# 3D Mesostructures Formed by Mechanical Buckling

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## Introduction

Professor Hangbo Zhao Lab:

**Mechanical Buckling**

The sudden change in shape (deformation) of a structural component due to compressive stresses in certain regions

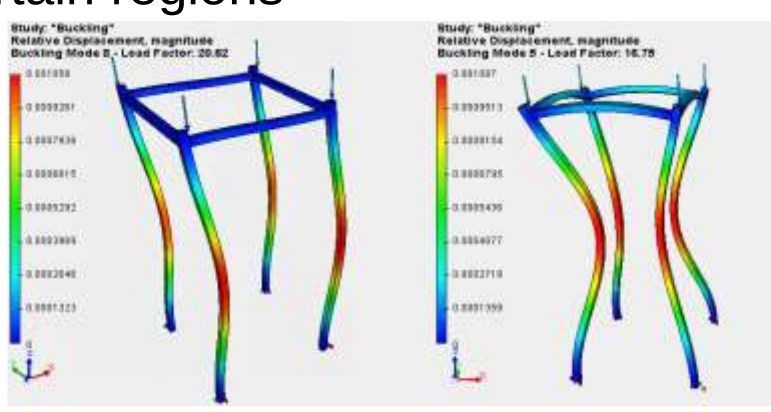

*Figure 1. A structure under a load exhibiting the characteristic deformation of buckling PC: AutoFEM Analysis*

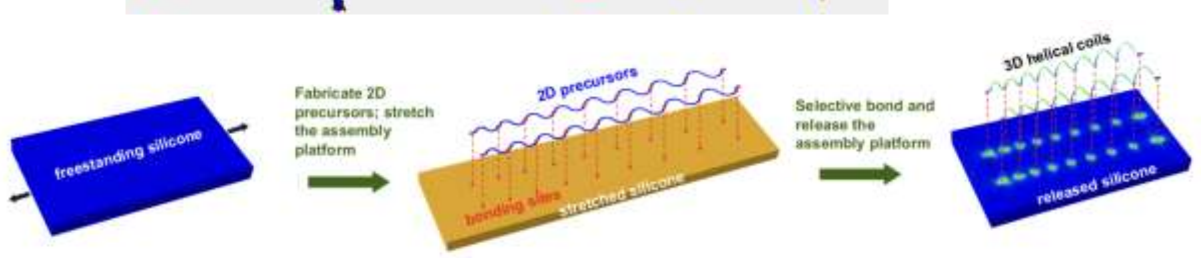


*Figure 2. Schematic illustration of the mechanical buckling process to form 3D structures Reference: Science, 347.6218 (2015): 154-159.*

3D micro/meso structures perform many important functions; they are key components in interfaces, sensors, actuators, and medical devices. Mechanically guided 3D assembly approaches based on controlled structure buckling provides a promising route to producing complex, functional 3D structures and devices.

**Finite Element Analysis (FEA)**

Using numeric methods to predict how a structure will behave under certain conditions (weak spots, areas of tension, etc.)

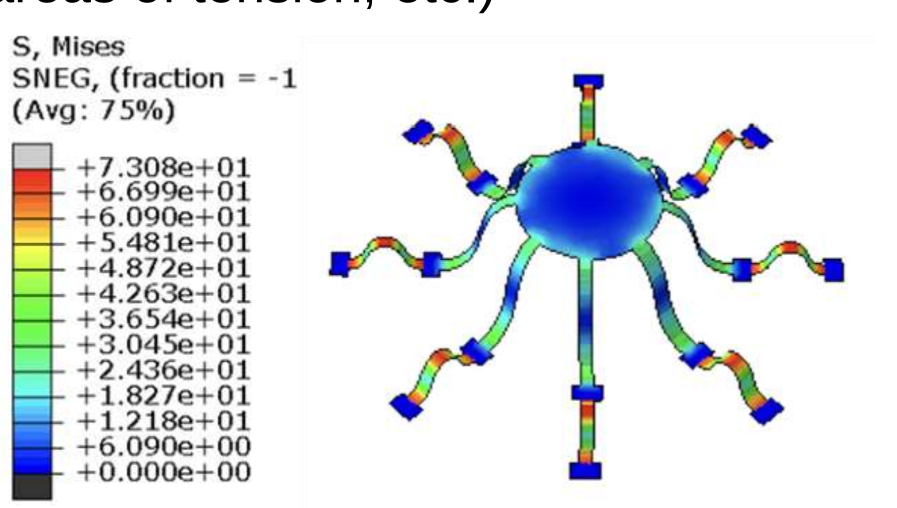


*Figure 3. FEA of stress distribution of a 3D structure formed by mechanical buckling. Different colors correspond to different levels of stress generated in buckling process. PC: Amanda Zhu*

**Research Goals**

- Design, simulate, and fabricate a 3D structure formed by mechanical buckling
- Study the deformation behaviors of the designed 3D structure under load using FEA

## Concepts Learned

- Stress
- Strain
- Displacement/deformation, fracture
- Young's Modulus (Modulus of Elasticity)
- Poisson's Ratio
- Simple Beam Theory
- Force analysis
- 3D network structures in biology
  - Bone structure
  - Neural circuit
  - Vascular system
- Formation of 3D structures by mechanical buckling
- AutoCAD
- Abaqus
  - Simulation of 3D buckling
  - Simulation of structure deformation under load

## Results

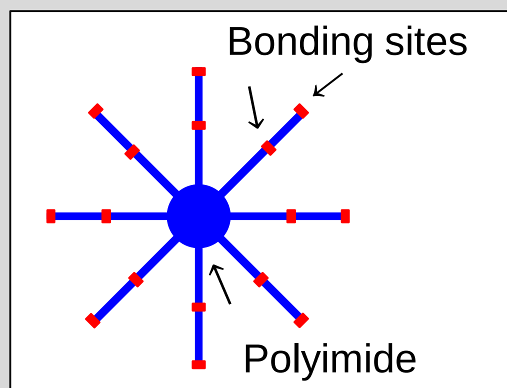


*Figure 4. Polyimide and bonding sites on 2D precursor PC: Amanda Zhu*

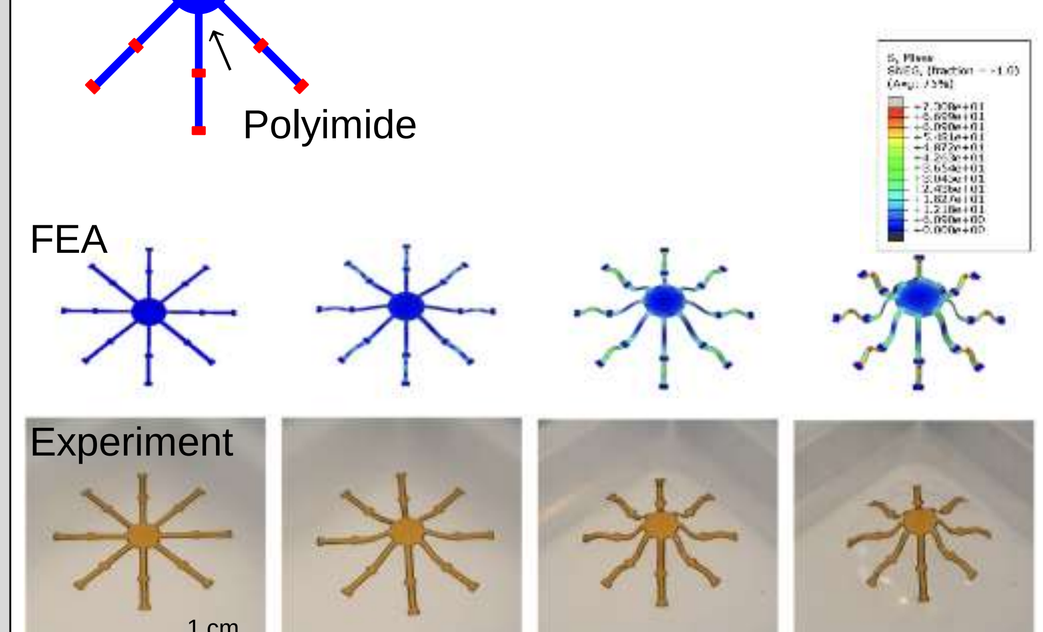


*Figure 5. Comparison between simulation and experiment during buckling process PC: Amanda Zhu*

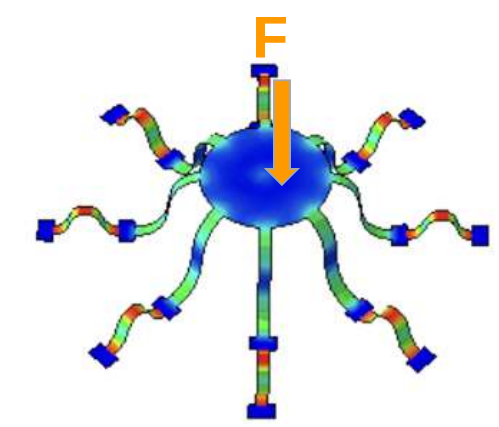


*Figure 6. 3D structure deforming under load. The deformation under load is a function of the structure and material properties. PC: Amanda Zhu*

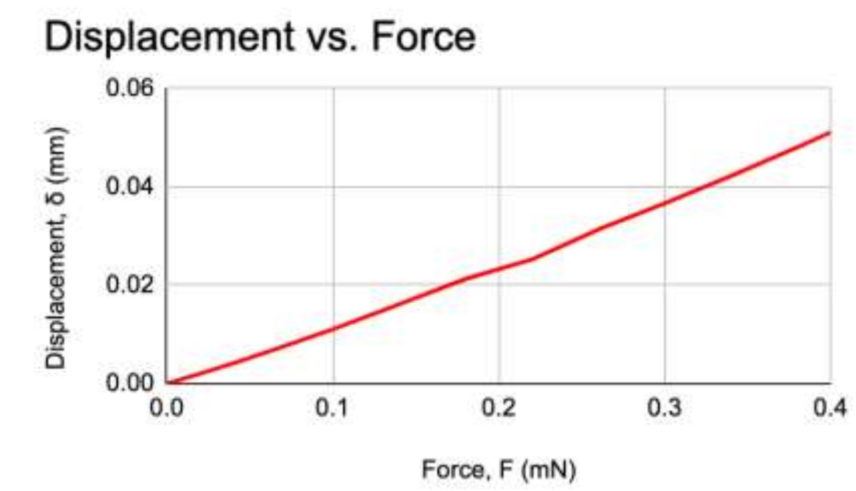


*Figure 7. Displacement plotted against various amounts of applied force PC: Amanda Zhu*

Approximate positive linear correlation between applied force and displacement.

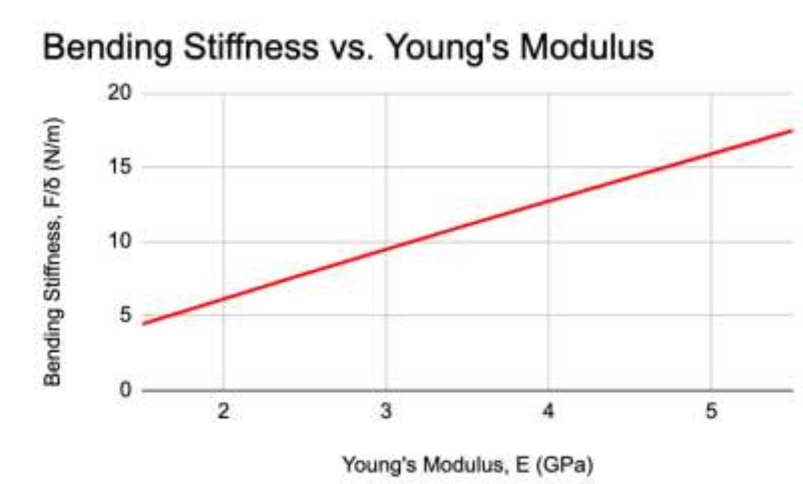


*Figure 8. Bending stiffness plotted against various Young's Modulus values PC: Amanda Zhu*

Positive linear correlation between Young's Modulus and bending stiffness.

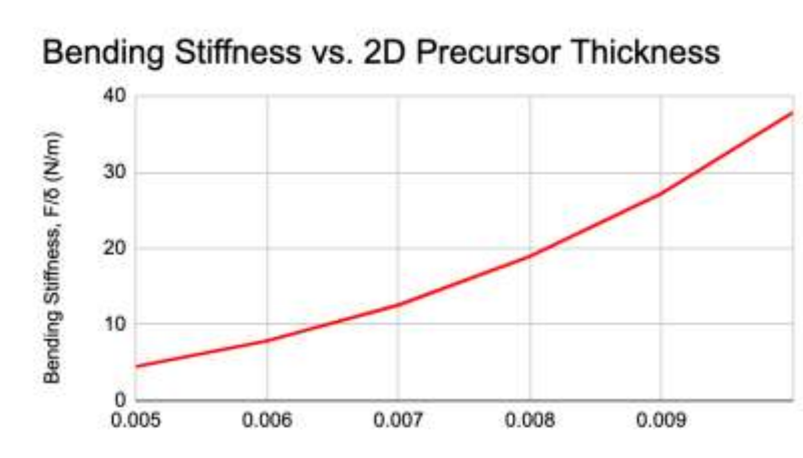


*Figure 9. Bending stiffness plotted against various 2D precursor thicknesses PC: Amanda Zhu*

Positive cubic correlation between 2D precursor thickness and bending stiffness.

## My STEM Coursework

SHINE has provided me with a deeper understanding and applications of the concepts I learned in AP Physics 1. It was also interesting to learn how mechanical engineering can be applied to different fields of study. This knowledge will prepare me for the material taught in AP Physics C as well as engineering courses in my later years of high school and college.

## Next Steps For Me

The SHINE experience has increased my interest in engineering, and I now plan on pursuing an engineering major in college. I will build upon my SHINE research by joining a mechanical engineering lab or pursuing an engineering internship during my undergraduate years.

## Acknowledgements

I would like to thank Professor Hangbo Zhao and my graduate mentor Qinai Zhao for accepting me into their research group allowing me to conduct research in their lab.

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