南方科技大学
SOUTH UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA

# Origami self-assamblly Micro\nano-robotics

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# Background: Robotics

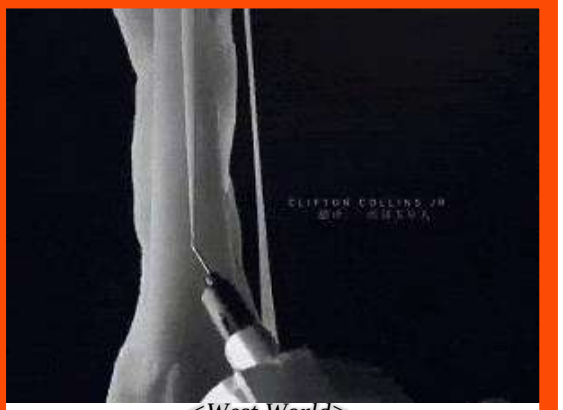
*What about the future !??*

BACKGROUND

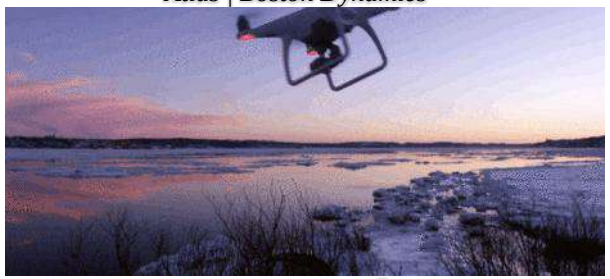
*Atlas | Boston Dynamics®*

*Kiva System® | Amazon®*


*ASIMO | Honda®*



*<West World>*



*Phantom | DJI®*


*da Vinci Surgical System | Intuitive Surgical®*

*Soft Robotic Fish | MIT, R.K.Katzschmann et al.*

*<Transformers>*

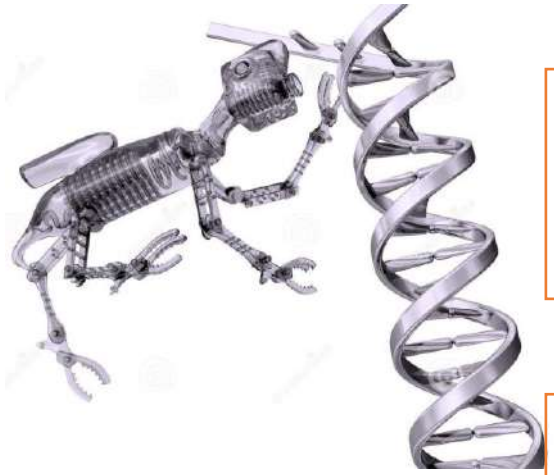

*Industrial robot | FANUC®*

*Mars Rover | Nasa*

*DARPA Warrior Web Exosuit | Ekso Bionics®*

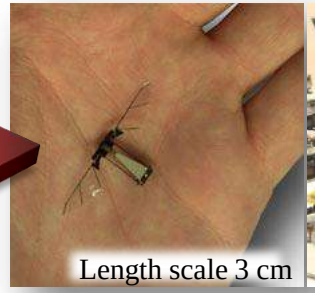
*<Big Hero 6>*

# Background: Micro/Nanostructures



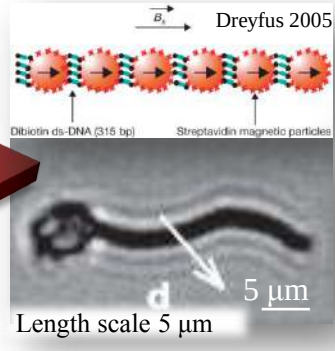
## Microrobotics
**(mm ~ µm)**

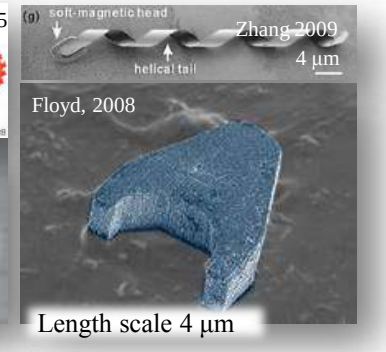
The term **"Microrobots"** are often refers to robots that are small, such as centimeter sized robots. Examples include micro air vehicle (MAV) and mini swarms robots





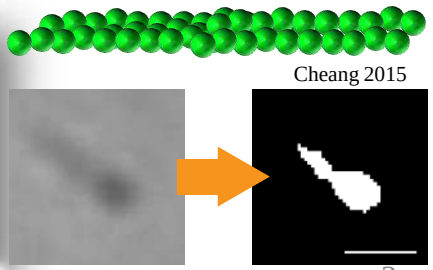
We consider the field of microrobotics to include **robotic micromanipulation --** manipulation of objects with characteristic dimensions in the millimeter to micrometer (mm ~ µm) range as well as the **design and fabrication** of robotic agents in a similar size range (**microrobots**).




## Nanorobotics
**(0.1 µm ~ 10 µm)**

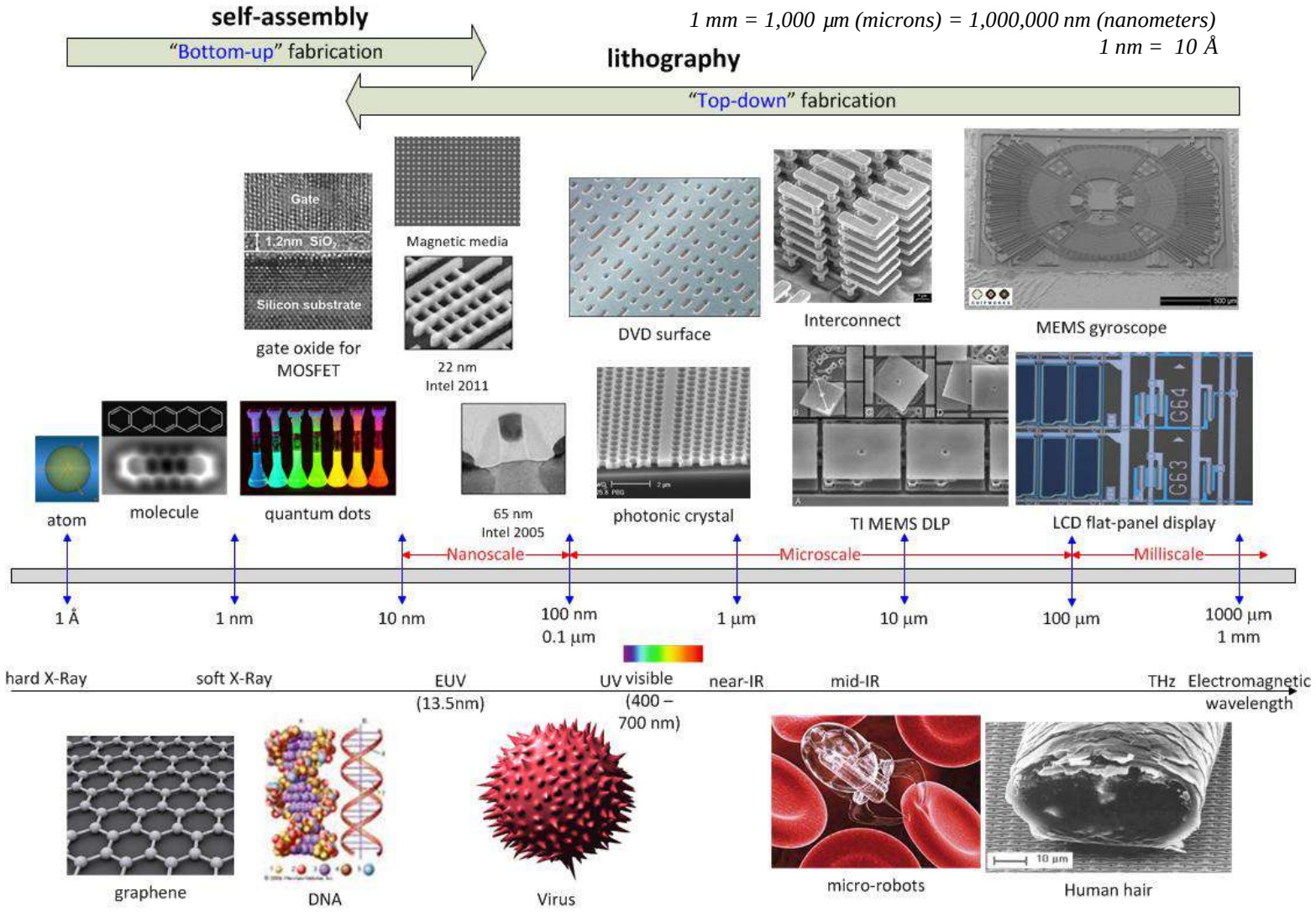
The terms **nanorobots**, **nanoids**, or **nanobots** are often refer to the devices: (1)with size range from 0.10 to 10 micrometers **(0.1 µm ~ 10 µm)**. (2)**constructed** of molecular or nanoscale components. (3)robot that allows **precision interactions** with nanoscale objects or which can **nano-manipulate with nanoscale resolution**.

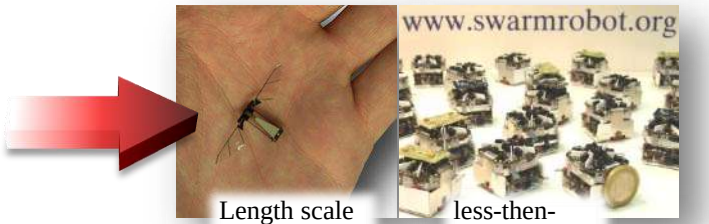



Ross, R. (2018). Robotic Insect Takes Off. [online] MIT Technology Review. Available at: https://www.technologyreview.com/s/408265/robotic-insect-takes-off/ [Accessed 5 Apr. 2018].
Abbott, J., Nagy, Z., Beyeler, F. and Nelson, B. (2007). Robotics in the Small, Part I: Microbotics. IEEE Robotics & Automation Magazine, 14(2), pp.92-103.
Magoda.com. (2018). Nanorobots Can Beat Cancer | Manufacturing America. [online] Available at: http://www.magoda.com/medical/nanorobots-can-beat-cancer/ [Accessed 5 Apr. 2018].
Dreamstime.com. (2018). Stock Photos And Royalty-Free Images By Dreamstime. [online] Available at: https://www.dreamstime.com/ [Accessed 5 Apr. 2018].

# Background: Why Small?



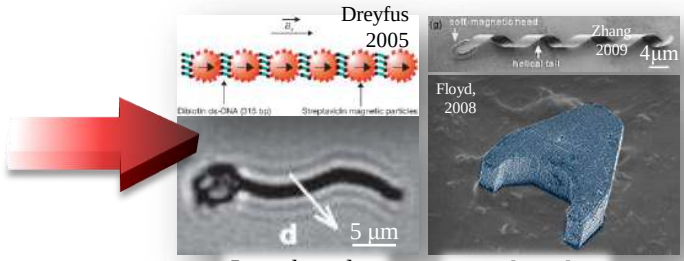

***Micro/nanorobots***




Length scale 3 cm

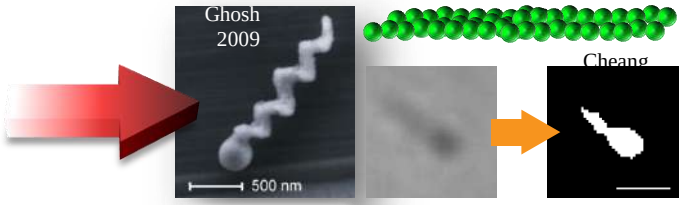
less-then-3cm-cube

*e.g. Micro Air Vehicle (MAV) and Mini Swarms Robots*




Length scale 5 μm

Length scale 4 μm




Length scale 500 nm



Ross, R. (2018). Robotic Insect Takes Off. [online] MIT Technology Review. Available at: https://www.technologyreview.com/s/408265/robotic-insect-takes-off/ [Accessed 5 Apr. 2018].

# Background: Why Small?

## Favorable Policy

*Micro/Nano-robots: The future of medicine?*

BACKGROUND

| Government Policy | |
|---|---|
| *<Made in China 2025>* | *<Healthy China 2030>* |
| "**Made in China 2025**" is putting forward in the field of **biomedicine** and **high-performance medical instrument** development in view of **new products of chemical drugs**, including **new mechanism** and **new targets for chemical drugs** and **personalized treatment**. | The goal of "**Healthy China 2030**" is to **provide health services to every citizen by 2030**. **Life expectancy is to reach 79 years old**, aimed at **meeting the standard of high-income countries**. |





Gov.cn. (2017). 中国制造2025_中国政府网. [online] Available at: http://www.gov.cn/zhuanti/2016/MadeinChina2025-plan/index.htm [Accessed 11 Dec. 2017].
Kisti.re.kr. (2017). 한국과학기술정보연구원. [online] Available at: http://www.kisti.re.kr/ [Accessed 11 Dec. 2017].

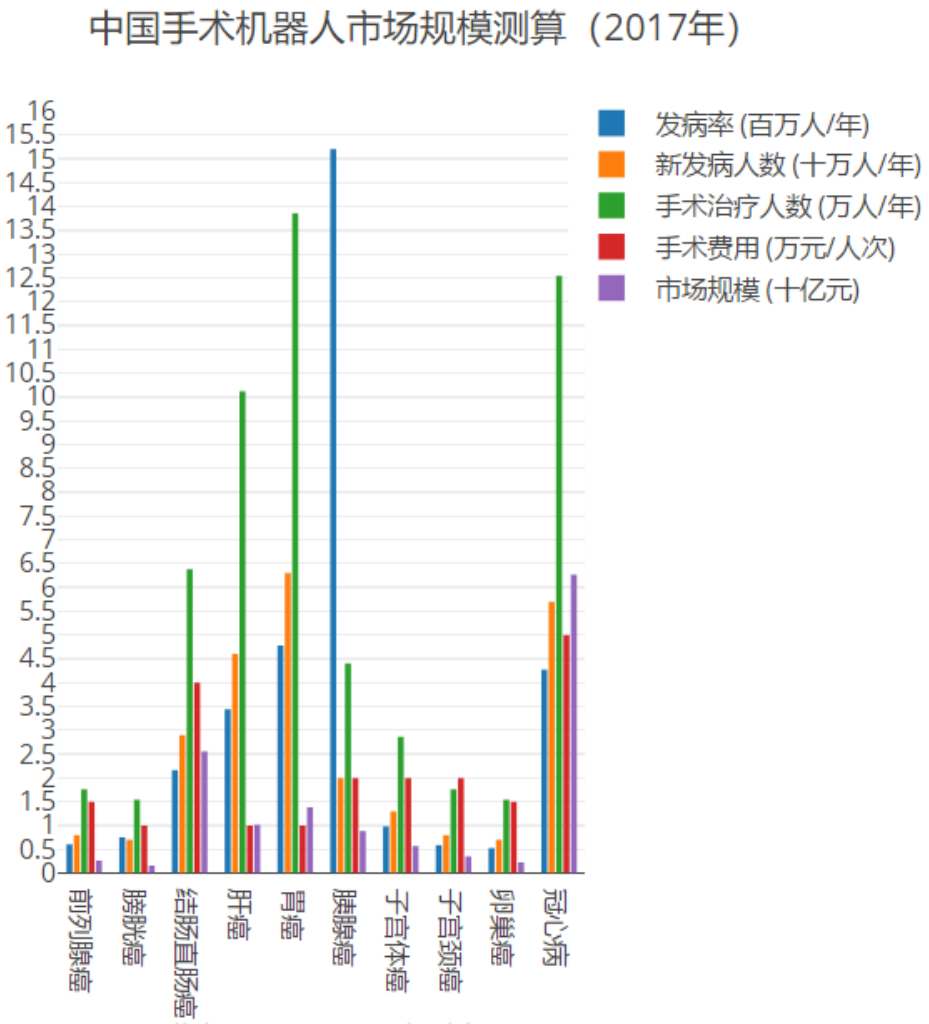
# Background: Why Small?

## Huge Market Potential

THE PROBLEM

| 科室 | 病种 | 发病率（十万人/年） | 新发病人数（万人/年） | 手术治疗人数（万人/年） | 手术费用（万元/人次） | 市场规模（亿元） |
|---|---|---|---|---|---|---|
| 泌尿外科 | 前列腺癌 | 6.03 | 8 | 1.76 | 1.5 | 2.64 |
| | 膀胱癌 | 7.49 | 7 | 1.54 | 1 | 1.54 |
| 普外科 | 结肠直肠癌 | 21.6 | 29 | 6.38 | 4 | 25.52 |
| | 肝癌 | 34.37 | 46 | 10.12 | 1 | 10.12 |
| | 胃癌 | 47.77 | 63 | 13.86 | 1 | 13.86 |
| | 胰腺癌 | 152 | 20 | 4.4 | 2 | 8.8 |
| 妇科 | 子宫体癌 | 9.84 | 13 | 2.86 | 2 | 5.72 |
| | 子宫颈癌 | 5.84 | 8 | 1.76 | 2 | 3.52 |
| | 卵巢癌 | 5.22 | 7 | 1.54 | 1.5 | 2.31 |
| 心胸外科 | 冠心病 | 42.68 | 57 | 12.54 | 5 | 62.7 |
| | | | 合计 | | | 136.73 |

资料来源：Cancer Statistics in China，申万宏源研究( 2017 )






Abbott, J., Nagy, Z., Beyeler, F. and Nelson, B. (2007). Robotics in the Small, Part I: Microbotics. IEEE Robotics & Automation Magazine, 14(2), pp.92-103.

# Background: Why Small?

## Huge Market Potential

THE PROBLEM

| Market Size | |
|---|---|
| Kisti.re.kr.(South Korea) | |
| Global Nano Drug Market | **$ 360.2 B(2016)** → **$ 639.9 B(2021)** |
| (1st.) Nanodrugs for Cancer Treatment | **$ 134.4 B(2017)** → **$ 300.0 B(2021)** |
| (2nd.) Central Nervous System Disease Treatment | **$ 131.4 B(2021)** |
| (3rd) Infectious Diseases Treatment | **.....** |

| WinterGreen Research (USA) | |
|---|---|
| Global **Medical Robots** Market | **$ 3.2 B(2014)** → **$ 20.0 B(2021)** |

| 科室 | 病种 | 发病率（十万人/年） | 新发病人数（万人/年） | 手术治疗人数（万人/年） | 手术费用（万元/人次） | 市场规模（亿元） |
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Abbott, J., Nagy, Z., Beyeler, F. and N E Robotics & Automation Magazine, 14(2), pp.92-103.

# Background: Why Small?

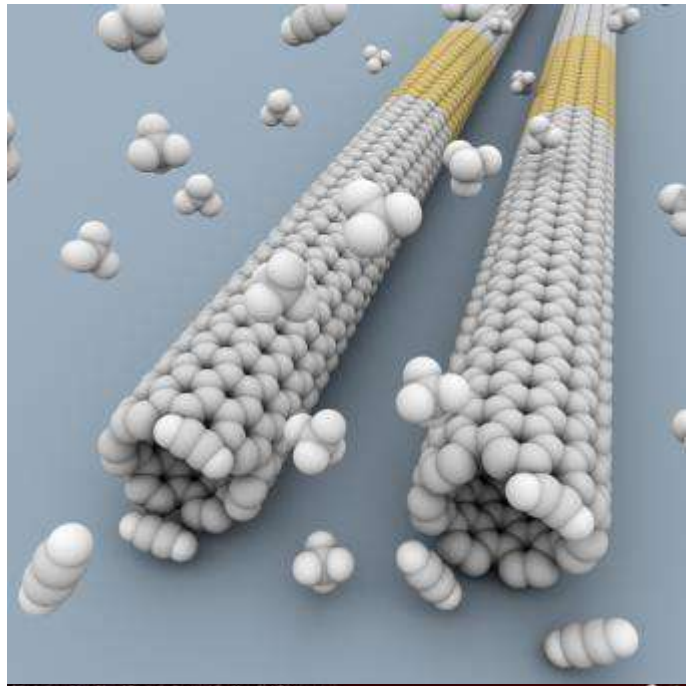
## Many applications made possible

***Micro/Nano-robots: The future of medicine?***

BACKGROUND

Examples:

| | |
|---|---|
| Materials Science | Powders, Coatings, Carbon Nano-Materials, C-NanoFabrics, Self-assembly |
| Energy | Solar Power and PhotoVoltaics, Hydrogen Fuel Cells, LED White Light |
| Medicine/Biotech | Genomics, Proteomics, Lab-on-a-Chip, C-Nanotubes, BuckyBalls, bioMEMS |
| Electronics | MRAM, NRAM, Q-Dots, Q-Bits, Sensors |
| Devices | Lithography, Dip Pen Lithography, Nanoimprinting, Laser Beam, AFM, TEM |
| Robotics | Micro/nanorobots, Precise Manipulation, Non-Invasive Surgeries, Targeted drug Delivery |




***Fruition of micro/nanorobotics can bring about a technological revolution in medicine***



Nanotechnology commercialization group lecture "Nanotechnology A Brief Overview"
Roşu, G. (2018). Mass Production Of Carbon Nanotube Made Possible Thanks To Japanese Researchers | eTeknix. [online] eTeknix. Available at: https://www.eteknix.com/mass-production-carbon-nanotube-might-become-possible-thanks-japanese-researchers/ [Accessed 5 Apr. 2018].
tanford, S. (2018). 'Disturbing New Phenomenon' Emerges - Medical Experts Don't Know What It Is - The Daily Coin. [online] The Daily Coin. Available at: https://thedailycoin.org/2016/10/11/disturbing-new-phenomenon-emerges-medical-experts-dont-know-what-it-is/ [Accessed 5 Apr. 2018].

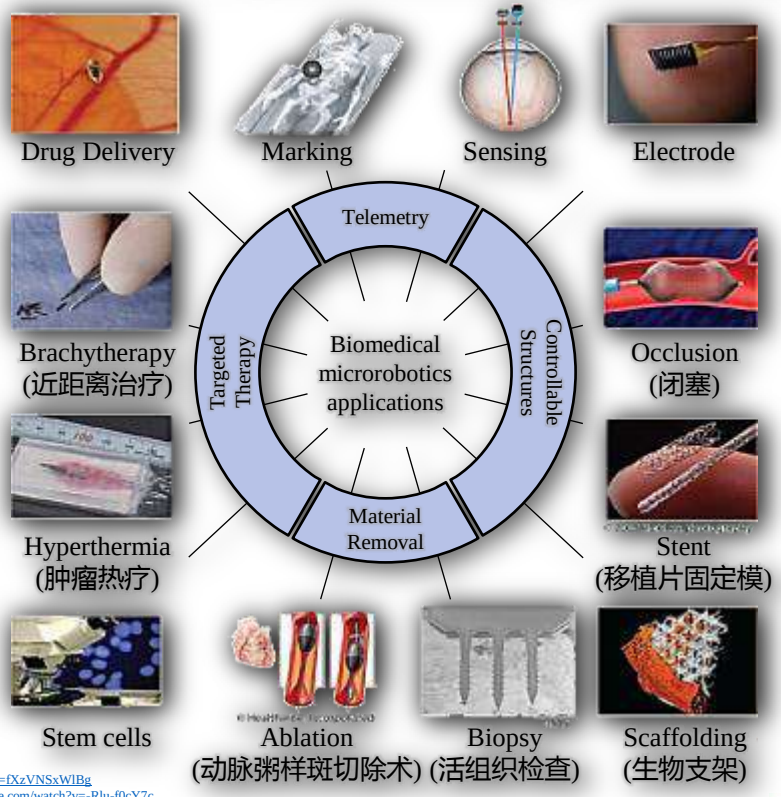
# Background: Why Small?

## Potential Medical Applications

BACKGROUND

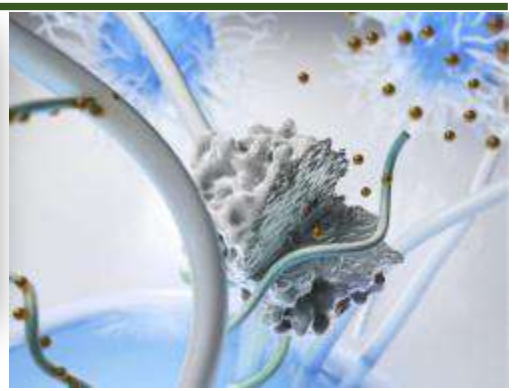

Fantastic Voyage (1966)

*Can Fantasy becomes Reality? Micro/Nanorobots, future of medicine?*



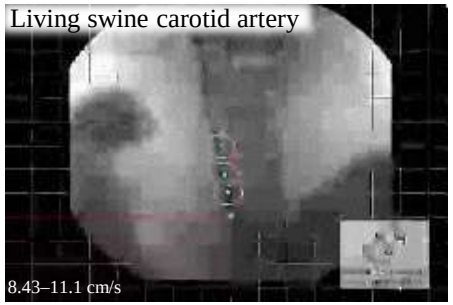


**Biopsy** – minimal invasive retrieval of tissue sample



**Genetic modification** – gene and cell therapy

**Drug delivery** – precise target, minimize side effects




**In vivo Navigation** – steer microparticles in artery


Johns Hopkins University - https://www.youtube.com/watch?v=-Rlu-f0cY7c
Nanorobots Can Beat Cancer - www.magenta.com/medical/nanorobots-can-beat-cancer/
Nelson, B. (2010). Microrobots for minimally invasive medicine. *Annual Review of …*, *12*(April), 55–85. http://doi.org/10.1146/annurev-bioeng-010510-103409
Martel, S., et al. (2007). Automatic navigation of an untethered device in the artery of a living animal using a conventional clinical magnetic resonance imaging system. APL, 90(11), 114105.
Gultepe, E., Randhawa, J. S., Kadam, S., Yamanaka, S., Selaru, F. M., Shin, E. J., Kalloo, A. N. and Gracias, D. H. (2013), Biopsy with Thermally-Responsive Untethered Microtools. Adv. Mater., 25: 514–519. doi:10.1002/adma.201203348
Ella Maru Studio - https://spectrum.ieee.org/the-human-os/biomedical/devices/magnetic-field-controls-drug-delivery?utm_source=thehumanosalert&utm_campaign=thehumanosalert-12-13-17&utm_medium=emailom/?ch=10&tn=93312537_hao_pg

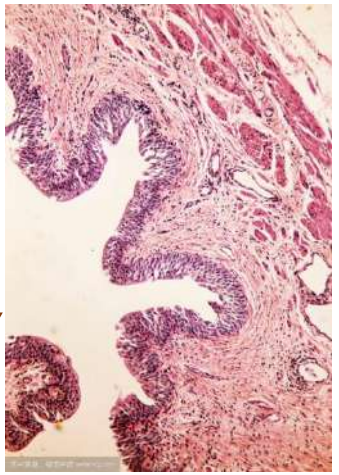
# Background: Origami Inspired Micro/Nano Composites

# Why Origami?

**1. Establish methods for controlling the properties of materials systems and the function of devices constructed with them, not only through chemistry and morphology, but also through 3D architectures.**

**2. Precise organization of biological and non-biological materials in three-dimensional (3D) space holds great promise for a vast array of applications in the fields of structural biology, biophysics, sustainable energy, photonics, electronics, medicine, etc.**

**3. More specific surface area as cells did, can carry more cargos.**





Gracias, D.H., et al., *Fabrication of Micrometer - Scale, Patterned Polyhedra by Self - Assembly. Advanced Materials, 2010. 14(3): p. 235-238.*

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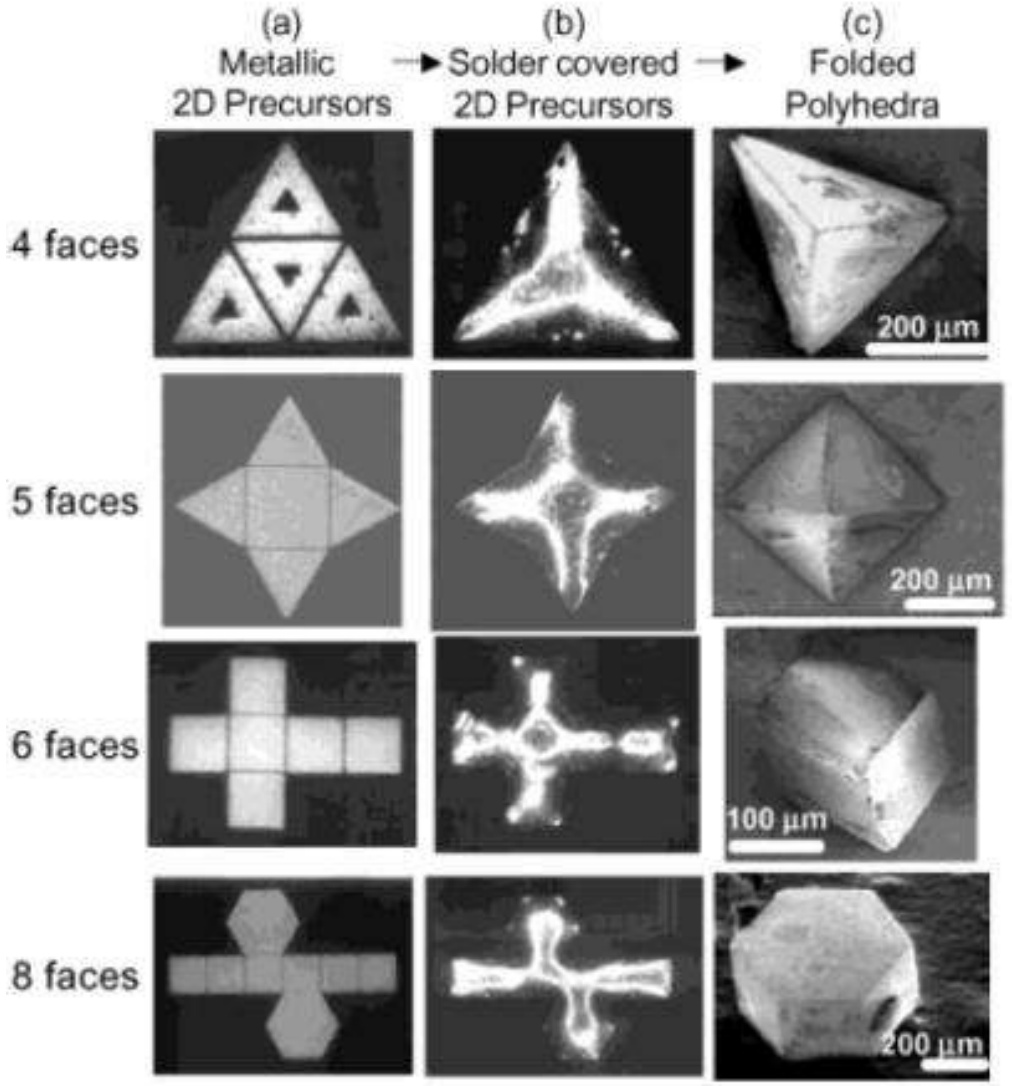


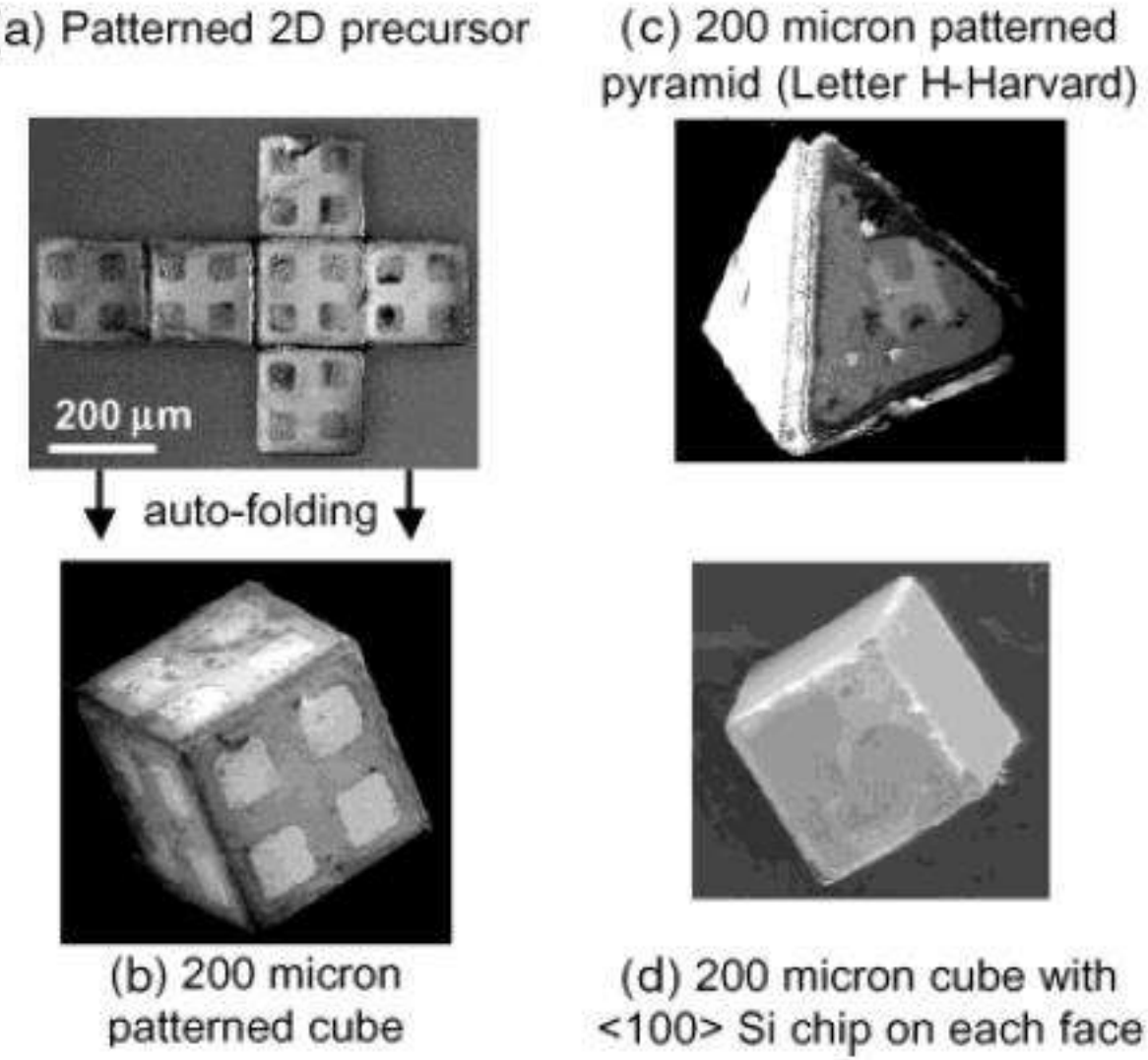




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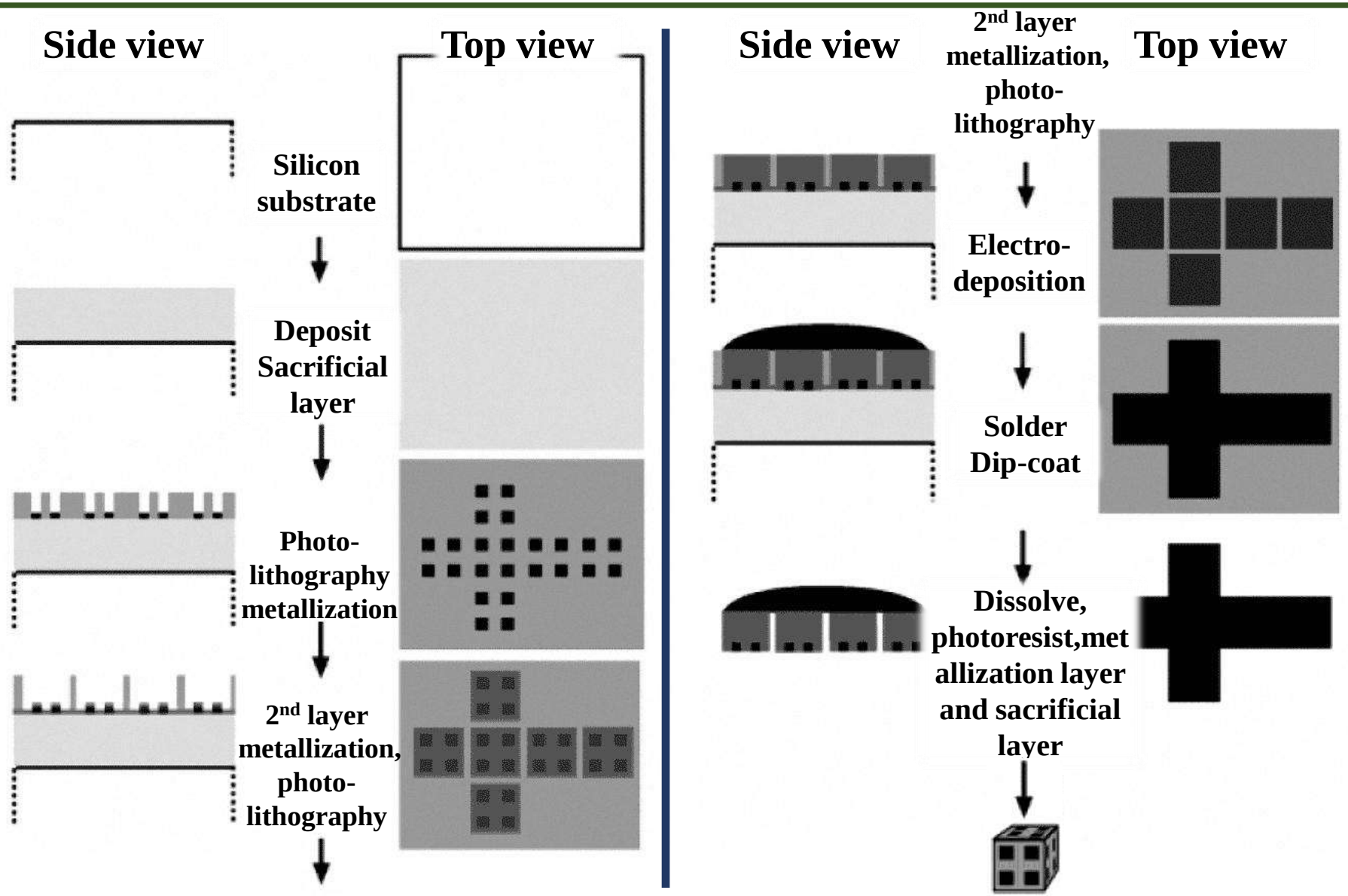


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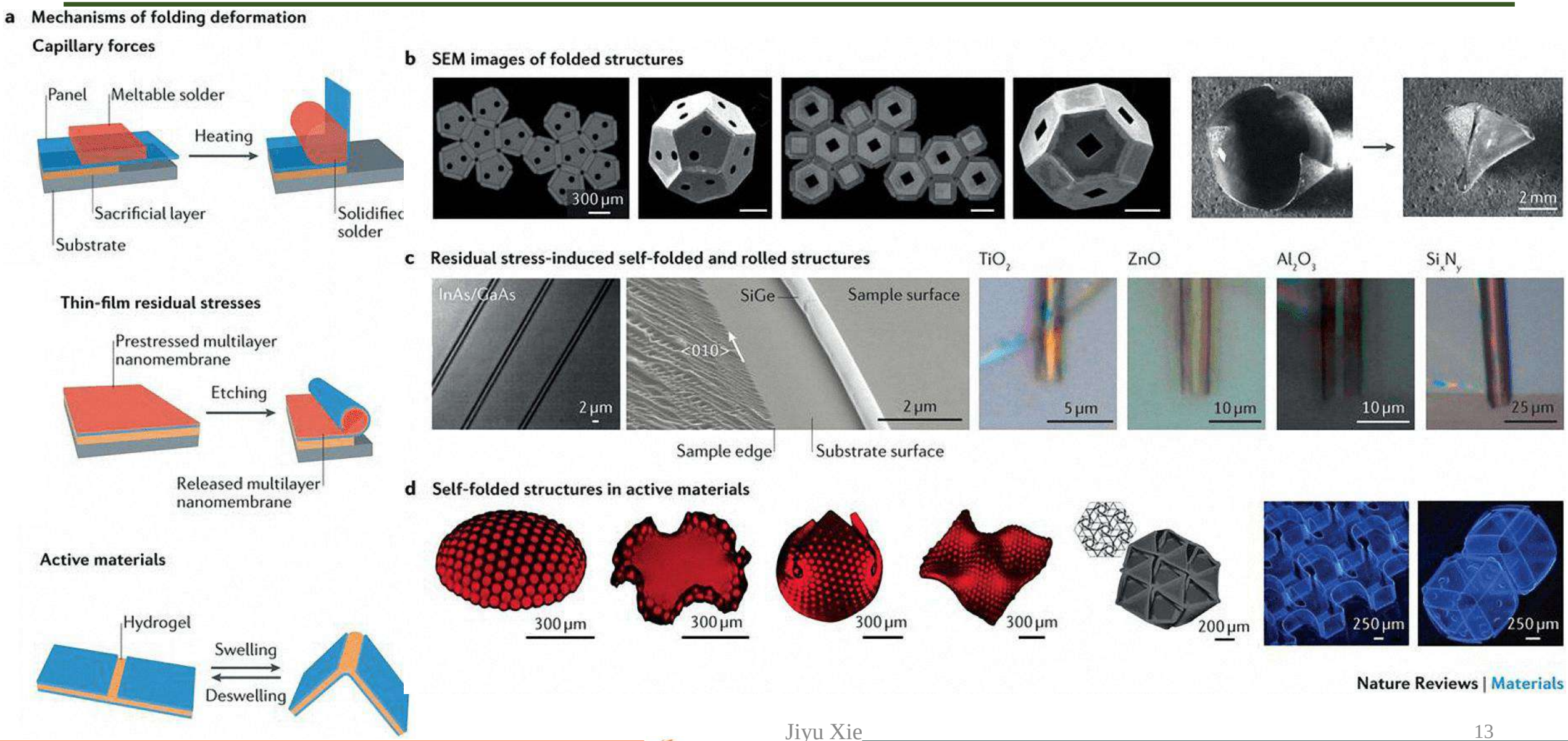
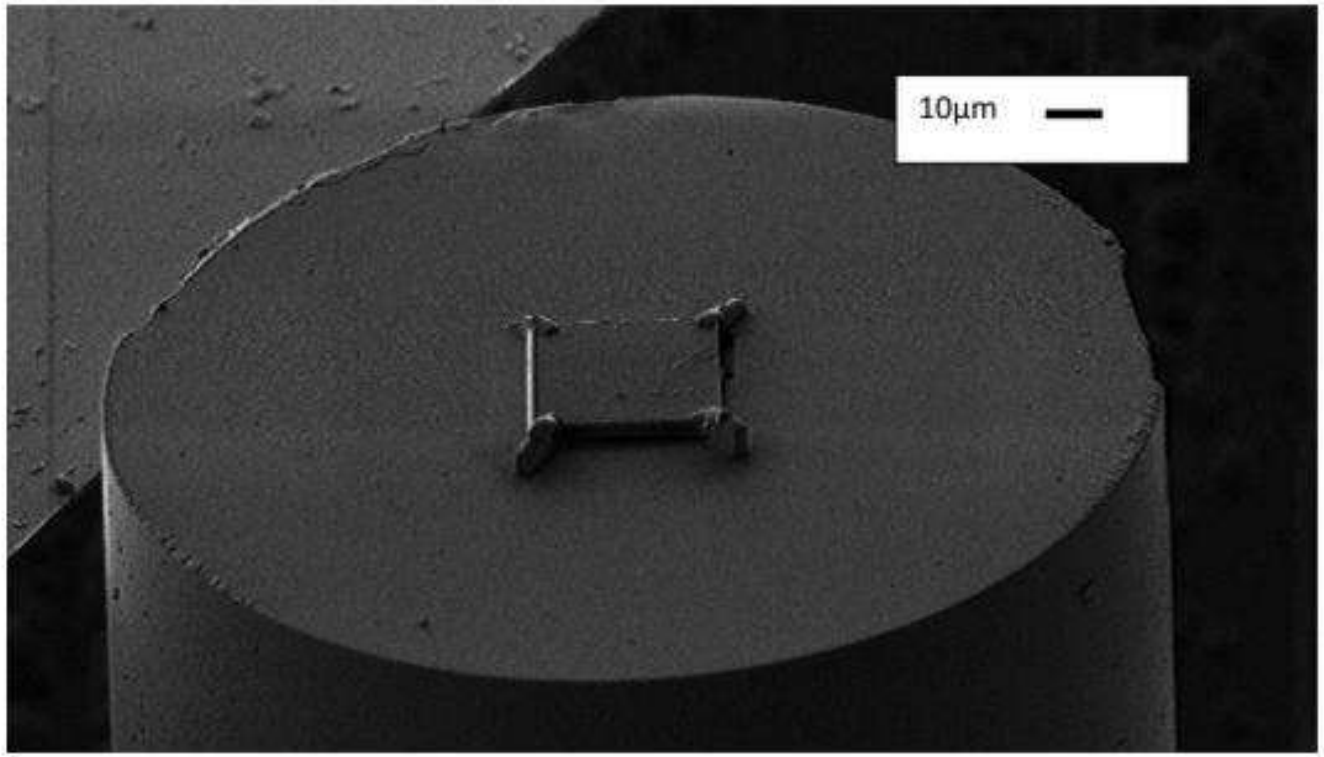


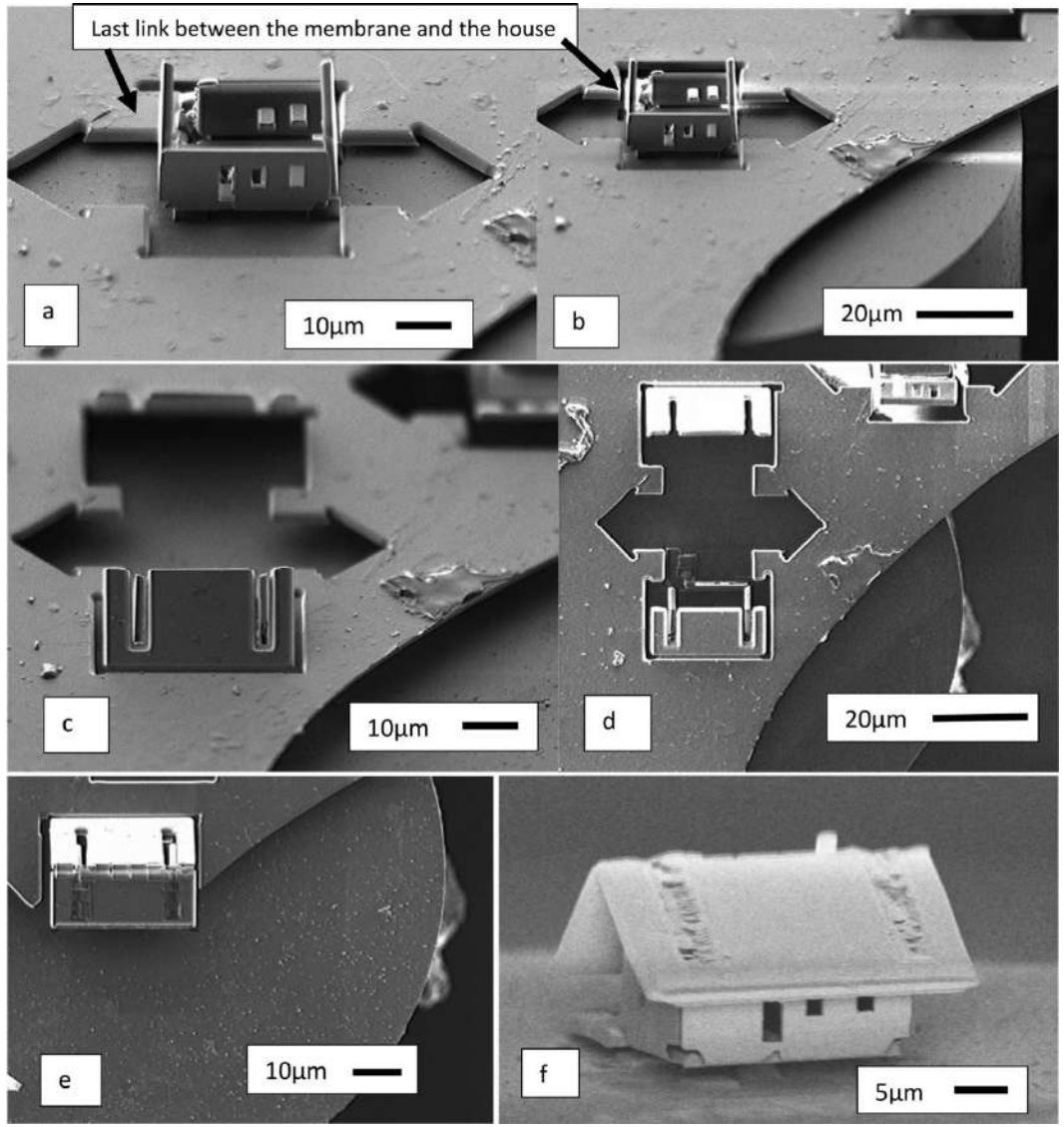



Zhang, Y., et al., *Printing, folding and assembly methods for forming 3D mesostructures in advanced materials. Nature Reviews Materials, 2017. 2(4).*

# Background: Origami Inspired Micro/Nano Composites



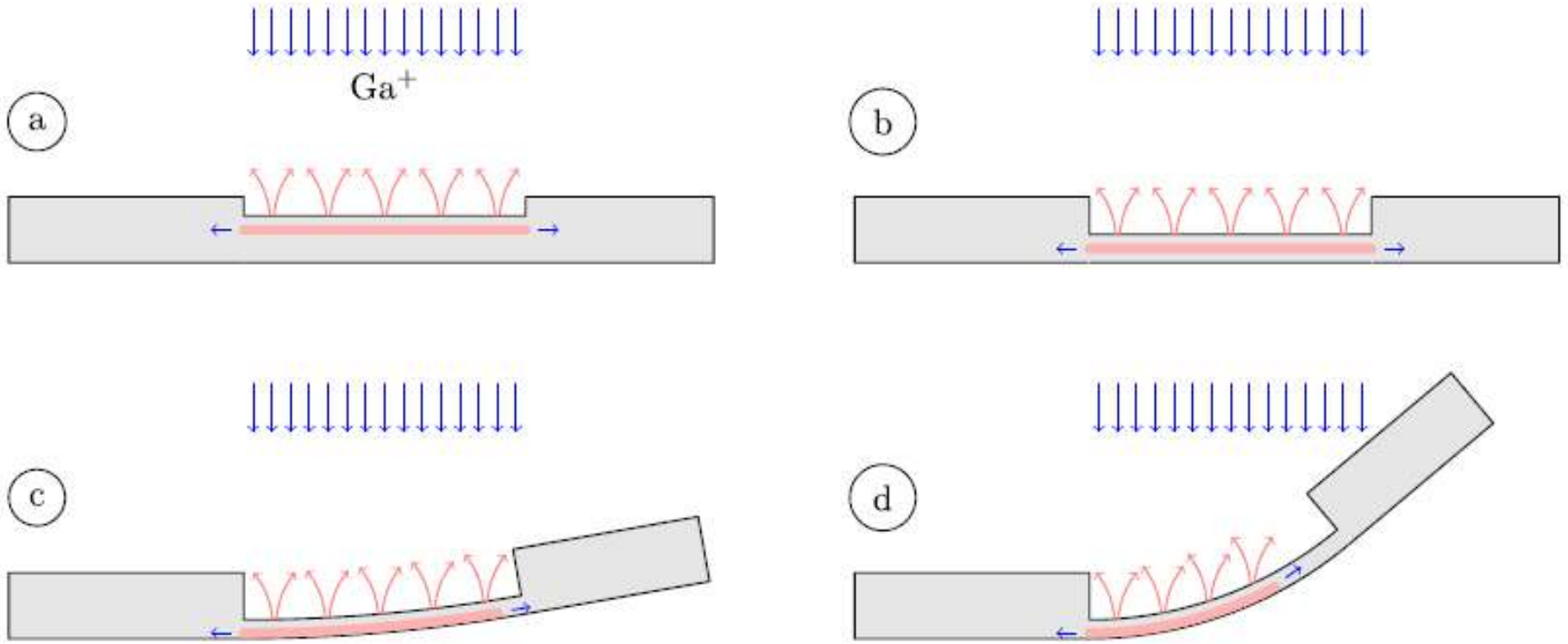

Mirror of silica is assembled at the center of an optical SMF28 fiber. The space between the top of the optical fiber and the back face of the mirror is controlled by four small plots of 1.4 lm thickness. The size of the mirror is 25*25*1.2 µm.






Rauch, J.-Y., et al., *Smallest microhouse in the world, assembled on the facet of an optical fiber by origami and welded in the µRobotex nanofactory. Journal of Vacuum Science & Technology A, 2018.* ***36(4).***

# Background: DNA Origami nano-machine

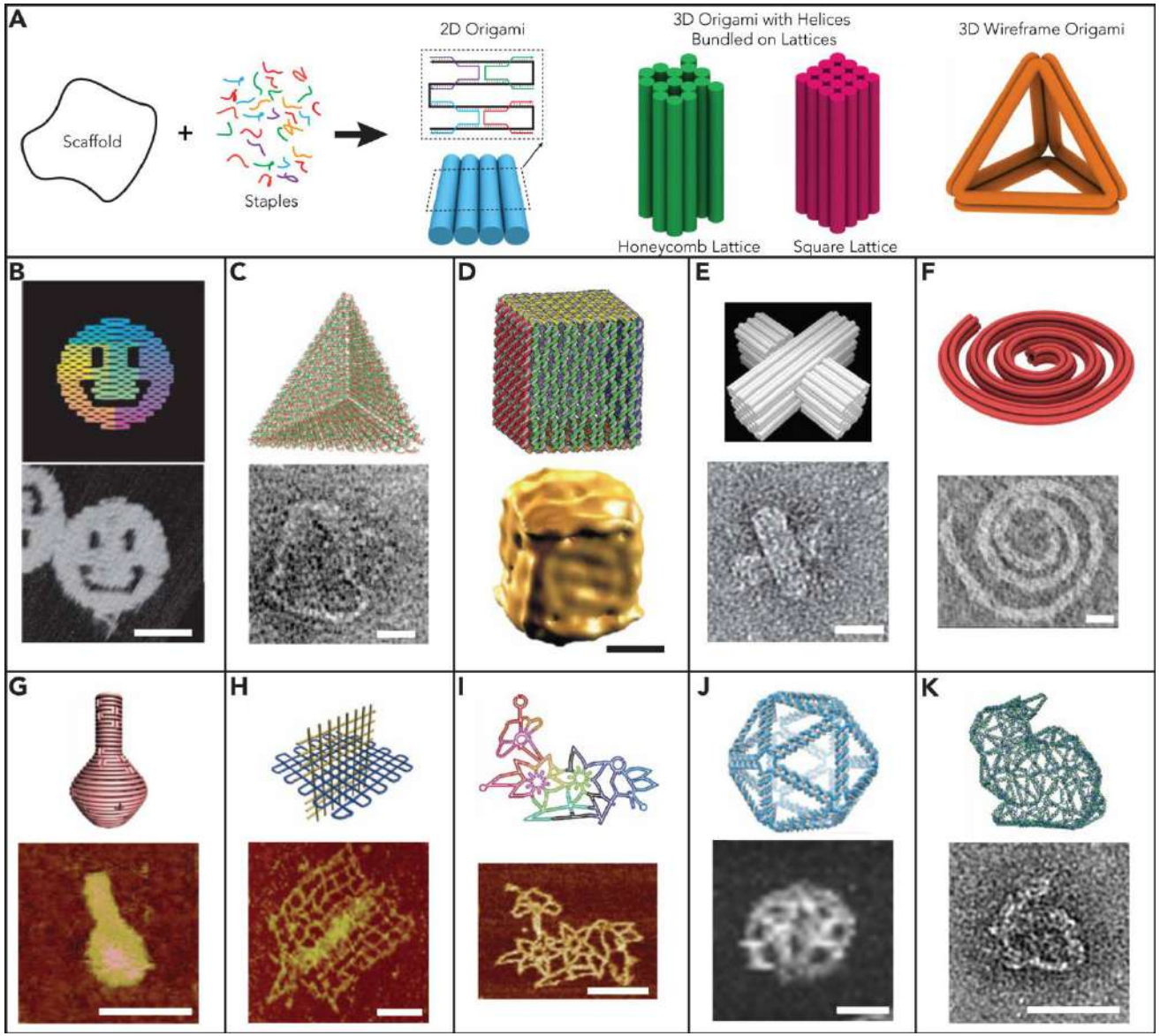


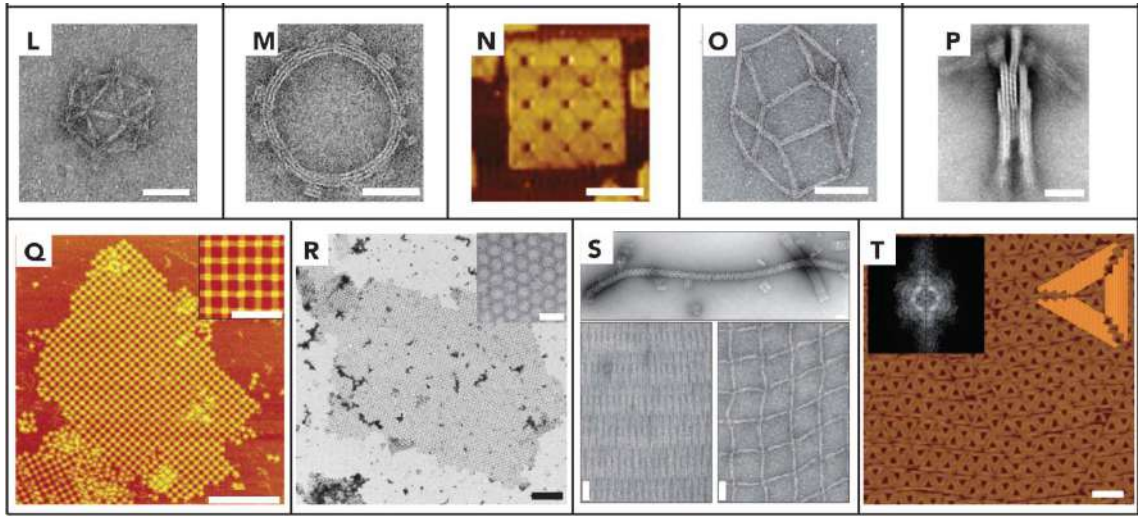

(Color online) Theory of the origami process:
(a) The first step of this process corresponds to a sputtering with gallium ions of the interesting area.
(b) When the bulk of the link between the membrane and the panel to fold corresponds to a specific thickness, a bimetallic strip appears.
(c) The effect of sputtering produces a differential dilatation coefficient into the upper part in white and the down part in red of the link.
(d) The panel self-fold from 0 to 90.

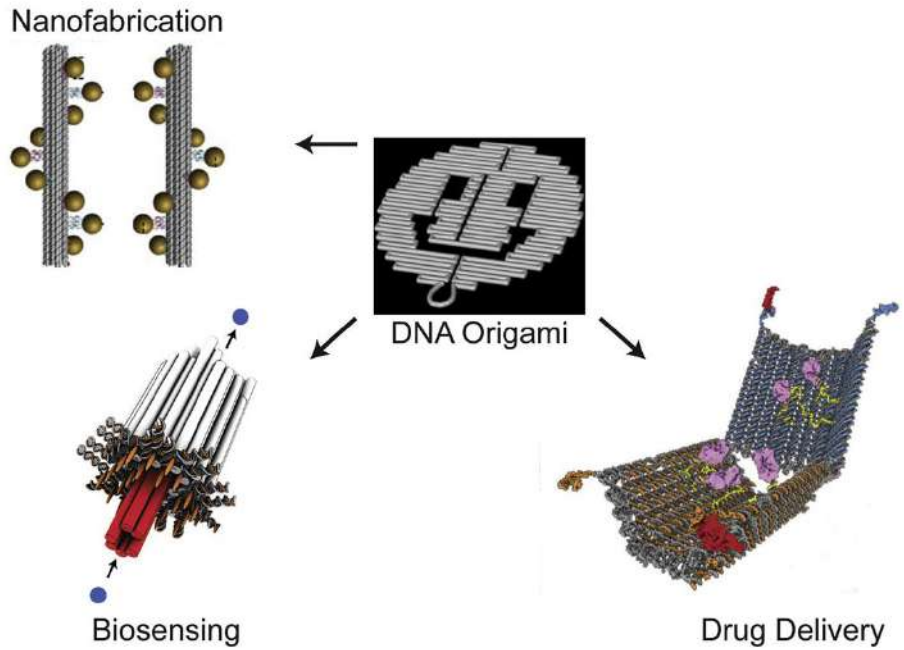


Rauch, J.-Y., et al., *Smallest microhouse in the world, assembled on the facet of an optical fiber by origami and welded in the μRobotex nanofactory. Journal of Vacuum Science & Technology A, 2018.* ***36(4)***.

# Background: DNA Origami nano-machine



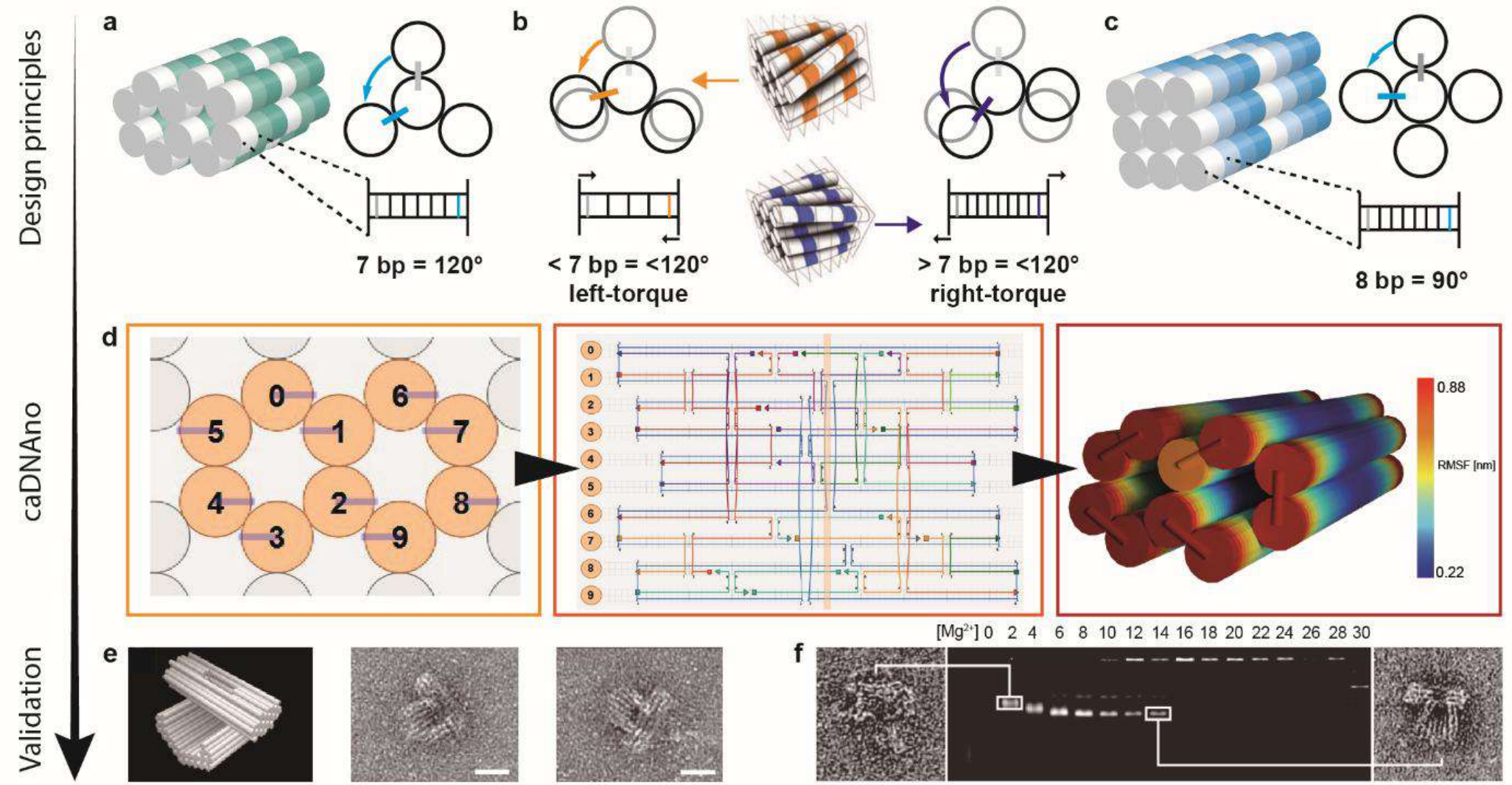




Wang, P., et al., *The Beauty and Utility of DNA Origami. Chem, 2017.* ***2(3): p. 359-382.***

SUSTech Southern University of Science and Technology

# Background: Origami Inspired Micro/Nano Composites



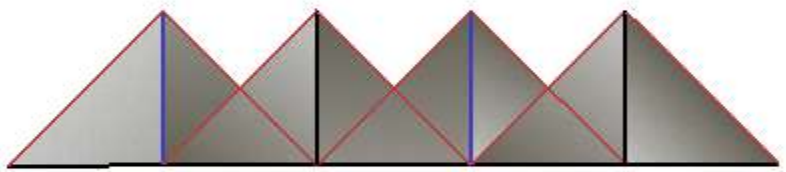



Gracias, D.H., et al., *Fabrication of Micrometer - Scale, Patterned Polyhedra by Self - Assembly. Advanced Materials, 2010. 14(3): p. 235-238.*

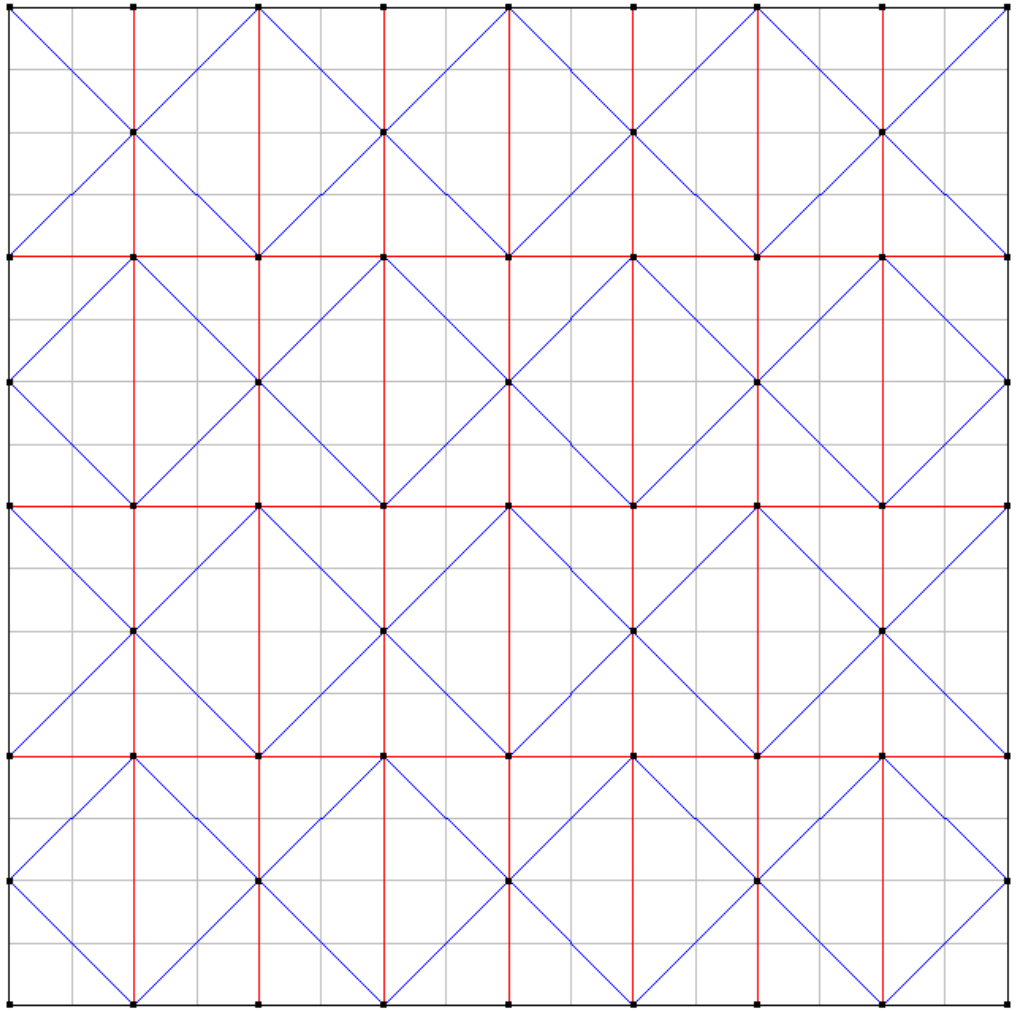
# My Design

# Design: Origami Inspired Micro/Nano Composites

**CAD**

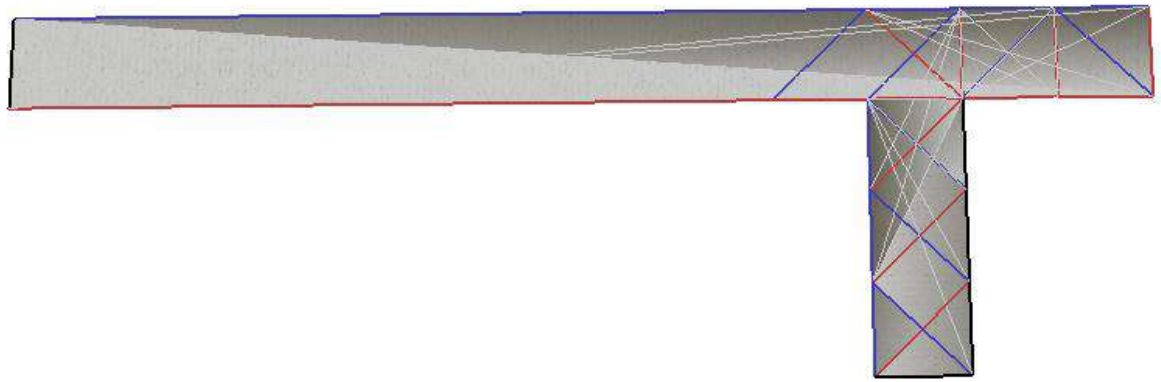


**Crease patterns (CP) (折痕图)**

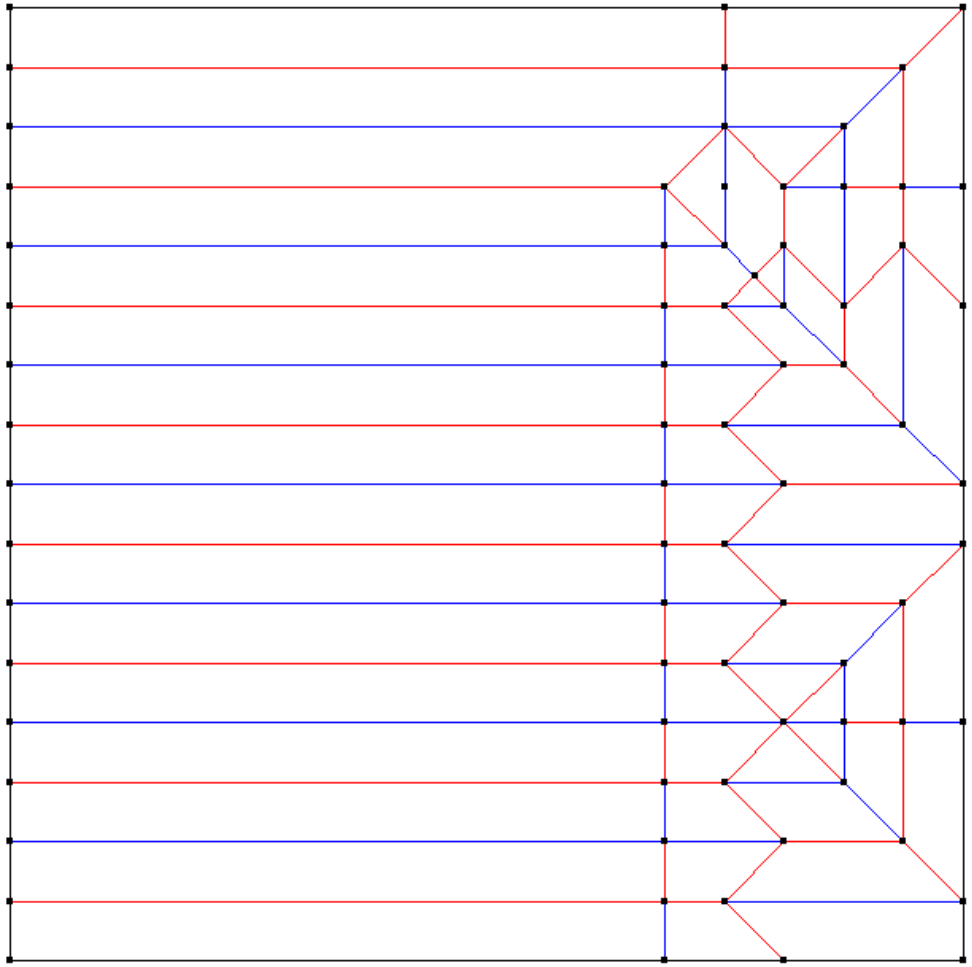


# Design: Origami Inspired Micro/Nano Composites

**CAD**



**Crease patterns (CP)**



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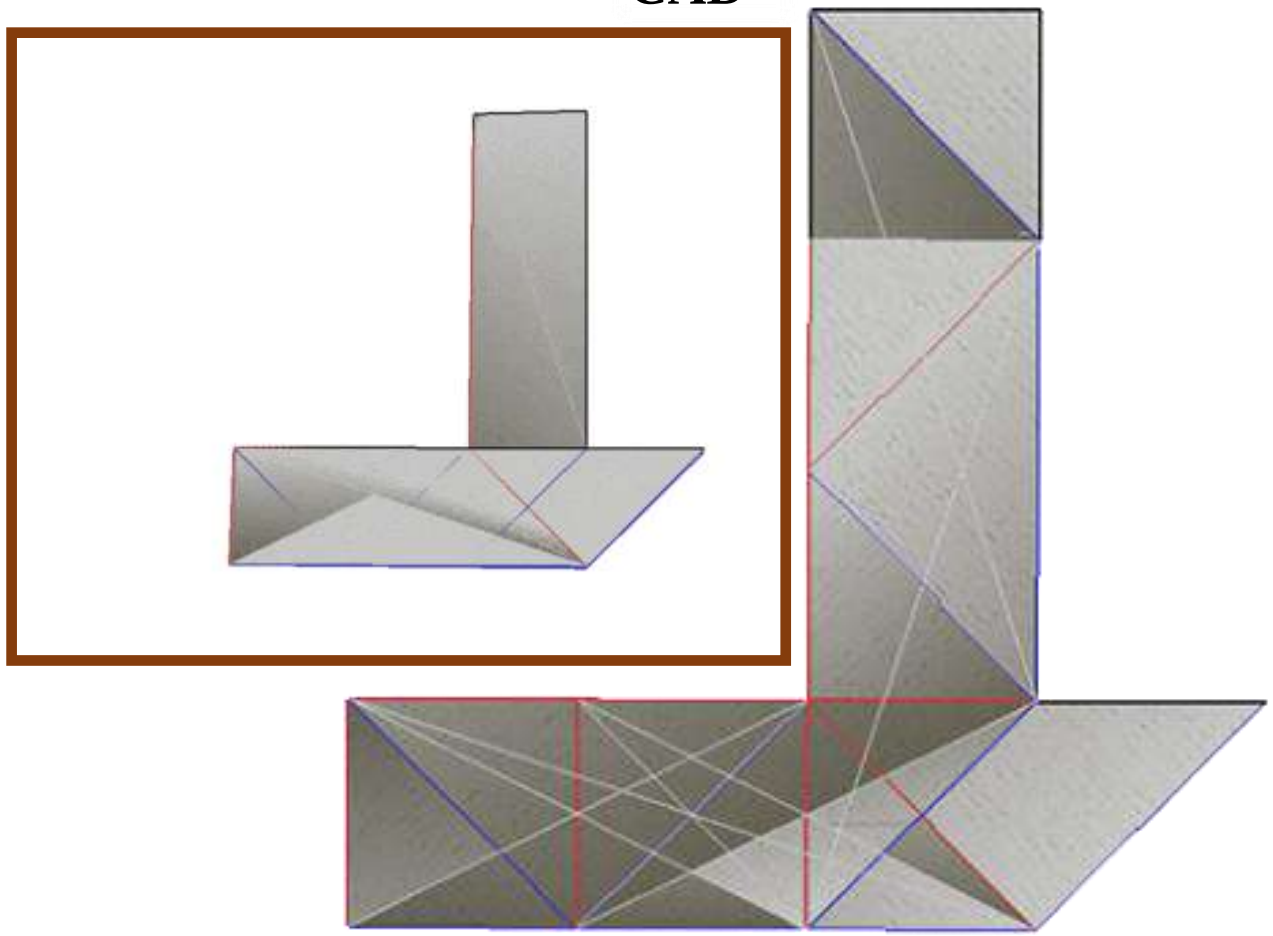
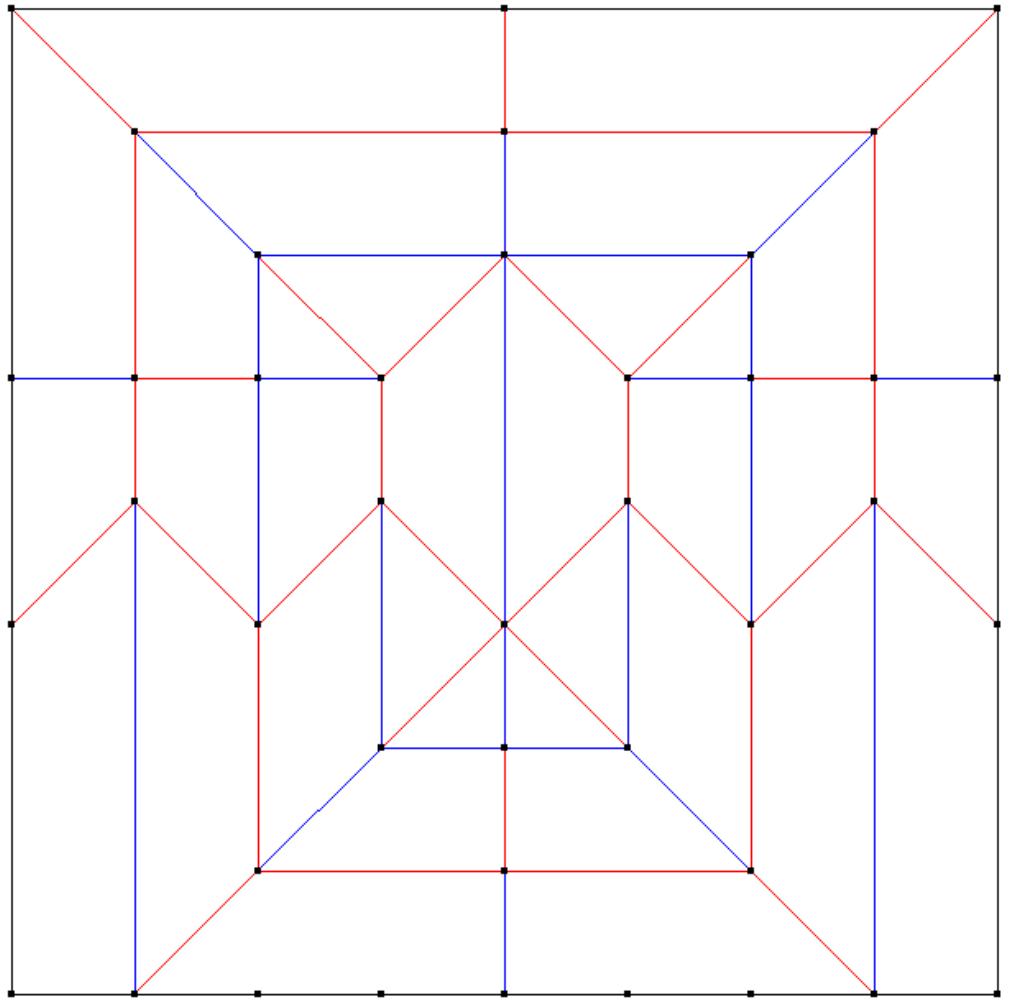


**Crease patterns (CP)**



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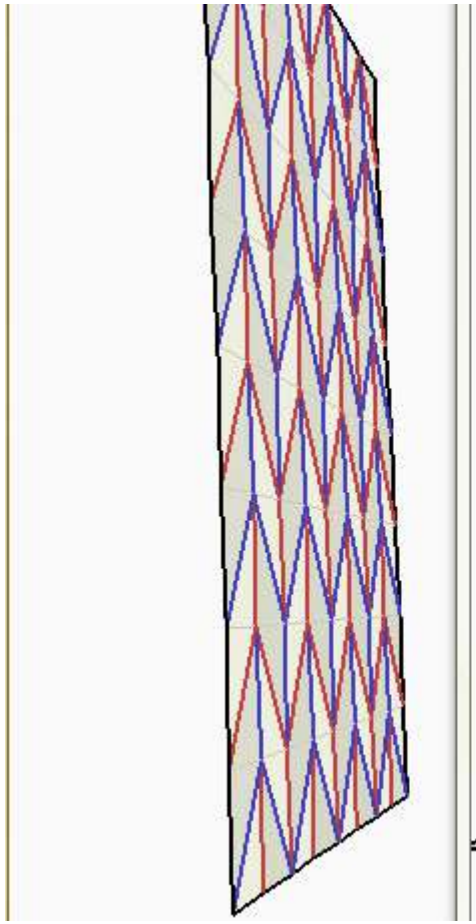
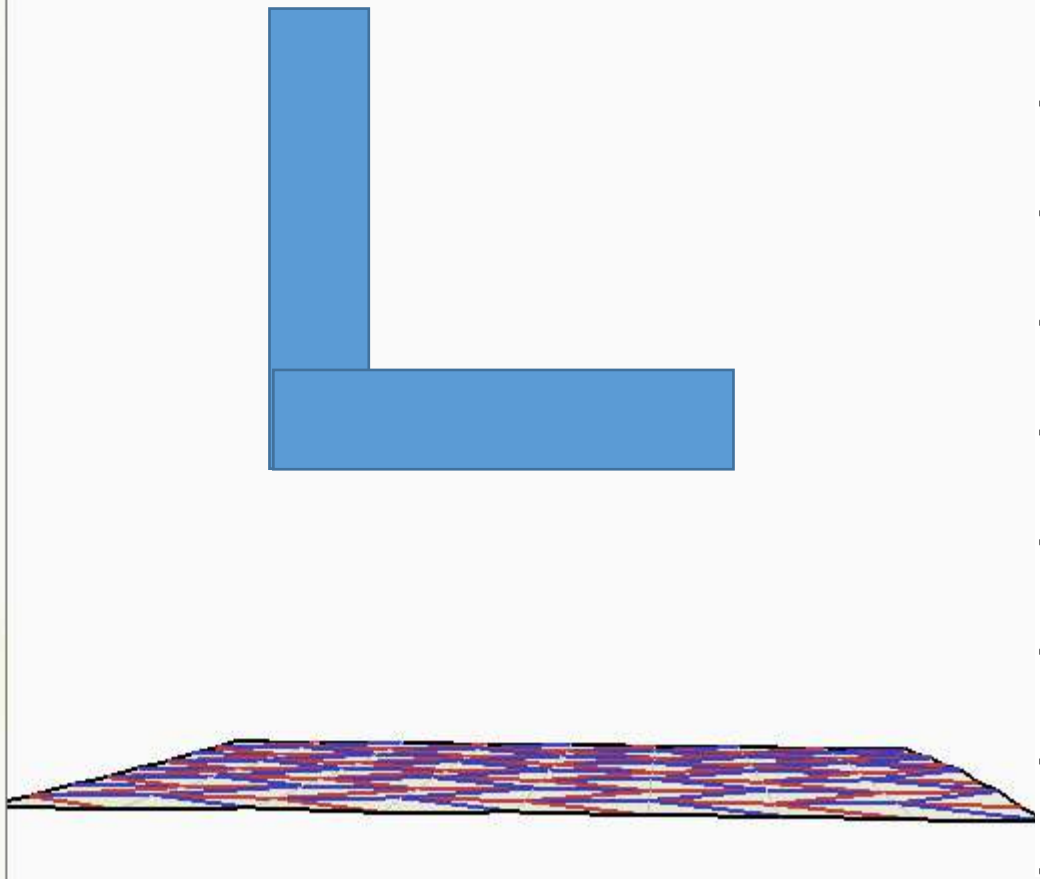
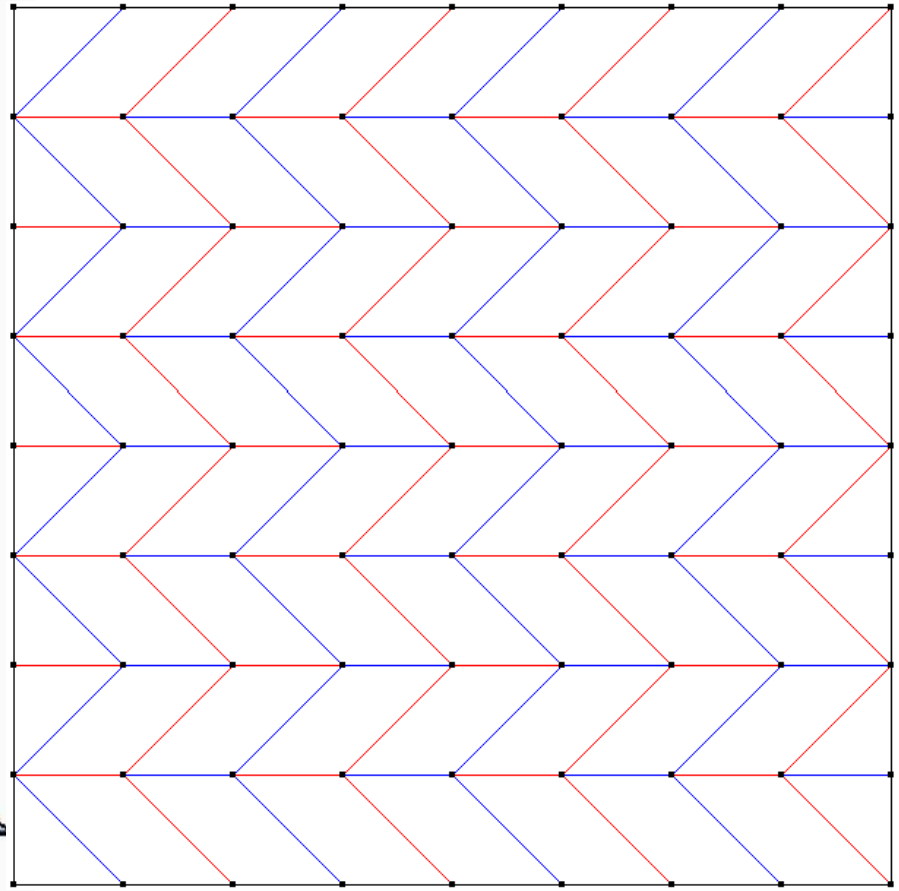


CAD



Crease patterns (CP)

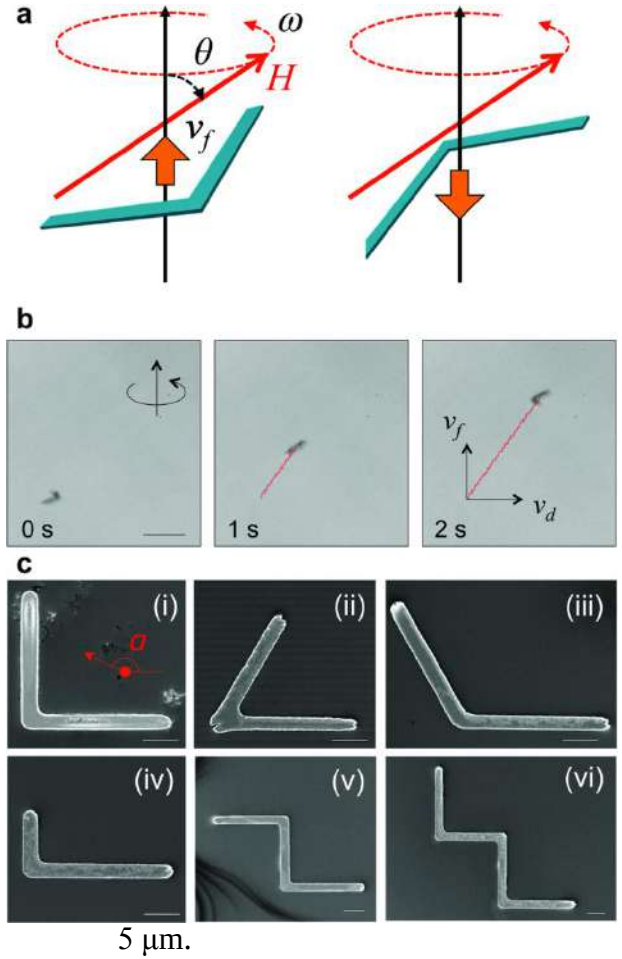


# Controlled Propulsion Properties

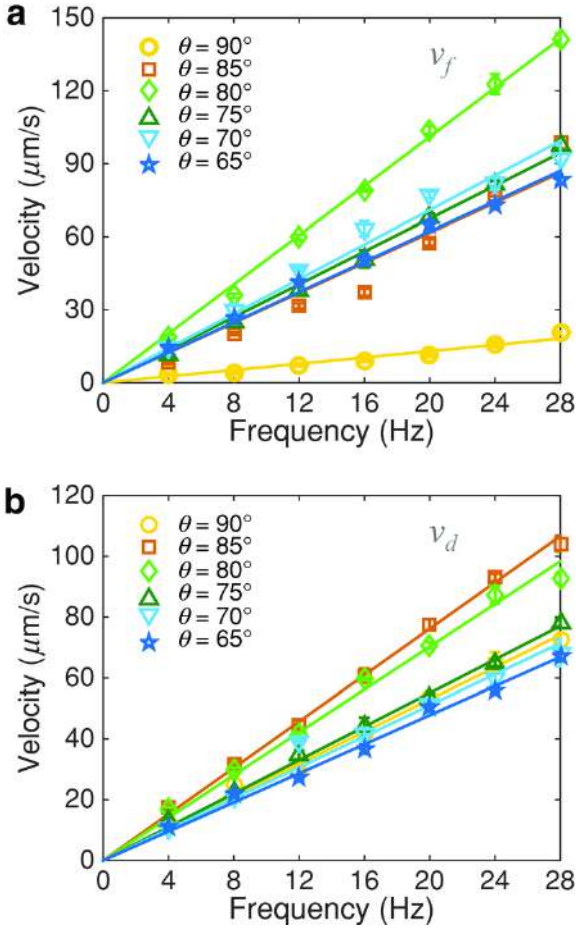
Controlled Propulsion of Two-Dimensional Microswimmers in a Precessing Magnetic Field

Soichiro Tottori, Bradley J. Nelson

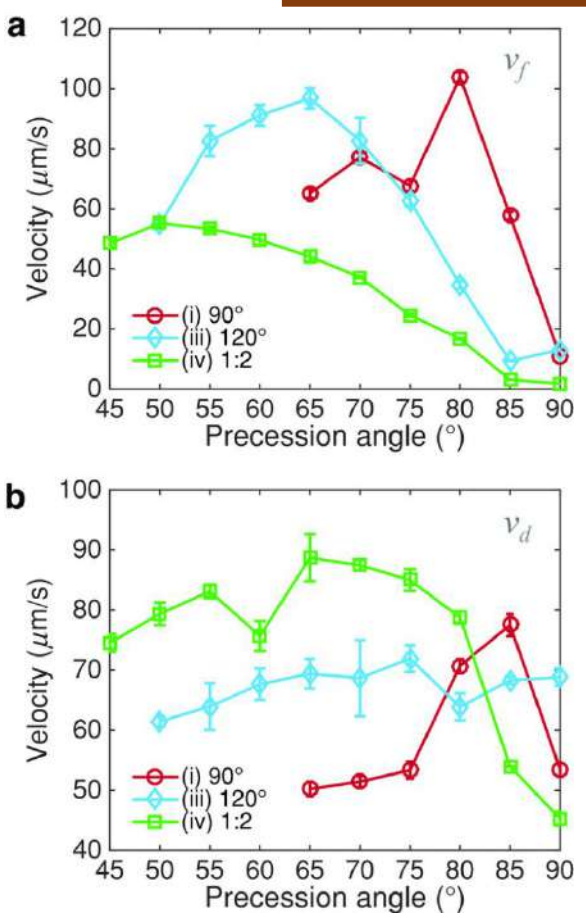
First published: 10 May 2018 | https://doi.org/10.1002/smll.201800722



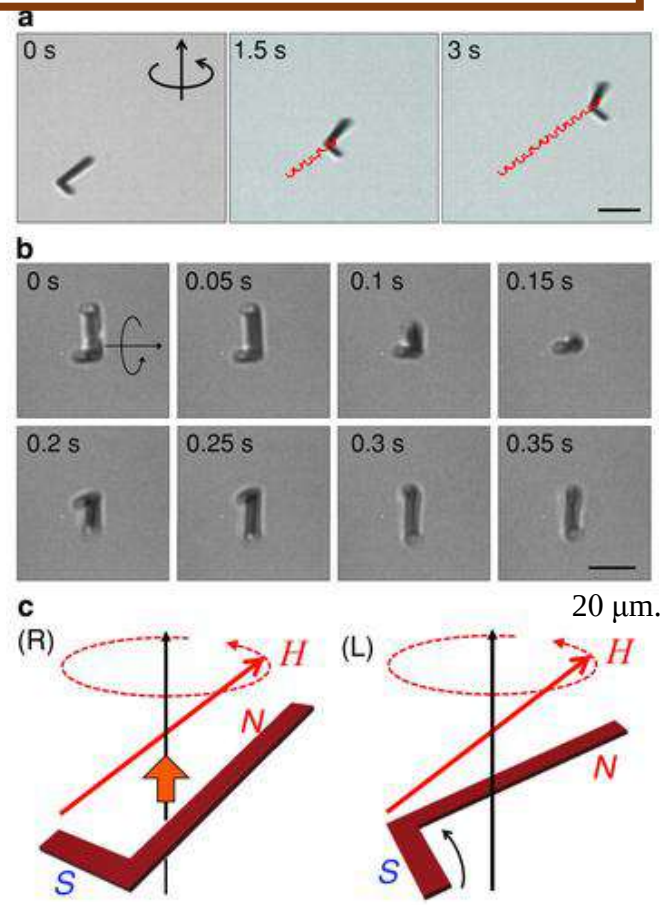

5 μm.




fixed field strength (5 mT)




fixed - frequency (20 Hz)

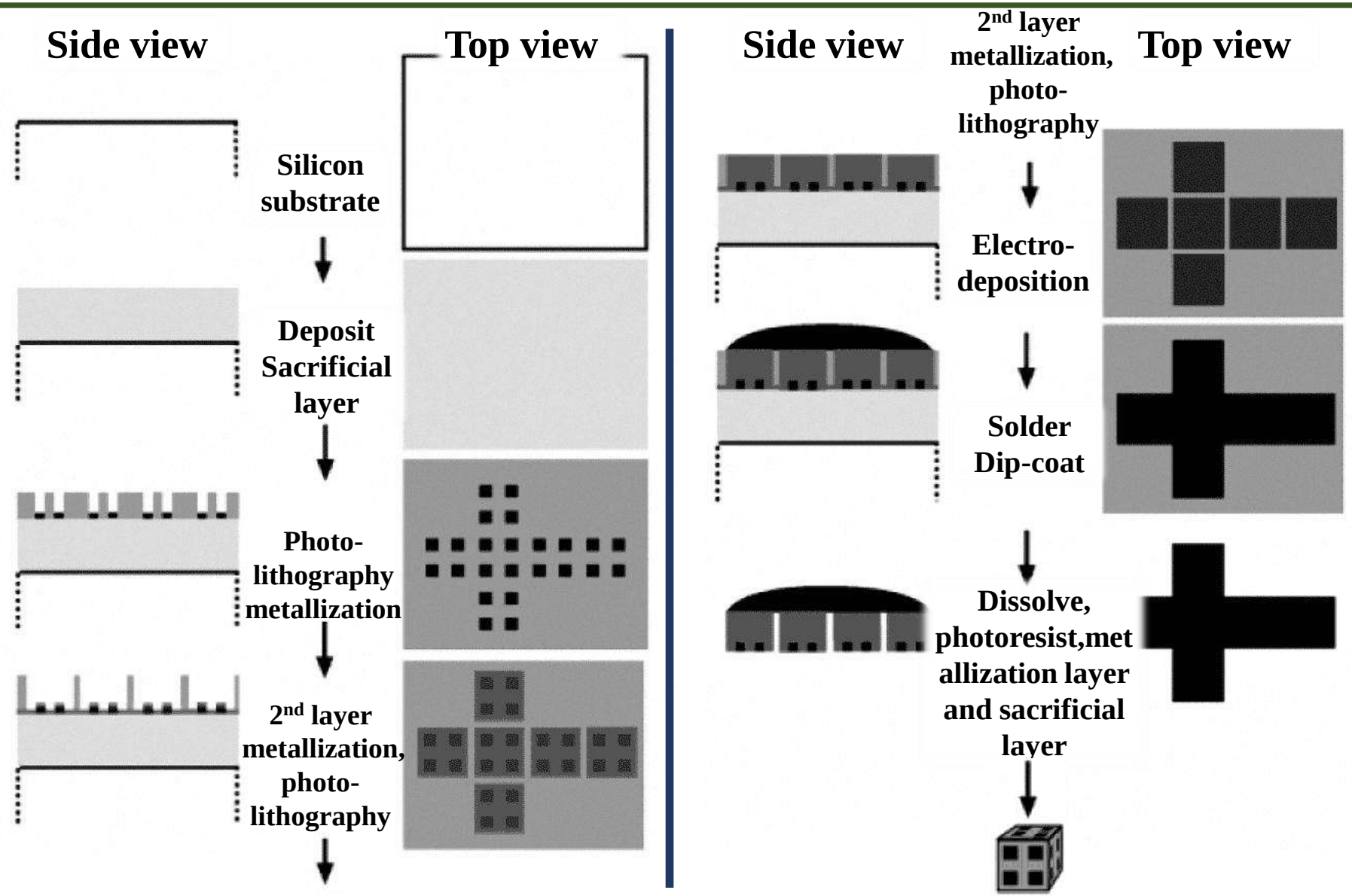



20 μm.

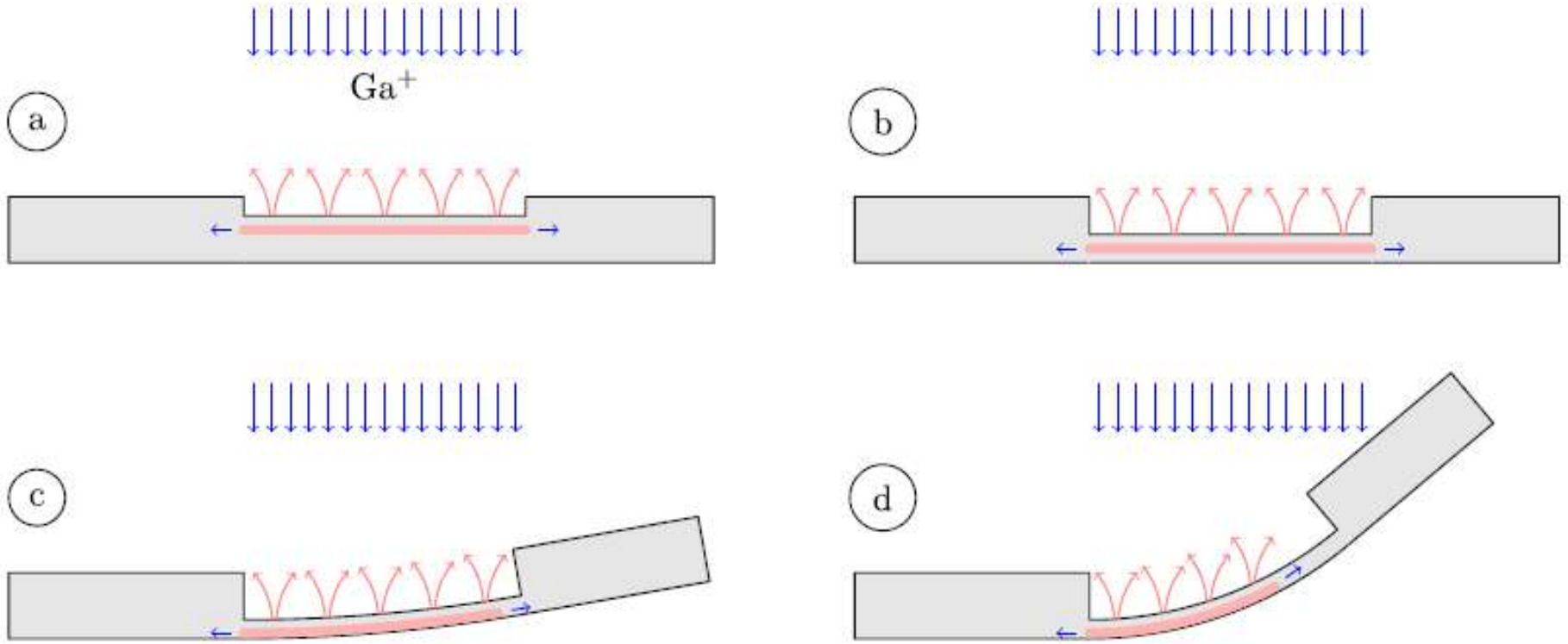


Soichiro, T. and N.B. J., *Controlled Propulsion of Two - Dimensional Microswimmers in a Precessing Magnetic Field. Small. 0(0): p. 1800722.*

# Fabrication Methods ②



# Fabrication Methods ①




(Color online) Theory of the origami process:
(a) The first step of this process corresponds to a sputtering with gallium ions of the interesting area.
(b) When the bulk of the link between the membrane and the panel to fold corresponds to a specific thickness, a bimetallic strip appears.
(c) The effect of sputtering produces a differential dilatation coefficient into the upper part in white and the down part in red of the link.
(d) The panel self-fold from 0 to 90.

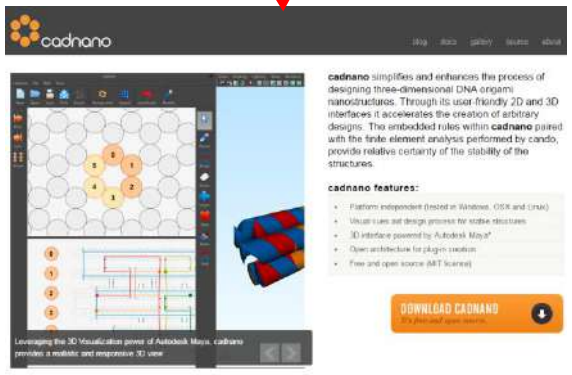


Rauch, J.-Y., et al., *Smallest microhouse in the world, assembled on the facet of an optical fiber by origami and welded in the μRobotex nanofactory. Journal of Vacuum Science & Technology A, 2018.* ***36(4)****.*

# Fabrication Methods ③: DNA Origami

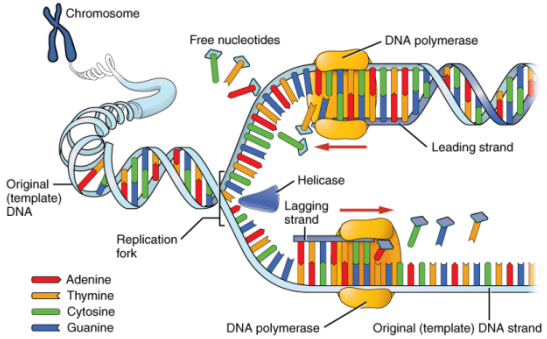
Design (caDNAno®) Verify (Cando®) Synthesis (PCR) View Results

(caDNAno®)



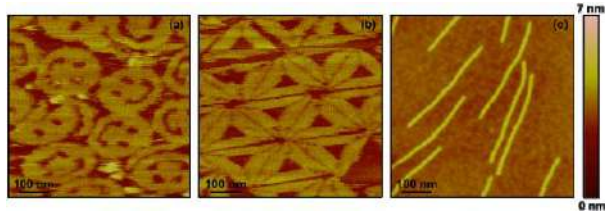

Online Simulation Website for DNA Origami

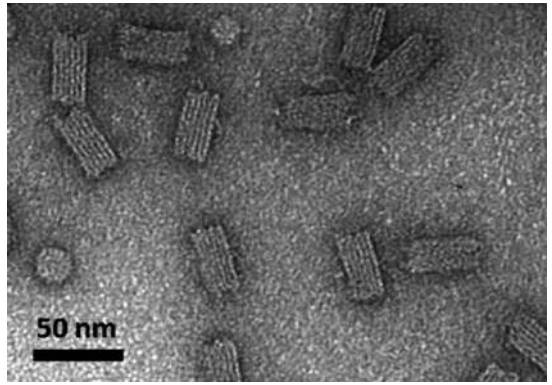
CanDo




PCR(Polymerase Chain Reaction) Annealing

AFM TEM



# Future Work

1. Analysis its material properties.

2. Study the swimming swimming performance.

3. Design more shape and functions.



Gracias, D.H., et al., *Fabrication of Micrometer - Scale, Patterned Polyhedra by Self - Assembly. Advanced Materials, 2010. 14(3): p. 235-238.*

# Thanks for listening !

# Q&A