



Developing Disordered Metamaterials

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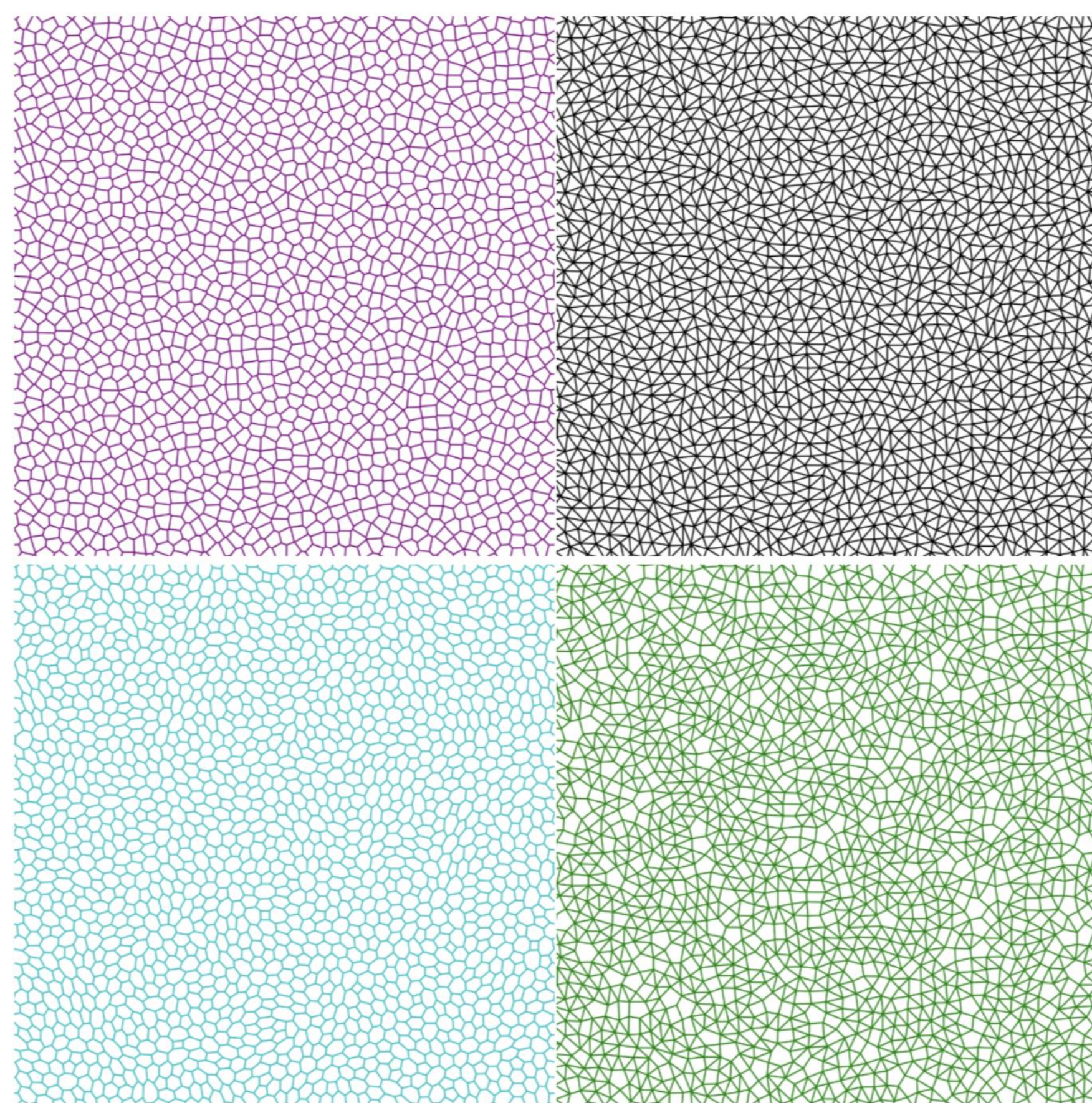
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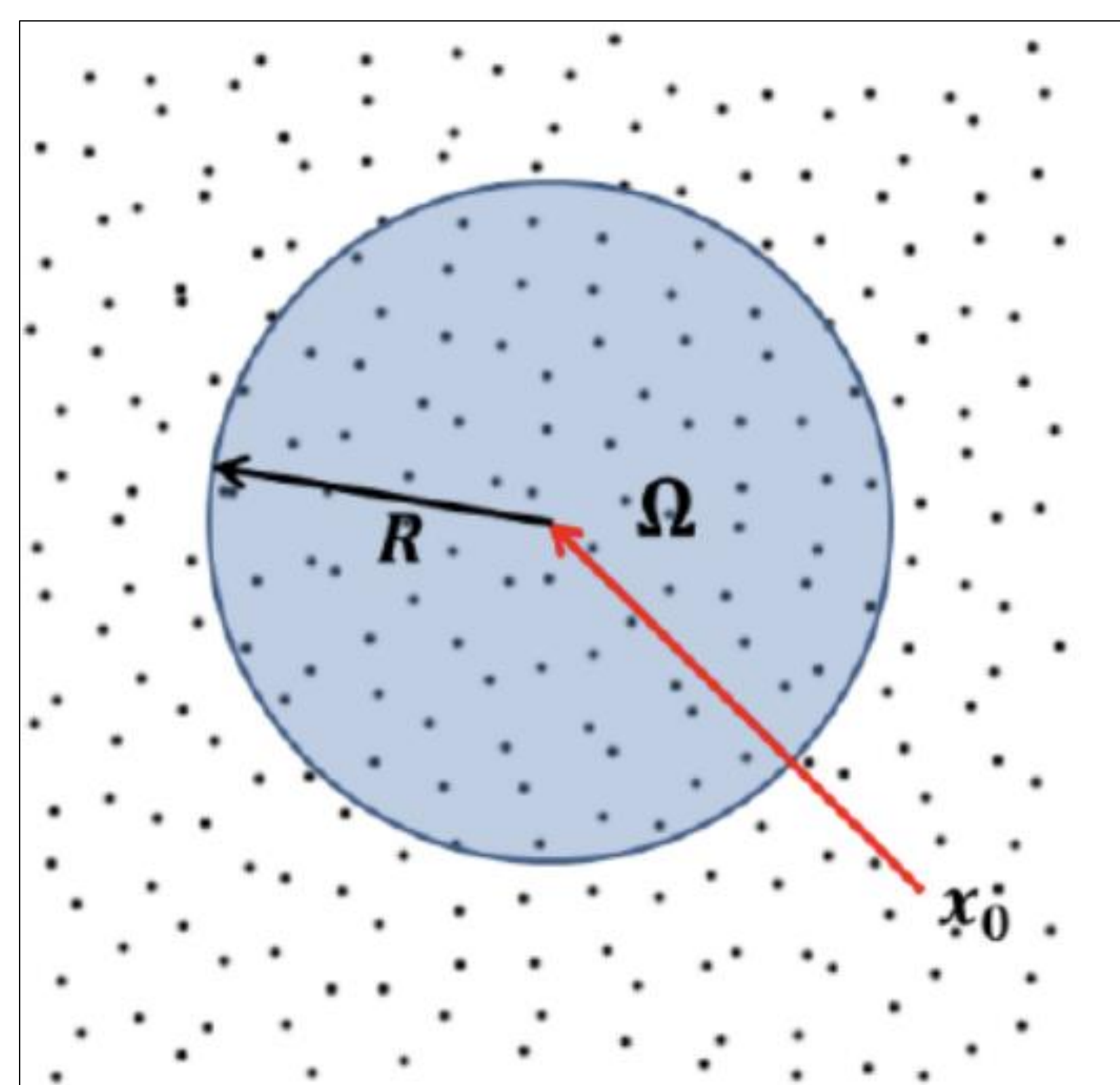
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HYPERUNIFORMITY

- Points that have density fluctuations (disorder) suppressed at larger scales
- Certain tessellations of these point clouds preserve hyperuniformity



a. Voronoi, b. Delaunay, c. Delaunay-centroidal, d. Gabriel
Adapted from Maher & Newhall "Characterizing the Hyperuniformity of Disordered Network Metamaterials"
arXiv:2503.22013v1

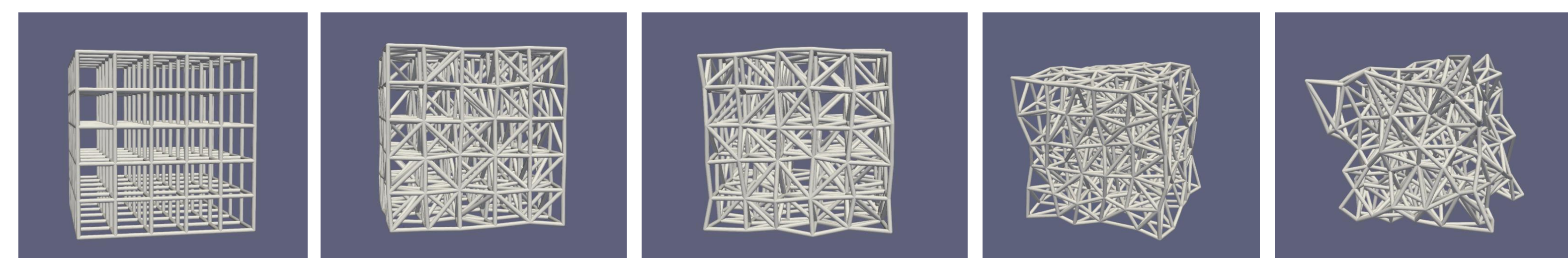


As the window radius varies, so does the density of the points
Adapted from Torquato *Physics Reports* 2018

QUESTIONS

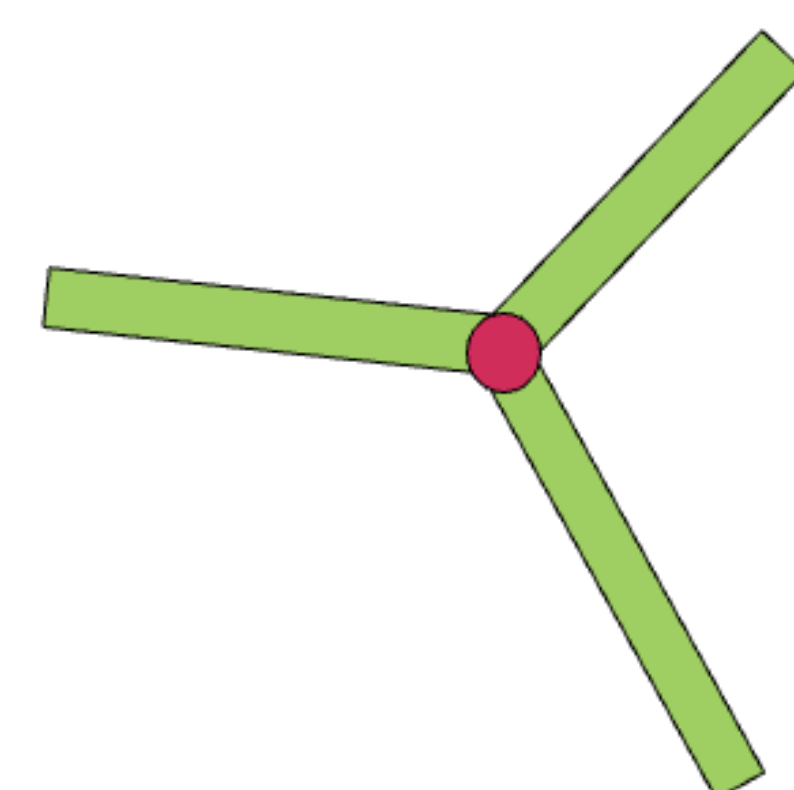
- Can we algorithmically create and then 3D print hyperuniform metamaterials?*
- How does hyperuniformity affect the elastic modulus of a metamaterial?*

ALGORITHMIC DISORDER



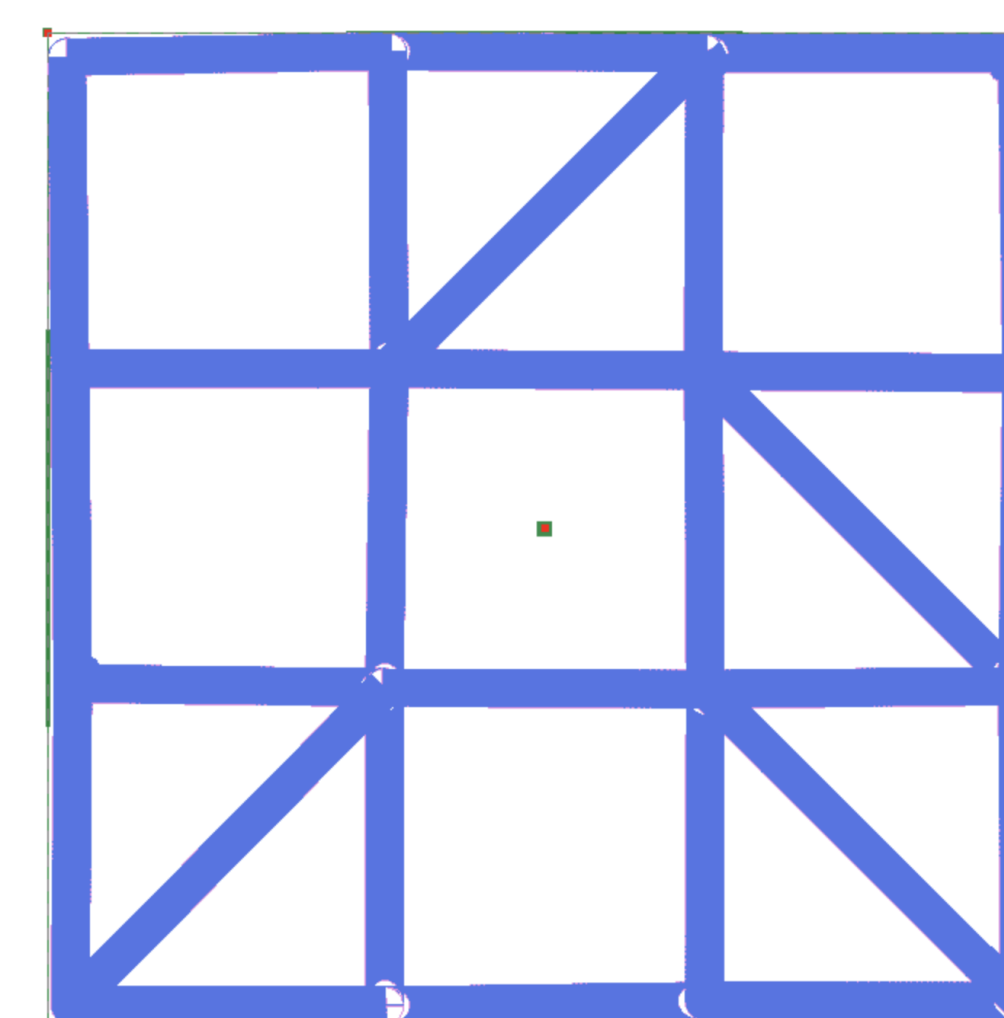
Progression of disorder ("kick factor") in one point cloud, $a=0.0$, $a=0.125$, $a=0.25$, $a=0.5$, $a=1.0$

STL GENERATION



Cylinders and spheres

- However, there were still holes in the small space between the spheres and cylinders.
- The image to the right is from a STL analysis software

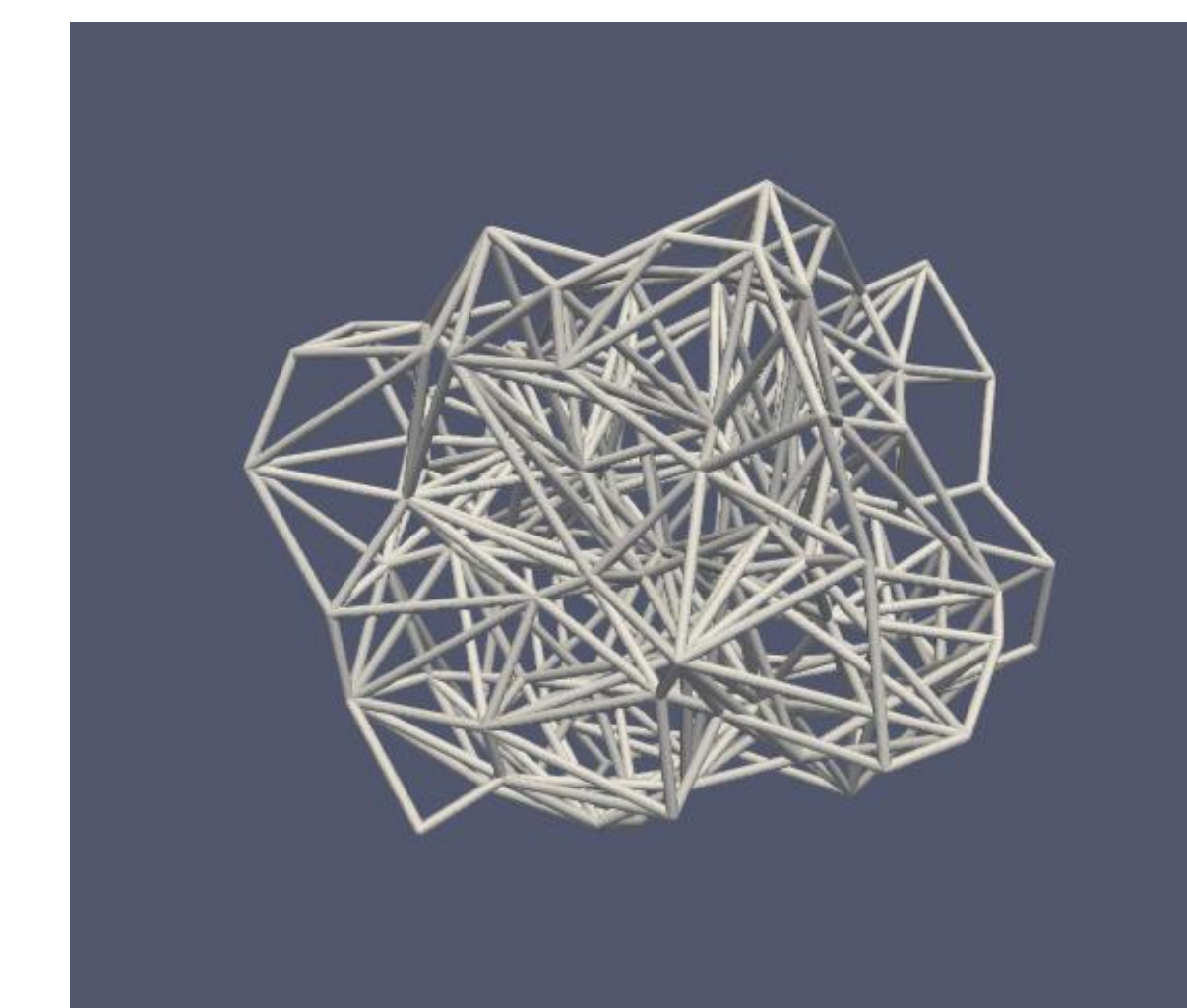


```
# combined_mesh = trimesh.util.concatenate(beams + spheres)
combined_mesh = trimesh.boolean.union( beams + spheres )
```

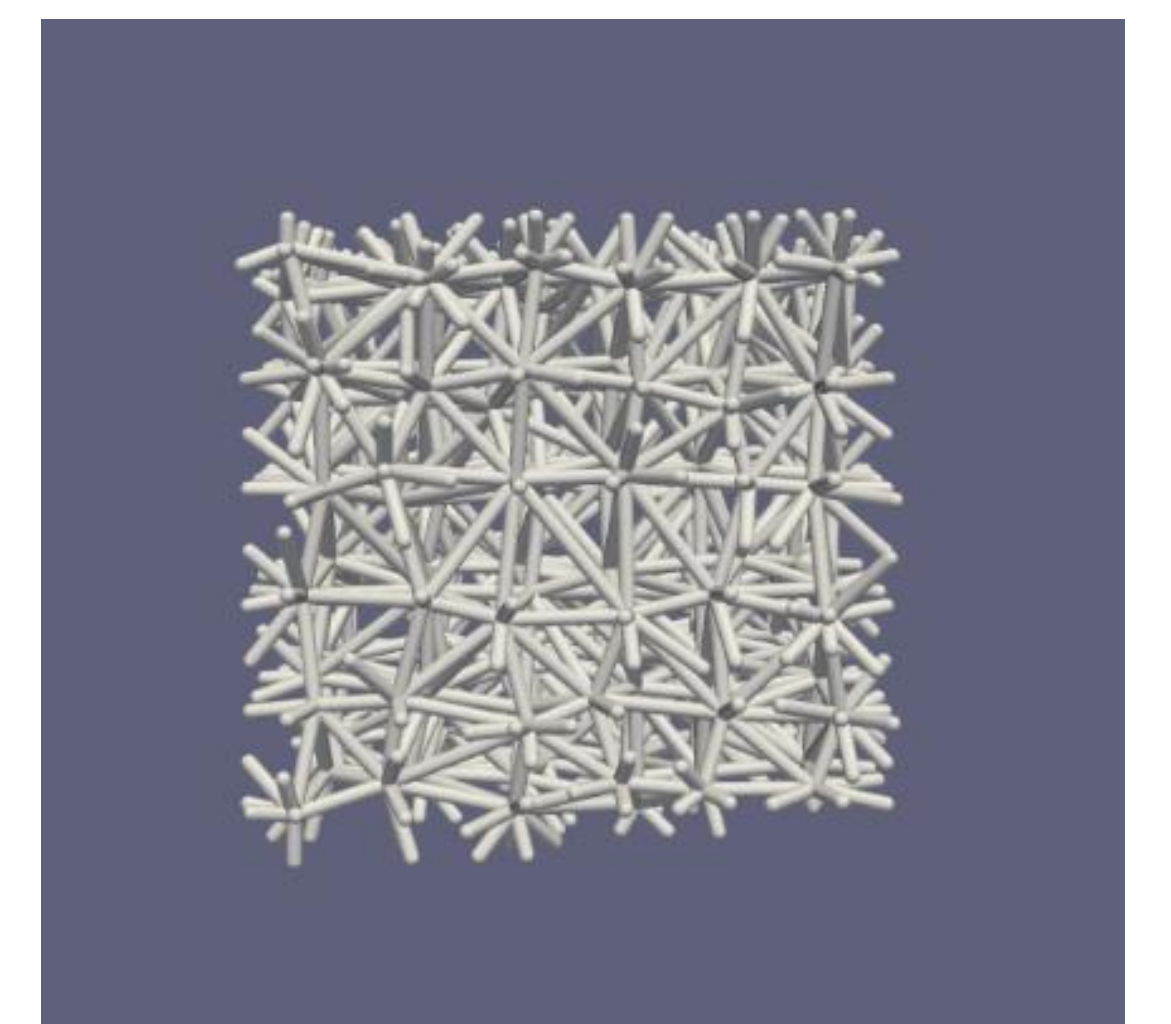
- Fixed by calling the union command on the cylinders and spheres rather than the concatenate command.

INSTRON TESTING

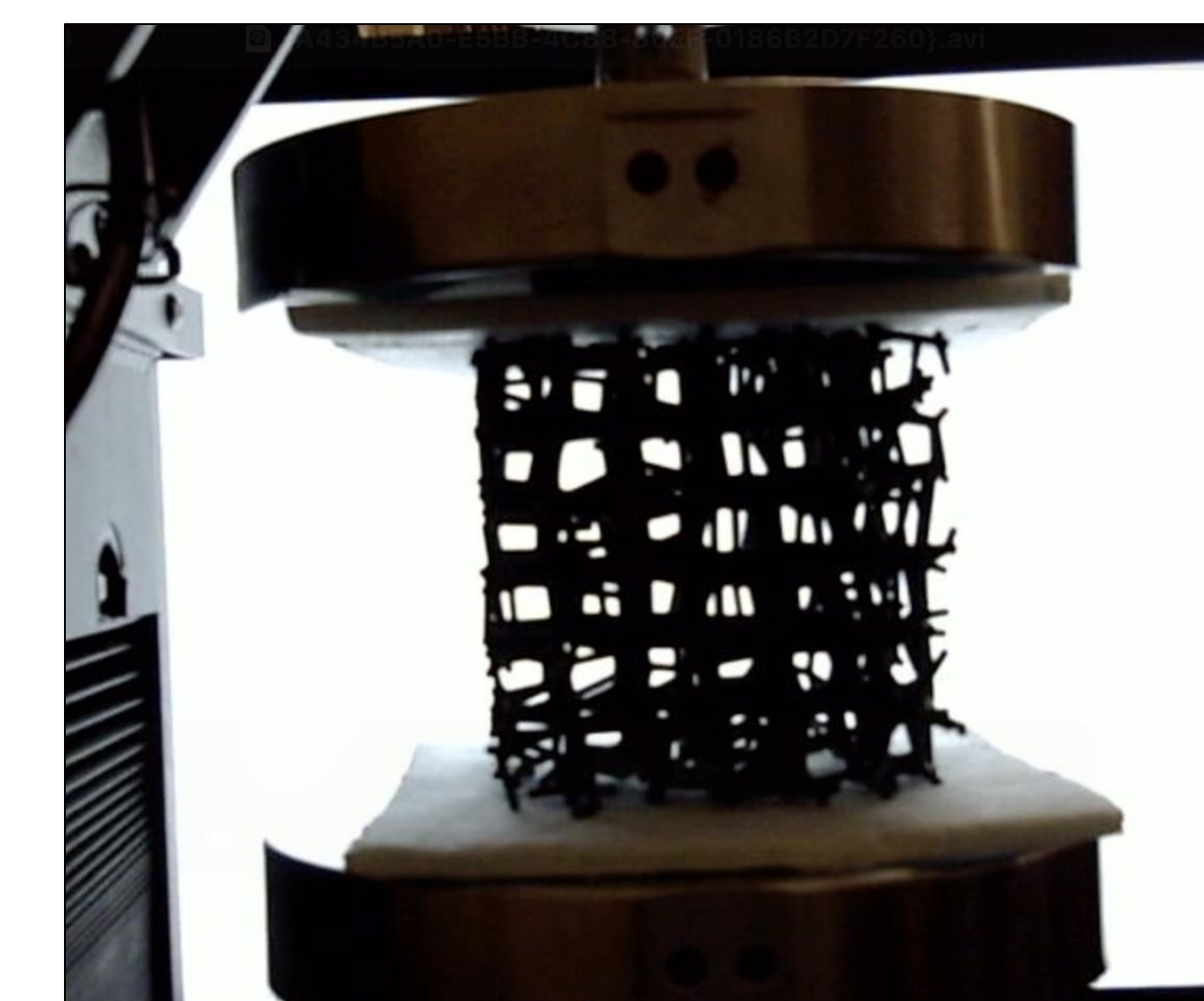
- Cyclical compression tests were designed for the Instron machine to find metamaterial stiffness



PROBLEM: Unstable on Instron



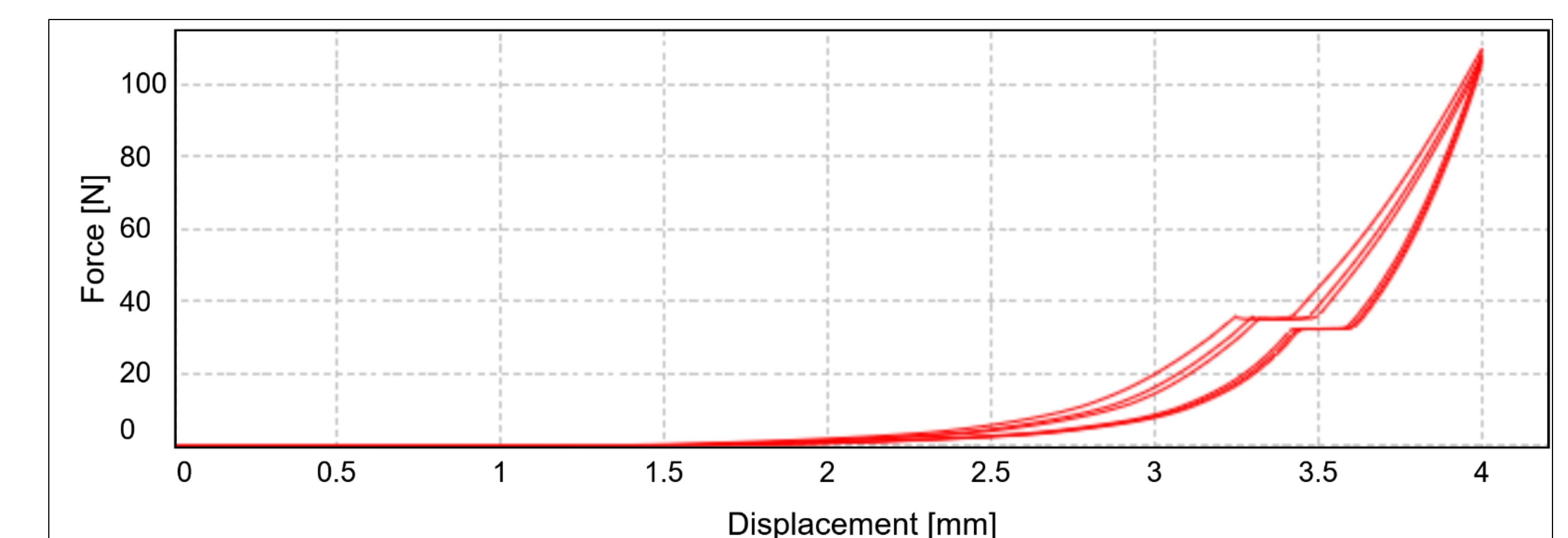
SOLUTION: Clip samples between nodes



Foam was used to make sure the twig-like edges didn't break



Instron set up



FIRST ROUND OF TESTS — Raw Instron data from a sample being compressed. The flat part shows the foam setting in. It has been repeatedly shown to set in at 30N. Only the data past the flat part will be fitted using the model below.

$$\sigma = M \varepsilon^{\beta}$$

$\sigma = \text{stress}, M = \text{stiffness}, \varepsilon = \text{strain}$