Interaction through shape-changing surfaces

Zhuzhi FAN

zhuzhi.fan@bristol.ac.uk

BIG Bristol Interaction Group

University of BRISTOL

DIVERSE-Ability Interaction Lab

inclusive Cross Play

cnrs

UGA Université Grenoble Alpes

LIG

Interaction through shape-changing surfaces

Octopus: no bone but remarkable shape-changing ability

Latest devices

manually change

between **limited shapes**

Latest devices

manually change

between **limited shapes**

Limitations

Limitations

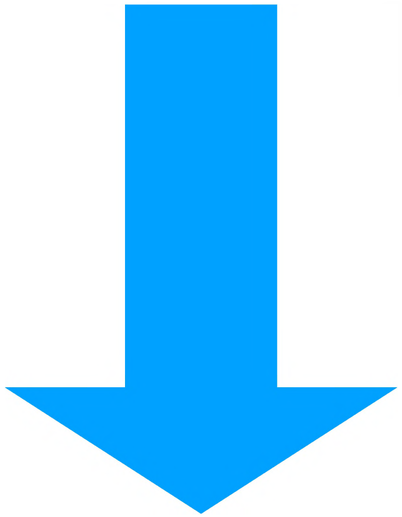
Rigid → **Unsuitable to wear on the body**

Not actuated → **Limited applications**

Limited shapes → **Limited functions**

Soft, **actuated**, and **more shape-changes**

Soft, **actuated**, and **more shape-changes**



Novel user interaction experience

programmable soft materials

programmable soft materials?

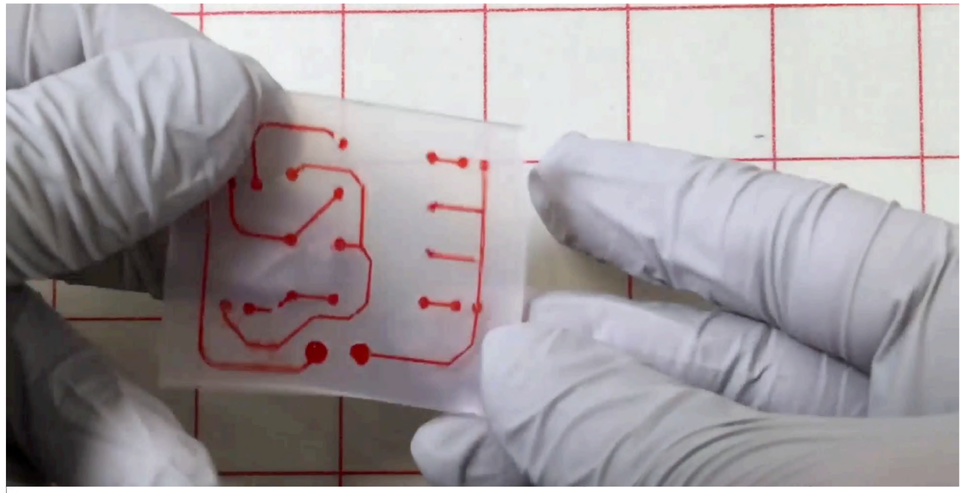
soft

Soft materials

Elastomer

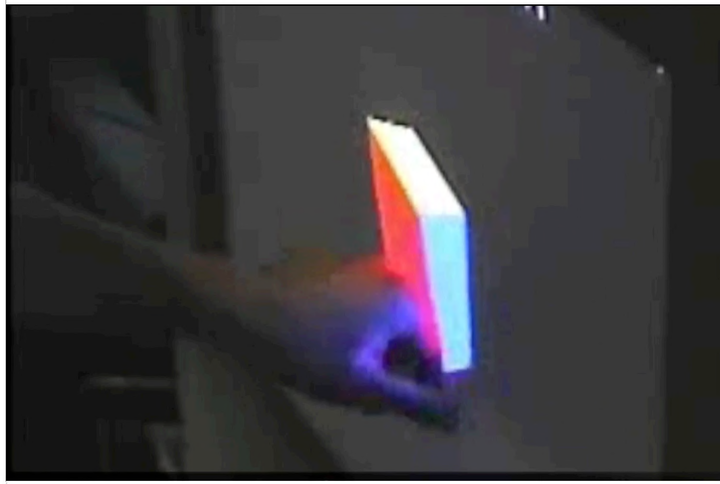
[Teyssier et al, UIST'19]

Hydrogel



[Yuk et al, Nature Communications 2016]

Fabric



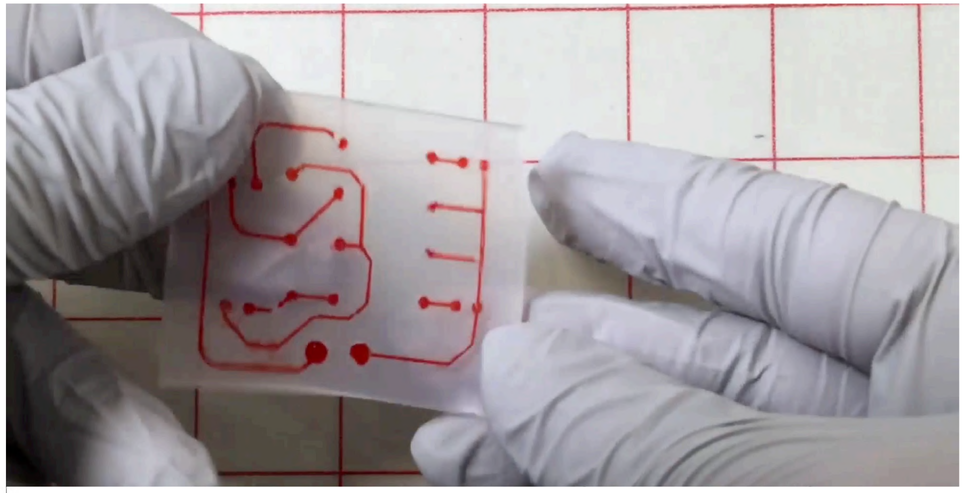
[Troiano et al, AVI' 14]

Soft materials

Elastomer

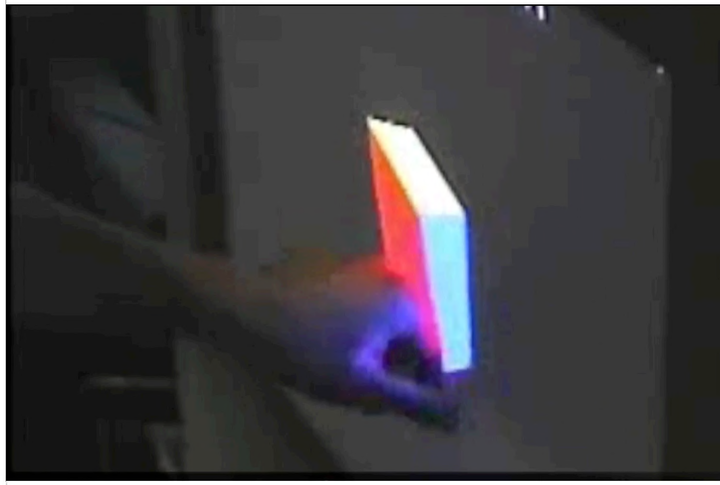
[Teyssier et al, UIST'19]

Hydrogel



[Yuk et al, Nature Communications 2016]

Fabric



[Troiano et al, AVI' 14]

programmable

Air pressure actuated elastomer

Baromorph
[Siéfert et al, Nature Materials 2019]

Humidity actuated hydrogel

Shape morphing hydrogel films
[Hu et al, Research 2021]

Heat actuated fabric

Active Textile Fabrics
[Pedro E. S et al, Advanced materials 2023]

Voltage actuated elastomer

Shape morphing dielectric elastomer actuators
[Hajiesmaili et al, Science Advances 2022]

Air pressure actuated elastomer

Baromorph
[Siéfert et al, Nature Materials 2019]

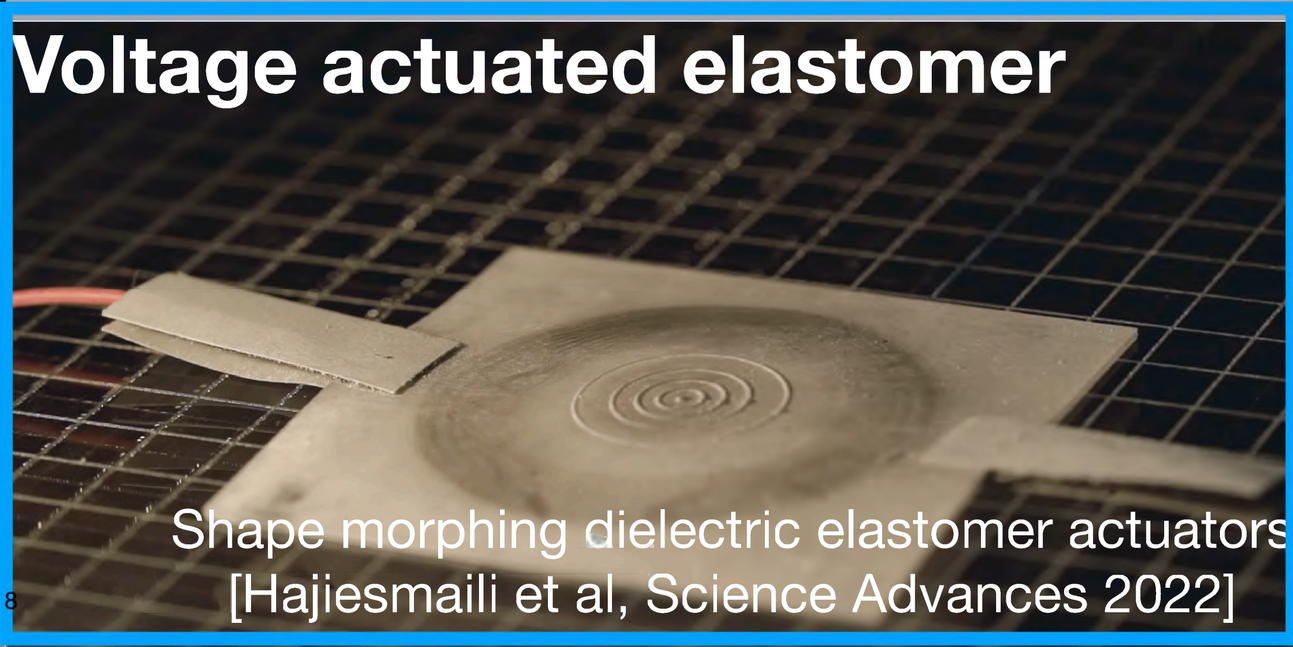
Humidity actuated hydrogel

Shape morphing hydrogel films
[Hu et al, Research 2021]

Heat actuated fabric

Active Textile Fabrics
[Pedro E. S et al, Advanced materials 2023]

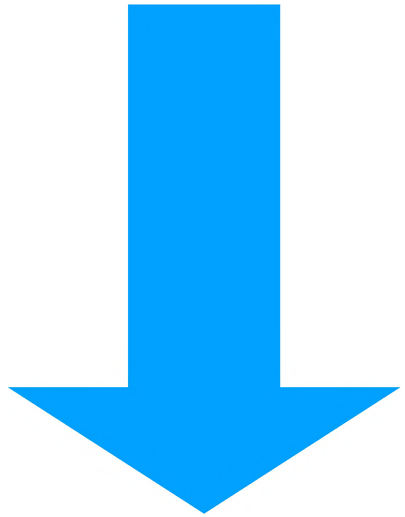
Voltage actuated elastomer



Shape morphing dielectric elastomer actuators
[Hajiesmaili et al, Science Advances 2022]

Programmable soft materials

Programmable soft materials



Shape-changing UIs

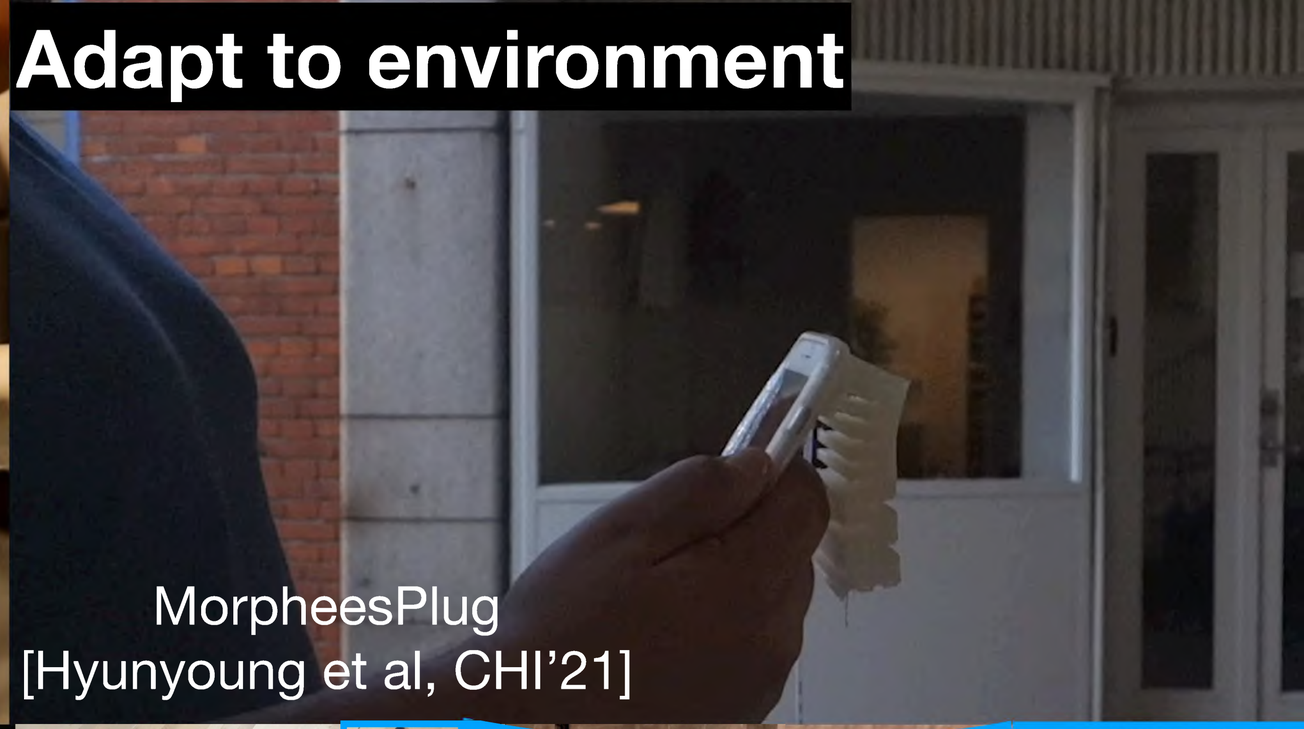
Adapt to users

ambienBeat
[Choi et al, TEI’ 20]

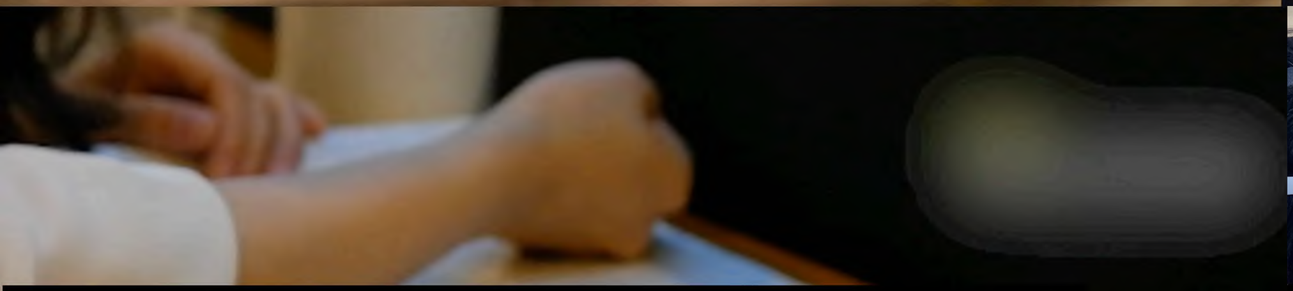
Adapt to task

PneUI
[Yao et al, UIST'13]

Adapt to environment



MorpheesPlug
[Hyunyoung et al, CHI'21]

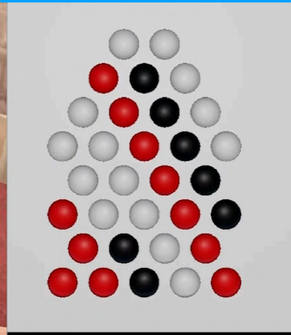


Communication information

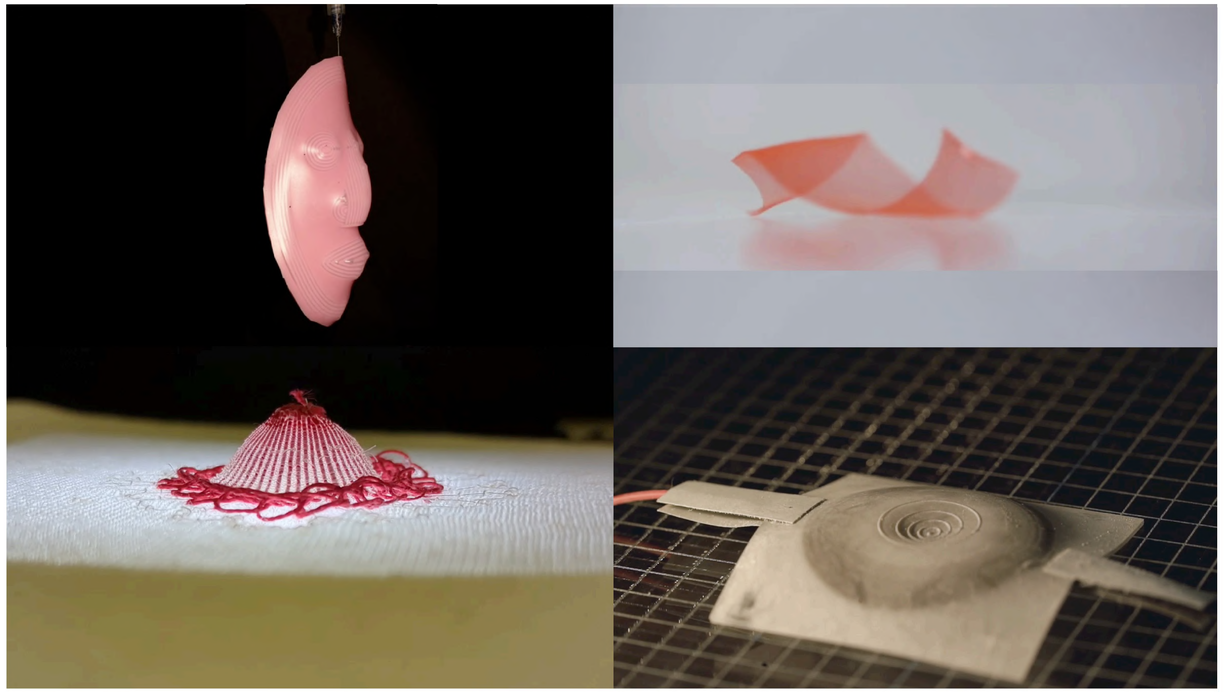
MorpheesPlug
[Hyunyoung et al, CHI'21]

Simulate objects

Fluid Reality
[Shen et al, UIST'23]

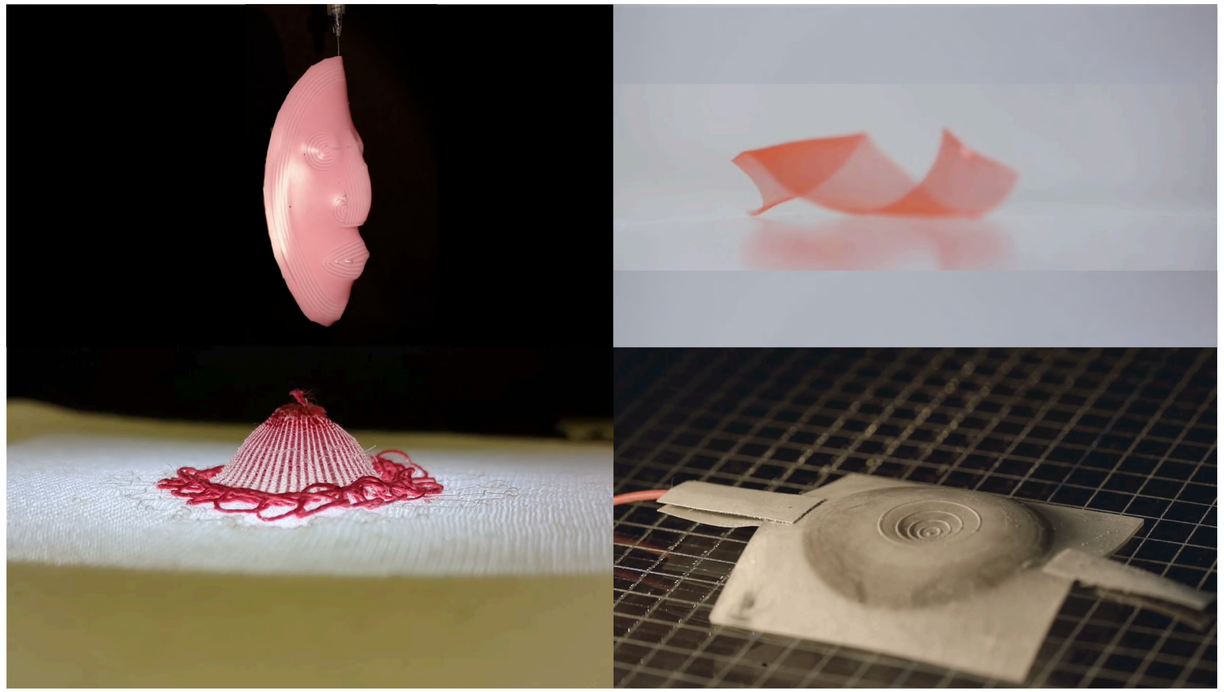


Programmable soft materials



Shape-changing UIs

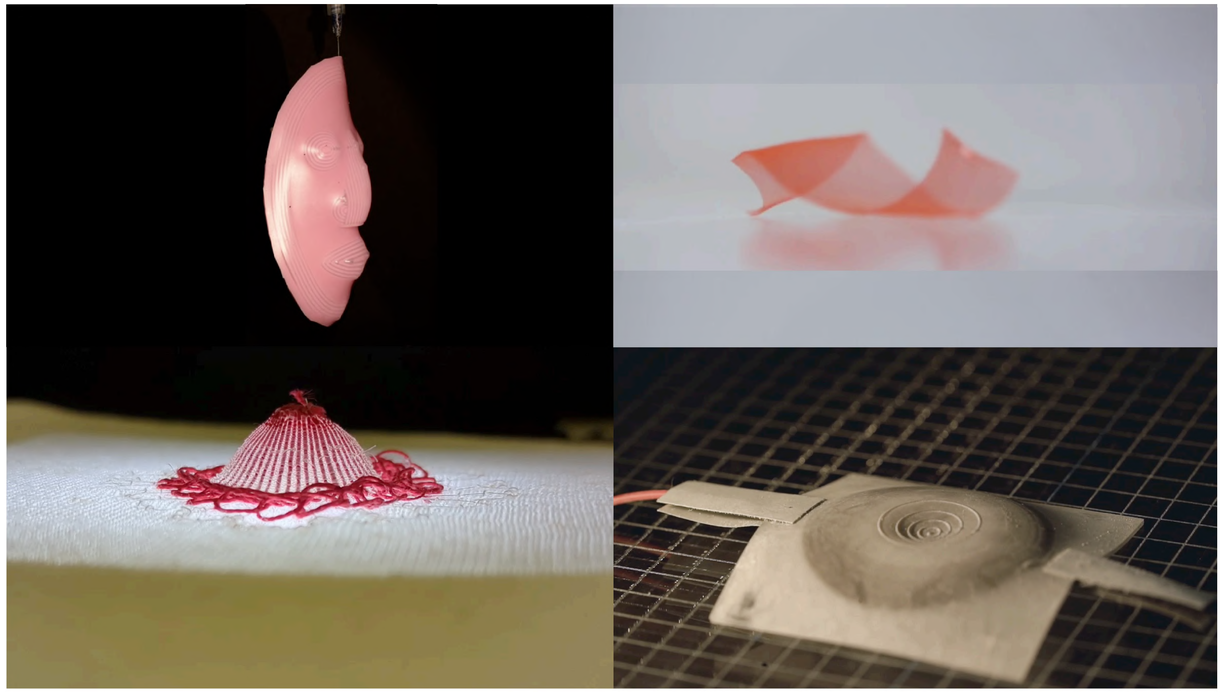
Programmable soft materials



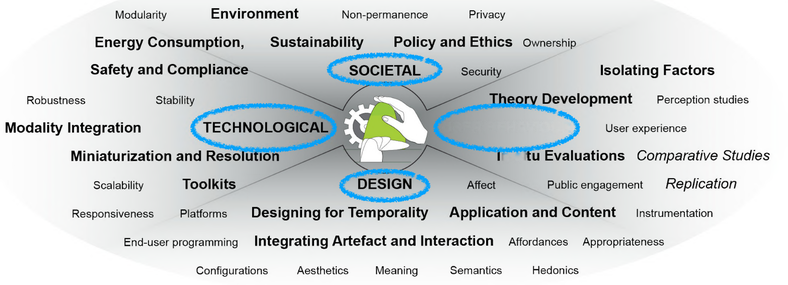
Shape-changing UIs

Challenges

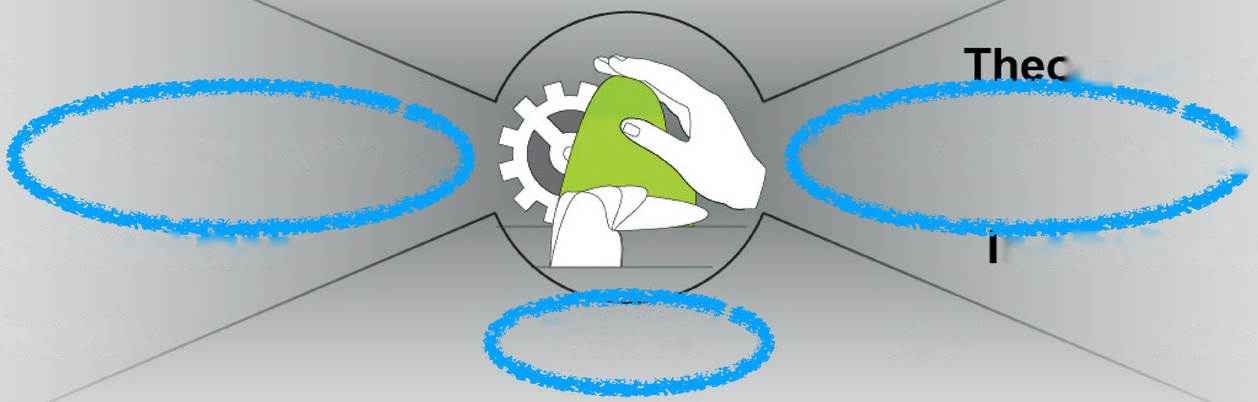
Programmable soft materials

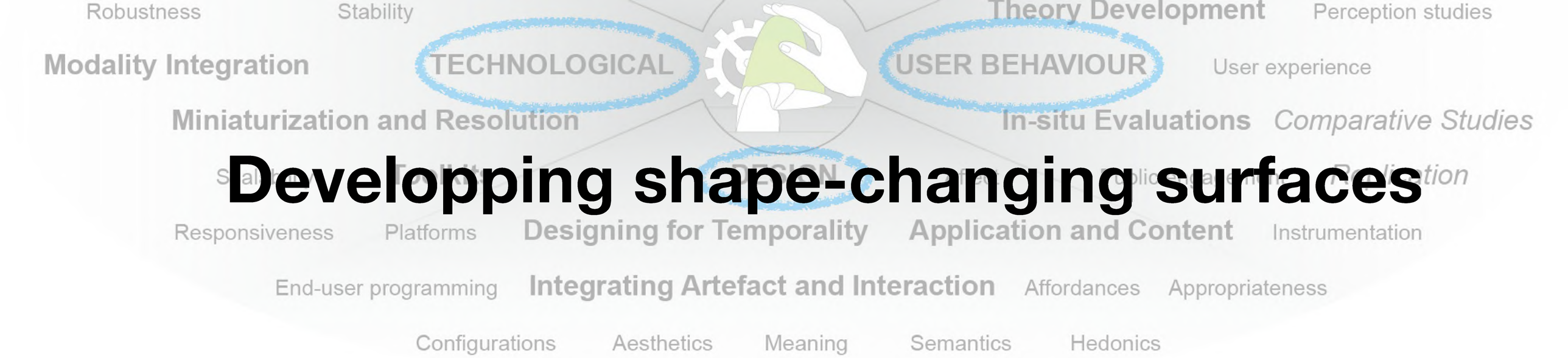


Shape-changing UIs



Grand Challenges
[Alexander et al, CHI'18]


Thec



Developping shape-changing surfaces

Other interaction information beyond shapes?

Developping shape-changing surfaces

+

Other interaction information beyond shapes?


Thec
I

Introduction

Technological explorations

User perception study

New device design

Interaction beyond shapes

Challenges and future work

Technological explorations

User perception study

New device design

Interaction beyond shapes

Challenges and future work

Technological explorations

User perception study

New device design

Interaction beyond shapes

Challenges and future work

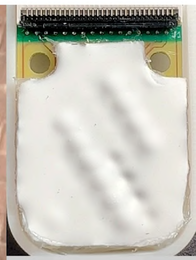
Technological explorations

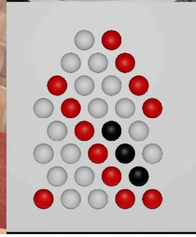
Programmable soft **materials**

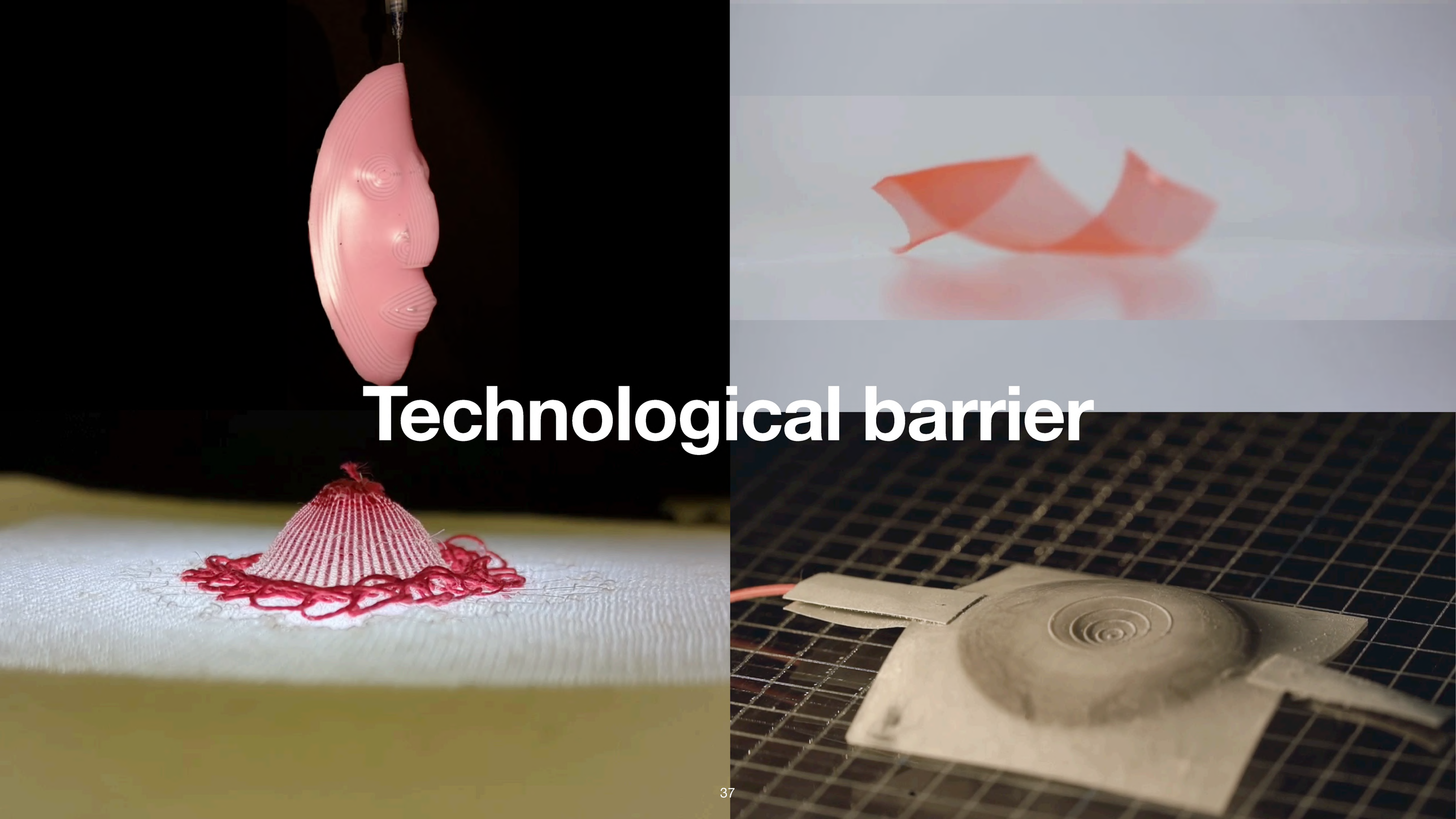
for **different shape-changing** UIs

Novel technology **addressing limits** of **current** programmable soft **materials**

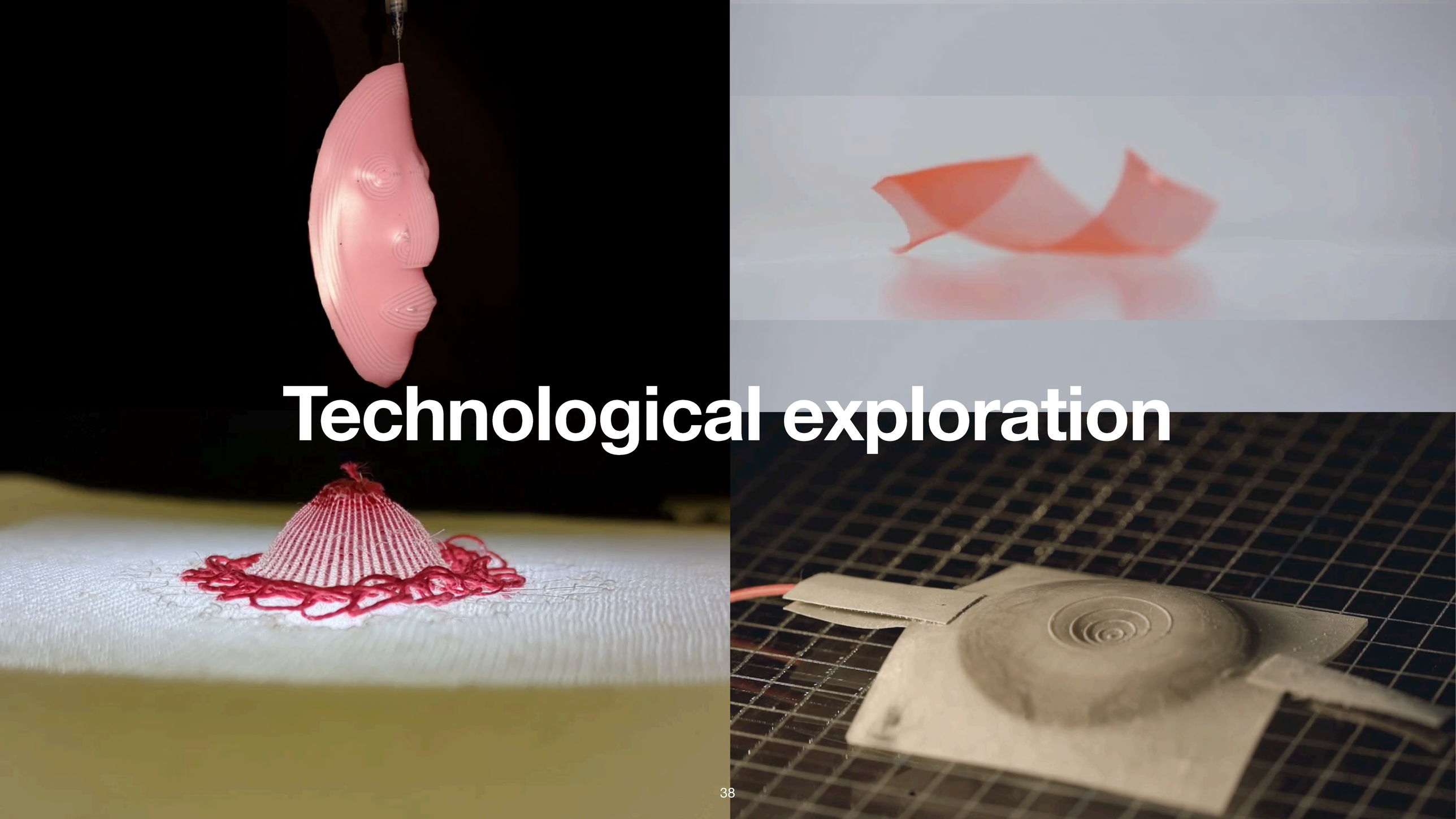
Proof of concept prototypes







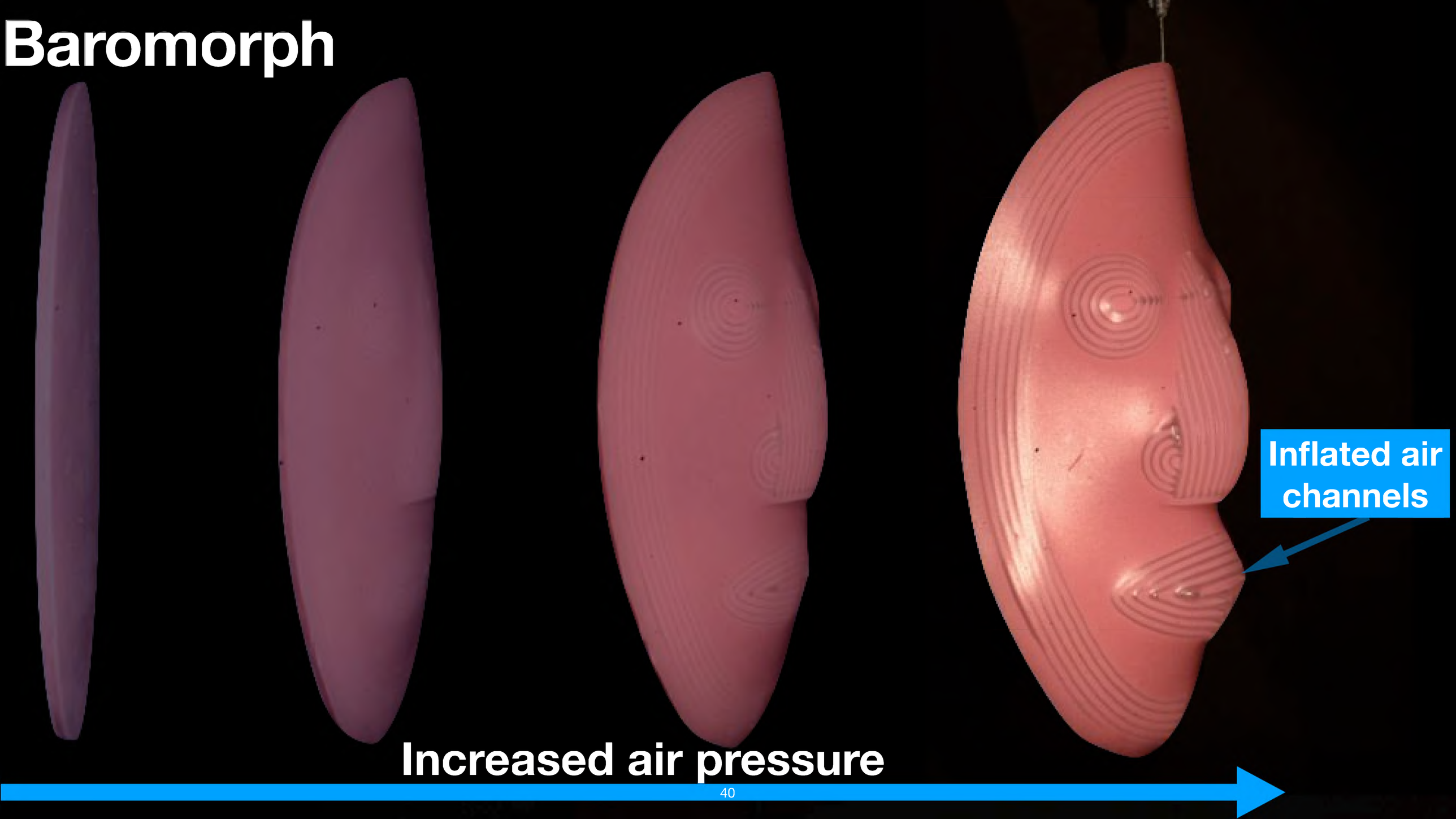
Technological barrier



Technological exploration

Baromorph
[Siéfert et al, Nature Materials 2019]

Baromorph



Advantages

Soft

Safe

Rapid actuation

High shape-changing potential

Advantages

Soft

Safe

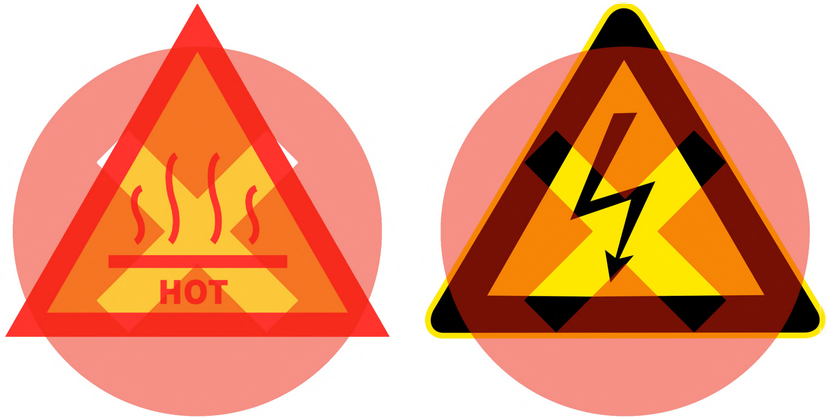
Rapid actuation

High shape-changing potential

Advantages

Soft

Safe



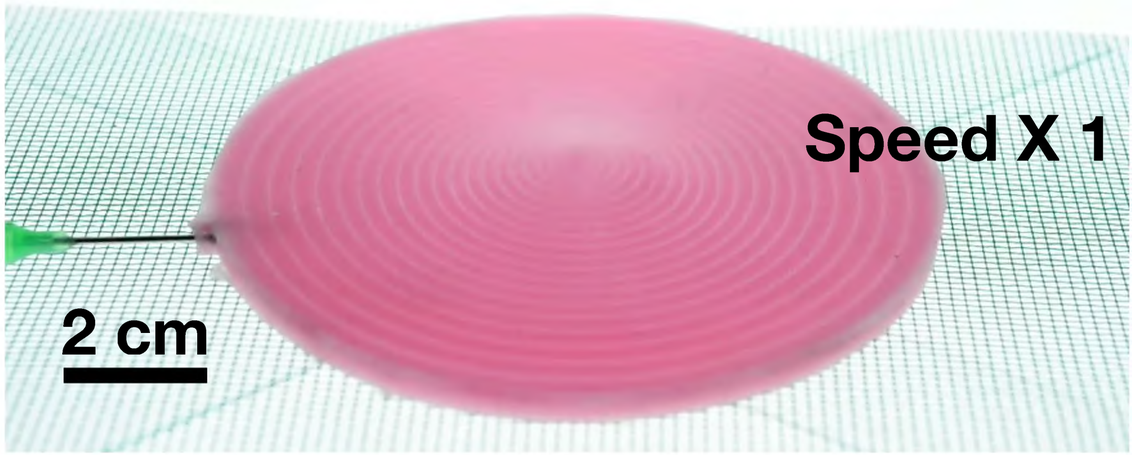
Rapid actuation

High shape-changing potential

Advantages

Soft

Safe



Rapid actuation

High shape-changing potential

Advantages

Soft

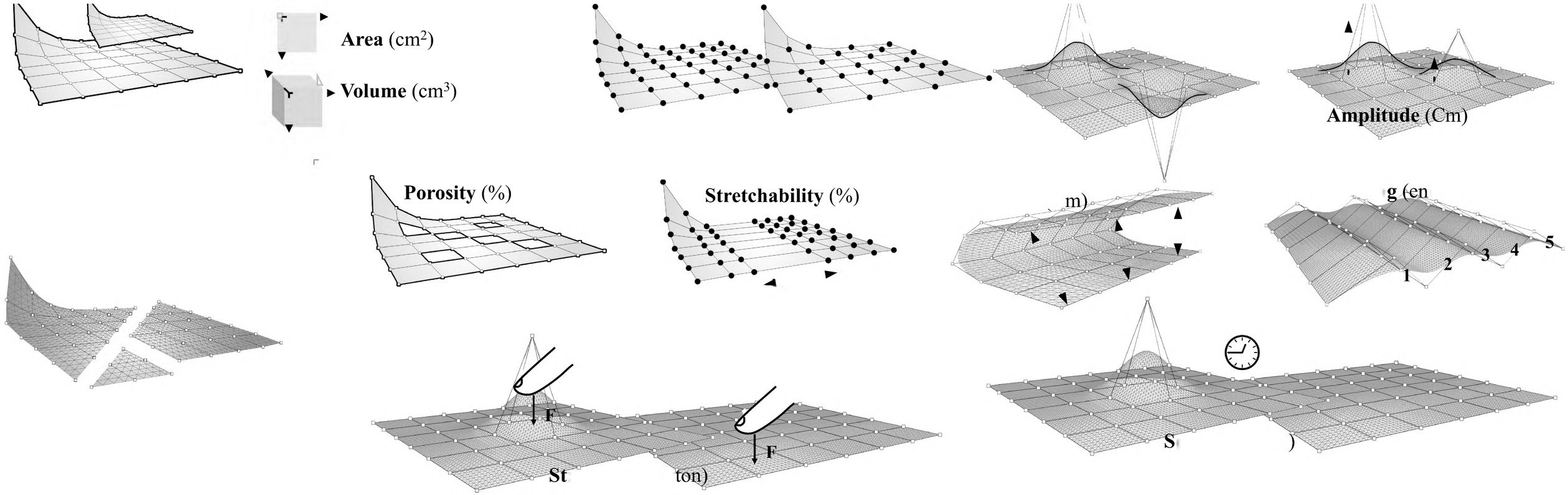
Safe

Rapid actuation

High shape-changing potential

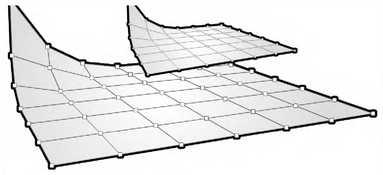
What shape-changes?

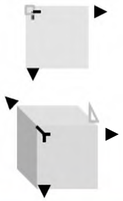
UIs' different shape-changes



Morphees+
[Kim et al, CHI'18]

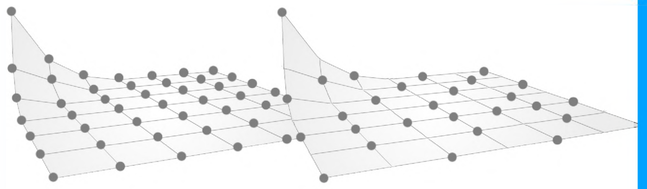
SoftMorphees

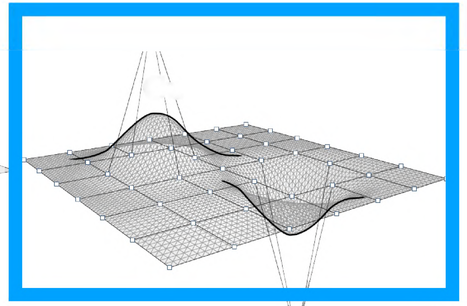


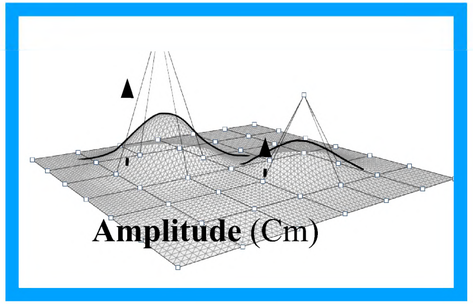


Area (cm^2)

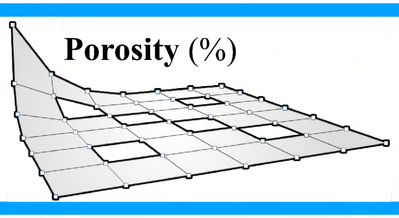
Volume (cm^3)



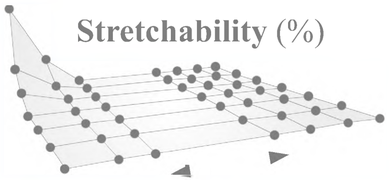




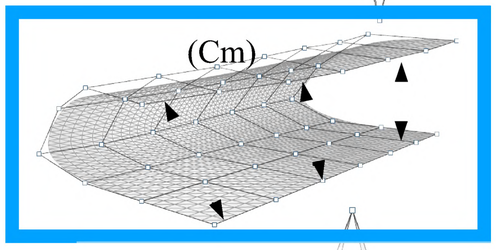
Amplitude (Cm)



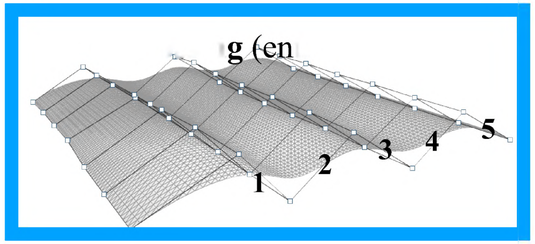
Porosity (%)



Stretchability (%)

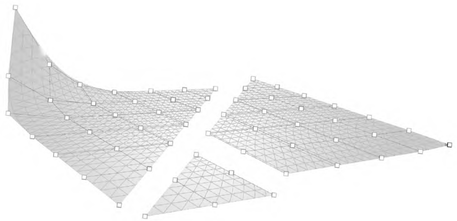


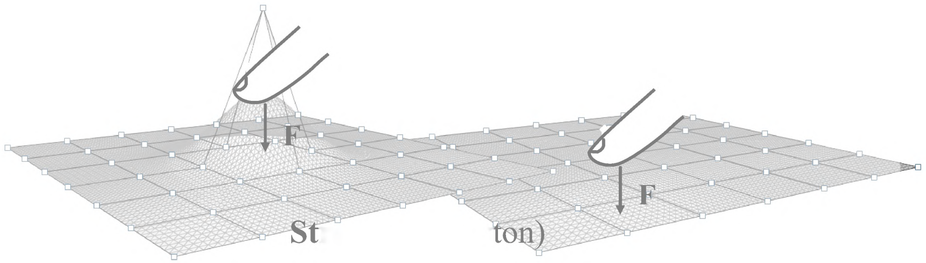
(Cm)



g (en

1 2 3 4 5



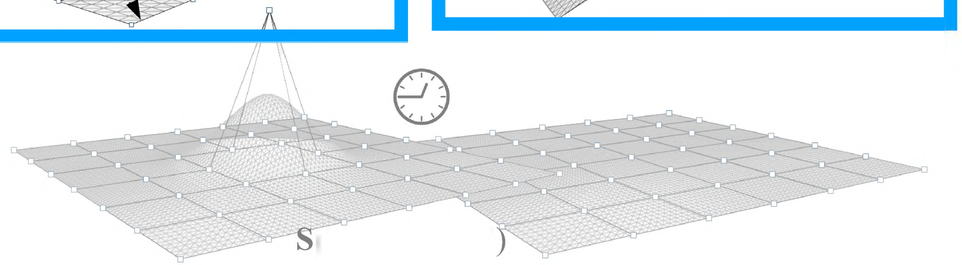


F

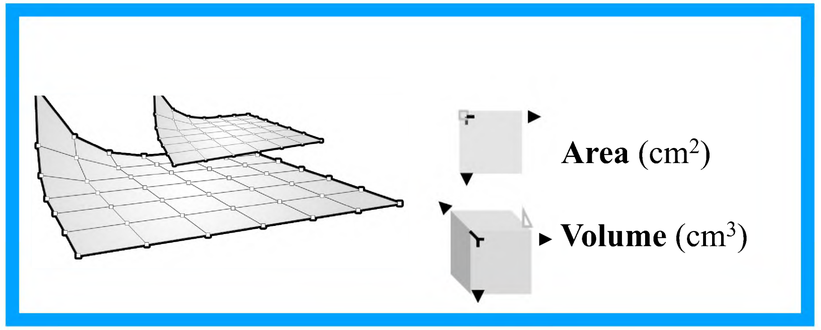
St

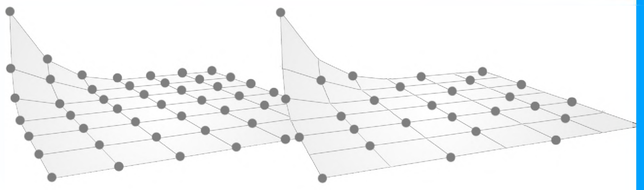
ton)

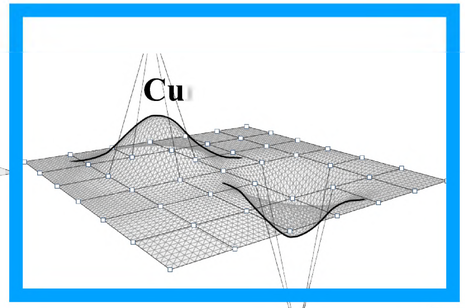
F

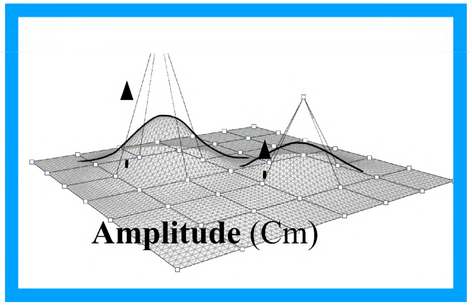


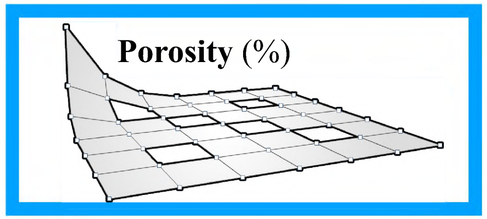
S)

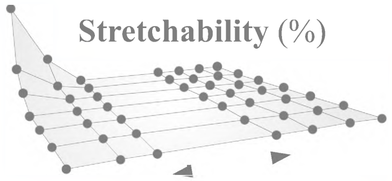


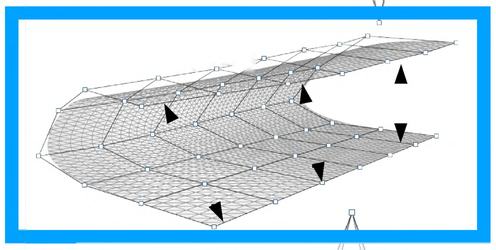


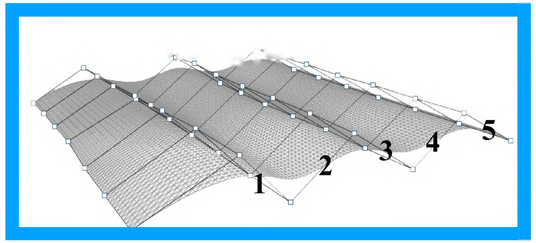


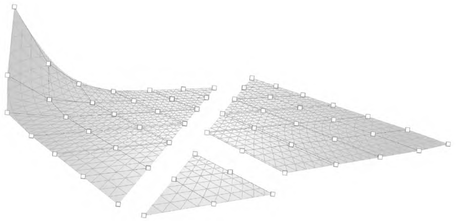


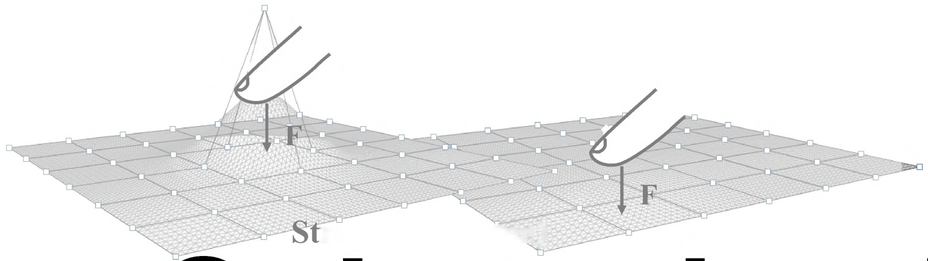


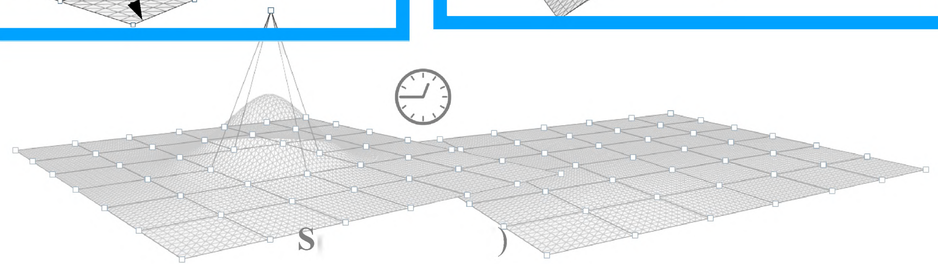






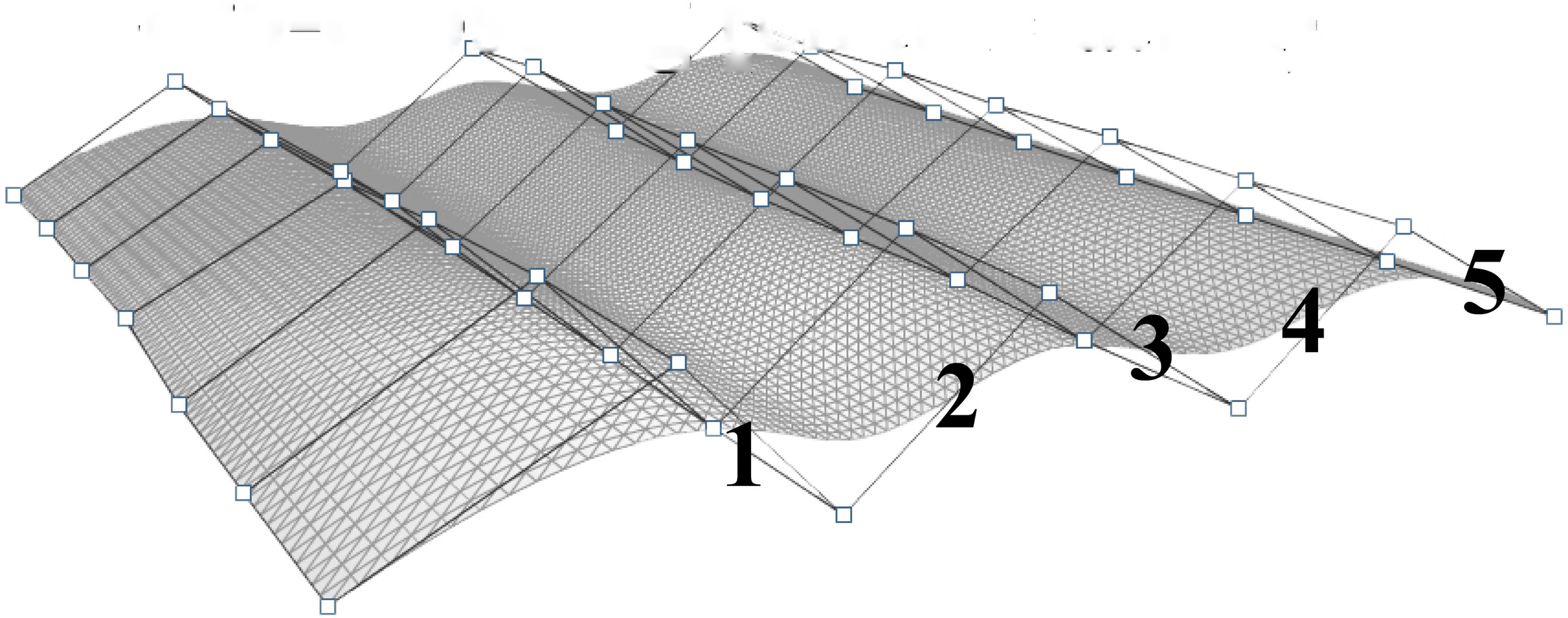




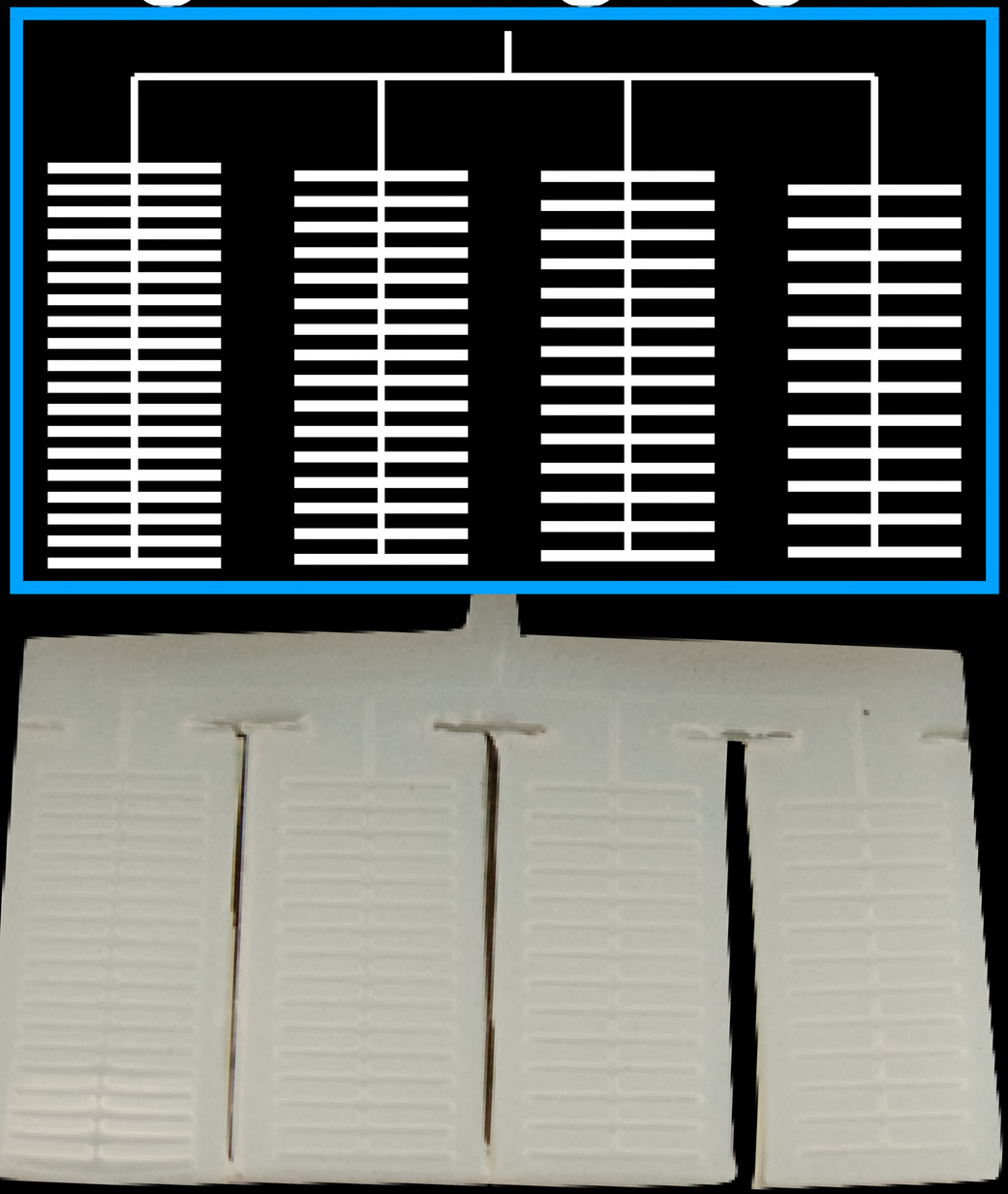


Only technology

to create **all these** six **shape-changing** features using **soft** materials


1
2
3
4
5

Zero-crossing changing module



10mm

Zero-crossing changing module

0 Psi

Side view:

Zero-crossing: 0

10mm

Above view:

Zero-crossing changing module

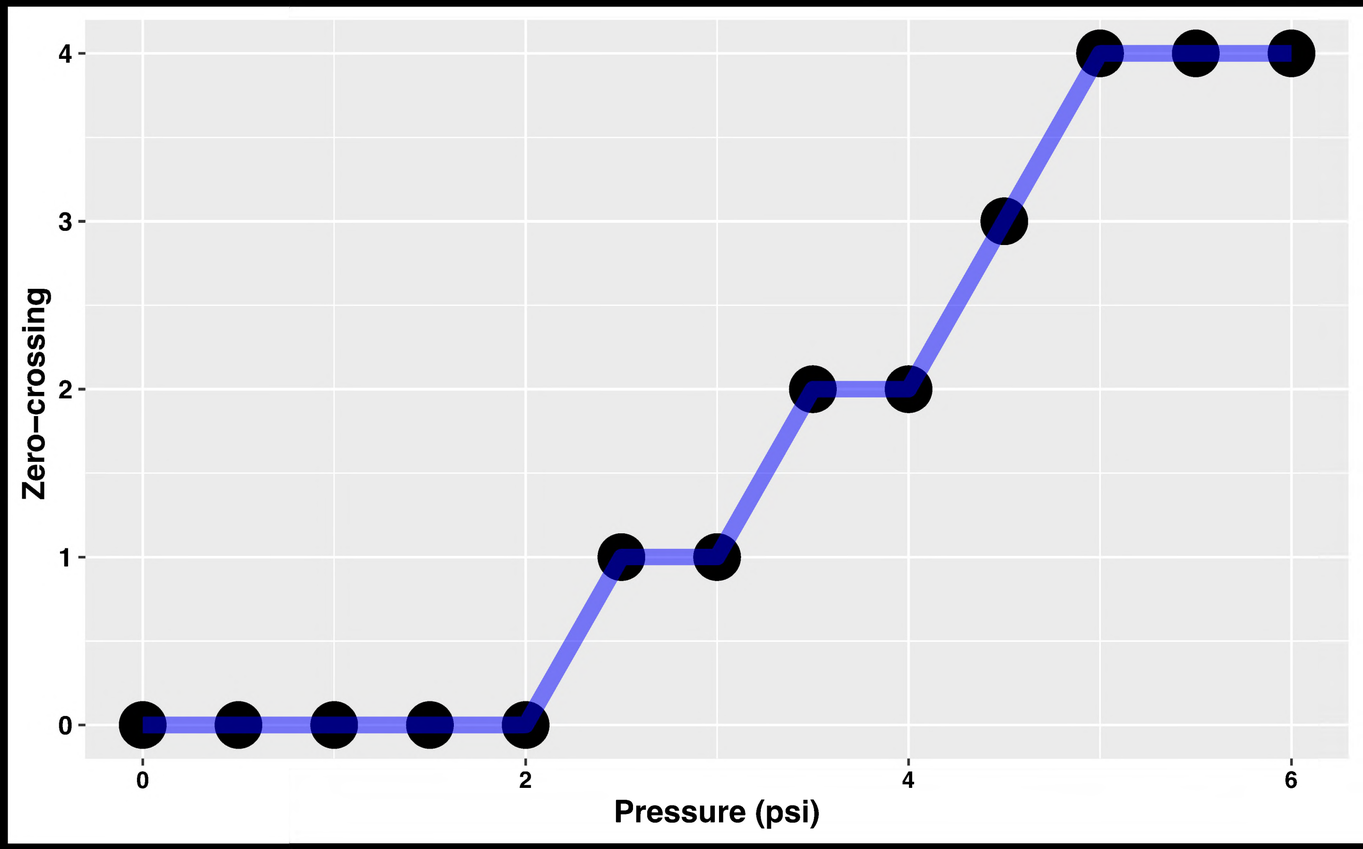
0 Psi

Side view:

Zero-crossing: 0

10mm

Above view:



SoftMorphees

Size

Curvature

Amplitude

Porosity

Closure

Zero-crossing

Technological explorations

Programmable soft **materials**

for **different shape-changing** UIs

Novel technology **addressing limits** of **current** programmable soft **materials**

A significant **drawback** of **elastomers**,

particularly for **shape-change**,

is the **trade-off** between **stretchability** and **strength**.

HCI meets Material Science
[Qamar et al, CHI'18]

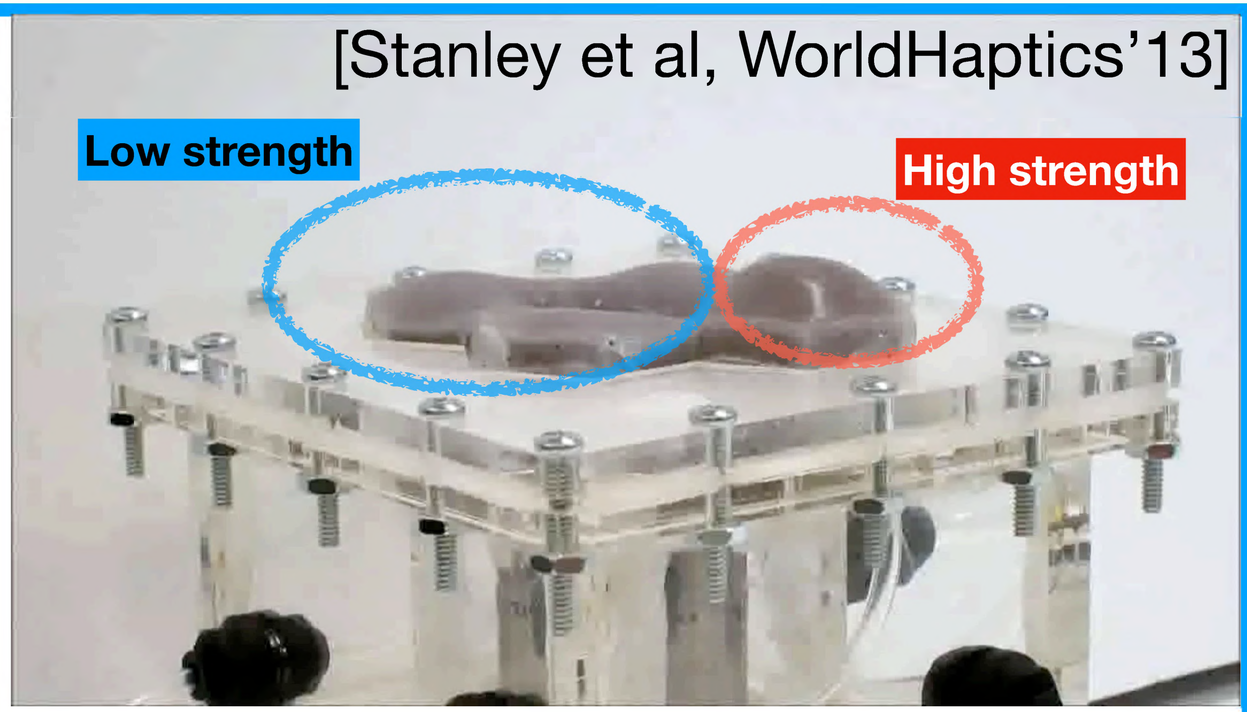
Stretchability-strength trade-off of elastomers

High stretchability

Low strength

Stretchability-strength trade-off of elastomers

High stretchability



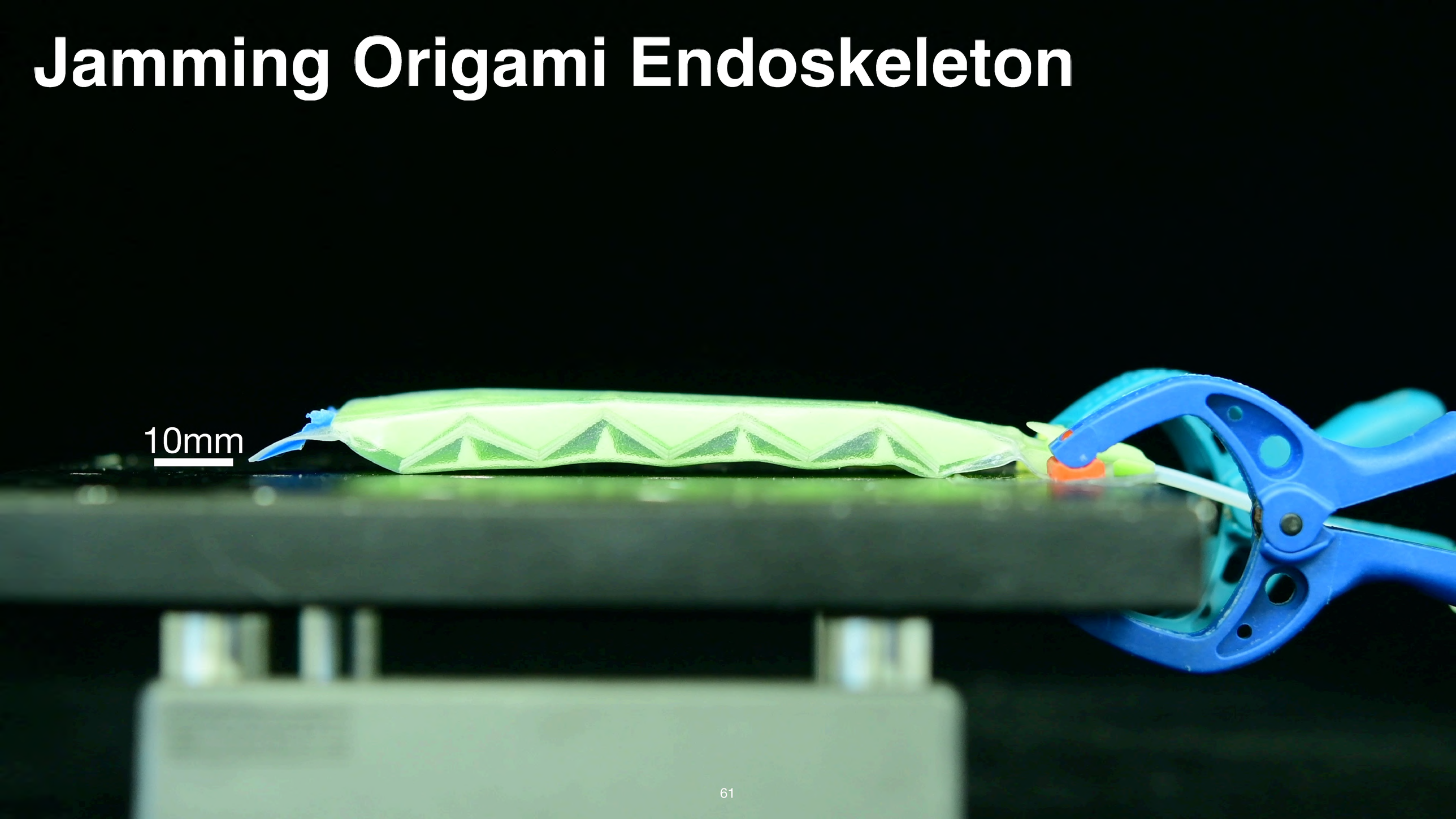
Low strength

Enhance the **strength**

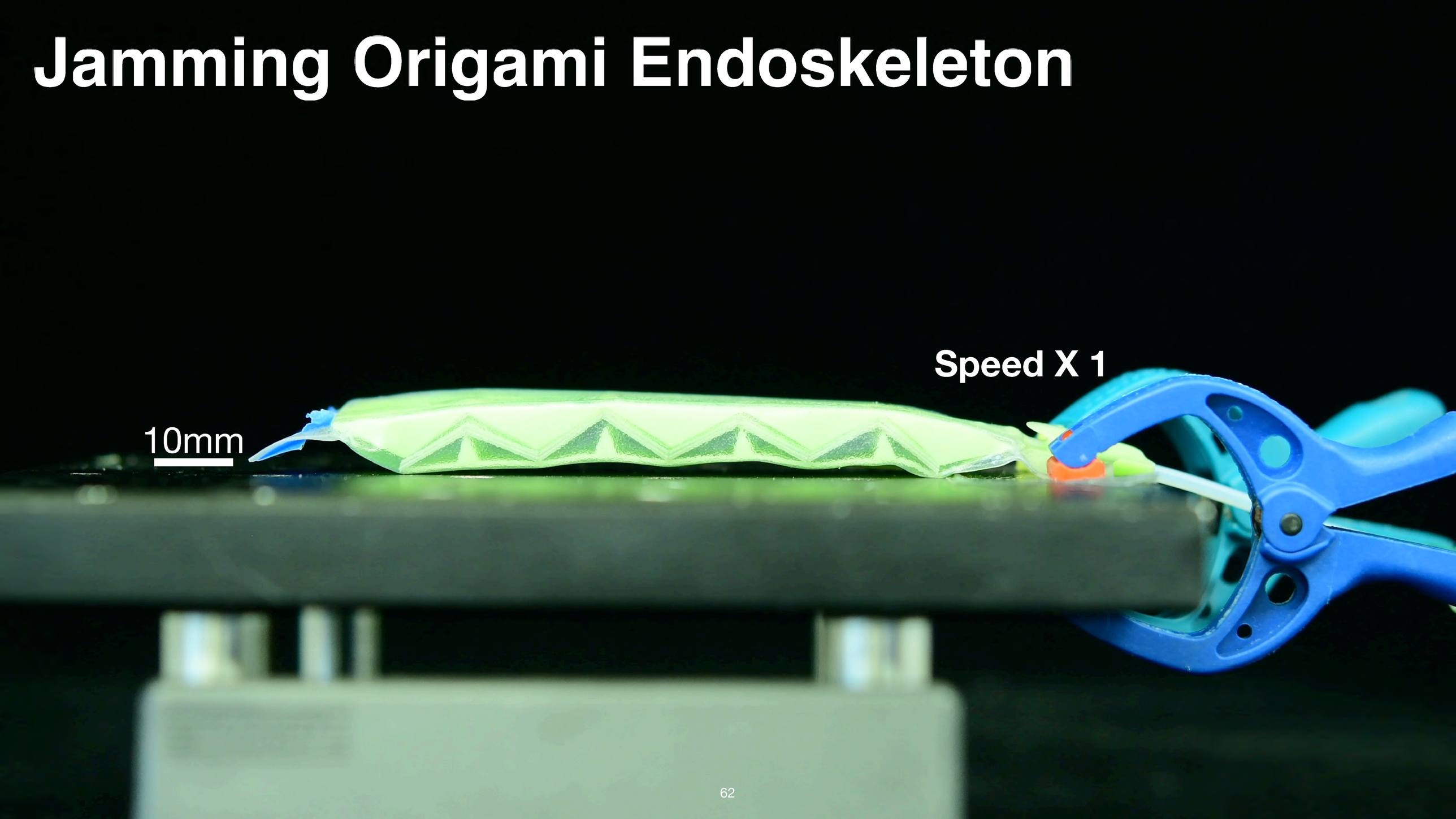
of **UIs** made of **soft materials**

Jamming Origami Endoskeleton

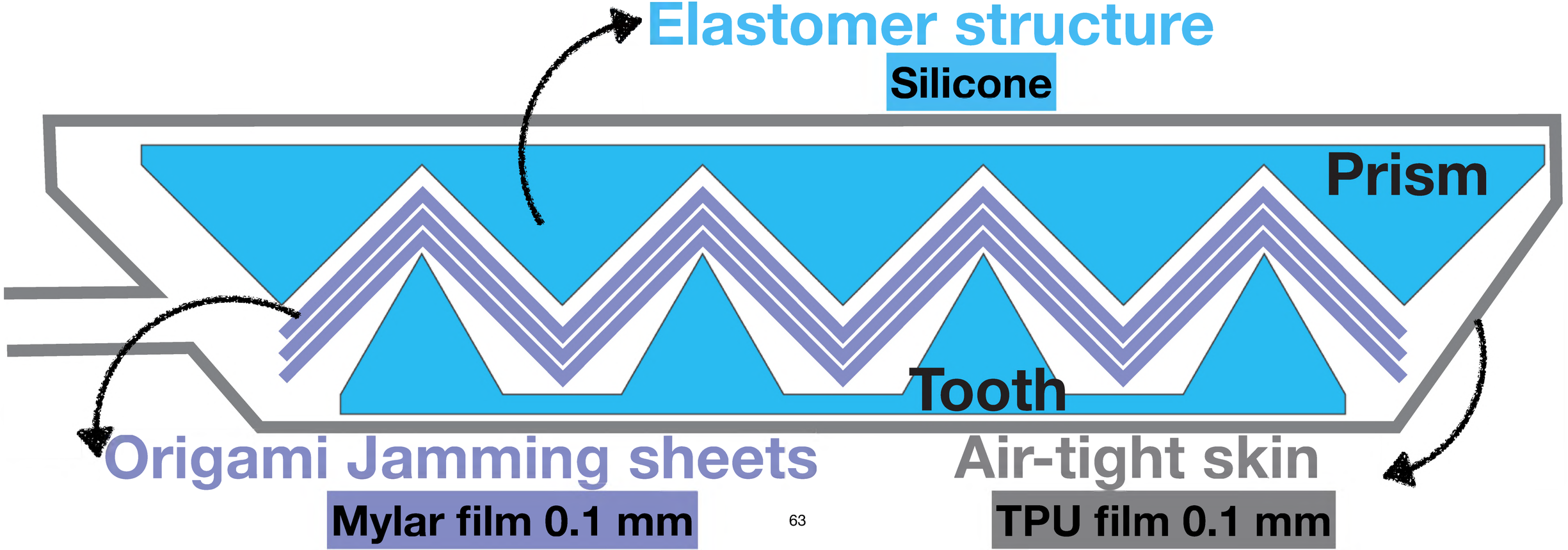
Jamming Origami Endoskeleton



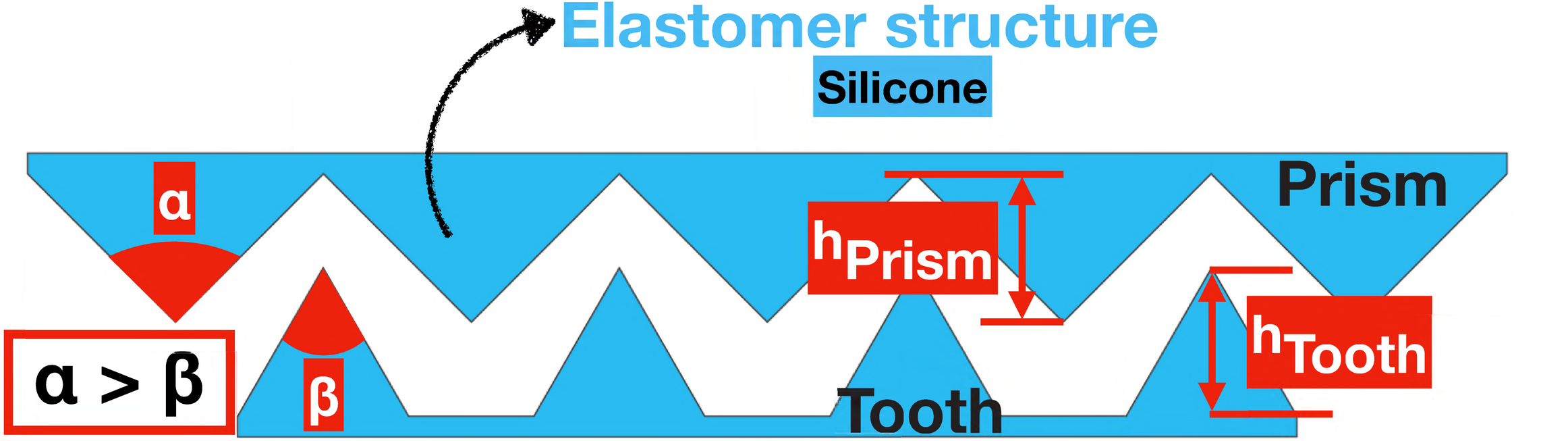
Jamming Origami Endoskeleton



Jamming Origami Endoskeleton



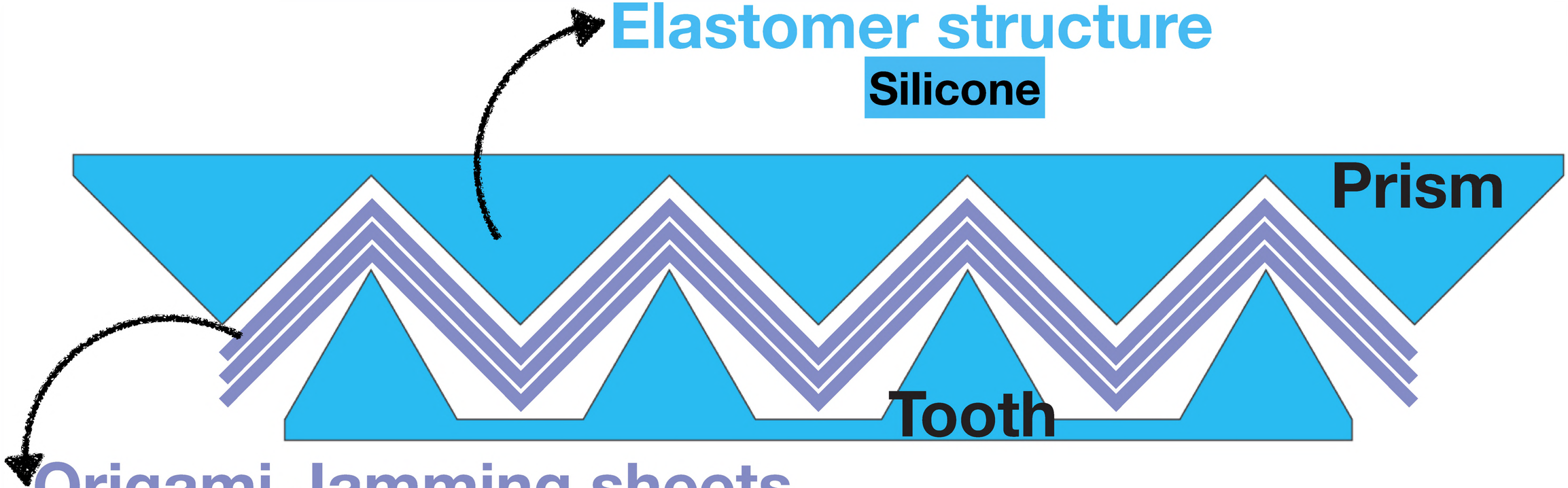
Jamming Origami Endoskeleton



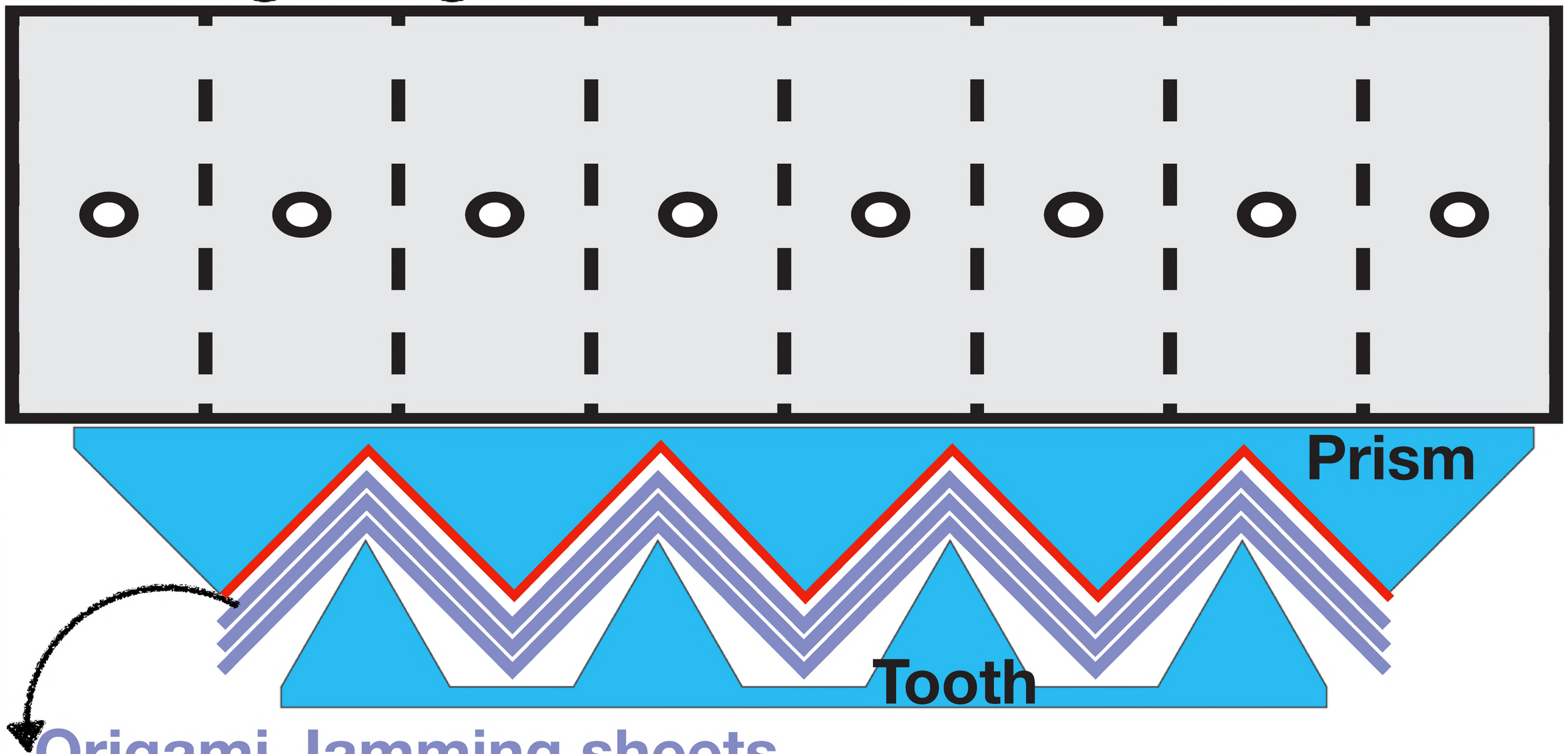
Imcompatible shapes

$h_{Prism} > h_{Tooth}$

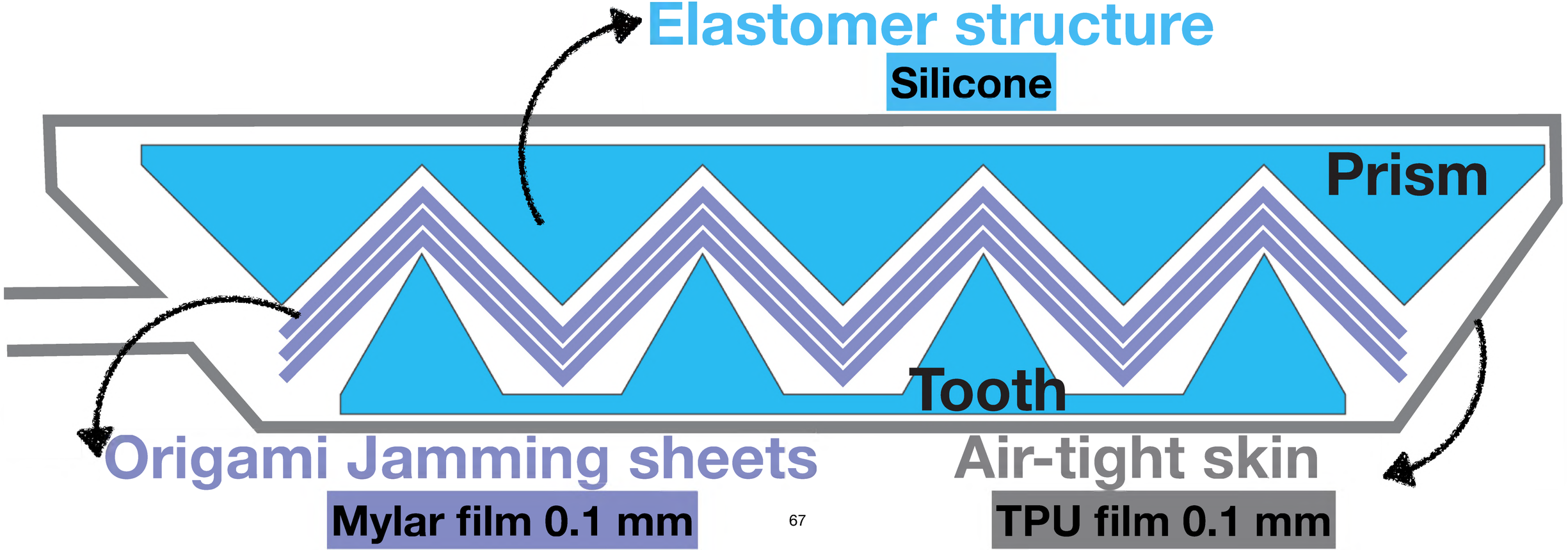
Jamming Origami Endoskeleton



Jamming Origami Endoskeleton

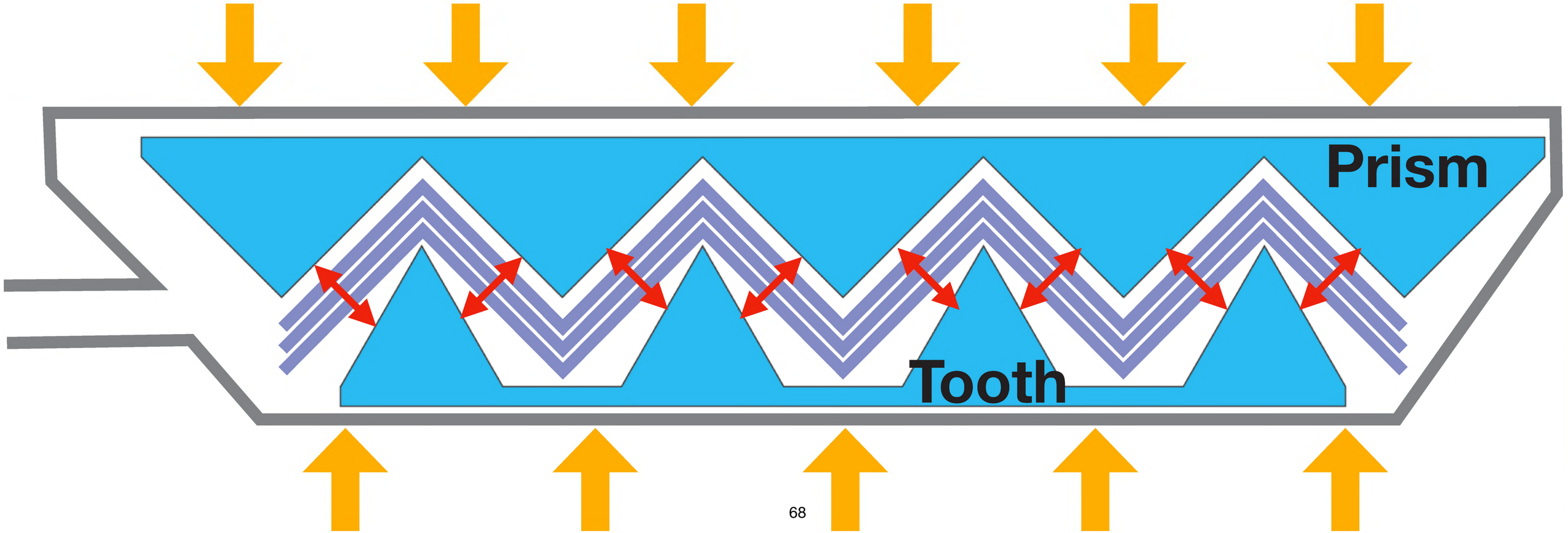


Jamming Origami Endoskeleton



Jamming Origami Endoskeleton

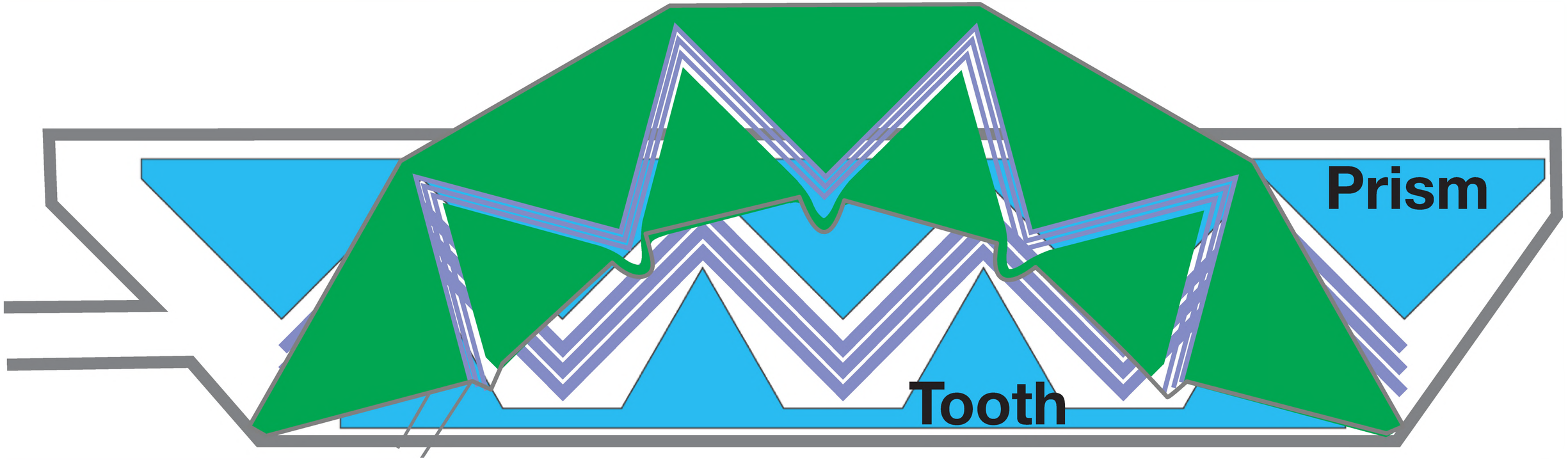
Atmosphere



Jamming Origami Endoskeleton

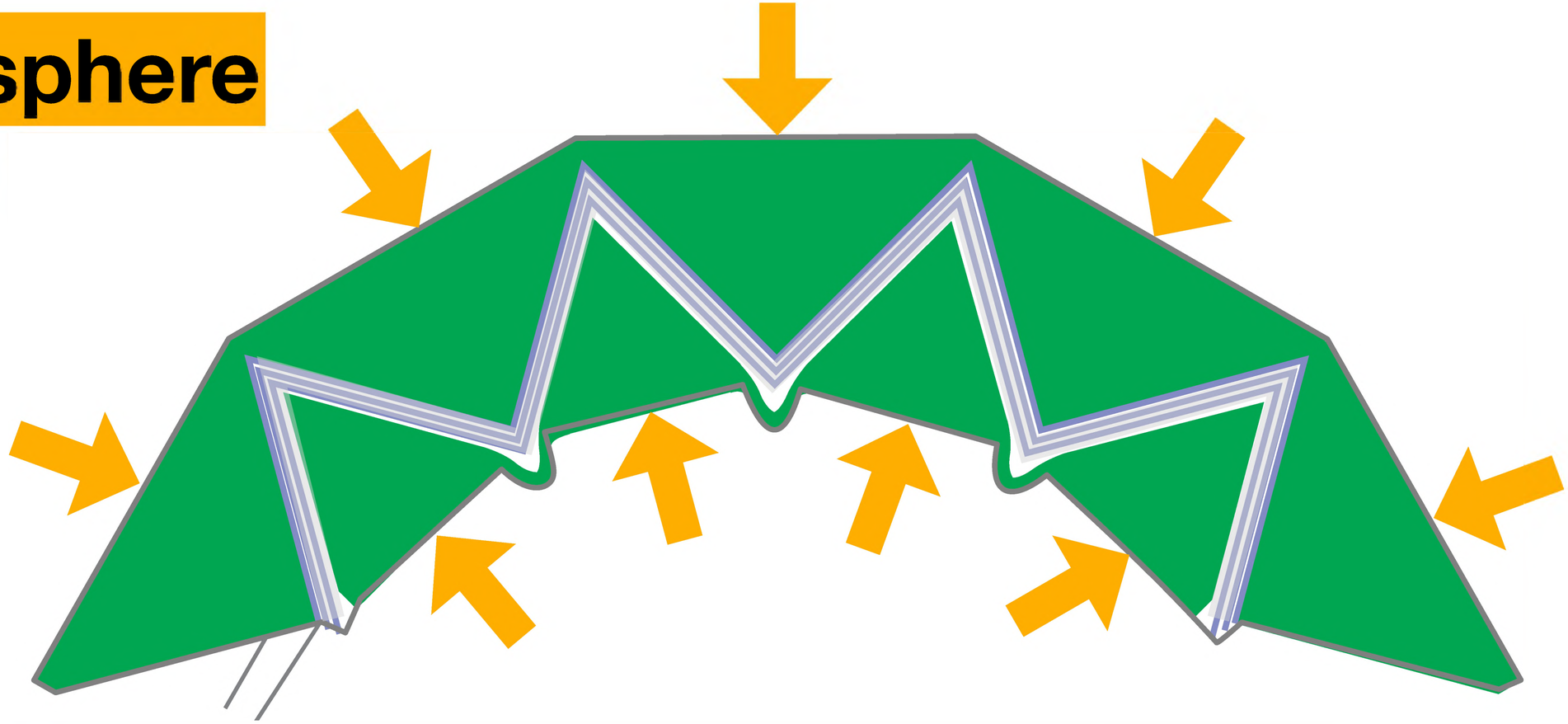
Atmosphere

Curvature



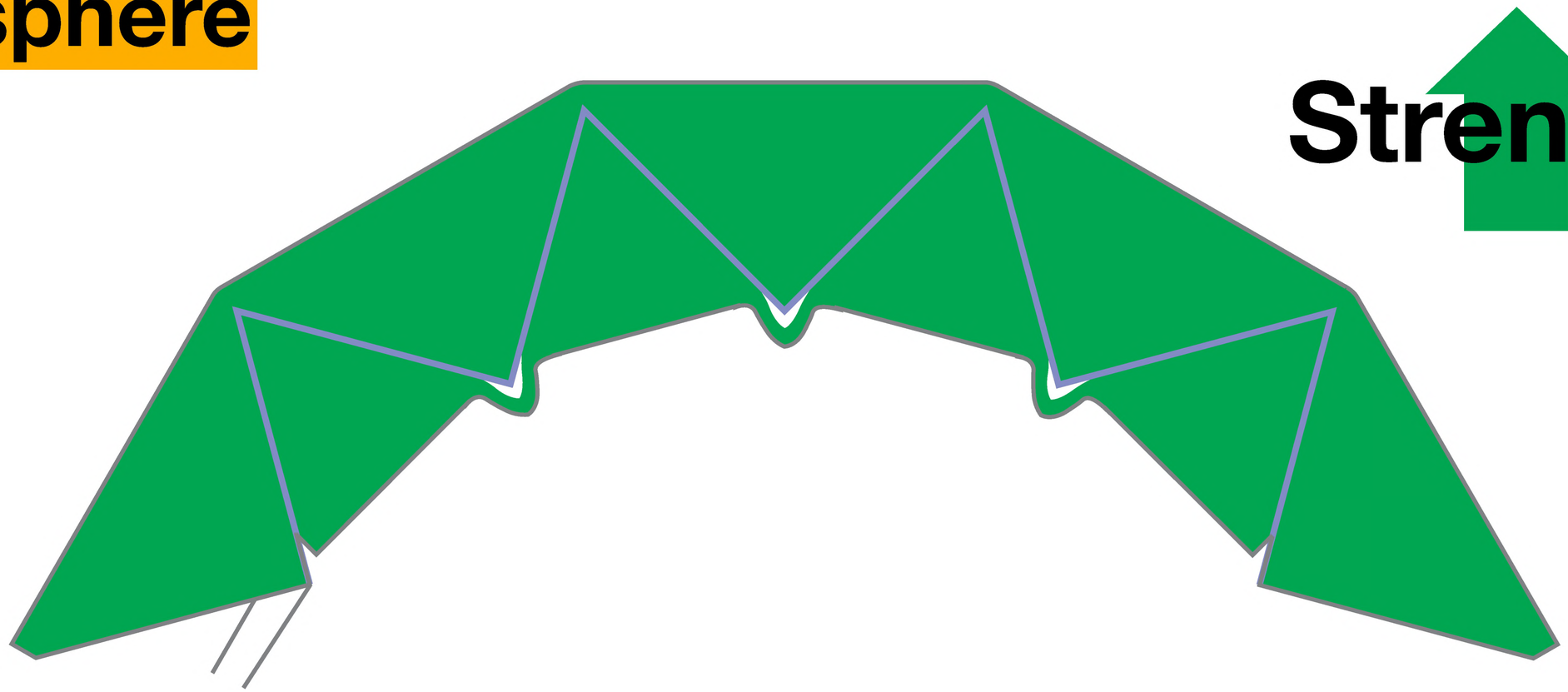
Jamming Origami Endoskeleton

Atmosphere



Jamming Origami Endoskeleton

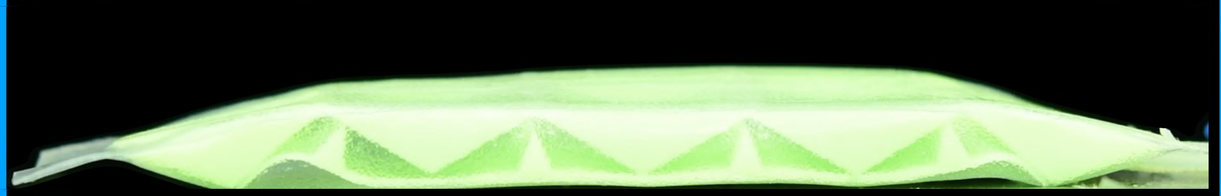
Atmosphere

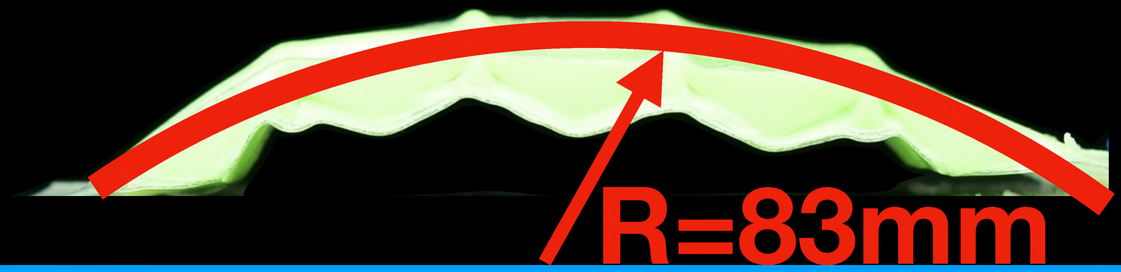


Strength

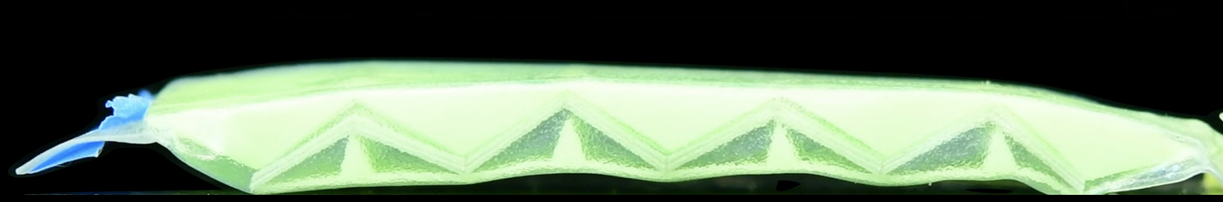
Improved curvature change

Without Jamming layers

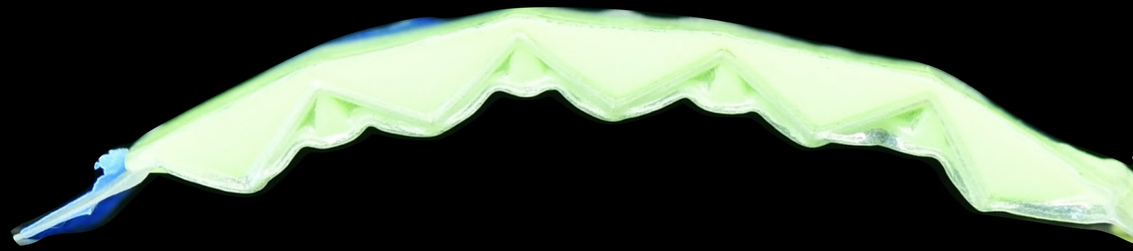




With Jamming layers

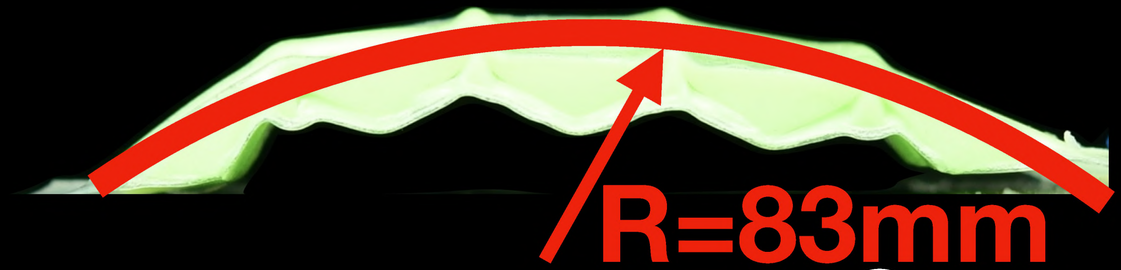


Air vacuumed

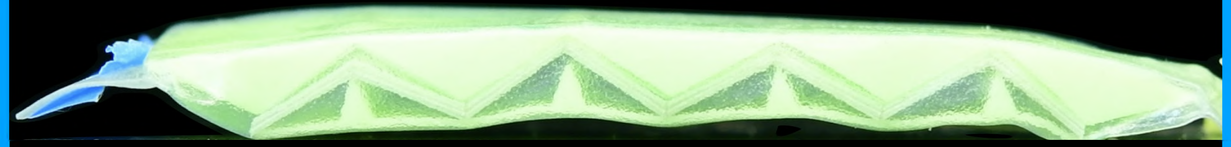


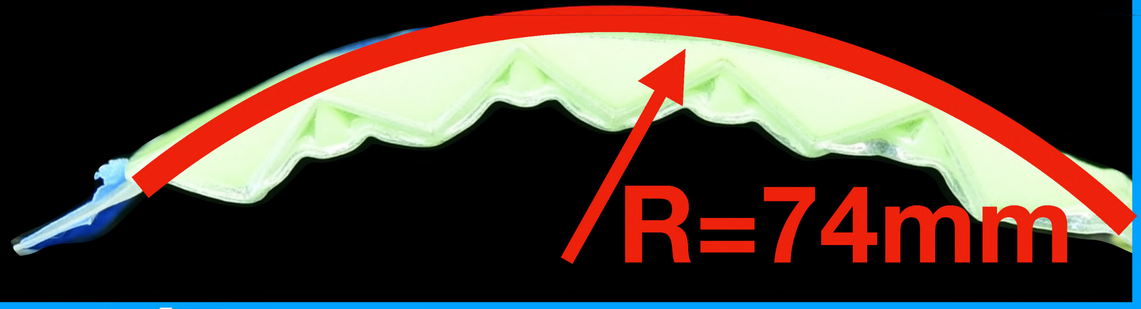
Improved curvature change

Without Jamming layers



With Jamming layers





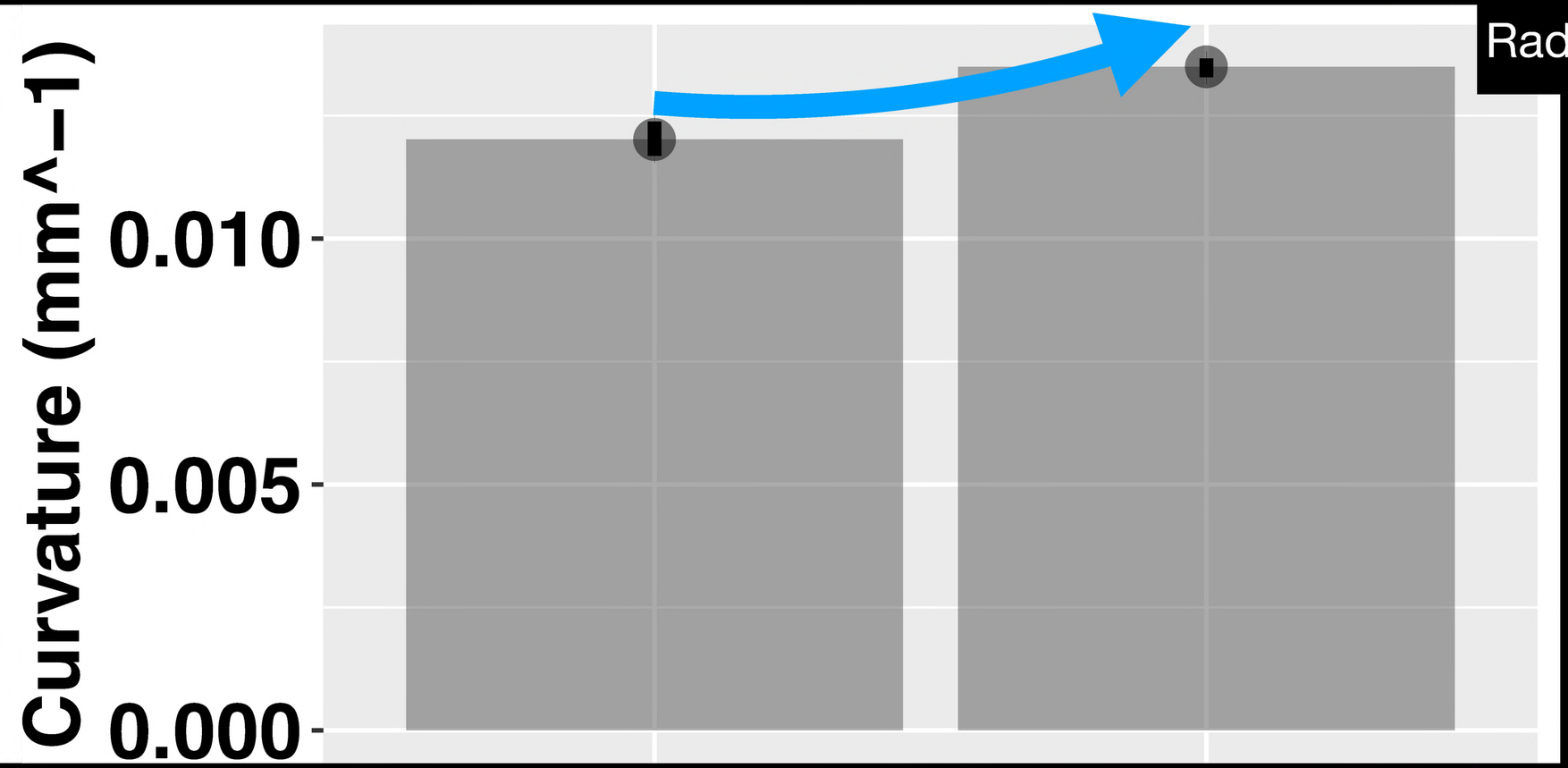
Air vacuumed

Curvature= 1/R

Improved curvature change

Increases by **12 %**

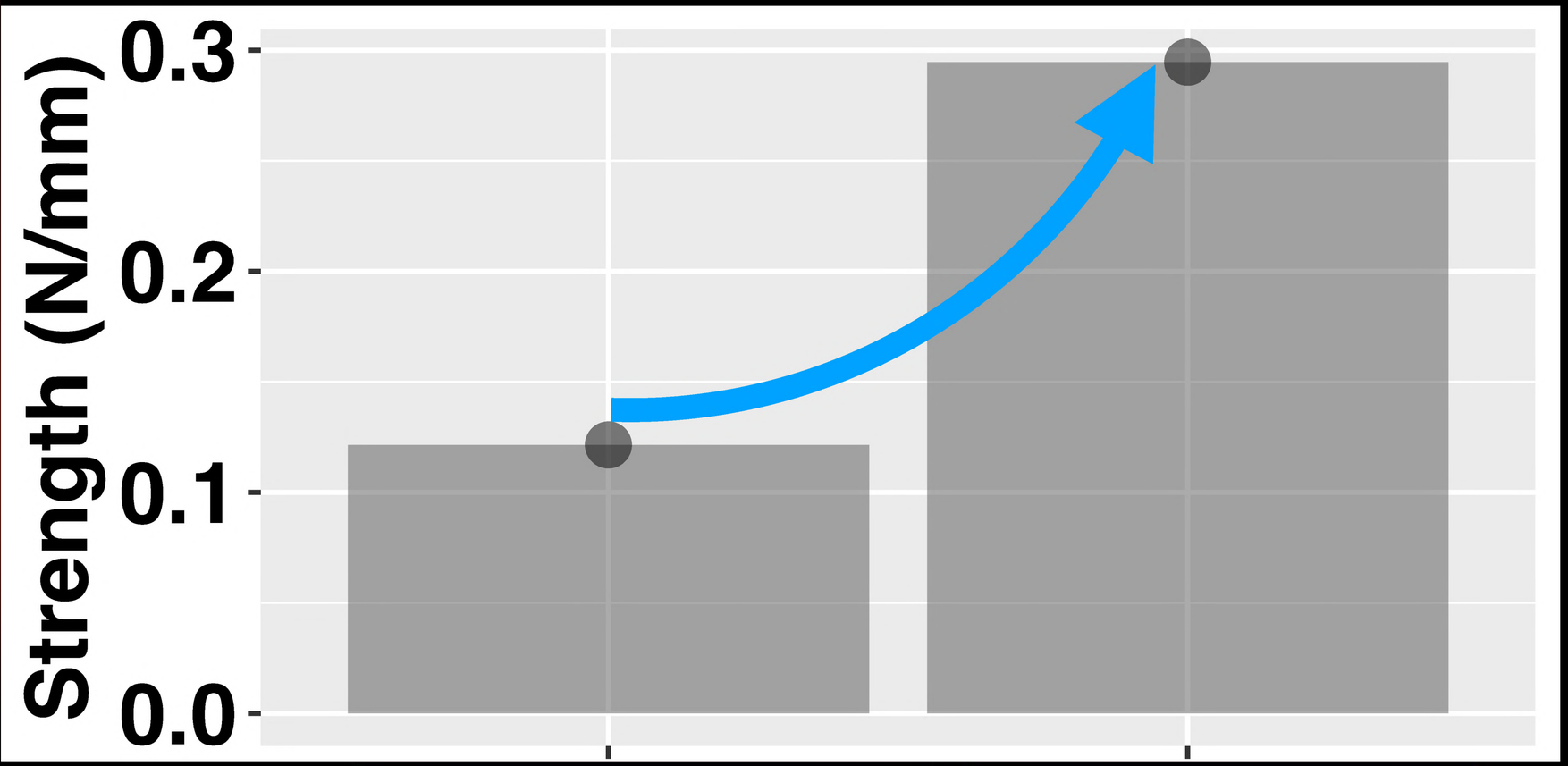
Radius from **83 mm** to **74 mm**



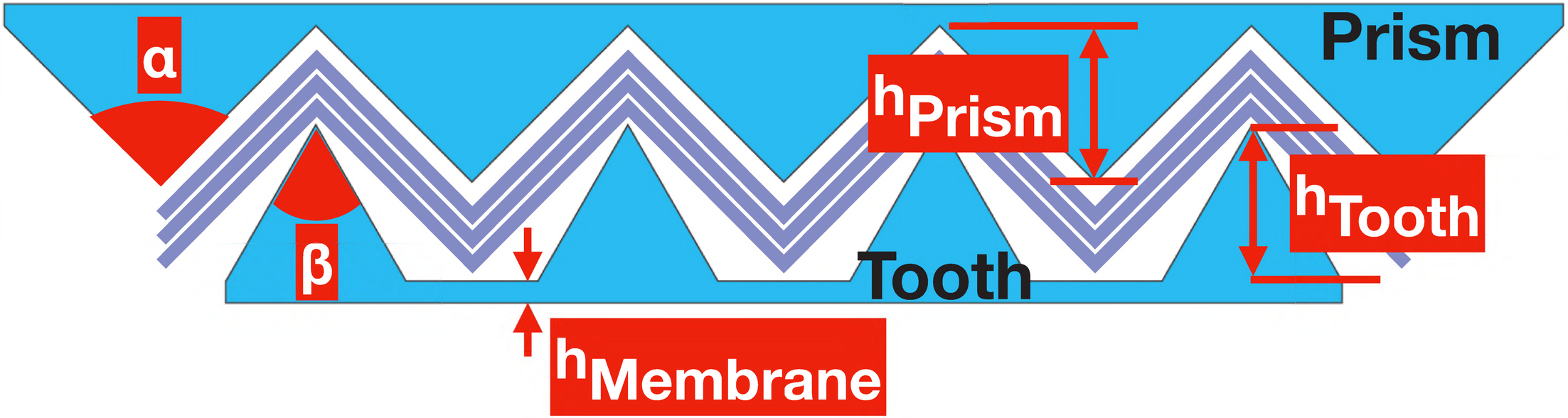
Enhanced strength

Increases by **150 %**

from 0.12 N/mm to 0.3 N/mm



Design Parameters



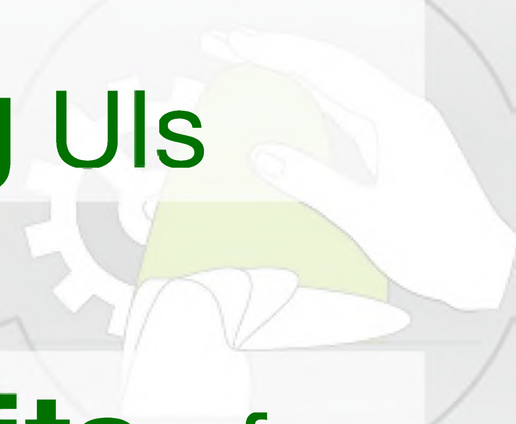
- $\Delta_{Thickness} = h_{Prism} - h_{Tooth}$
- $\Delta_{Angle} = \alpha - \beta$
- h_{Prism}
- $h_{Membrane}$
- Pressure


Modularity
Environment
Non-permanence
Energy Consumption,
Sustainability
Polic
Safety and Compliance
SOCIETAL
Robustness
Stability
Modality Integration
TECHNOLOGICAL
Miniaturization and Resolution
Scalability
Toolkits
DESIGN
Responsiveness
Platforms
Designing for Temporality

Technological explorations

Programmable soft **materials**

for **different shape-changing** UIs



Novel technology **addressing limits** of **current** programmable soft **materials**

Technological explorations

Lower technological barrier

Novel technology **addressing limits** of **current** programmable soft **materials**

Technological explorations

Lower technological barrier

Addressed stretchability-strength trade-off