# FleXARs - Everything-free surface

## Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications

**Presented by**

**Dr. Nithi Atthi**

**(Research Team Leader)**

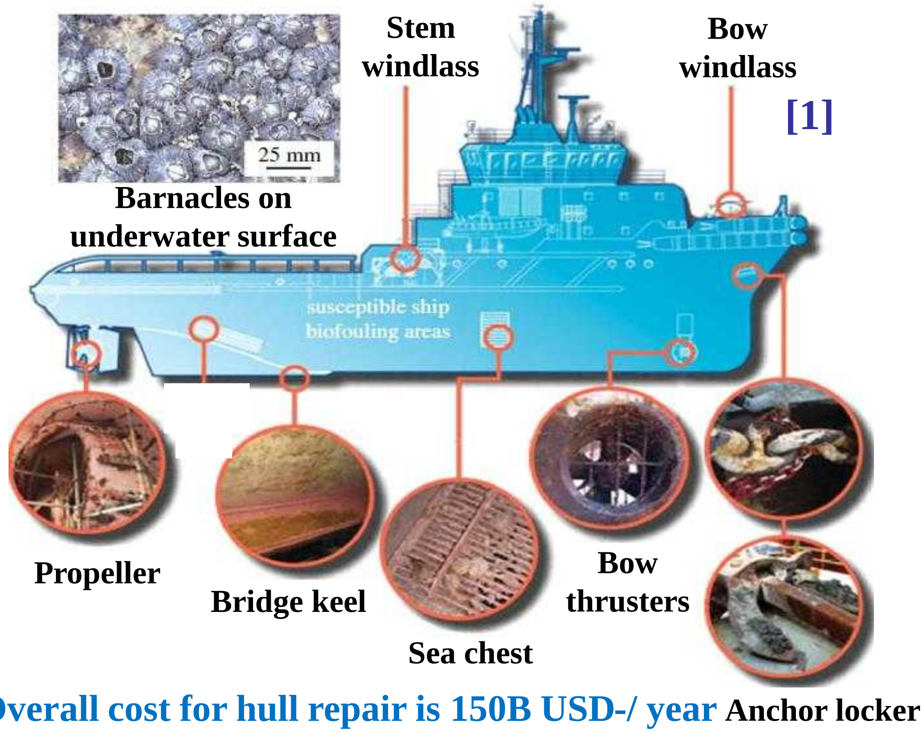
**Surface and Microfluidic Device Innovation Research Team (SMDRT)**

**Thai Microelectronics Center (TMEC)**

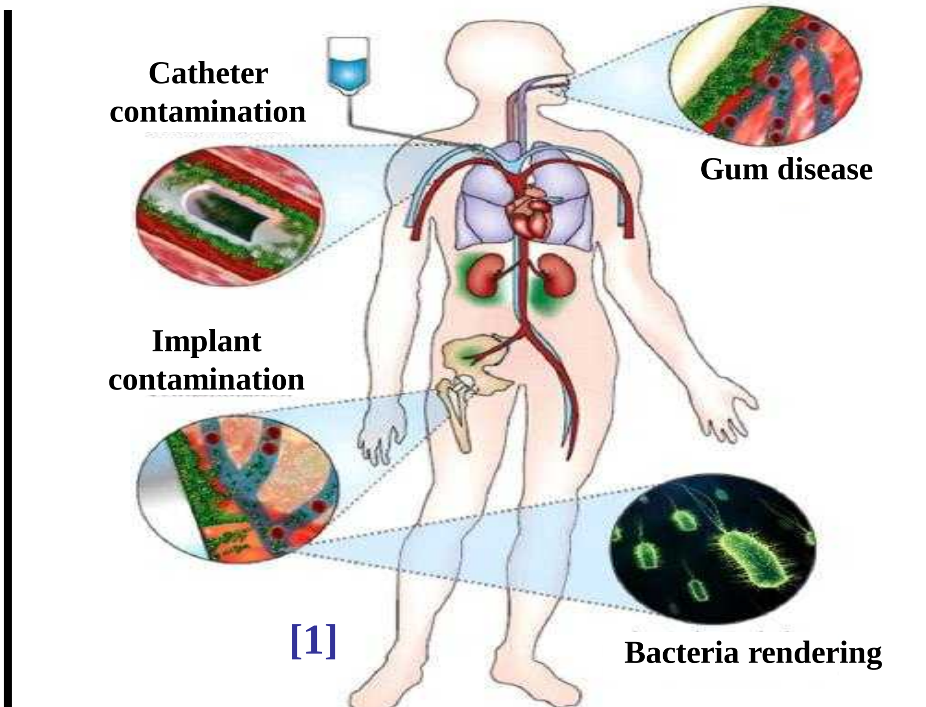
# Biofouling

## Marine field
(Barnacle attachment on ship)

## Medical field
(Body susceptible to infectious biofilms)




Overall cost for hull repair is 150B USD-/ year




More than 5,000 annual deaths owing to infections in US.

**Biofouling in marine environment**

- Ship hull drag, fuel consumption
- $CO_2$ emission, invasive species
- Corrosion, High maintenance cost

**Biofouling in surgical/medical site**

- Bacterial infections
- Catheter and implant contamination
- Health risks and financial losses


[1] G. D. Bixler and B. Bhushan, *Phil. Trans. R. Soc. A*, 370, pp. 2381-2417 (2012).

# Biofouling on ship hull and pier

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# Biocidal paint (TBT, Cu)




**Antifouling biocidal paint**

- **Most effective technology**
- **High toxic and non-environmental friendly**
- **Banned → Required an alternative technologies**

**TBT: Tributyl Tin paint**
**Cu: Copper-based paint**

[1] https://www.turbosquid.com/3d-models/3d-container-ship-model-1159396

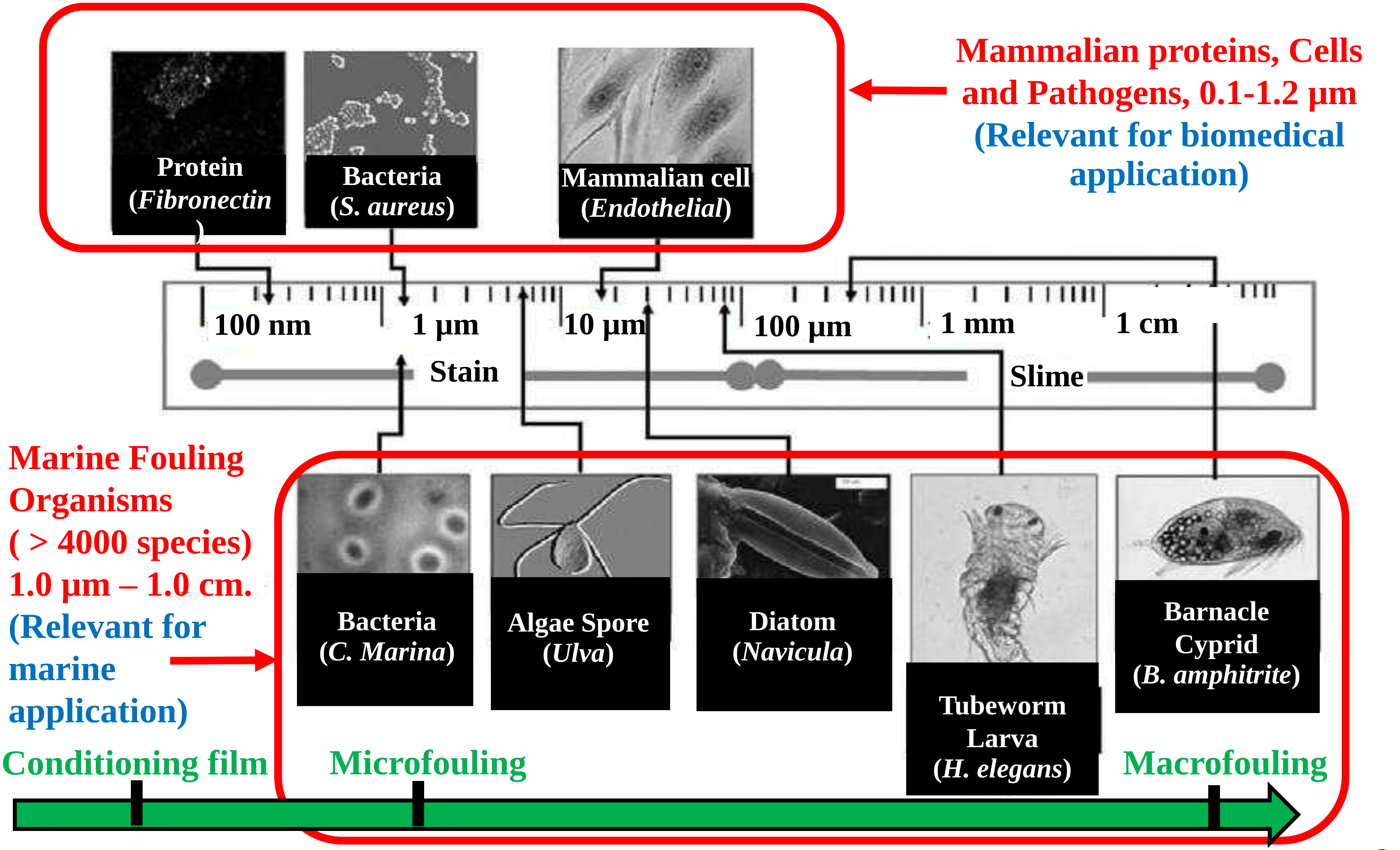
# Inflection in surgery room

<u>Current antibacterial technology</u>

- Cleanroom environment (low humidity)
- UV light for killing a bacteria
- Ag, $TiO_2$ nanoparticles (NPs) wall and ceiling

[1] https://health.clevelandclinic.org/avoid-dangerous-infections-heart-surgery/

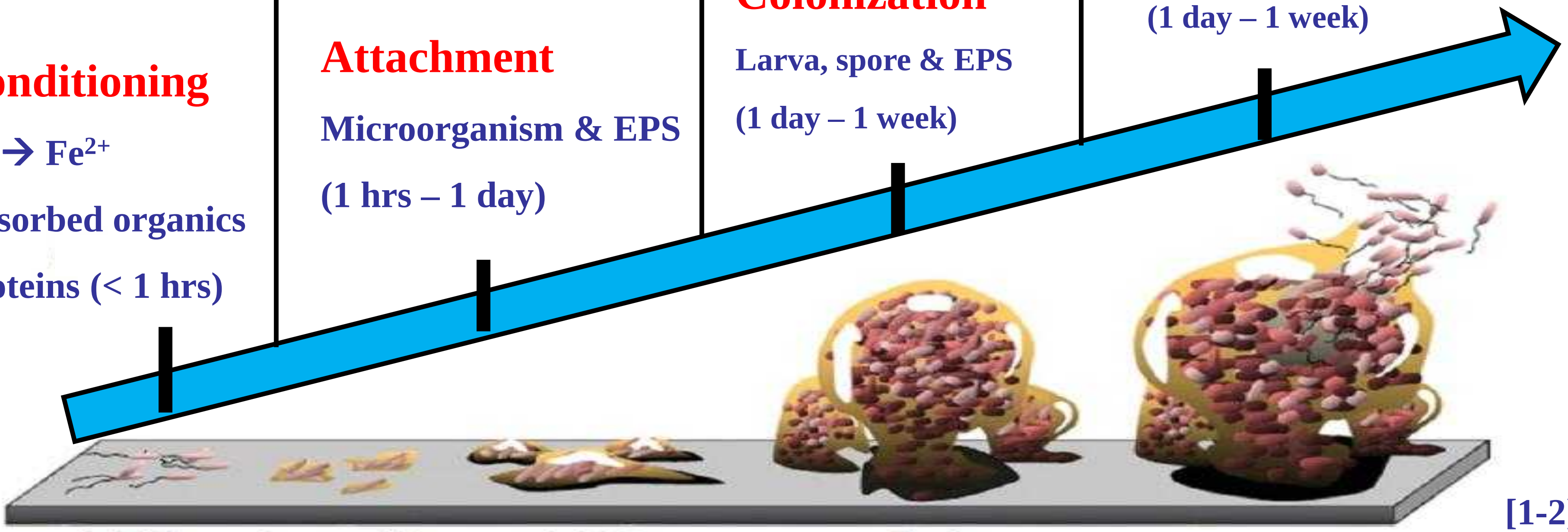
# Hierarchy of fouling organisms




[1] C. M. Magin, S. P. Cooper and A. B. Brennan, *Mater. Today*, 13 (4), pp. 36-44 (2010).

# Fouling mechanism (Biofilm formation)

**(Five-stage colonization)**



**Conditioning**

$O_2 \rightarrow Fe^{2+}$

Adsorbed organics

Proteins (< 1 hrs)

**Attachment**

Microorganism & EPS

(1 hrs – 1 day)

**Colonization**

Larva, spore & EPS

(1 day – 1 week)

**Growth**

Larva, spore & EPS

(1 day – 1 week)

(1) Initial attachment (2) Irreversible attachment (3) Initial growth (4) Final growth (5)Dispersion

[1-2]

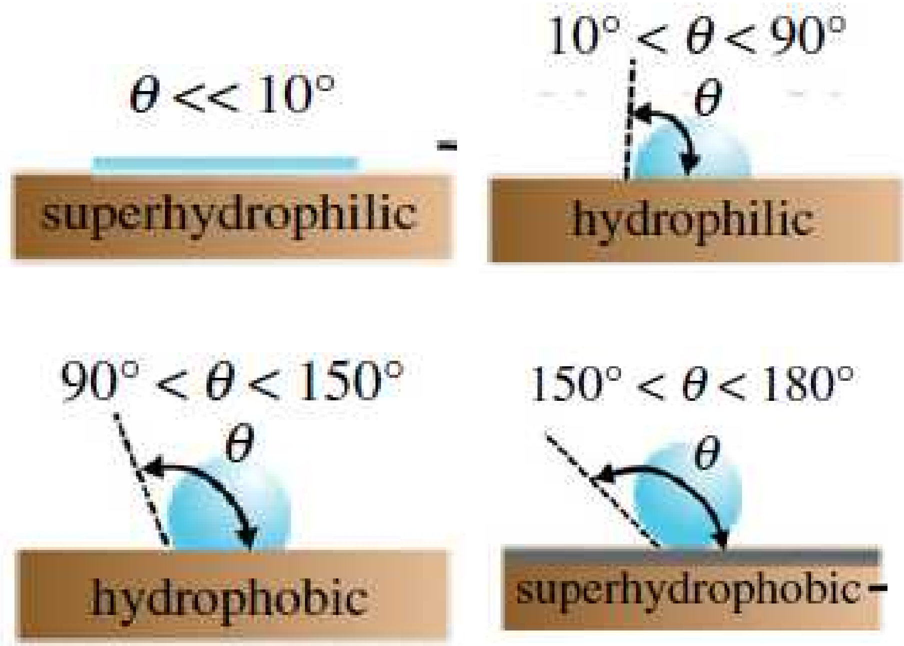
- **Surface wettability influences fouler colonization**
- **Superhydrophobic is required to prevent an initial attachment**

[1] G. D. Bixler and B. Bhushan, *Phil. Trans. R. Soc. A*, 370, pp. 2381-2417 (2018).
[2] J. A. Callow and M. E. Callow, *Nature Communications*, 2, pp. 1-10 (2011).

EPS: Extracellular Polymeric substance

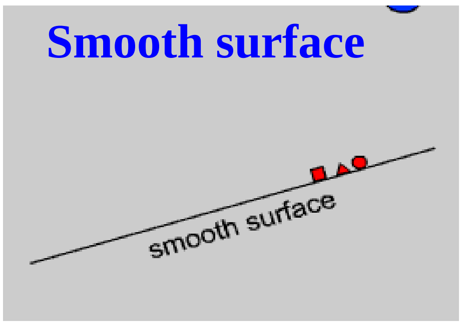
# Antifouling mechanism

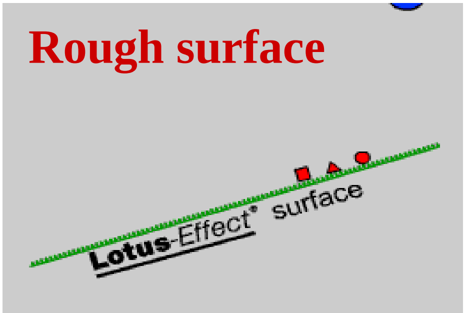
**Superhydrophobic surface**
**(Water repellent surface)**




**Superhydrophobic surface**

**Low surface energy materials ($\gamma_s$)** + **Rough surface (Micro-patterns)**




- **Superhydrophobic (θ > 150°).**
- **Lotus effects that makes a self-cleaning mechanism**
- **Antifouling surface**

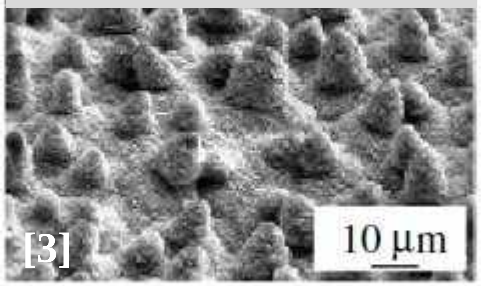

[1] G. D. Bixler and B. Bhushan, *Phil. Trans. R. Soc. A*, 370, pp. 2381-2417 (2018).
[2] J. A. Callow and M. E. Callow, *Nature Communications*, 2, pp. 1-10 (2011).


θ: Water contact angle (WCA)

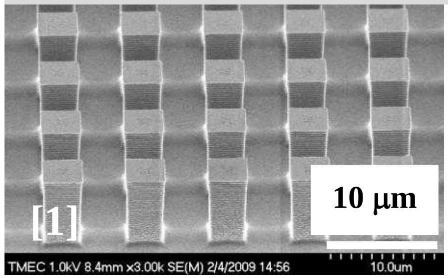
# Biomimetic superhydrophobic surface

## Biomimetic micro-patterns

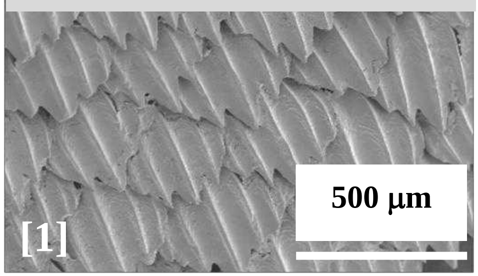
**Lotus leaf**



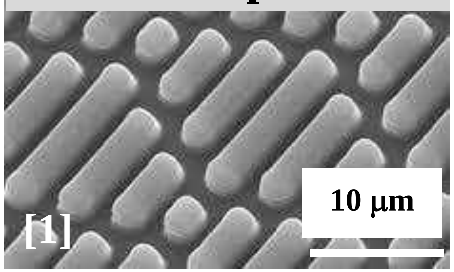

**Pillar pattern**



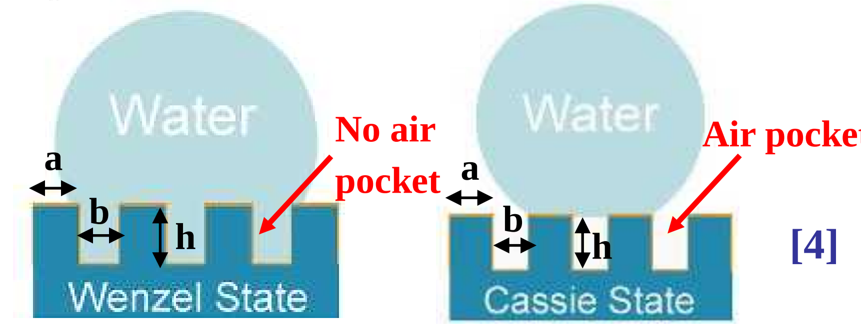

**Shark skin**




**Sharklet pattern**




## Effects of surface roughness




**Wenzel regime (no air pocket)**

$$cos\theta = R_f cos\theta_f; R_f = \frac{A_{SL}}{A_F} \quad (1)$$

**Cassie-Baxter regime (air pocket)**

$$cos\theta = R_f f_{SL} cos\theta_f - 1 + f_{SL} \quad (2)$$

$R_f$: roughness factor
$\theta_f$: contact angle on solid surface
$\theta$: WCA, fSL: fractional solid − liquid contact area

**To obtain antifouling surface (superhydrophobicity; θ > 150°)**

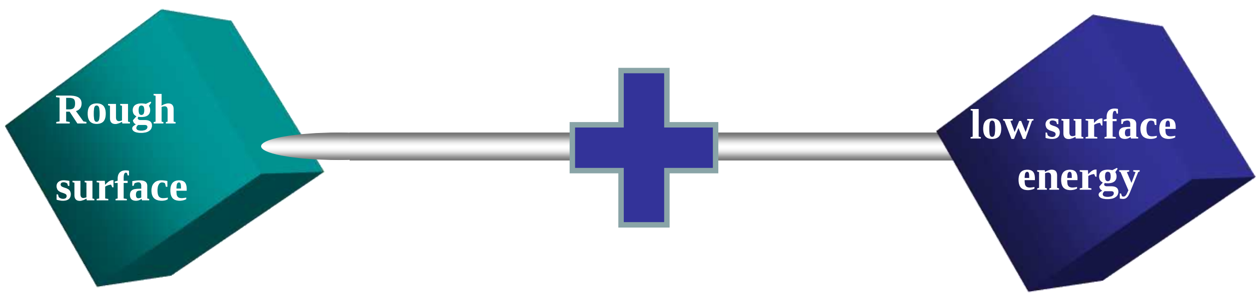
- **Low $\gamma_s$ material (Polydimethylsiloxane, PDMS → $\gamma_s$ : 12.3 mJ/m$^2$)**
- **Highest $R_f$ → Max. packing factor (P = a/b) + Max. aspect ratio (A.R. = h/a)**

*a*: pattern size, *b*: space between pattern, *h*: pattern height, *P*: Packing factor, *A.R.*: Aspect ratio


[1] G. D. Bixler and B. Bhushan, *Phil. Trans. R. Soc. A*, 370, pp. 2381-2417 (2018).
[3] C. Neinhuis and W. Barthlott, *Ann. Botany*, 79, pp. 667-677 (1997). [4] J. Genzer and K. Efimenko, *Biofouling*, 22 (5), pp. 339-360 (2006).

# Artifacts hydrophobic surface

## Techniques to make Superhydrophobic surfaces




**Method to make a rough surface:**

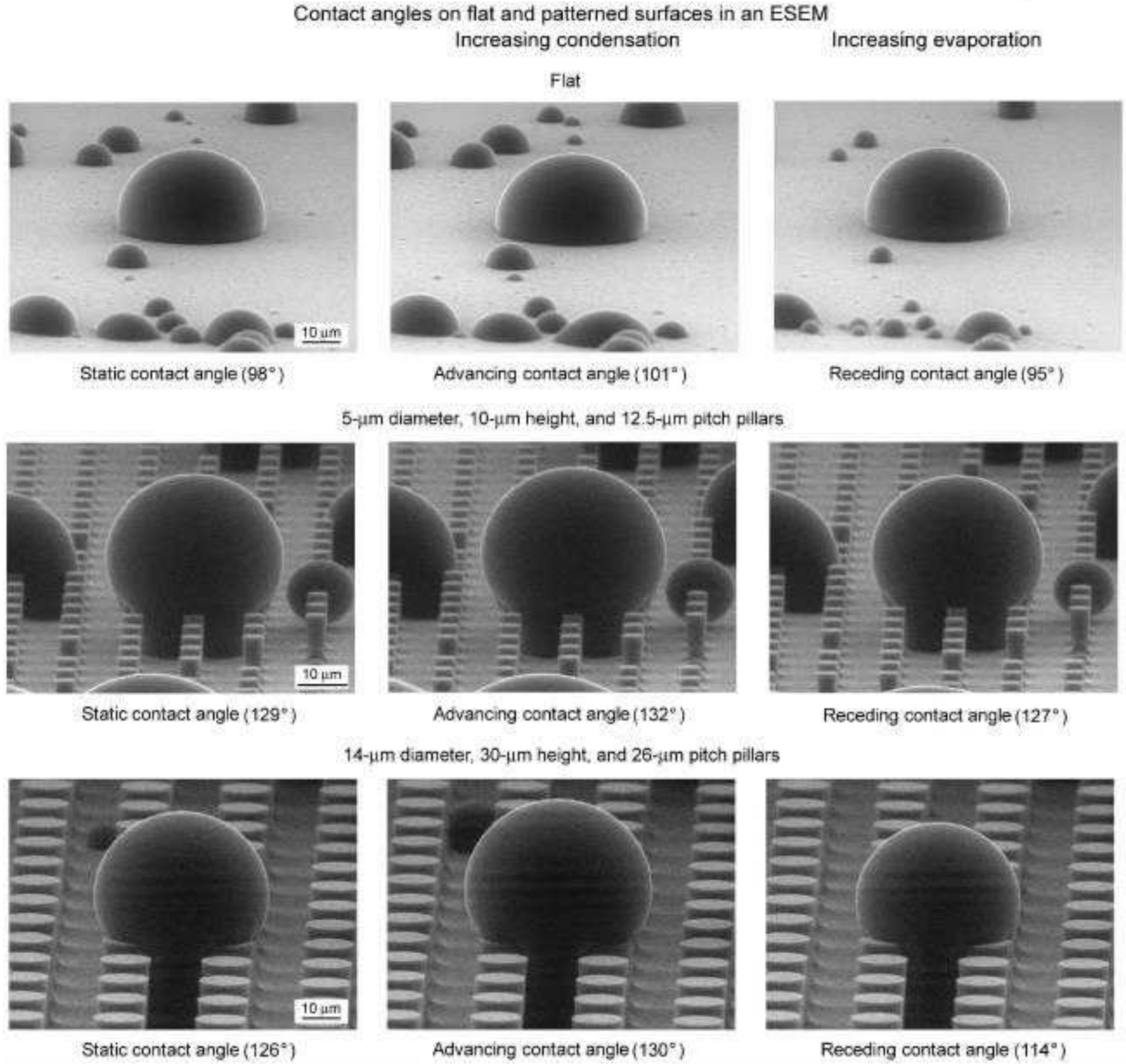
- ❖ **Lithography and etching**
- ❖ **Electrochemical reaction and deposition**
- ❖ **Mechanical abrasion**
- ❖ **Crystallization control**

**Low surface energy materials:**

- ➢ **Fluorocarbons: Teflon, PFOS, etc.**
- ➢ **Silicones: TPFS, PDMS , SFS**
- ➢ **Organic materials: PE, PS, polyamide, etc.**
- ➢ **Inorganic materials: ZnO, $TiO_2$**

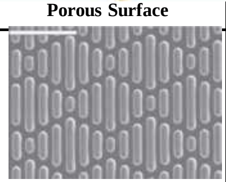
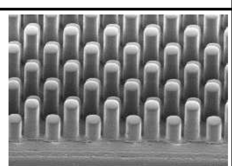
**TPFS: trichloro(1H,1H, 2H,2H-perfluorooctyl)silane**
**PDMS: Polydimethylsiloxane**
**SFS: Semiflourinate silane**

# ESEM images of water droplet on pattern




**ESEM: Environmental Scanning Electron Microscope**

# Current antifouling technologies

| Fouling release/ Antifouling Technologies | | Antifouling (Marine app.) | Anti Bacterial (Medical app.) | Environmental/ hospital friendly | Transparency | Large-area application | Cost |
|---|---|---|---|---|---|---|---|
| **Water jet cleaning** https://www.kamat.de/en |  | ✓ | ✗ | ✗ | ✗ | ✓ | $$ <br> $ 33/m$^{2}$/5 years |
| **Biocide paint (TBT, Cu)** www.imo.org/en |  | ✓ | ✗ | ✗ | ✗ | ✓ | $$ <br> $ 67/m$^{2}$ |
| **Ultrasonic wave** http://www.ultrasonic-antifouling.com |   | ✓ | ✗ | ✗ | ✗ | ✓ | $$$$ <br> $ 267/m$^{2}$ |
| **SLIPS®** https://wyss.harvard.edu |  Slippery Liquid Infused Porous Surface | ✗ | ✓ | ✓ | ✓ | ✓ | $$$ <br> > $ 200/m$^{2}$ |
| **Sharklet®** https://www.sharklet.com |  | ✗ | ✓ | ✓ | ✓ | ✓ | $$$ <br> > $ 200/m$^{2}$ |
| **FleXARs** |  | ✓ | ✓ | ✓ | ✓ | ✓ | $ <br> $ 20/m$^{2}$ |

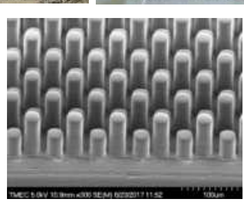
# Milestone of FleXARs project

TMEC Thai Microelectronics Center

## 2008-2014

- Superhydrophobic surface on silicon and glass substrate
- Ultra-hydrophobic surface
- Ultra-oleophobic surface
- Si mold fabrication
- Soft lithography process of PDMS

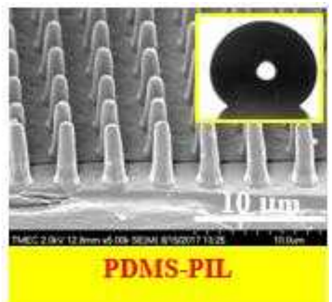




PDMS: Polydimethylsiloxane
PU: Polyurethane

## 2015

- PTT project Phase#1 (Micro-patterns for barnacle antifouling)

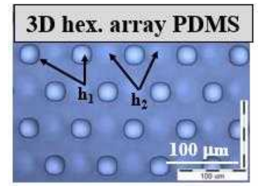



## 2016

- PTT project phase#2 (micro-scale patterned on PDMS and PU)
- Black resin as 2nd mold for various resin casting
- Field-test in seawater environment
- 3D microstructure

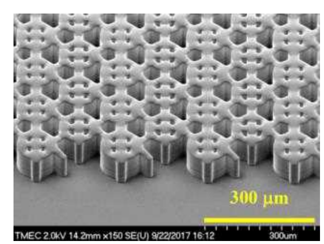
## 2017

- Antibacterial/ algae antifouling field test




## 2018

- Robust micro-structure

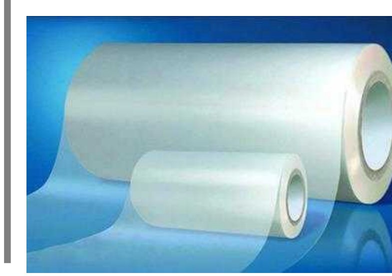



## 2019-2022

- Composite PDMS/PU
- Superoleophobic surface
- Pattern size scaling
- Large-area patterning (R2R NIL production)
- Field-test in marine and medical applications

## 2023-2024

- Spin-off (Commercialization)



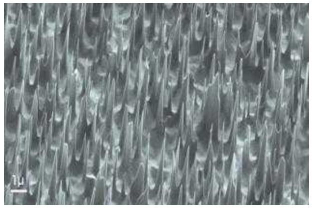
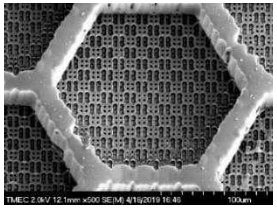
# Nanoparticles (NPs) Vs FleXARs

| Properties | Nanoparticles (NPs) | | | | FleXARs |
|---|---|---|---|---|---|
| Materials | Ag | $TiO_2$ | Ag+$TiO_2$ | ZnO | Composite PDMS-PU |
| Objectives/ applications | Antibacterial for Medical, Food, and Textile applications | | | | Antifouling for BOTH marine and medical applications |
| Core Technology | Ag, Zn: Adhere to cell wall → lead to cell death<br>Ti: Photocatalytic redox effect (Need UV, light) | | | | Robust microstructure on low surface energy materials |
| Fabrication method | Milling, Laser ablation, Etching, Pyrolysis, Sol-gel, Precipitation, Thermal decomposition, Green synthesis, Vapor deposition | | | | Soft lithography<br>(+Stitching casting)<br>** R2R NIL |
| Action | Active action<br>(Biocide, Bacteria killer) | | | | Passive action<br>(Reduce protein adsorption) |
| Mechanism | (1) Oxidative stress induction<br>(2) Metal ion release<br>(3) Non-oxidative mechanisms | | | | Superhydrophobic/Oleophobic with low surface energy materials |
| Advantages/ Differentiate | Low-cost and large-area applications<br>Applicable to various surfaces | | | | Robust pattern, durable in seawater, biocompatible |
| Disadvantages | Difficult to control the Dimension and size of NP<br>Too many toxic and hazardous by-products<br>Biocide and non-environmental friendly | | | | Small sample size (10x10 cm)<br>Low throughput<br>Degrade with high temperature |

[5] K.-S. Huang, *et. al.*, Int. J. Mol. Sci., 17, p. 1578 (2016).

R2R NIL: Roll-to-roll Nano Imprint Lithography

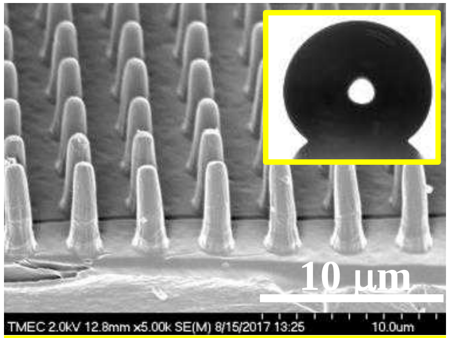
# FLEXPOL VS FleXARs

| Properties | FLEXPOL [1] | FleXARs |
|---|---|---|
| Materials | Polypropylene (PP) | Composite PDMS-PUA |
| Objectives | Antimicrobial adhesive film | Non-biocide antifouling film |
| Applications | Medical applications | Marine and medical applications |
| Core Technology | (SLIPS)<br>Essential oil emulsions embedded in PP micro-patterns matrix | (Superhydrophobic +oleophobic)<br>• Robust microstructure<br>• Low surface energy materials |
| Fabrication | Roll-to-roll Nano-imprint lithography (R2R-NIL) +R2R process for large-area patterning with low-cost manufacturing | |
| Robustness | Very weak  | Very robust  |
| Swelling in seawater | Yes | No |
| Biocompatible (Non-biocide) | Yes | |

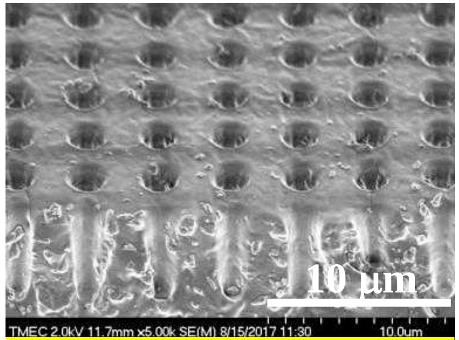
FLEXPOL: Antimicrobial FLEXibal POLymers for its use in hospital environments

NIL: Nano Imprint Lithography

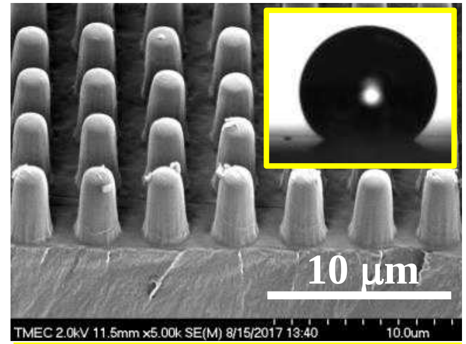
# Micro-patterning of Polymers



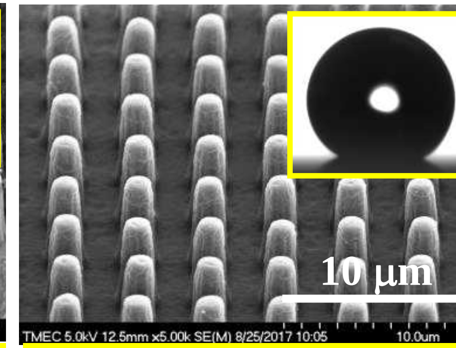

PDMS-PIL



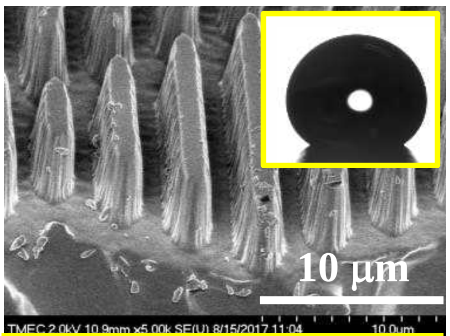

BLRE-PIL (mold)



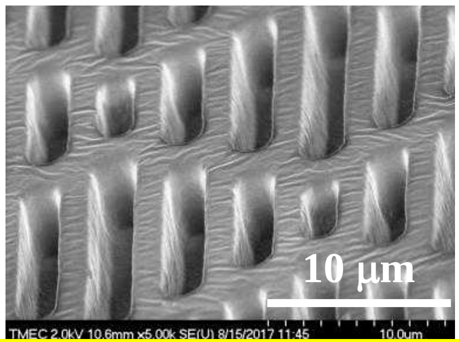

PUCC-PIL



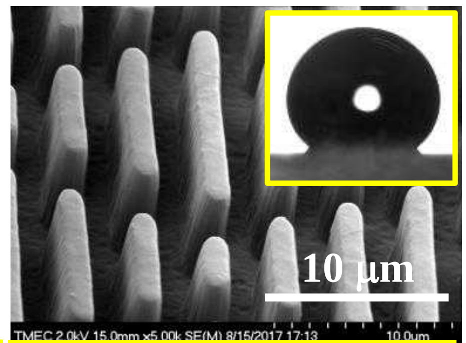

PUPX-PIL



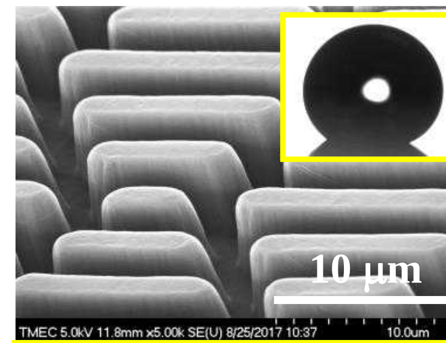

PDMS-SHK




BLRE-SHK (mold)



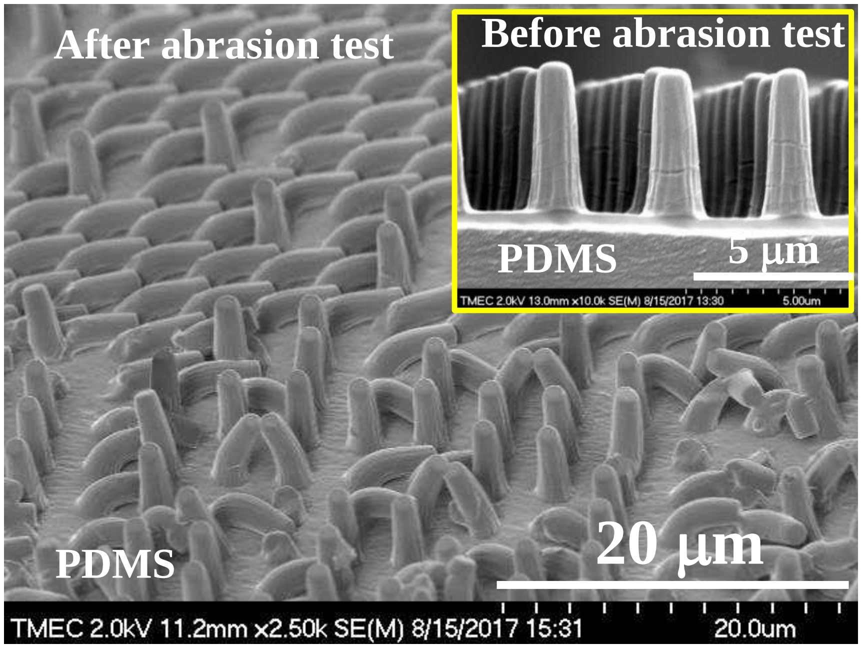

PUCC-SHK

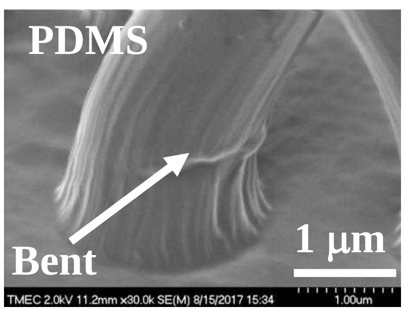


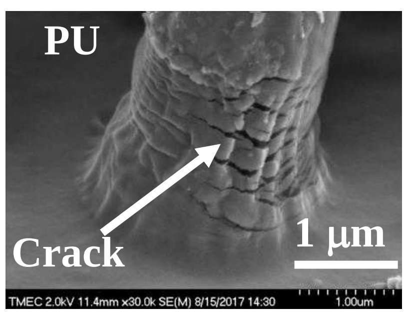

PUPX-SHK

| Materials | Mold castability/Pattern qualities | | | WCA [degree] using 3 µL of water droplet | | |
|---|---|---|---|---|---|---|
| | Mold releasable | Air bubbles | Pattern collapse after mold release | Flat (FLT) | Pillar (PIL) | Sharklet (SHK) |
| PDMS (Sylgard-184) | Yes | No | No | 117±1.3 | 143±1.4 | 146±2.7 |
| PU (Crystal clear 204) | Yes | No | No | 100±4.6 | 152±5.7 | 148±4.2 |
| PU (PX5210) | Yes | No | No | 104±3.3 | 145±1.7 | 148±7.4 |

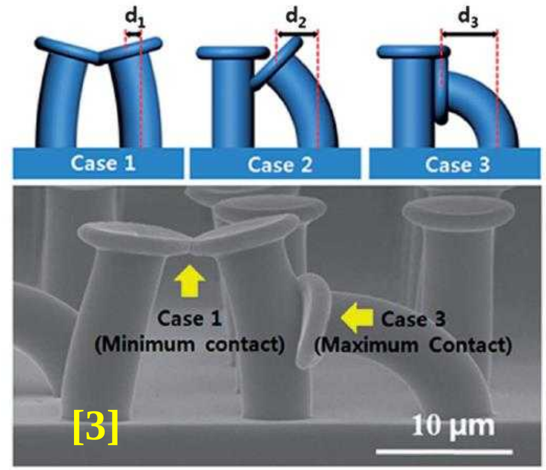
# Issue: Pattern collapse




## Pattern mating & clumping




$$F_{vdw} \; \alpha \; \frac{c}{b^3}$$

$$P \; \alpha \; \frac{V}{h^3}$$

*h*: pillar height, *V*: displacement of pillar, *c*: contact area
*b*: distance between pillar

- Soft and flexible (σ: 5.0 MPa, ε: 116%)
- Hardly replicate dense pattern (a < 400 nm) with high A.R. (> unity)
- Pattern mating and clumping ($P < F_{vdw}$)

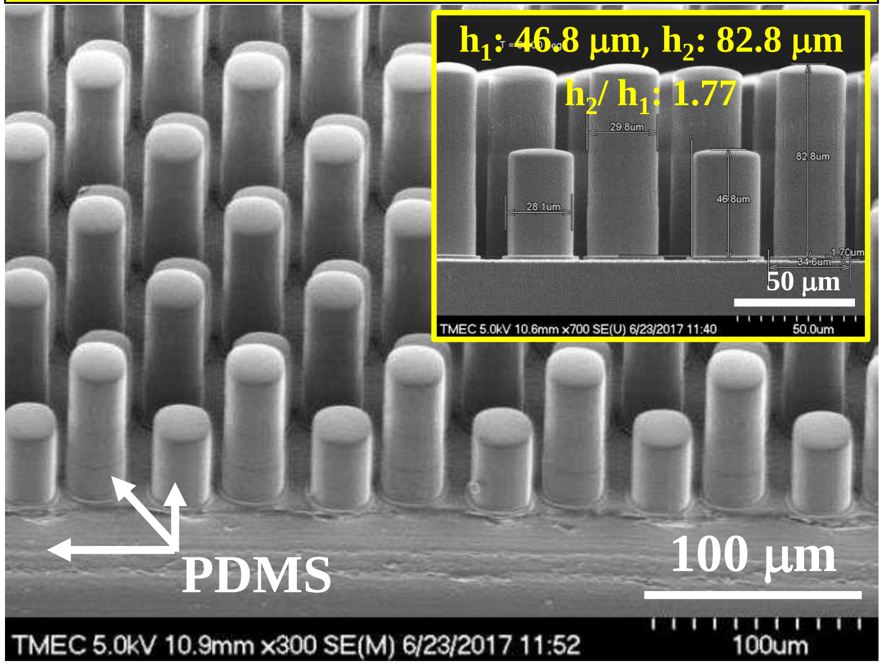
**3D microstructure with two-steps height is required to maximize displacement and minimize contact area to prevent pattern mating and pattern clumping ($P > F_{vdw}$)**

Note: Mating is pillar-to-pillar interactions (lateral collapse).
Clumping is pillar-to-substrate interactions (ground collapse).
Van der Waals force ($F_{vdw}$) is adhesion force between adjacent pillars.
Pulling force (P) is a recovery force.

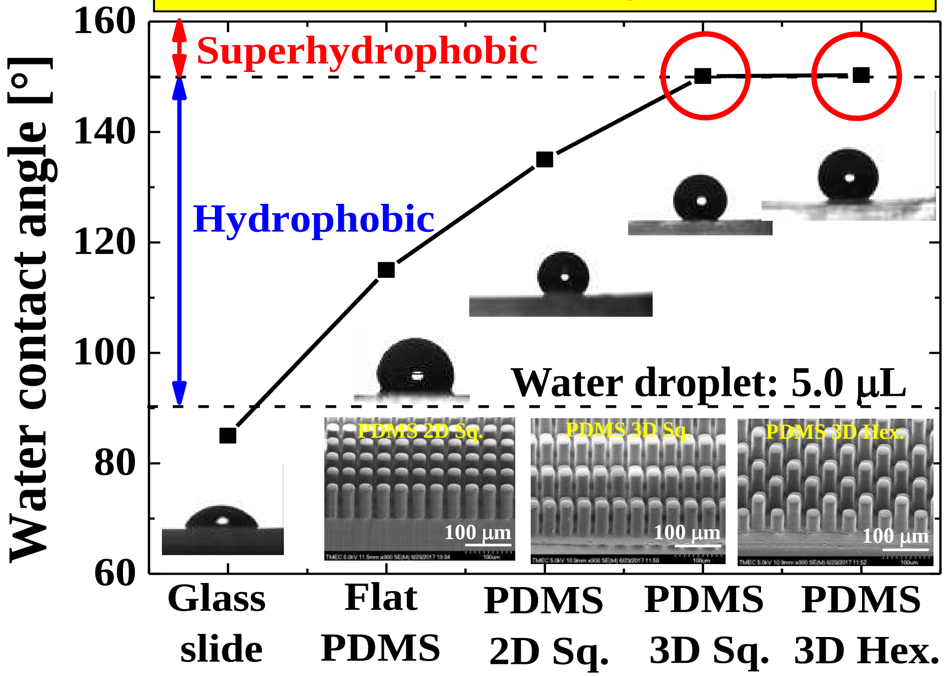

[1] N. Atthi, *et. al.*, *J. Nanosci. Nanotechnol.*, 11, pp. 1-7 (2011).
[2] N. Lu, *et. al.*, *Food control*, 68, pp. 344-351 (2016).
[3] W.-G. Bae, *et. al.*, *Soft Matter*, 9, pp. 1422-1427 (2013).

# 3D Microstructure, WCA and CAH

## SEM images of PDMS pillar




## Water contact angle (WCA)




- Pattern height is under-estimated due to loading effects during Bosch etching process.
- 3D Sq. and 3D Hex. → Superhydrophobicity.
- Lower CAH → Low adhesive contaminant and self-cleaning surface.

| Pillar type | WCA [°] | CAH [°] |
|---|---|---|
| 2D Sq. | 139.2±4.0 | 6.2 |
| 3D Sq. | 150.1±2.9 | 2.9 |
| 3D Hex. | 150.3±4.2 | 1.2 |

**3D microstructure increases surface roughness and decreases pattern displacement**

SEM: Scanning Electron Microscope

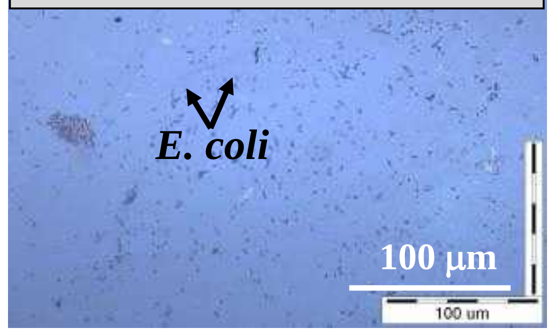
# Bacterial antifouling performance

## Bacteria adhesion assay

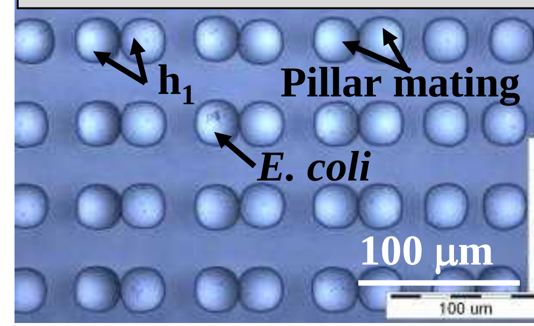
- UV sterilization (Prevent pattern collapsed)
- Immersed in Nutrient broth with inoculated *E. coli.* ATCC 8739 (~ $10^5$ CFU/mL) at 37°C/7 days
- Rinse with PBS
- Dyed with Gram's stain
- OM measurement

## *E.coli adhesion* on PDMS samples

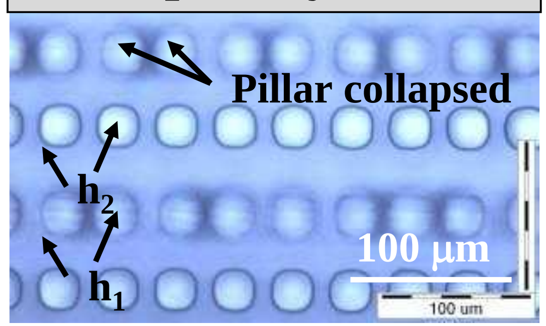
**Flat PDMS**



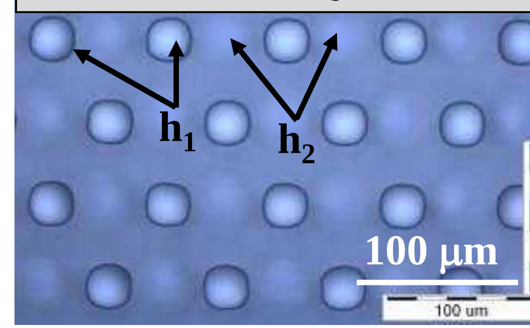

**2D sq. array PDMS**




**3D sq. array PDMS**



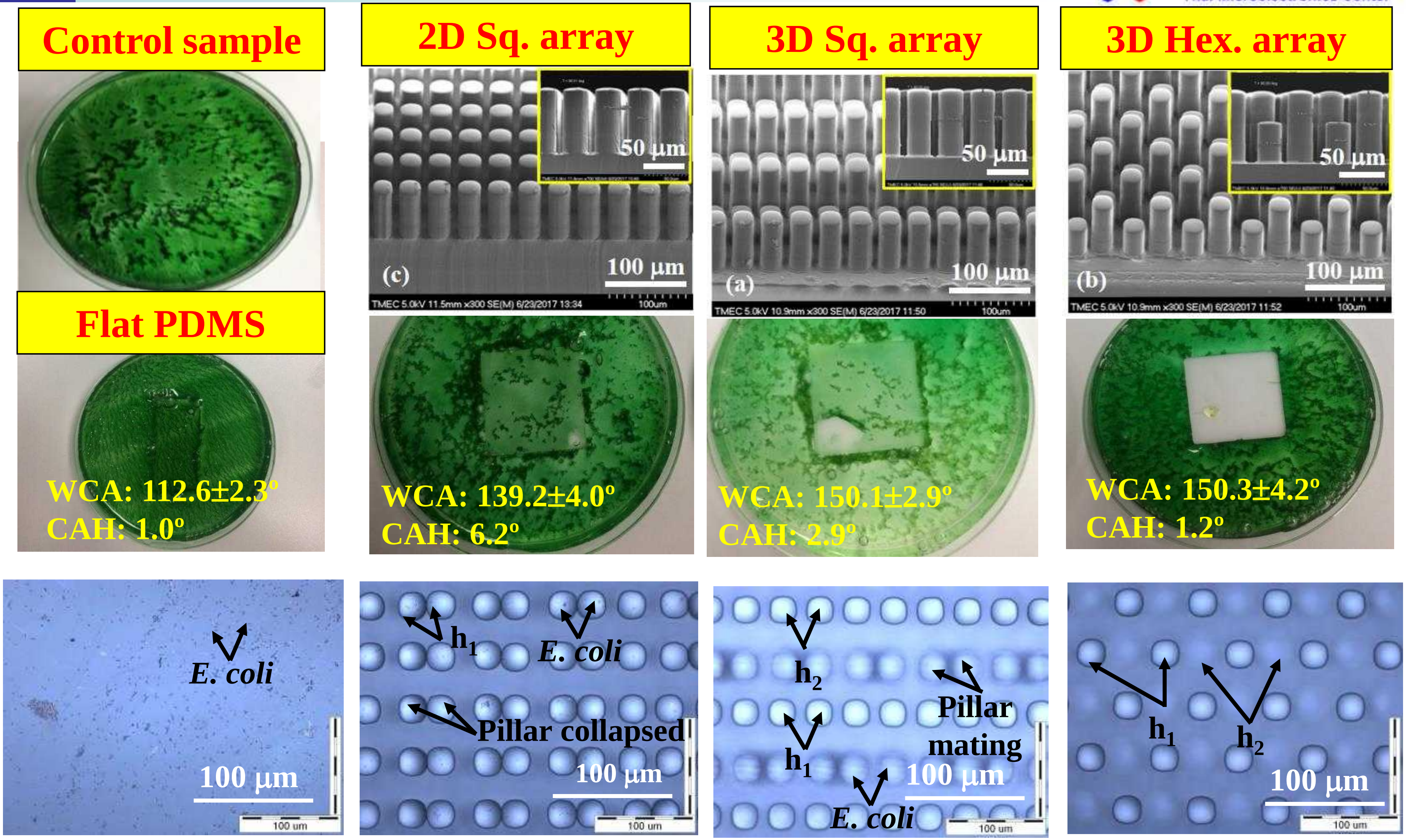

**3D hex. array PDMS**




- **UV sterilization is not degrade the PDMS pattern qualities compared to other sterilization methods (Autoclave, Ethanol, Ethylene).**
- **3D Hex. arrays prevent *E. coli* adhesion → No pattern mating and clumping.**

*E. coli.: Escherichia coli* PBS: Phosphate buffer saline OM: Optical microscope UV light: Ultraviolet light

# Algae antifouling and Antibacterial




**No pattern mating and clumping on 3D structure due to P > $F_{vdw}$**

# Summary

**Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications**

**(FleXARs Project)**

- **Environmental-friendly non-biocide antifouling technology**
- **Low surface energy materials and micro/nano-patterning**
- **Superhydrophobic and oleophobic surface (Water-and-oil repellent)**
- **Robust 3-D micro-structures**
- **Antibacterial and Algae antifouling**
- **Marine, medical and public transportation applications**

**TBD: Composite materials + Robust microstructure +Pattern scaling + Superoleophobic + large-area patterning**

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Integrate Ideas Into Reality

FlexARs
Antifouling Surface

NECTEC-ACE 2019 ANNUAL CONFERENCE & EXHIBITION


**Thai Microelectronics Center (TMEC)**
**51/4 Moo 1, Wang Takien District,**
**Amphur Muang, Chachoengsao,**
**Thailand 24000.**

**Tel: +66-38-857100-9**
**Fax: +66-38-857175**
**Email: info-tmec@nectec.or.th**
**Website: http://tmec.nectec.or.th**

Fraunhofer IPT
PERDO PETROMAT
金沢大学 KANAZAWA UNIVERSITY
Sirindhorn International Thai-German Graduate School of Engineering (TGGS)
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morphotonics
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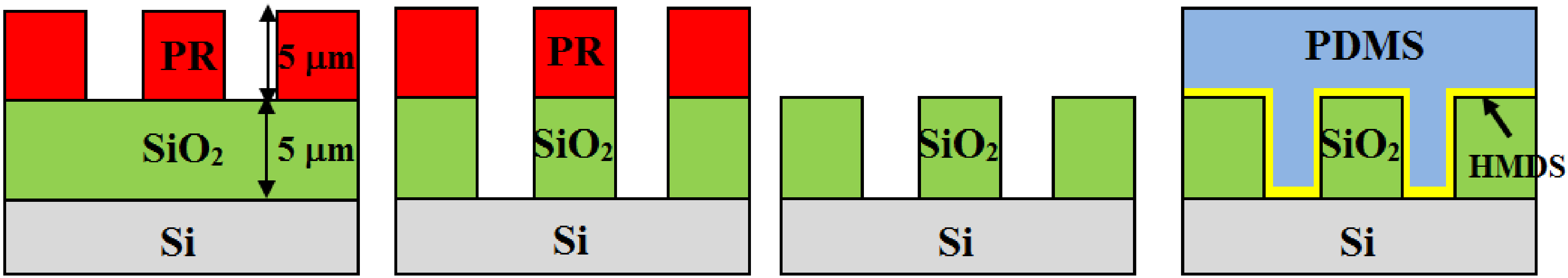
**FleXARs:** **Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications**

# Soft Lithography (Si mold & 2nd resin mold)



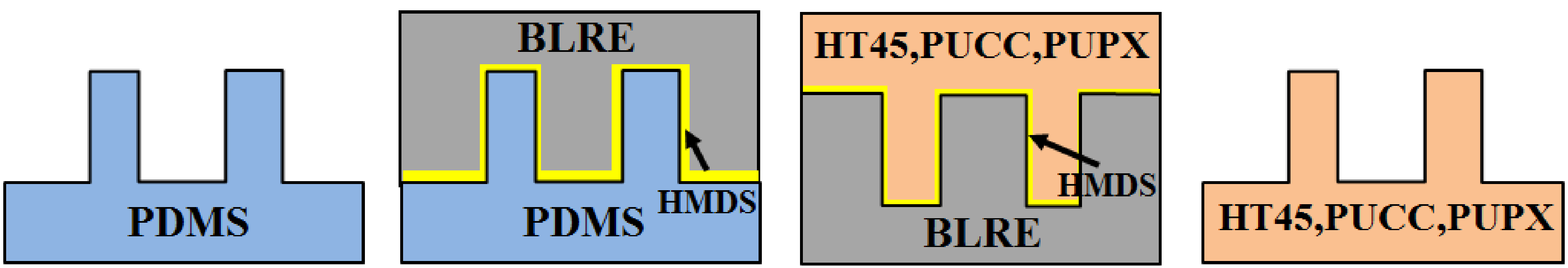

(a) → (b) → (c) → (d)

(a) PR pattern on $SiO_2$/Si substrate

(b) 5.0 μm depth $SiO_2$ etching

(c) $SiO_2$/Si mold after PR strip

(d) PDMS casting from $SiO_2$/Si mold




(e) → (f) → (g) → (h)

(e) PDMS pattern

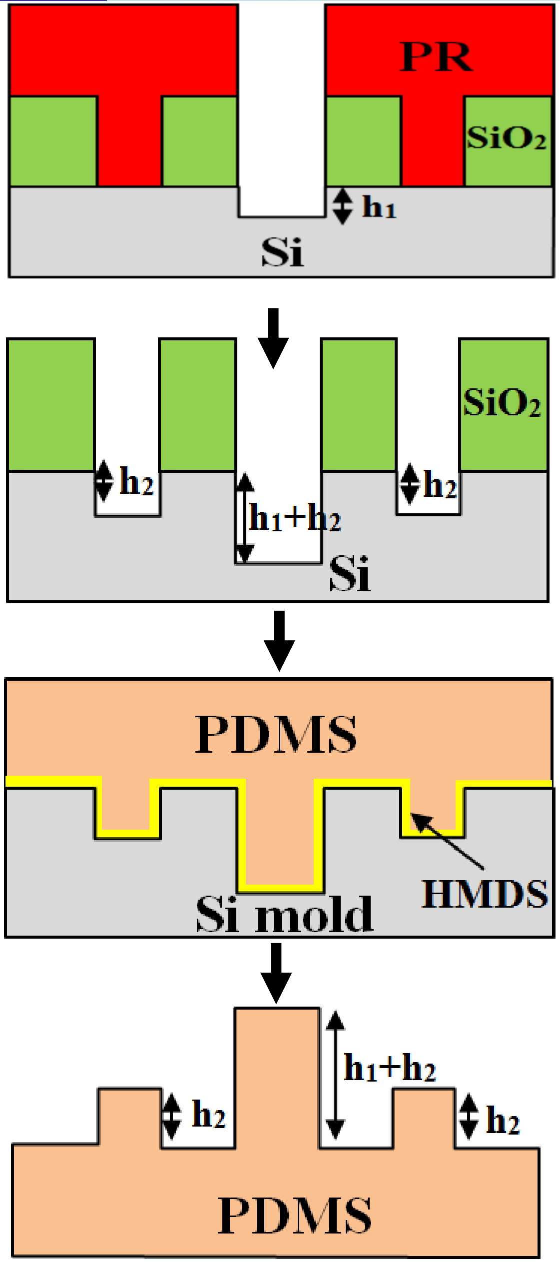
(f) 2nd resin (BLRE) mold casting from PDMS sample

(g) HT45, PUCC and PUPX casting from BLRE mold

(h) HT45, PUCC and PUPX pattern

**Pattern size: L/S 2 μm**
**Height 5.0 μm**

# Fabrication of 3D microstructure




**Si mold fabrication (LELE process)**

- PECVD oxide film (5.0 µm)/p-Si(100)
- 1st lithography (PR: 5.0 µm, CD: 20 µm)
- Oxide hard mask etching ($h_2$ area) (RIE, $CF_4/CHF_3/Ar$:10/50/100 sccm, RF:800W/20 min
- 2nd lithography (CD: 20 µm) + oxide etching ($h_1$ area)
- 1st Si etching ($h_1$), (Bosch process: 38 and 75 loops)
  Dep.: $C_4F_8/SF_6$: 200/5 sccm, ICP/RIE: 2000/10W, 8s
  Etch: $SF_6$: 400 sccm, ICP/RIE: 200/25W, 5s
- PR strip ($O_2$ ashing + SC1)
- 2nd Si etching ($h_1$+ $h_2$), (Bosch process: 75 loops)
  Dep.: $C_4F_8/SF_6$: 200/5 sccm, ICP/RIE: 2000/10W, 8s
  Etch: $SF_6$: 400 sccm, ICP/RIE: 200/25W, 5s

**PDMS casting (Soft lithography)**

- PR strip and HMDS priming (48 hrs)
- PDMS casting (10 wt%)
- Curing at 85°C/120 min and release Si mold

SEM, contact angle, contact angle hysteresis (CAH), bacteria adhesion, salt spray corrosive test

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# FleXARs - Everything-free surface

## Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications

## (Pattern design and Conceptual structure)


Presented by

**Dr. Nithi Atthi**

(Research Team Leader)

Surface and Microfluidic Device Innovation Research Team (SMDRT)

Thai Microelectronics Center (TMEC)

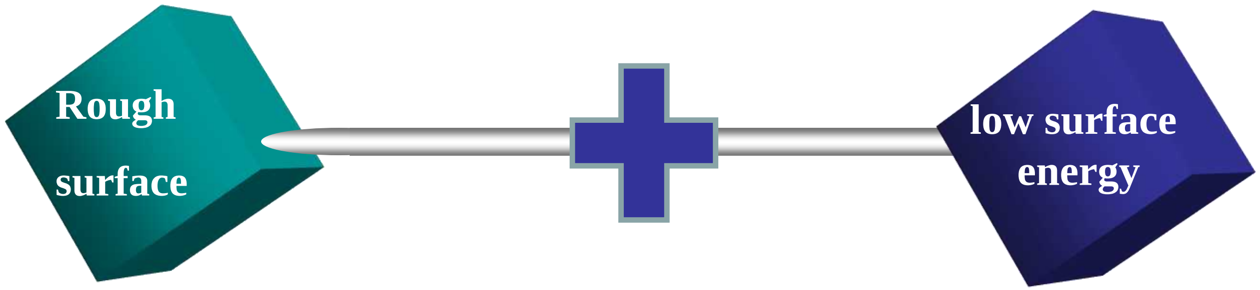



NECTEC a member of NSTDA

สวทช NSTDA

# Artifacts hydrophobic surface

## Techniques to make Superhydrophobic surfaces




**Method to make a rough surface:**

- <u>**Lithography and etching**</u>
- **Electrochemical reaction and deposition**
- **Mechanical abrasion**
- **Crystallization control**

**Low surface energy materials:**

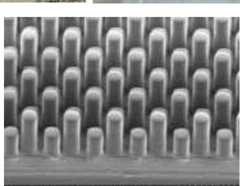
- **Fluorocarbons: Teflon, PFOS, etc.**
- <u>**Silicones: TPFS, PDMS , SFS**</u>
- **Organic materials: PE, PS, polyamide, etc.**
- **Inorganic materials: ZnO, $TiO_2$**

**TPFS: trichloro(1H,1H, 2H,2H-perfluorooctyl)silane**
**PDMS: Polydimethylsiloxane**
**SFS: Semiflourinate silane**

# Milestone of FleXARs project

## 2008-2014

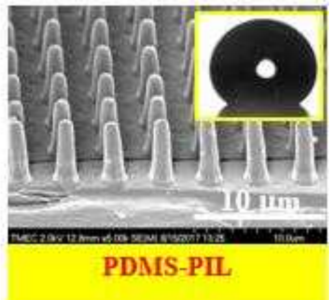
- Superhydrophobic surface on silicon and glass substrate
- Ultra-hydrophobic surface
- Ultra-oleophobic surface
- Si mold fabrication
- Soft lithography process of PDMS



PDMS: Polydimethylsiloxane
PU: Polyurethane

## 2015

- PTT project Phase#1 (Micro-patterns for barnacle antifouling)

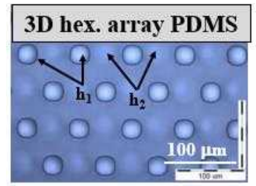



## 2016

- PTT project phase#2 (micro-scale patterned on PDMS and PU)
- Black resin as 2nd mold for various resin casting
- Field-test in seawater environment
- 3D microstructure

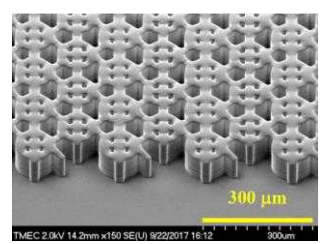
## 2017

- Antibacterial/ algae antifouling field test




## 2018

- Robust micro-structure



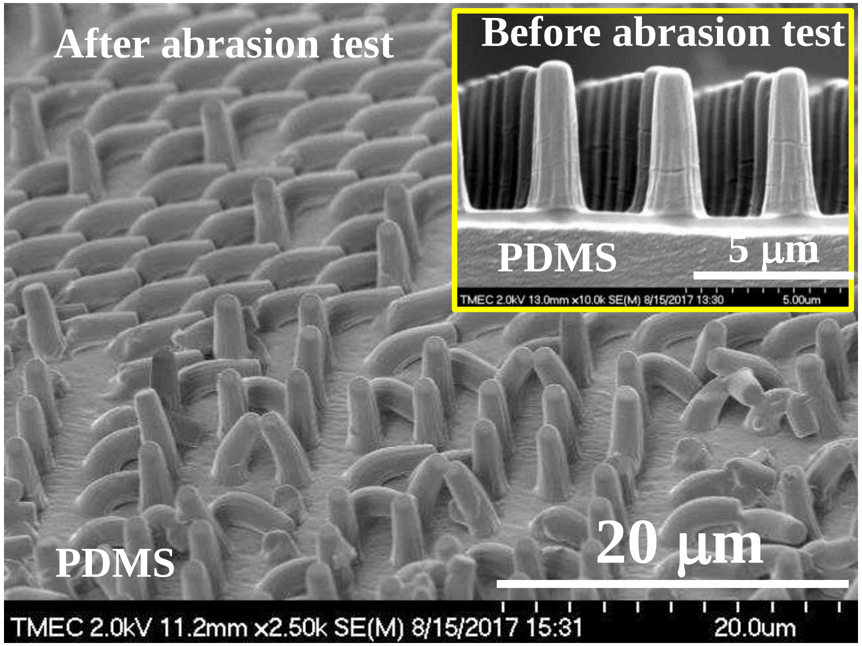

## 2019-2022

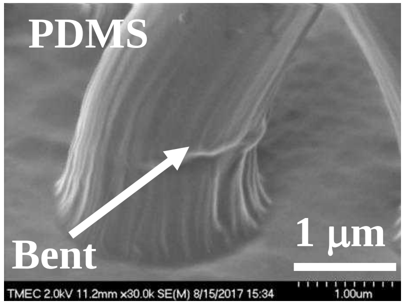
- Composite PDMS/PU
- Superoleophobic surface
- Robust Pattern and pattern size scaling
- Large-area patterning (R2R NIL production)
- Field-test in marine and medical applications

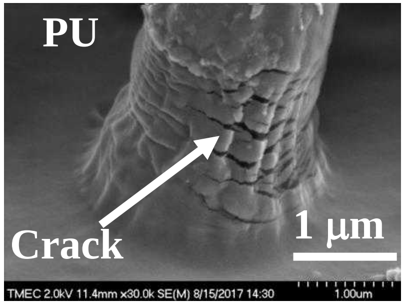
## 2023-2024

- Spin-off (Commercialization)

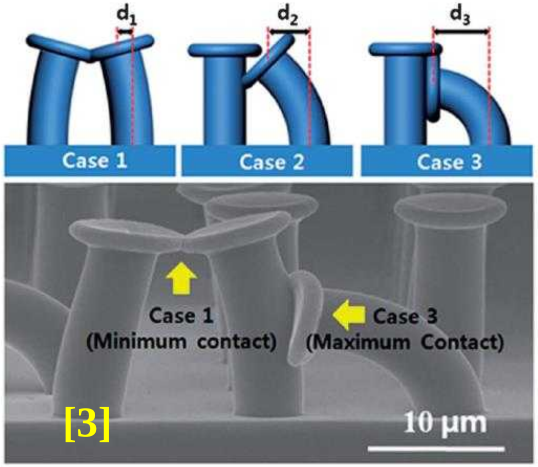
# Pattern collapsed by external forces




## Pattern mating & clumping




$$F_{vdw} \propto \frac{c}{b^3}$$

$$P \propto \frac{V}{h^3}$$

*h*: pillar height, *V*: displacement of pillar, *c*: contact area
*b*: distance between pillar

- Soft and flexible (σ: 5.0 MPa, ε: 116%)
- Hardly replicate dense pattern (a < 400 nm) with high A.R. (> unity)
- Pattern mating and clumping ($P < F_{vdw}$)

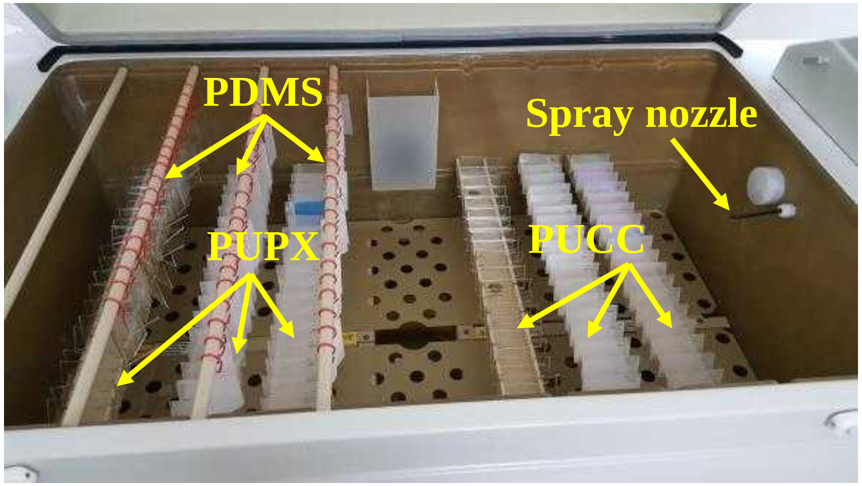
**3D microstructure with two-steps height is required to maximize displacement and minimize contact area to prevent pattern mating and pattern clumping ($P > F_{vdw}$)**

Note: Mating is pillar-to-pillar interactions (lateral collapse).
Clumping is pillar-to-substrate interactions (ground collapse).
Van der Waals force ($F_{vdw}$) is adhesion force between adjacent pillars.
Pulling force (P) is a recovery force.

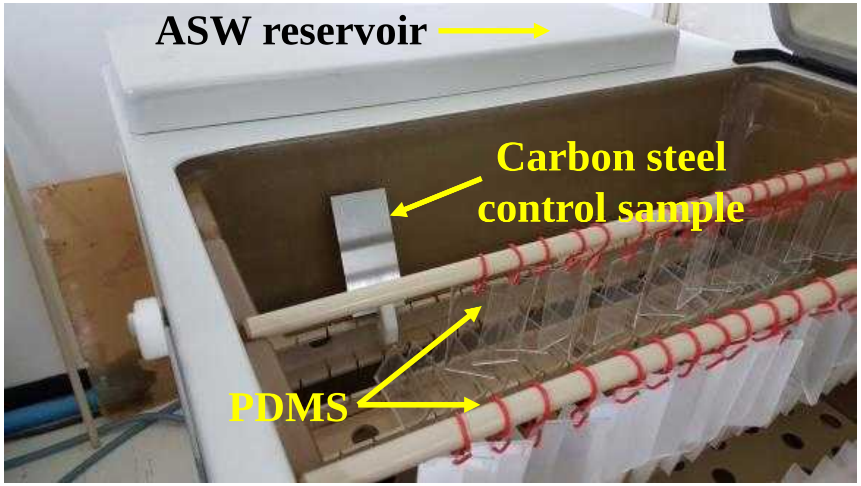
[1] N. Atthi, *et. al.*, *J. Nanosci. Nanotechnol.*, 11, pp. 1-7 (2011).
[2] N. Lu, *et. al.*, *Food control*, 68, pp. 344-351 (2016).
[3] W.-G. Bae, *et. al.*, *Soft Matter*, 9, pp. 1422-1427 (2013).

# Salt spray corrosion testing (354 hrs)

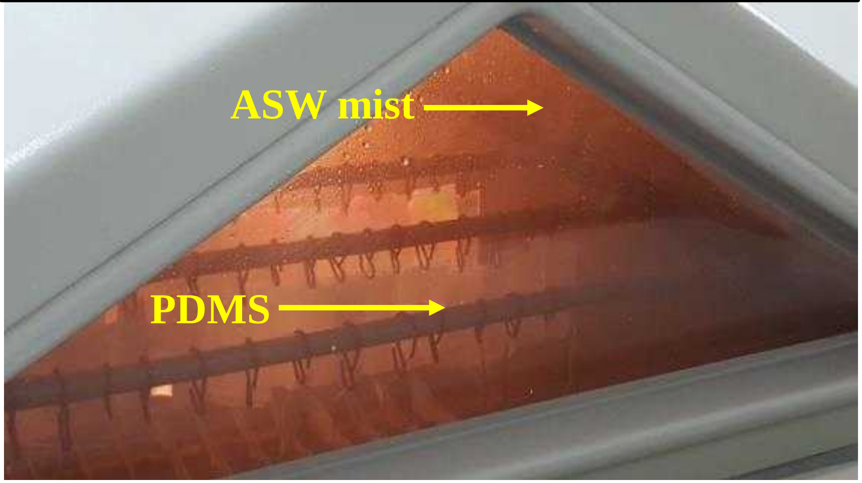
**PUCC and PUPX sample (15-30° tilt)**




**PDMS sample (Hanging)**




**During salt spray testing**




## Testing condition
## (Q-FOG cyclic corrosion tester)

- ASW (ASTM D1141-98)
- pH = 8.314.
- Sample size: 5x10 cm, thickness: 2 mm.
- Sampling: 0, 18, 66, 162, 234, 306, 354 hrs

ASW: Artificial Sea Water

# Pillar pattern collapse after SST

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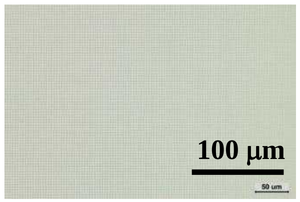
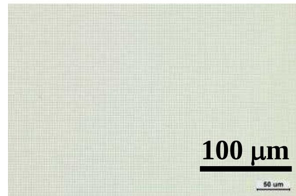
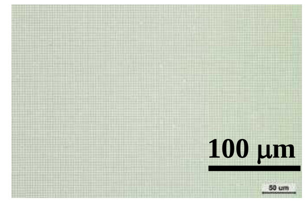
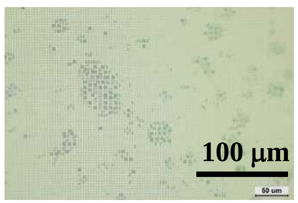
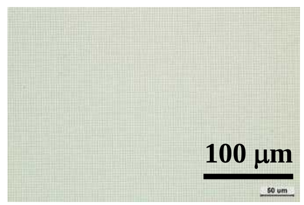
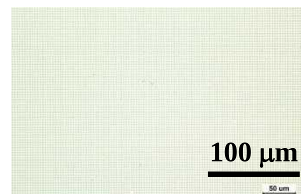
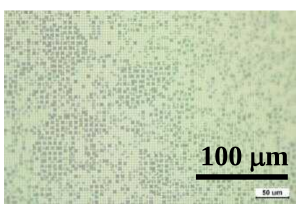
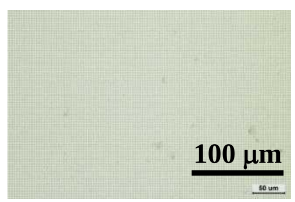
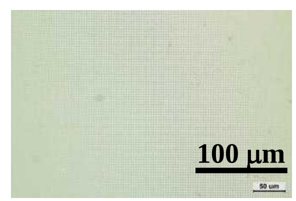
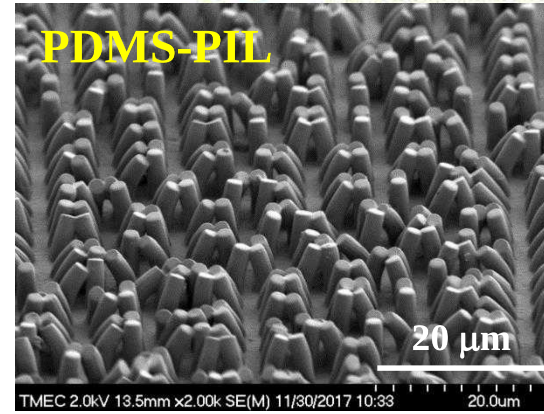
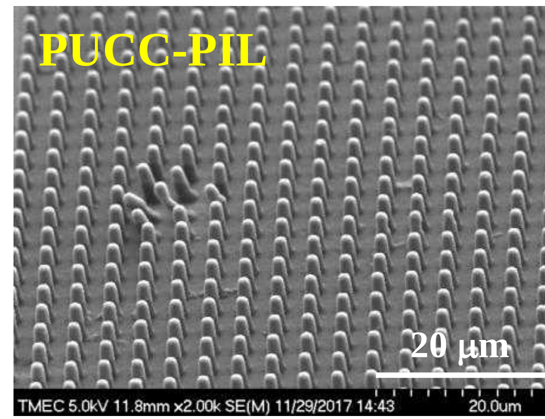
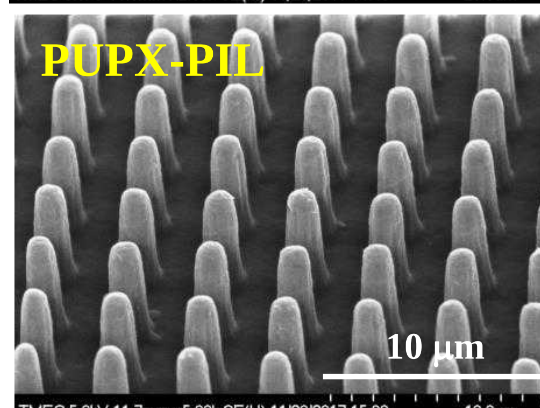
| Date | PDMS-PIL | PUCC-PIL | PUPX-PIL |
|---|---|---|---|
| Day 0 (17/10/2017) |  |  |  |
| 162 hrs (24/10/2017) |  |  |  |
| 354 hrs (01/11/2017) |  |  |  |



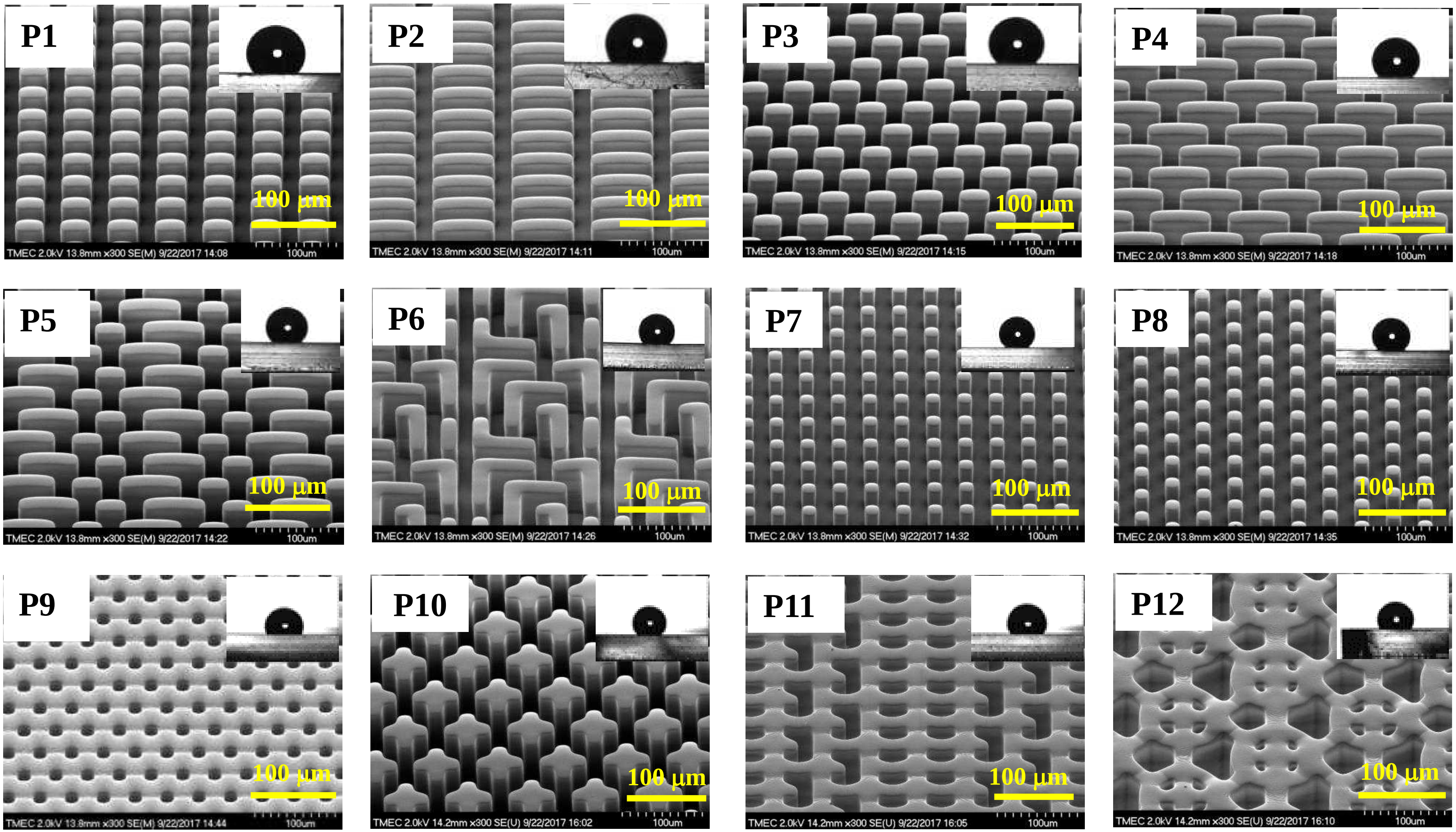




**PDMS: soft and flexible**
**PUPX: Hard and tough**
**PUCC: Hard and tough**

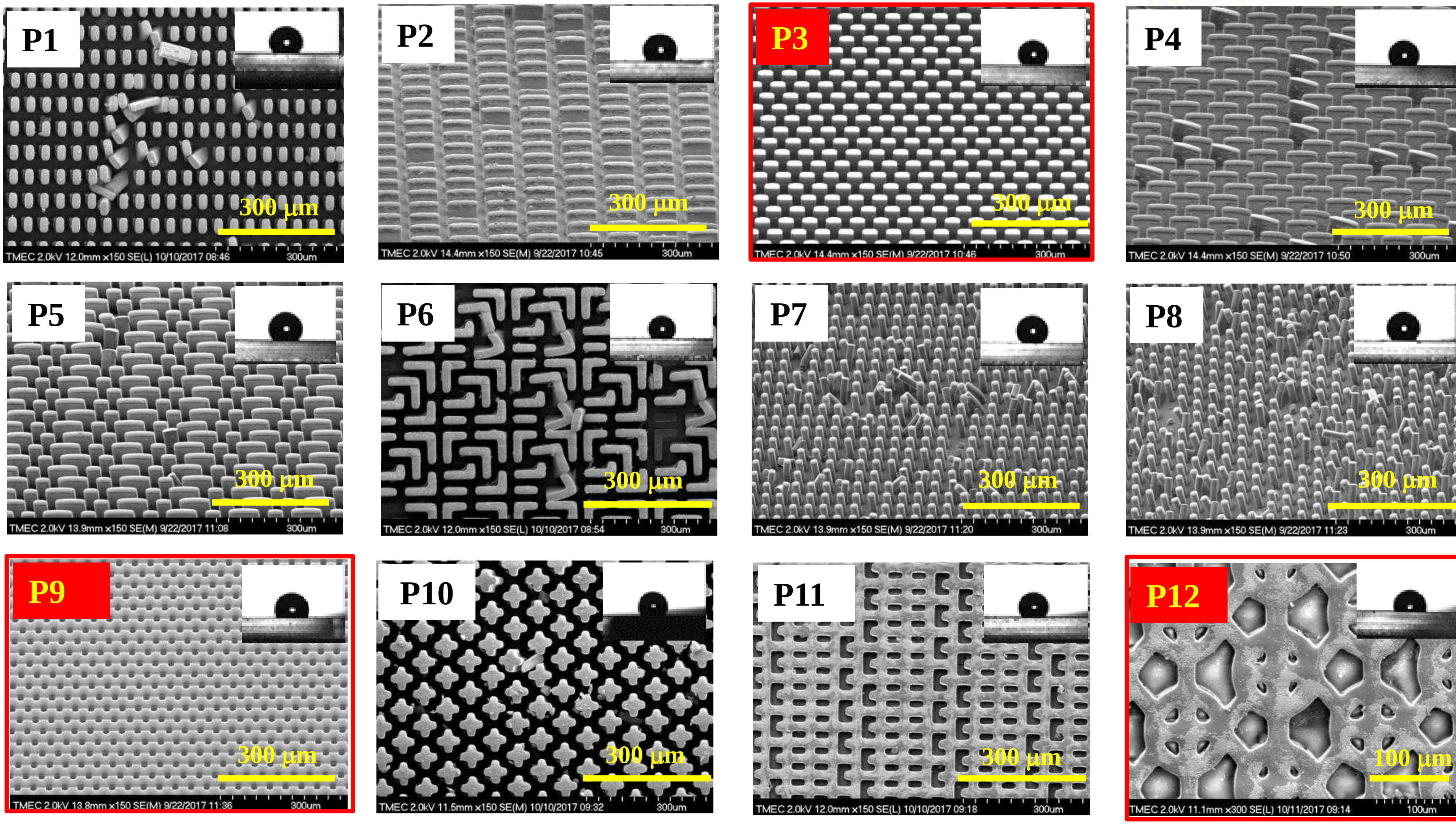
| Materials | σ [MPa] | ε [%] | τ [MPa] |
|---|---|---|---|
| PDMS | 5 | 116 | 1.8 |
| PUCC | 53 | 4.2 | 34.8 |
| PUPX | 16 | 0.9 | 41.8 |

# PDMS pattern (Before abrasion)



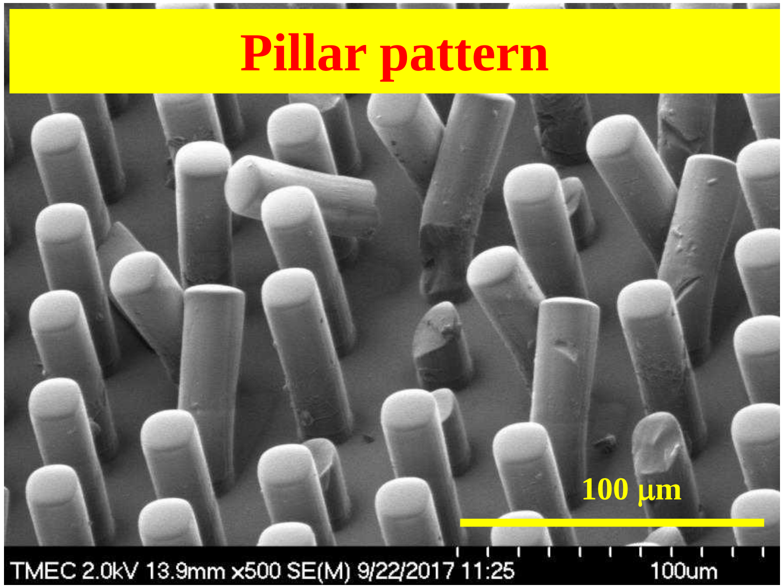

**After release PDMS pattern from Si mold, all 12 different PDMS patterns are not collapsed. The pattern sidewall is near vertical.**

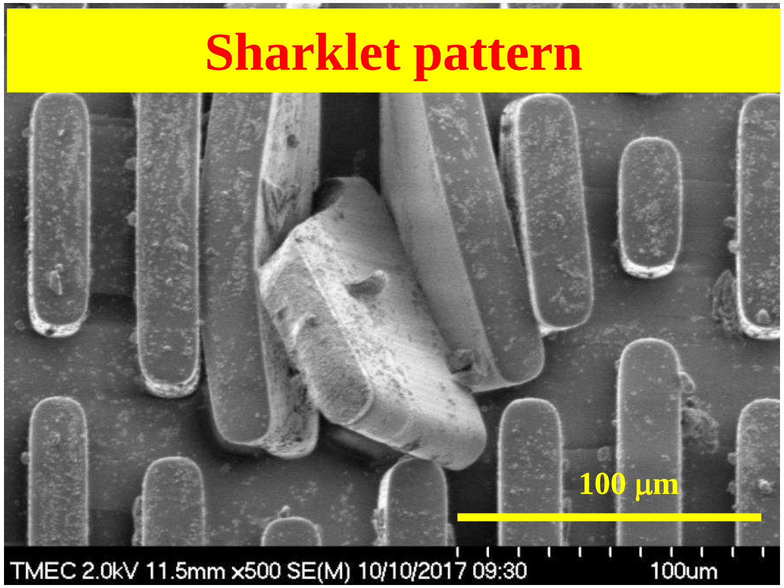
# PDMS pattern (After abrasion)

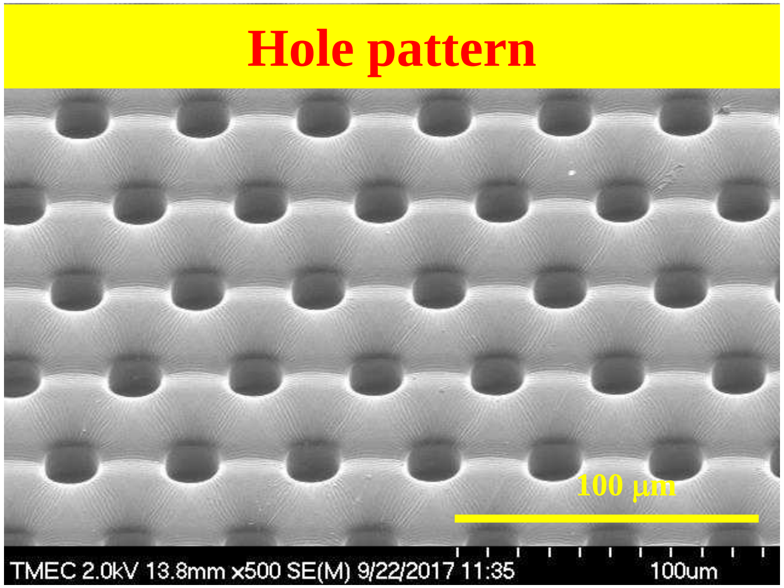


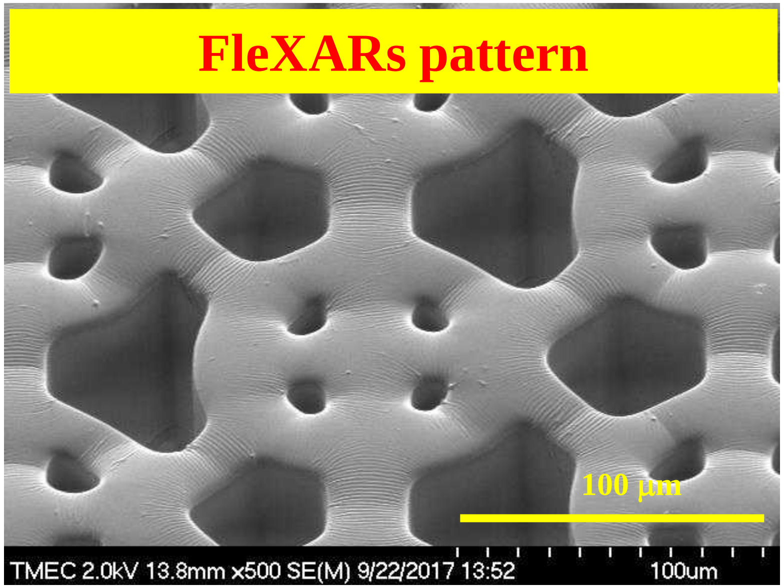

- **After abrasion test the samples by hands for 30 cycles, almost PDMS pillar-like patterns (excepted F3) were collapsed.**
- **Hole-like PDMS patterns (F9, F10, F14) has more durability.**

# PDMS pattern (After abrasion)



# Scratch test Vs Hydrophobicity

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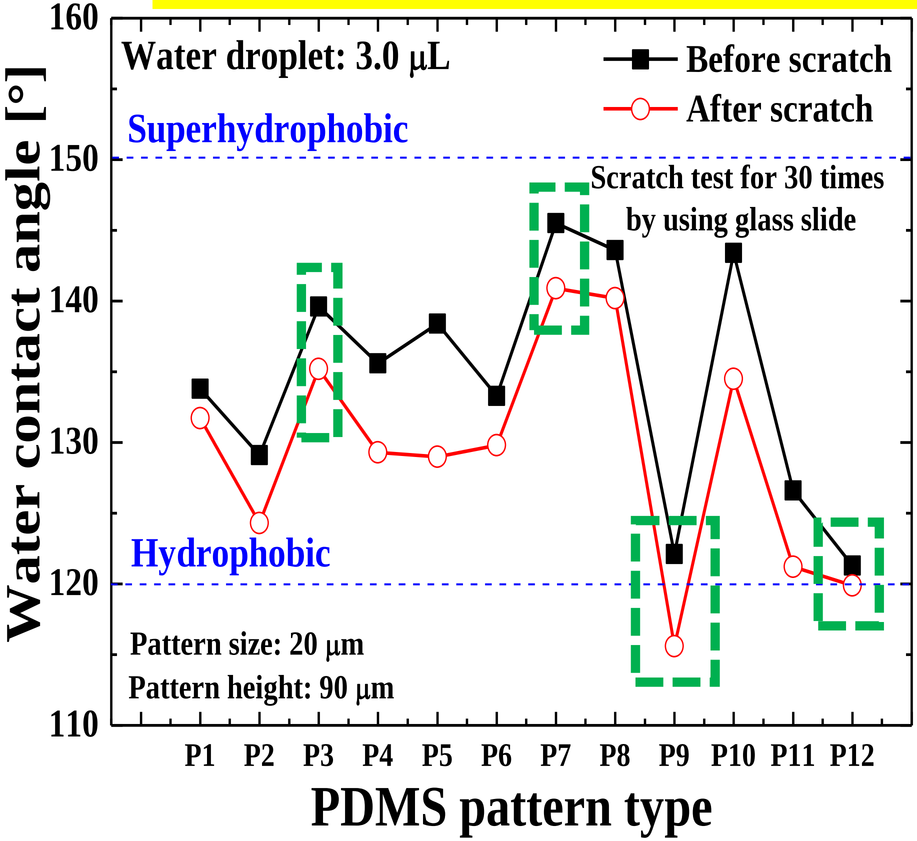
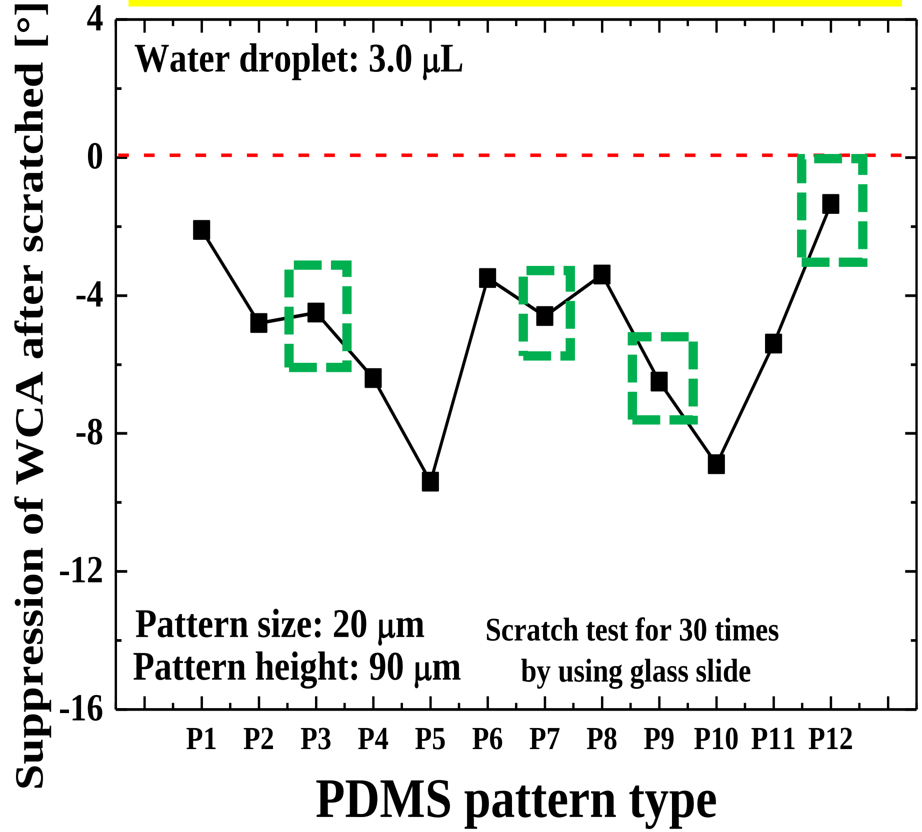
**Before and after scratch**




**Hydrophobicity**



# FleXARs film stacks structure

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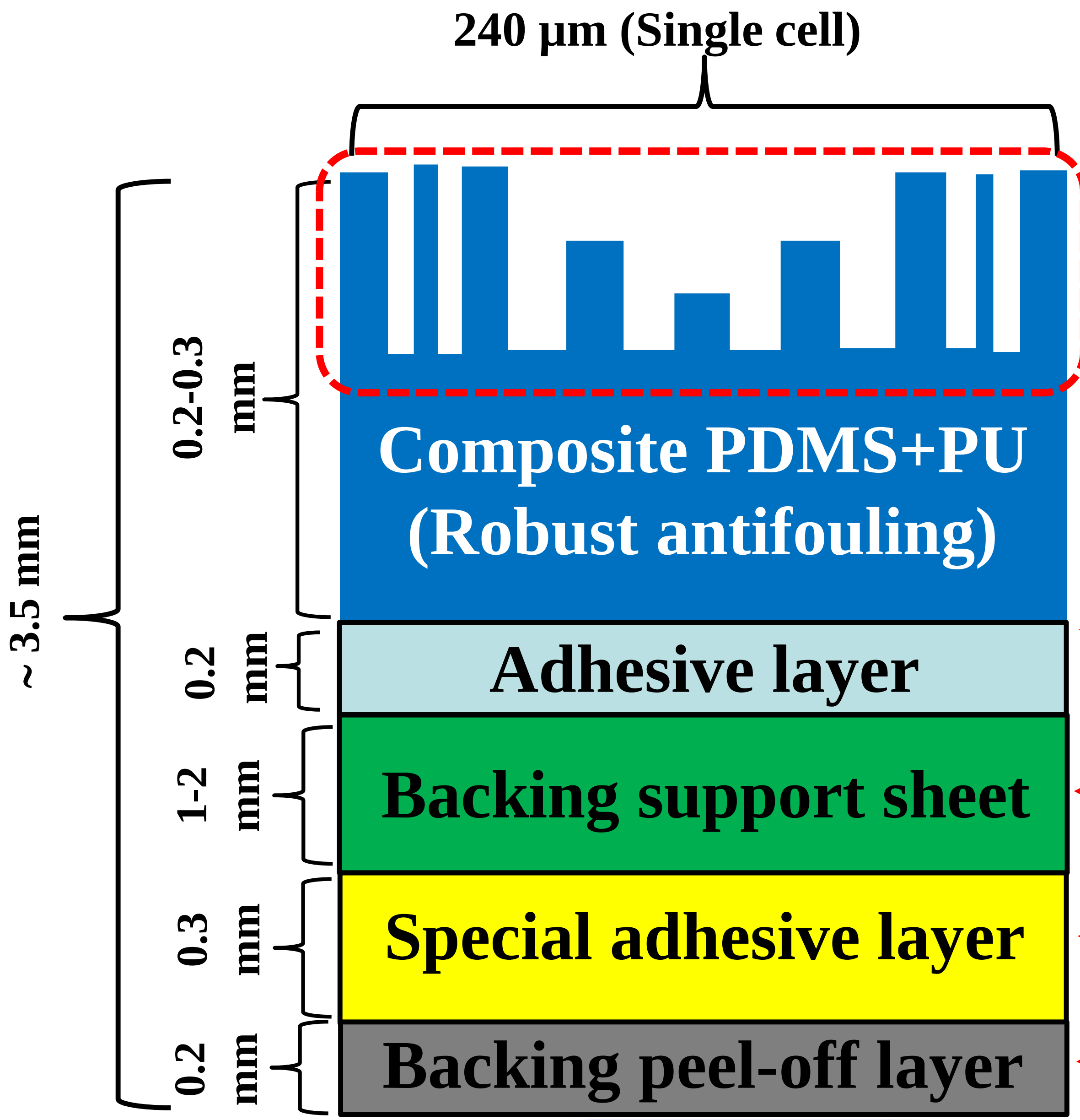
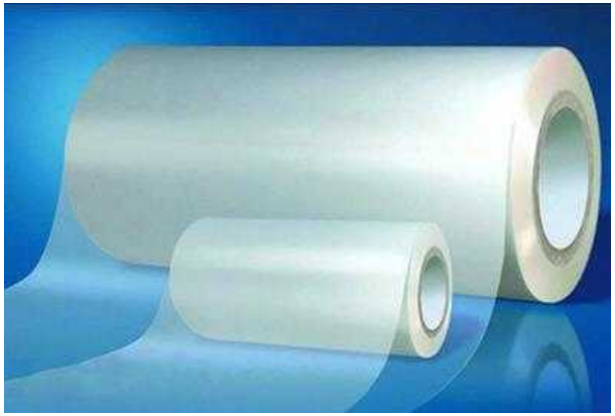



## Technical requirements



Interface functionalization for good adhesion

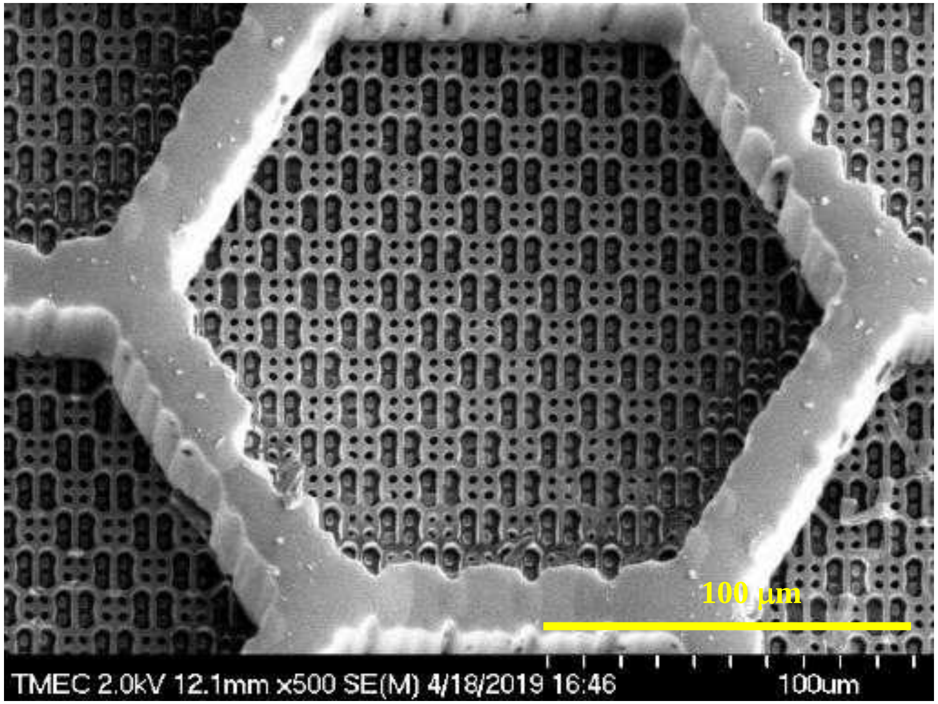
Biocompatible/marine durable /antifouling/Low-cost (PP, PE, PET)

Good adhesion properties for medical applications

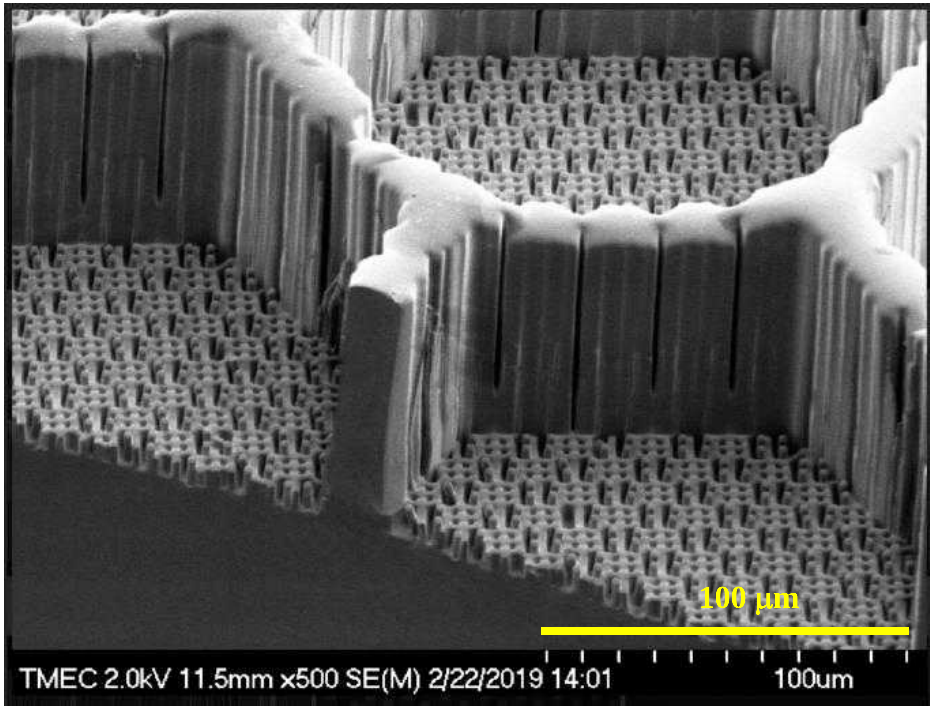
Low-cost/transparency PVC

# FleXARs robust microstructure

**Top-view SEM image**



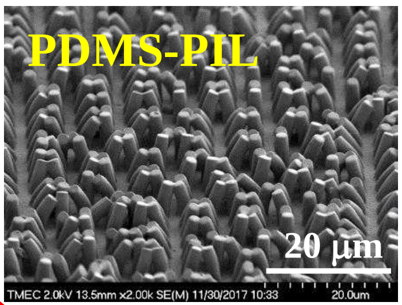

**Side-view SEM image**

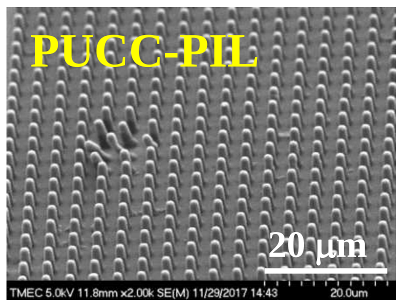


# Future plan

## (1) Composite PDMS-PU material

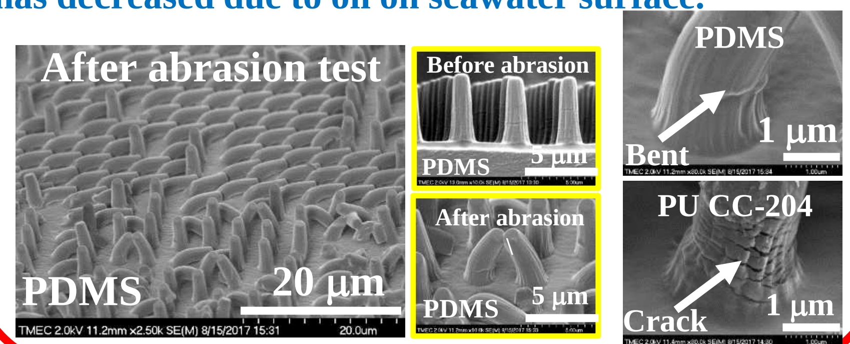
PDMS has swelled and pattern collapsed in seawater while PU has low WCA and not suitable for antifouling in seawater.



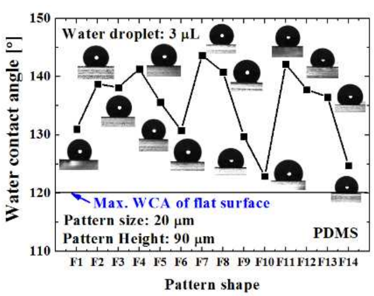

## (2) Antifouling robust microstructure with superoleophobic properties

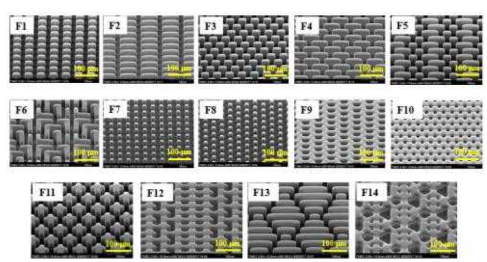
PDMS pattern has collapsed and PU has cracked after abrasion test for 30 cycles. Moreover, WCA has decreased due to oil on seawater surface.




## (3) Pattern size smaller than 500 nm

The current pattern sizes are 20 μm and 2 μm, which not small enough to prevent initial attachment stage. Then WCA is lower than 150°




## (4) Large-area patterning

The maximum pattern size by using soft lithography from 6 inch Si mold is 10x10 cm. However, large-area sample is required for actual applications.

# Target Customers

## Health care

**Hospital & Veterinary hospital**

**Nursery, school, living room**


**Escalator handrails**

**Trolley in supermarket/ airport**

## Marine applications

**Oil-rig platform columns**

**Container ship, Cruise, Warship**

**Fiber optic/ telecommunication network**

## Public transportation

**BTS/MRT/ARL systems**

**Public bus (BMTA)**

**Train station/bus stop/airport**

# Summary

TMEC Thai Microelectronics Center

**Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications**

**(FleXARs Project)**

- **Development of composite biocompatible PDMS-PU materials**
- **Design robust superoleophobic micro-patterns with guard-ring**
- **Pattern size scale down below 500 nm**
- **Large-area patterning by using roll-to-roll process (30 cm width, 100 m length)**
- **Development a backside glue layer stacks**
- **Benchmark with SLIPS®, Sharklet®, and FLEXPOL®**
- **Mass production by R2R NIL**
- **Target customers/users: PTT, SCG, Hospitals, BTS, MRT, etc.**

TMEC
Thai Microelectronics Center
Integrate Ideas Into Reality


**Thai Microelectronics Center (TMEC)**
**51/4 Moo 1, Wang Takien District,**
**Amphur Muang, Chachoengsao,**
**Thailand 24000.**

**Tel: +66-38-857100-9**
**Fax: +66-38-857175**
**Email: info-tmec@nectec.or.th**
**Website: http://tmec.nectec.or.th**

**FleXARs:** **Large-area Flexible Polymers with Antifouling Robust Micro-structure for Marine and Medical Applications**