Intelligent Soft-robotics Lab

Principal Investigator – Doyeon Bang

Principal Investigator

Doyeon Bang

Associate Professor,

Department of Artificial Intelligence Convergence, Graduate School of Data Science,

Robotics Engineering Major and Robot Research Initiative

Chonnam National University, Gwangju, Korea

E-mail: db@jnu.ac.kr

Education

2002~2007	B.S., Chemical Engineering,	Yonsei University, Seoul Korea
2002~2007	B.S., Physics,	Yonsei University, Seoul Korea
2007~2012	Ph.D., Nanomedical Science,	Yonsei University, Seoul Korea

Research Experiences

2012~2014	Post-Doctoral Researcher,	Yonsei University, Seoul Korea
2014~2018	Post-Doctoral Researcher,	University of California, Berkeley USA
2019~2021	Senior Researcher,	Korea Institute of Medical Microrobotics

Research interests

- Developing micro-scale soft robots for healthcare application
- Developing stimuli-responsive soft materials for micro-/macro-scale 3D/4D printing
- Developing unconventional meta-structure, Origami and Kirigami for next-generation soft-robotics

Lab Members

Prof. Doyeon Bang

Dr. Taeksu Lee (Chemical Engineering)

Tongil Park (Mechanical Engineering)

Seunghyun Im (Chemical Engineering)

Hana Choi (Mathematics)

Youngji Ko (Robotics Engineering)

Kyomin Hwang (Data Science)

Saad Shaikh (Mechanical Engineering)

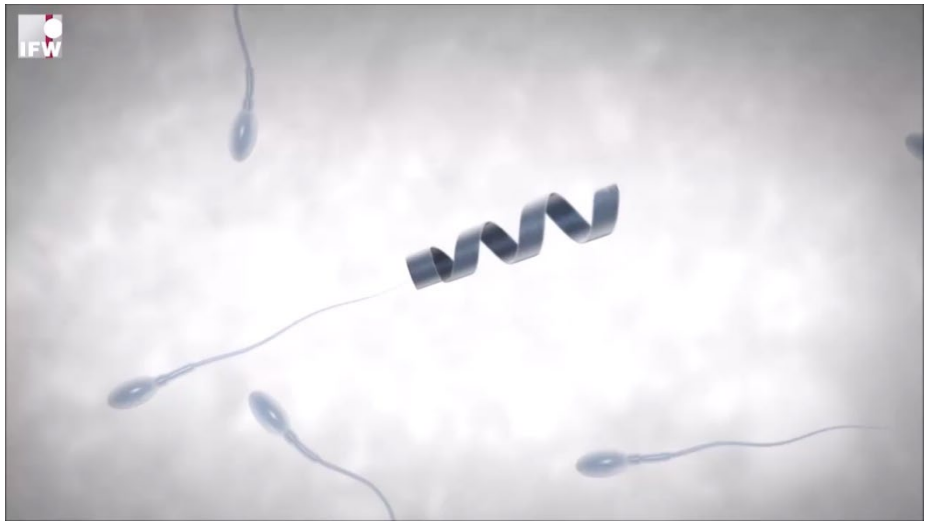
Sridhar Pusparaja (Mechatronics)

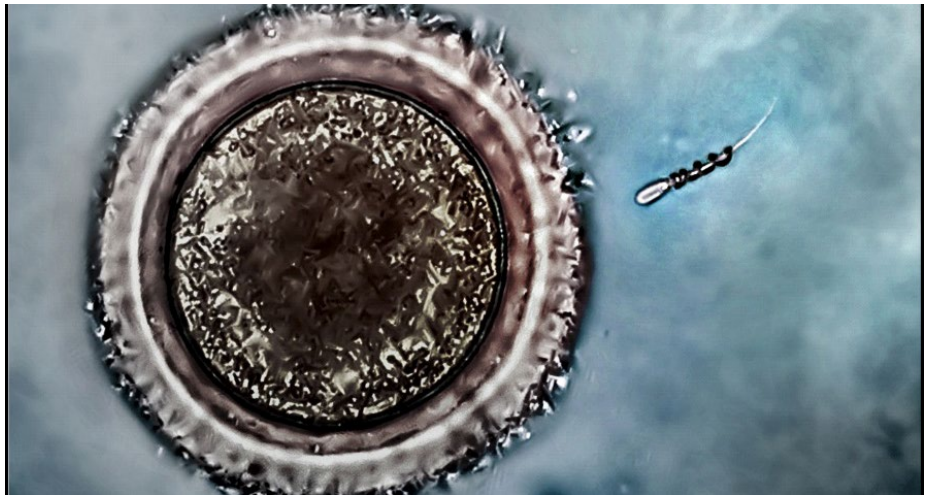
Praveen Madhjiyazhagan (Mechatronics)

Publications (2020~2023)

Title	Journal	Impact Factor	Date	Role
Plasmonic Approach to Fluorescence Enhancement of Mesoporous Silica–Coated Gold Nanorods for Highly Sensitive Influenza A Virus Detection Using Lateral Flow Immunosensor	ACS nano	17.1	2023.08.18	
Tunable and Highly Accessible Plasmonic Gap Nanostructures on Flexible Film as a High–Performance Surface–Enhanced Raman Scattering Sensor	Materials Today Nano	10.3	2023.06.22	Corresponding
A Simple Method to Fabricate the Highly Sensitive SERS Substrate by Femtosecond Laser–Based 3D Printer	Chemosensors	4.2	2023.06.08	Corresponding
Wearable Localized Surface Plasmon Resonance–Based Biosensor with Highly Sensitive and Direct Detection of Cortisol in Human Sweat	BIOSENSORS	5.4	2023.01.24	Corresponding
Multifunctional microrobot with real–time visualization and magnetic resonance imaging for chemoembolization therapy of liver cancer	SCIENCE ADVANCES	13.6	2022.11.18	
Microrobot with Gyroid Surface and Gold Nanostar for High Drug Loading and Near–Infrared–Triggered Chemo–Photothermal Therapy	PHARMACEUTICS	5.4	2022.11.06	
Bending-Insensitive Flexible SERS Sensor for Stable and Sensitive Detection on Curved Surfaces	ADVANCED MATERIALS TECHNOLOGIES	6.8	2022.09.01	Corresponding
Magnetically controlled reversible shape–morphing microrobots with real–time X–ray imaging for stomach cancer applications	JOURNAL OF MATERIALS CHEMISTRY B	7.0	2022.06.01	
Biomimetic Nano–Pine–Pollen Structure–Based Surface–Enhanced Raman Spectroscopy Sensing Platform for the Hypersensitive Detection of Toxicants: Cadmium and Amyloid	ACS SUSTAINABLE CHEMISTRY AND ENGINEERING	8.4	2022.02.25	Corresponding
Programmed Shape–Morphing Material Using Single–Layer 4D Printing System	MICROMACHINES	3.4	2022.01.31	Corresponding
Single–layer 4D printing system using focused light: a tool for untethered microrobot applications	CHEMISTRY OF MATERIALS	8.6	2021.09.29	Corresponding
Bio–inspired Ag nanovilli–based sandwich–type SERS aptasensor for ultrasensitive and selective detection of 25–hydroxy vitamin D3	BIOSENSORS AND BIOELECTRONICS	12.6	2021.09.15	
Modular Capsules with Assembly and Separation Mechanism: Proof of Concept	ACTUATORS	2.6	2021.07.12	
Optimization of field–free point position, gradient field and ferromagnetic polymer ratio ··· controlled polymer–based microrobots in blood vessel	MICROMACHINES	3.4	2021.04.13	
A Magnetically Guided Self-Rolled Microrobot for Targeted Drug Delivery, Real-Time X-Ray Imaging, and Microrobot Retrieval	ADVANCED HEALTHCARE MATERIALS	10	2021.03.01	Corresponding
Self–folded microrobot for active drug delivery and rapid ultrasound–triggered drug release	Sensors and Actuators B: Chemical	8.4	2020.12.01	Corresponding
High–performance biocompatible nanobiocomposite artificial muscles based on ammonia–functionalized graphene nanoplatelets–cellulose acetate combined with PVDF	Sensors and Actuators B: Chemical	8.4	2020.11.15	
Bioinspired Micro Glue Threads Fabricated by Liquid Bridge–to–Solidification as an Effective Sensing Platform	ACS SENSORS	8.9	2020.06.23	
Magnetically actuated miniature walking soft robot based on chainedmagnetic microparticles–embedded elastomer	Sensors and Actuators A: Physical	7.4	2020.01.01	Corresponding

Research topic of our lab → Microscale soft robots examples





Nano Lett. **16**, 555−561 (2016)

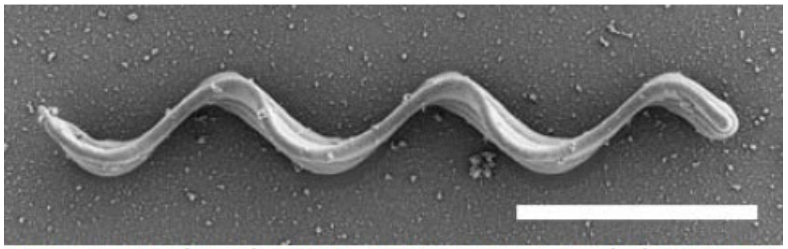
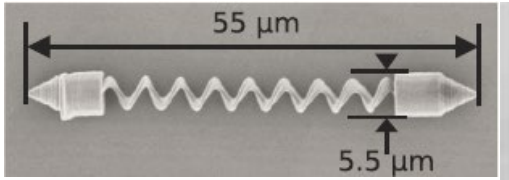
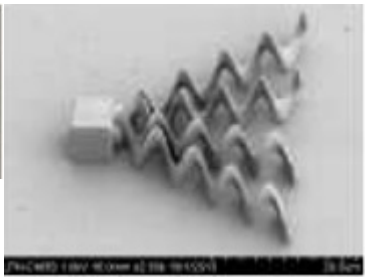


Figure 4: Hydrogel ABF in SEM top view; Scale bar: 10 µm

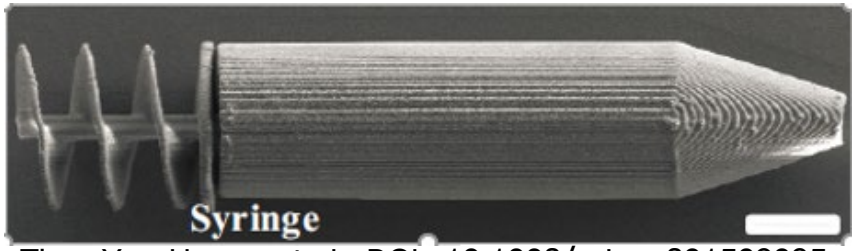
C. Peters et al., DOI: 10.1109/TRANSDUCERS.2015.7181035, (2015)



Antoine Barbot et al., DOI: 10.1038/srep19041 (2016)

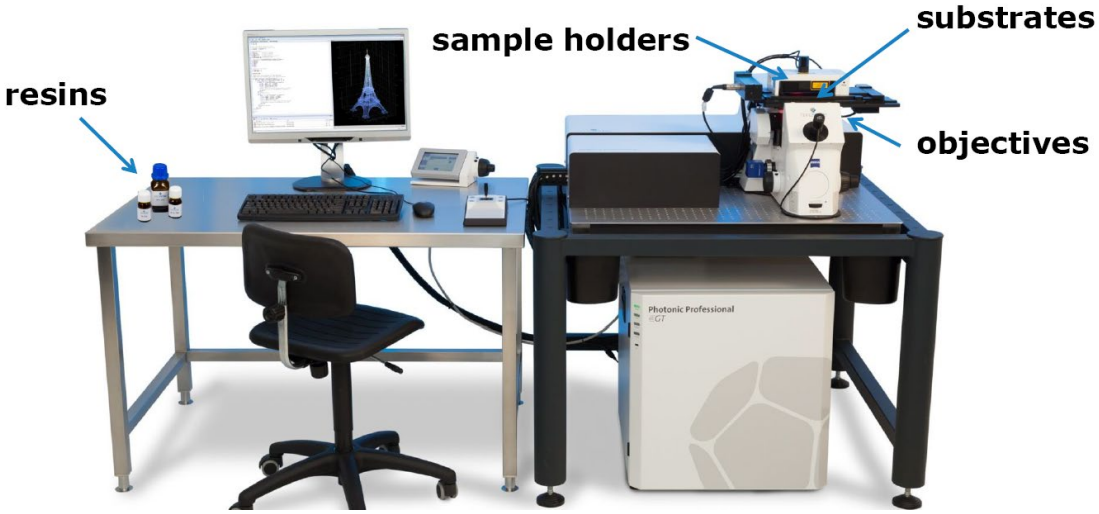


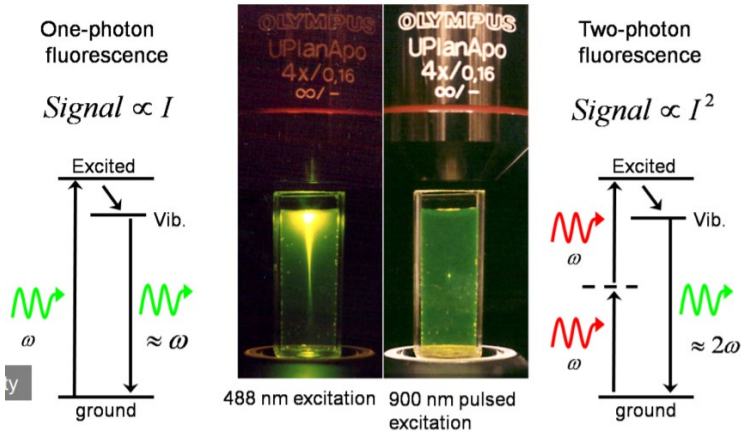
N. Beyrand et al., 2015 IEEE/RSJ IROS conference



Tian−Yun Huang et al., DOI: 10.1002/adma.201503095 (2015)

How to make microrobots? → Microscale 3D printing





Micro-scale 3D printing system (Nanoscribe Photonic Professional GT)

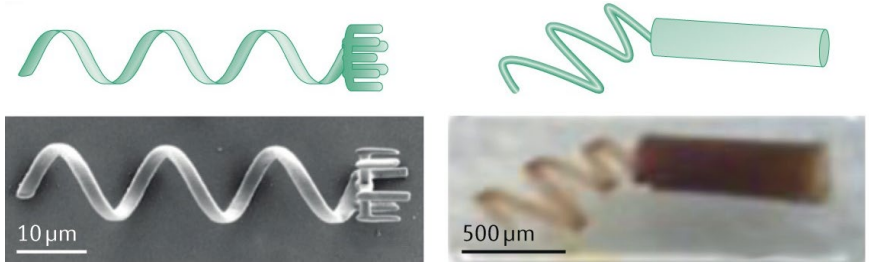
- Femto-second NIR layer → Two-photon lithography
- Through objective lens → Focusing laser in tiny spot (~ 200 nm)
- Price ~ $ 350,000 (cf. Honda Civic ~ $ 20k)
- Minimum feature size: ~200nm

Micro 3DP has same chemistry with SLA, but has different physics

- Laser focusing using objective lens
- Two photon excitation using fs laser

Limitation: is a robot can be static?

However, 3D printed microscale soft robots are static!



Definition of robot

A machine that resembles a living creature in being capable of moving independently and performing complex actions (such as grasping and moving objects)
by Webster dictionary

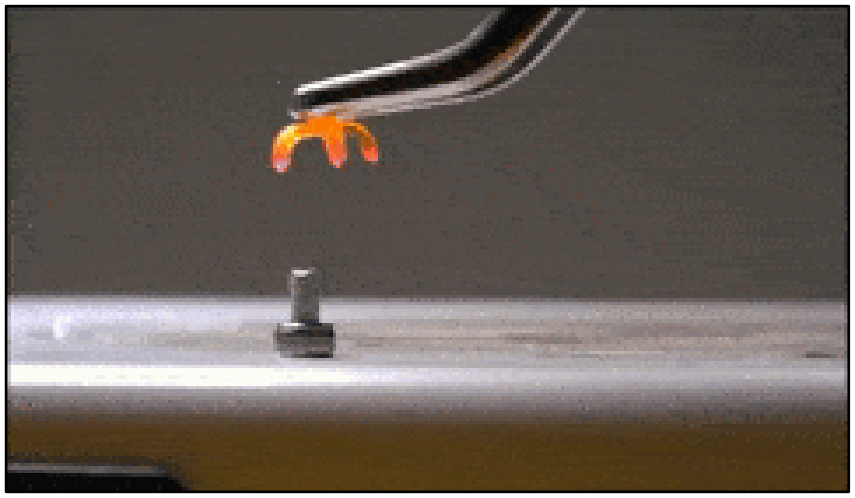
Various complicated jobs, which exceed our imagination can be realized
if real microscale soft robot is developed

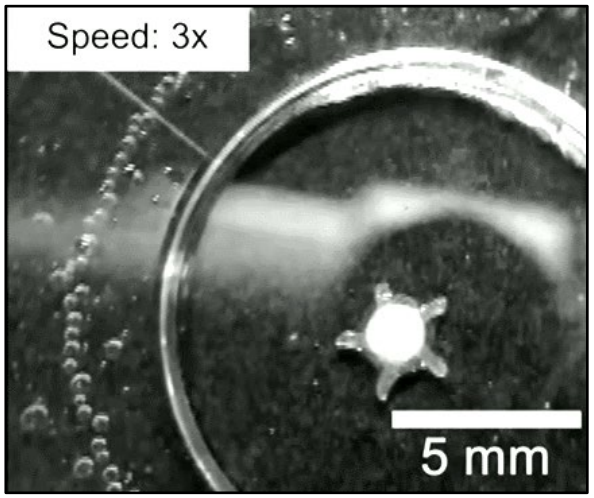
4D printing technology definition / meaning

However, making complicated actively moving parts in micro/nanoscale is challenging

Candidate solution

- Complicated structure → micro 3D printing (2PP + Obj. Lens)
- Actively moving part → 4D printing (Traditional FDM, SLA or DLP)
- Future technology: microscale 4D printing (my ongoing research topic)

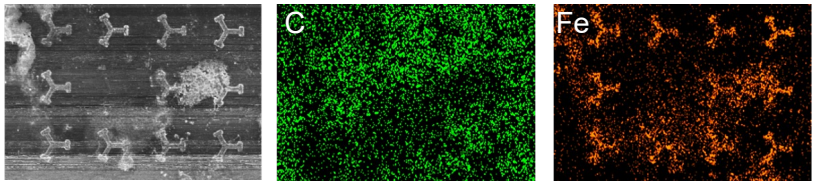




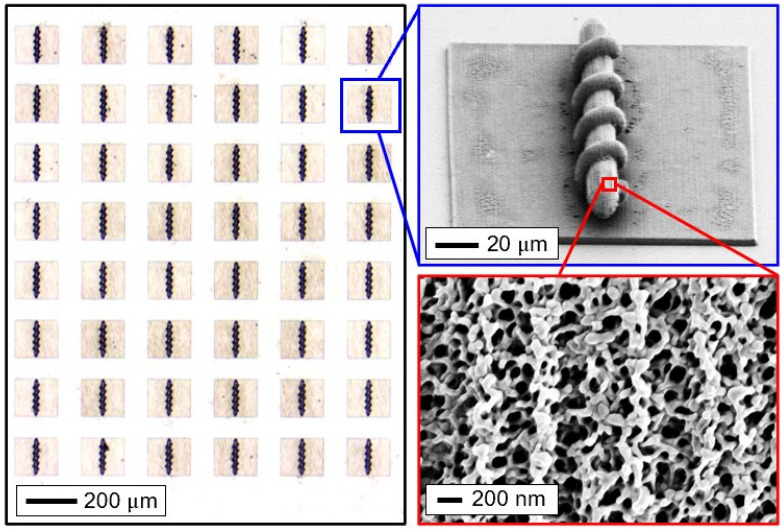
4D printing example: Temperature responsive (left) and polarity responsive (right) materials

Microscale 3D/4D printing research in our lab

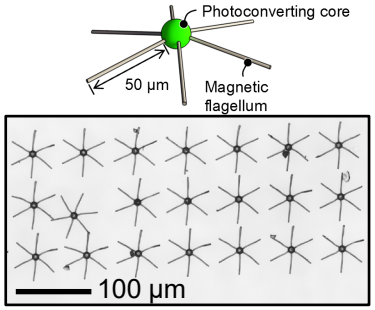
- Microscale 3D/4D printing of <u>functional materials</u>
  - Pure materials: PEG, PNIPAAm, PANI, PCL
  - Metal/ceramic printing in polymer (e.g. Fe_3O_4)

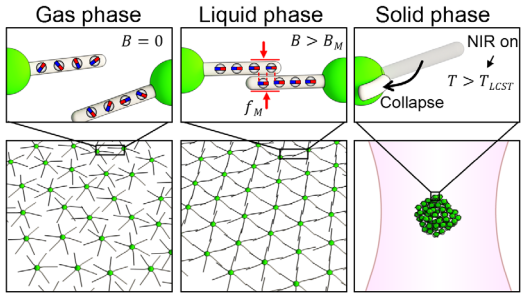


  - Nanoporous material

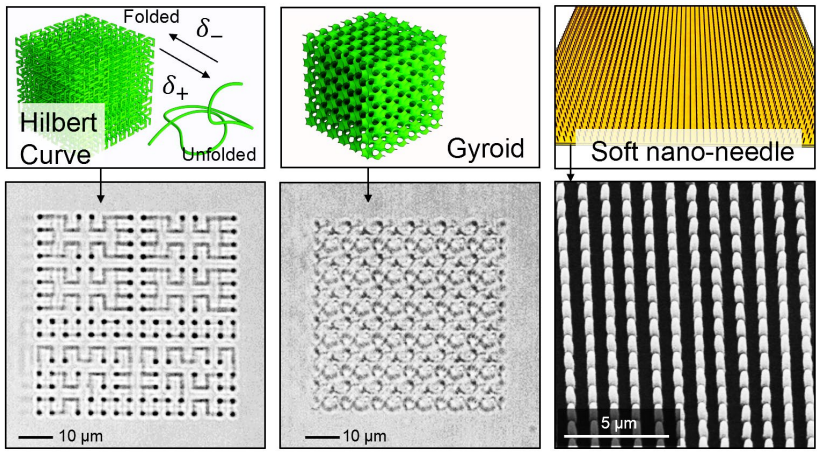


- Parametric design of <u>3D Microstructures</u>





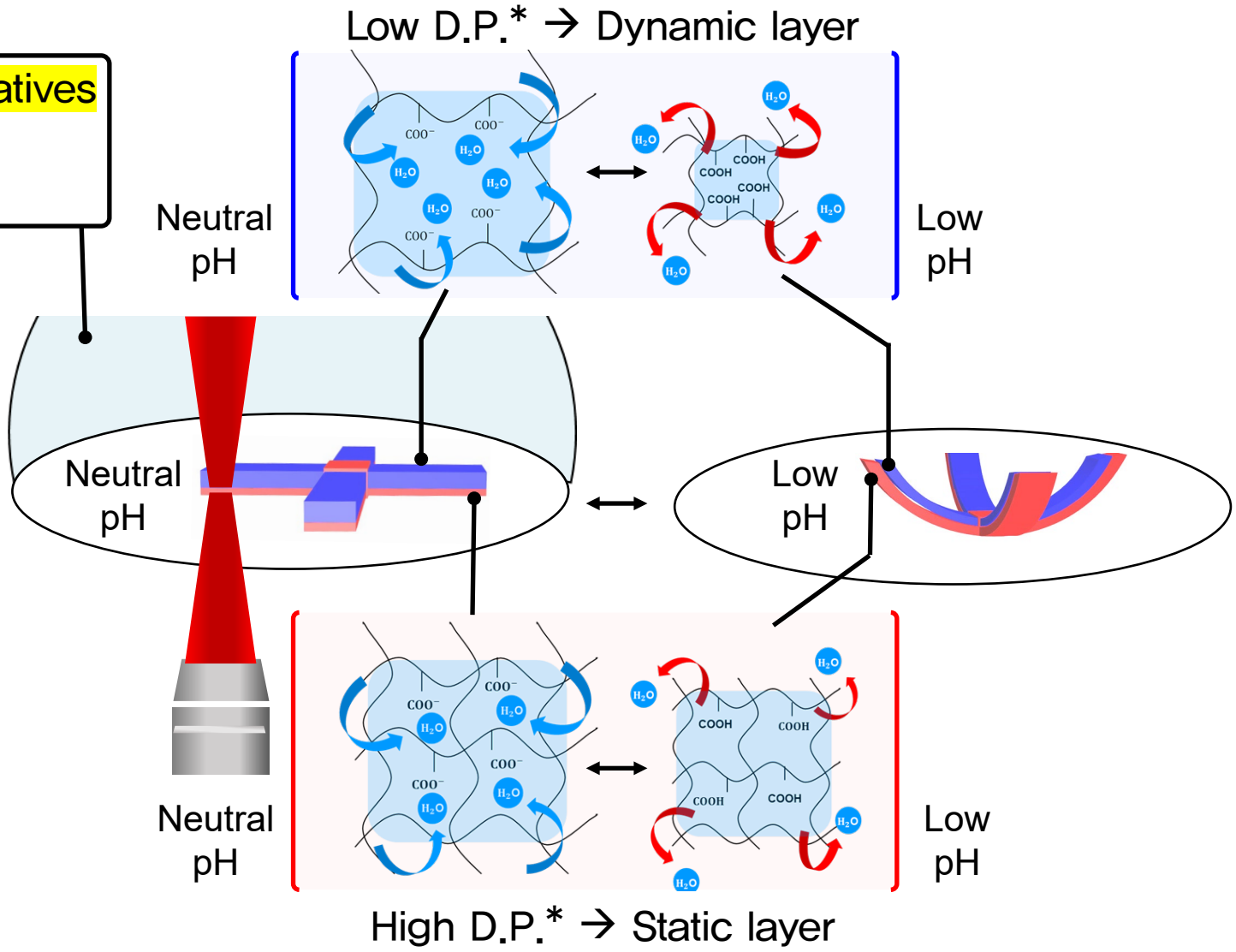
  - Hexaflagellar microrobot: use collective motion of the swarm
  - Phase changing and application of each phases



  - Hilbert structure: shape changing cube ↔ line
  - Gyroid: surface loading / delivery
  - Nano needle: cell attach, penetration …

μ3D printing of pH-triggered shape morphing material

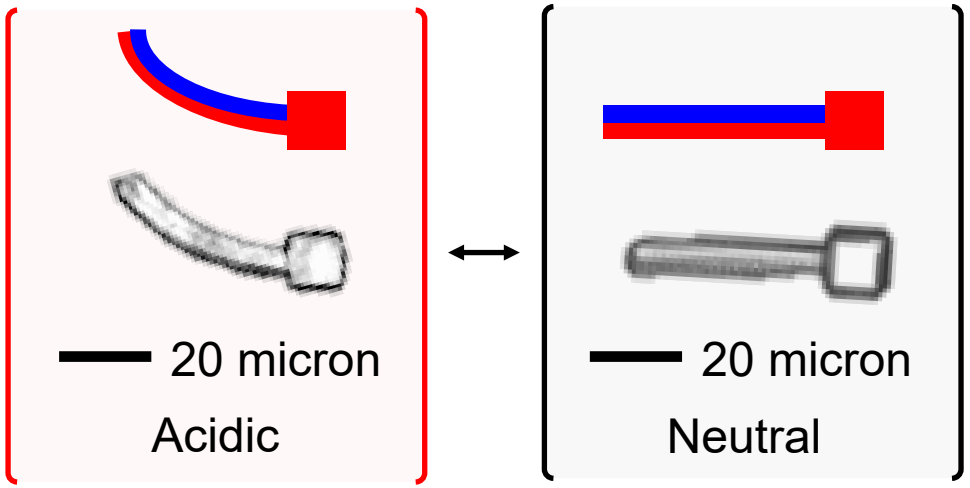
Acrylic acid derivatives
Crosslinkers
Photo initiators

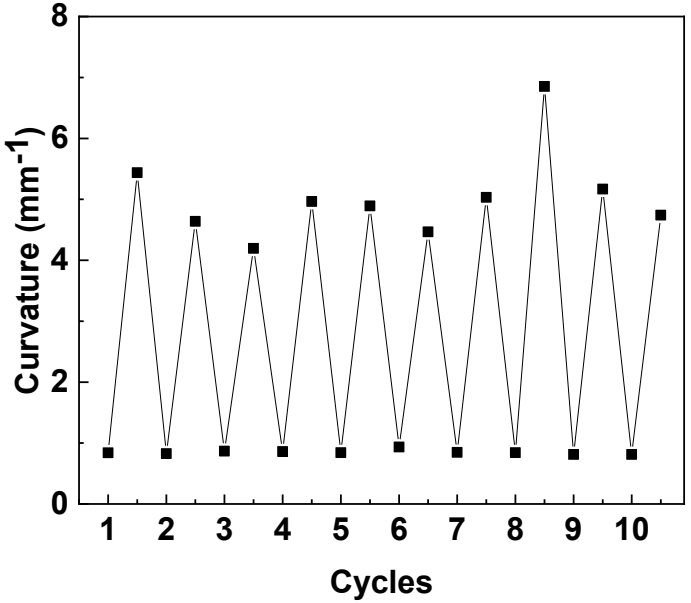


*Degree of Polymerization

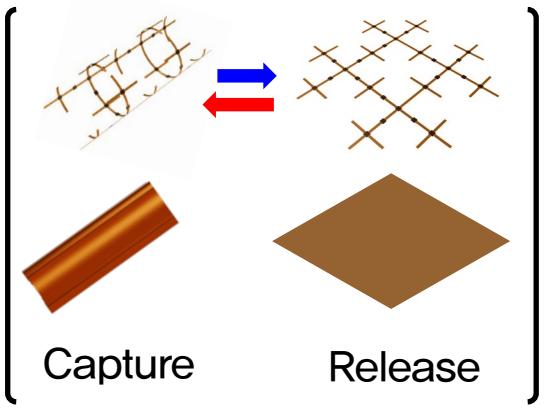
μ3D printing of pH–triggered shape morphing material

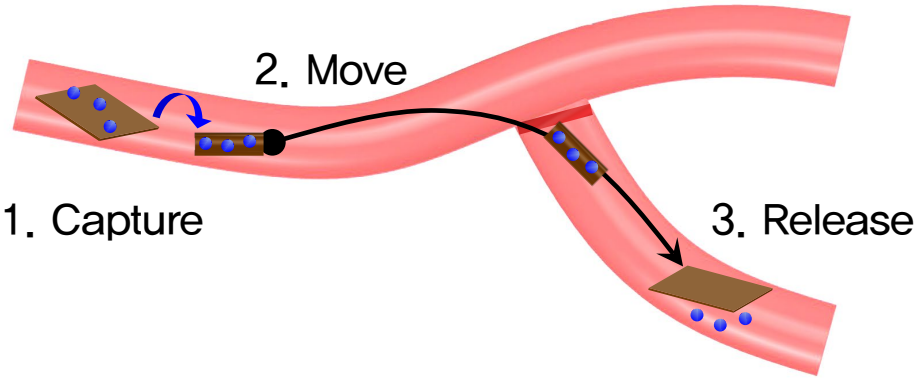
pH triggered actuation



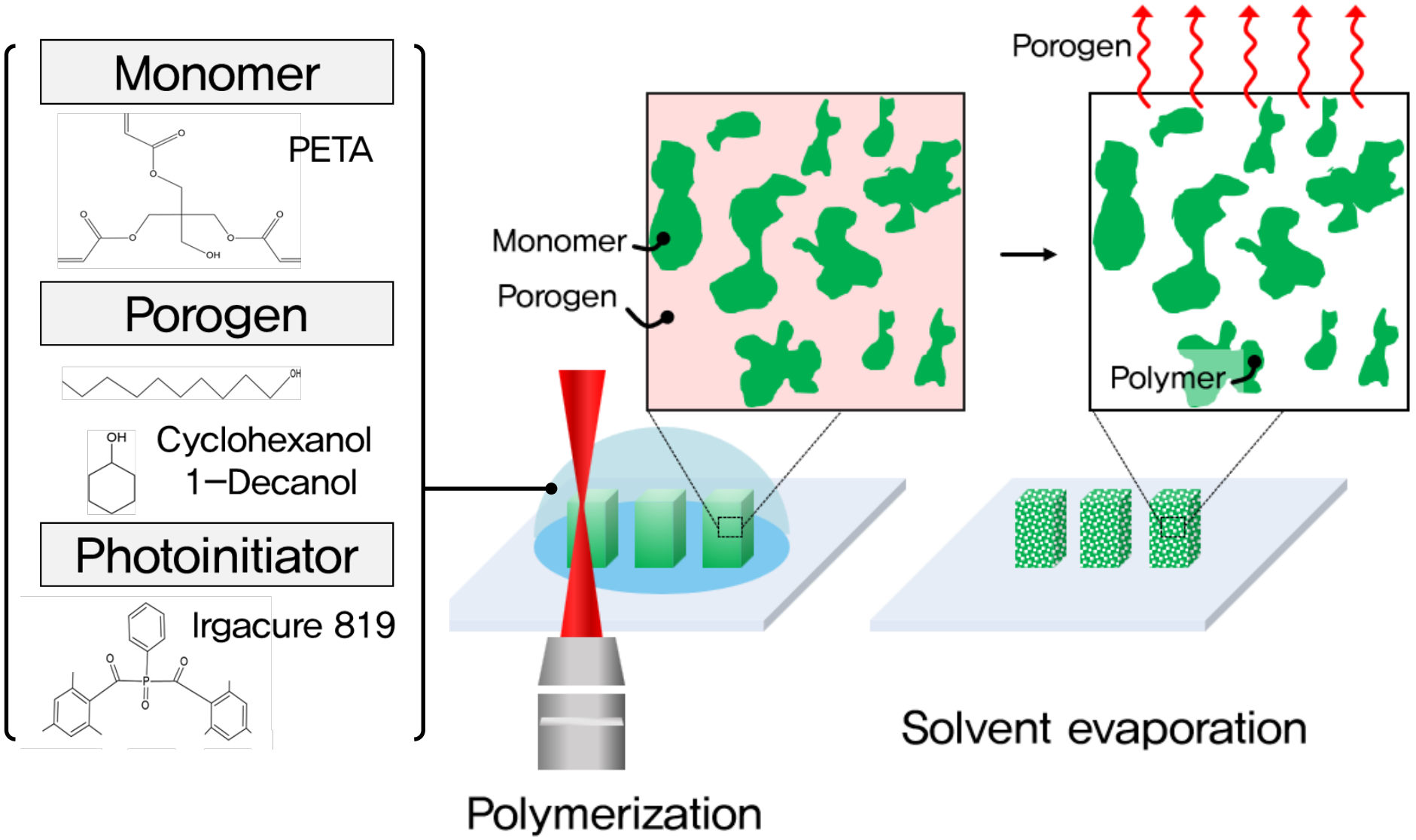


Application Scenario

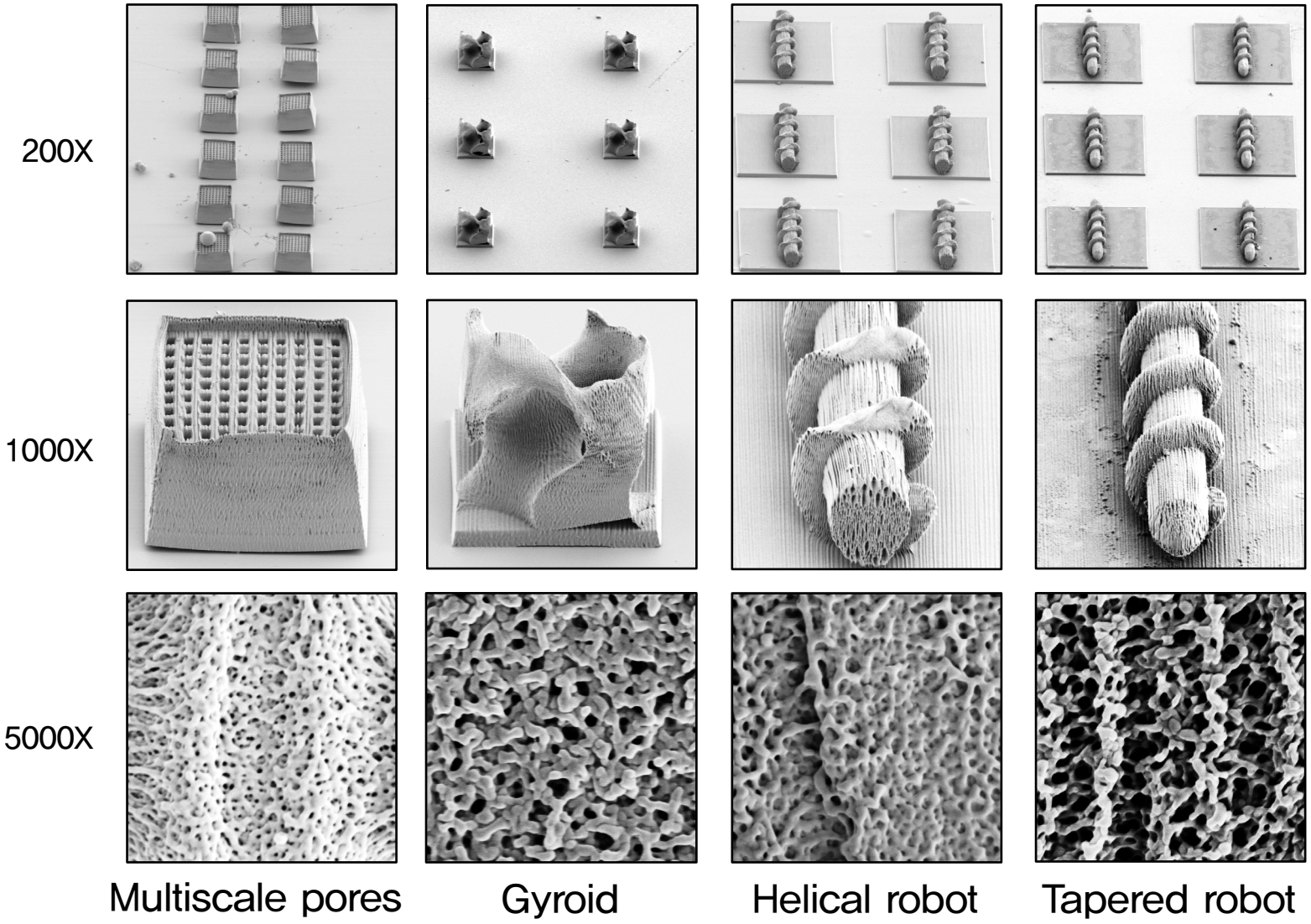




Micro 3D printing with nanoporous structure

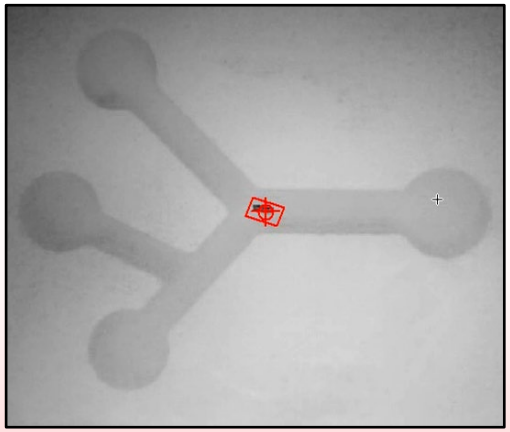


Micro 3D printing with nanoporous structure



Future research direction

Conventional Medical Technology
- Limitation in active delivery of drugs/cells to the target area
- Limitation in approach to the target area through capillaries



Microscale Soft Robots for Medical Application with AI
- Actively move in human body & targeting
- Intelligent functions (Sensing, Delivery or new functionality)
- Automated system (with AI imaging)
  - → Remote healthcare w/o trained medical doctor
  - → Everyone gets benefits (Healthcare Democratization)

To achieve goal,
Aim 1. Synthesis Functional Soft-Materials for microscale 3D/4D Printing
Aim 2. Parametric design of 3D Microstructures to overcome size limitations