3D Printed Gyroid Elastomer and Silicone Composite for Controlled Anisotropy for Simulating Human Tissue

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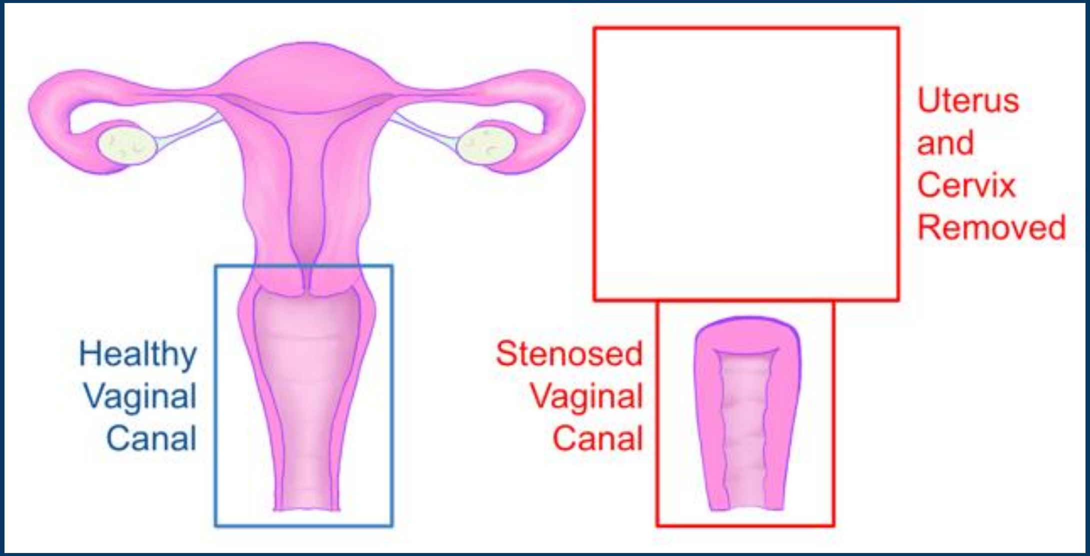
Outline

- Introduction
- Composite Structure
  - Materials Used
  - 3D Printed Pattern
- Material Behavior Results
- Summary

Medical Background

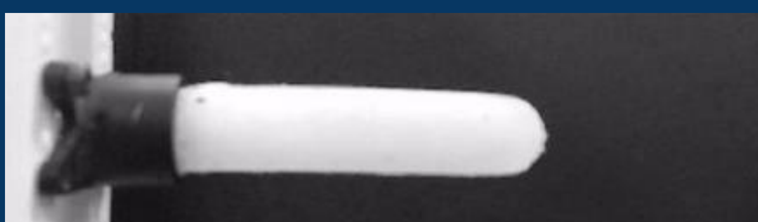
Radiation Induced Vaginal Stenosis



- Common complication for cervical cancer treatment
- Treatable with medical intervention

Medical Background

- Dilators are the prescribed treatment but…
- 80% of patients quit in 4 months



Patient friendly dilator:

- Continuous variable
- Conforms to patients anatomy
- Track progress

Medical Phantom of The Vaginal Canal

Medical phantoms are non-organic organ analog used for:

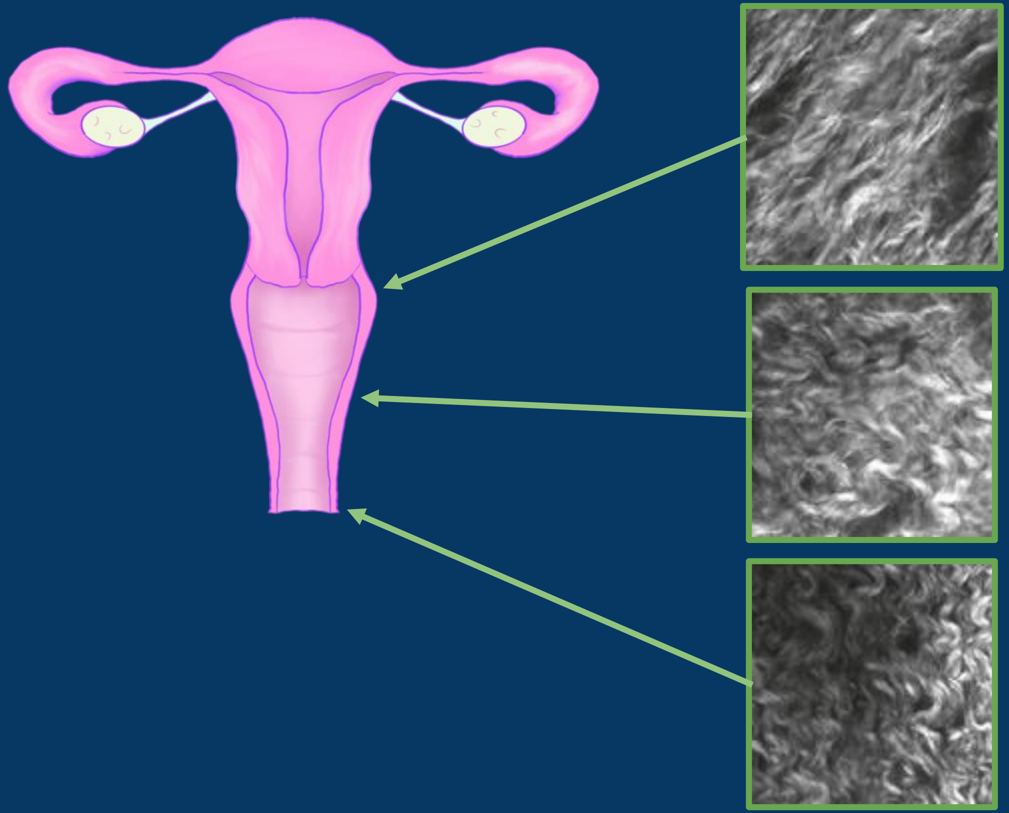
- **Physician training**
- **Medical device calibration**
- ***Ex vivo* Medical device testing and validation**

Research goal: Develop a biomechanically accurate vaginal phantom for testing vaginal dilators

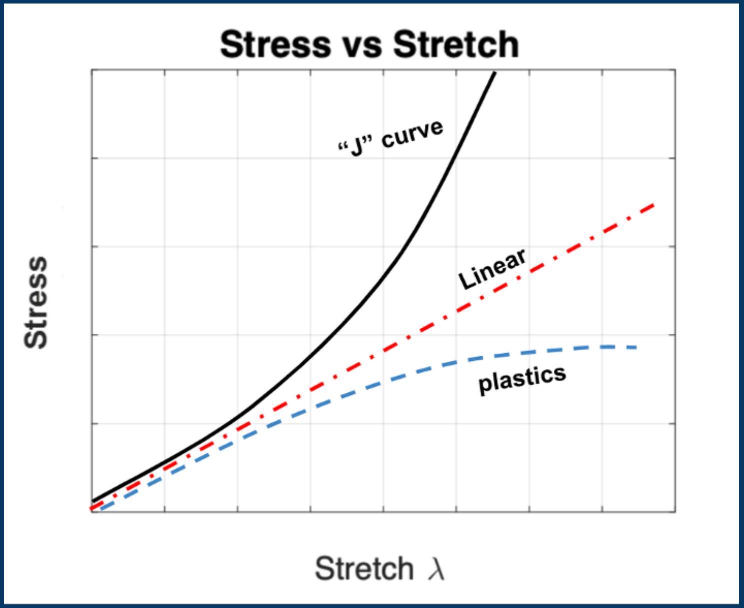
Medical Phantom of The Vaginal Canal

- Basic vaginal phantom
  - Silicone
- Our approach
  - Silicone Composite

Medical Phantom of The Vaginal Canal



Collagen fibers



Note

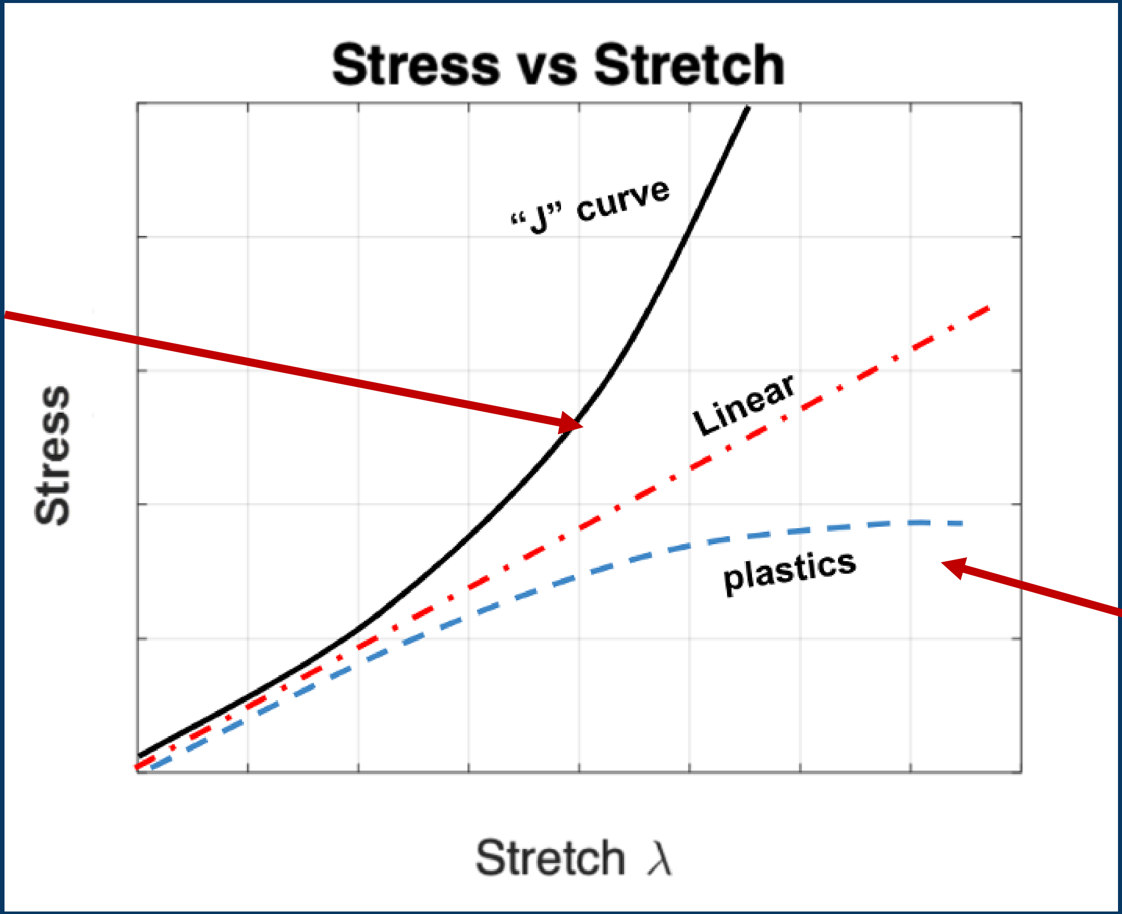
Human soft tissue is <u>stress hardening</u> and <u>anisotropic</u>

Goal

We want to design a material that simulates human tissue properties

Design New Composite Material

stress hardening



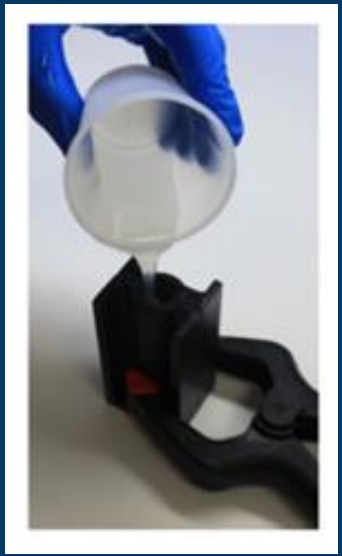
stress softening

Composite Structure

The new material composed of stiff Thermoplastic Polyurethane (TPU) scaffold and soft silicone matrix.

Composite Structure

+



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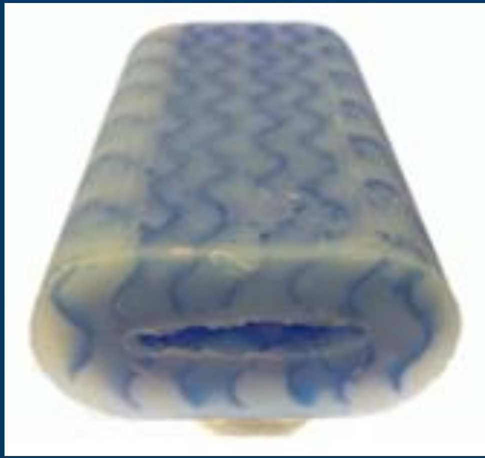


3D printed TPU scaffolding

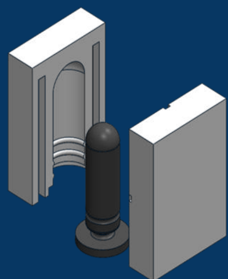
Liquid silicone resin

Resultant material

Manufacturing of Composite Materials

3D Modeling of 3-Part Mold

(a)



Prototype Mold

(b)

3D Printed Infill

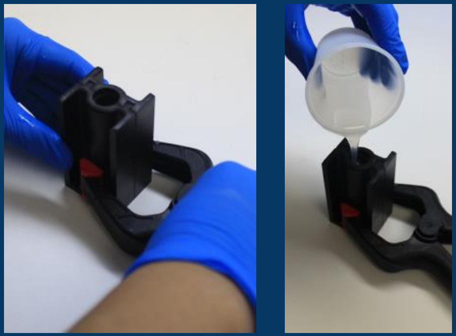
(c)

Additive Manufacturing

(d)

Silicone Molding with Infill

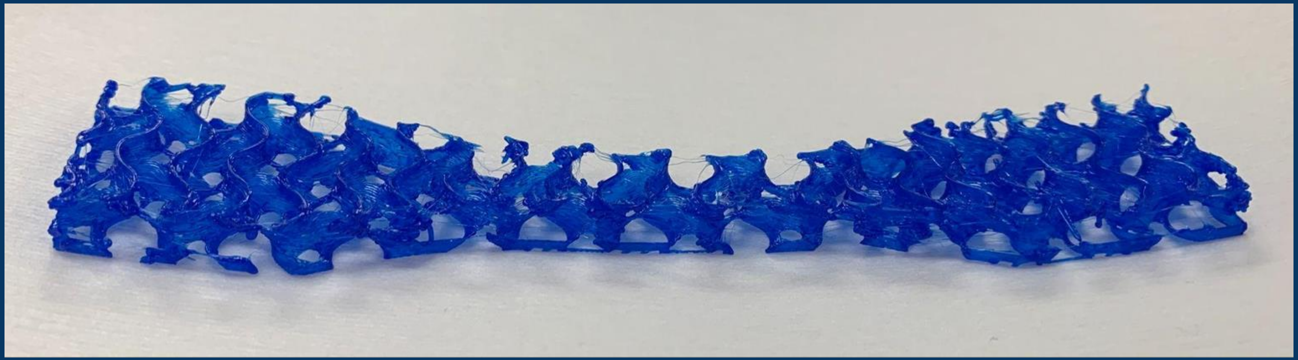
(e)



Vaginal Phantoms

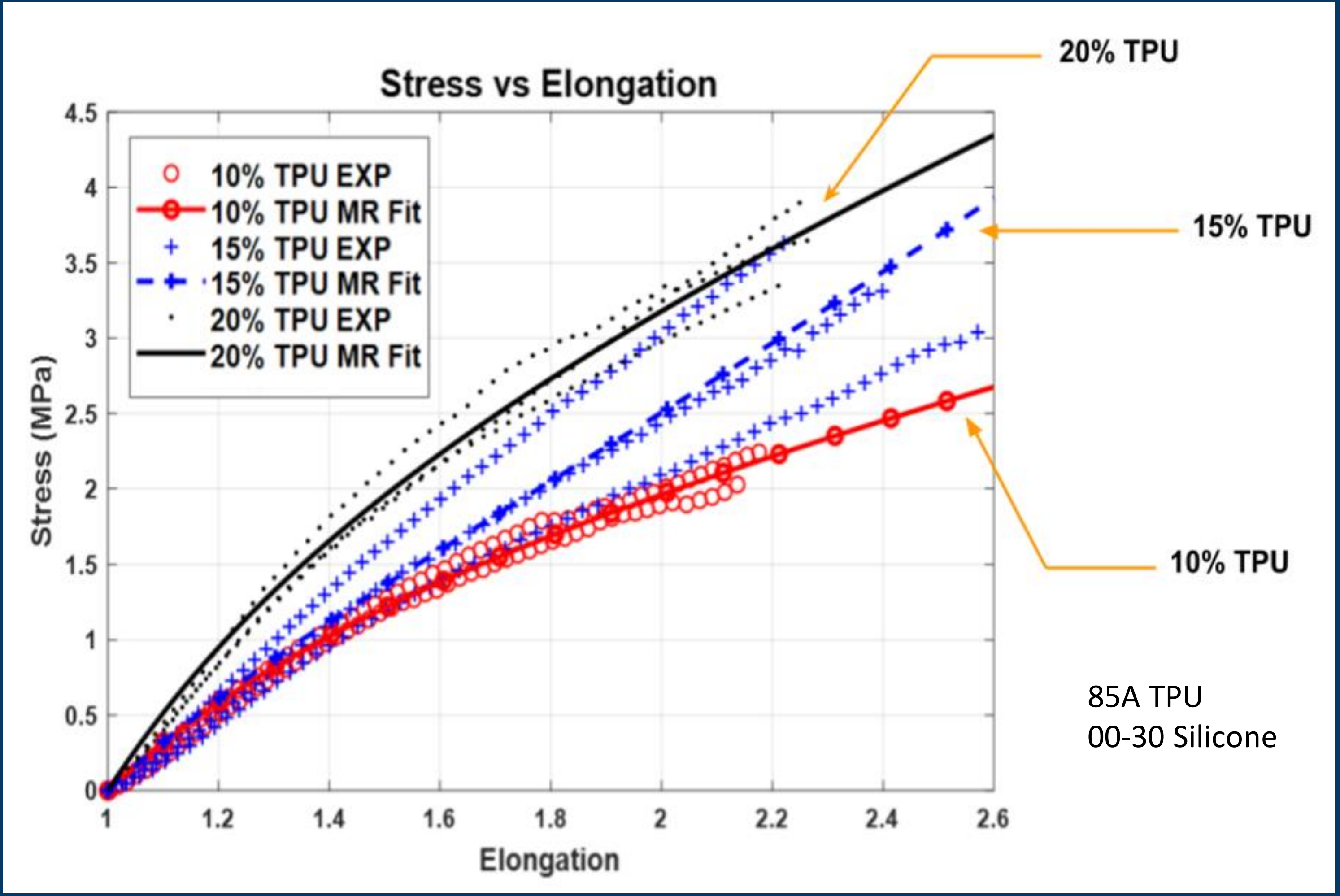
(f)

3D Printed Scaffolds



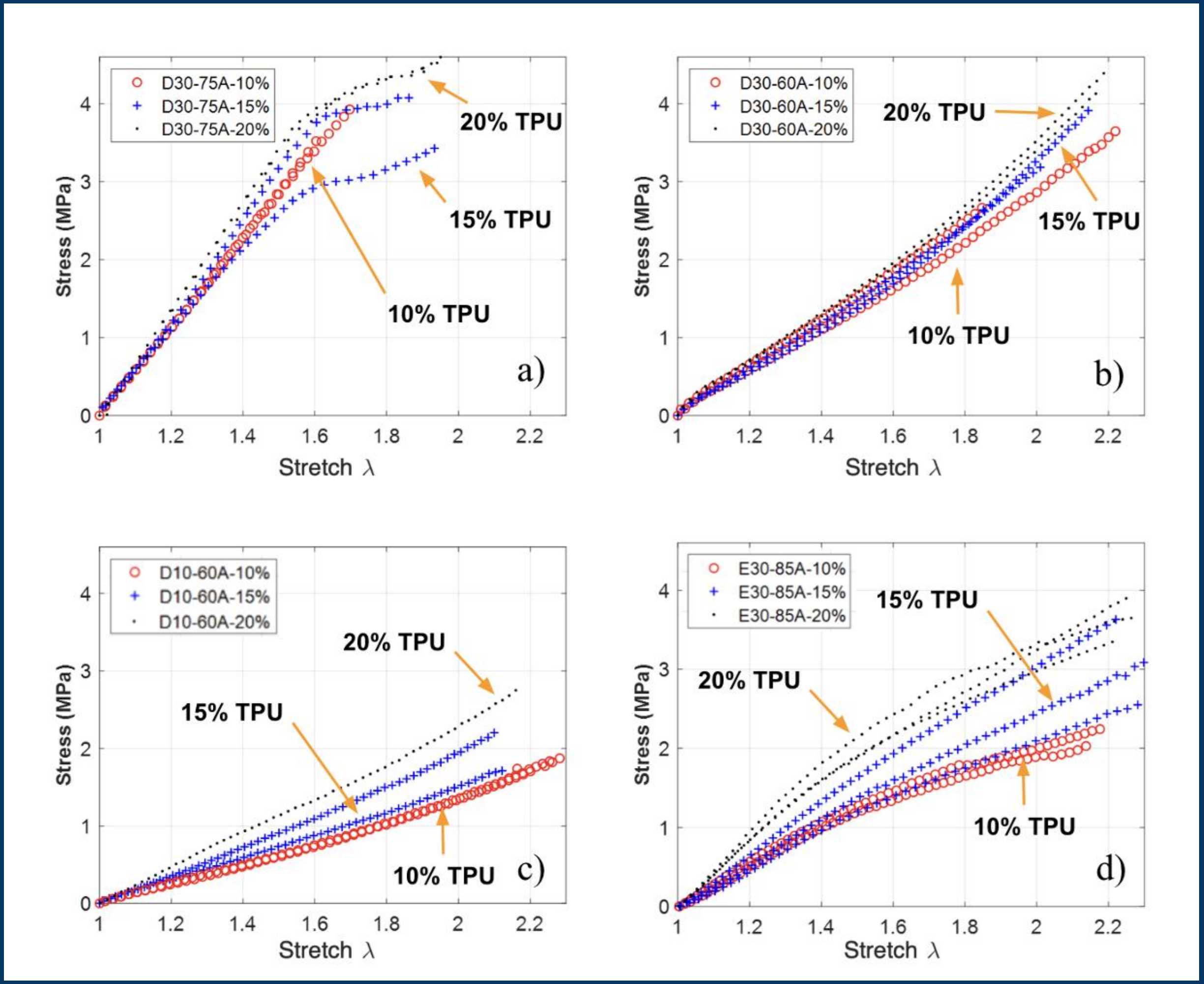
- Allows rapid manufacturing of complex geometric shapes
- Print at different volume percentages, hardness, and distortion
- Bending to stretching deformation transition

Initial Results



85A TPU
00-30 Silicone

Extended Material Testing



Stiffness and anisotropy can be changed by gyroid parameters

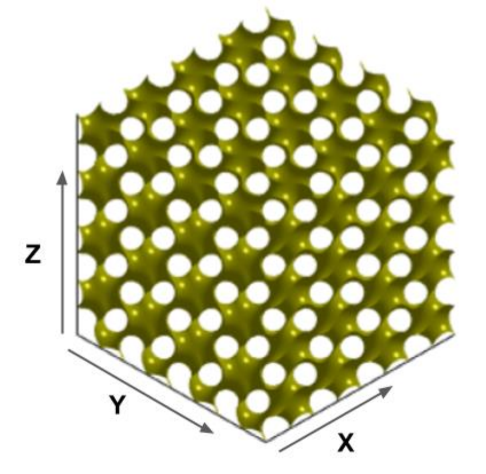
Gyroids

$t = \sin(x*2\pi/A)\cos(y*2\pi/B) + \sin(y*2\pi/B)\cos(z*2\pi/C)$

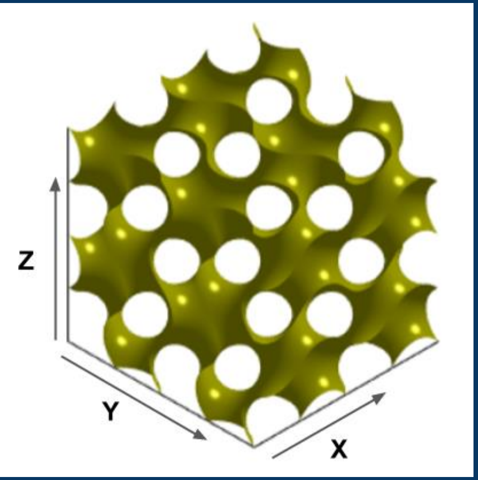
$+$

$\sin(z*2\pi/C)\cos(x*2\pi/A)$

Scaffold Density



A,B,C = 1

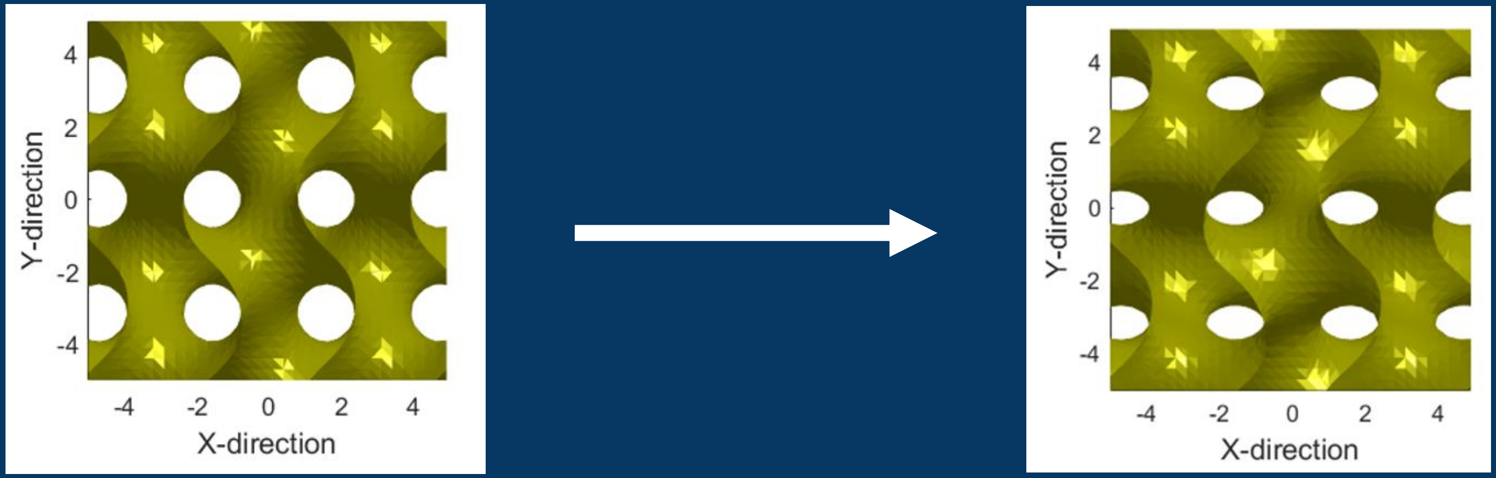


A,B,C = 2

Anisotropy

To mimic tissue anisotropy caused by collagen orientation

- **Use anisotropic scaffold structures**



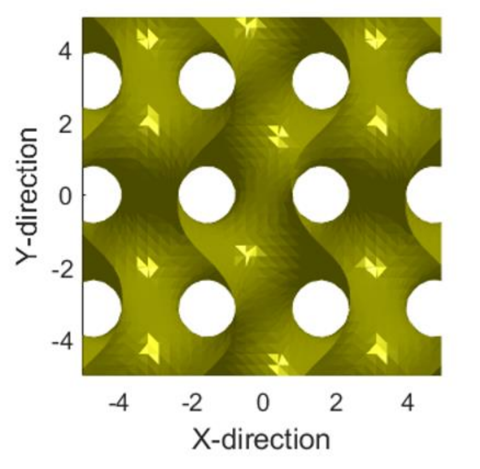
Gyroids

$t =$ sin(x*2π/A)cos(y*2π/B) + sin(y*2π/B)cos(z*2π/C)

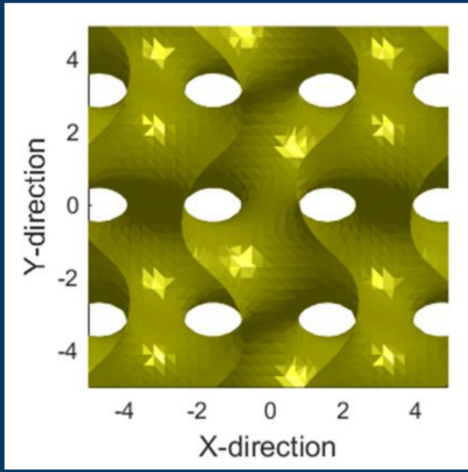
\+

sin(z*2π/C)cos(x*2π/A)

Anisotropy

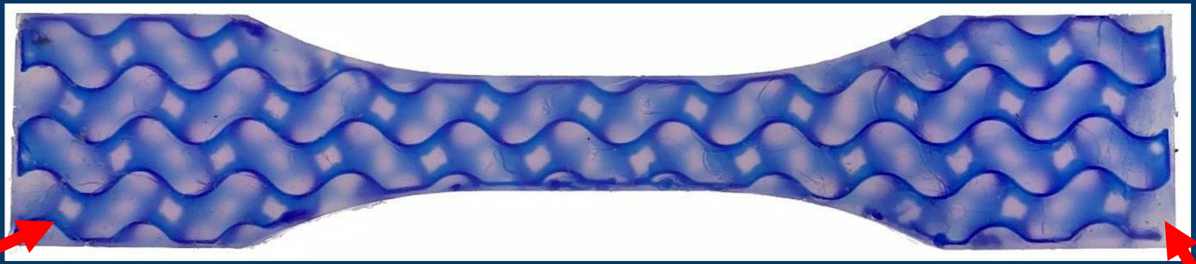


A,B,C = 1



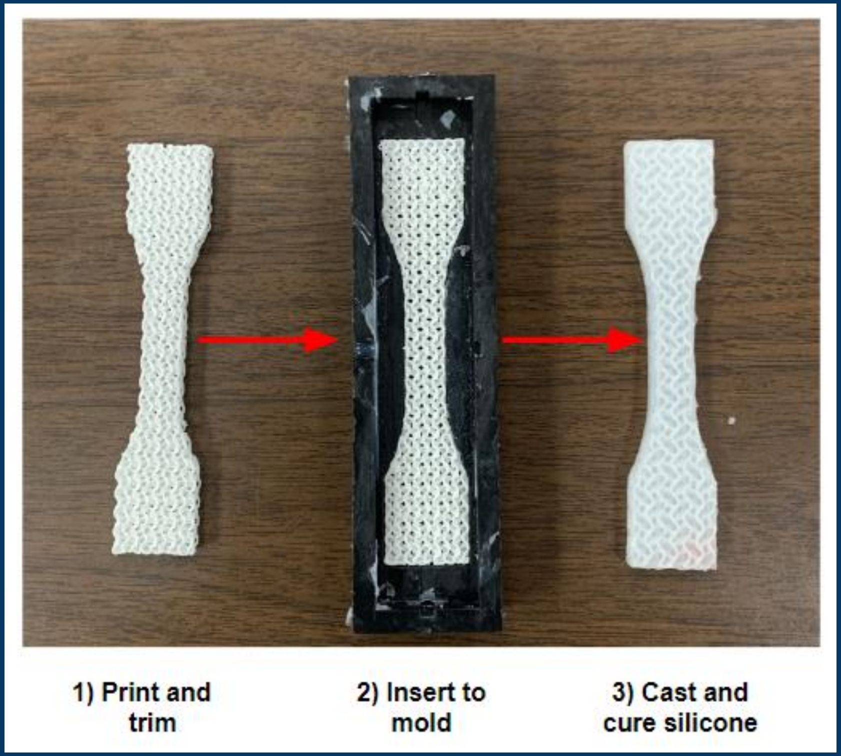
A,C = 1
B = 2

Manufacturing of Composite Materials



Polyurethane

Gyroid Scaffold

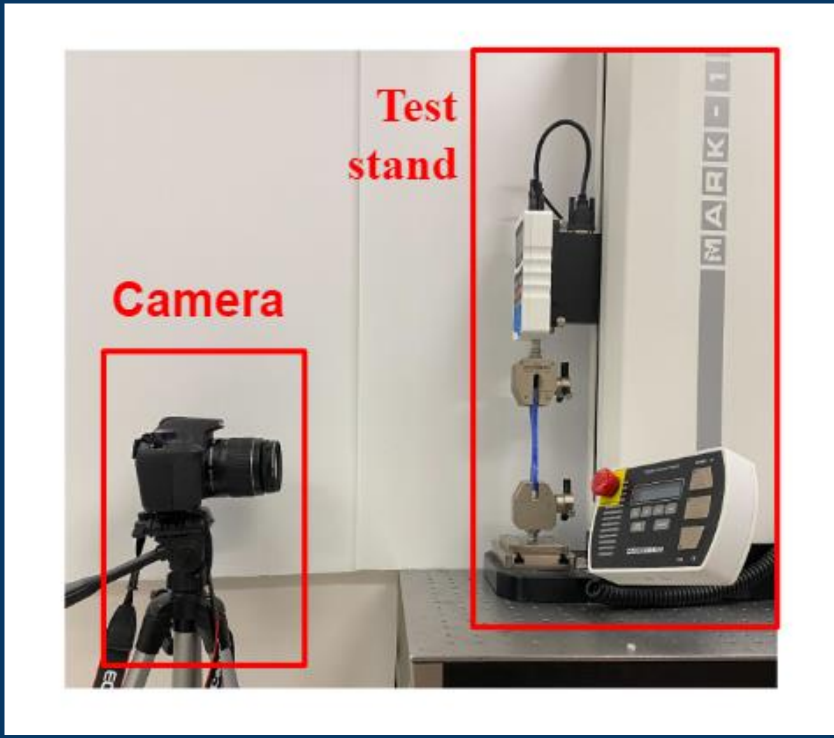


Silicone

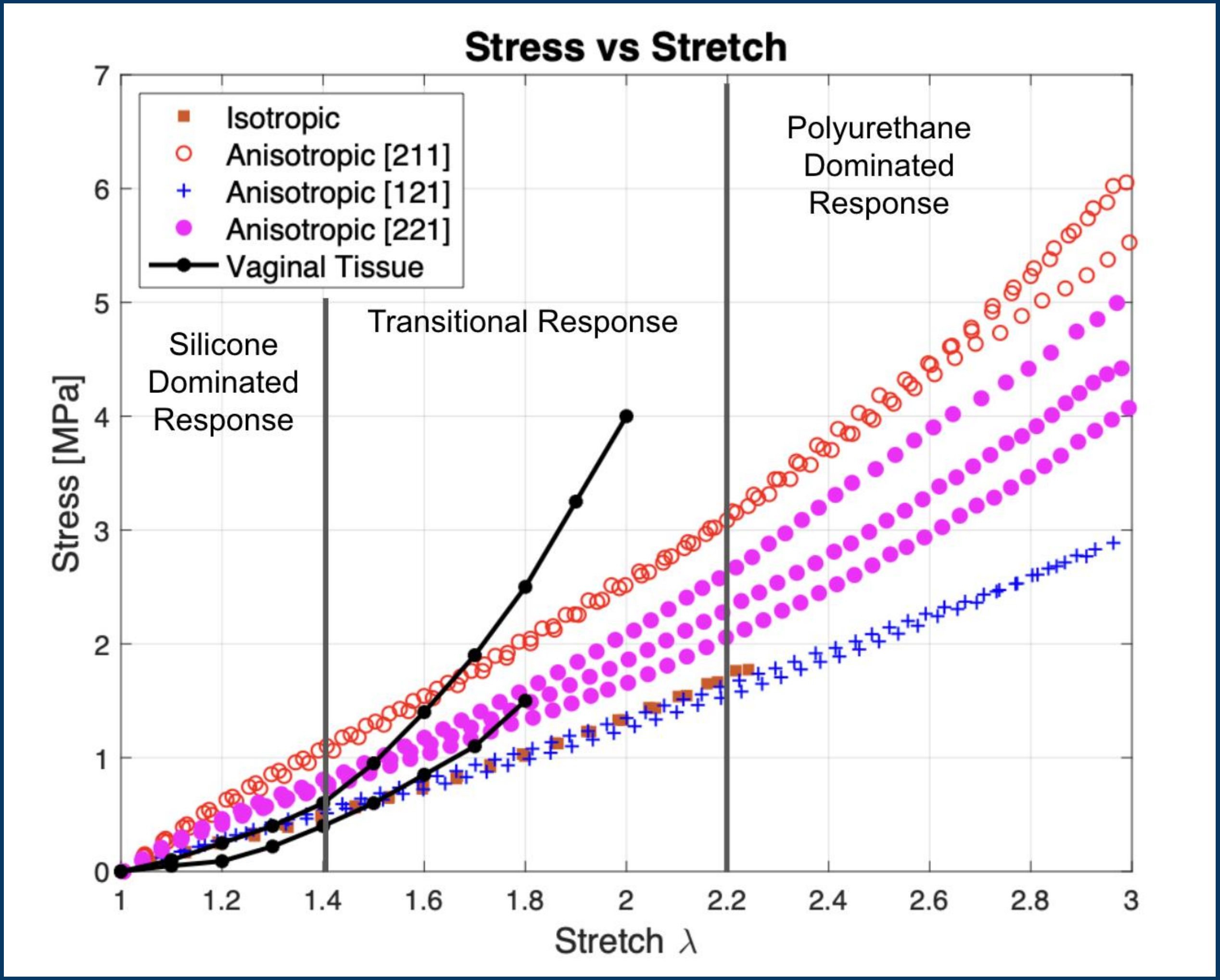
Matrix

Digital Image Correlation

- Complements uniaxial tensile tester
- Contactless strain measurement
- High resolution strain and displacement data



Typical Results



Summary

- A composite material was designed consisting of a polyurethane scaffold and a soft silicone matrix
- The mechanical properties of the composite material can be tuned to simulate human tissue (strain-hardening and anisotropy)
- Anisotropy and strain-hardening is determined by gyroid parameters

Future Work

- Open source scaffold generation software
- Improve strain hardening behavior of composite
- Material model for CAD of composite materials
- Finite element analysis

Thank you!

Questions?