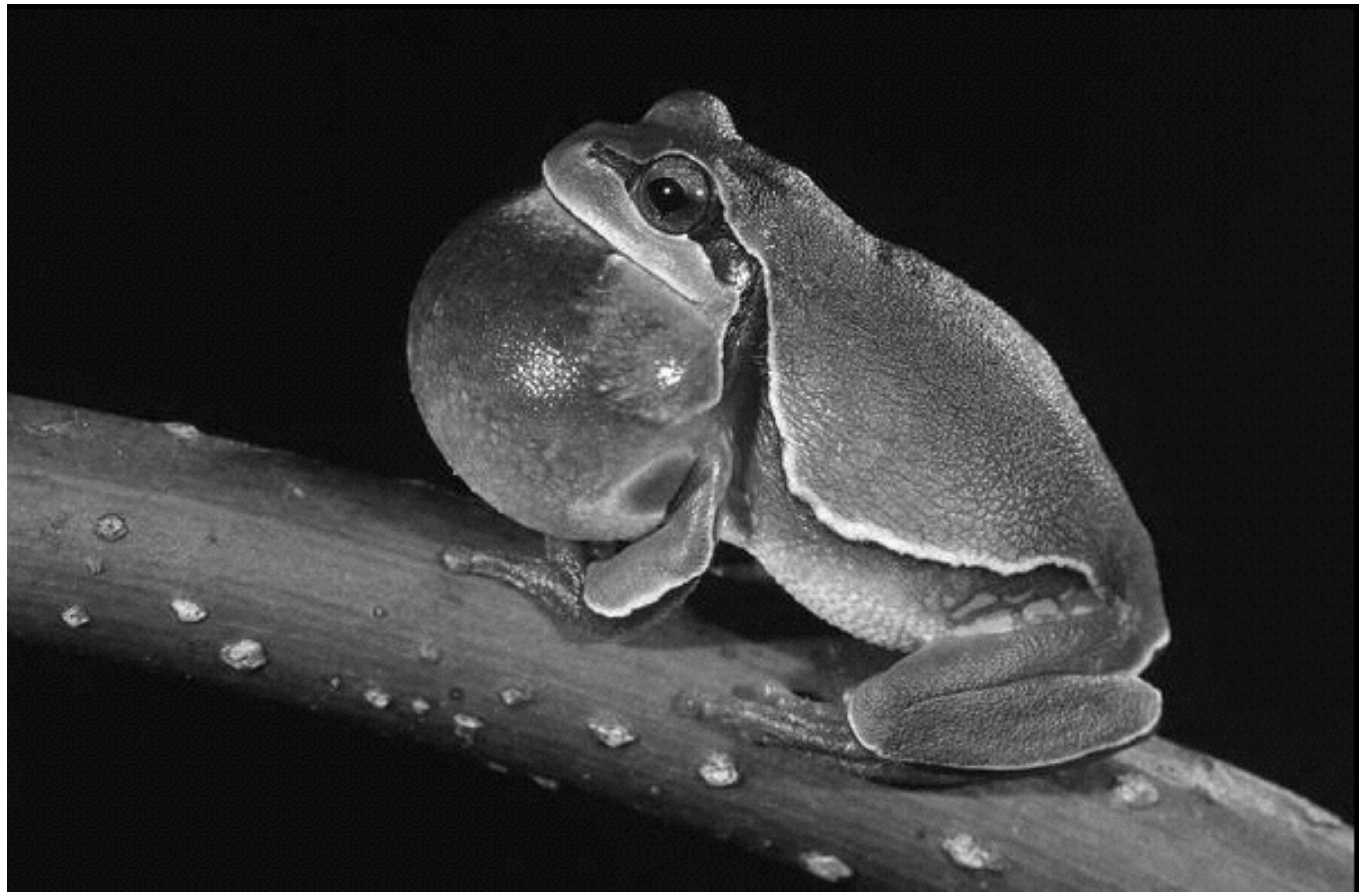
Shape Change and Soft Matter


Dried tomatoes
Spherification by Chef Jose Andres

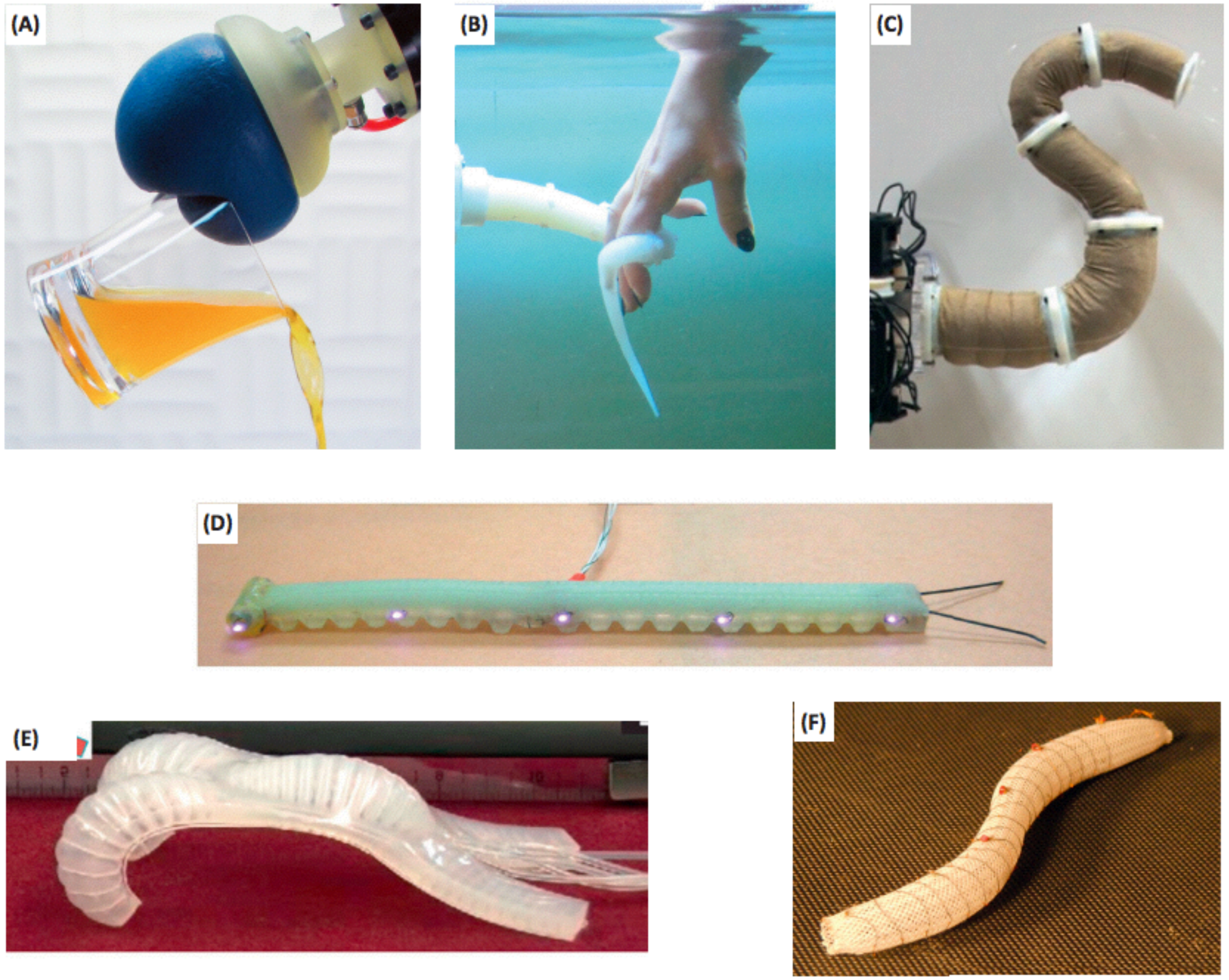
Soft Shape Change in Food

Soft Shape Change in Nature



For sound

Soft Shape Change in Robotics



1. Sangbae Kim, Cecilia Laschi, Barry Trimmer. Soft robotics: a bioinpsired evolution in robotics

Soft Shape Change in HCI

From the left to the right:

1. Harrison, C. and Hudson, S.E. Providing dynamically changeable physical buttons on a visual display. Proc. of CHI 2009, ACM Press (2009), 299–308.
2. Gomes, A. and Nesbitt, A. MorePhone : A Study of Actuated Shape Deformations for Flexible Thin-Film Smartphone Notifications. (2013), 583–592.
3. Jonas Togler, Fabian Hemmert, and Reto Wettach. 2009. Living interfaces: the thrifty faucet. In Proceedings of the 3rd International Conference on Tangible and Embedded Interaction (TEI '09). ACM, New York, NY, USA, 43-44.

Soft Shape Change in Design and Life

For inflation

For floating

For stiffness changing

Overview of Soft Shape Change

Soft Shape Change in Robotics - "Soft Robotics"

Guest Lecture by Dr. Kevin C. Galloway from Harvard Microrobotics Laboratory, Wyss Institute
"History, applications and fabrication recipes of soft robotics"

Soft Shape Change in HCI and Design - Case Studies and Reflection

Overview on history and applications in HCI
Case study 1: PneUI, by Lining Yao from TMG
Case study 2: JamSheets, by Jifei Ou from TMG
Reflection: Unique contribution of soft shape change in HCI and design

Soft Shape Change - Toolkits

Fabrication
Actuation Mechanisms
Material Composition and Material Structure
Part list
Electronic and Pneumatic Circuit
Fabrication 1: Elastomeric Actuators (Silicon Rubber)
Fabrication 2: Non-elastic Actuators, with live demonstration

Soft Shape Change in Robotics - “Soft Robotics”

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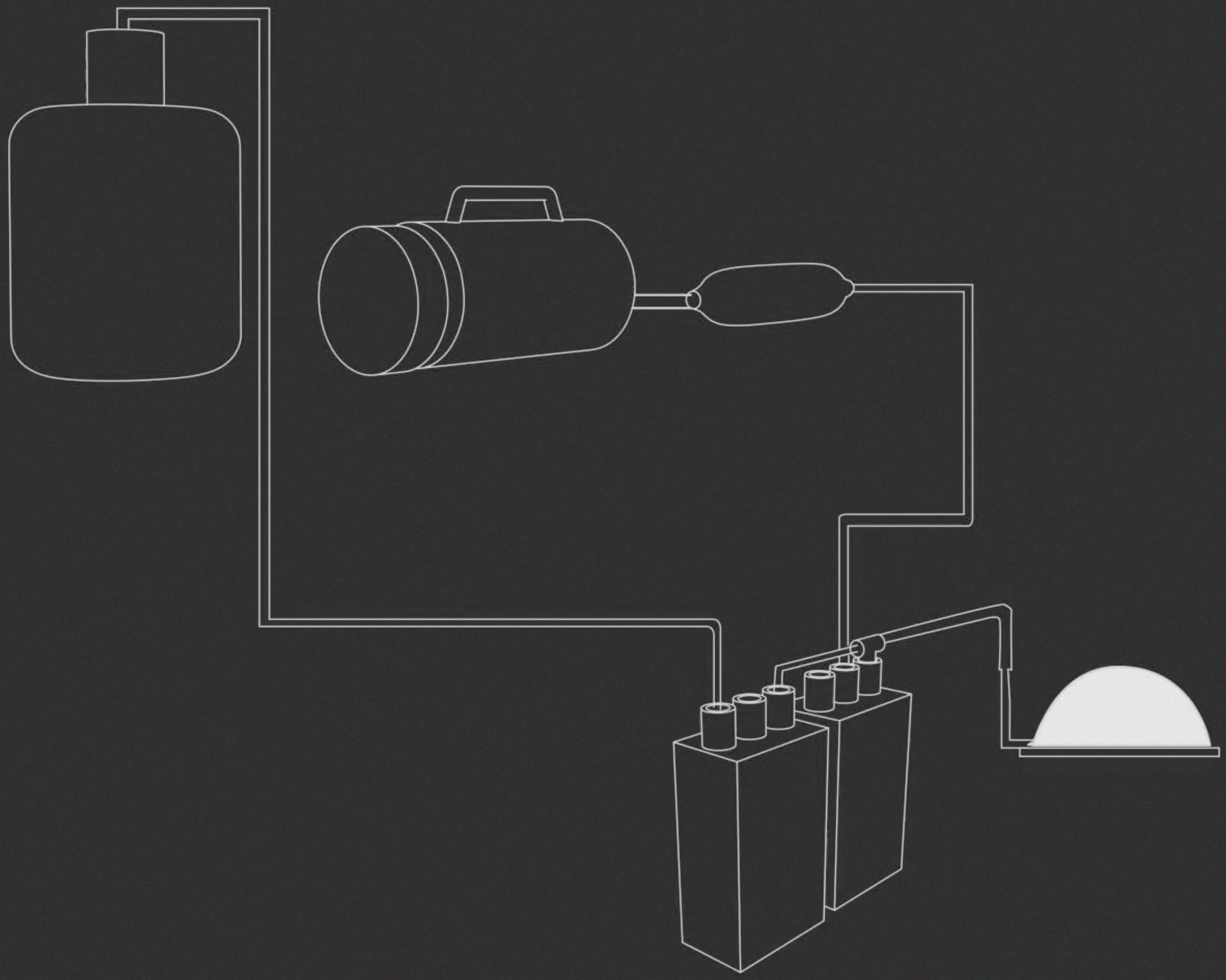
氣

a i r

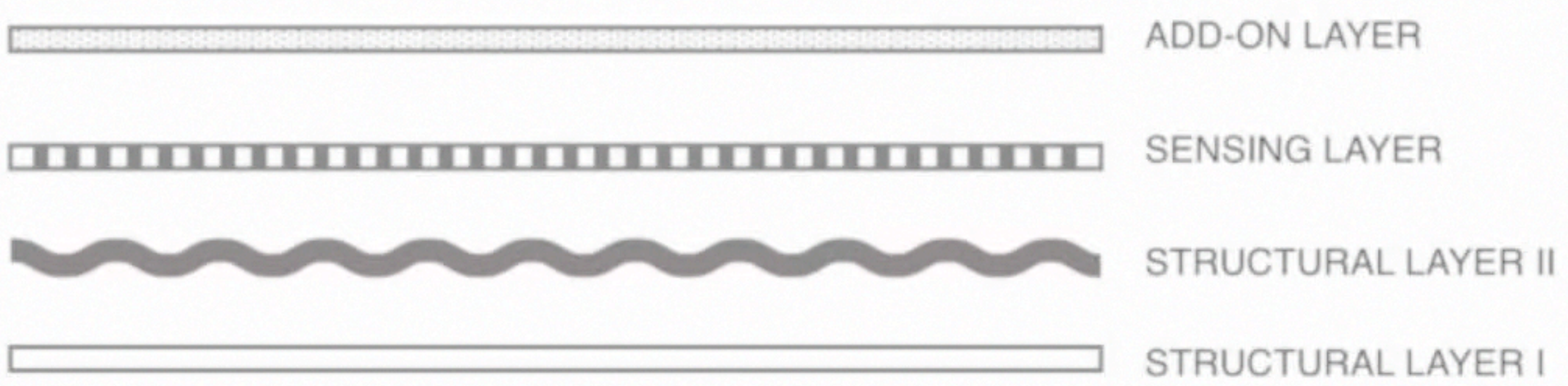
Surrounding the earth is a blanket of air


Multigait Soft Robots.Harvard Whitesides Group. 2011


24VDC
24VDC
24VDC
24VDC



Three Types of Shape Changing Primitives



CURVATURE

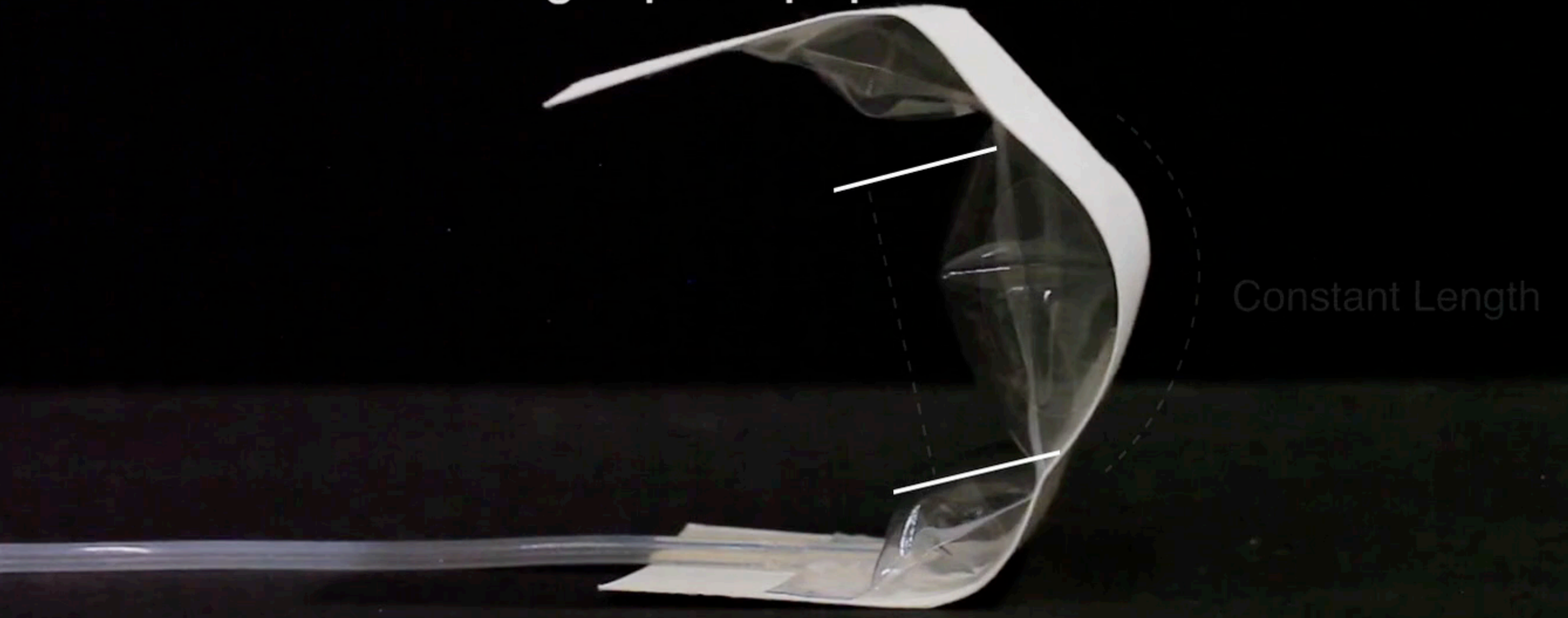
VOLUME

TEXTURE


Curvature - Elongation for Bending

Compression for Bending

non-elastic airbag + plain paper



CURVATURE

VOLUME

TEXTURE


Volume
Linear elongation

CURVATURE

VOLUME

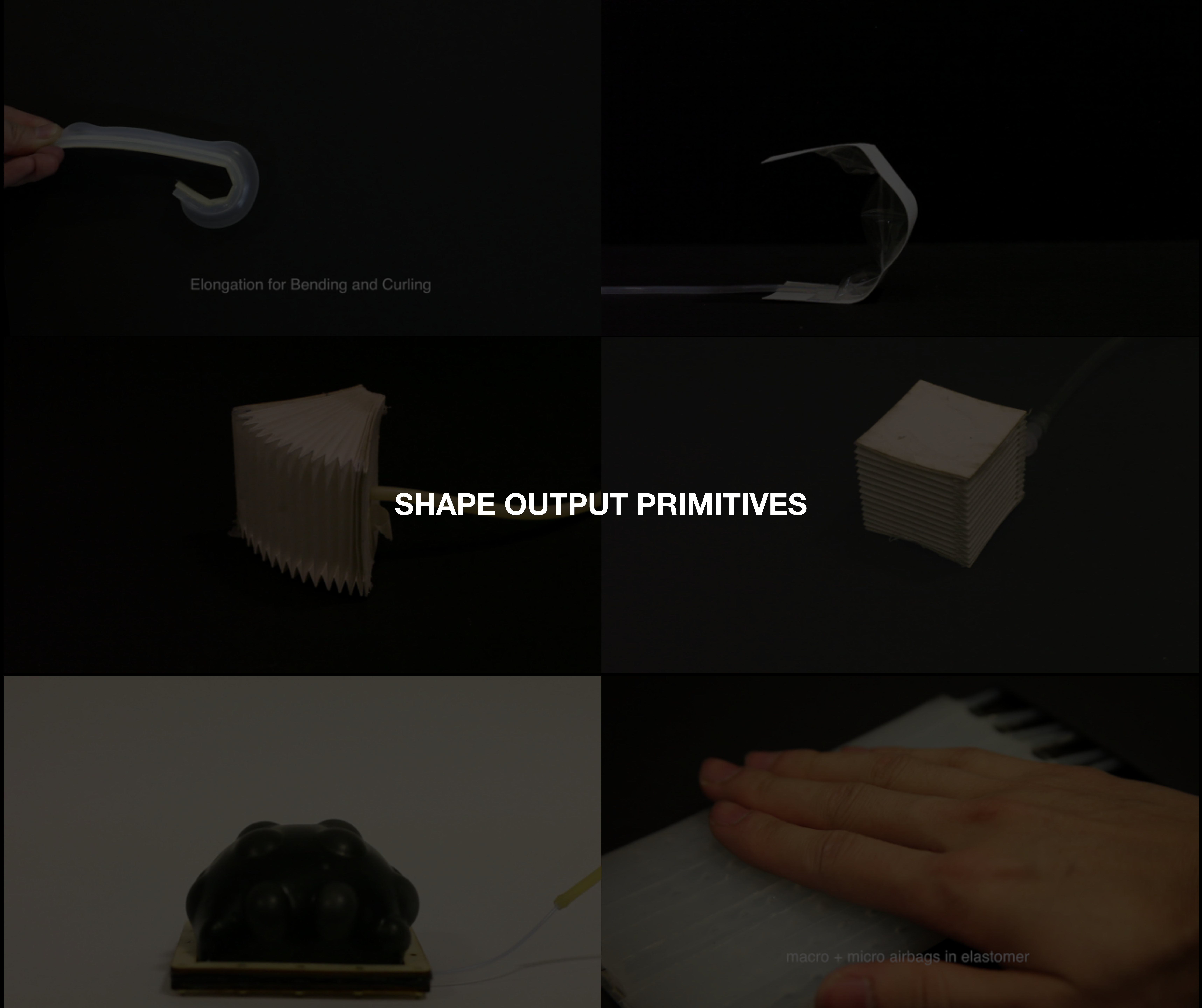
TEXTURE

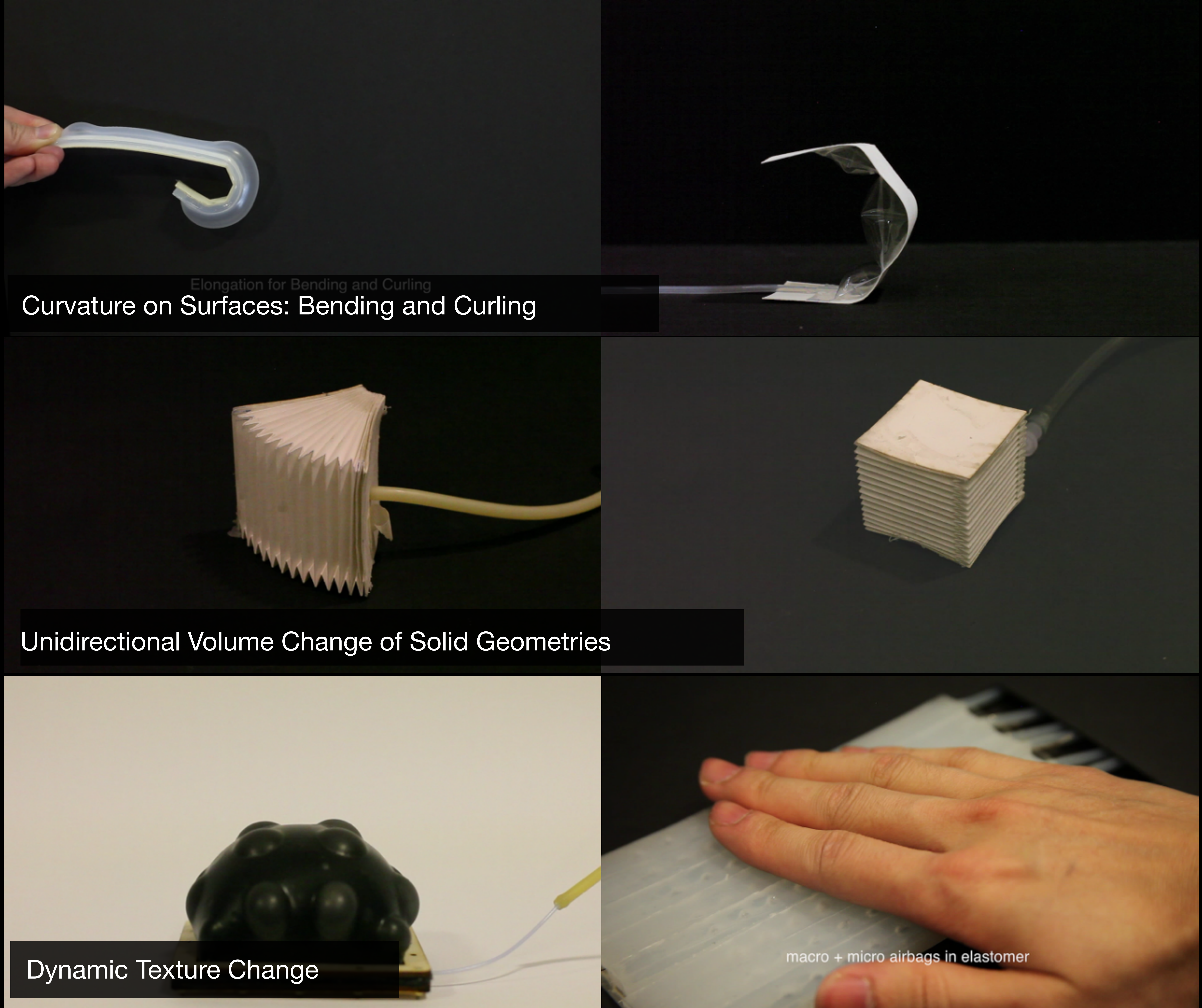
Texture - Two-stage Texture


Texture - Multilayer Texture
macro + micro airbags in elastomer

SHAPE OUTPUT PRIMITIVES

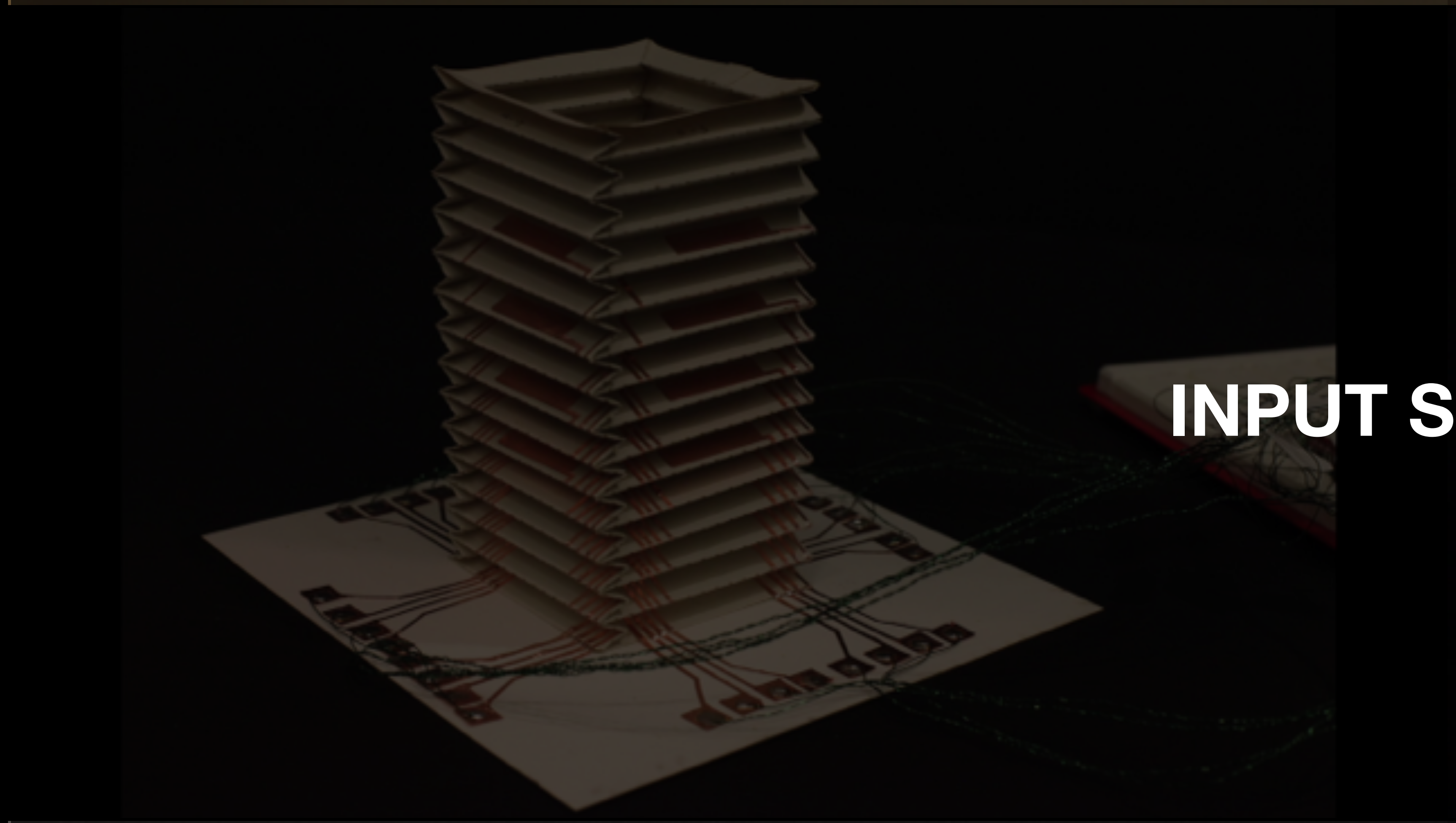
SHAPE OUTPUT PRIMITIVES

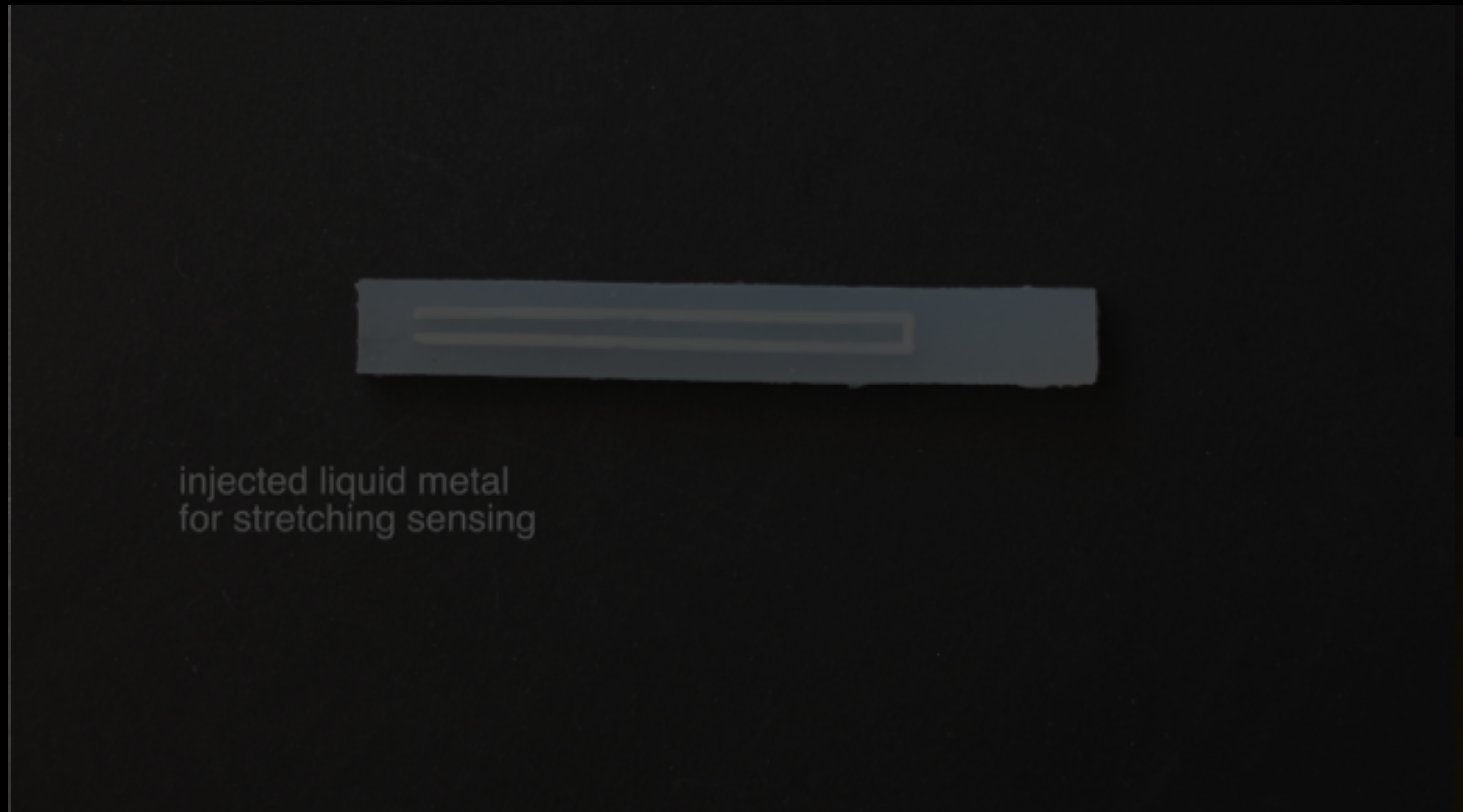


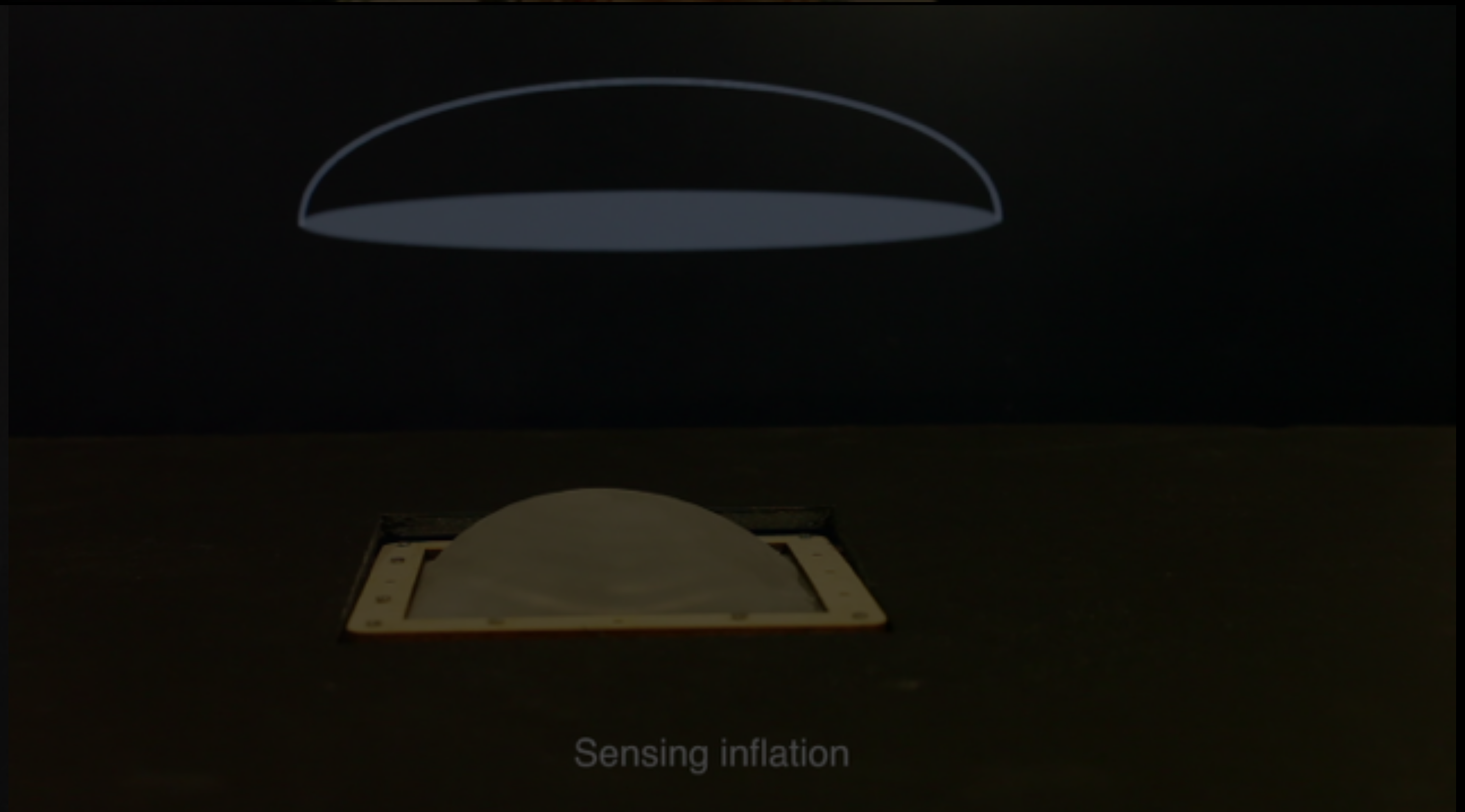

Elongation for Bending and Curling
Curvature on Surfaces: Bending and Curling
Unidirectional Volume Change of Solid Geometries
Dynamic Texture Change
macro + micro airbags in elastomer

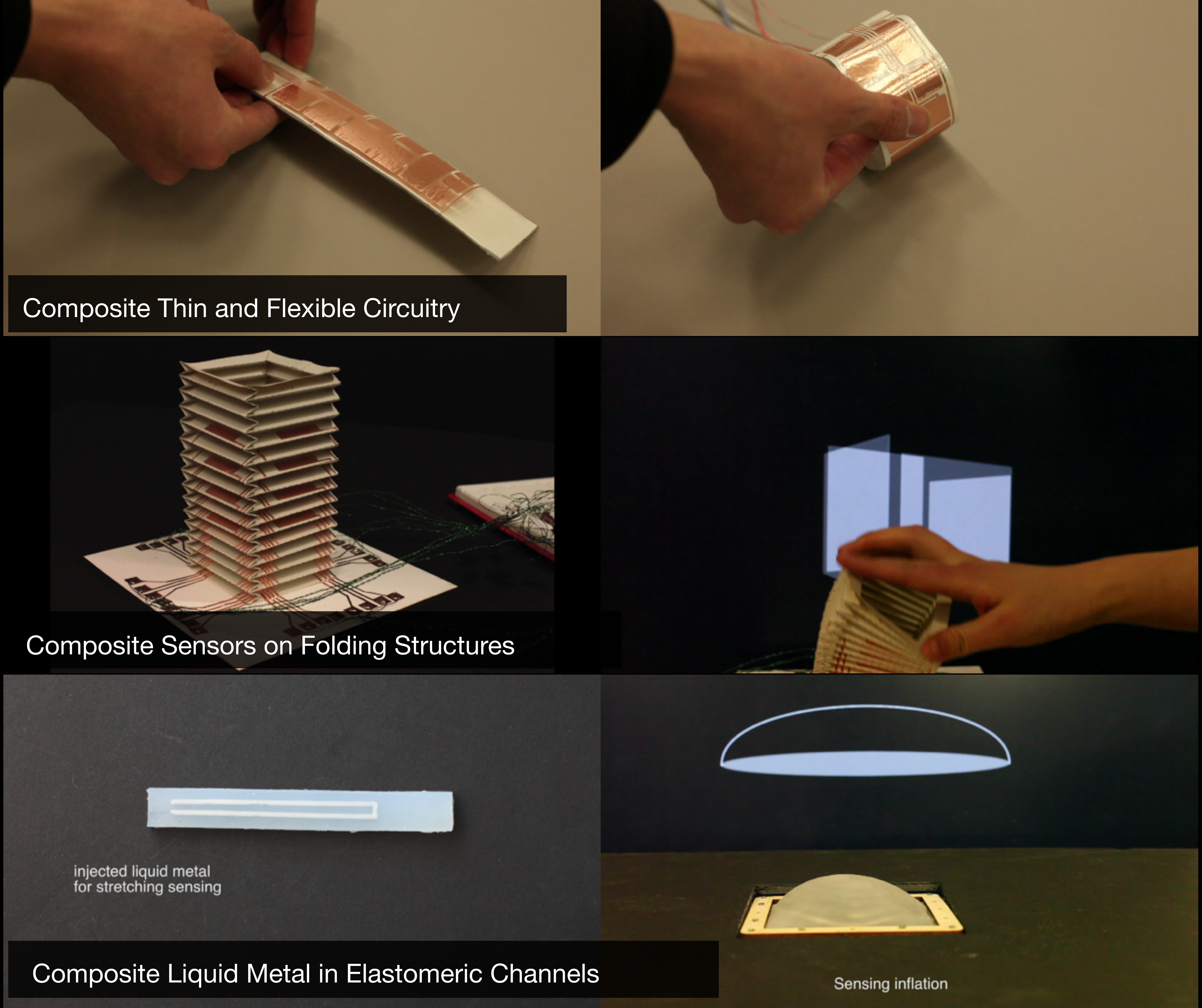
INPUT SENSING

INPUT SENSING








Composite Thin and Flexible Circuitry
Composite Sensors on Folding Structures
injected liquid metal
for stretching sensing
Composite Liquid Metal in Elastomeric Channels
Sensing inflation

Soft Shape Change in HCI and Design - Case Studies and Reflection

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Reflection: Unique Opportunity of Soft Shape Change in HCI and Design

Mechanical Property	Opportunity for HCI and Design
elastically deformable	lifelike form and motion
mechanical compliance matching with the human skin	friendly for onbody/wearable applications
potential for multi-functionality	integrate both input sensing and shape output
potential for utilizing material anisotropy	complex transformation behaviors
unique actuation mechanism (pneumatic, smart materials)	silent/soft change

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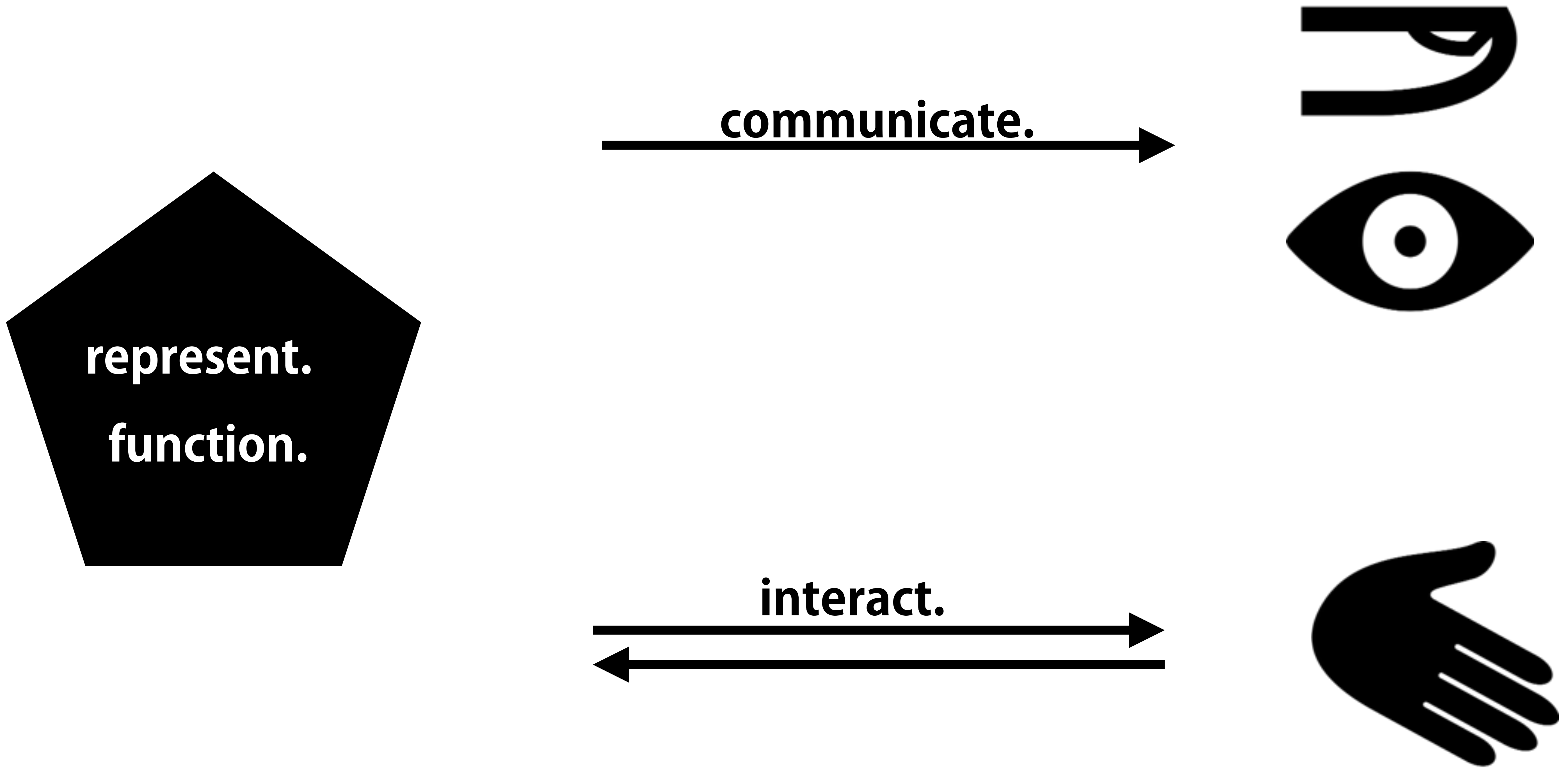
Dynamic shape can be perceived as media with which to function, represent, communicate and interact.

With shape to



To represent and communicate through lifelike motion. [Design]

Piero Manzoni, Pneumatic for Light and Gas Ballets, 1960

To represent and communicate through lifelike motion. [HCI]

PneUI, 2013 ~ current

To communicate lifelike form and haptic sensation. [Design]

Tokyo Fiber ’07, Senseware. Panasonic.

To function. [Design]

Tokyo Fiber '07, Senseware. Spacesuit, Takuya Onishi

To function. [HCI]

JamSheets, 2013 ~ current

To Interact with the environment. [Design]

WIPING CLEANER “FUKITORIMUSHI”, Panasonic Corporation

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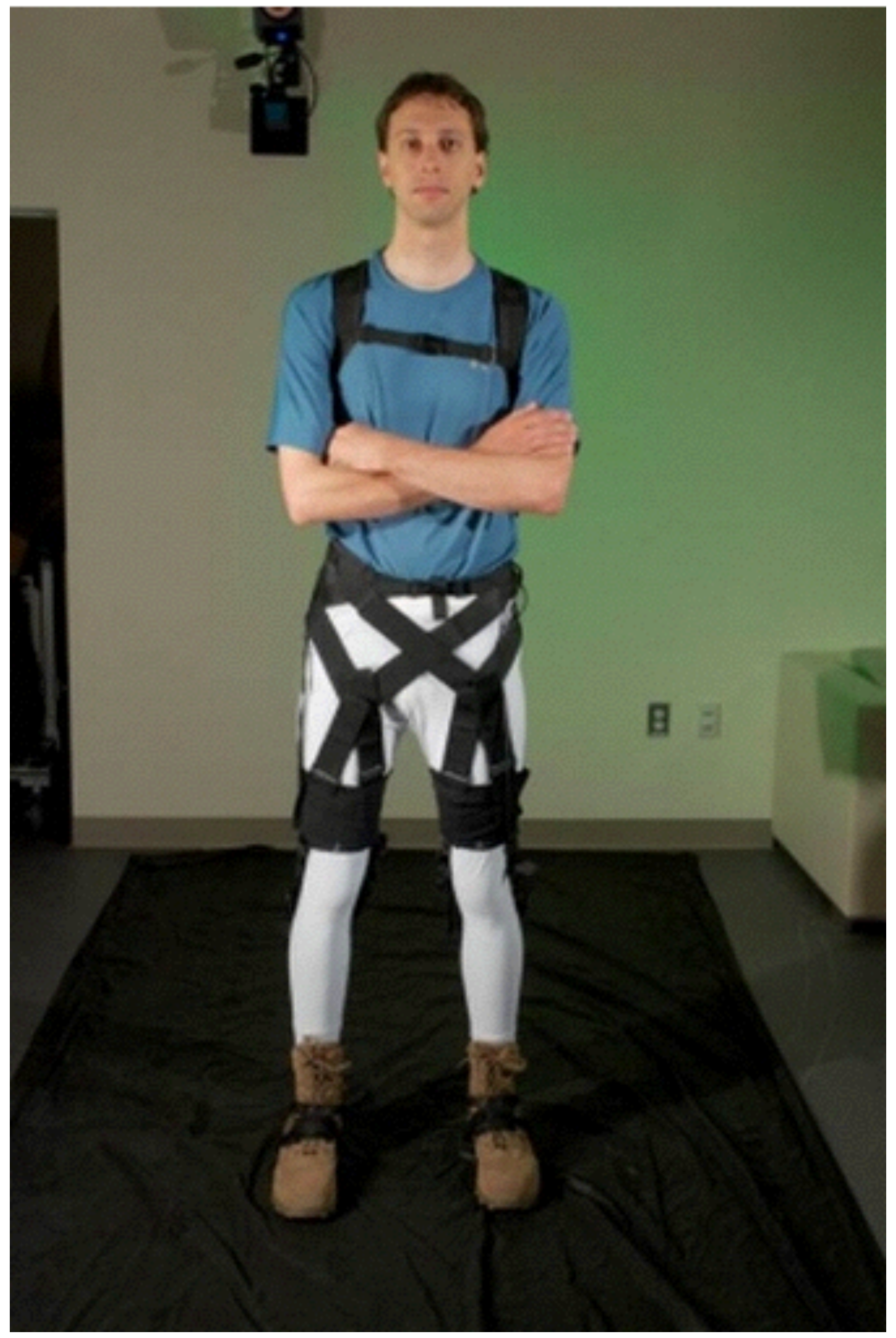
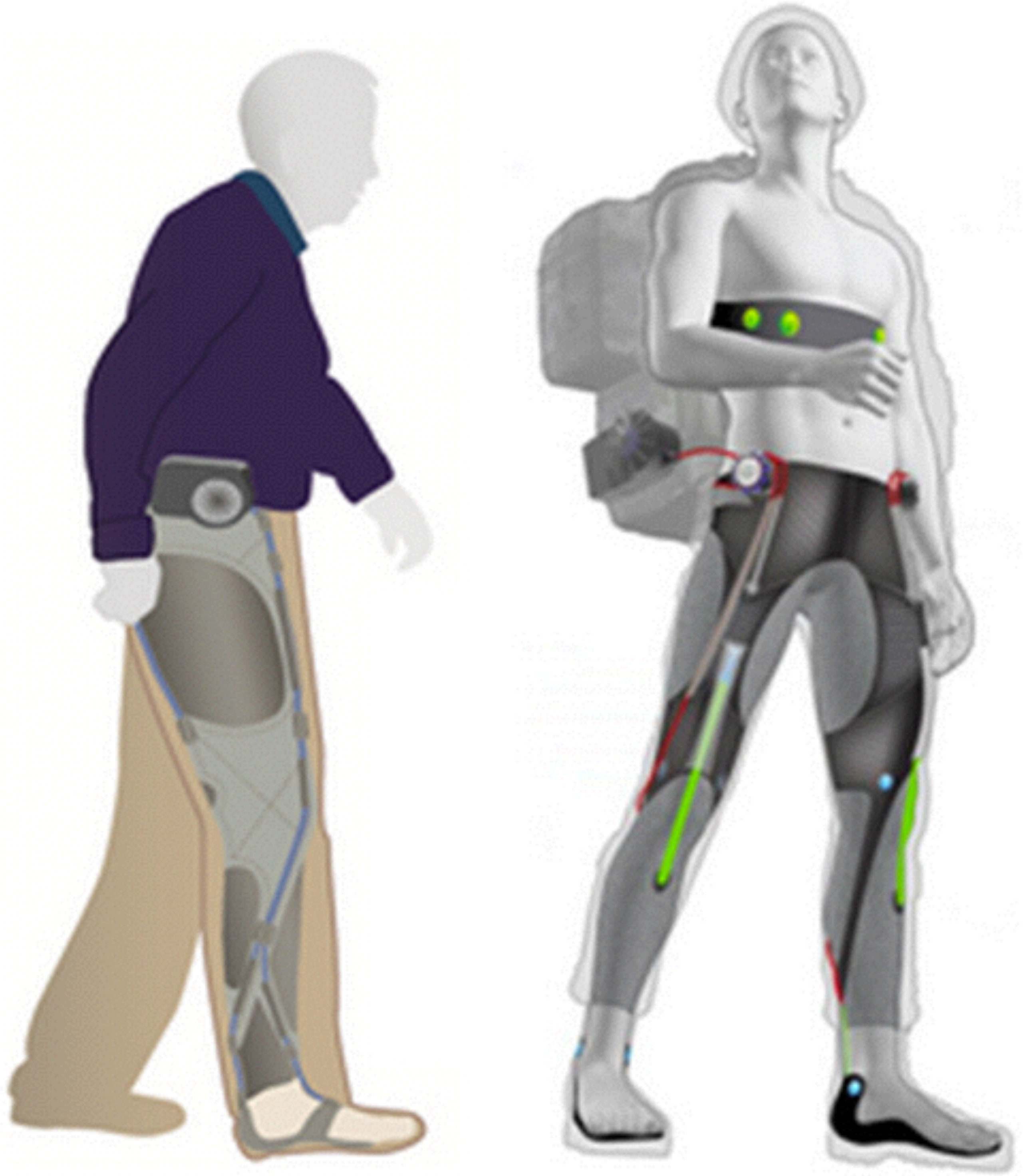
Harvard Biodesign Lab

Augmenting and restoring human performance





Wearable sensors, structural functional textiles, translation applications

PneUI, 2013 ~ current

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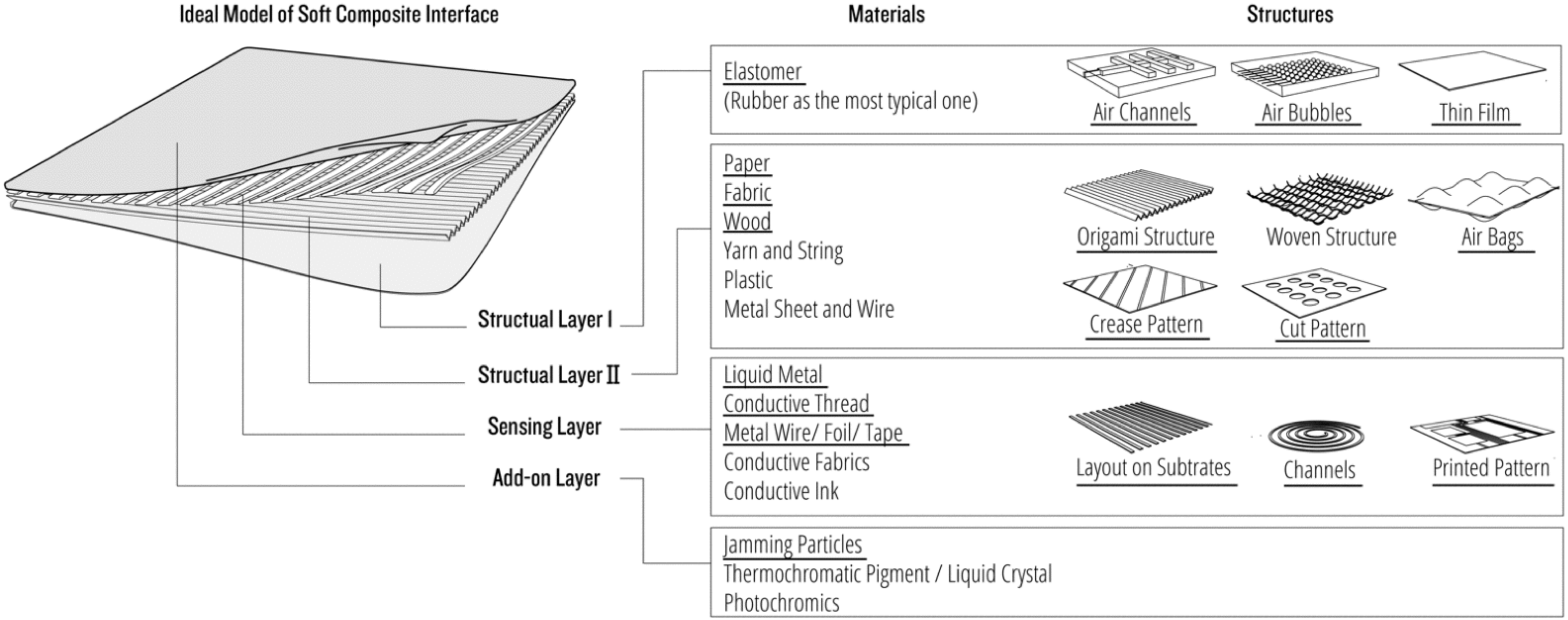
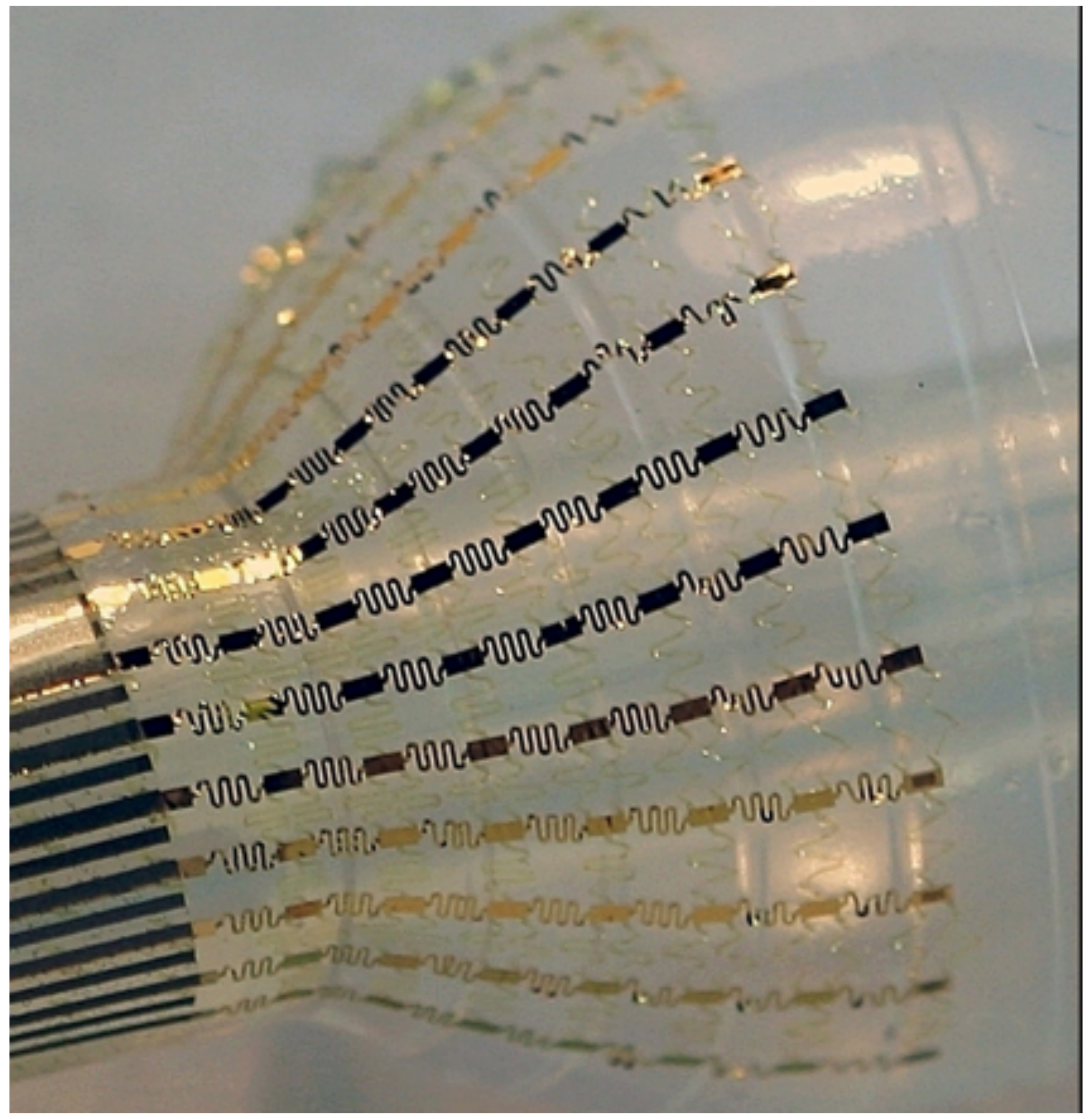
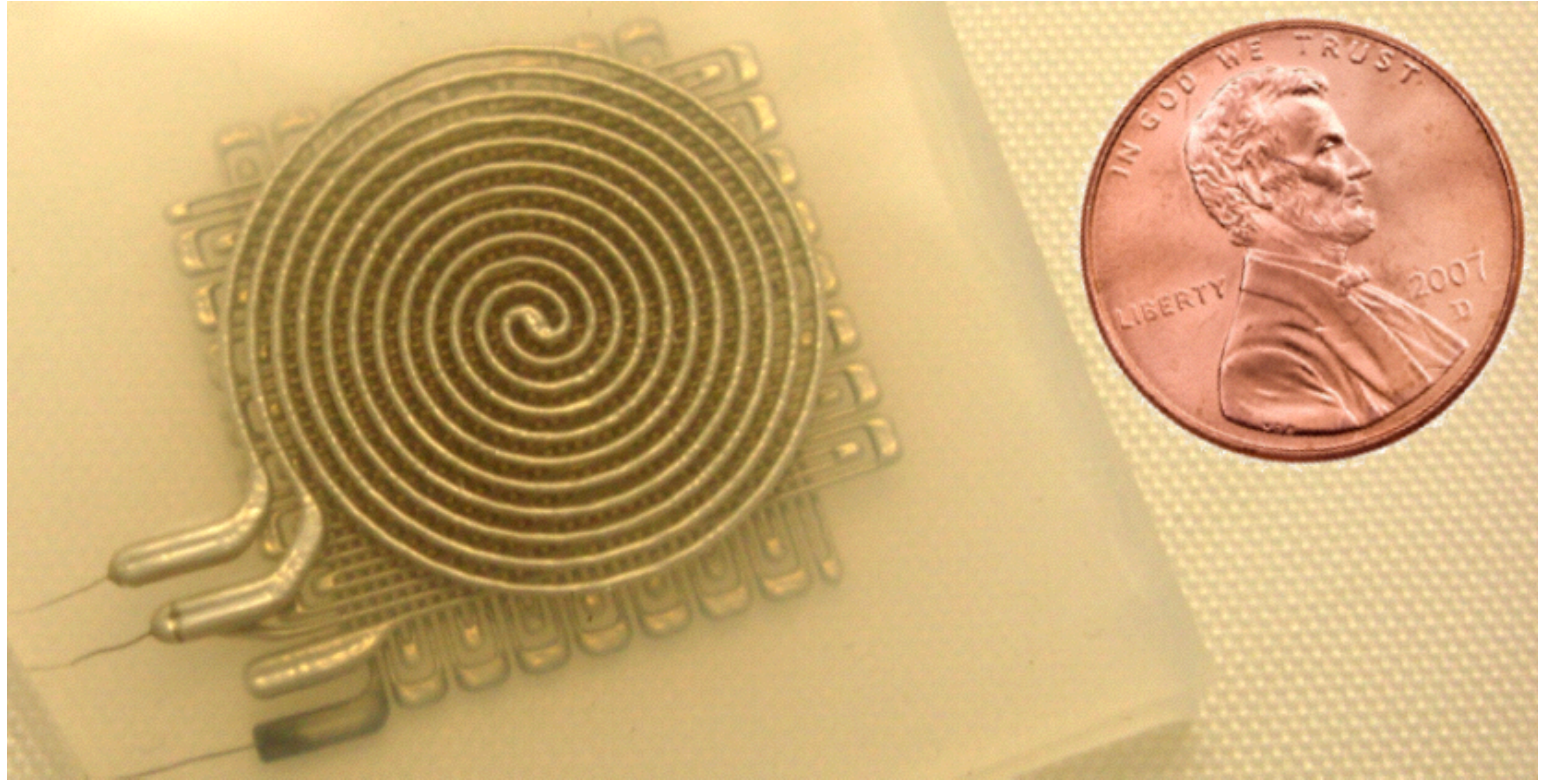

Ideal Model of Soft Composite Interface
Materials
Structures
Structual Layer I
Structual Layer II
Sensing Layer
Add-on Layer
Elastomer
(Rubber as the most typical one)
Air Channels
Air Bubbles
Thin Film
Paper
Fabric
Wood
Yarn and String
Plastic
Metal Sheet and Wire
Origami Structure
Woven Structure
Air Bags
Crease Pattern
Cut Pattern
Liquid Metal
Conductive Thread
Metal Wire/ Foil/ Tape
Conductive Fabrics
Conductive Ink
Layout on Subtrates
Channels
Printed Pattern
Jamming Particles
Thermochromatic Pigment / Liquid Crystal
Photochromics





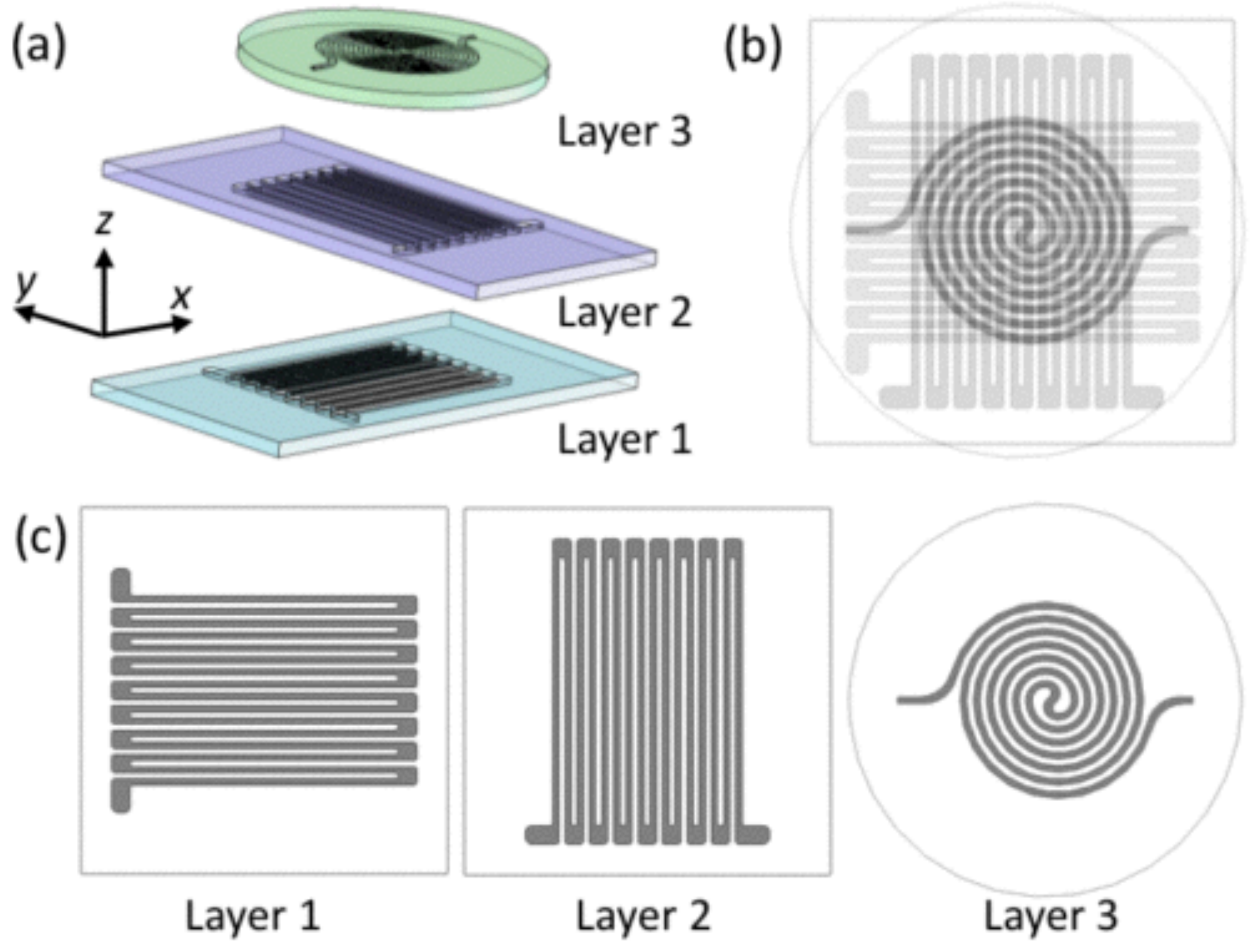
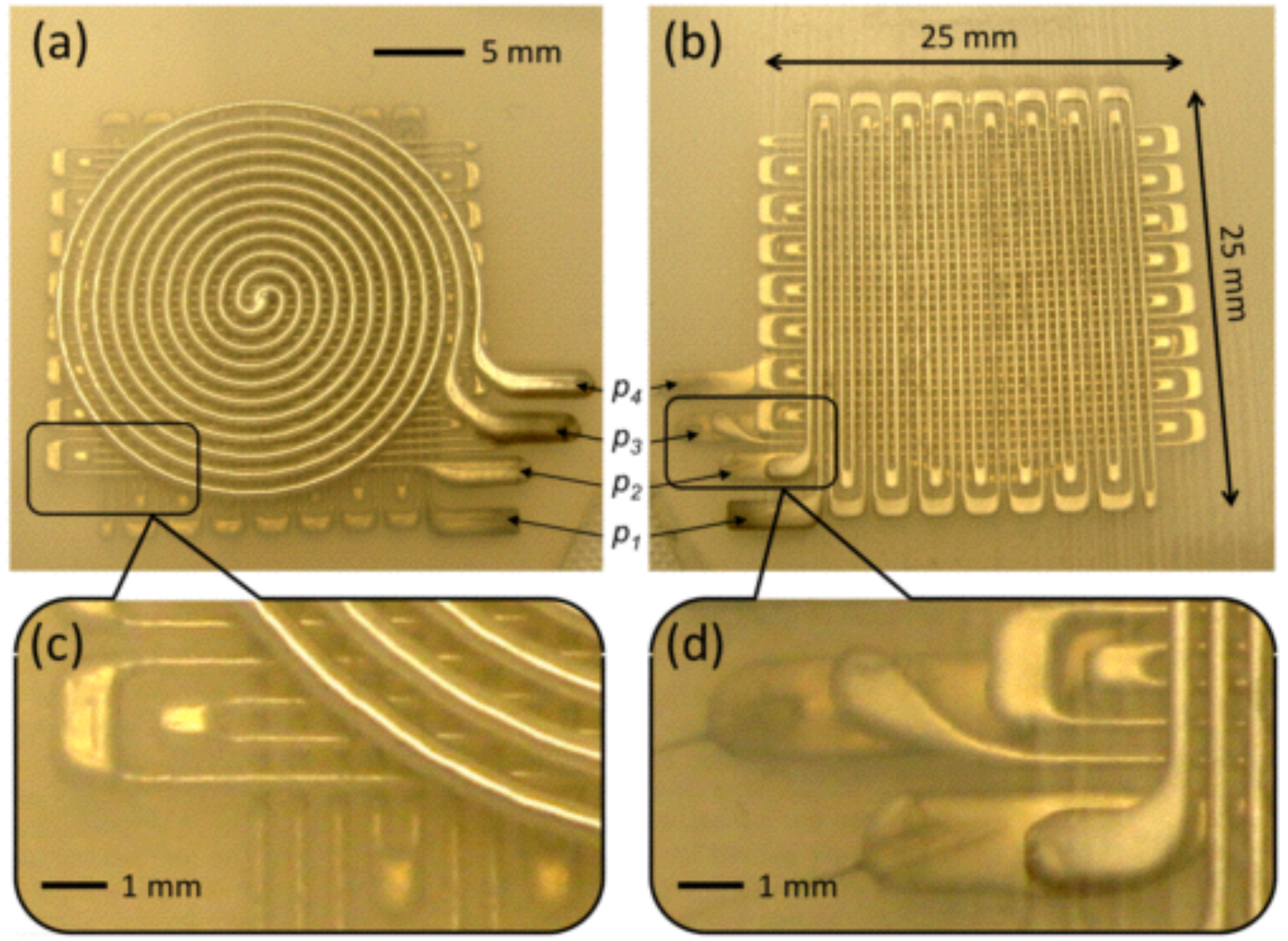
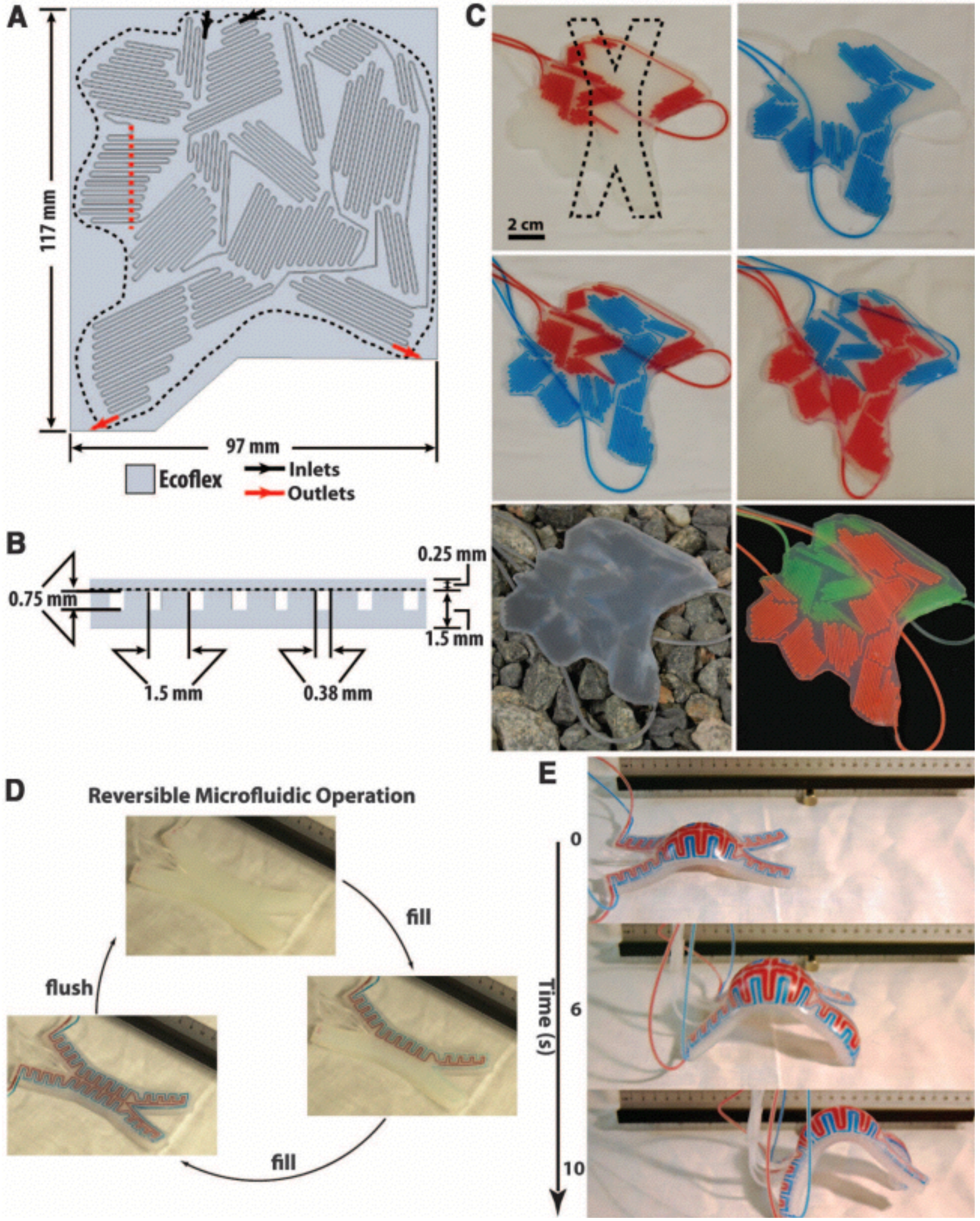
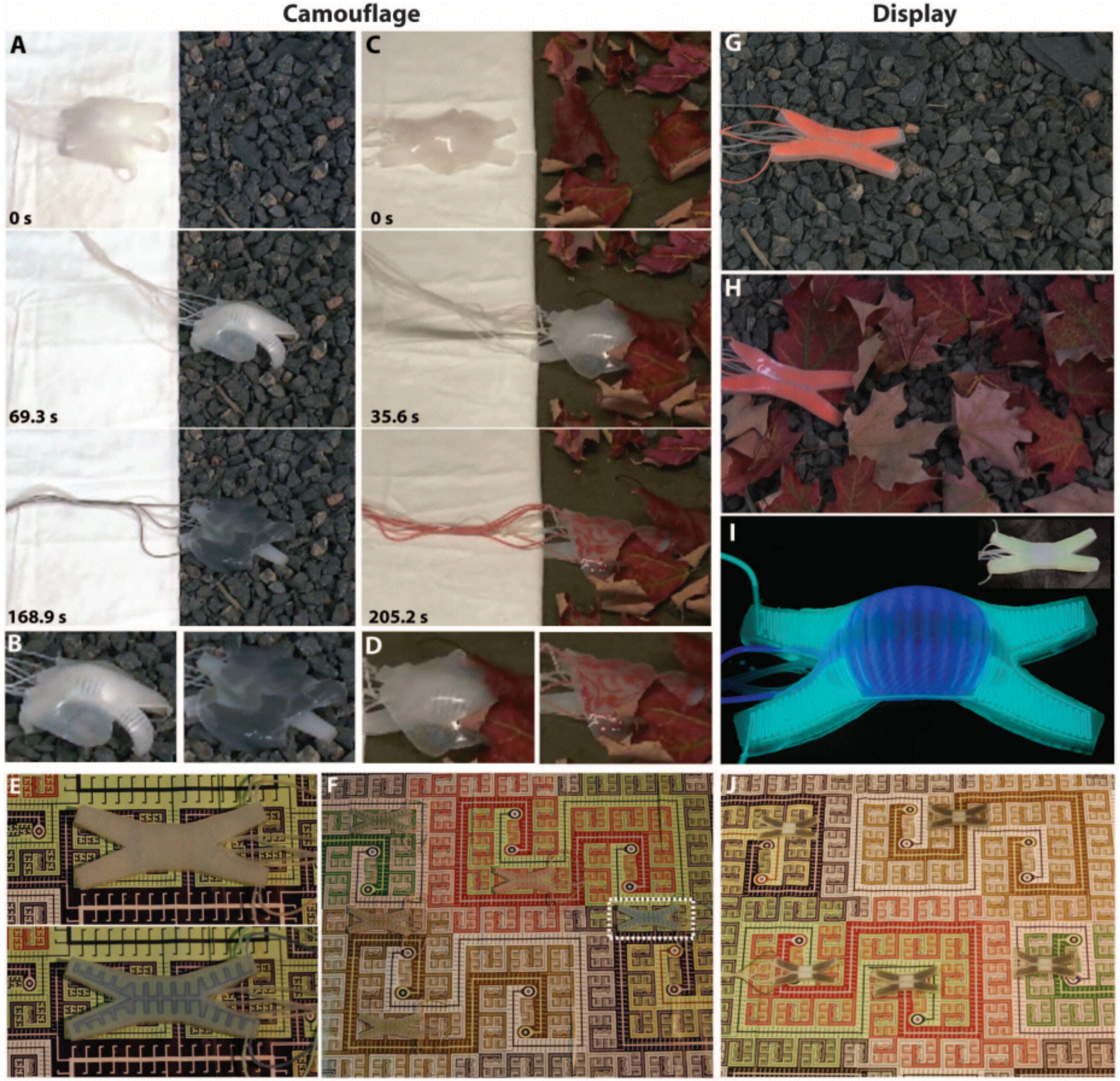


Fig. 2. Design of three sensor layers with embedded microchannels: (a) Exploded view. (b) Assembled view. (c) Each sensor layer design.





A
117 mm
97 mm
Ecoflex
Inlets
Outlets
B
0.25 mm
0.75 mm
1.5 mm
1.5 mm
0.38 mm
C
2 cm
D
Reversible Microfluidic Operation
fill
flush
fill
E
0
6
10
Time (s)



Camouflage
Display
A
0 s
69.3 s
168.9 s
B
C
0 s
35.6 s
205.2 s
D
E
F
G
H
I
J

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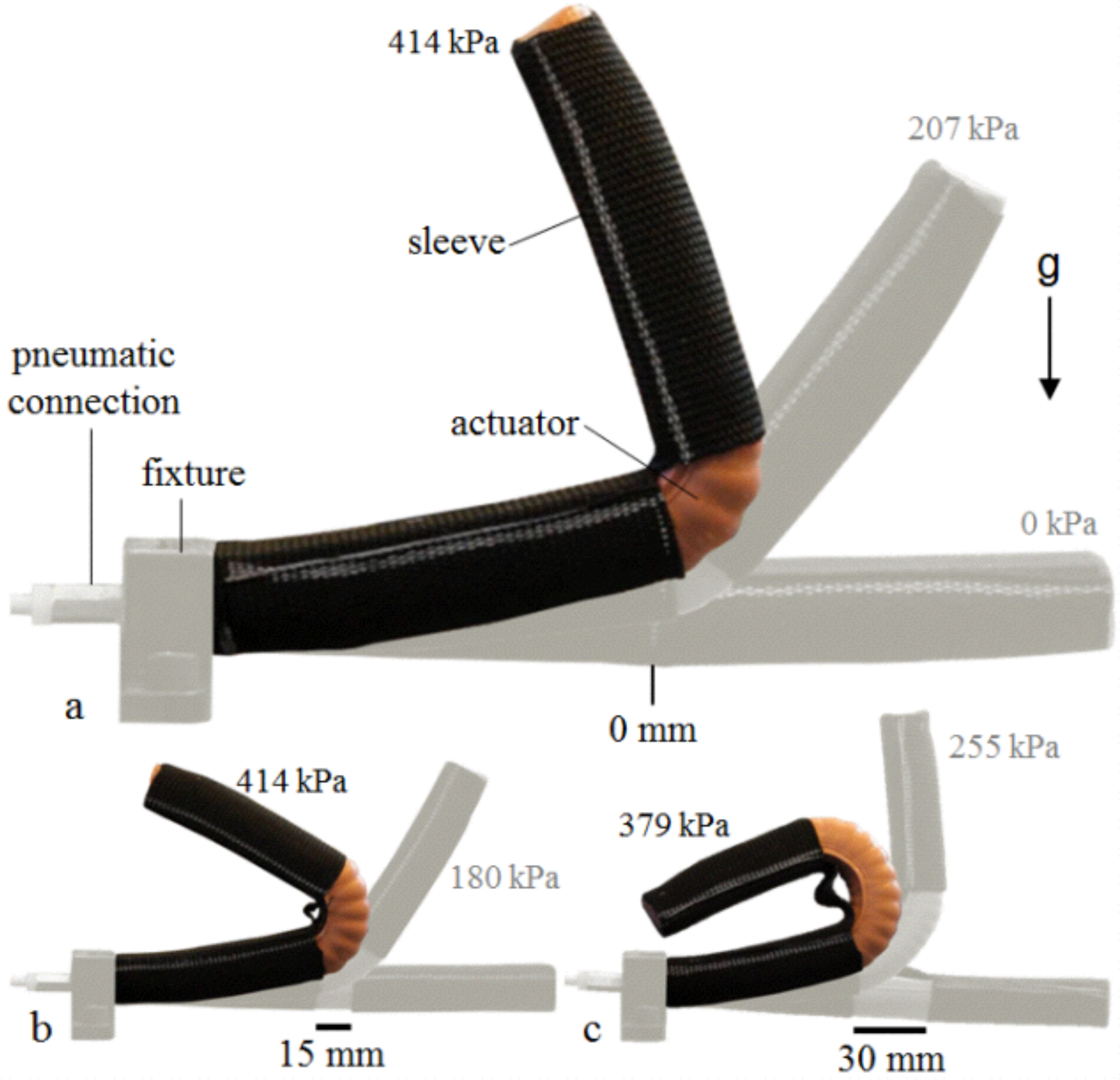
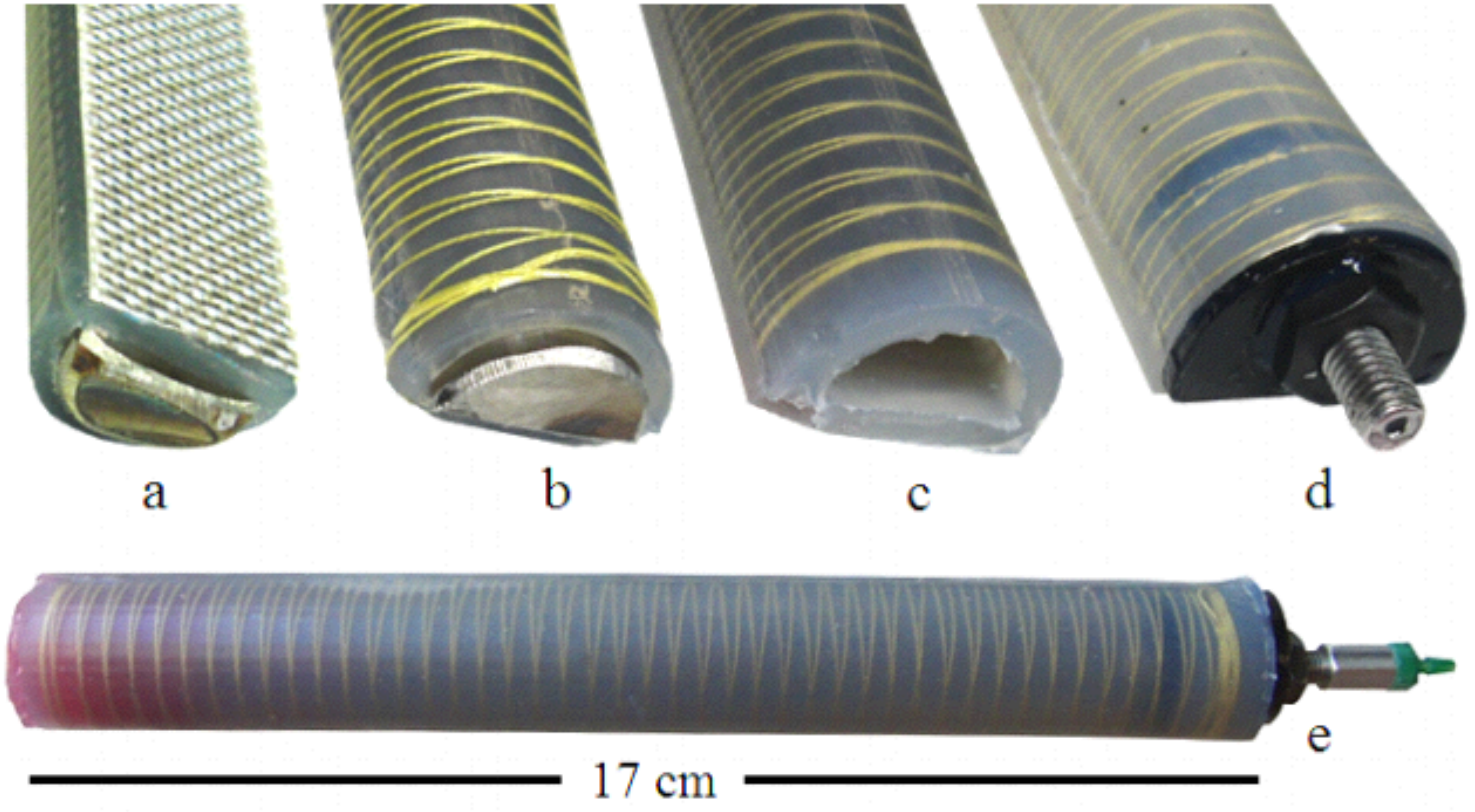
Mechanical Design through Computation

Shape matching, string reinforcement





P_{atm} | $P_1 = 80$ mbar | $P_2 = 120$ mbar | $P_2 = 120$ mbar | $P_2 = 120$ mbar | $P_2 = 120$ mbar

Reflection: Unique Opportunity of Soft Shape Change in HCI and Design

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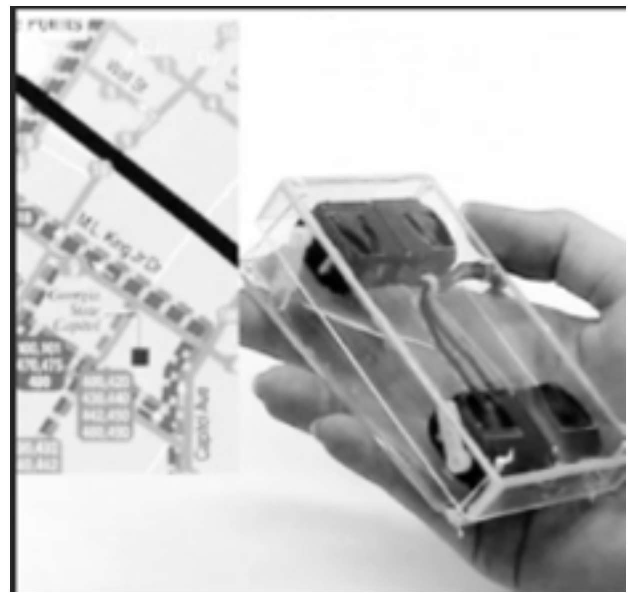
potential for utilizing material anisotropy	complex transformation behaviors
unique actuation mechanism (pneumatic, smart materials)	silent change with large force

GEARED MOTOR /SOLENOID

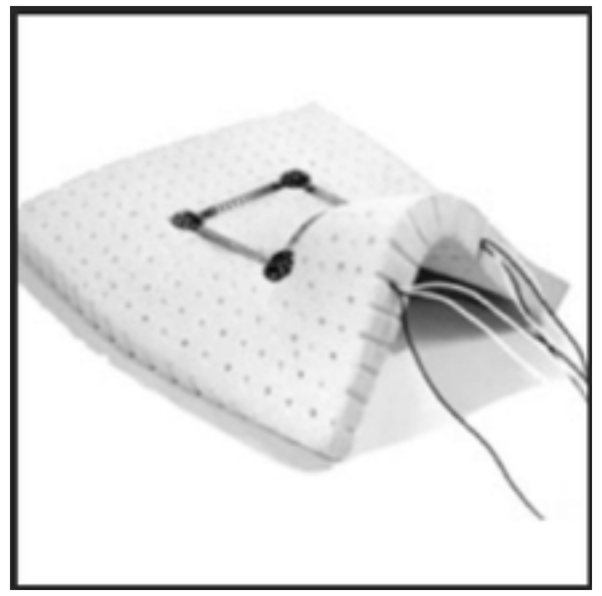
Relief/Recompose. Daniel.L. et,al



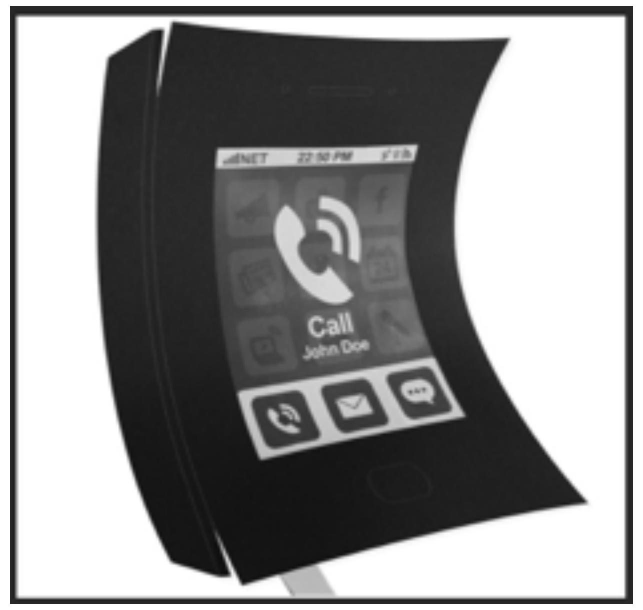
Shape Changing Phone.

Rigid;
Constrained by its own size/weight;
Controllability.

SHAPE MEMORY ALLOY



Surflex. Marcelo, C. et,al

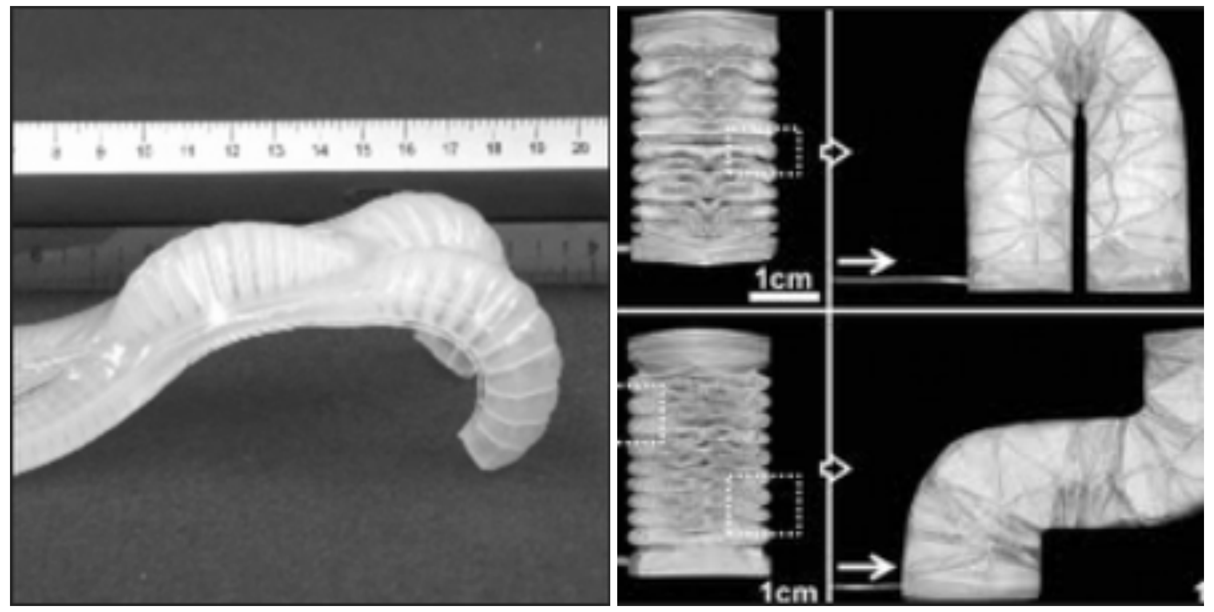


Morephone. Antonio.G.et,al

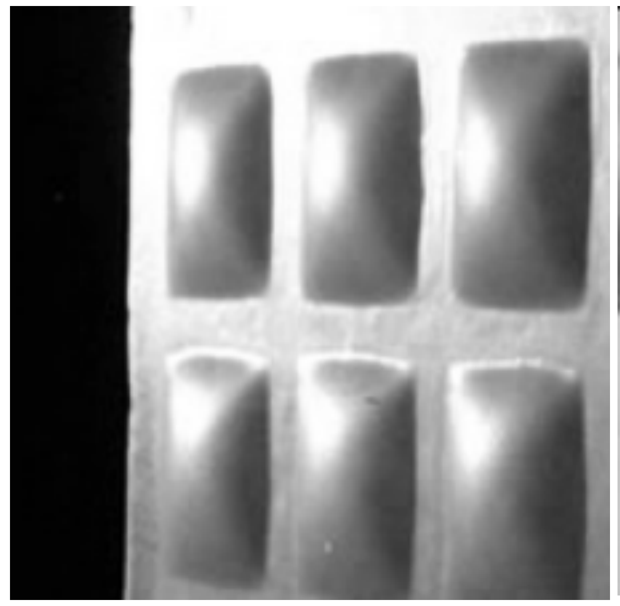
Flexible
Light weight

controllability
small force output

PNEUMATIC/HYDRAULIC



Soft Robots. Whitesides Group. Harvard



Dynamic Buttons. Harrison. C. et.al

Jamming UI. Sean, F. et.al

light weight
controllability
compliance (soft, flexible)
water proof
large force output (compare to SMA)
volumetric deformation

Other alternative approaches to actuate soft matter

Dielectric elastomer actuators (DEAs), SMAs, compressed fluid, combing with electromagnetic actuators.

Soft robotics: a bioinspired evolution in robotics. Sangbae Kim, Cecilia Laschi, Barry Trimmer.

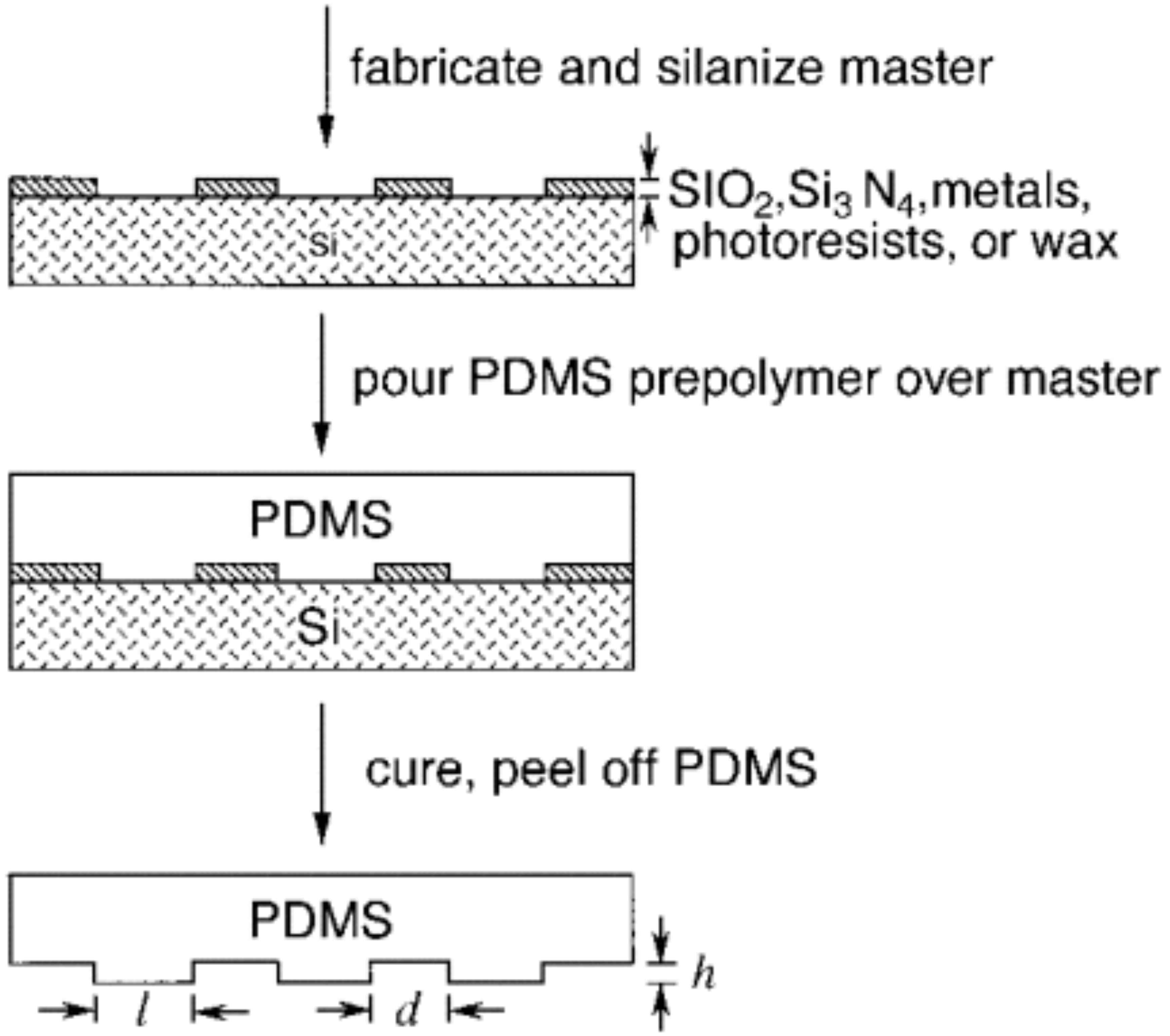
Soft Shape Change - Toolkits

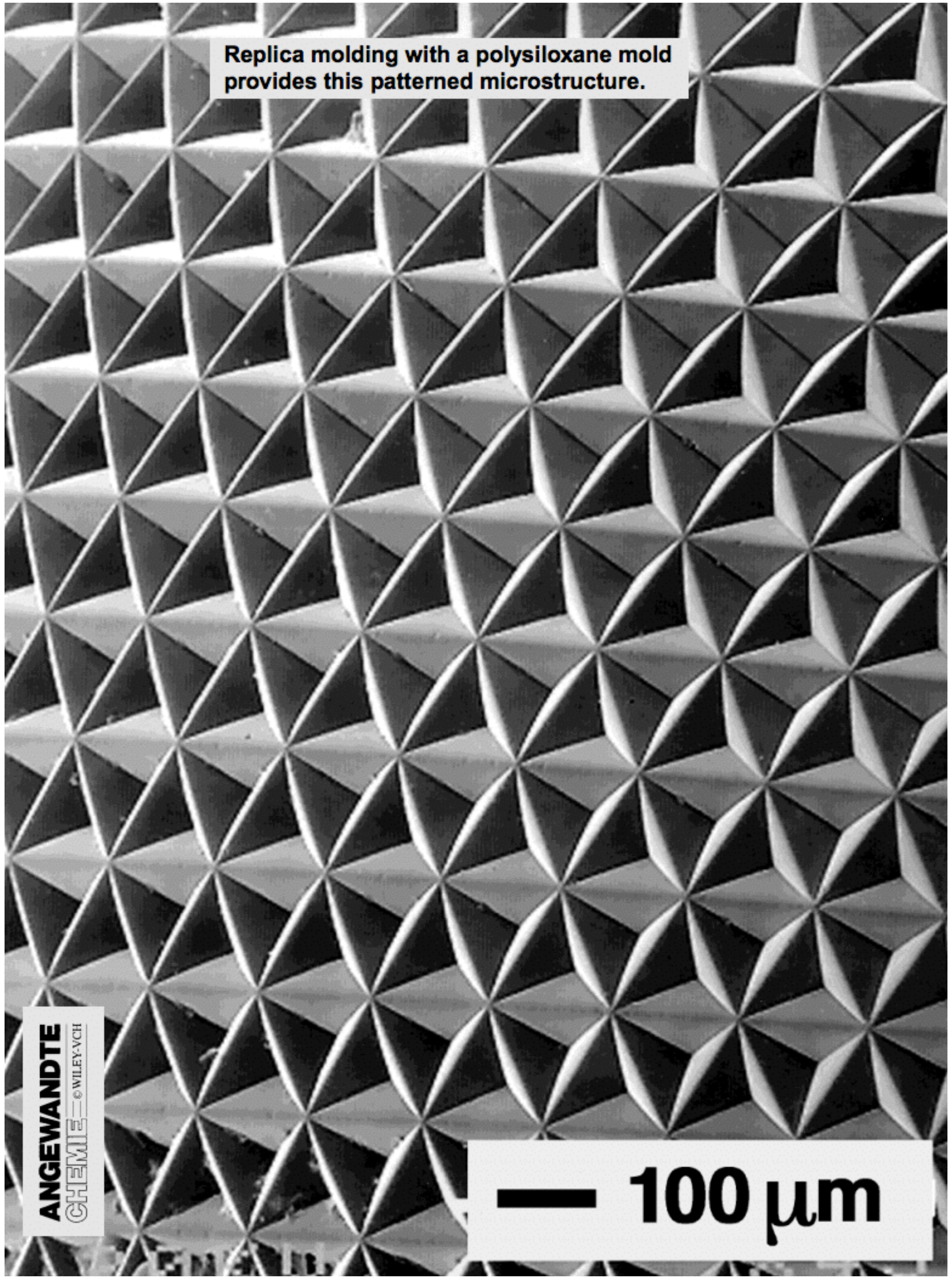
```
Make    it : Fabrication
Control it : Electronic and Pneumatic Circuit
```

Make it: Fabrication

Soft lithography
Modular Assembly
3D printing
Your own way

Soft Lithography





Soft Lithography. Younan Xia and George Whitesides. Elastomer stamp and molding.

Modified Soft Lithography

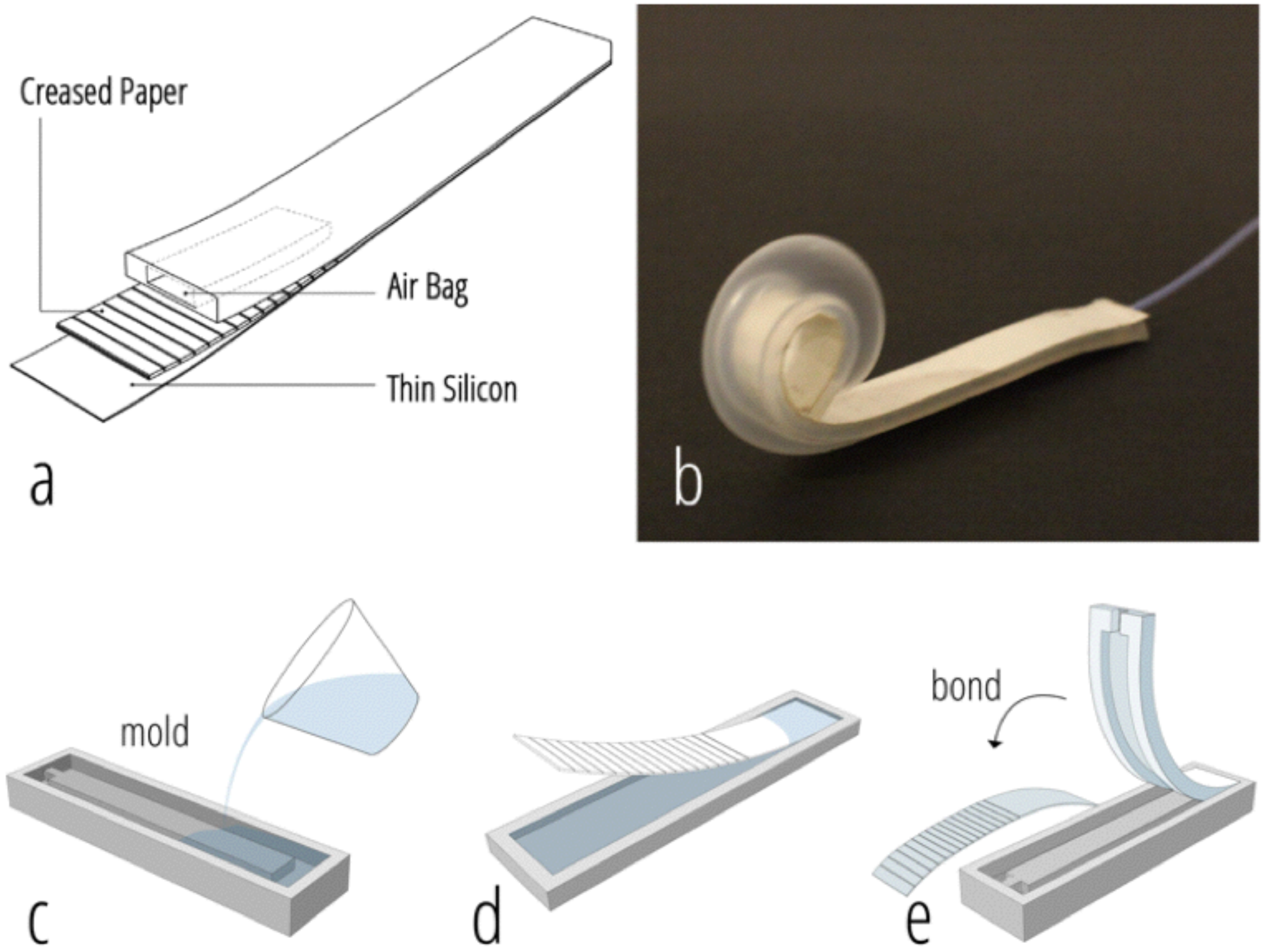


Figure 5: (a, b) Structure of the composite. (c, d, e) Fabrication process. (c) Pre-mixture of silicon (EcoFlex 00-30, Smooth-on, Inc) is poured into a 3D printed mold designed to form a shape with air channels. (d) Creased paper is soaked into the same silicon mixture. (e) Silicon and paper layer are peeled off molds separately once thermally cured. Two layers are then bonded with uncured silicon.

Specs
Materials: silicone rubber, paper, spandex, acrylic sheets
Tools: air compressor, vacuum, laser cutter, 3D printer

PneUI

An elastic pneumatic interface takes its cues from living things.

Describe what you made. Our project is called PneUI. It includes a series of pneumatic (inflatable) artifacts and interfaces. They are transformable and responsive objects, such as a lamp that can wrap its own body when pulled, a transformable iPad cover that inflates bubbles when players of racing games need to turn left or right, and a cellphone that turns into a wrist band. Technically, we envision a future material with an embedded grammar that can sense and transform, either through geometrical or structural computation.

Briefly describe the process of how this was made. We see the fabrication process as not only a labor procedure, but also a process to embed computation inside materials. Soft lithography has been used by soft roboticists, biologists, and other scientists to fabricate elastomers with micro-scale air channels. We have adapted this process, enlarged the scale, and combined it with traditional molding and casting methods to fabricate our pneumatic artifacts.

What for you is the most interesting thing about what you made? We started with making new actuators, but it turned out that we wanted to create the feeling of artificial life. We think the elastomeric pneumatic actuators go far beyond generating bending curvature. The unique physicality of translucent silicone rubber and the natural transformability of inflatable structures convey a type of motion and form factor that resembles or reminds us of life.

What was the biggest surprise in making this? Surprisingly, and a bit strangely, we feel like we are developing a unique relationship with the materials we are working with. They are like your pets. They have their personalities and unexpected behaviors. In order to let them achieve the performance you hoped for, you need to really invest time, patience, and passion into interacting with them, trying everything you can think of to play with them.

What is the one thing about making this that you would like to share with other makers? Try to minimize errors from the very beginning. You thought you just wanted to try out something quick, so instead of milling or 3D printing a proper mold, you just laser cut and glued a mold with a thin, heat-distorted acrylic. And of course you will fail in this experiment. Then you realize the quick failure has prevented you from going down this route and spending more time on it. But the possible truth is the failure might be only in the accuracy of your fabrication, and you have just missed a chance to create a great invention.

As told by Lining Yao, Tangible Media Group, MIT Media Lab

Project Members: Lining Yao, Ryuma Niiyama, Jifei Ou, Sean Follmer, and Hiroshi Ishii, Tangible Media Group, MIT Media Lab

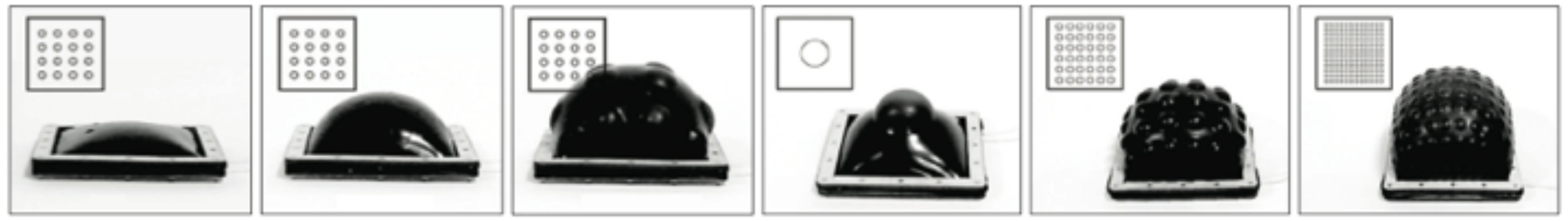
http://tangible.media.mit.edu/project/pneui-pneumatically-driven-soft-composite-material/

DOI: 10.1145/2626273

Lining Yao is fabricating the PneUI lamp, a shape-changing object that can morph from a single strip into an energy-saving bulb shape.

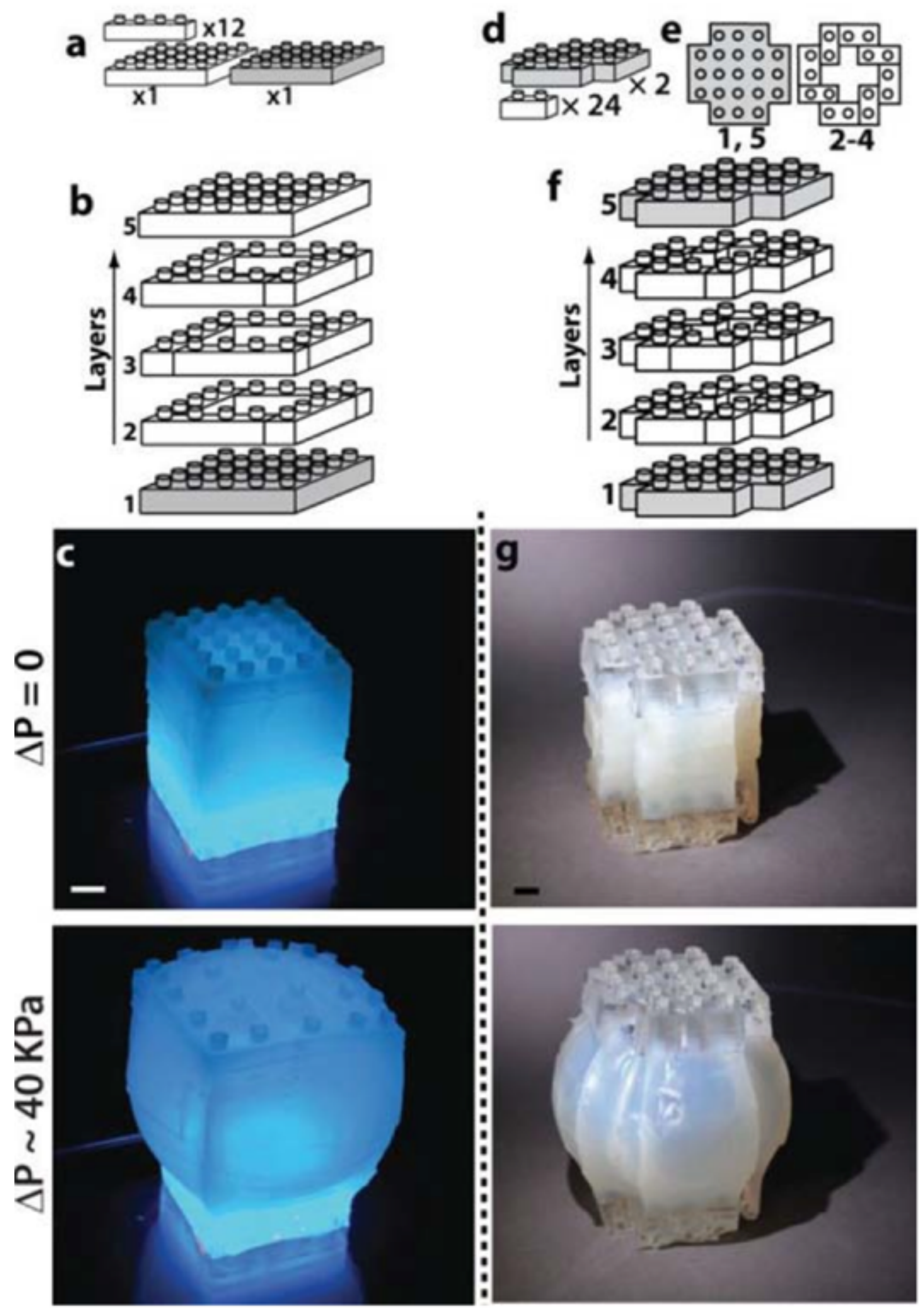
The PneUI lamp.

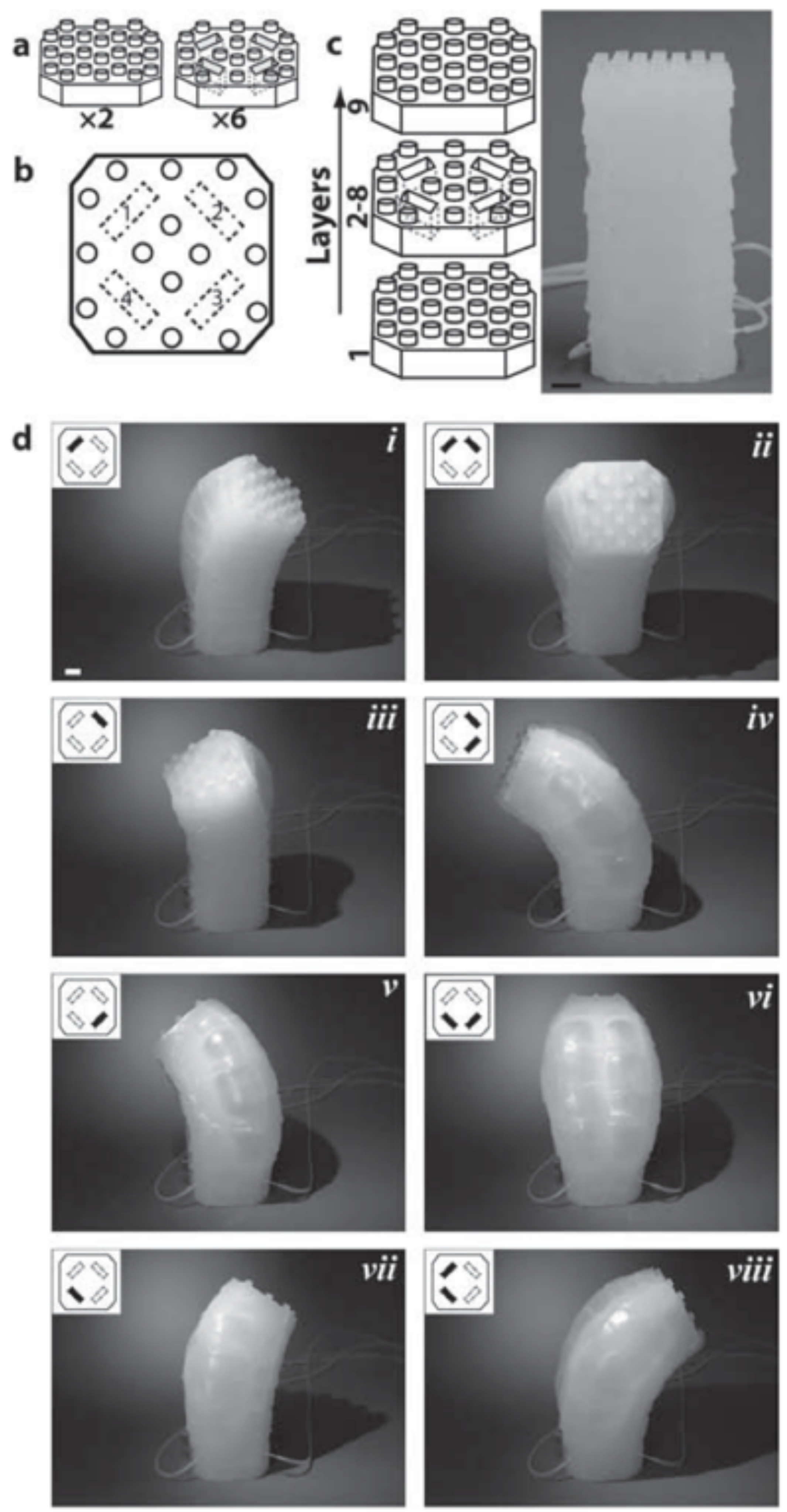
Jifei Ou is fabricating the multi-state air bladder. Bubbles can grow on bubbles; balloons can grow on balloons.

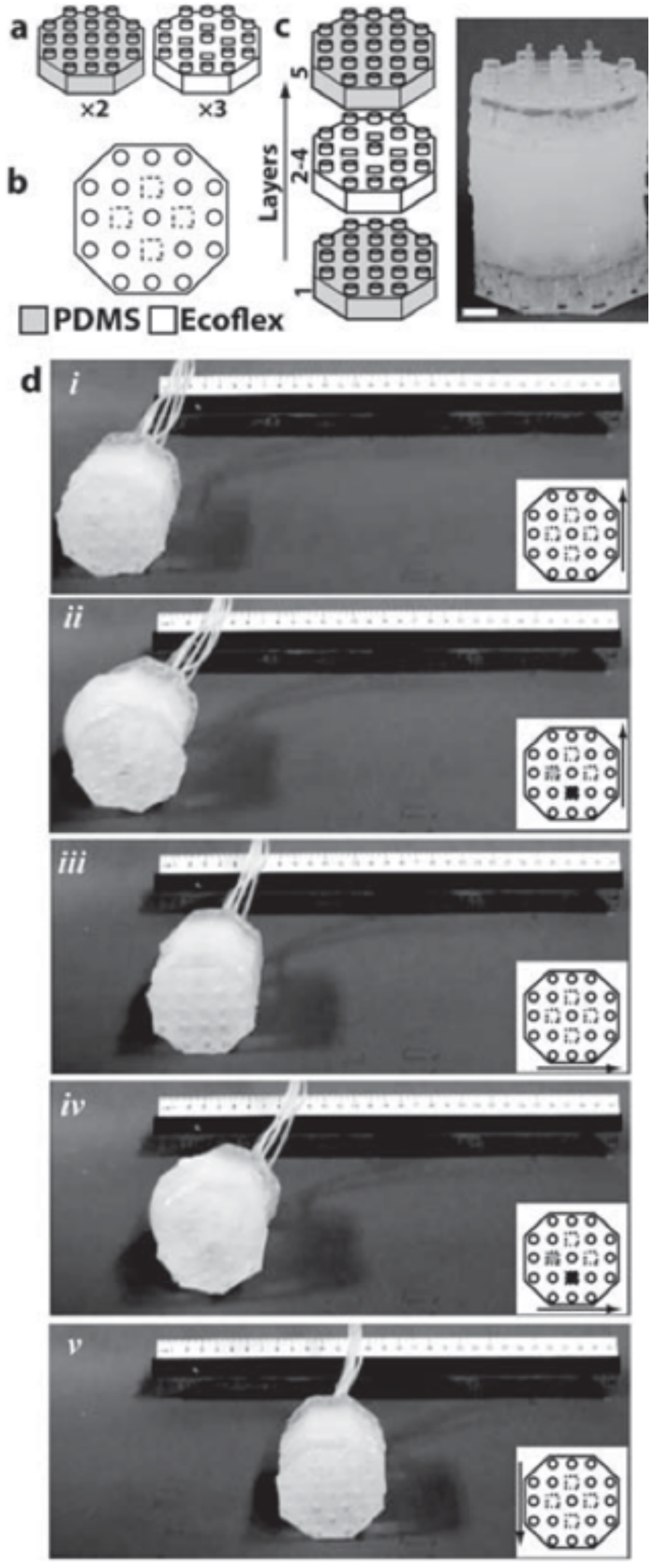


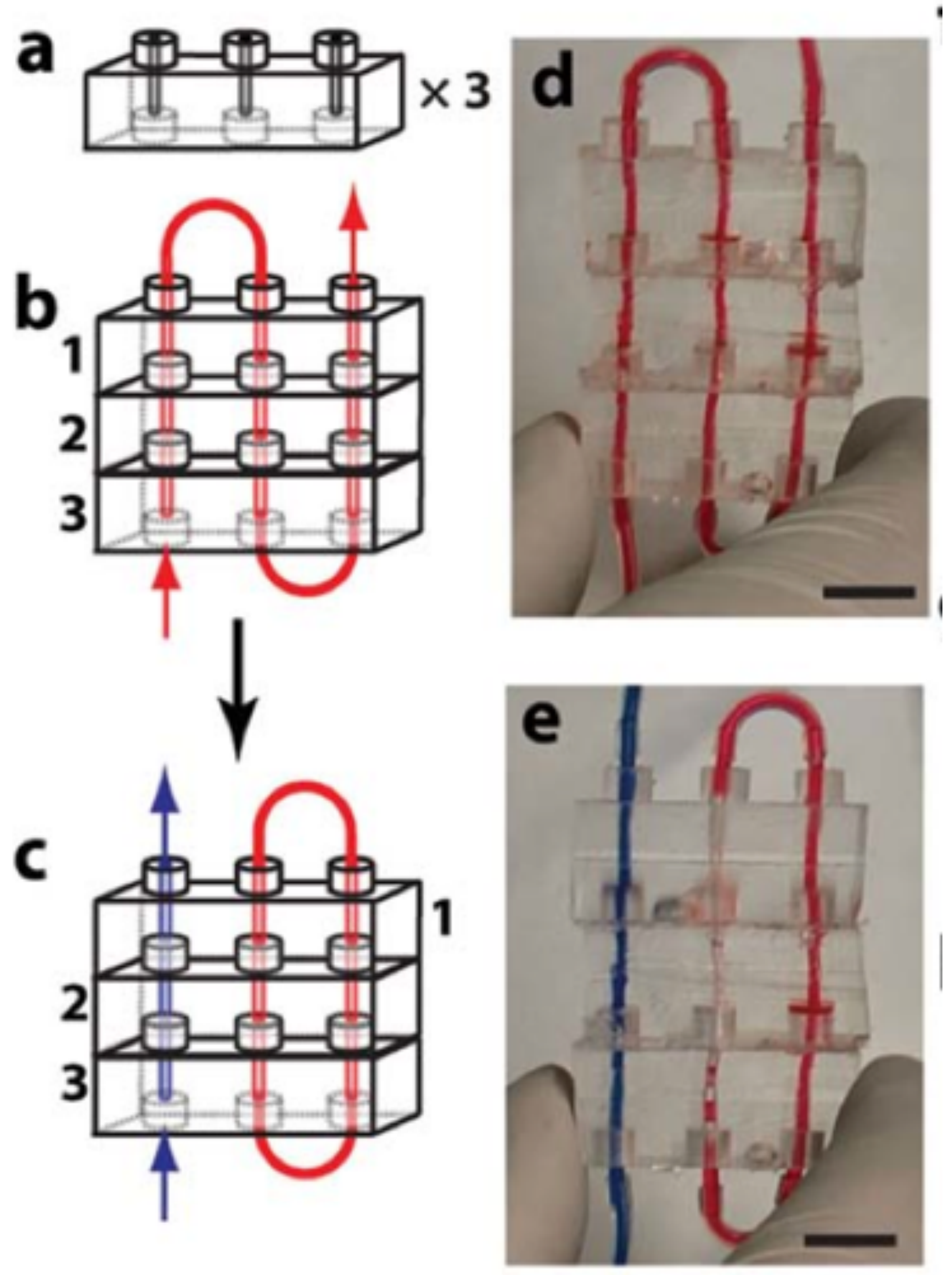
Multi-state texture samples with different cut patterns.

Modular Assembly - Lego Assembly

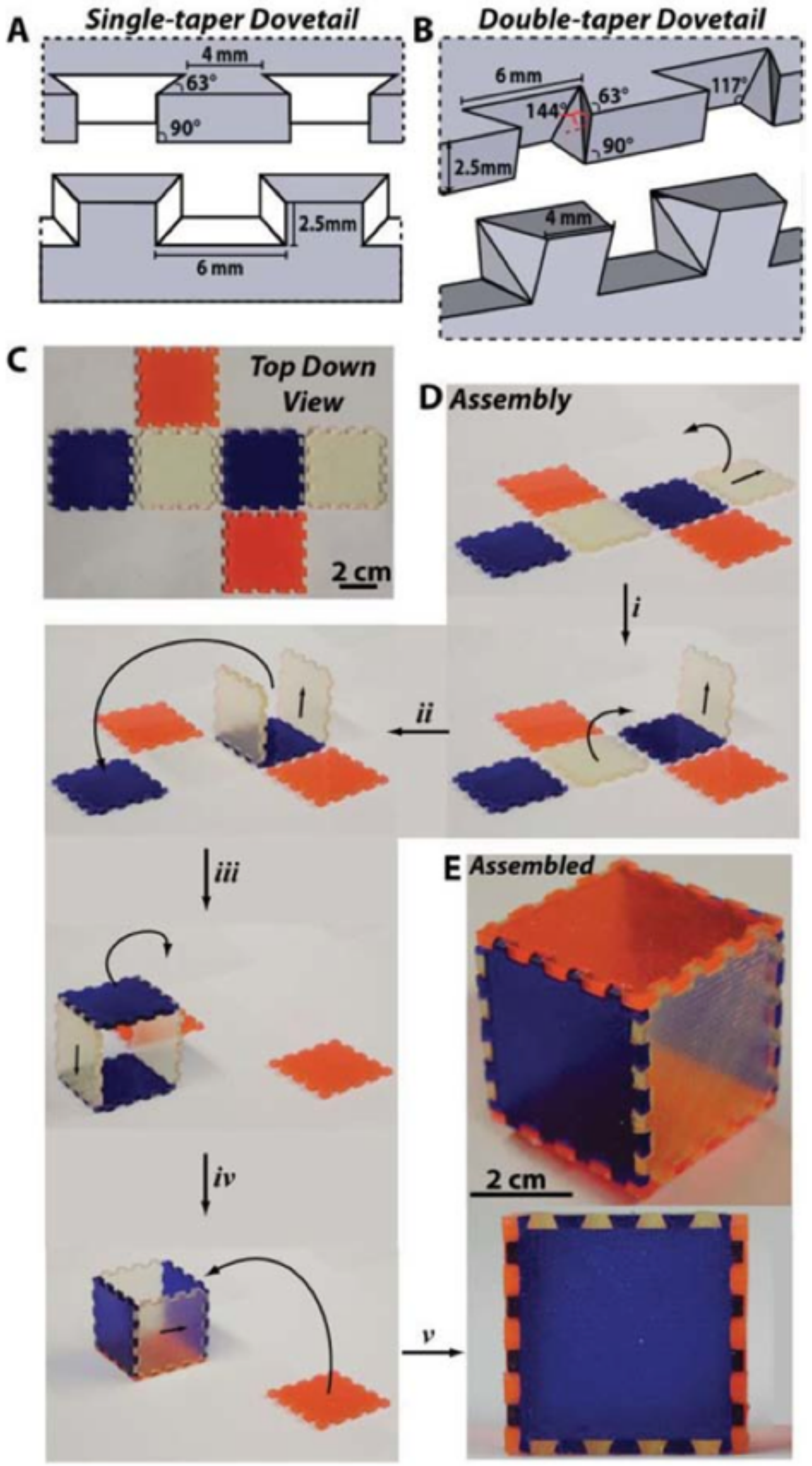


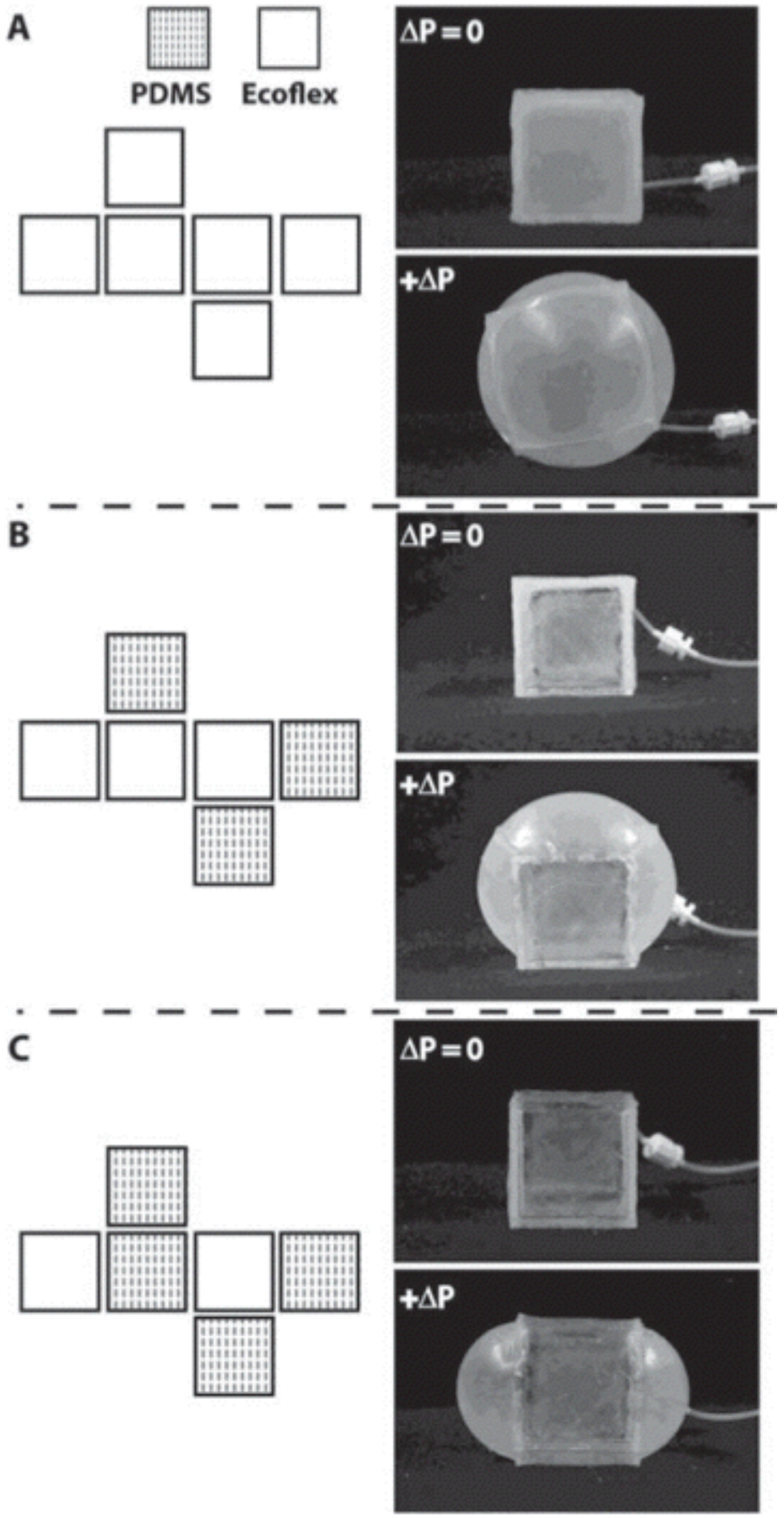


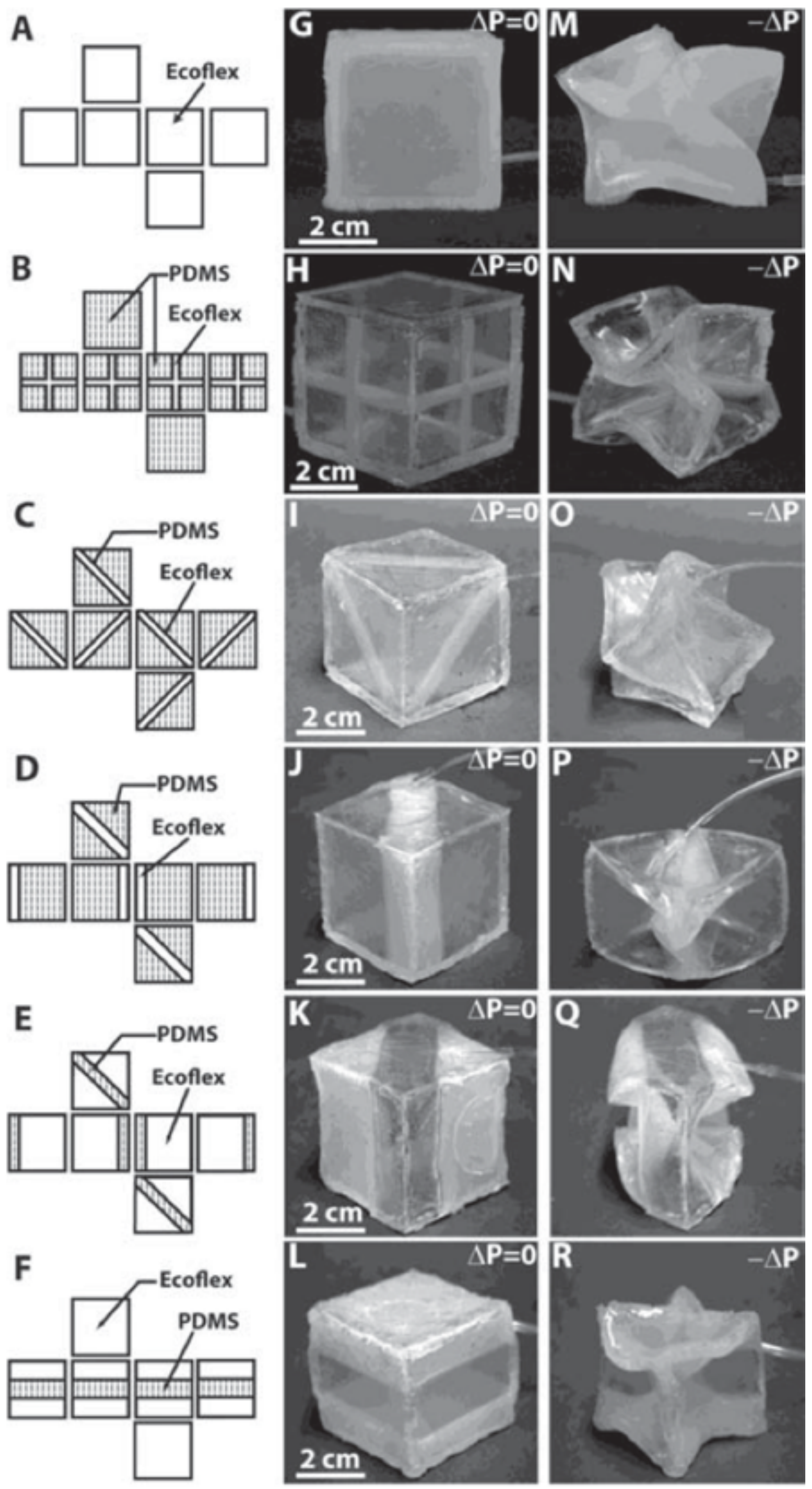




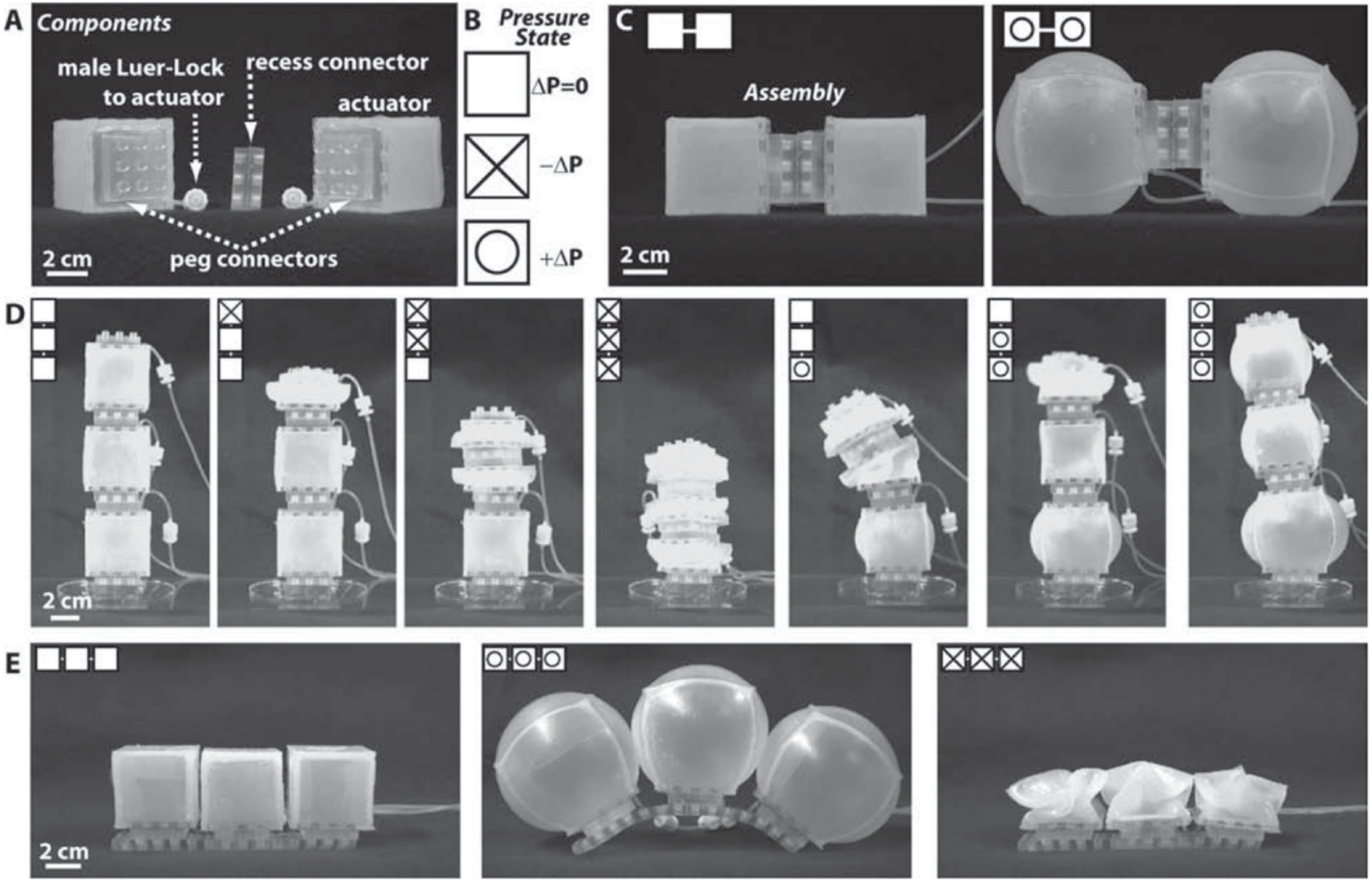
Modular Assembly - Soft Joinery



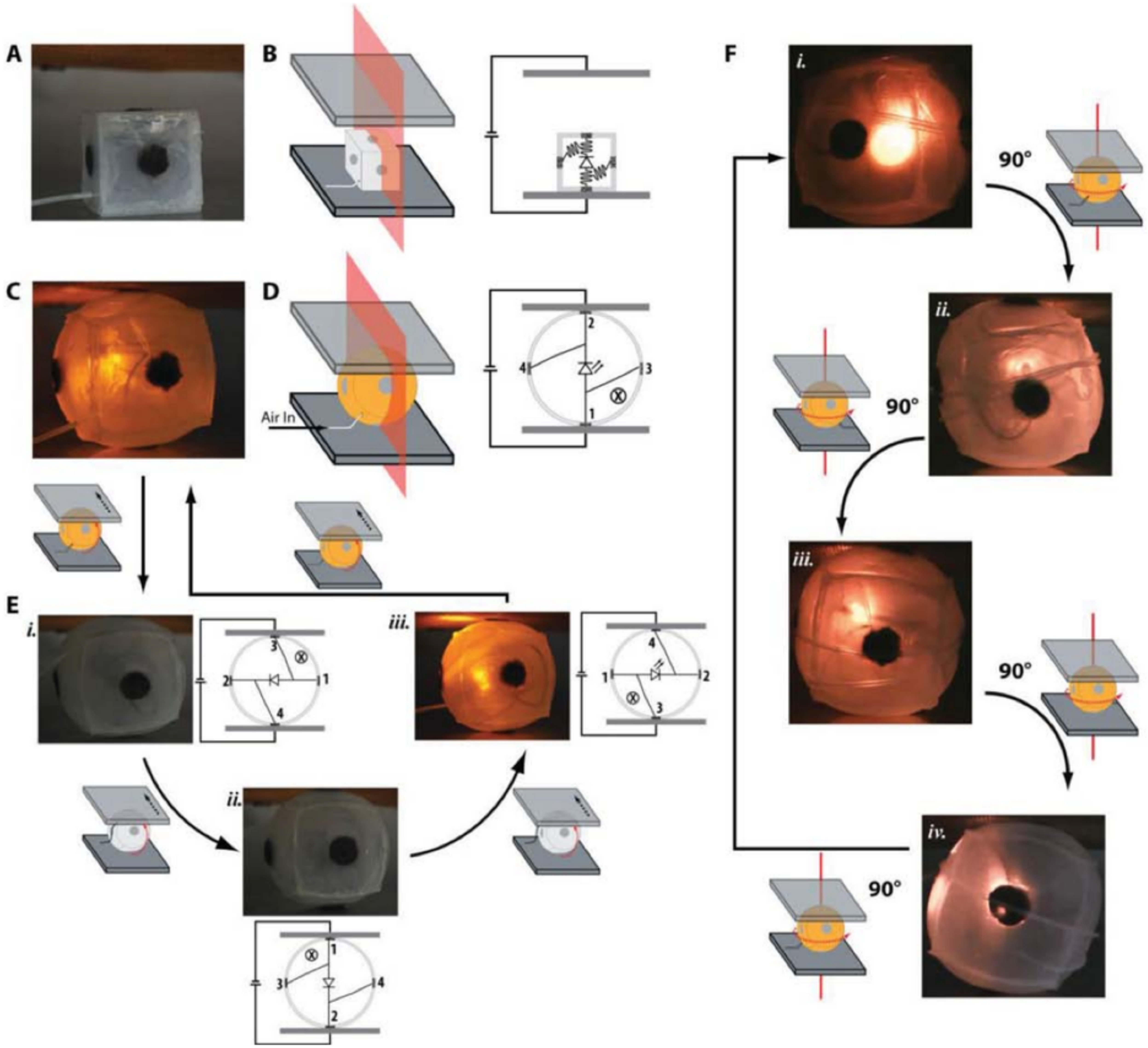




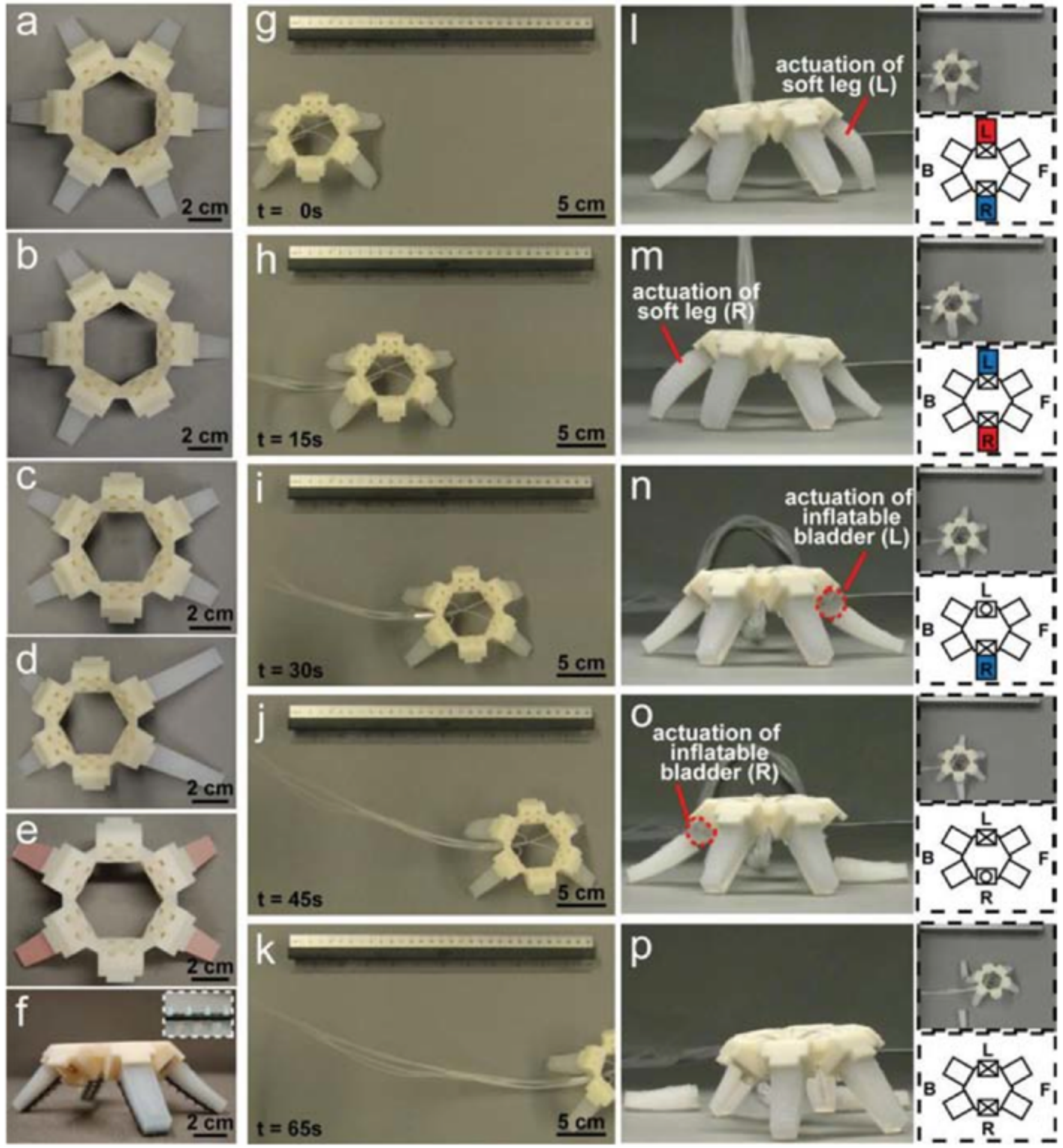
Modular Assembly - Soft Joinery

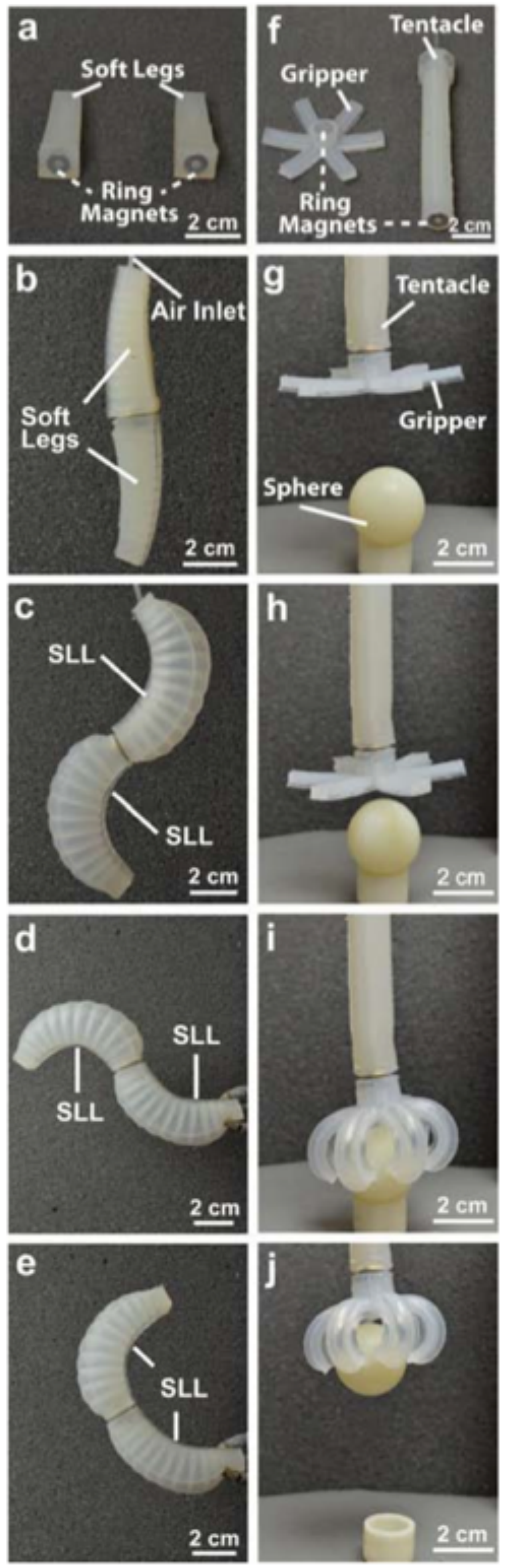


Modular Assembly - Soft Joinery

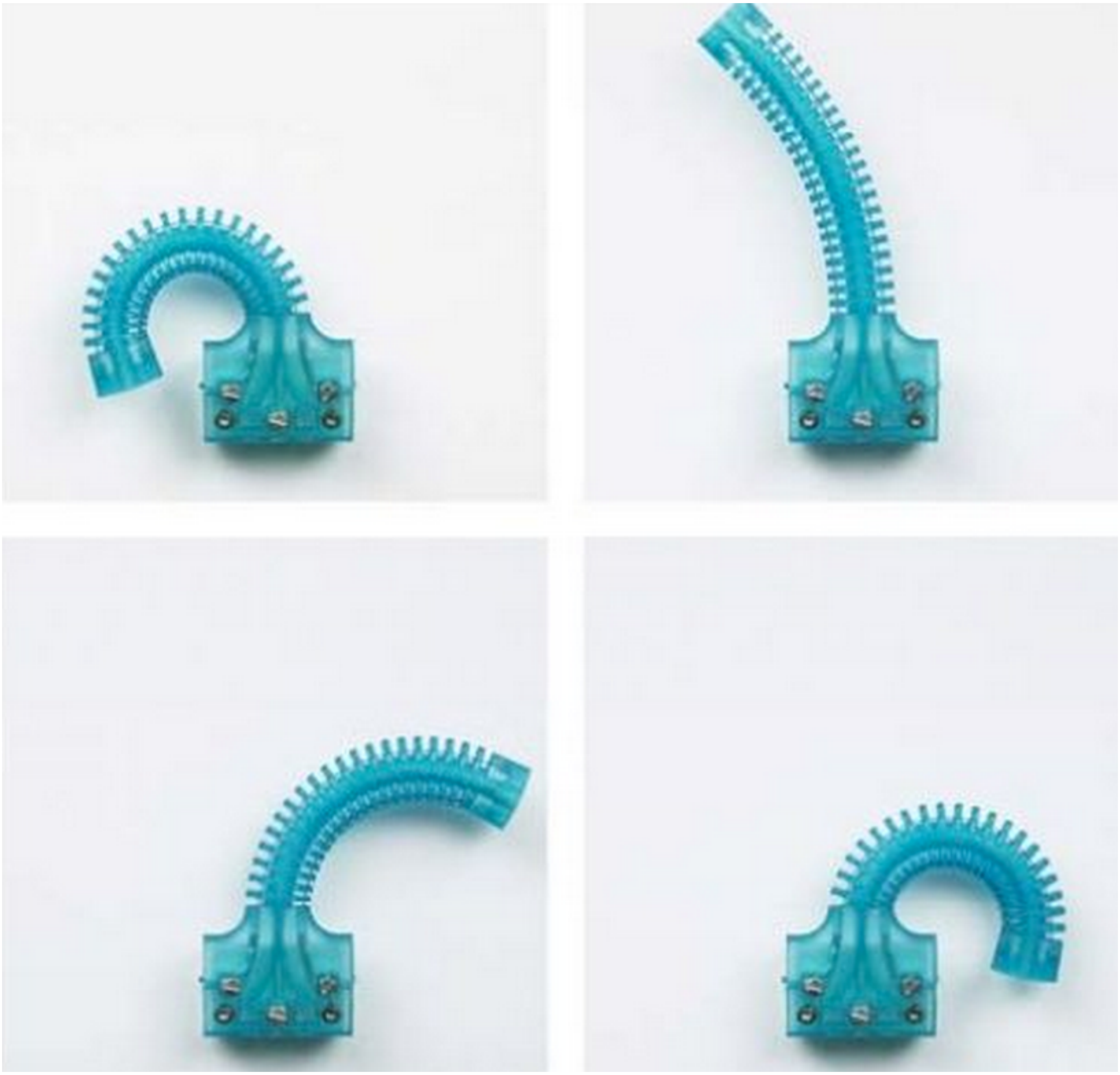


Modular Assembly - Magnetic Assembly





3D Printing



3D Printing

Stratasys

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Rubber-like

3D print flexible, soft-touch models

With Rubber-like PolyJet photopolymers, you can simulate rubber with different levels of hardness, elongation and tear resistance. Gray, black, white and translucent, Rubber-like material enables you to simulate a very wide variety of finished products, from soft-grip handles to footwear. With Connex3 systems, you can add color to the mix for exceptional final-product realism.

GET A SAMPLE PART U.S. ONLY

3D Printing


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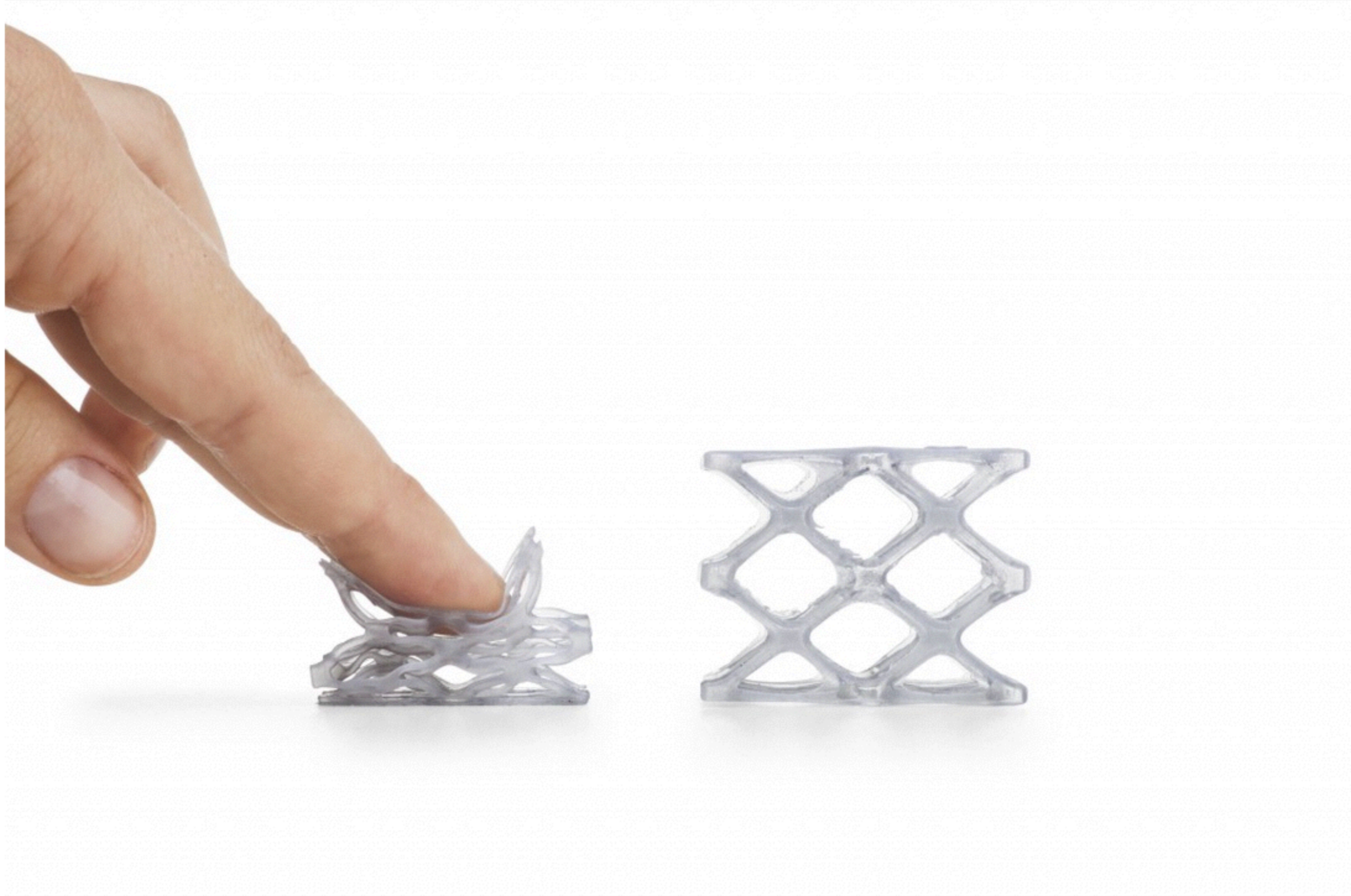
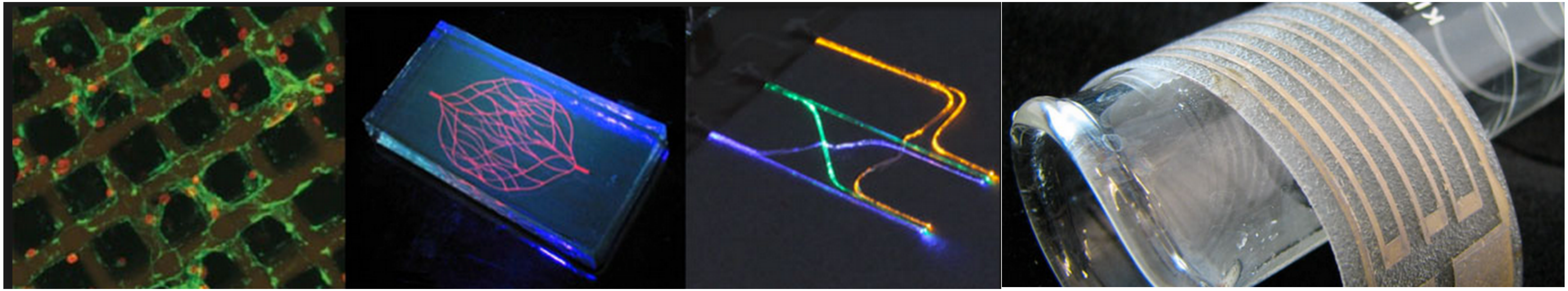


Formlabs Flexible Resin



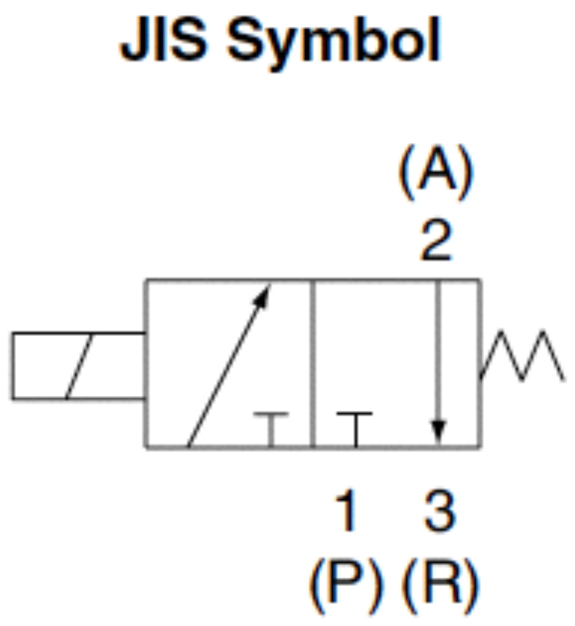
Your Own Way

Texture - Fabrication Process

Control

Control Toolkits

Pneumatic Valves



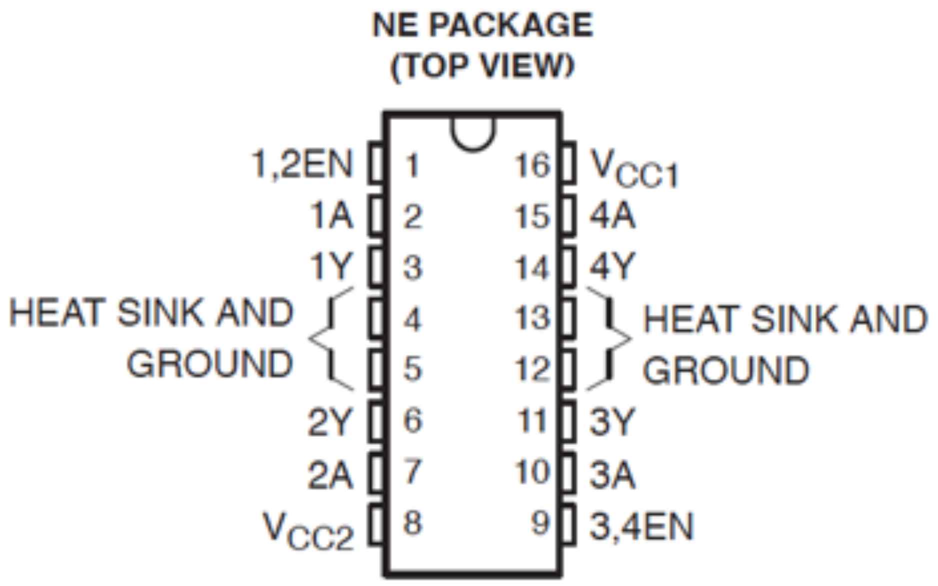
3 port S070, SMC

Pumps

0-32PSI Pressure,
0-16''Hg Vac,
Sparkfun

6 PSI Pressure
Koge KPM12A

Motor Drivers (H-bridge)



SN754410 Half-H driver

Power Supply

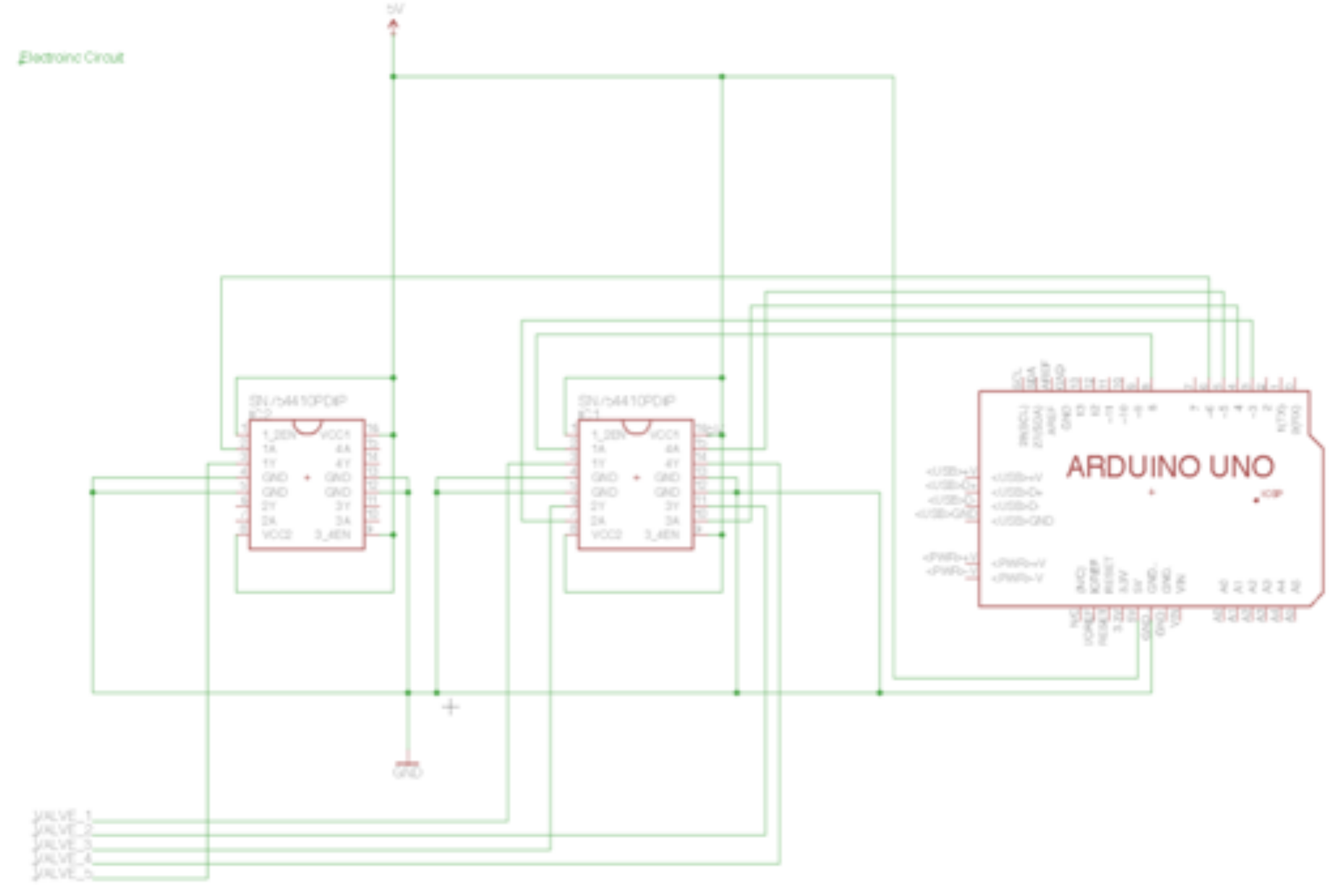
12V, wall adaptor power supply

Micro-controller

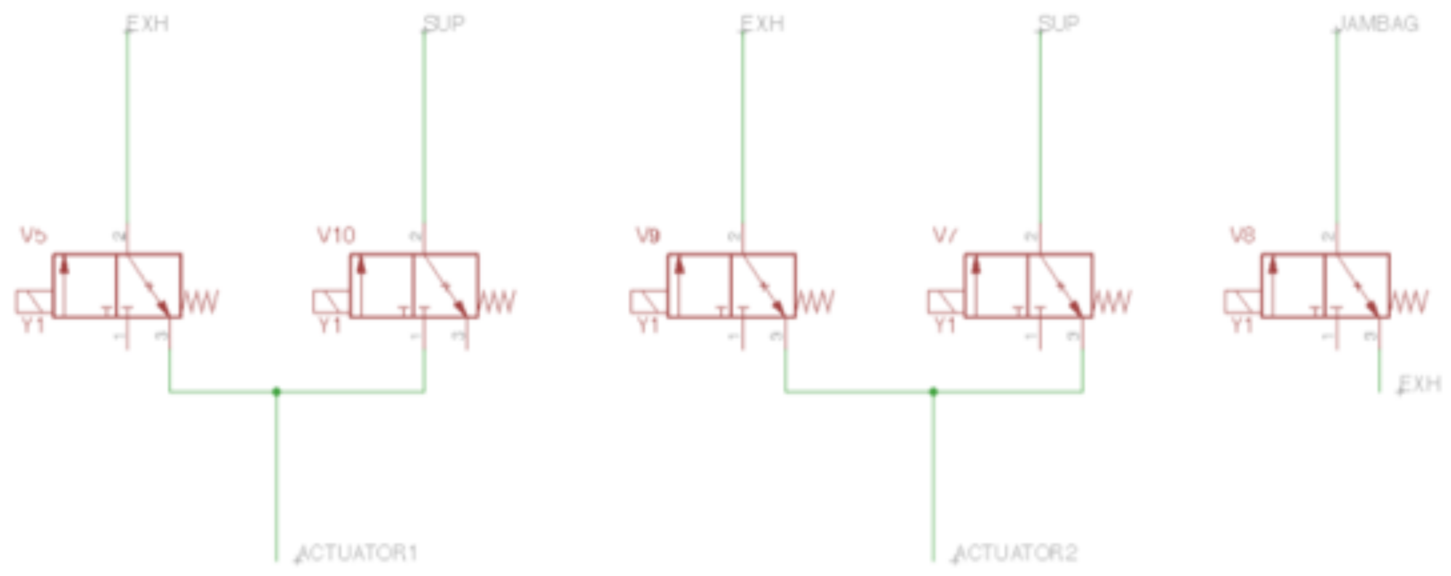
arduino.cc

Control

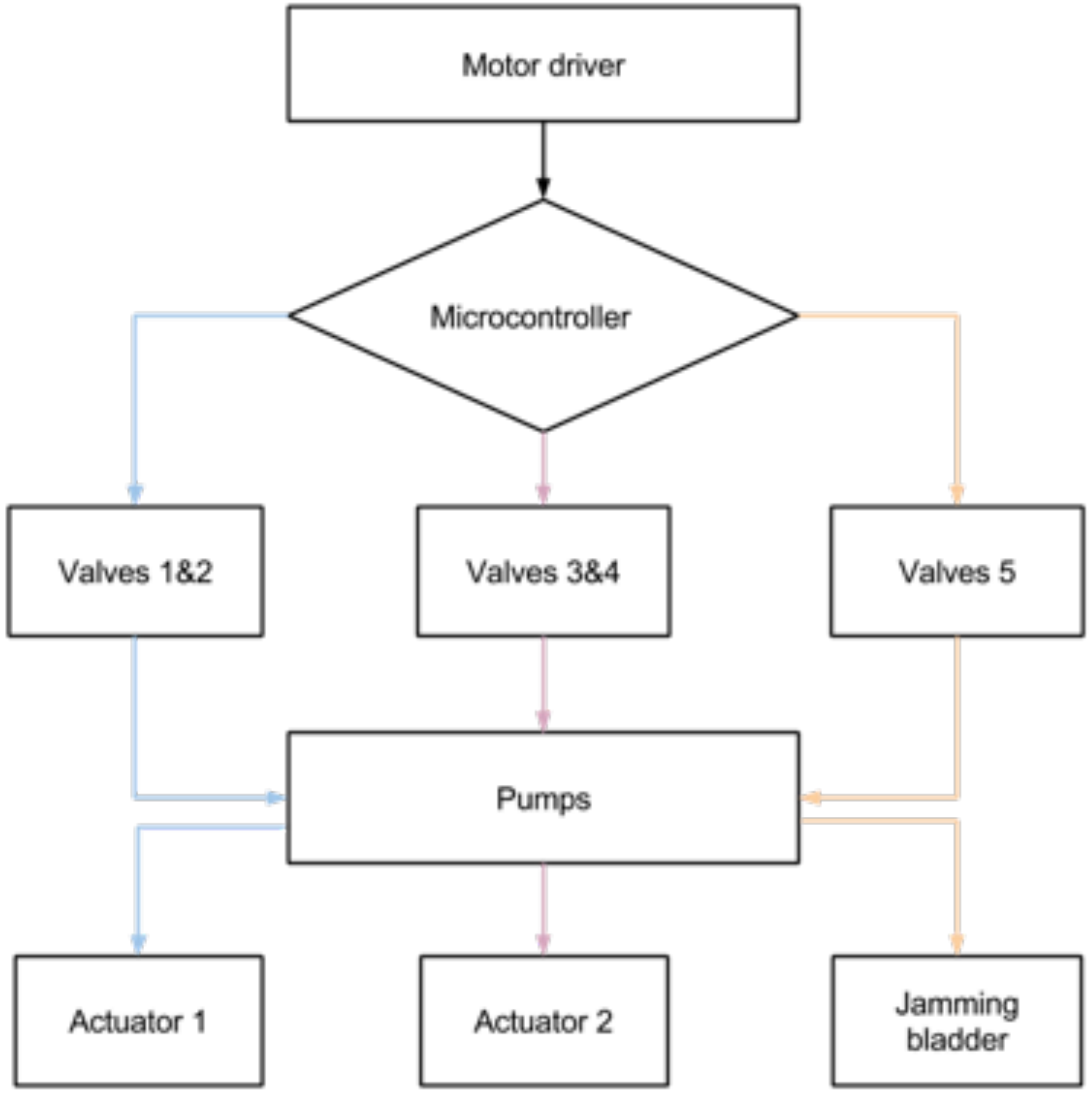
Electronic Example Circuit



Pneumatic Example Circuit



Control Toolkits



http://softroboticstoolkit.com/

soft robotics toolkit

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What is soft robotics?

Soft robotics is a growing field that takes inspiration from biological systems to combine classical principles of robot design with the study of soft, flexible materials. Many animals and plants are composed primarily of soft, elastic structures which are capable of complex movement as well as adaptation to their environment. These natural systems have inspired the development of soft robotic systems, in which the careful design of component geometry allows complex motions to be "pre-programmed" into flexible and elastomeric materials. The use of compliant materials to embed intelligence in the mechanics of the body enables designers to simplify the more complex mechanisms and software control systems used in traditional, rigid robotics. The inherent compliance of soft robots makes them highly adaptable to a wide range of tasks and environments. In particular, they are ideally suited for interactions with humans, from assisting with daily activities to performing minimally invasive surgery.

Live Demo

Supplementary Material: More Relevant Work

How are human beings using it? (except breathing)

Soft Robotics

Technical Properties

Mechanical compliance matching, elastically deformable,
- large contact area to transfer force between the robot and the surface
- Maneuvering through confined spaces
- friendly, not harmful to the skin

Multi-functionality
Elastic Versatility

(compliance matching: the principle that contacting materials should share similar mechanical rigidity in order to evenly distribute internal load and minimize interfacial stress concentrations.)

Biomimetic: octopus squeeze through a small hole

Applications

Locomotion and manipulation
“Versatile, lifelike, compatible for human interaction
Medical robots that interact with soft materials such as skin muscle tissue
Field Robots encountering deformable surfaces like sand, mud, and soft soil
Cooperative Human assistance
Wearables