UNSW
THE UNIVERSITY OF NEW SOUTH WALES

38APS
38TH AUSTRALASIAN POLYMER SYMPOSIUM
18-21 FEBRUARY 2024 · GRAND MILLENNIUM AUCKLAND · NEW ZEALAND

Hierarchical Polymer Structural Design on Hydrogel Surfaces for Artificial Skin

A/Prof. *Jiangtao (Jason) Xu*

Never Stand Still | Faculty of Engineering | School of Chemical Engineering

CAMD
Centre for Advanced Macromolecular Design

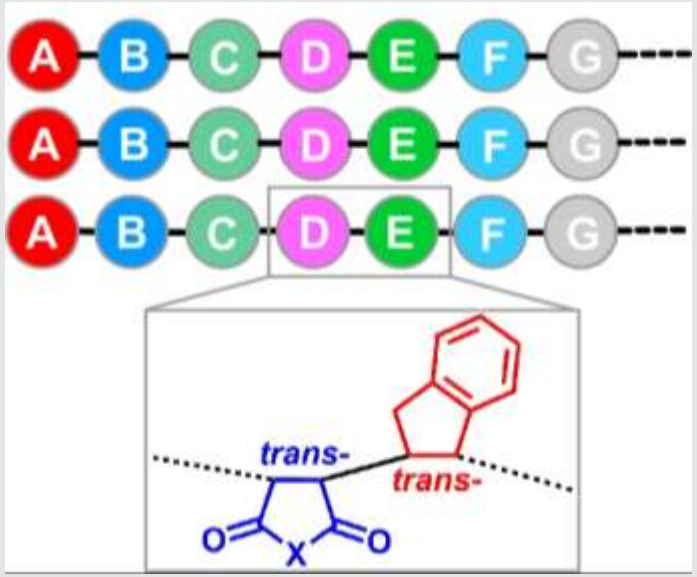
ACN
Australian Centre for NanoMedicine

Xu Group Research Projects

Chemistry

PRECISION POLYME SYNTHESIS

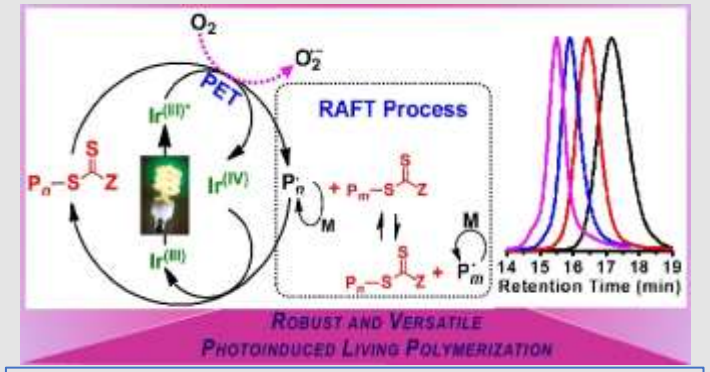
Single Unit Monomer Insertion (SUMI)
for *sequence*, *stereo* and *chain length* control



Chemistry + Engineering

GREEN POLYMER SYNTHESIS

Visible Light Photoredox Catalysis for Living Polymerization
PET-RAFT technique

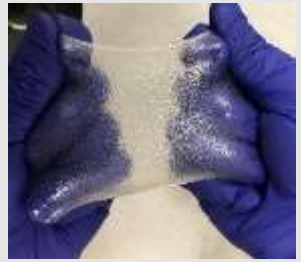


Heterogeneous Catalysis
for Living Polymerization

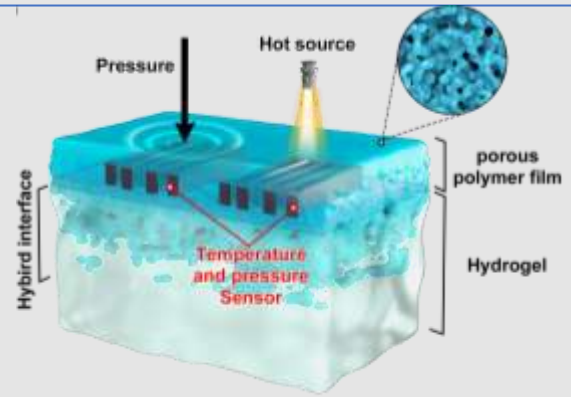
Materials

POLYMER HYDROGELS

Double Network Hydrogel
for biomedical devices

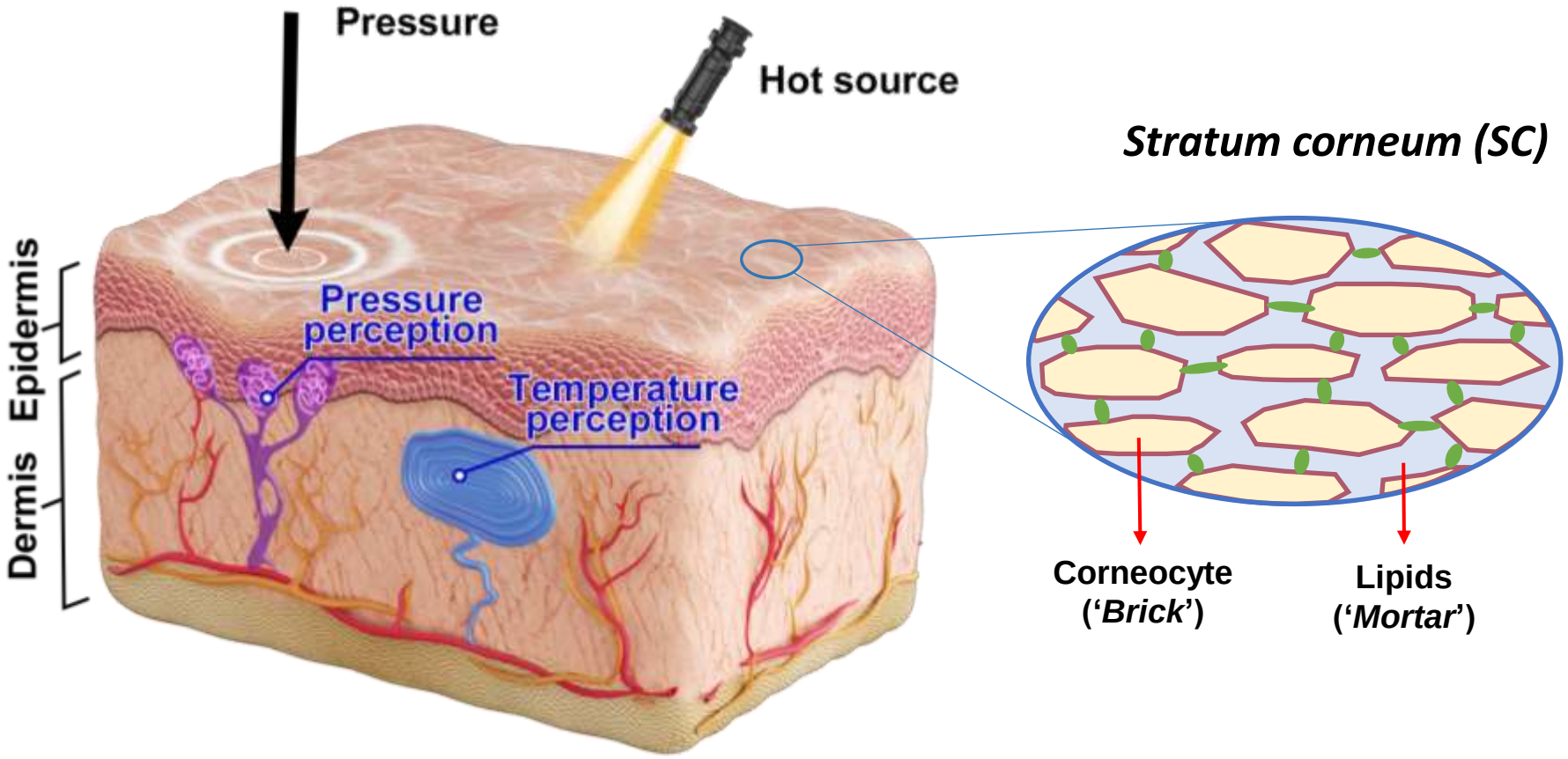


Artificial and Electronic Skin



Biomimetic E-Skin

Artificial and Electronic Skin

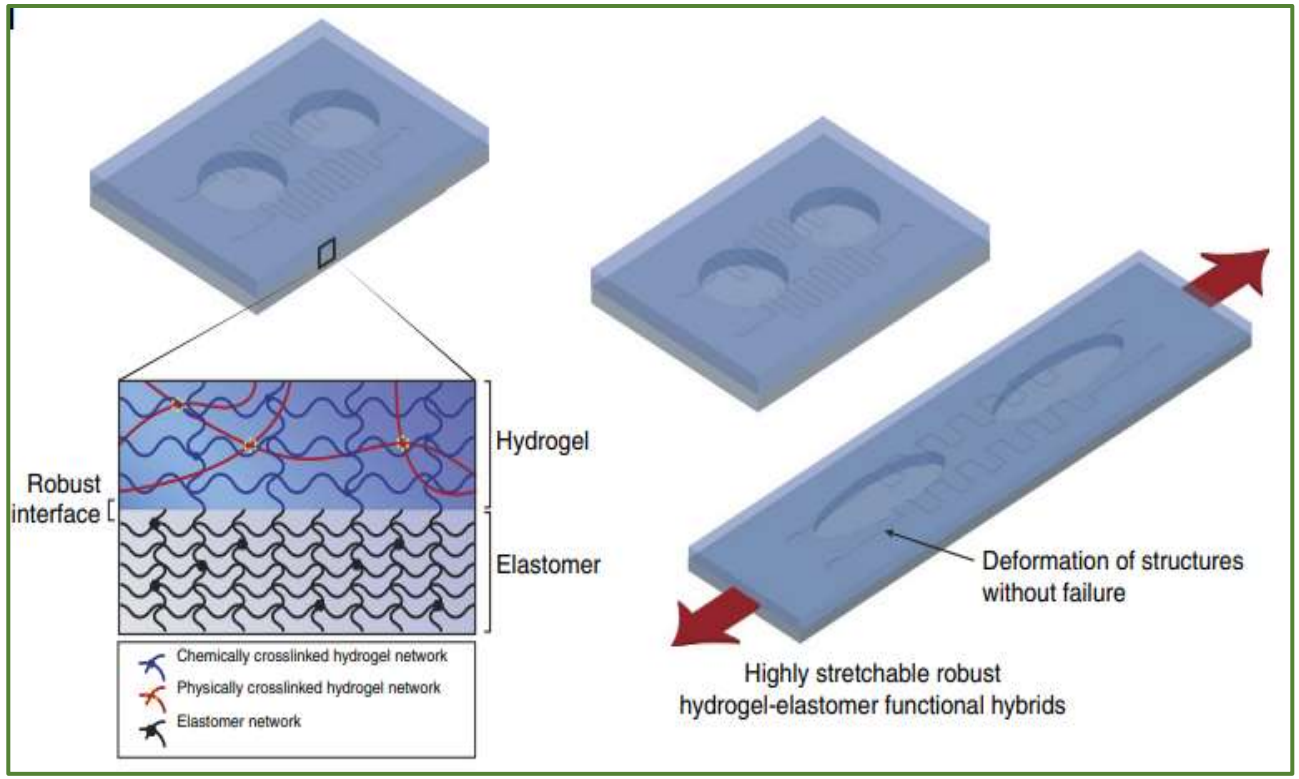


Two Major functions of skin:

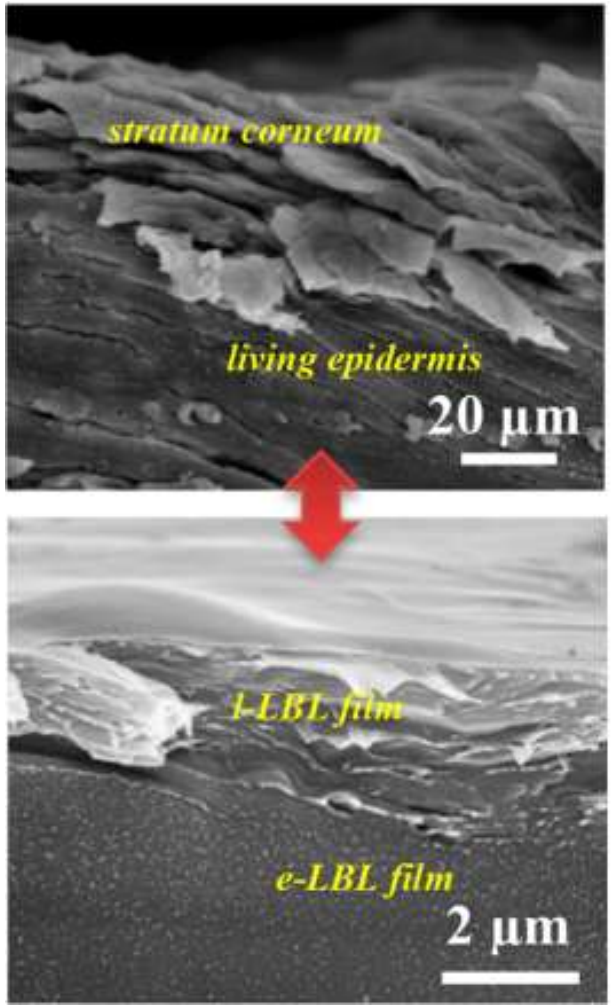
- ✓ **Protection (Mechanical, chemical, UV irradiation, water loss, etc)**
- ✓ **Sensation (pressure and temperature, etc)**

Existing materials to mimic dermis-epidermis bilayer

Hydrogel-elastomer hybrid



Polymer film-Inorganic materials (Graphene oxide, etc)

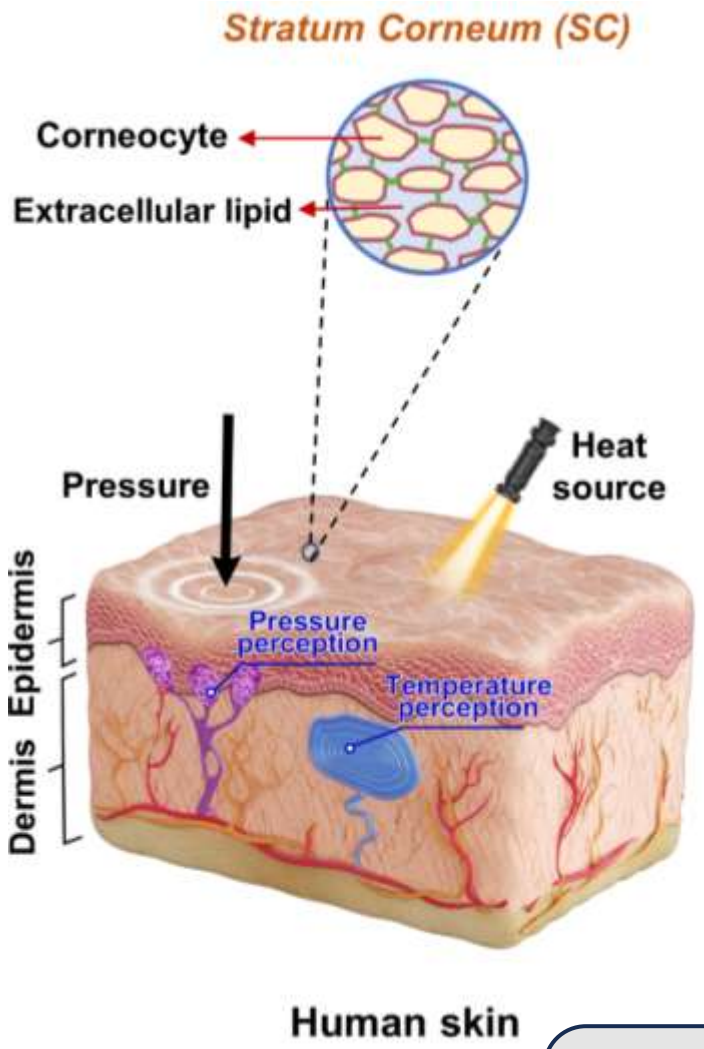


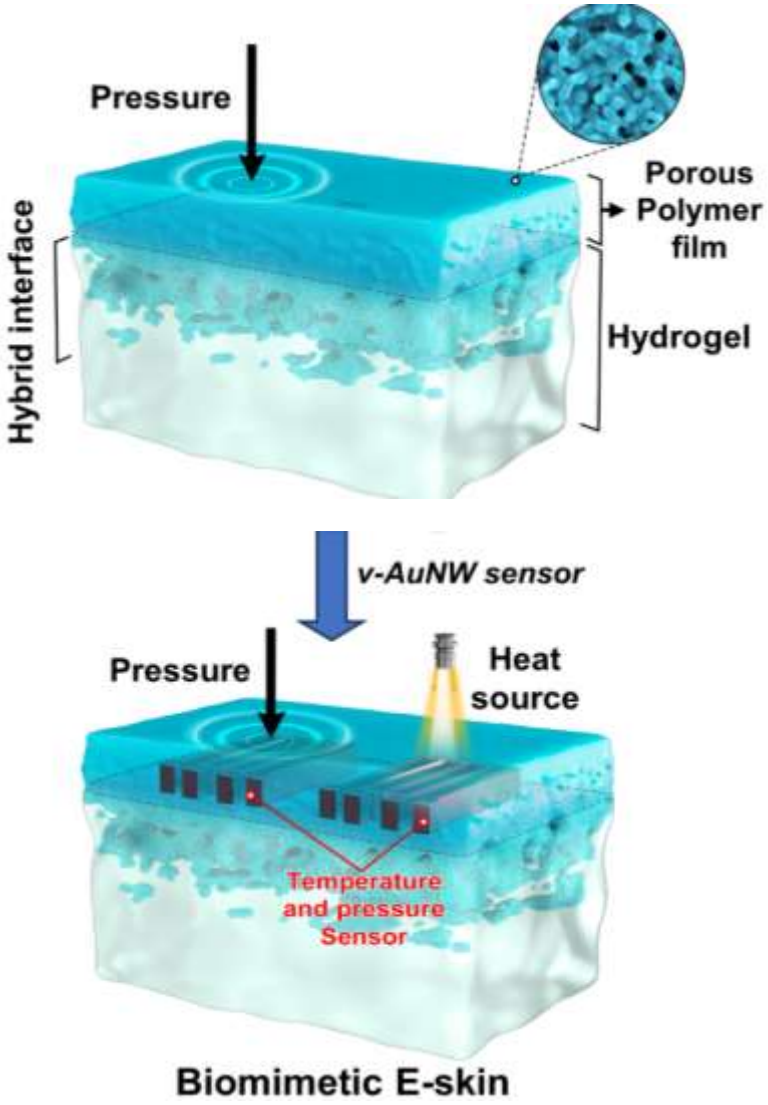
Flaws:

- ✓ **Low structural similarity and stability**
- ✓ **Low water permeability**
- ✓ **Difficult to make complex electronic devices**

Nat. Commun. ***2016****, 7, 12080*
ACS Nano **2018**, *2*, 1062–1073

Our polymer design





Interlocked corneocyte	VS	Porous Polymer film
Dermis	VS	Hydrogel
Epidermis-dermis junction	VS	Hybrid interface
Sensory receptors	VS	Embedded sensors

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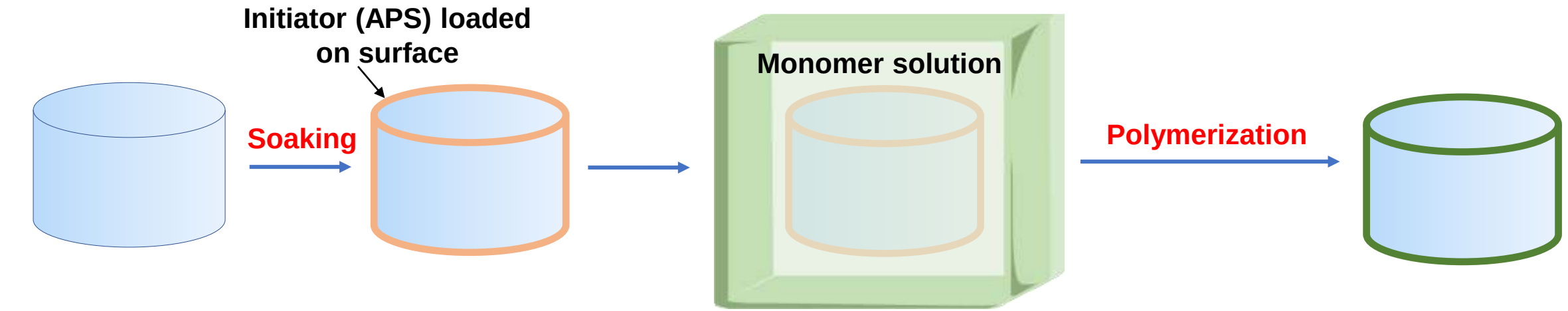
Preparation

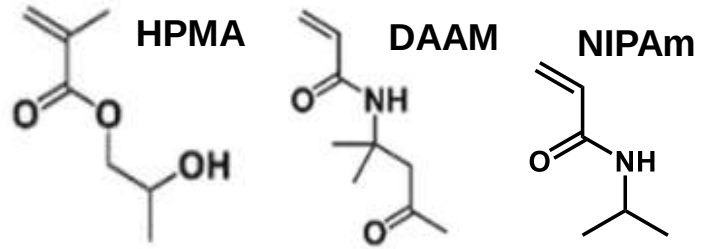
In situ **Growth of Porous Polymer Films from Hydrogel Surface**

Synthetic procedure



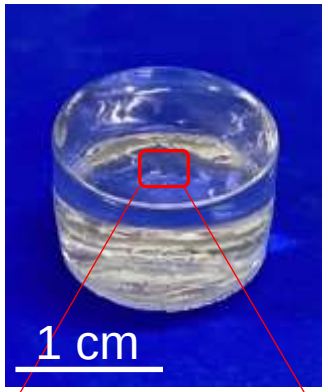
Monomer solution:

- Monomer
- TMEDA
- Crosslinker

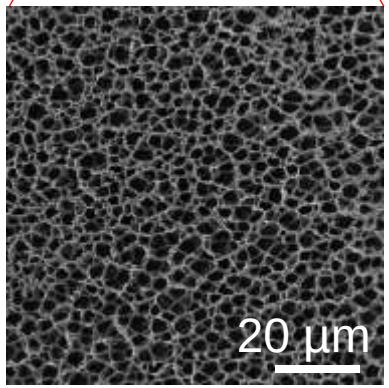


Structural characterization – Morphology, thickness and nanoparticle size

Before coating
(pristine hydrogel)

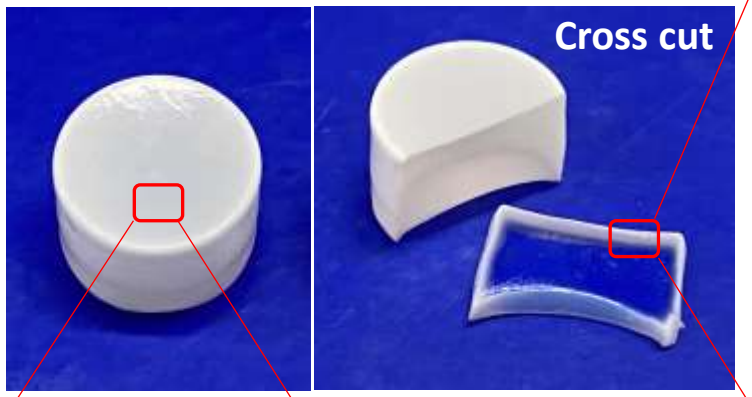


SEM

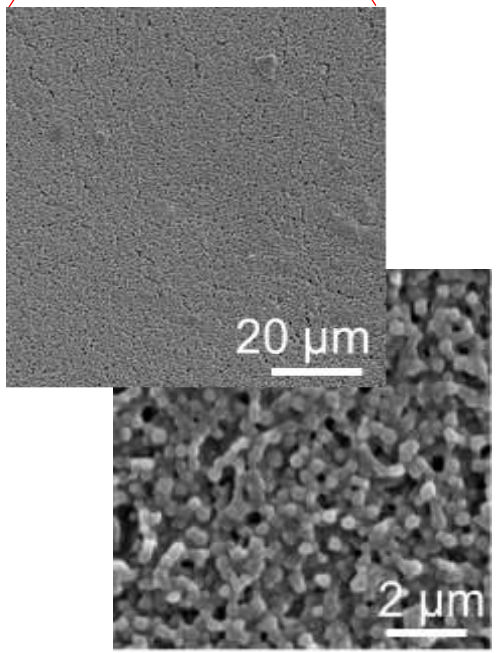


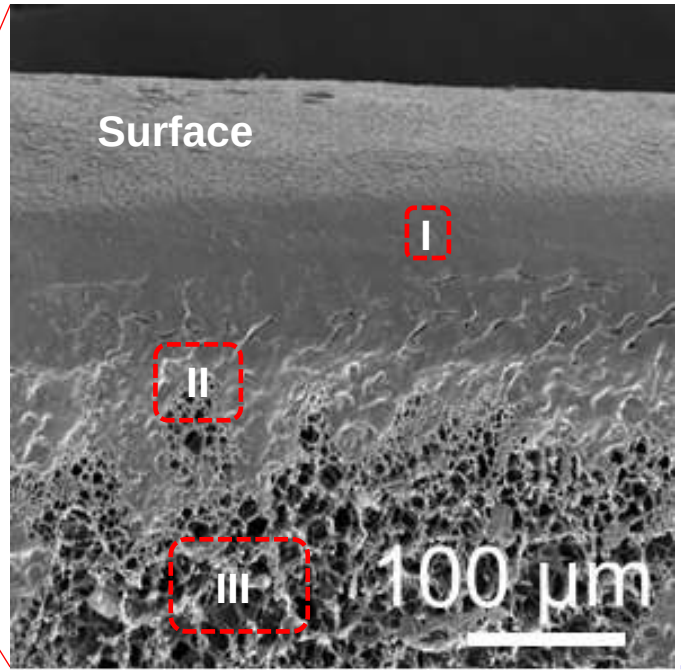
Surface morphology

After coating



SEM

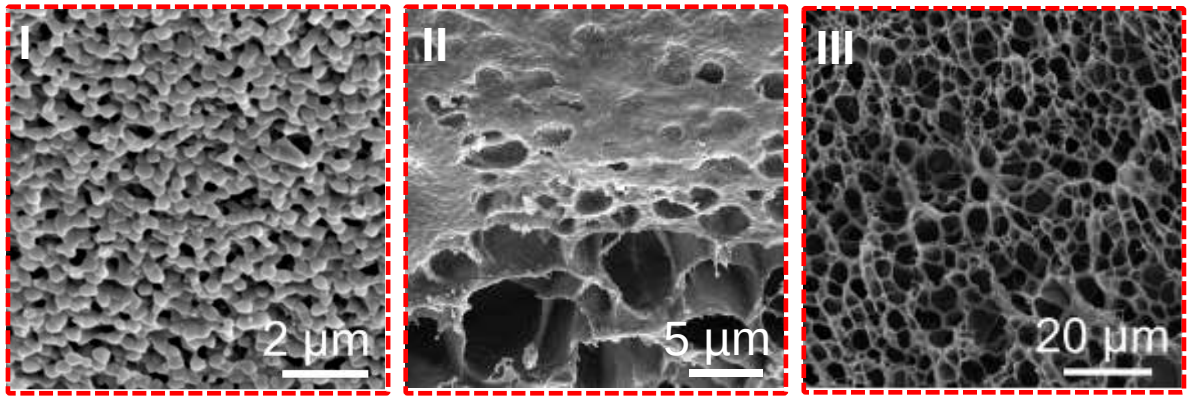




Porous polymer film

hybrid interface

Hydrogel



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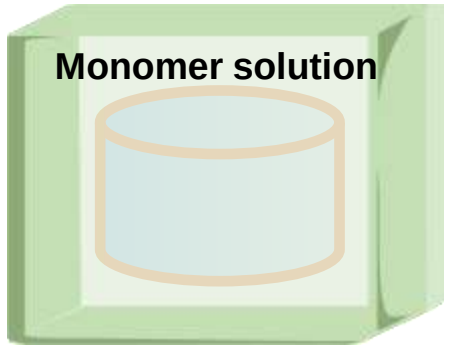
Mechanistic insights

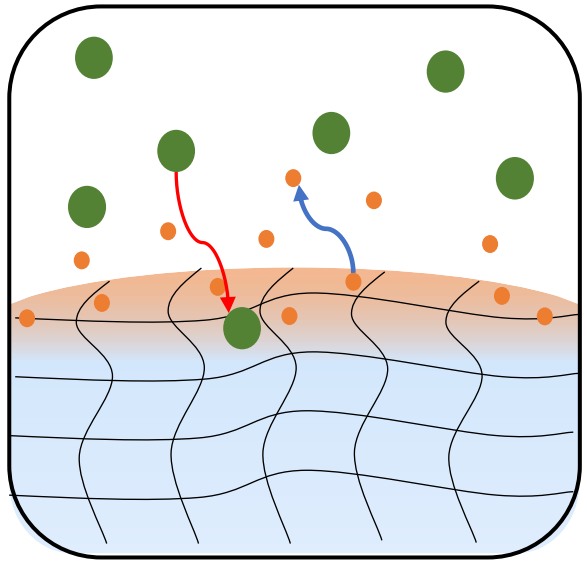


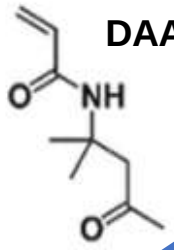
Monomer solution:

Monomer

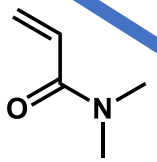
TMEDA

Crosslinker



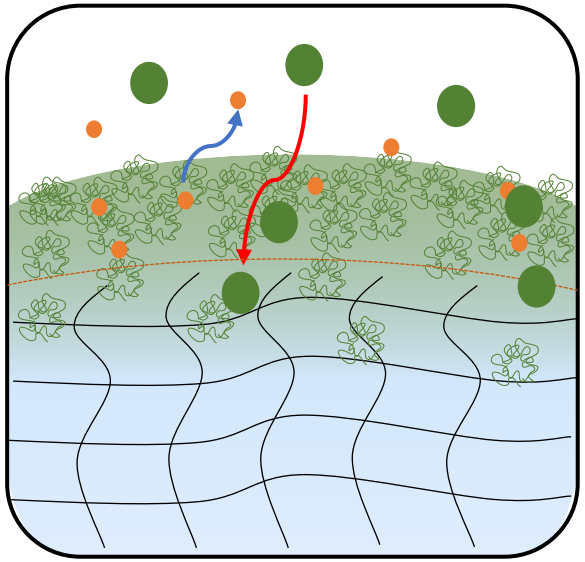


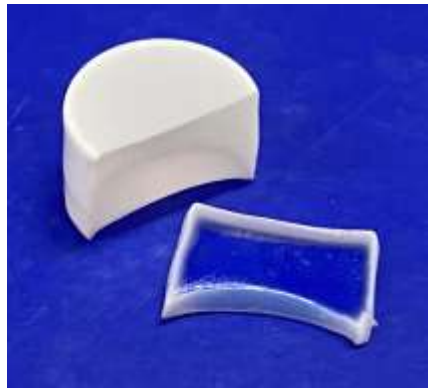
DAAM



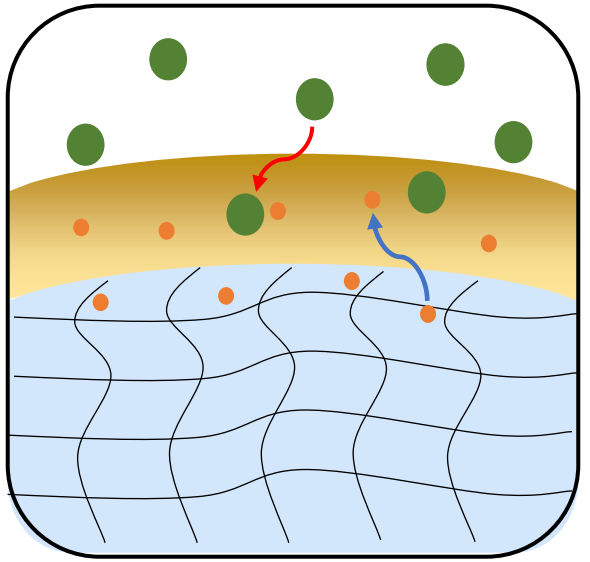
DMA

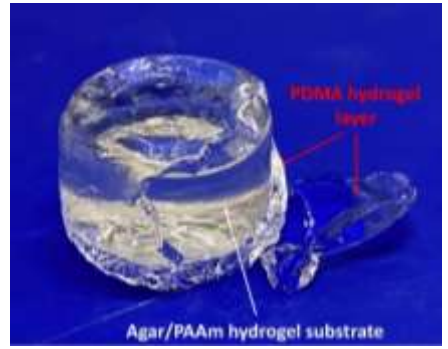
Two-way diffusion and precipitation polymerization





One-way diffusion and Solution polymerization



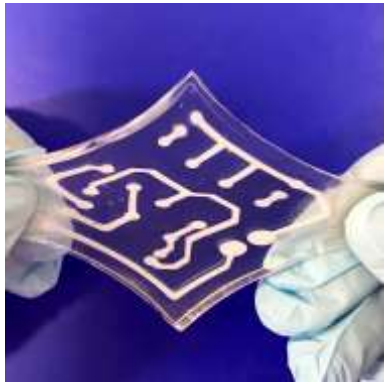


Surface patterning

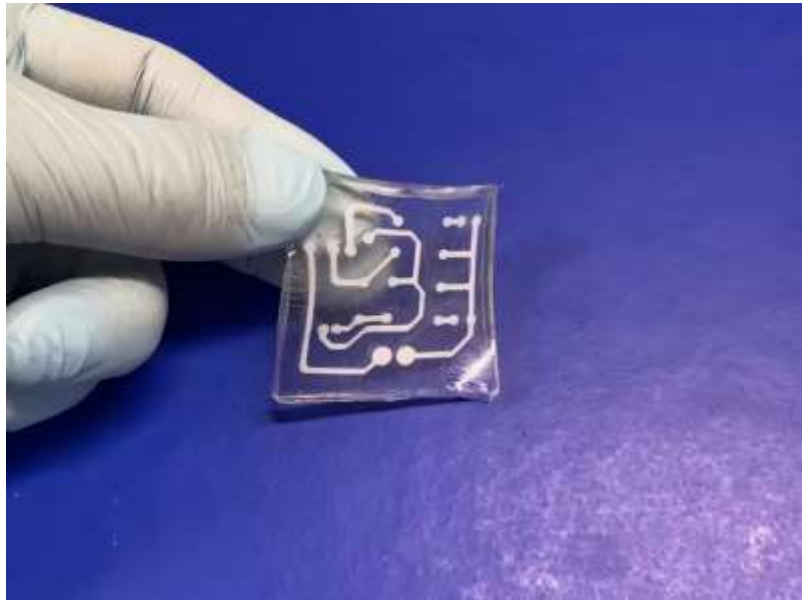
Plastic mask with patterns

After film growth

Cover & Coating

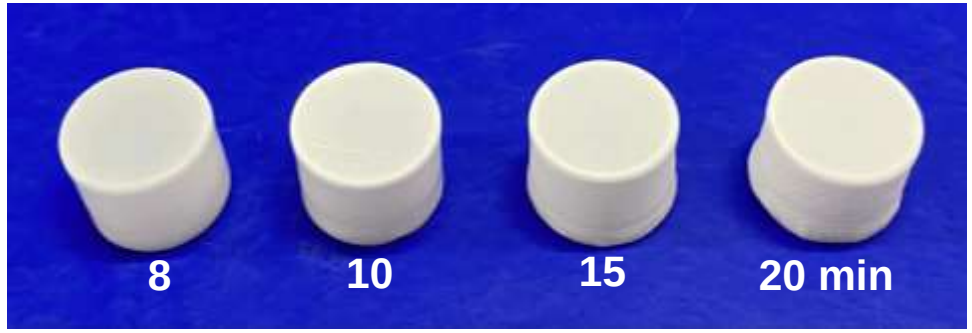


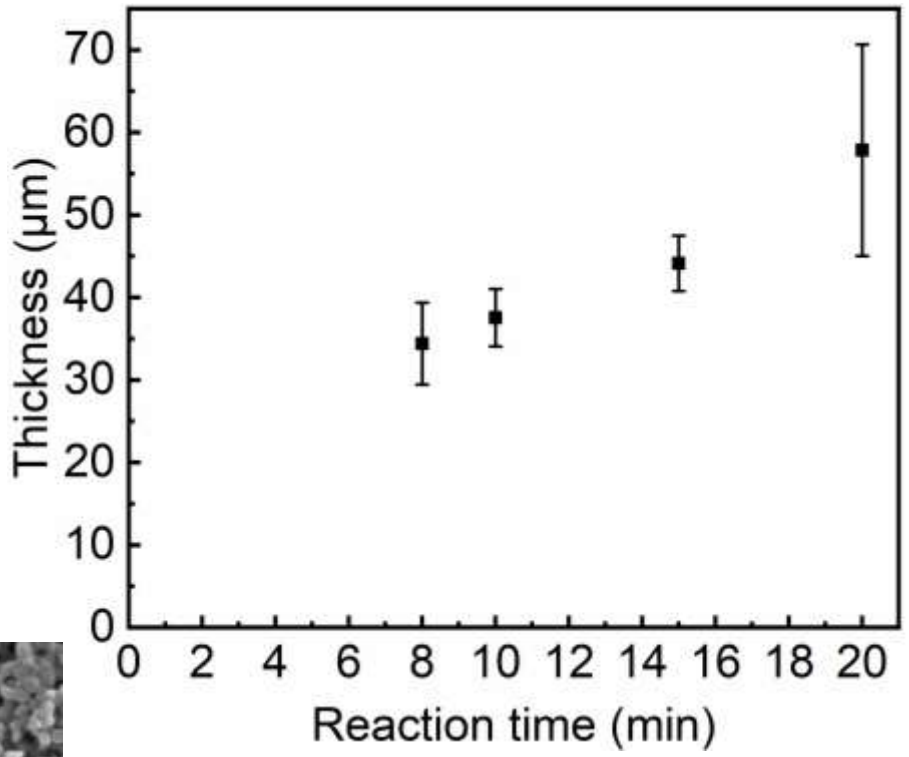
Cover & Coating

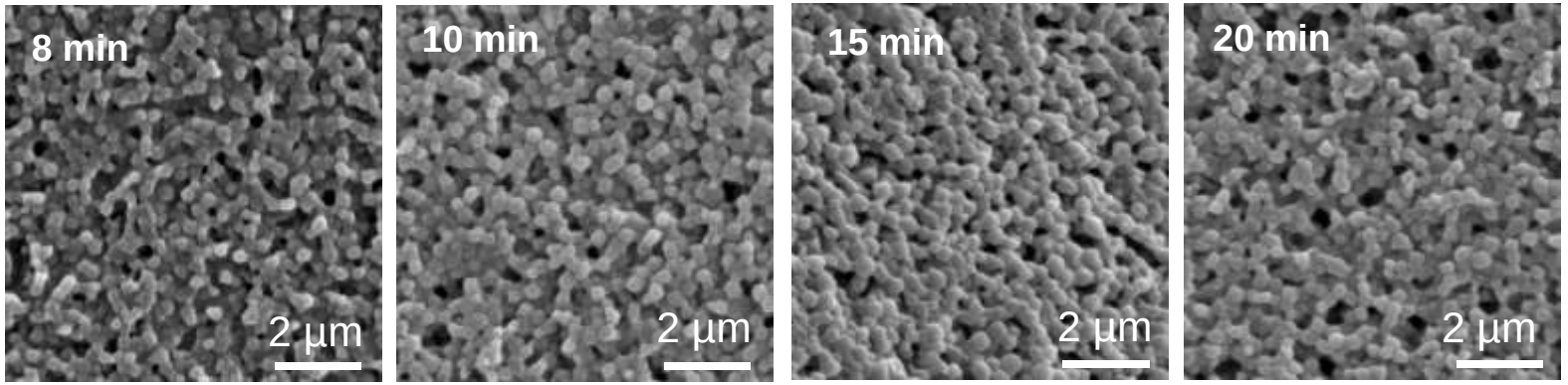


Thickness control of porous polymer film

A). Polymerization time

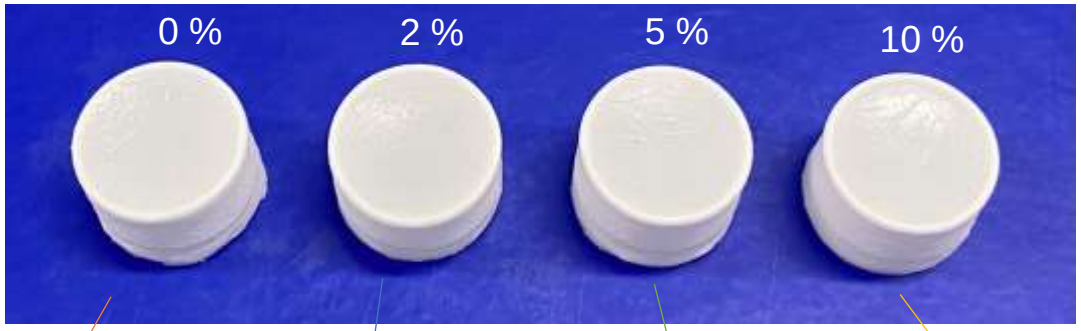


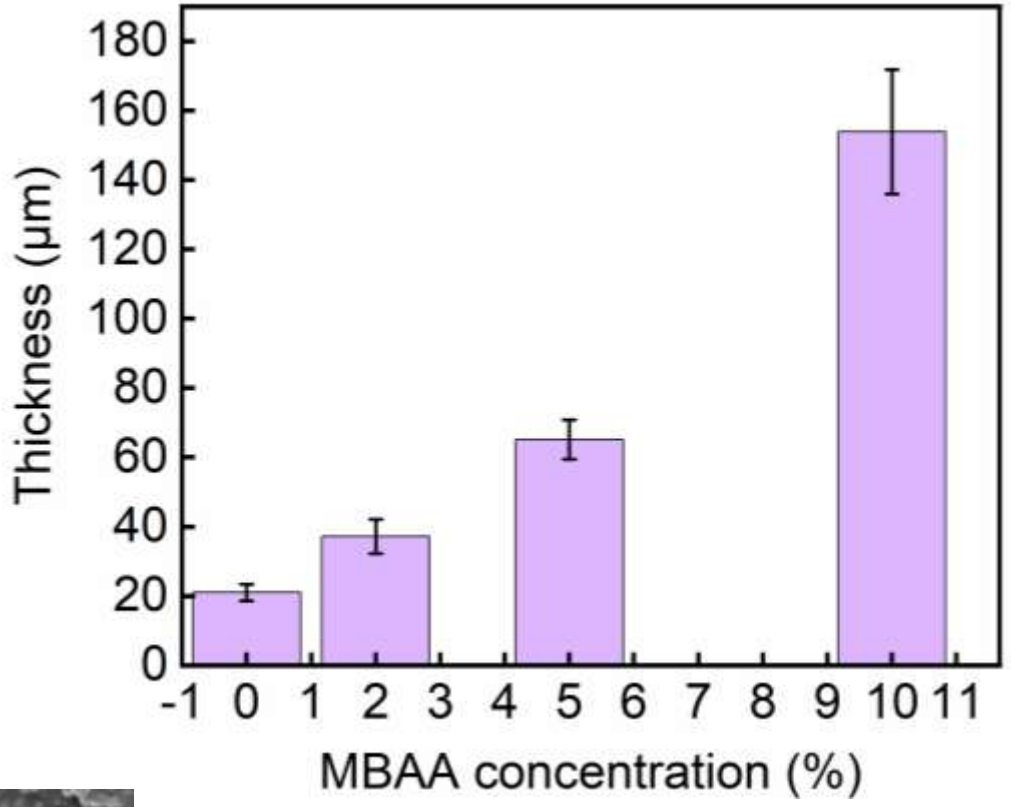


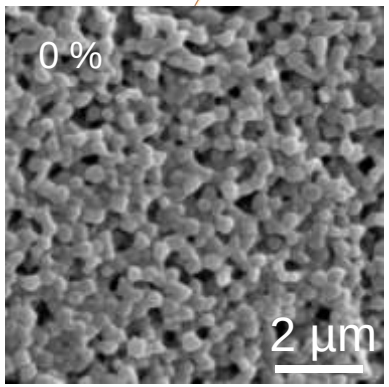


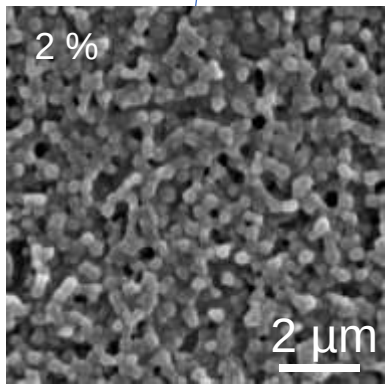
Nanoparticle size: ~300 nm

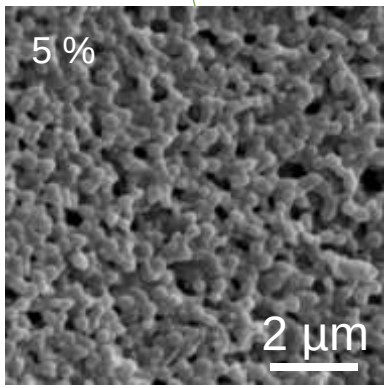
B). Crosslinker concentration

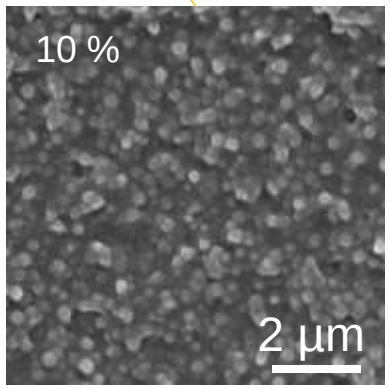






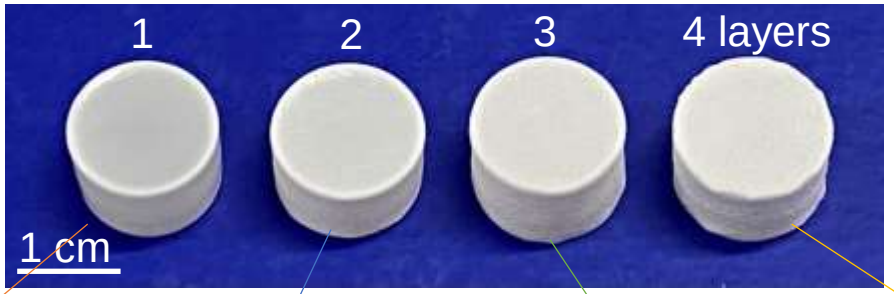


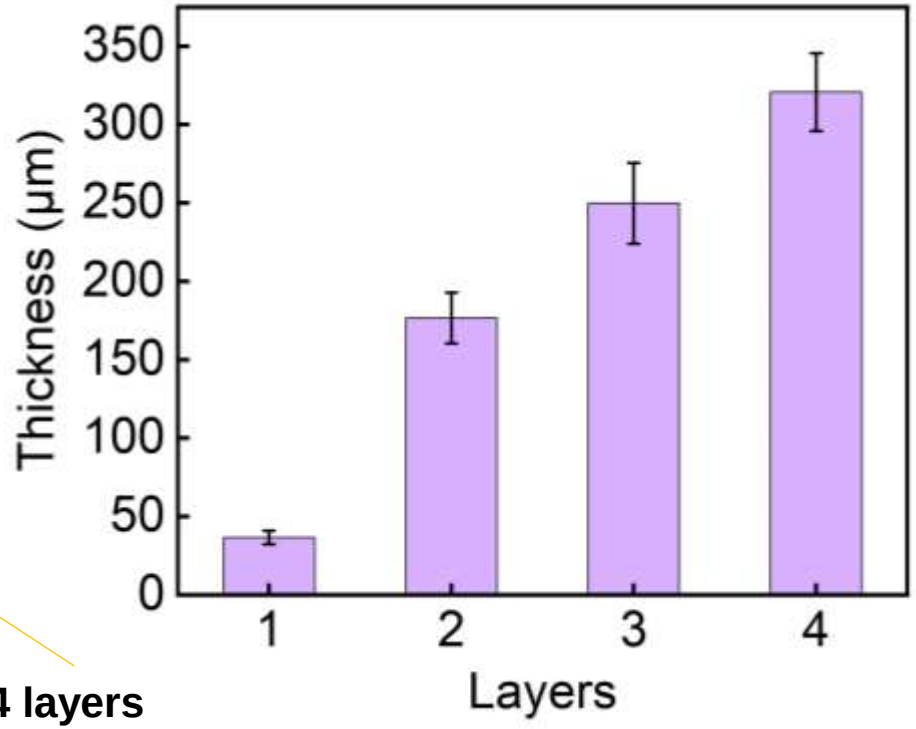




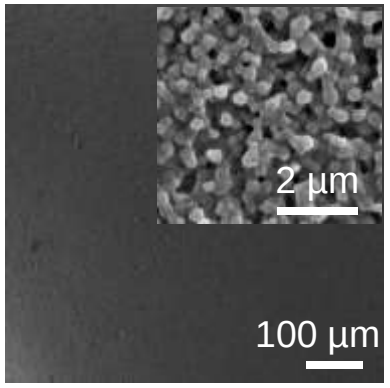
Nanoparticle size: ~300 nm

C). Multi-layer



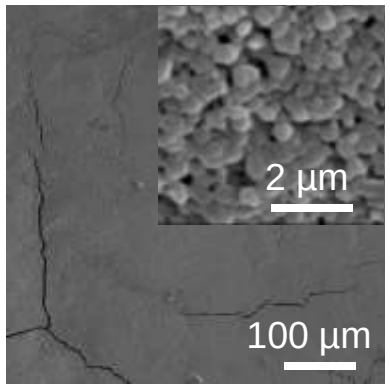


1 layer



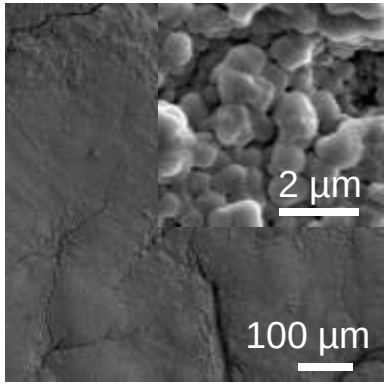
Particle size: 300 nm

2 layers



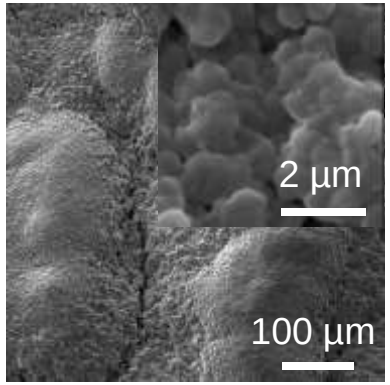
Size: 550 nm

3 layers



Size: 750 nm

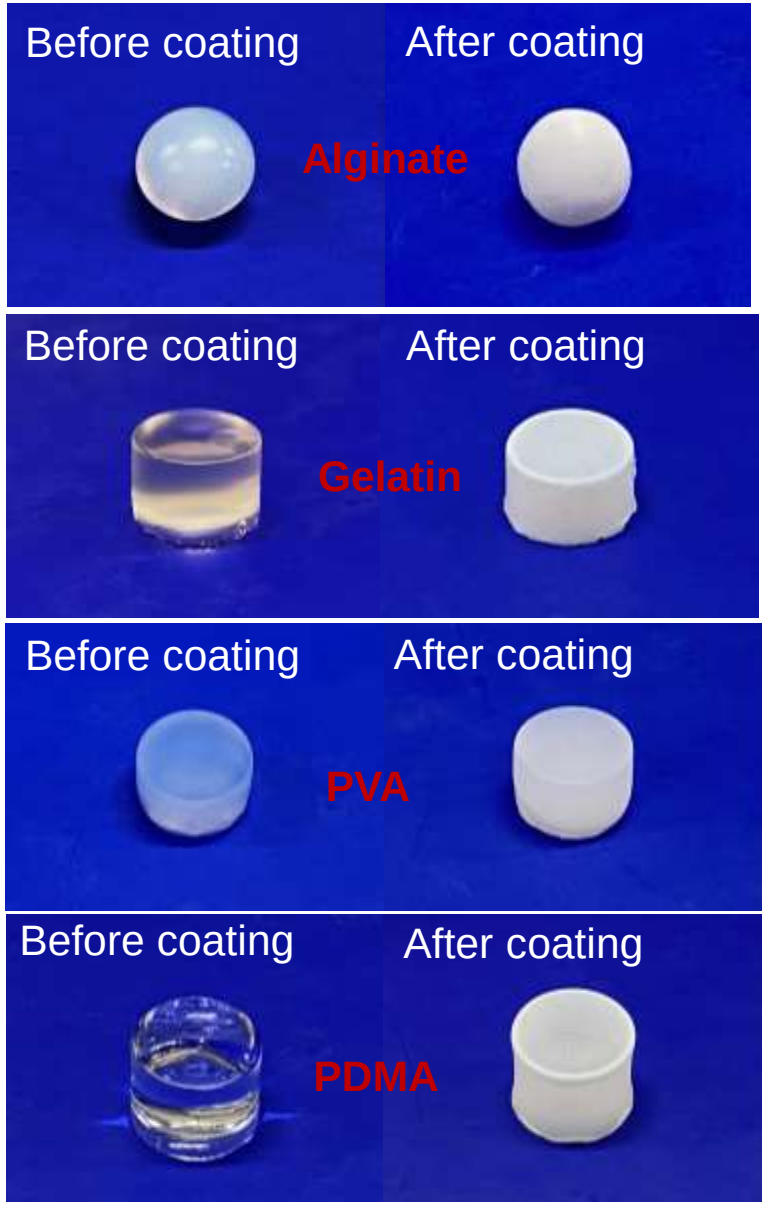
4 layers



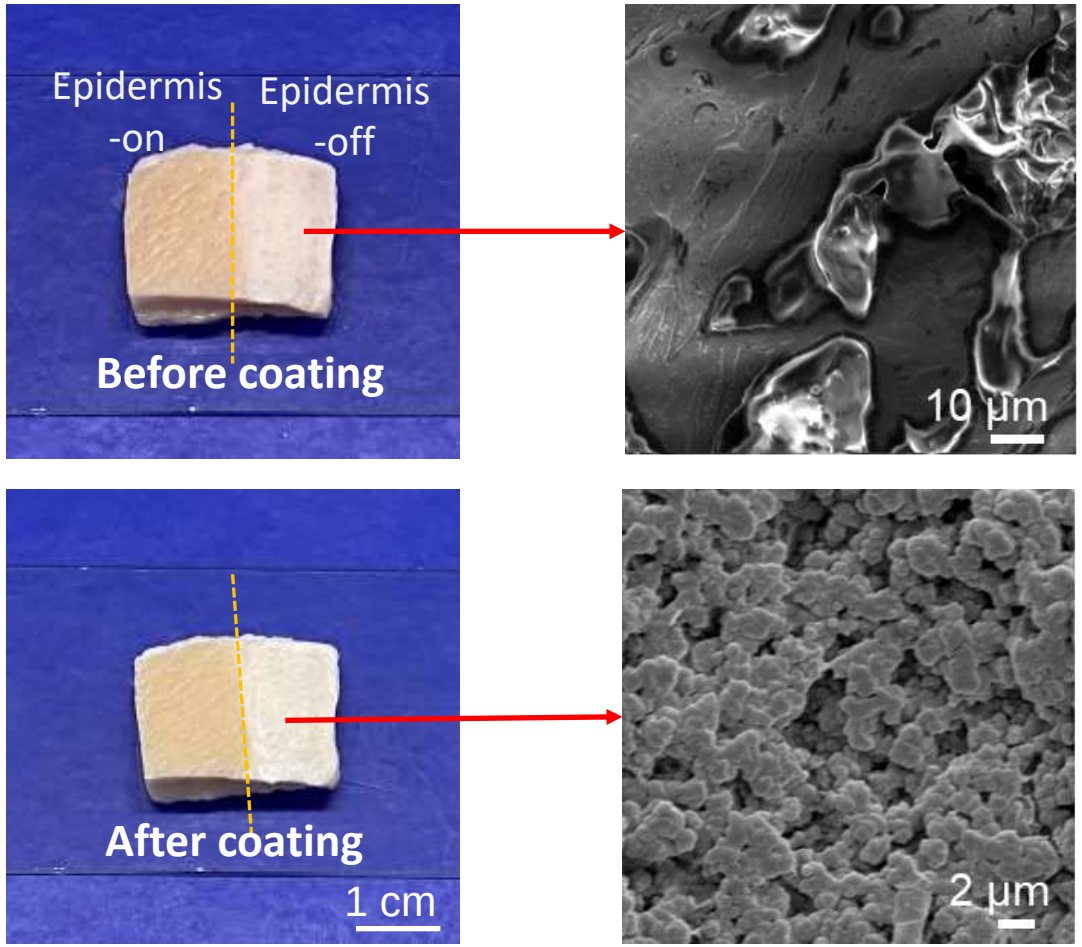
Size: 860 nm

Hydrogel substrate scope

A). Polymer hydrogels



B). Biological tissue



Function

A) Water loss control

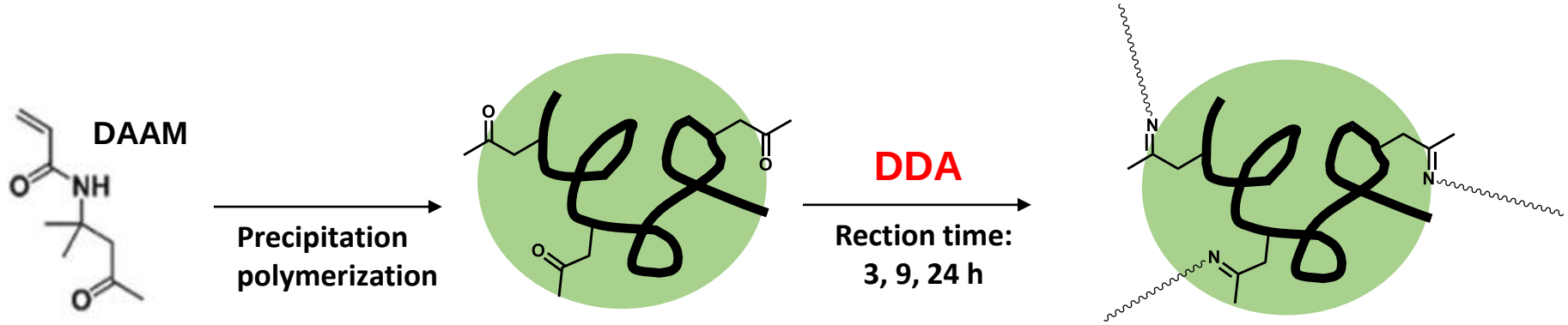
B) TENG sensor

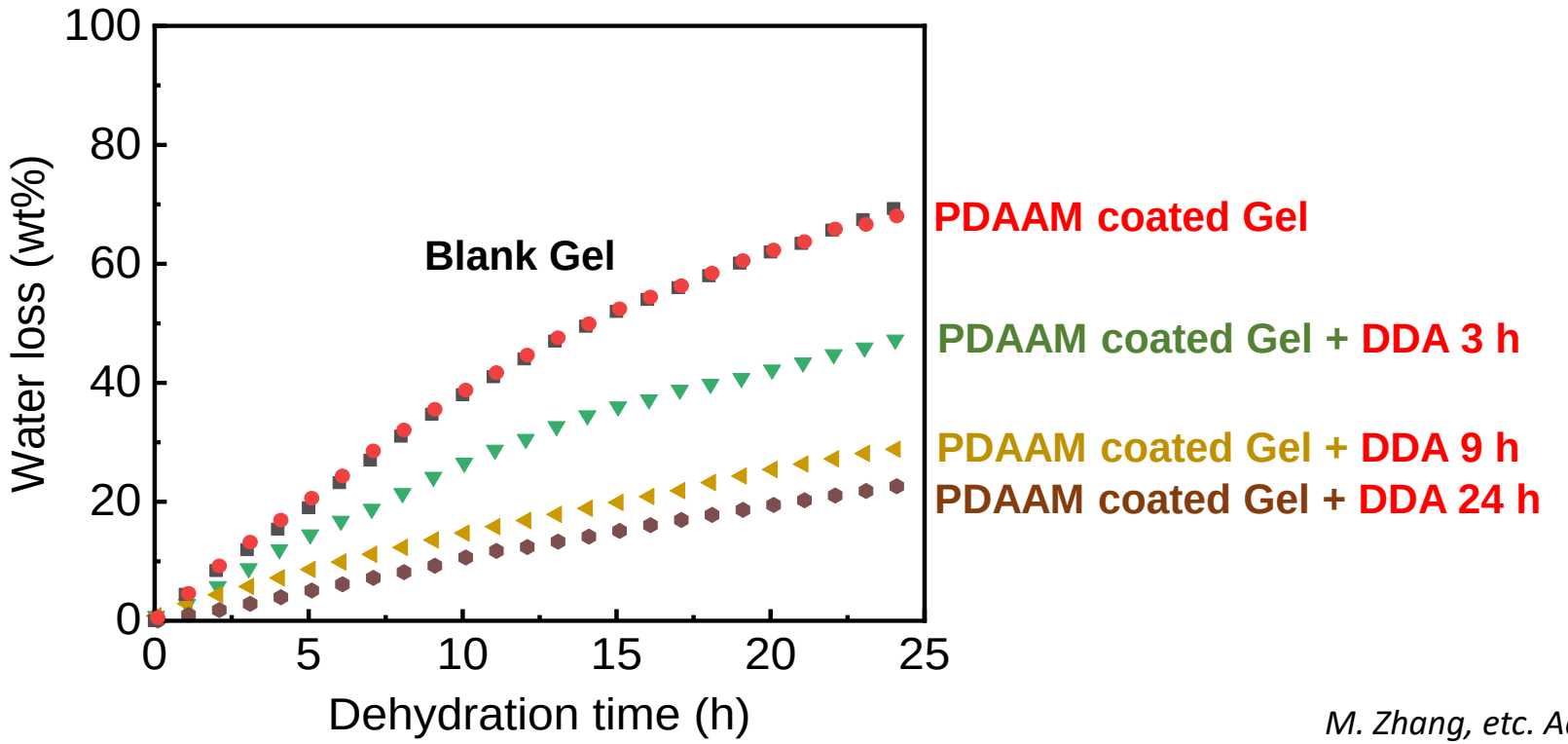
C) Electronic skin by integrating
a temperature and pressure sensor into hydrogel bilayer

D) Actuator

A) Water loss control

One protection function of epidermis: Protection against excess water loss





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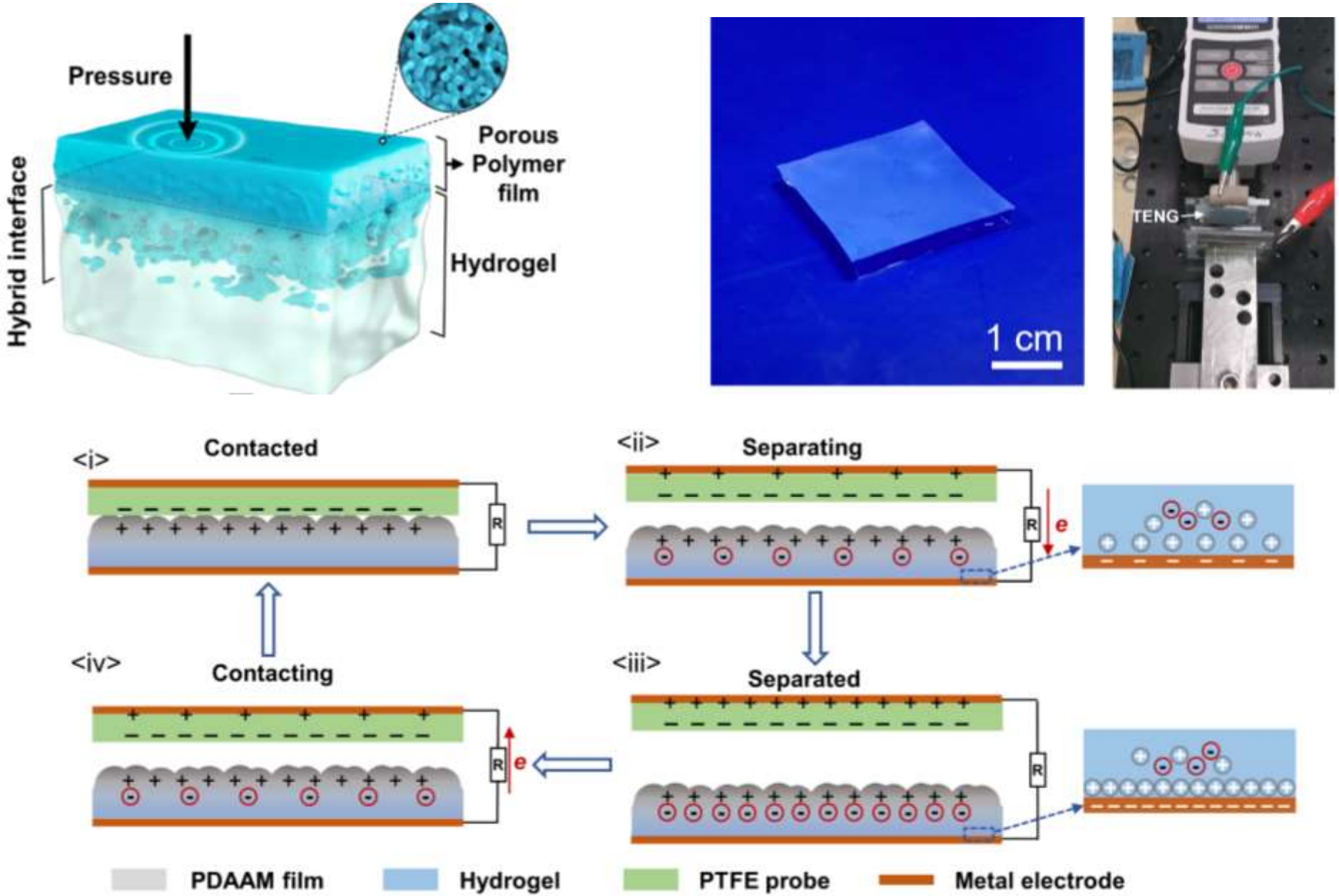
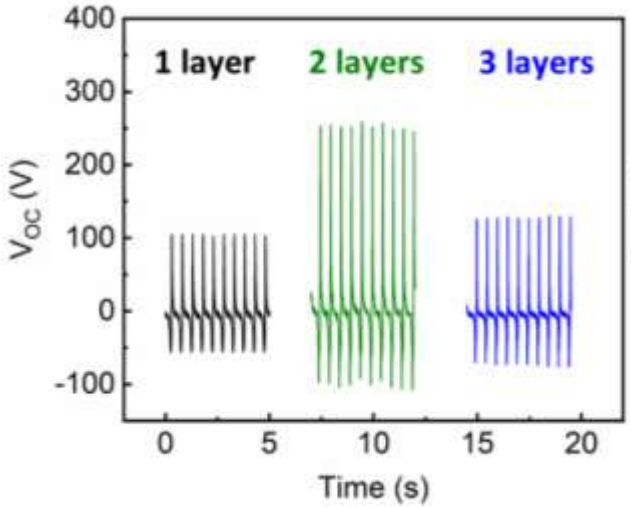
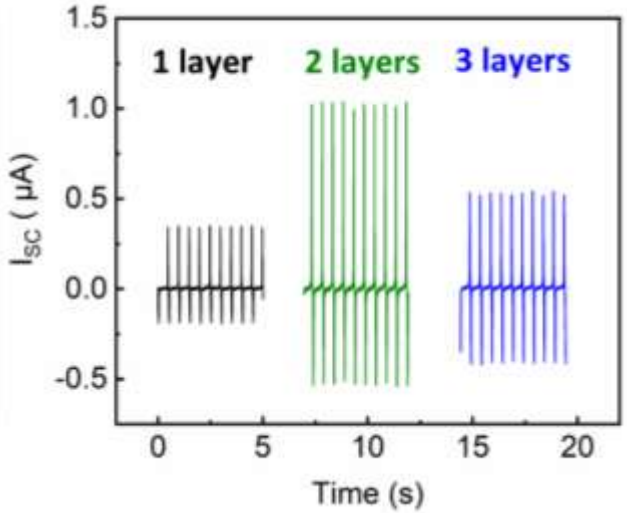
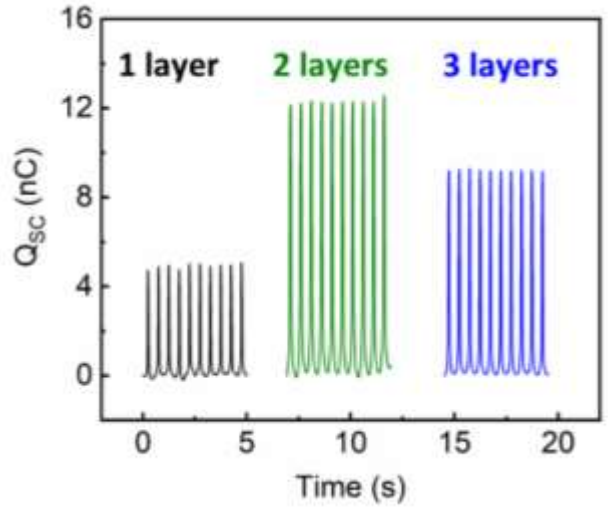
B) TENG (triboelectric nanogenerator) sensor



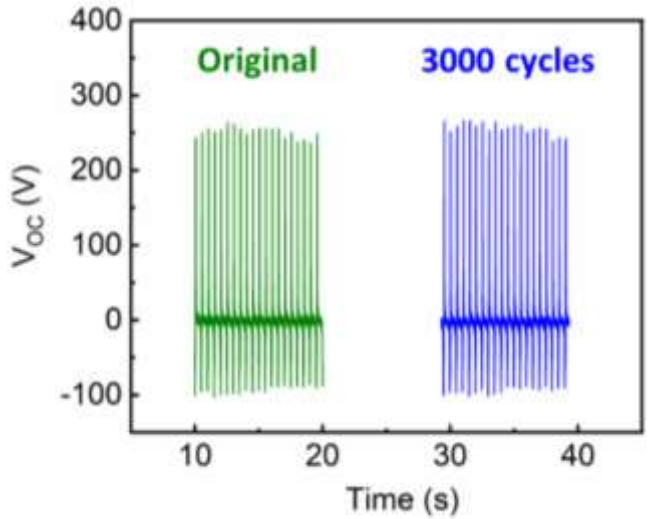
Typical TENG signals



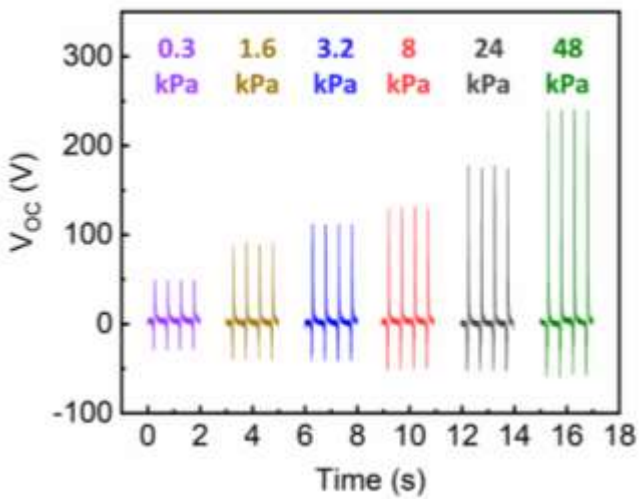


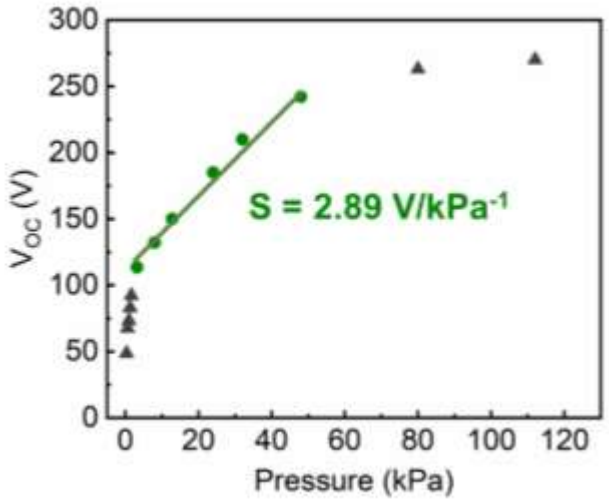


Stability

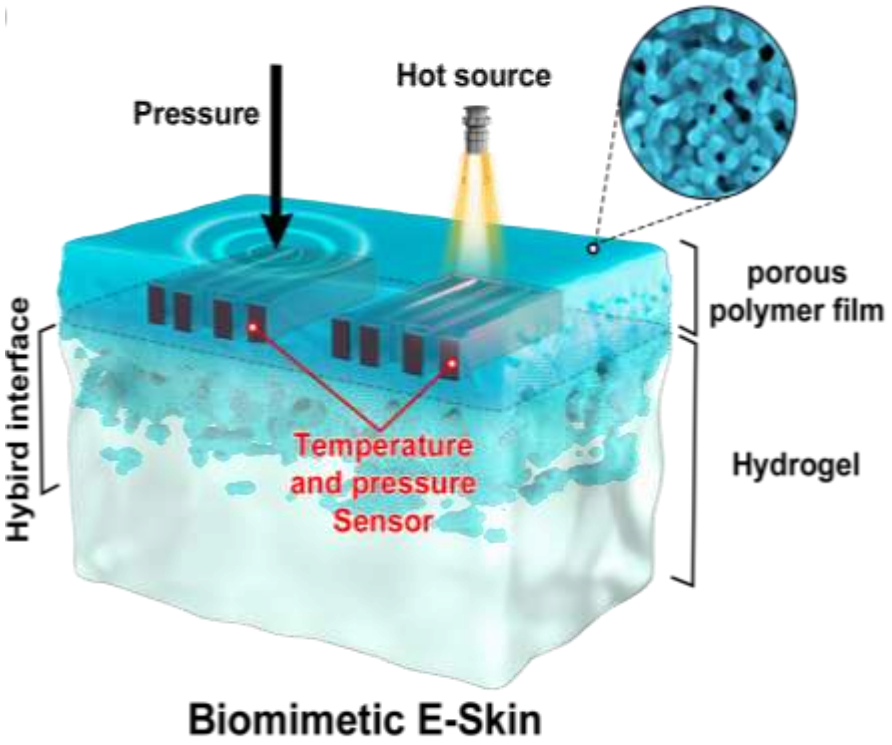


Pressure sensing

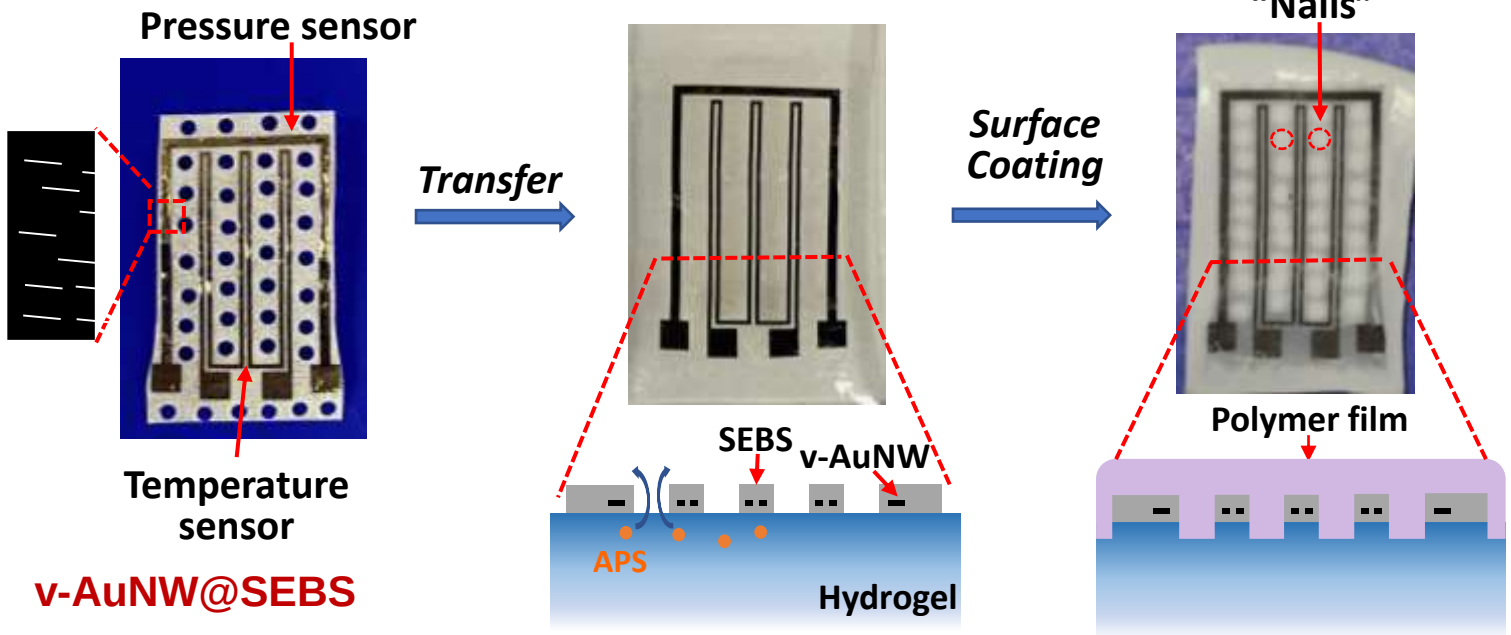


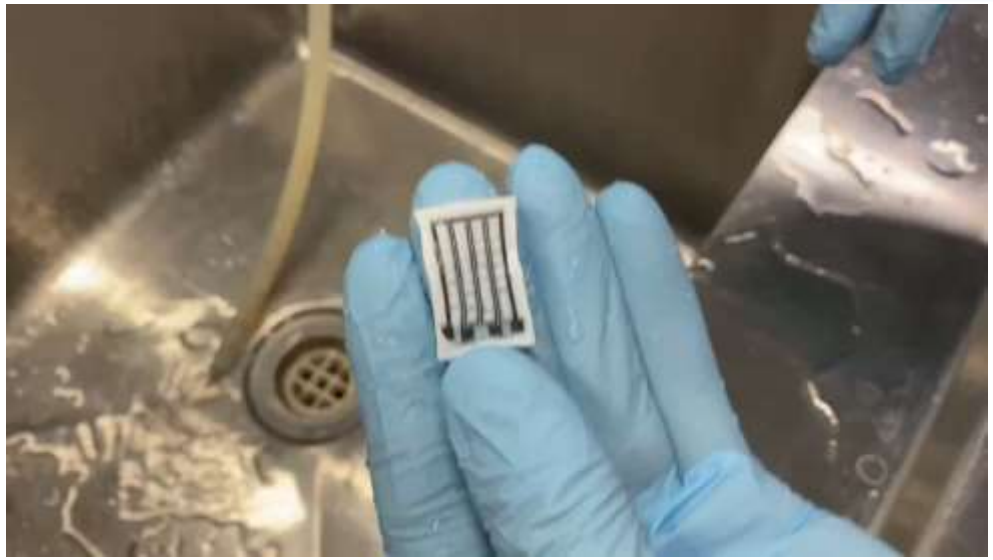


C) Electronic skin by integrating a sensor into hydrogel bilayer



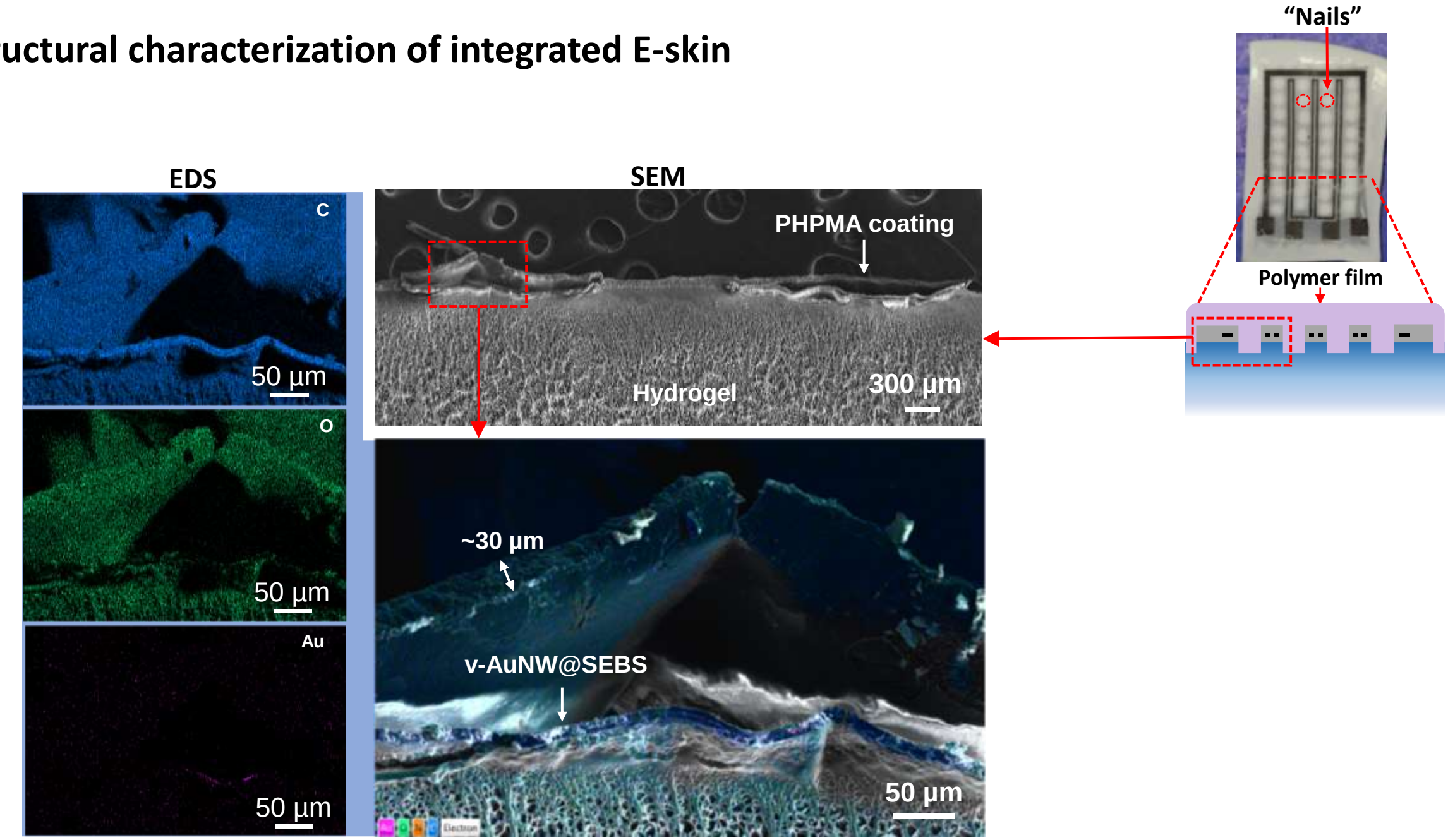
Biomimetic E-Skin





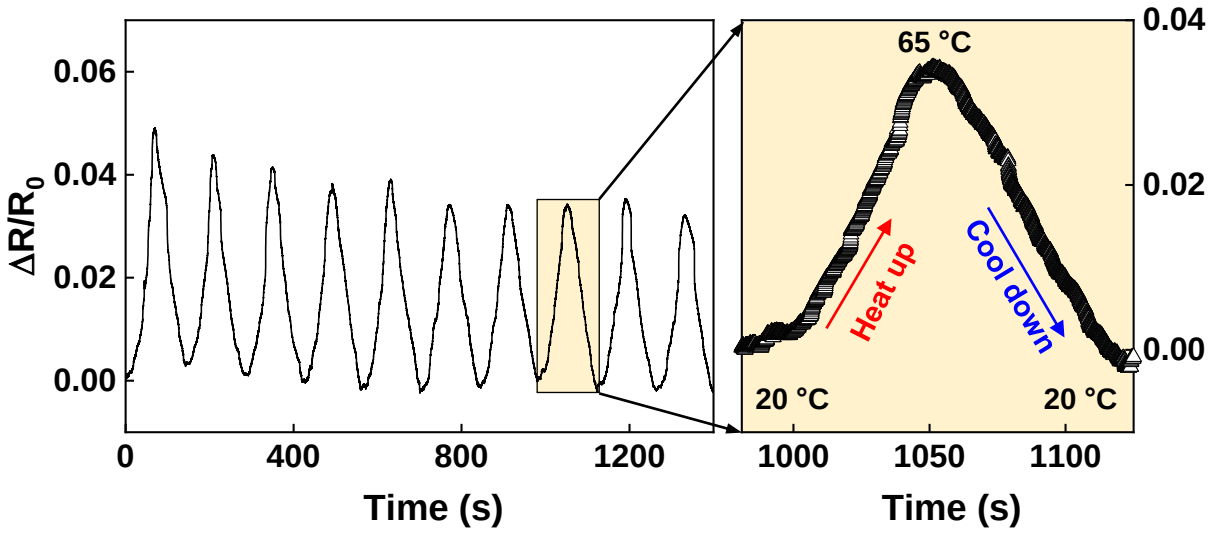
Collaboration with
Prof. Wenlong Cheng (Monash)

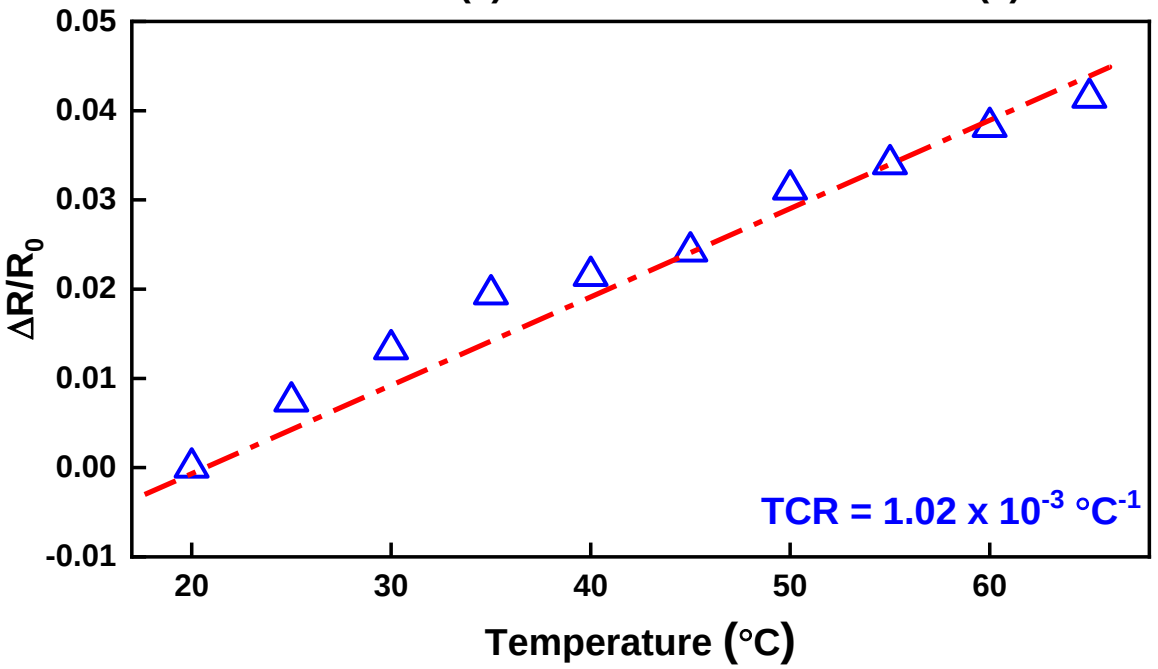
Structural characterization of integrated E-skin



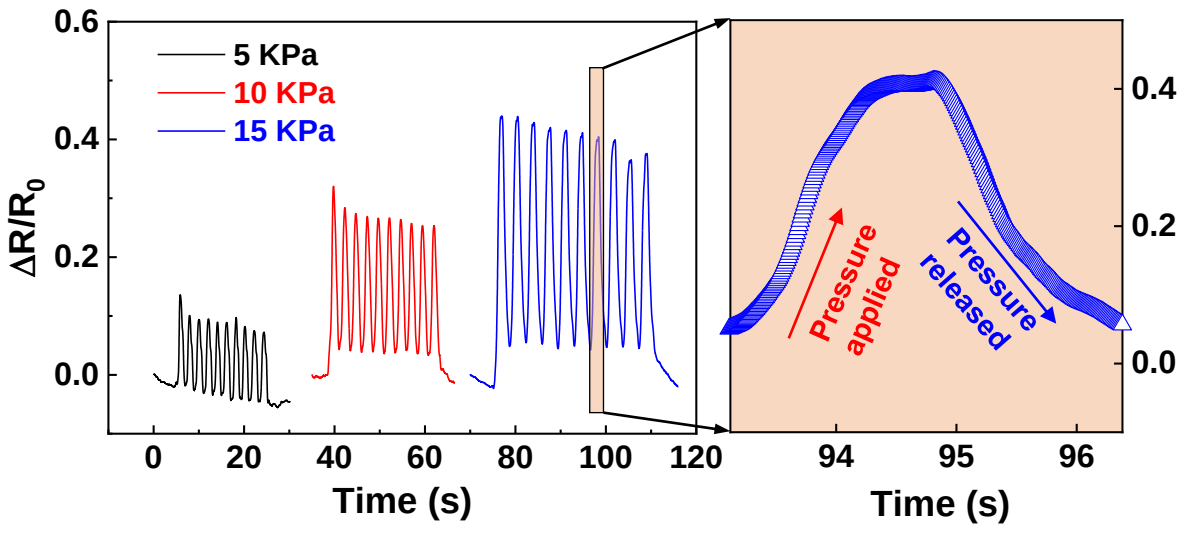
Sensing performance

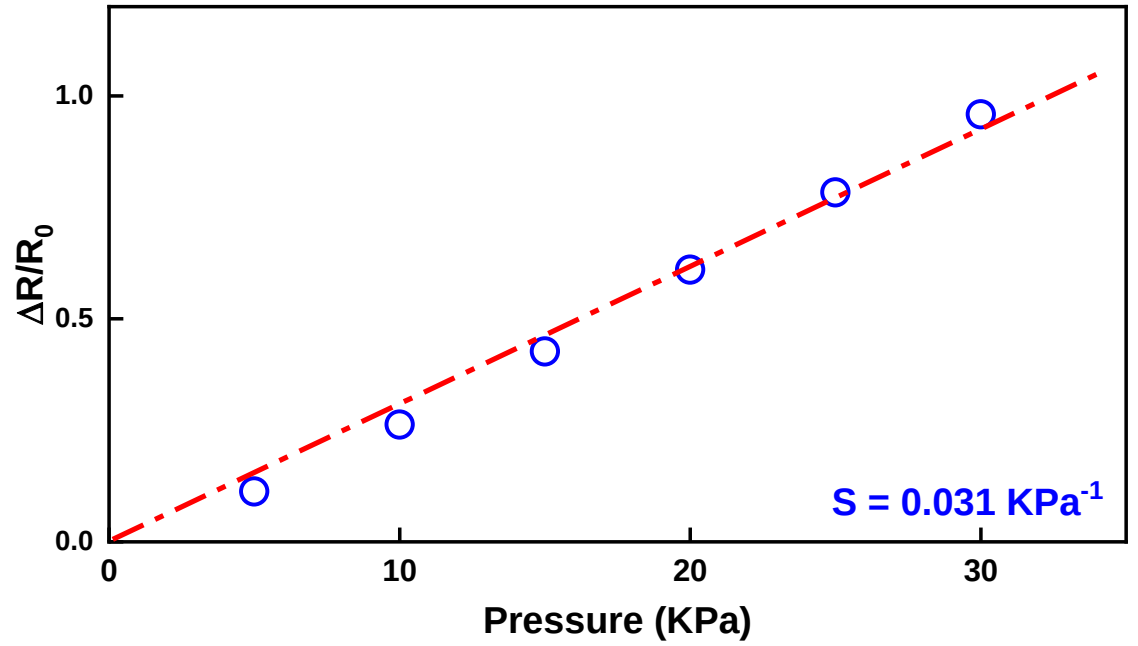
Temperature sensing



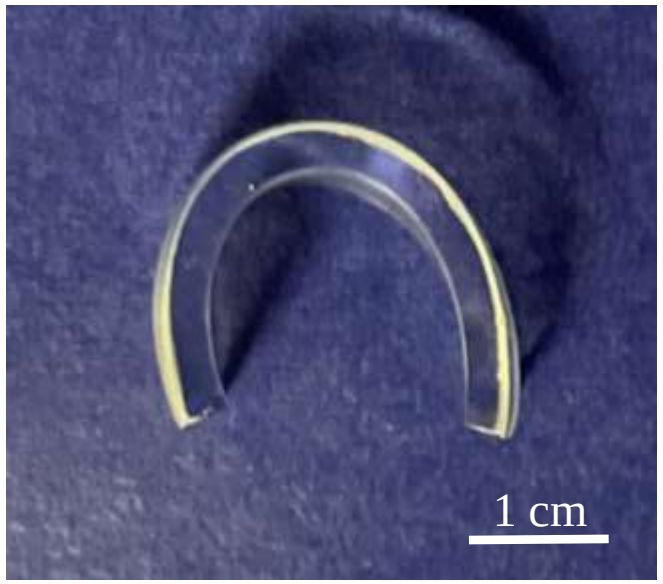


Pressure sensing



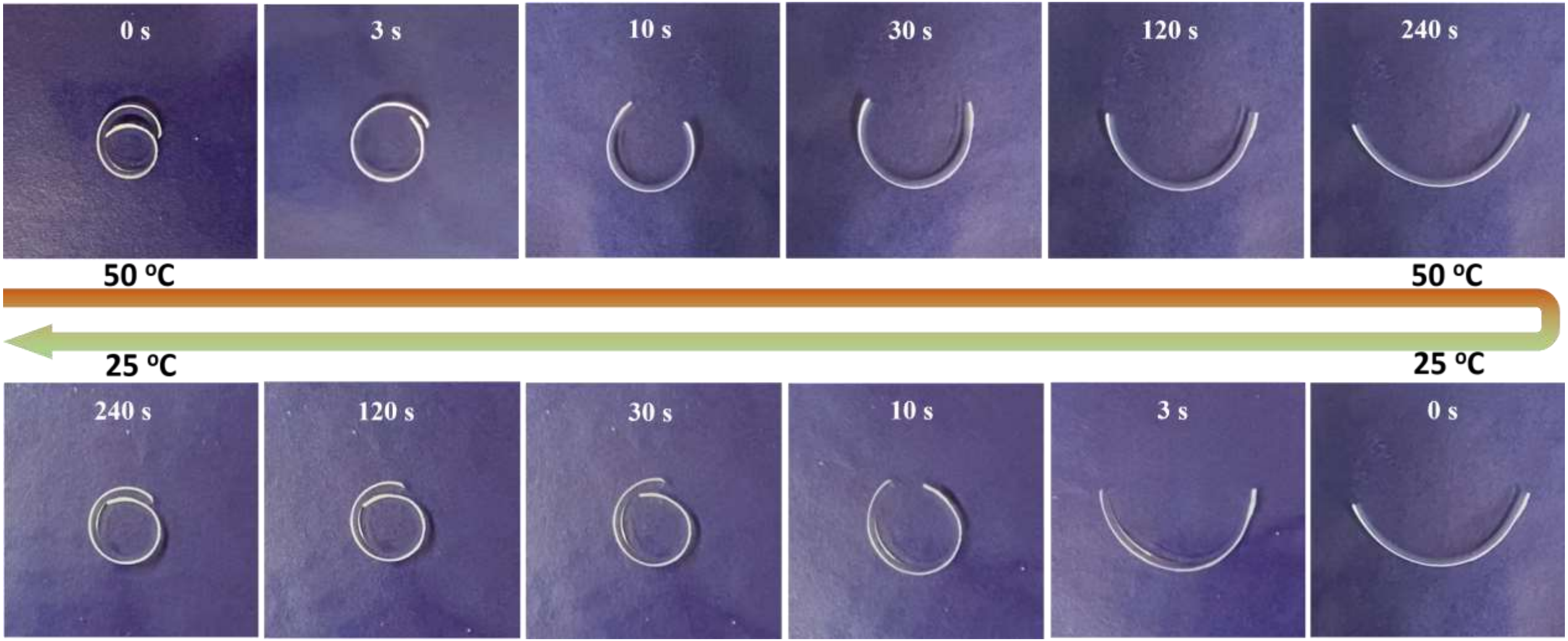


D) Actuator

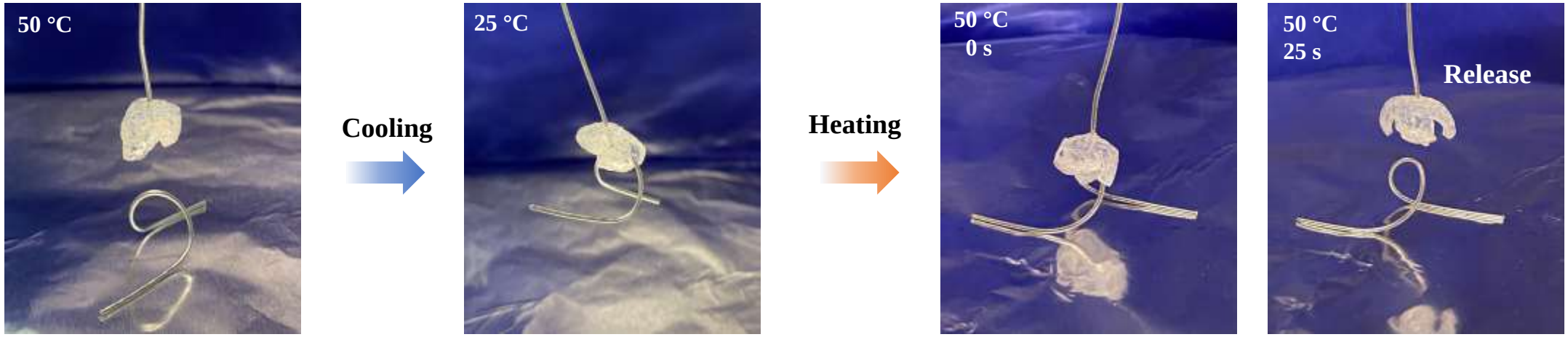


M. Zhang, H, Shen, etc. Small. Under revision

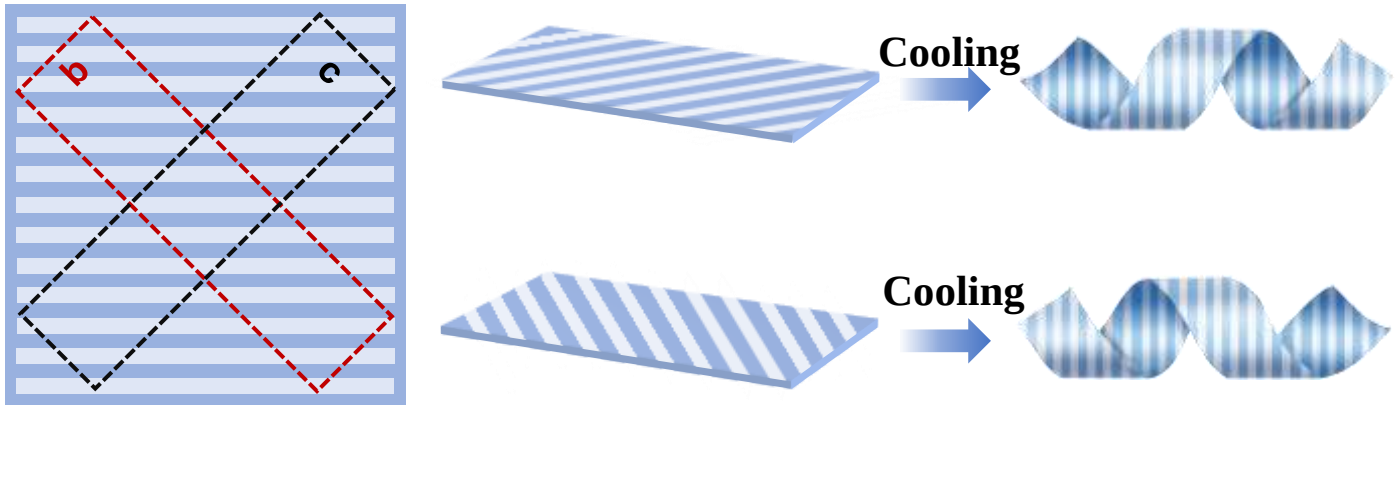
Bending/unbending with temperature changing



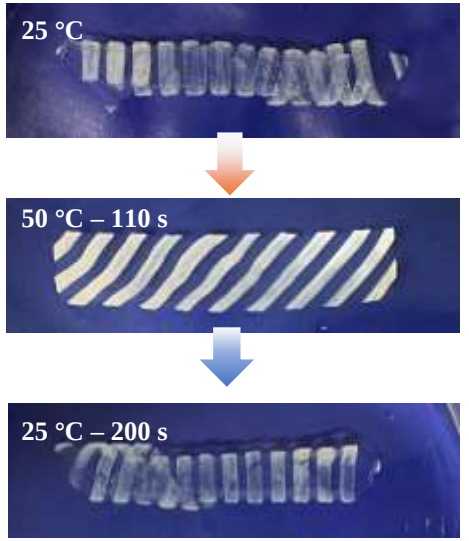
Soft robotic gripper



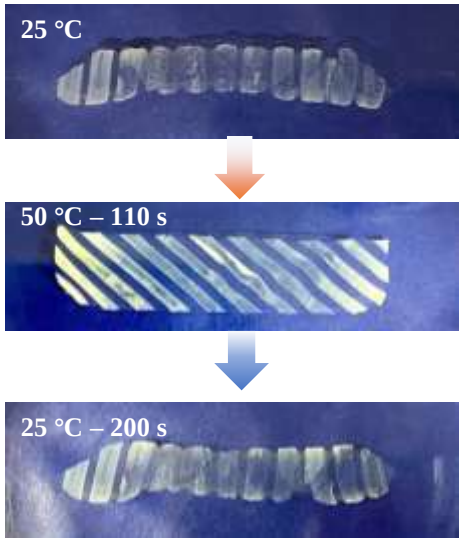
3D acturation



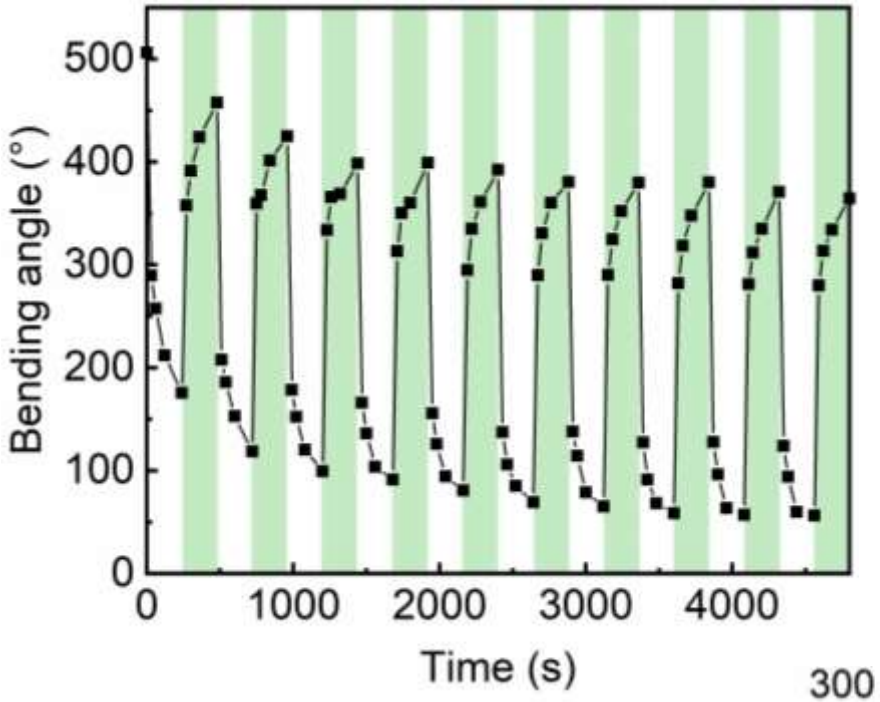
Left-hand twisting



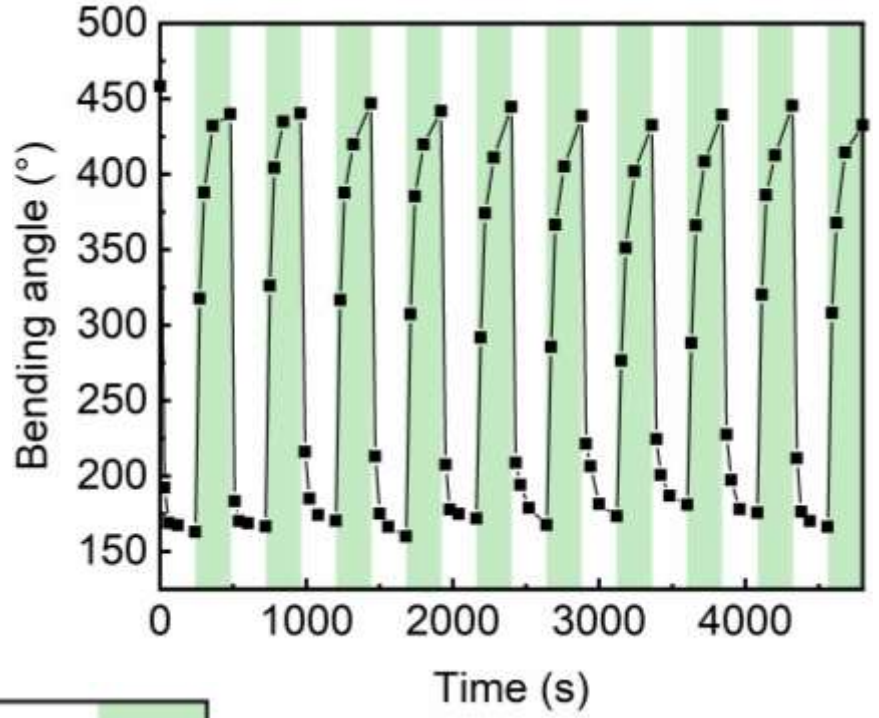
Right-hand twisting



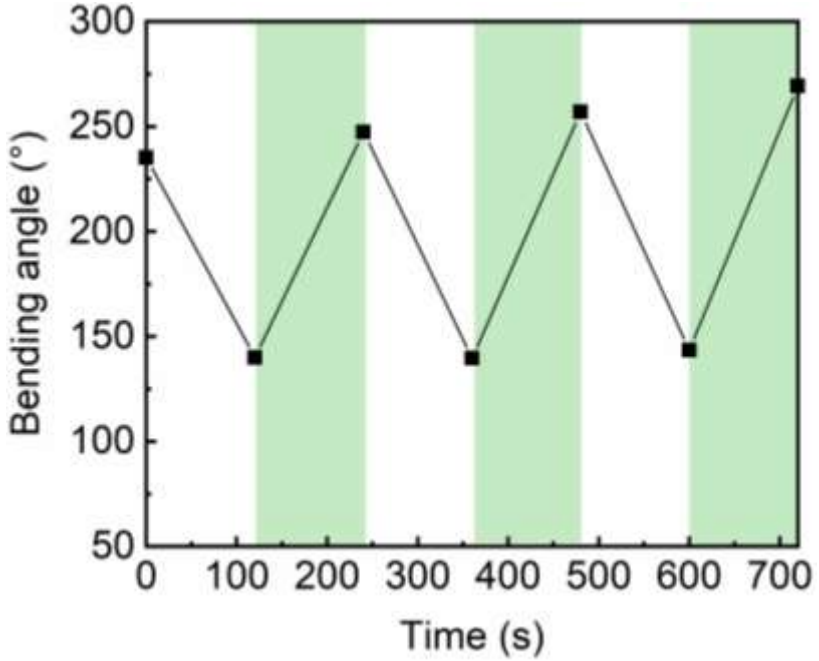
In Water



In Oil



In open-air

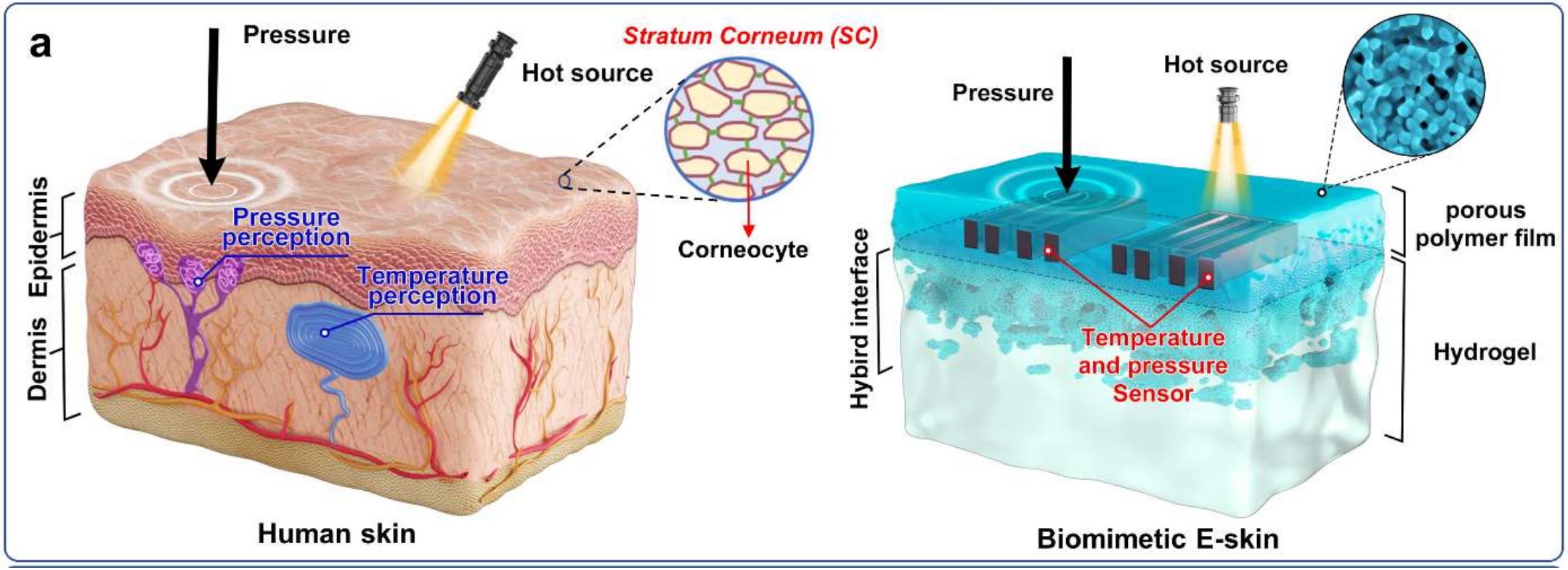


Poster 42:
Haokun Shen

Summary

- A simple *in situ* process to grow porous polymer films from hydrogel surfaces through interfacial precipitation polymerization, which resembles the dermis-epidermis bilayer structure of skin

- Porous polymer films to mimic interlocked corneocytes in epidermis
- Functional mimicry of human skin: protection of water loss, TENG sensing, built-in AuNW sensors, and actuation



Research Fellows and PhD Students

Ms. Mengnan Zhang
Mr. Haokun Shen
Dr. Karen Hakobyan
Mr. Zixuan (Zack) Huang
Dr. Guofeng Li
Mr. Ruizhe Liu
Ms. Lei Zhang
Dr. Nathaniel Corrigan
Dr. Yingying Chu
Mr. Shiyang Lin
Dr. Chenyu Wu
Ms. Kaiqi Pan
Mr. Amer Rathore
Dr. Fayaz Ali
Ms. Hira Khaleeq

Collaborators

Prof. Wenlong Cheng, Dr. Shu Gong (Monash)
A/Prof. Kang Liang (UNSW)
Dr. Shuhua Peng (UNSW)
Dr. Shuying Wu (MQ)
Prof. Xiaojing Hao (UNSW)
Dr. Zhen Jiang (UOW)
Dr. Edgar H. Wong (UNSW)

Financial Support

ARC Future Fellowship (FT16)
ARC Discovery Project (DP19 and DP21)
UNSW Sydney
School of Chemical Engineering
Materials and Manufacturing Future Institute

Australian Government
Australian Research Council

UNSW AUSTRALIA

Poster 42:
Haokun Shen

Poster 53:
Mengnan Zhang