Voxel 3D Printing and Computer Simulations to Prototype Bimaterial Attachments Based on Local Interface Patterning

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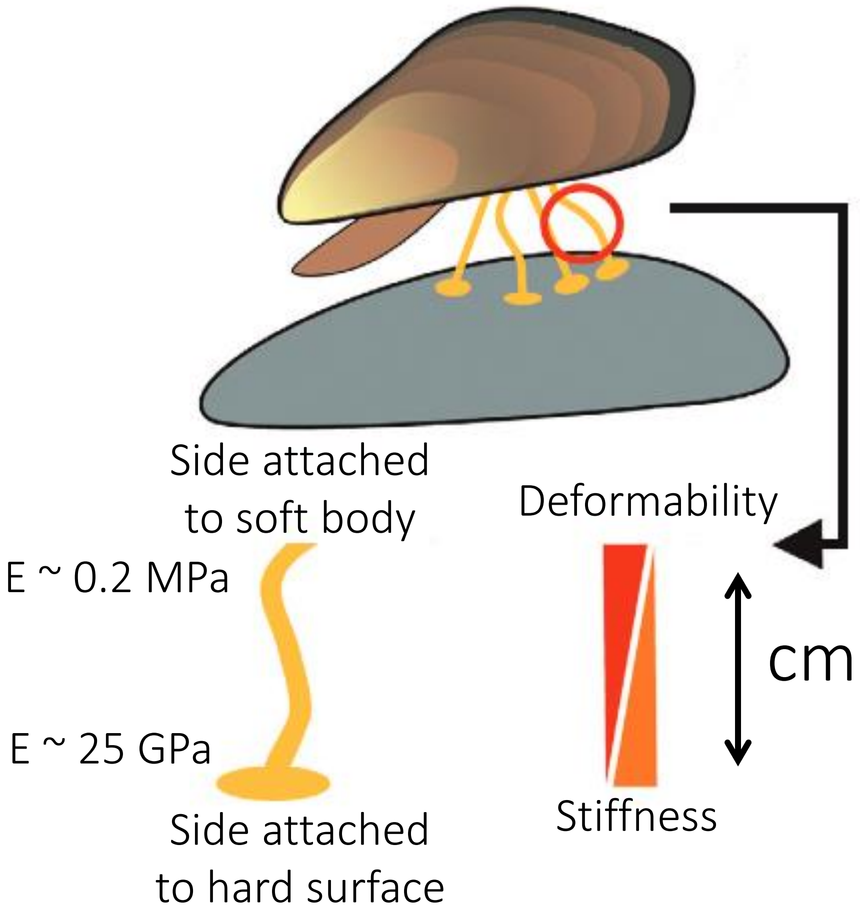
Bimaterial Attachments In Nature

Long gradient

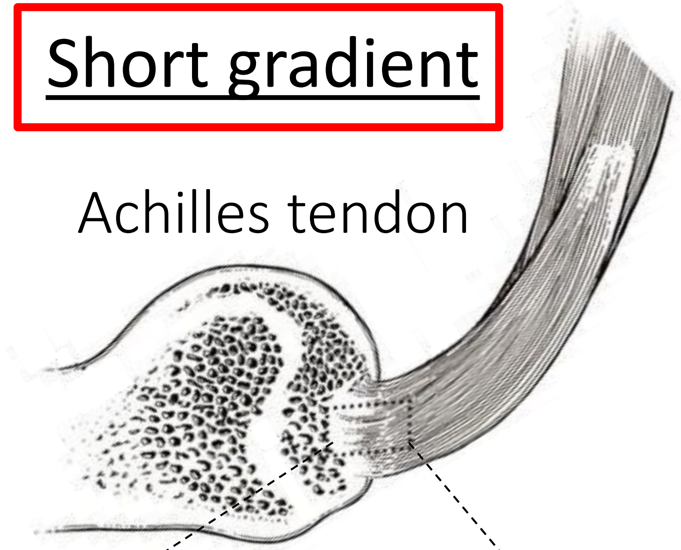


Dunlop at al., Materials Today 2011

OR

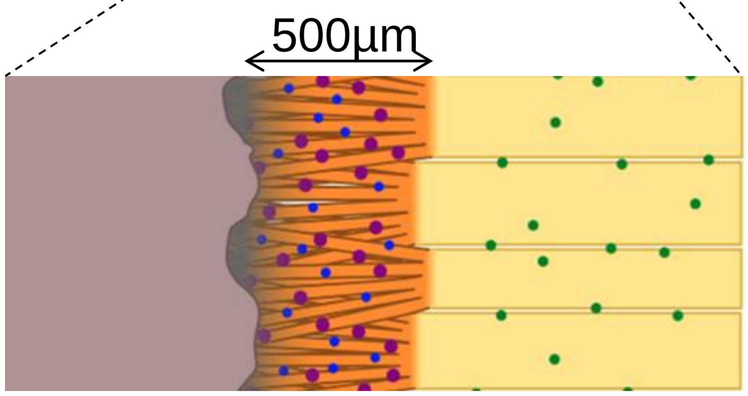
Short gradient

Achilles tendon



Locke et al., ACS Biomaterials 2016

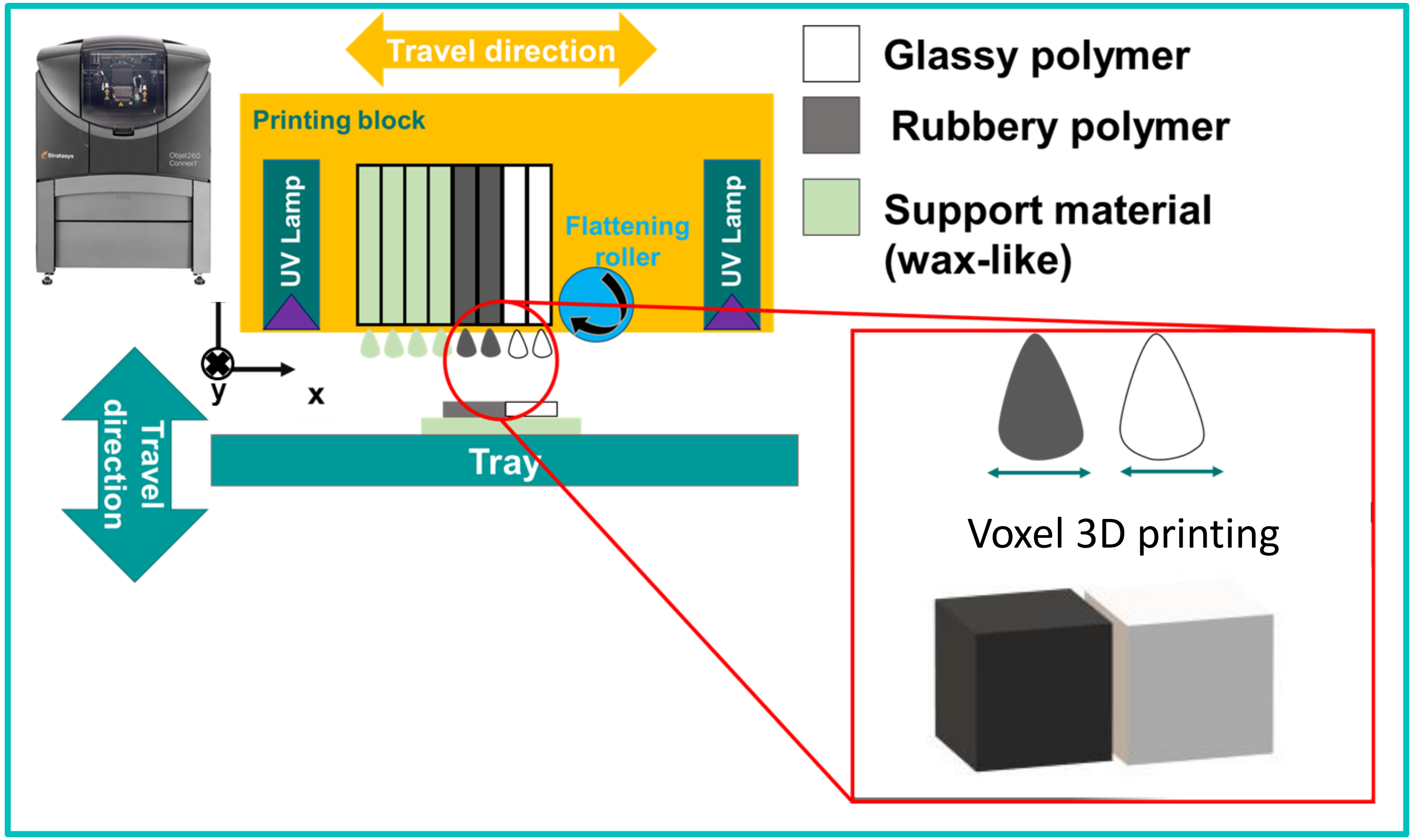
E ~20 GPa



E~0.5 GPa

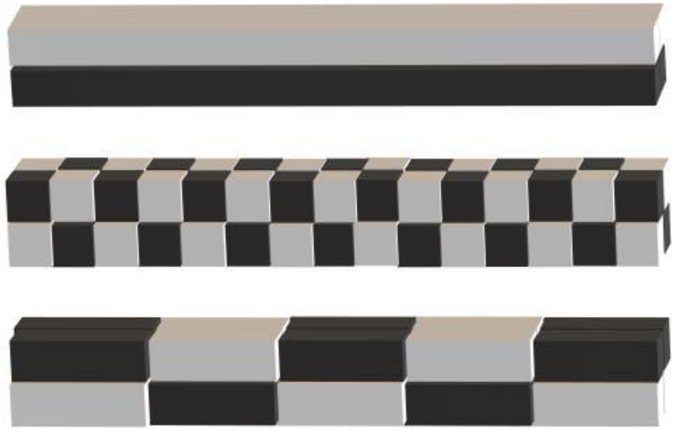
Rossetti et al, Nat Mat 2017

Bimaterial Interfaces with 3D Printing Technology



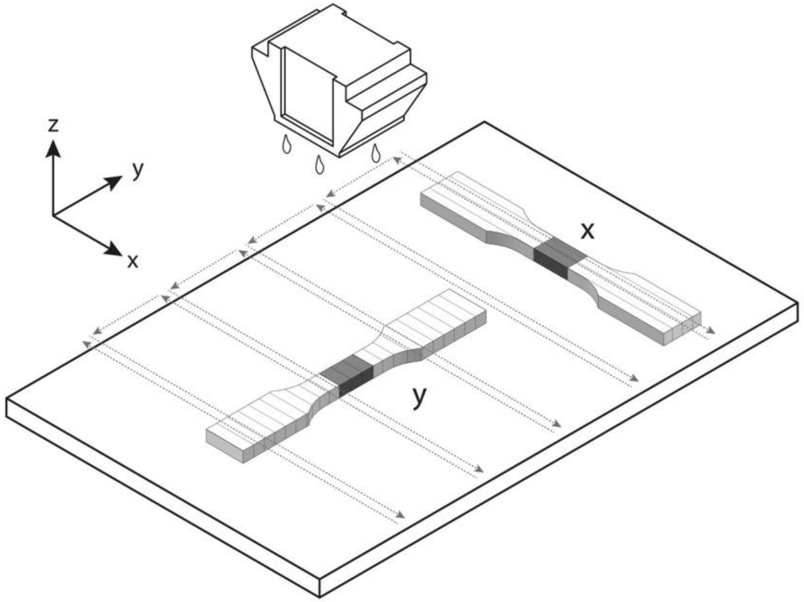
Stratasys Objet260 Connex2 :

- Droplets dimension : 40 µm
- Control on local microstructure and mechanical properties
- High geometrical freedom
- Allows Voxel 3D printing



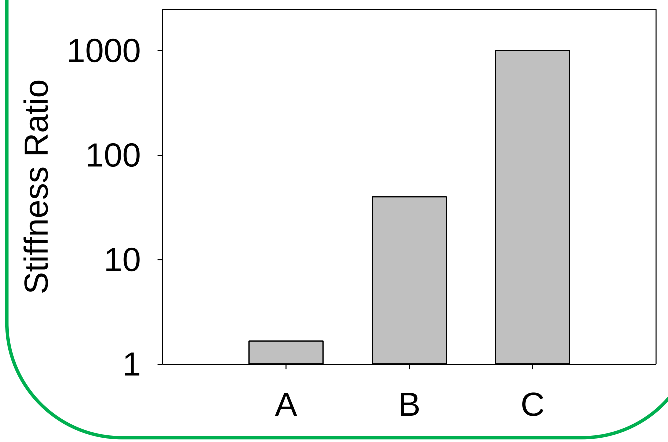
Interfaces in Polyjet Printing as Weak Regions

Printing direction

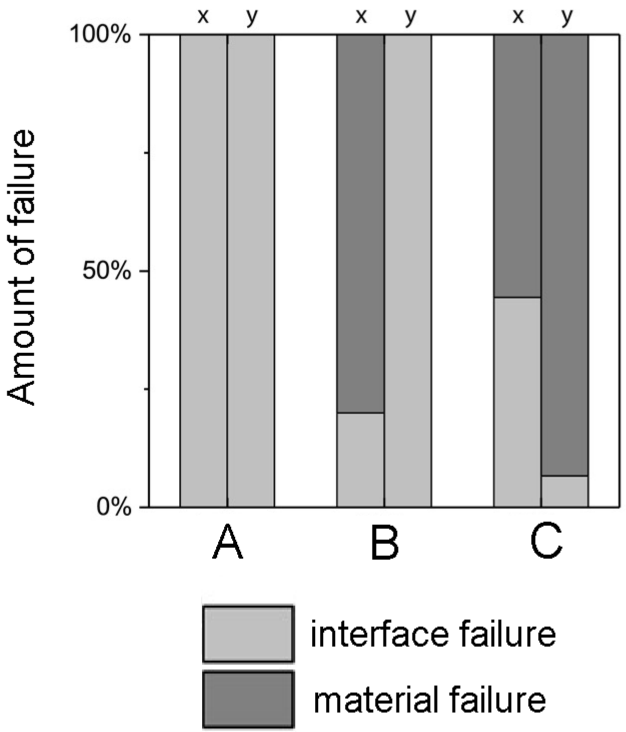


Material properties

Stiffness ratio = $\frac{E_{Rigid}}{E_{Soft}}$



Results



Adapted from Lumpe et al., Materials and Design 2019

Interface as weakness :

- Printing direction (y)
- Elastic contrast should not be too high

Aims

Aim 1 : Prototype new bimaterial attachments based on minimal perturbation using voxel 3D printing

Aim 2 : Understand impact of perturbations on stiffness, strength, failure behaviour

Aim 3 : Compute local stress inside stiff and compliant voxels

Methodology

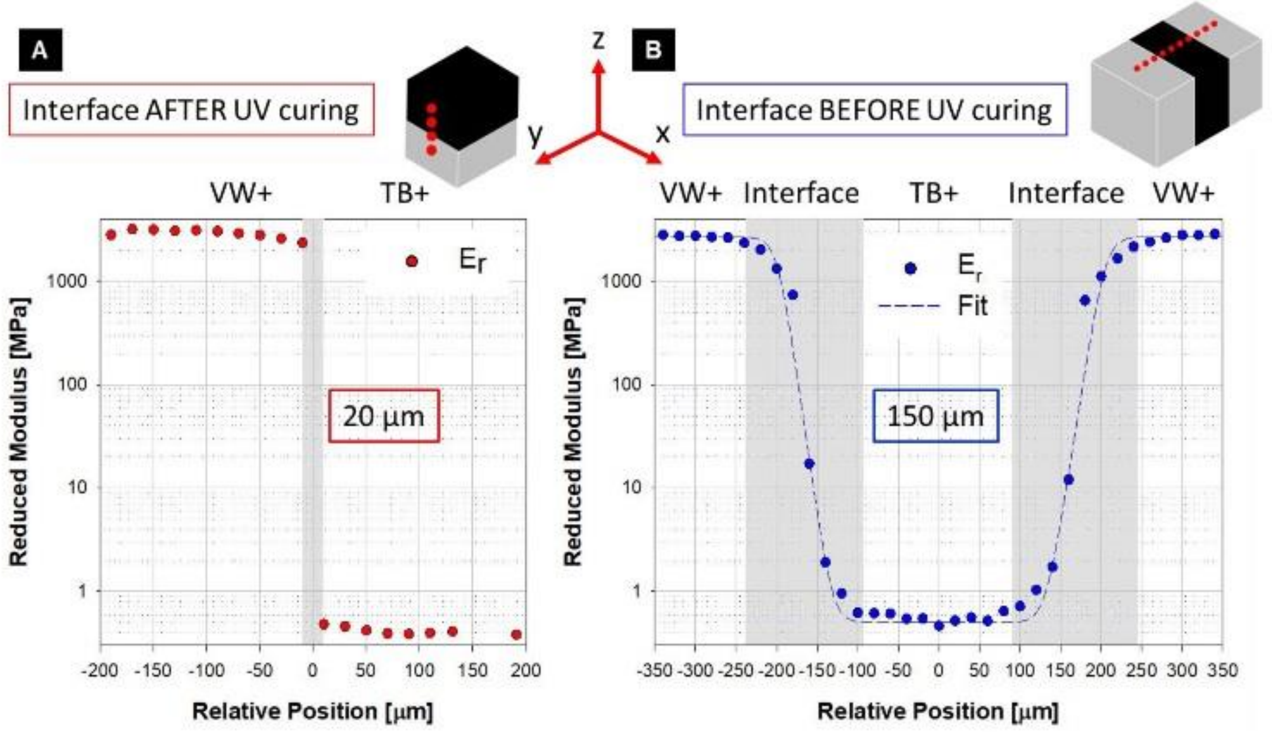
Droplets mix

- Voxel size chosen is 420x420 µm²

Types of bimaterial attachments :

Minimal perturbation : < 10% length

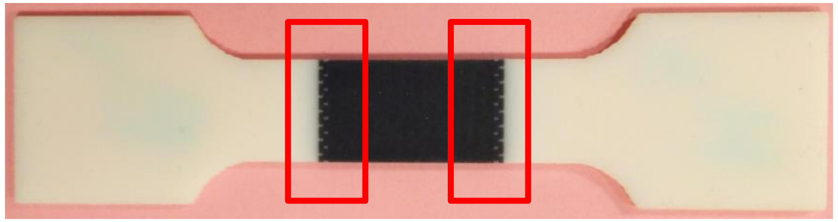
- Flat interface (Reference case)
- Ordered Interface patterning (6 configurations)
- Random interface patterning (3 configurations)



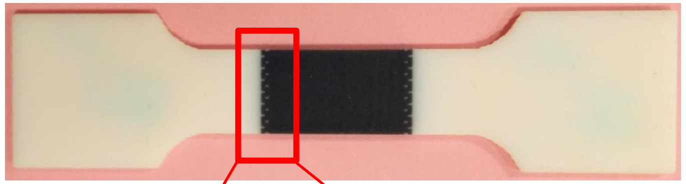
Zorzetto et al., Scientific Reports 2020

Methods :

- Experimental testing on 3D printed bimaterial samples
- Voxel based finite element simulations

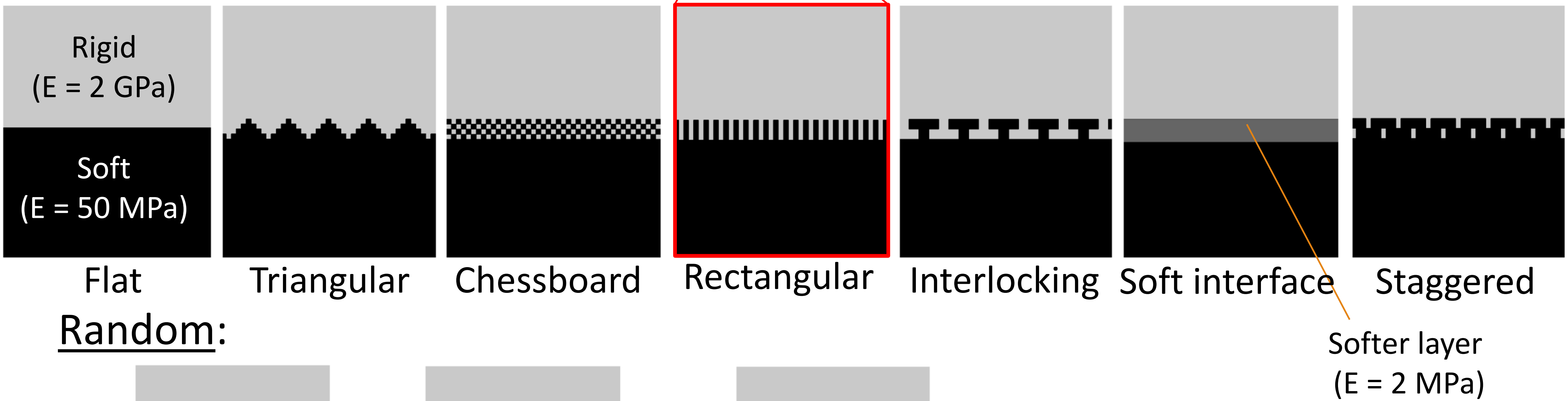


Methodology



Only 4 voxels perturbation

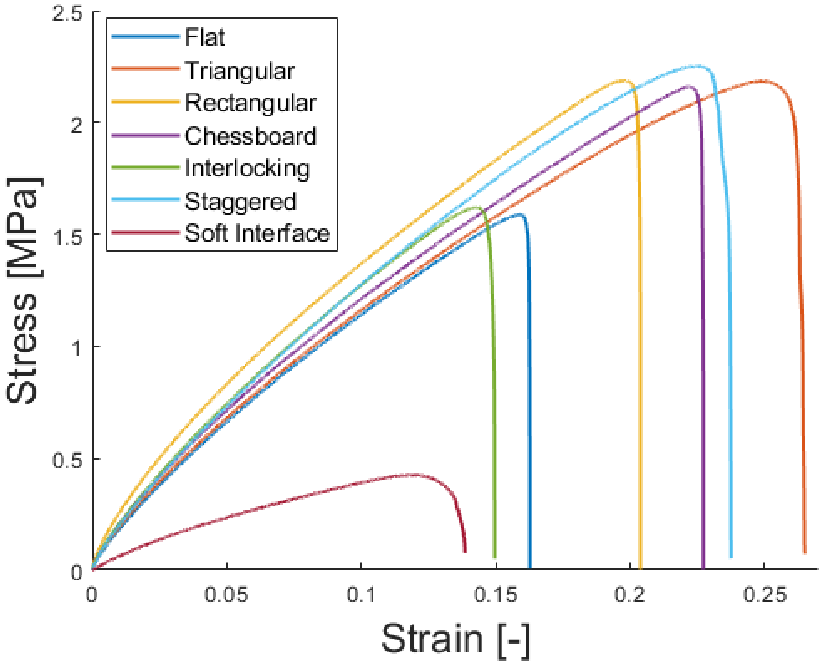
Ordered:

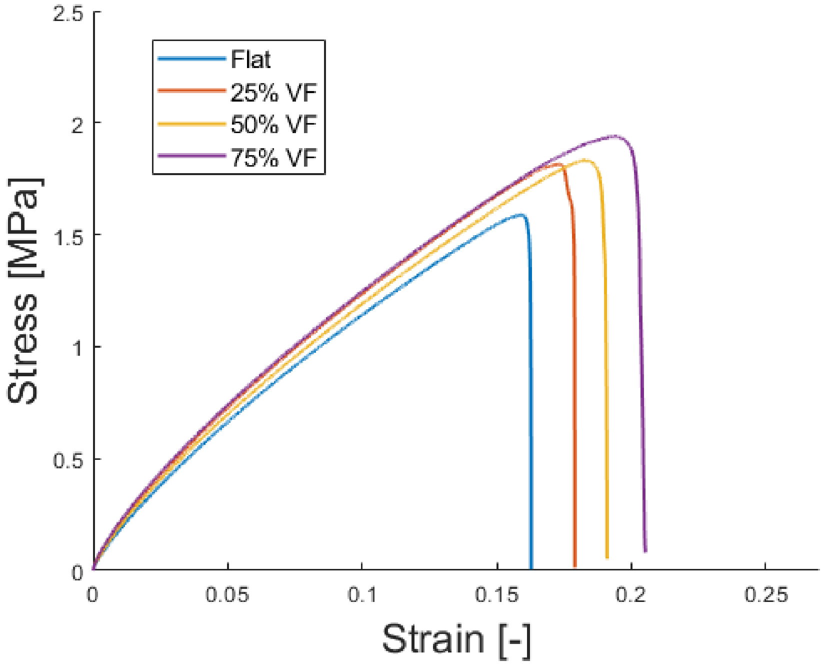


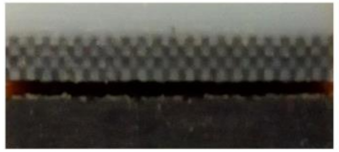
Random:

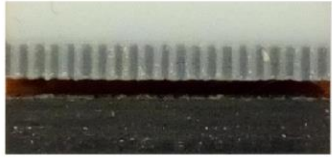
Volume Fraction of soft voxels = 25%, 50% & 75%

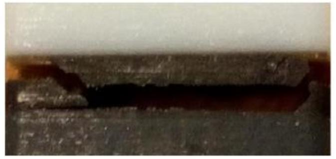
Results : Stress-strain

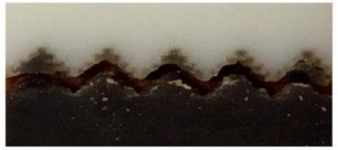


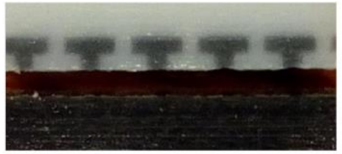




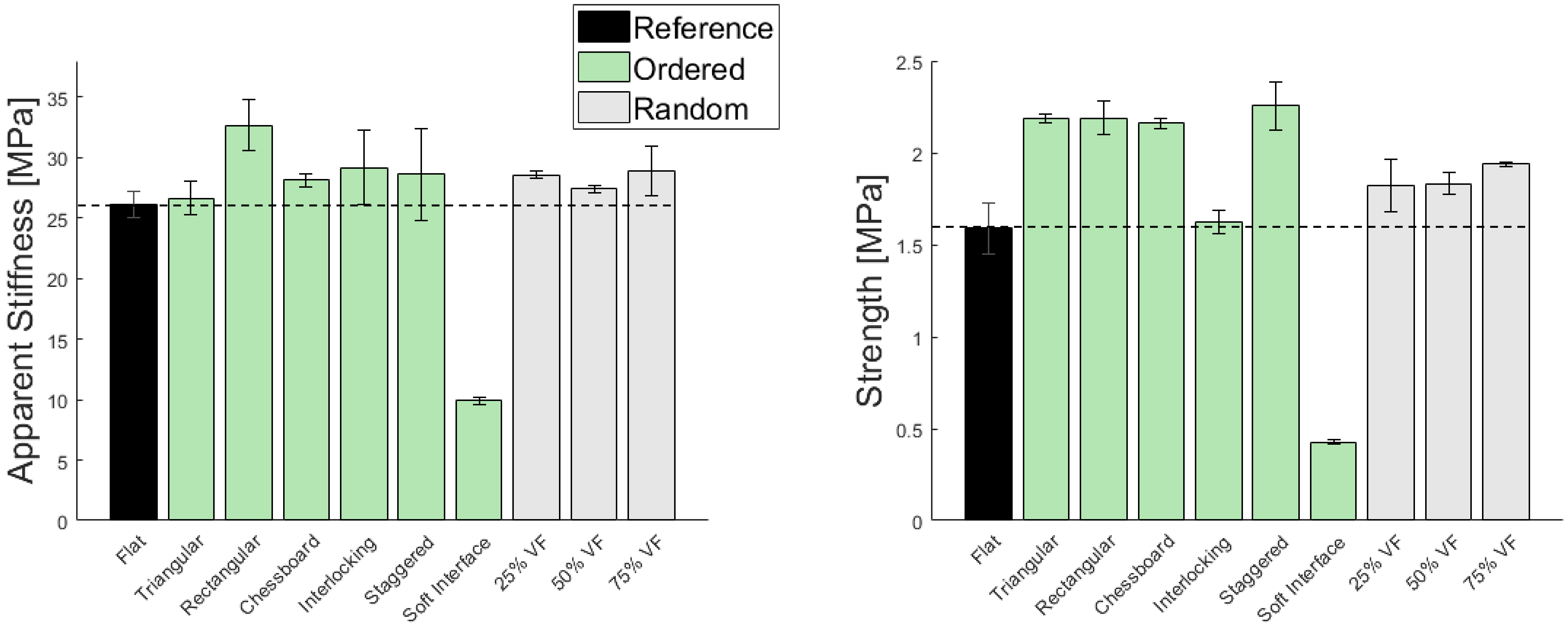








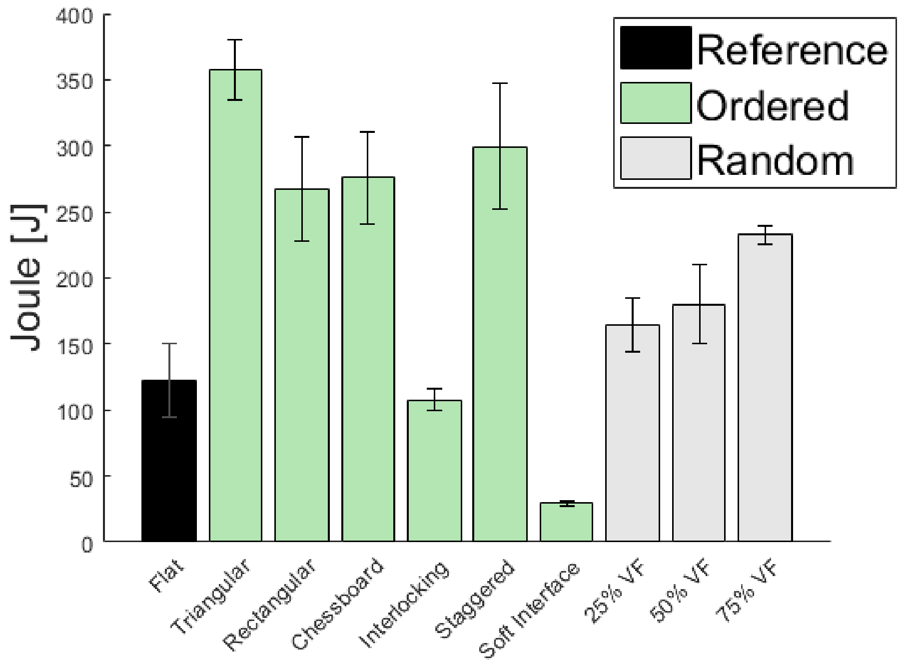
Results : Apparent Stiffness & Strength



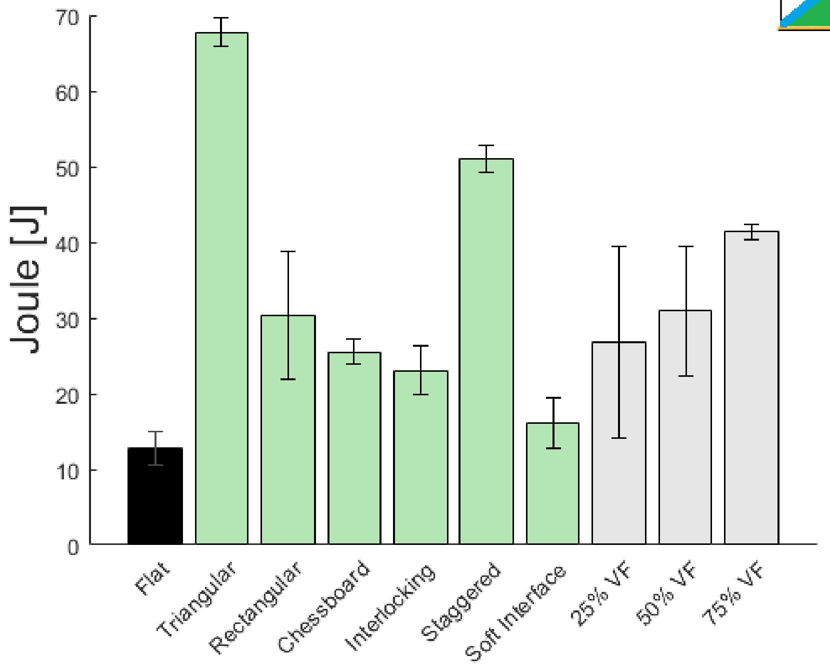
→ Strength increases significantly while apparent stiffness stays approximately constant

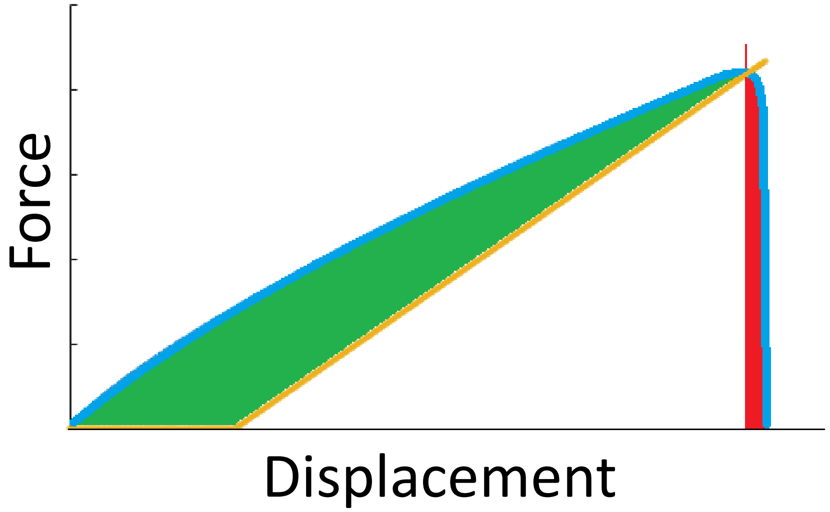
Results : Work Pre/Post-Failure

Pre-failure work



Post-failure work



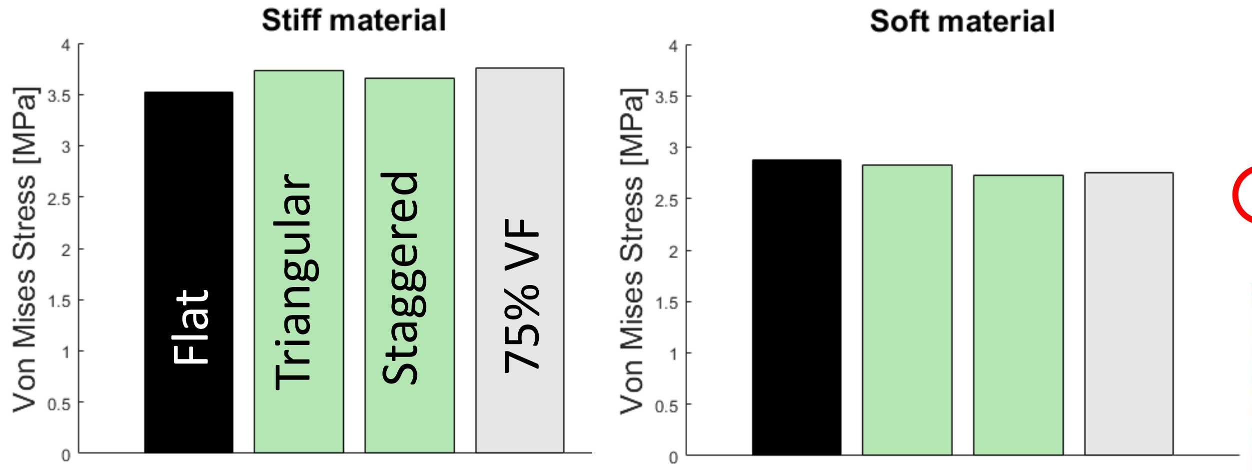


→

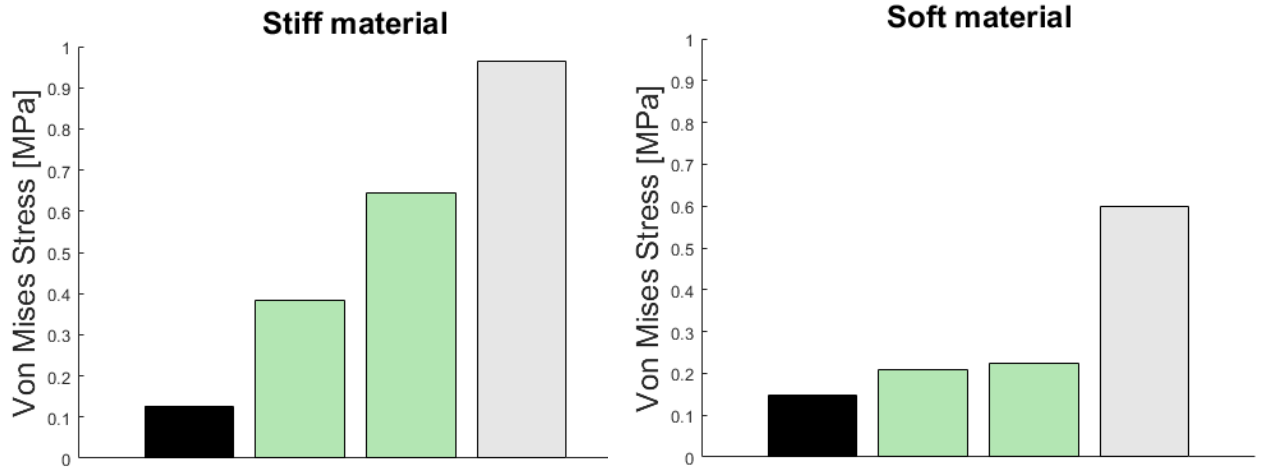
		Ordered	Random
Max increase :	pre-failure work	3x	2x
	post-failure work	5x	3x

Von Mises Stress Distribution

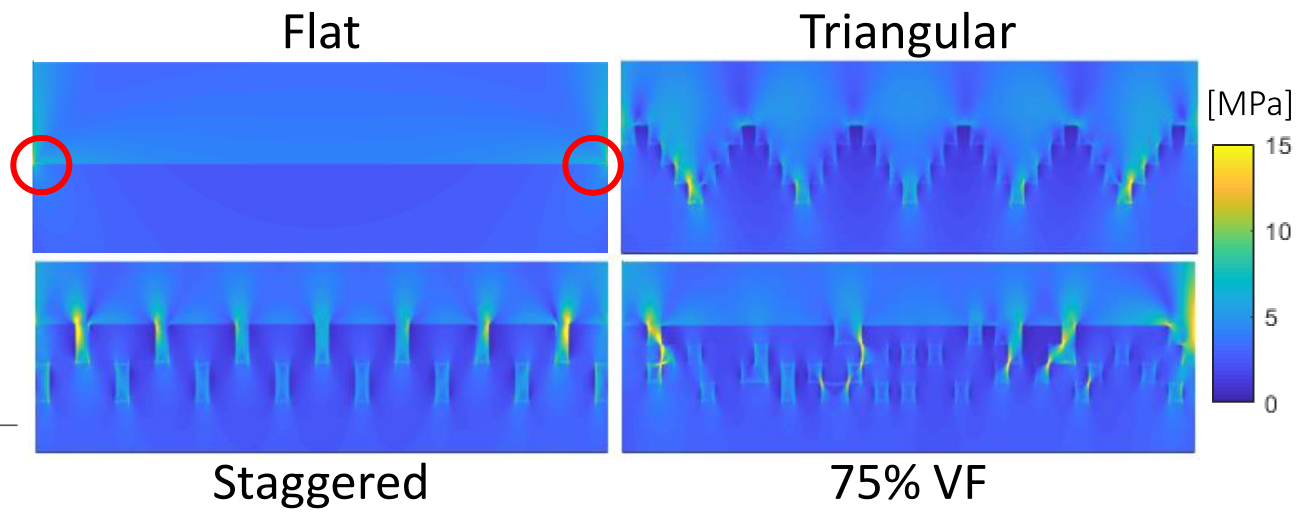
Mean VM



Std VM



Distribution



- Stress concentration is taken away from edges
- Spread of Stress : Higher amount of voxels with high and low Stress

Conclusions

- ✓ Minimal perturbations increase strength and failure resistance of bimaterial attachment.
- ✓ Ordered surface patterning are more performant than random patterning.
- ✓ Interface patterning induces more heterogeneous stress distribution in soft and stiff voxels.