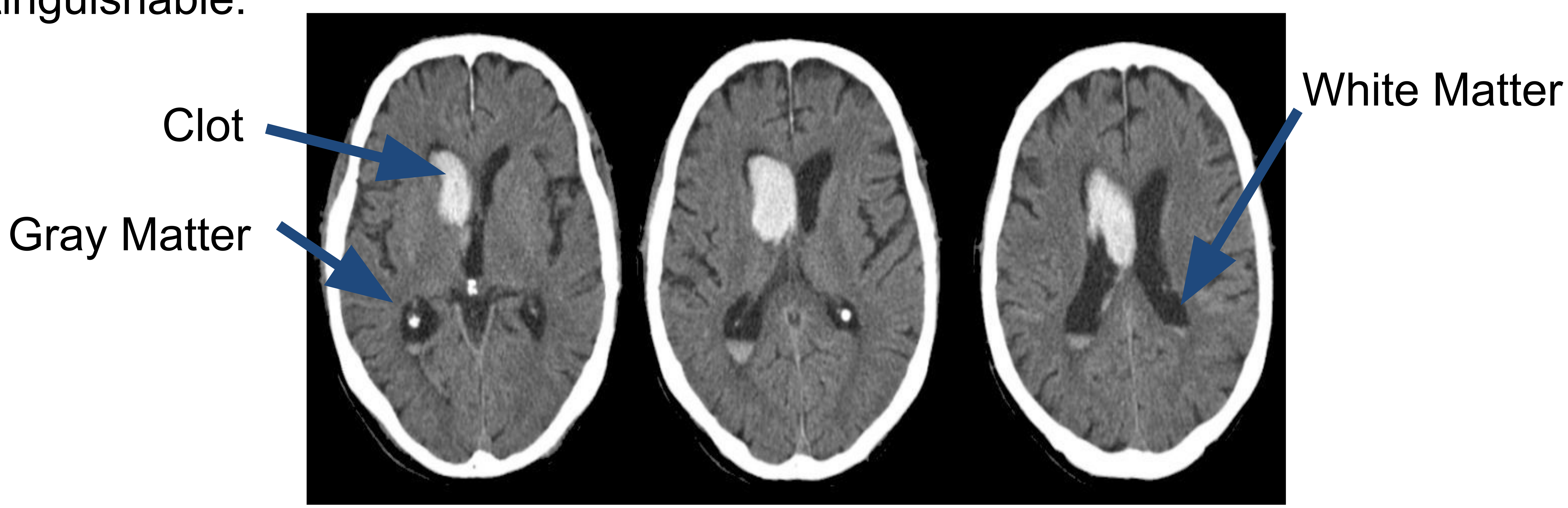

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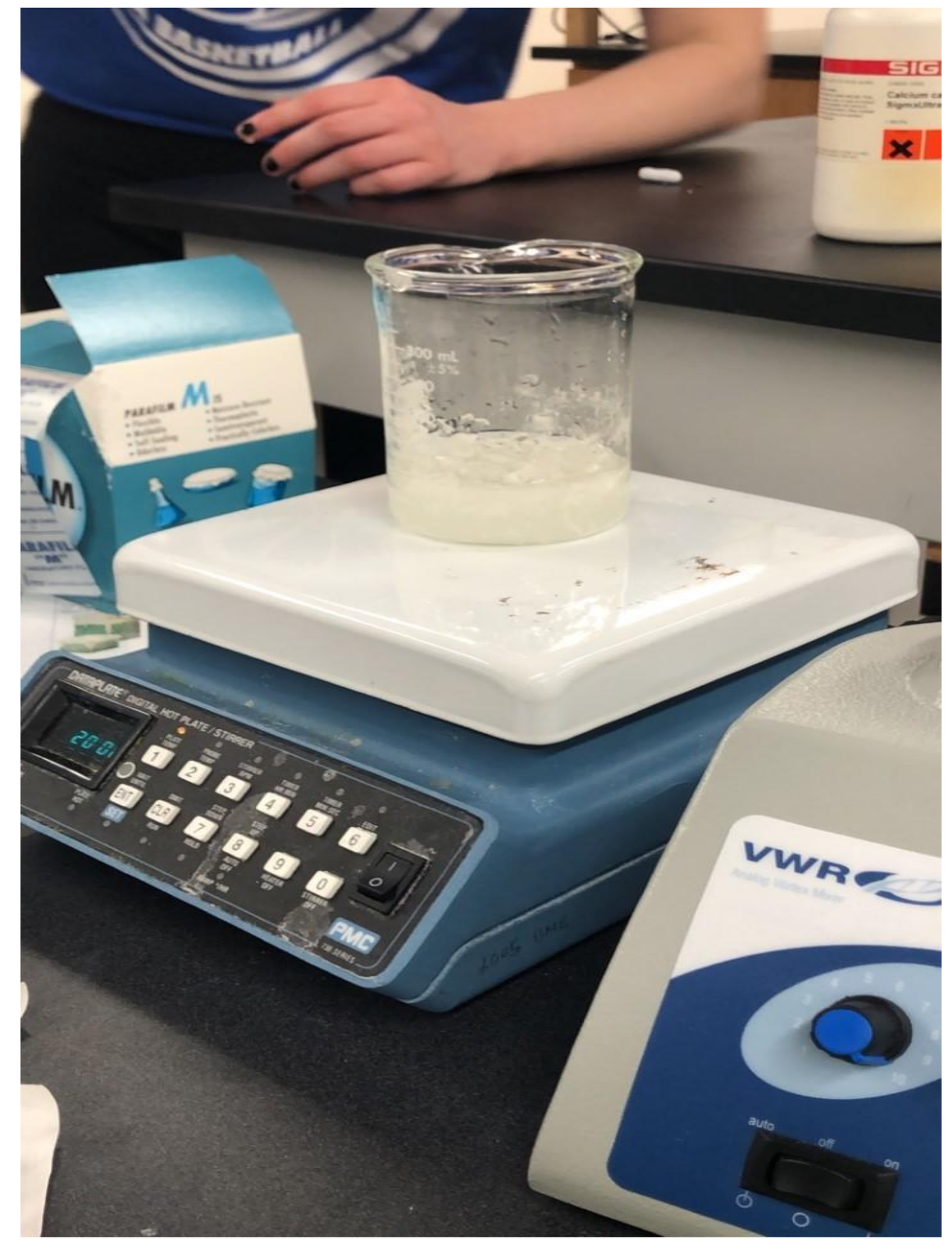

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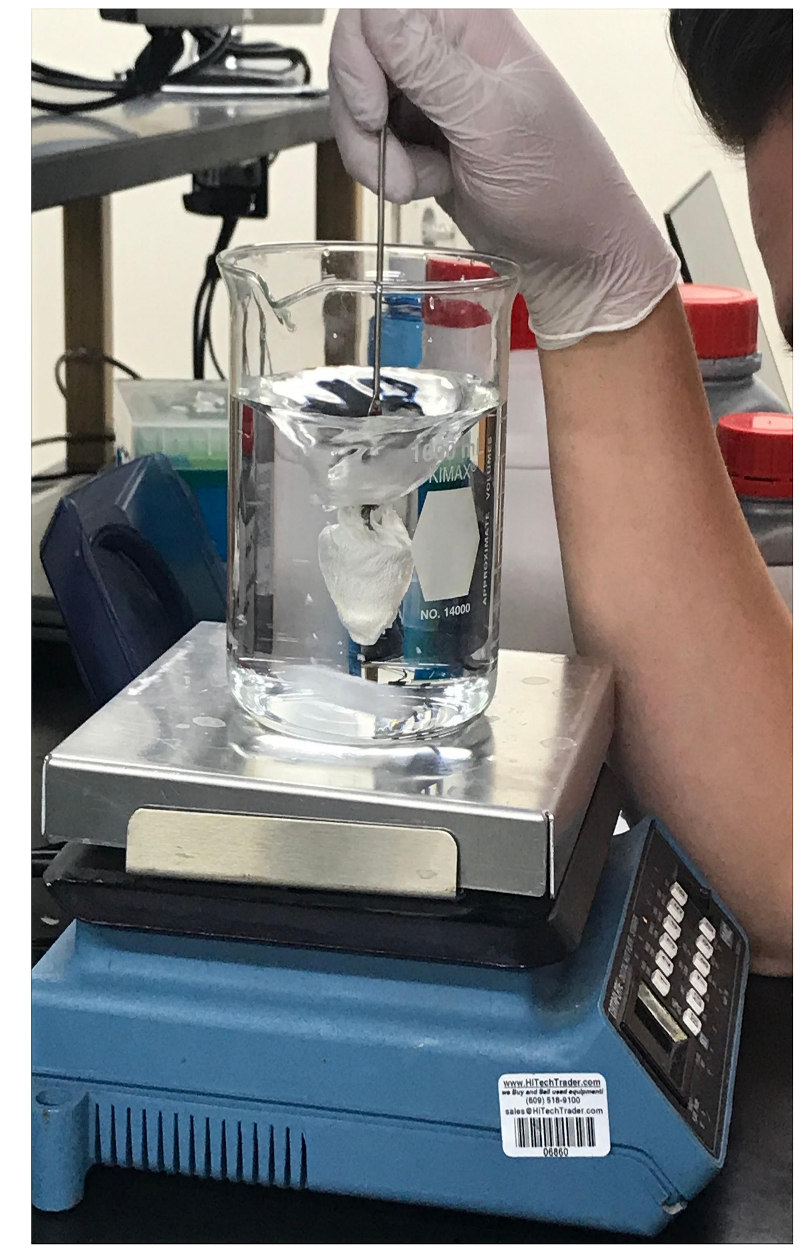

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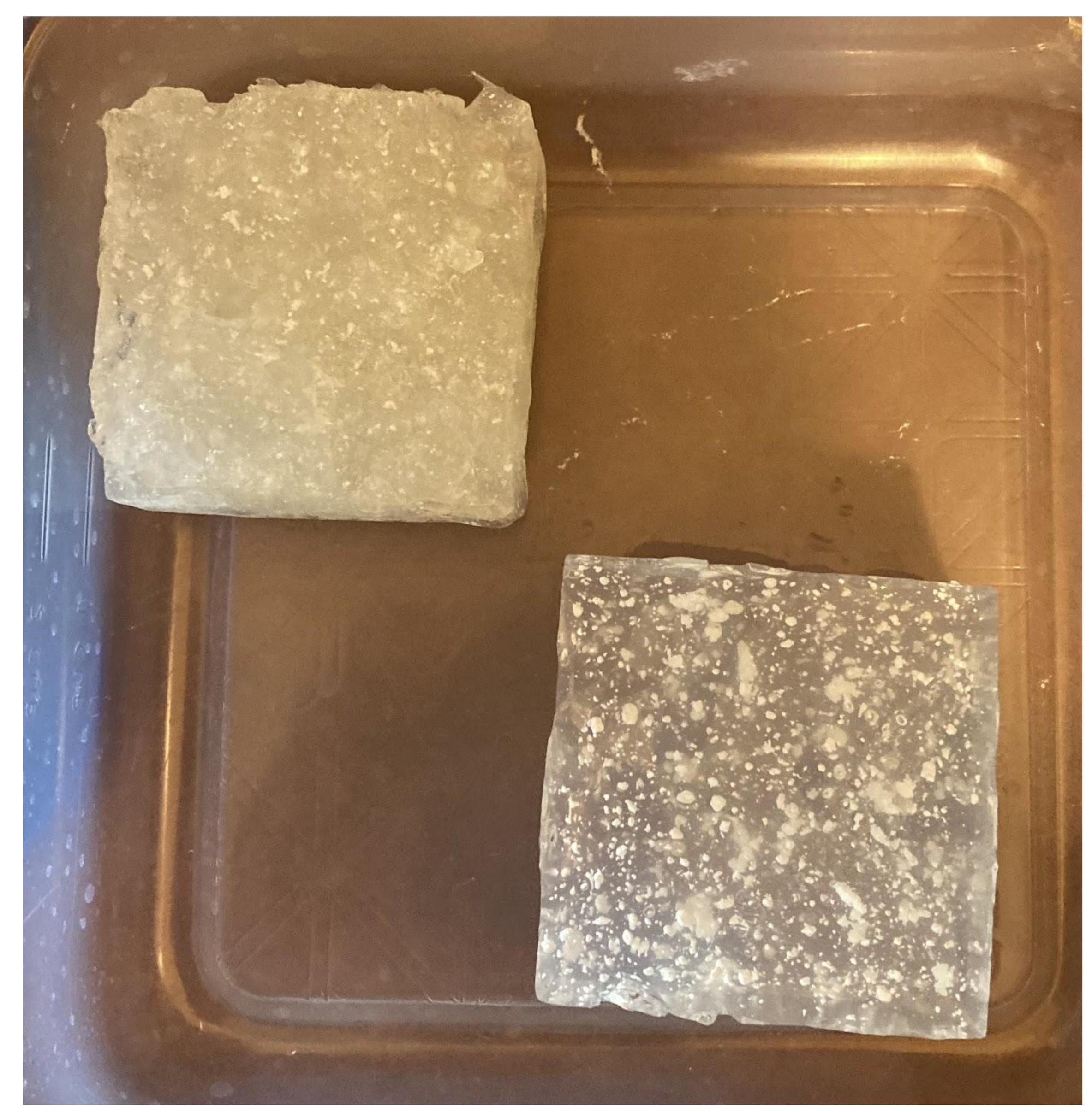

Figure 2.3 Complete gels

Imaging Timeline

- Create a working phantom with “clot” gels of varying stiffness and ensure a difference can be detected
- Successful but discovered noise issues due to wave transfer into phantom
- Need shape that better fits MRI bed

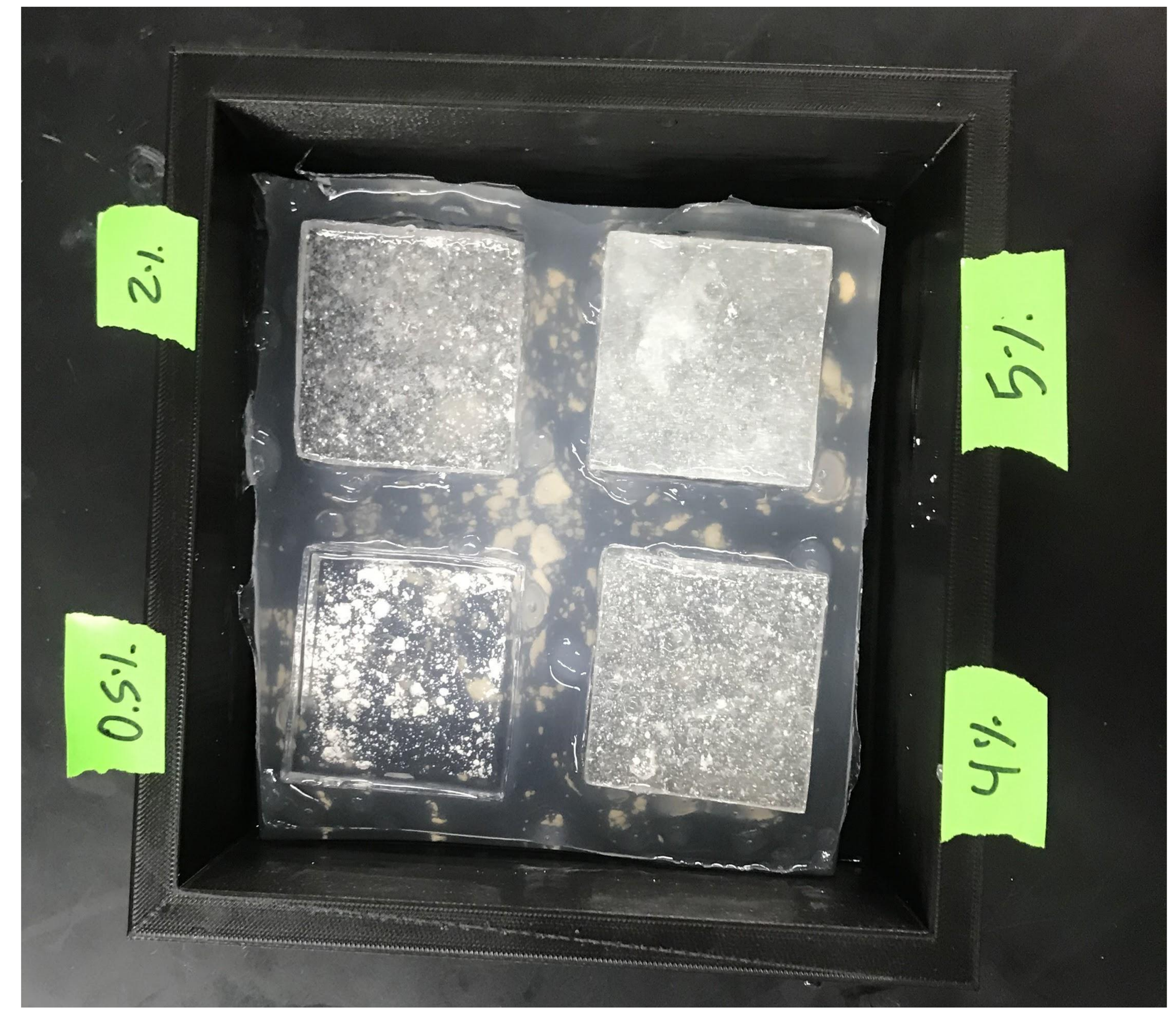

Figure 3.3 Current phantom

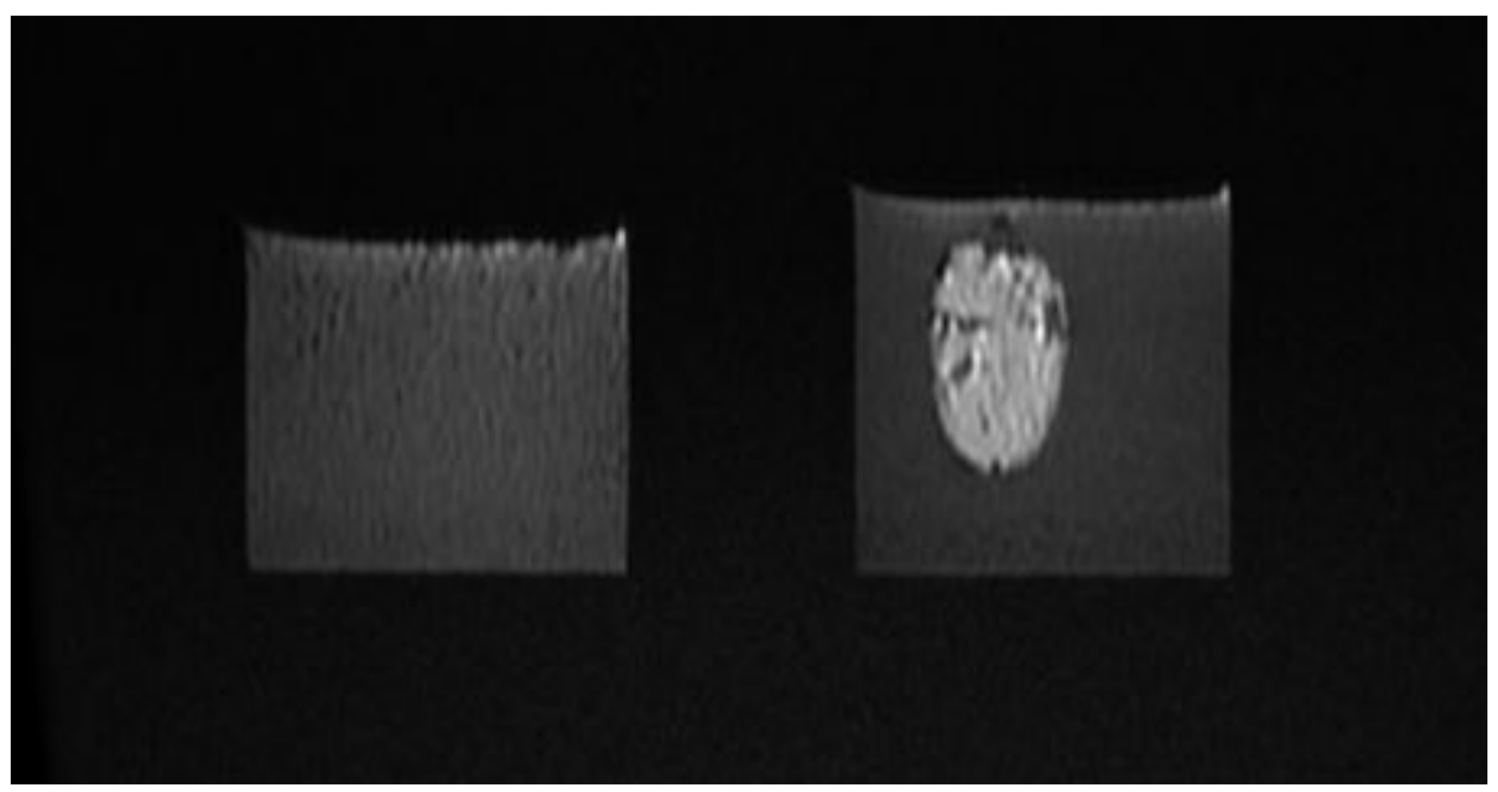

Figure 3.1 T1 Imaging Result

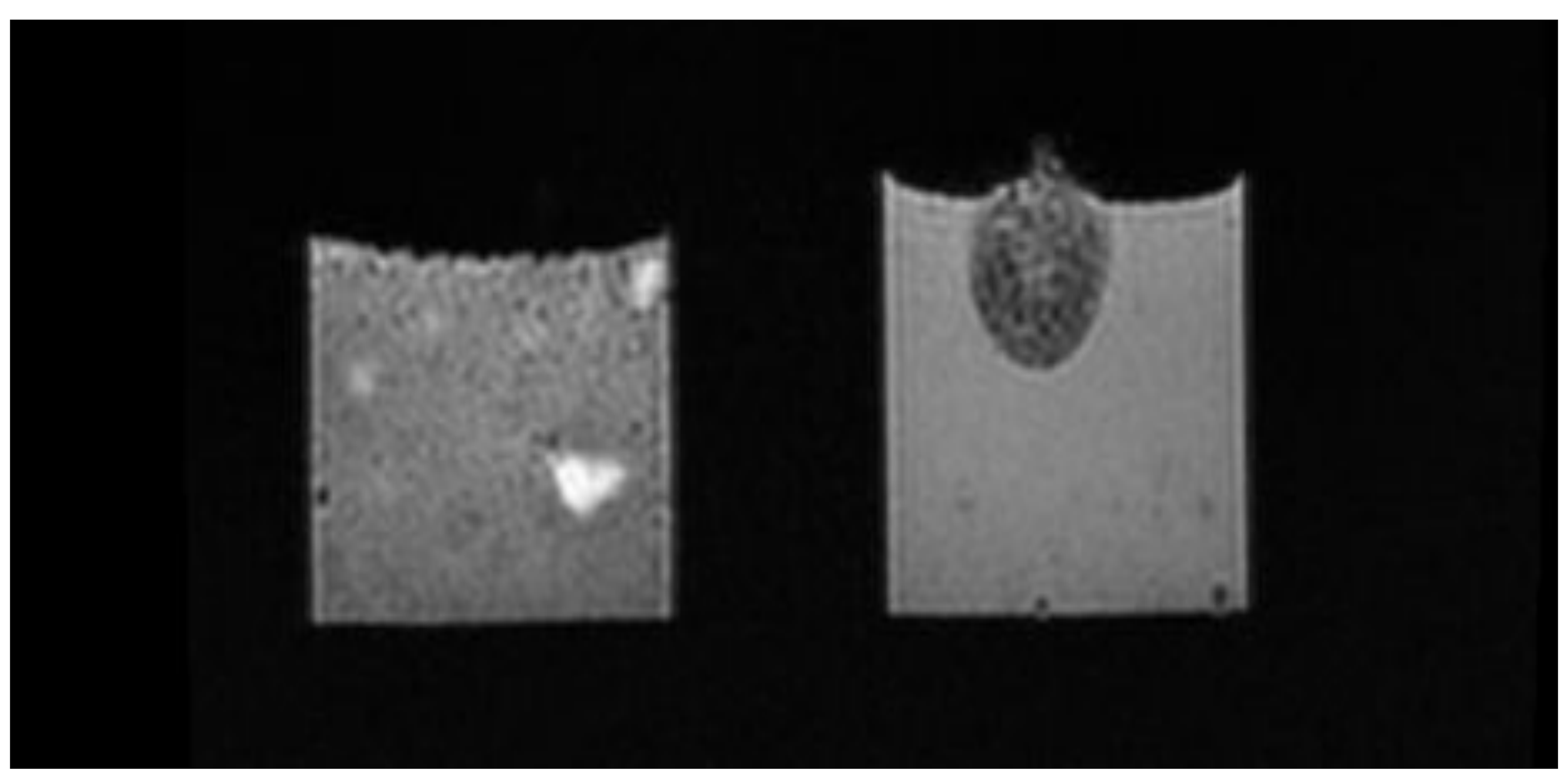

Figure 3.2 T2 Imaging Result

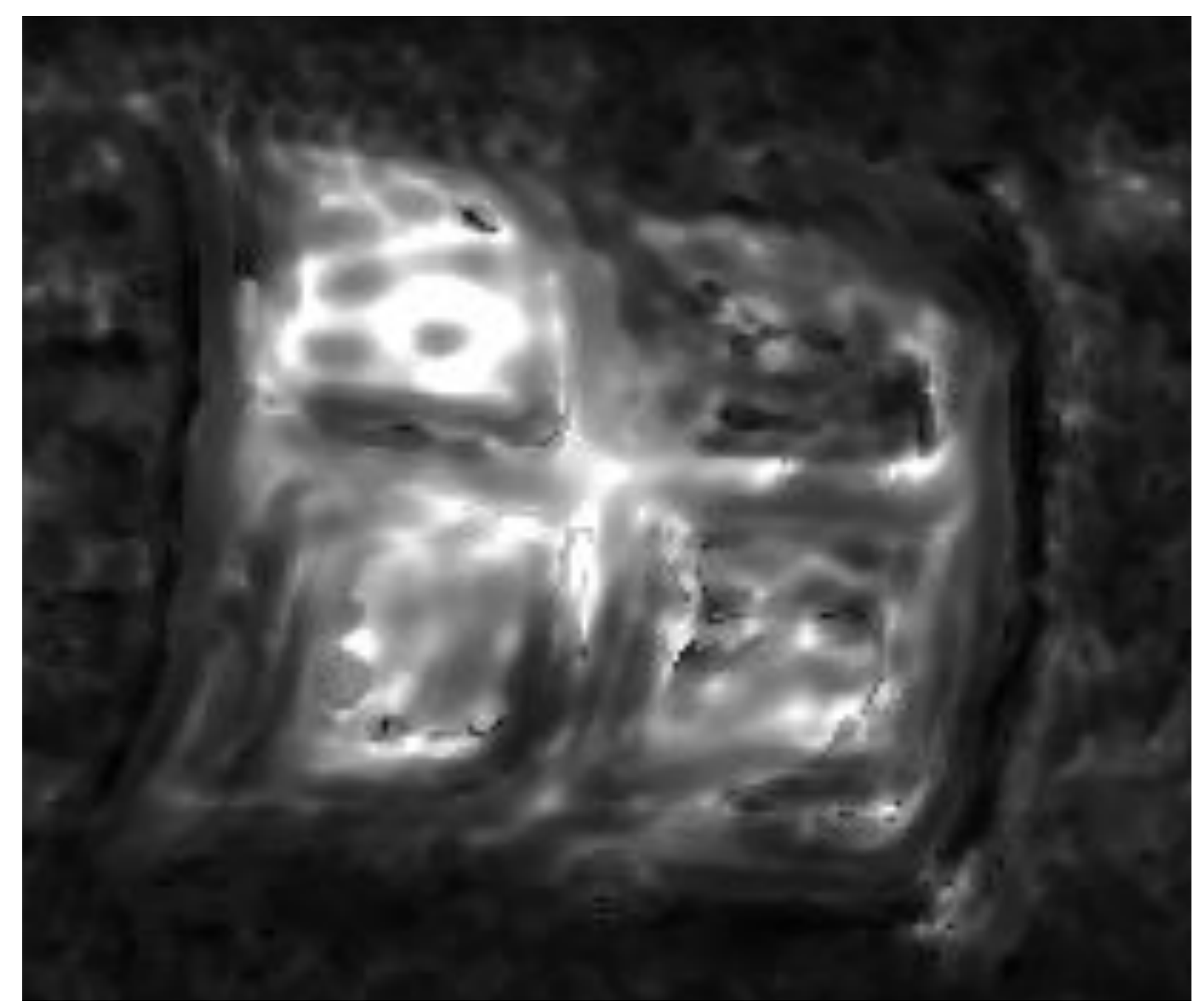

Figure 3.4 Imaged phantom with phase issues

Improved Sample Holder Design

- Design meant to more closely mimic the cranial structure
- Clot gels suspended in layered base gels to avoid gel-air interface
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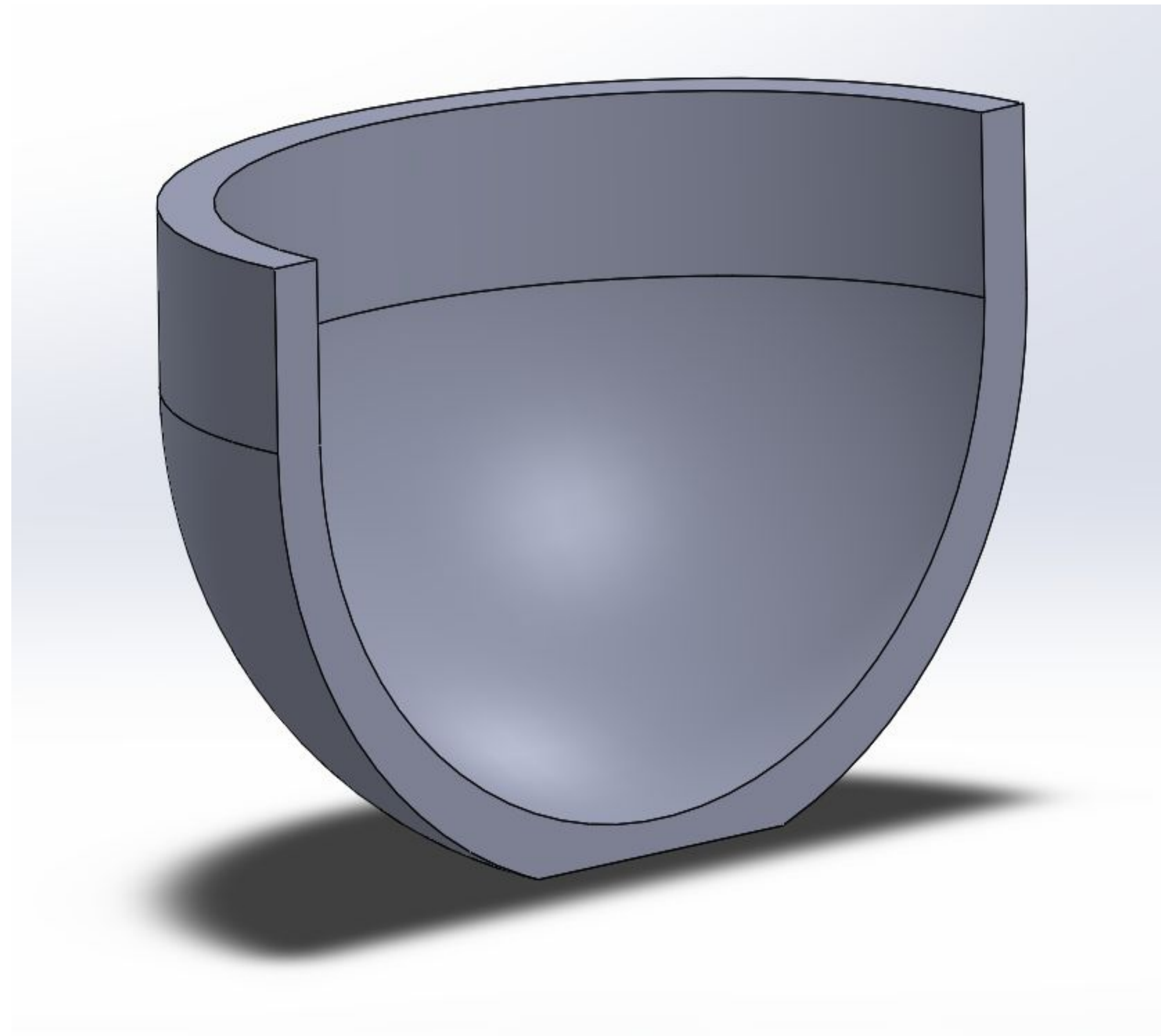

Figure 4.1 Sectional cut of sample holder designed to mimic cranial cavity

Imaging Timeline, cont.

- Make phantom anatomically relevant by including air and fluid pockets to model ear canal, sinuses, CSF
- Increase complexity with many clots, different sizes/shapes/rigidities
- Identify imaging capacity by trying to find smallest detectable size/stiffness differences in clots
- Incorporate numerical values into stiffness imaging

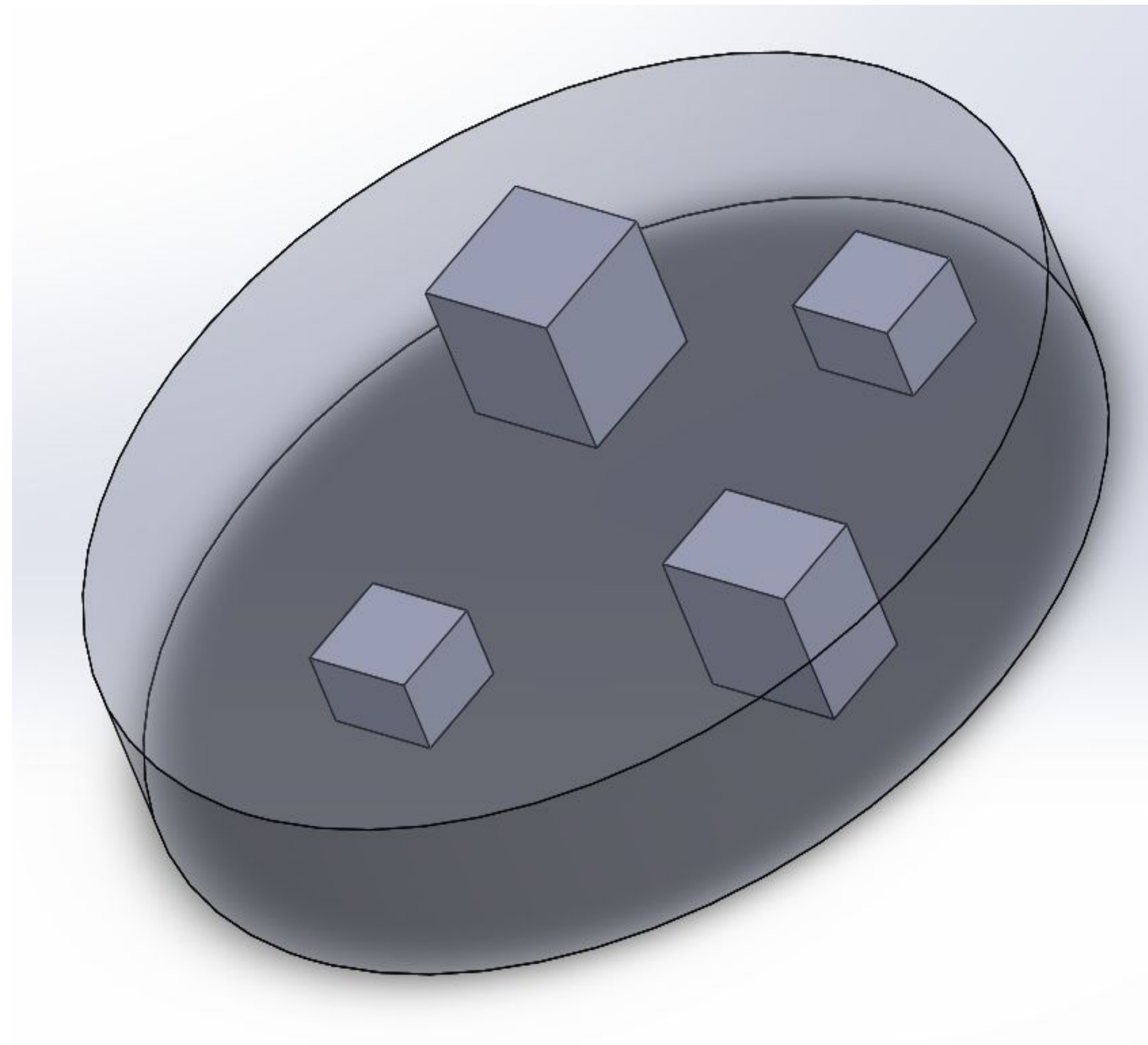

Figure 5.1 Sample holder mocking anatomy, containing different size and stiffness clots

Mechanical Testing Results

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- Running a one-tailed T-test between the Young's Moduli of the two gel types, at .05 significance we get a t value = -3.50
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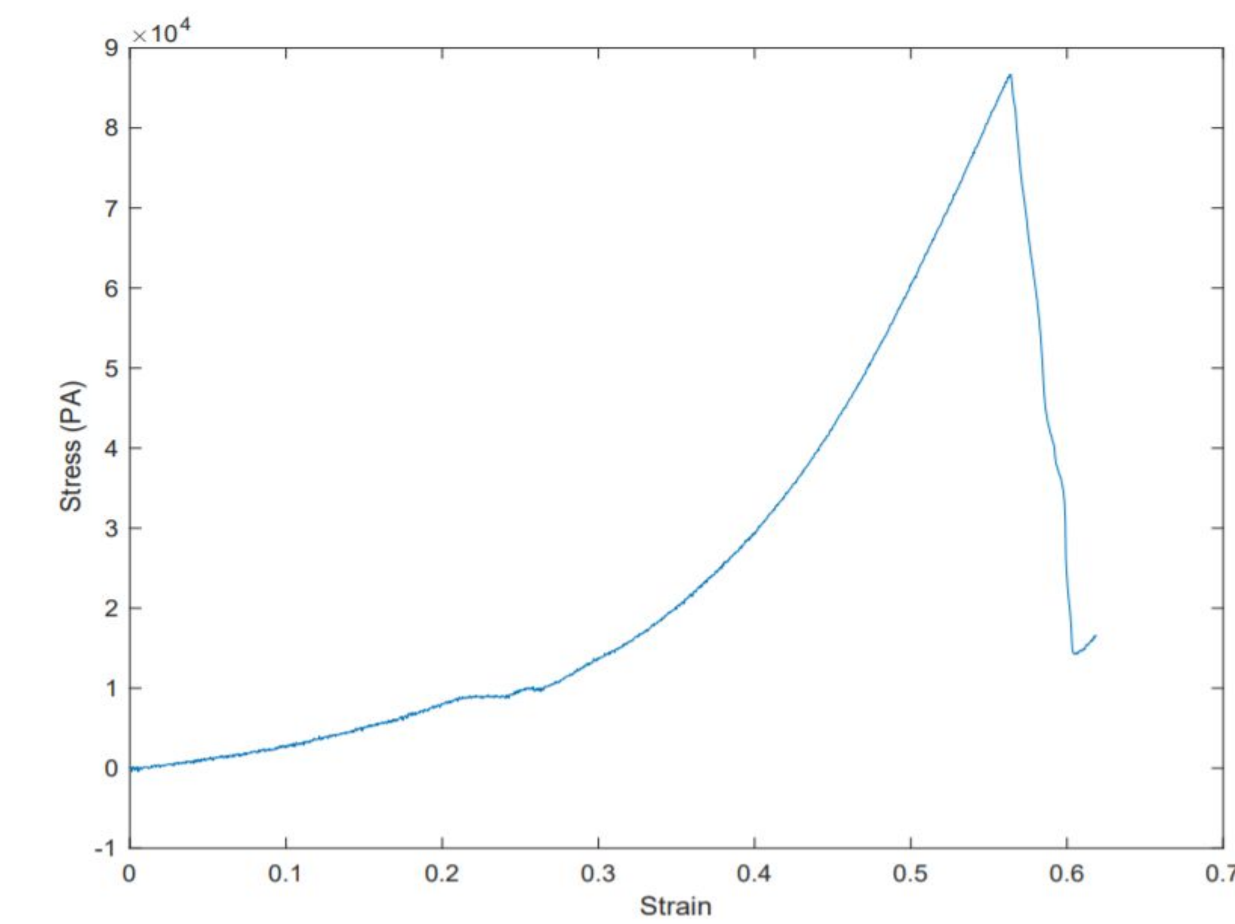
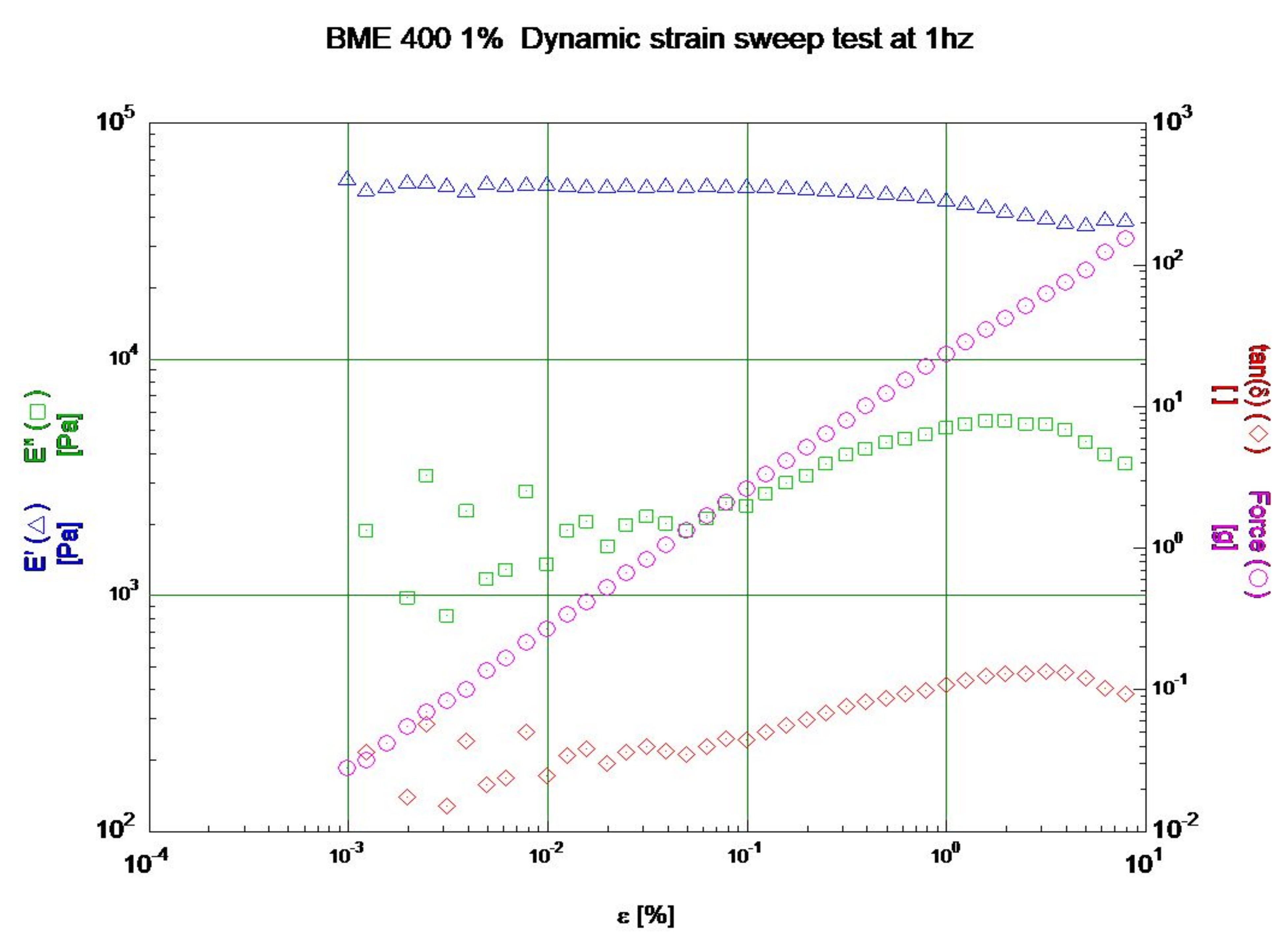


Figure 7.2 Stress vs. Strain results of 1% Alginate Gel. Y-axis = Stress (Mpa), X-axis = Strain



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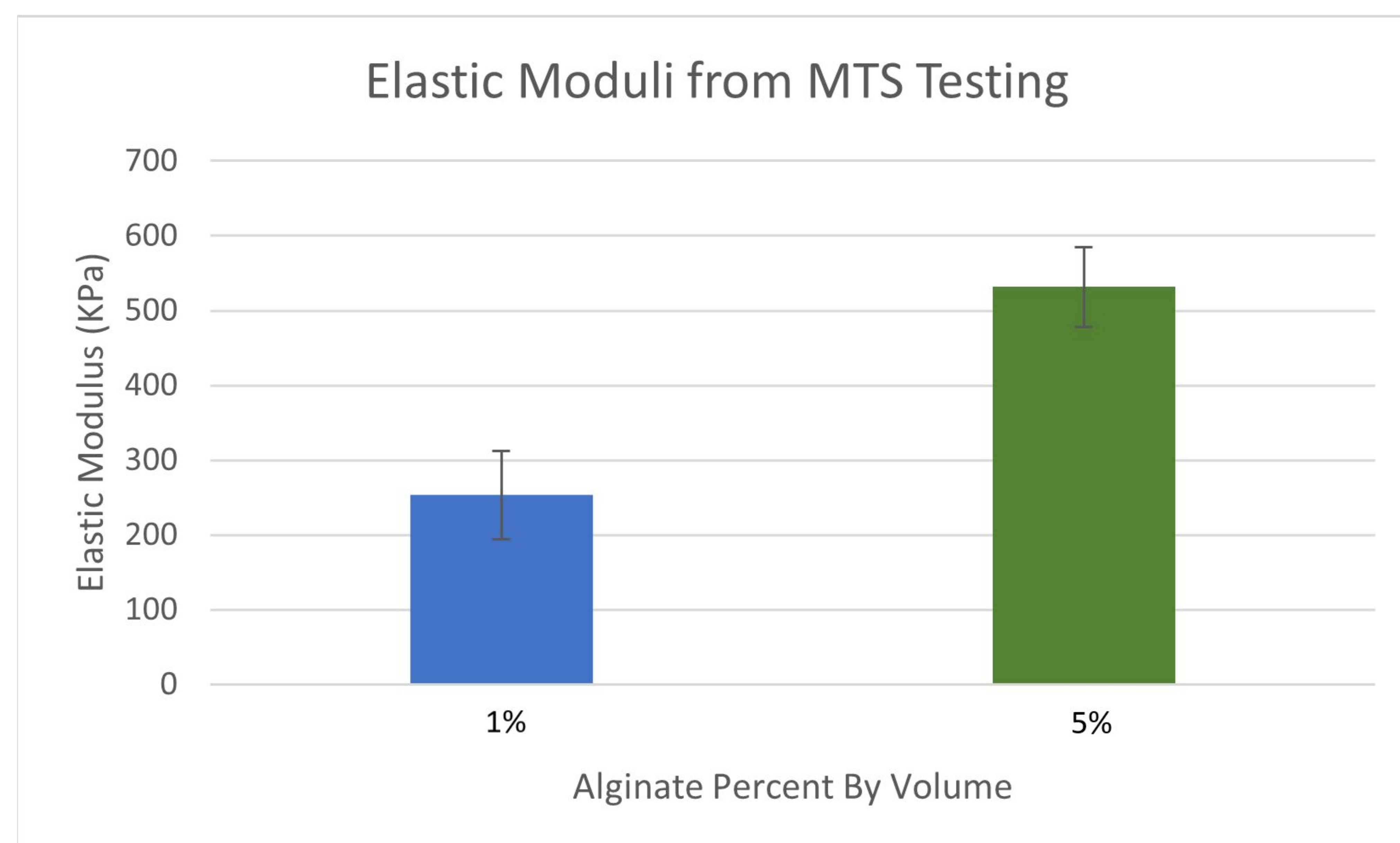
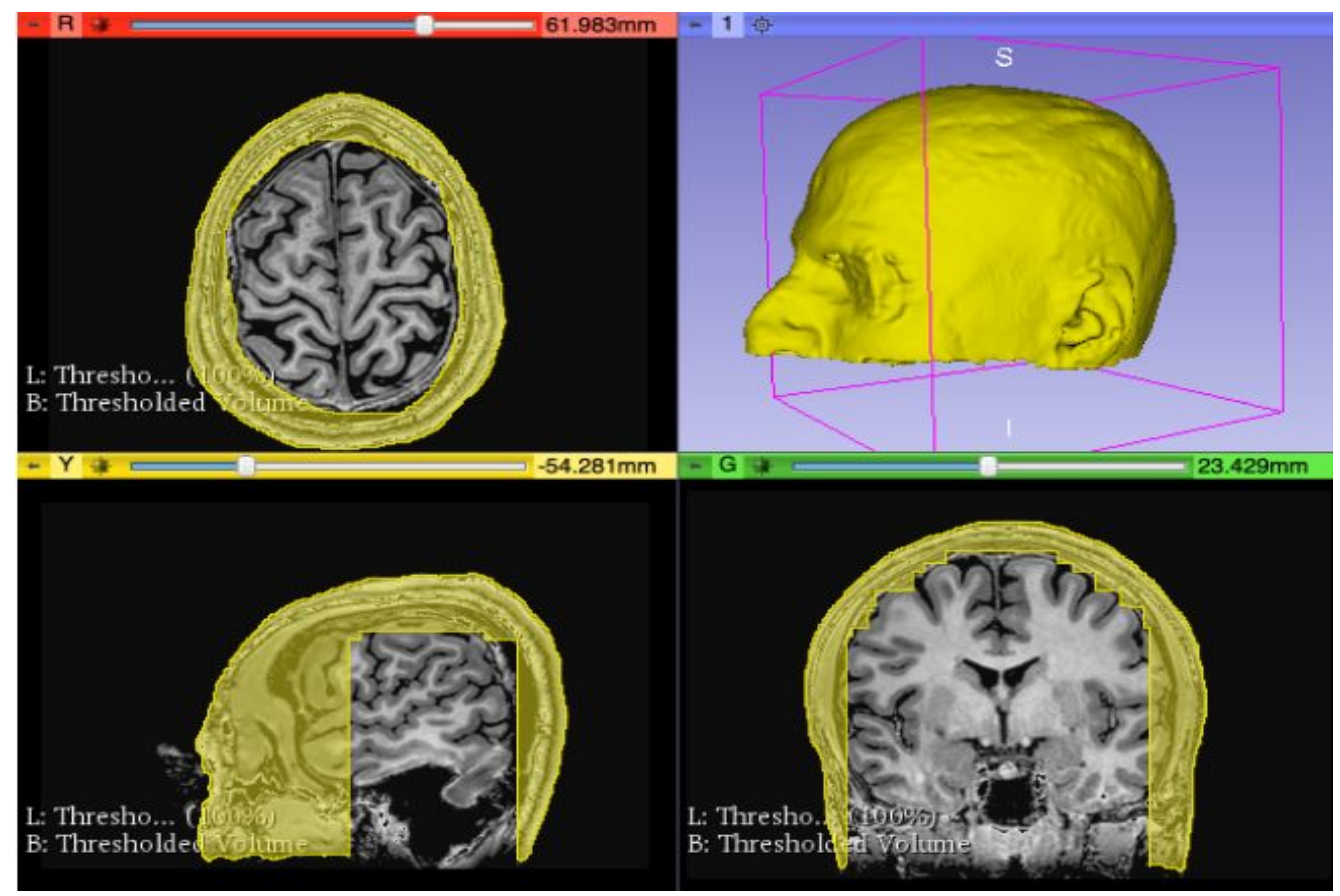


Figure 7.3 Young's Moduli Values Averages for both gel concentrations

Future Project Development

- Integrate clots into anatomical model
- Integrate air and liquid compartments into model
- Fine tune clot accuracy to white and gray matter of brain
- Increase complexity of phantom (different size/shape/amount/rigidity of clots)
- Incorporate mechanical testing values into scans

Figure 8.1 Model of the inner ear canal to be placed into the 3D brain phantom



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Acknowledgements

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- Julie Morasch
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- Dr. Christa Wille
- Dr. Aviad Hai
- Dr. Kristyn Masters
- Robert Moskwa

- **Fall 2020's Team Members**
- Cate Fitzgerald
- Zayn Kayali
- Kristen Schill

- UW-Madison Makerspace
- Dept. of Biomedical Engineering

References

[1] “Figure 2f from: Irimia R, Gottschling M (2016) Taxonomic revision of Rochefortia Sw. (Ehretiaceae, Boraginales). Biodiversity Data Journal 4: e7720. https://doi.org/10.3897/BDJ.4.e7720.”

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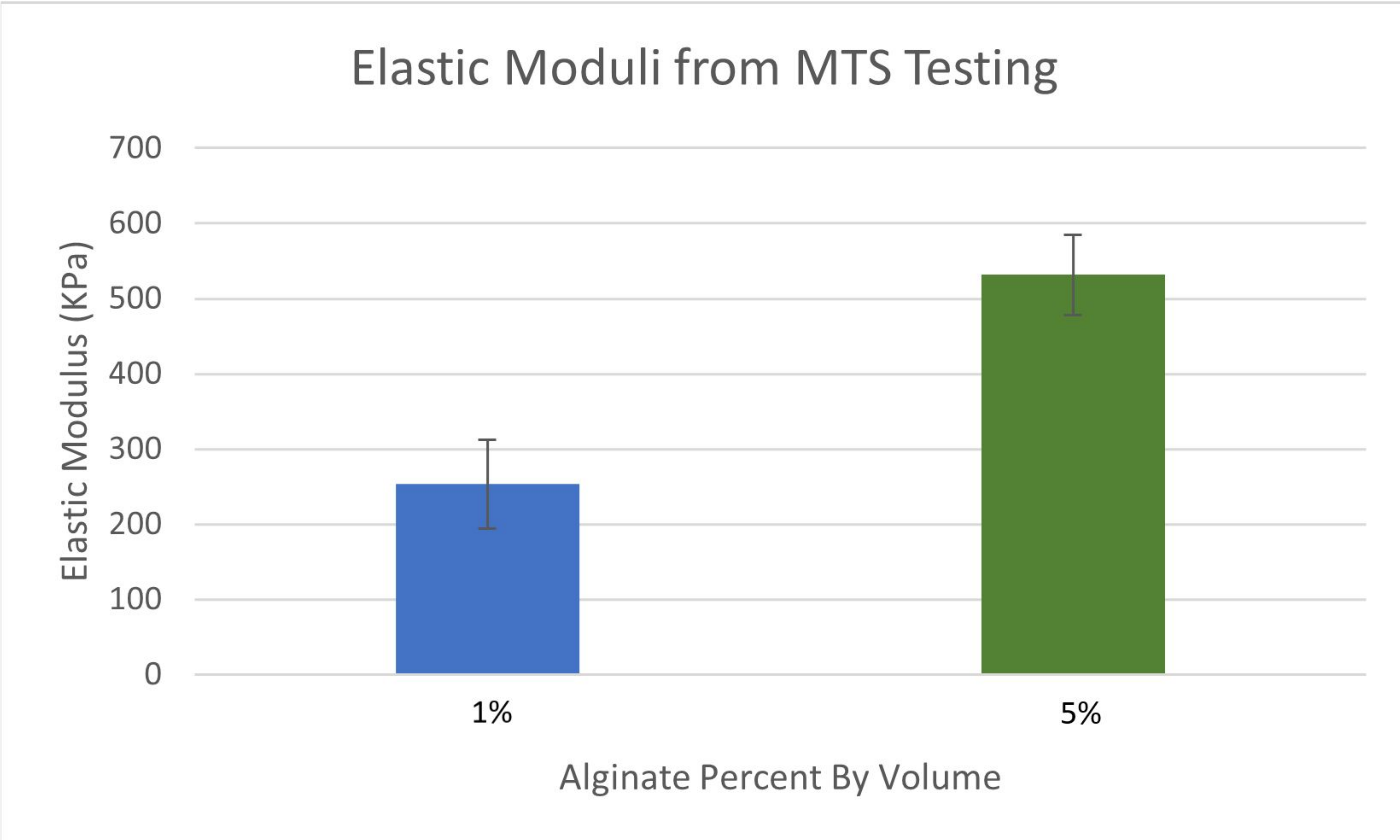

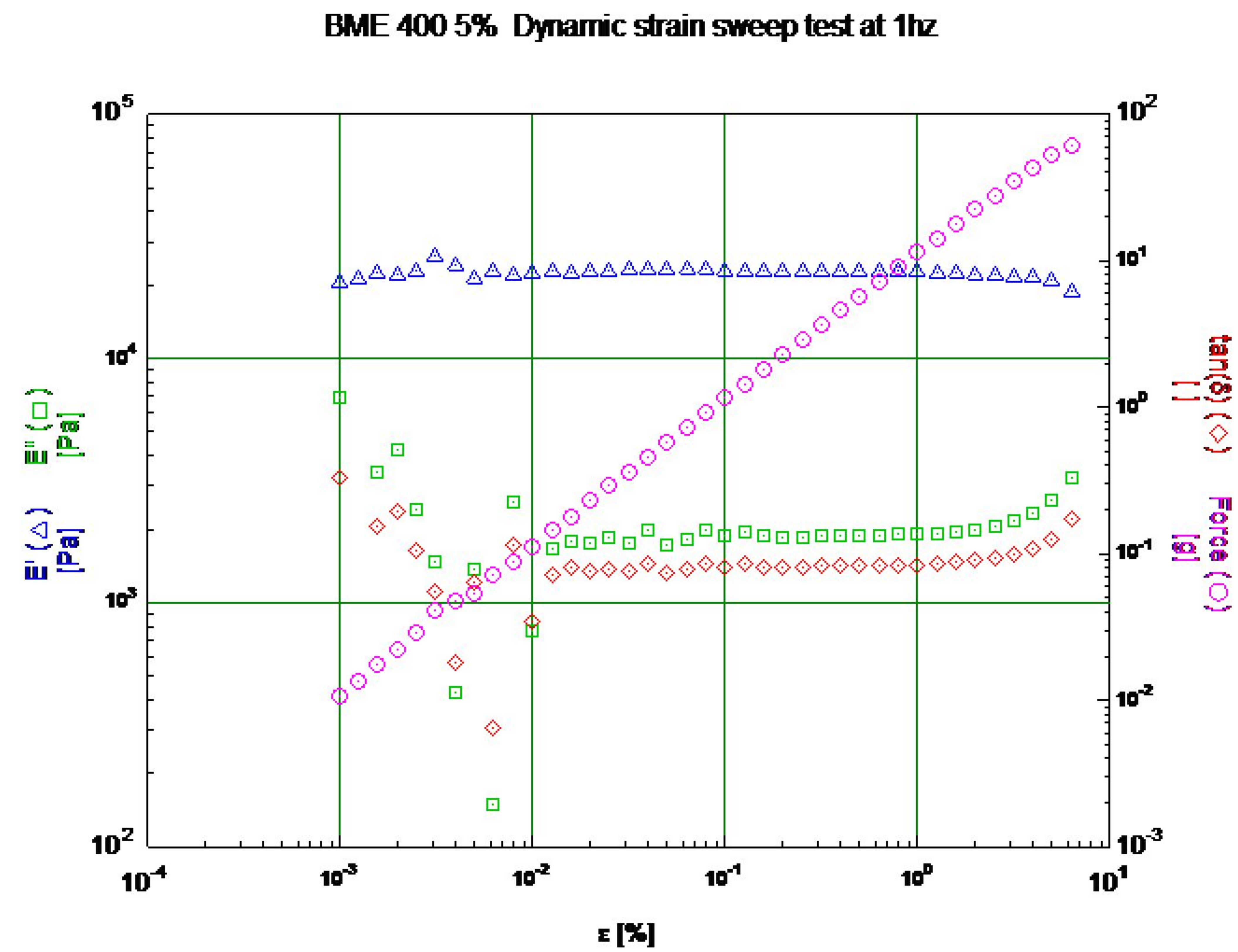

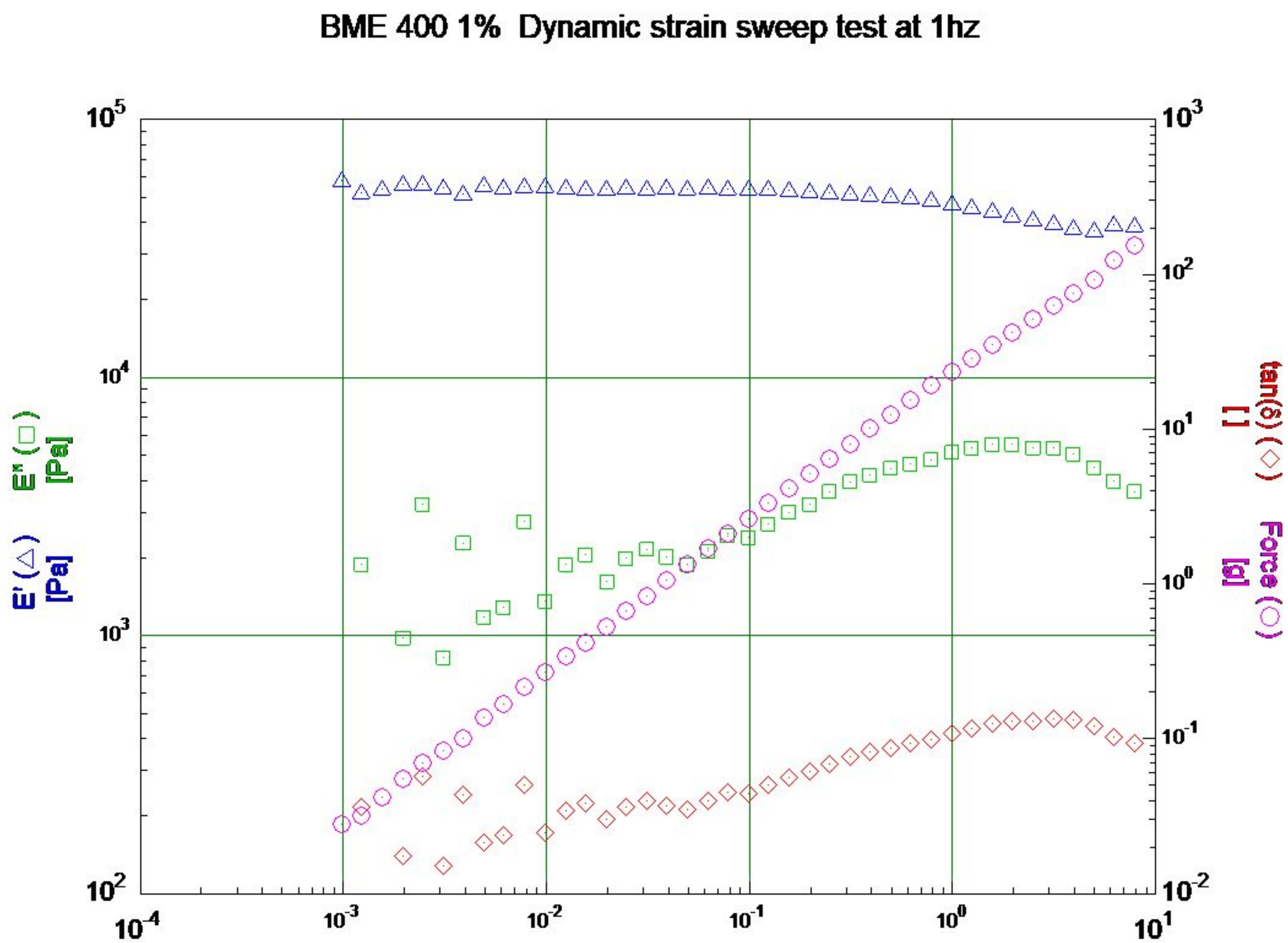

this link has a PDF that explains what storage/loss is really well, look at slide 49 - on if you wanna know

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