Snake-skin Inspired Auxetic Design as a Candidate for Mechanically Adaptive Scaffolds for Cells

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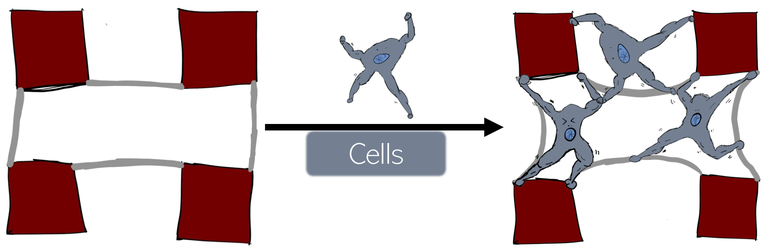
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Motivation

- Cells are well known to have the ability to not only respond to the changes in their environment but also actively take part in stimulating and changing their environment.[1,2,3]
- The idea is to provide cells with scaffolds which respond to the mechanical cues provided by cells, such as expansion/contraction and traction forces exerted during migration.

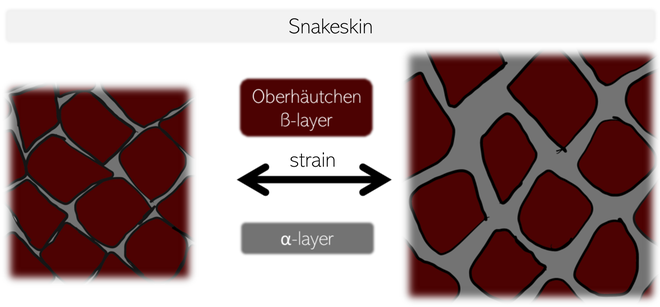
Aim

- Use of snake-skin inspired design to create 3D scaffolds to study cell mechanics in a structurally dynamic environment.



Snakeskin Kirigami pattern

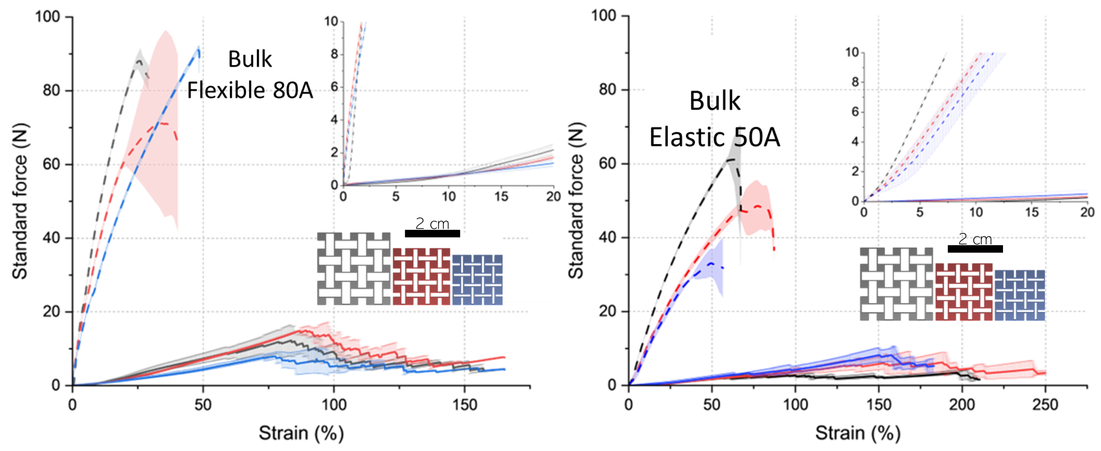
- Life inspired auxetic metamaterial design.
- Snakeskin is flexible yet protective against the harsh environments.





Prototyping

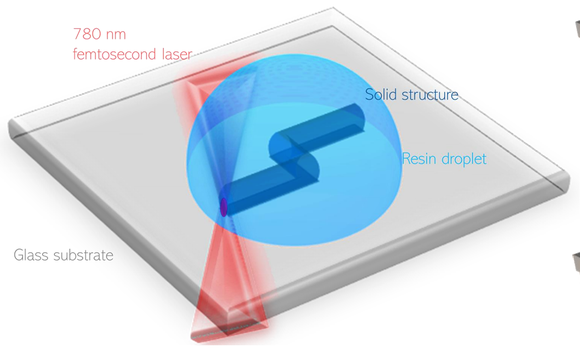
- Macroscale samples were printed with an SLA printer Form 3B (Formlabs USA).

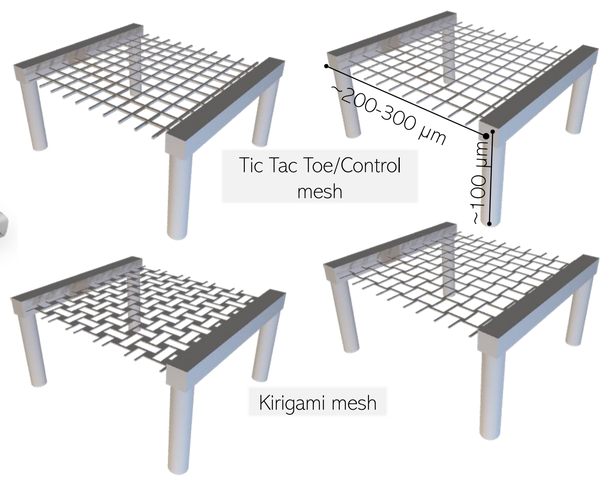


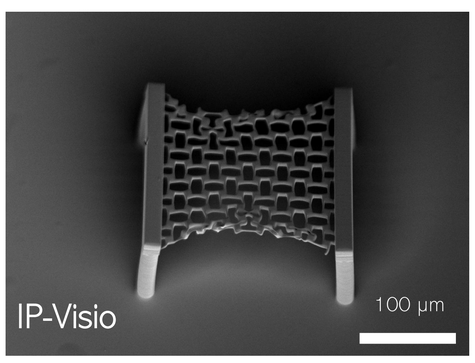
- Tensile test confirms 80-90% drop in the maximum force from design changes.
- Design change induces a change in the nature of the stress strain curve in comparison to the bulk material.

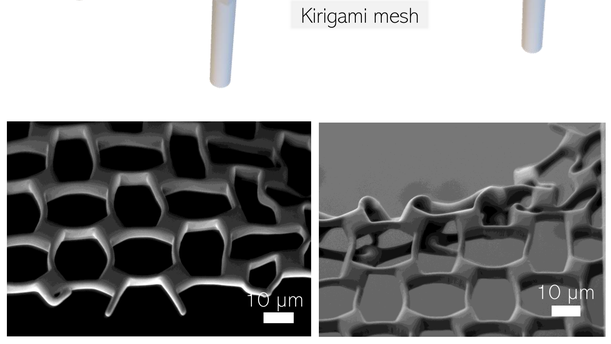
2-Photon-polymerization-based 3D printing of micro-scaffolds

- Structures were printed by the device Photonic Professional GT2 from IP-Visio(stiff thermoset resin, storage modulus 3.50 GPa) purchased from Nanoscribe GmbH.







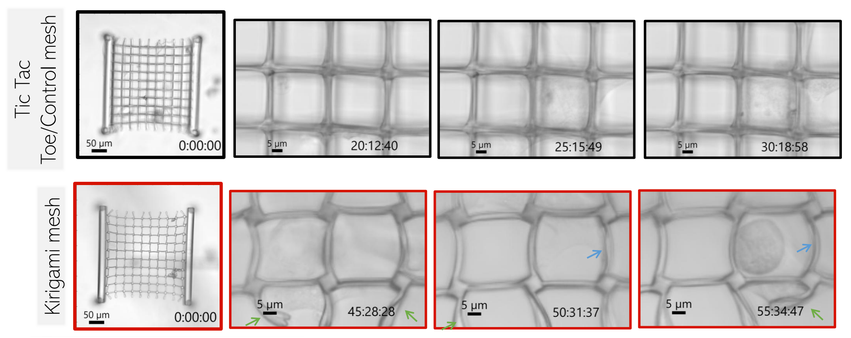


- Successful fabrication of the structures was confirmed via scanning electron microscopy and confocal microscopy.

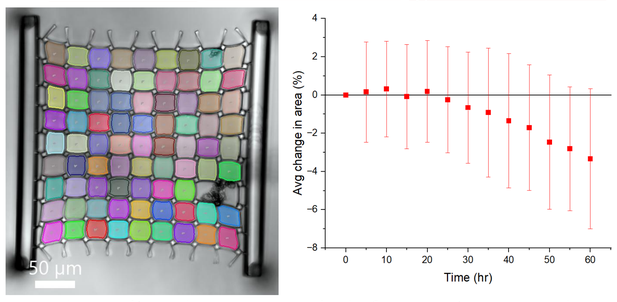
In vitro studies with C2C12 myoblast cells

Migration of cells into the structure

- IP-Visio Structures were coated with rhodamine conjugated fibronectin before cell seeding.
- A total of 5000 cells were seeded onto the structures and observed for 3 days.



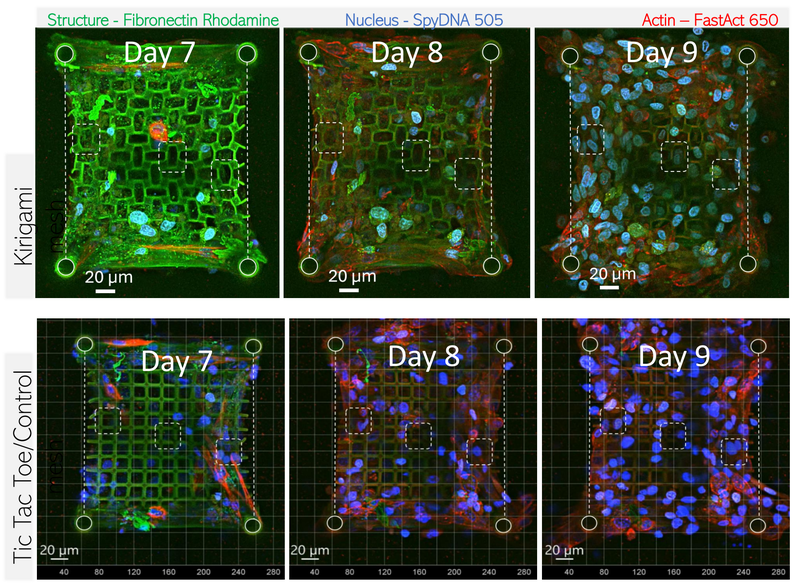
- Cells on the control mesh are unable to generate any deformations.
- Green and blue arrows in the kirigami mesh highlight the movement of free ends and the flexible motifs, respectively.



- To quantify the change in the kirigami mesh geometry, the area of the empty pocket represented by colorful boxes in the image was tracked over 13 time points.
- The graph highlights the overall shrinkage in the pocket sizes with increase cell confluency on the mesh as well as the contribution of the contractile forces exerted by the cells.

- Localized structural deformation can be observed in the kirigami mesh structures induced by migration of C2C12 across the mesh.
- In contrast, the control mesh of the same material shows no morphological change.

Migration of cells out of the structure



- Cell seeded structures were maintained till confluency on the mesh was achieved.
- The cells on the surface were scratched with a micromanipulator.
- Following this, the outgrowth of cells from the structure was observed.

- Over the three days of cell outgrowth, the kirigami mesh is seen to expand in the non-restricted directions.

Summary & Outlook

- ✓ Successful design and fabrication of the structures.
- ✓ Geometry driven tuning of structural stiffness achieved at the microscale.
- ✓ Confocal images confirm cell induced deformation of the kirigami meshes.
- ✓ Study highlights the effectiveness of the approach in producing lower stiffness structures from stiff materials.
- ✓ Next steps involve a deeper analysis of the structural deformations.
- ✓ A thorough mechanical characterization of 3D micro structures.
- ✓ Characterize the biological impact of these systems on cells.

References

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