

Picture of speaker and team with names



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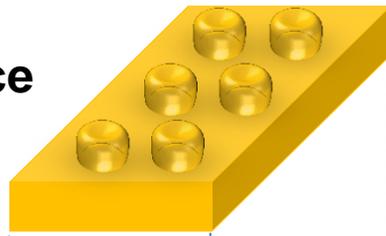


Group members involving in this project

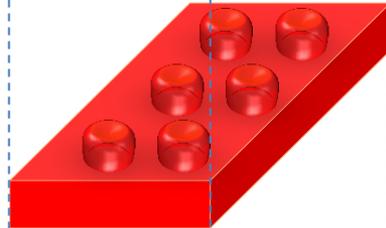
- Chang-Hyung Choi
- Jae-Min Jung
- So-Young Han

Executive Summary : Microscopic self-assembly

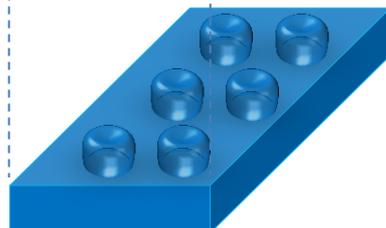
1. Combination of force



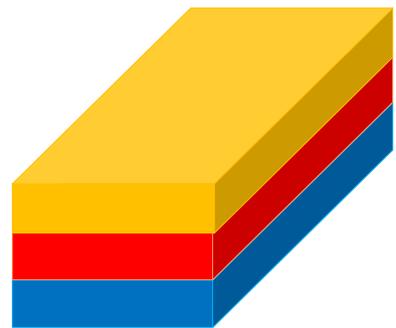
2. Shape



3. Topology



Particle assembly



New Functional Materials

Novel building block
"atoms" & "molecules" of tomorrow's materials

Ref : Science, 306, 2004
Nature materials, 10, 2011

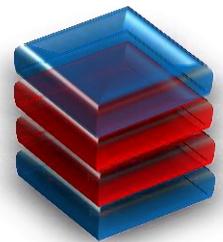
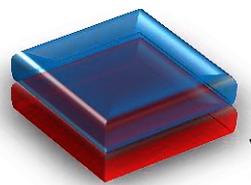
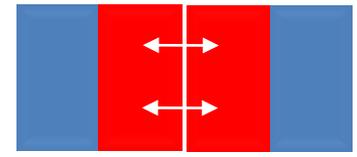
Executive Summary : Microscopic self-assembly

: Plan 1

Anisotropic building blocks
(Janus amphiphilie)

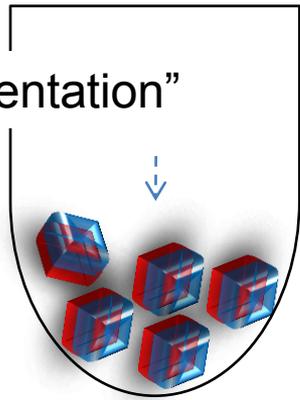


Programmed assembly for dimers

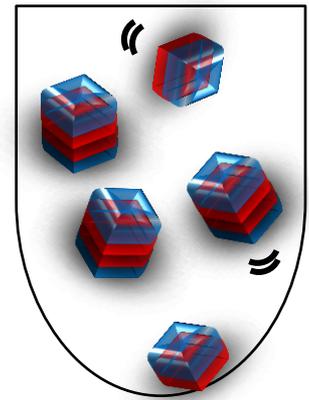


“Self-assembly”

“Sedimentation”



Ground state



Microgravity

Low probability of assembly under the ground state

Executive Summary

: Plan 2

Microscale building block
(Janus lock & Hydrophobic key)

Lock



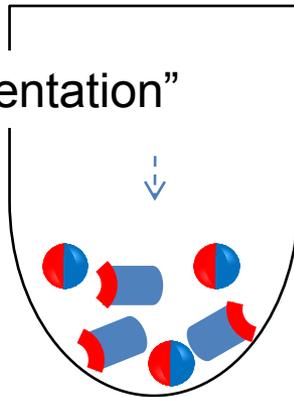
Key



Programmed assembly for dimers

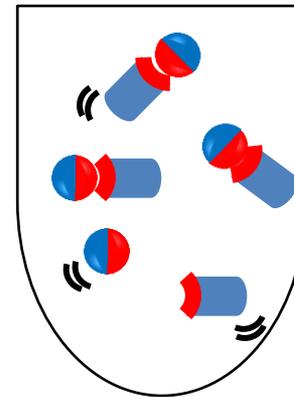


“Sedimentation”



Ground state

“Self-assembly”



Microgravity

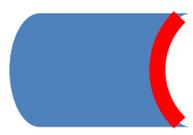
Low probability of assembly under the ground state

Executive Summary

: Plan 3 (analogy Multivalent ligand)

Microscale building block
(Janus lock & Hydrophobic key)

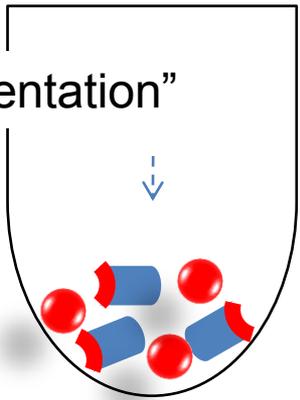
Lock



Key



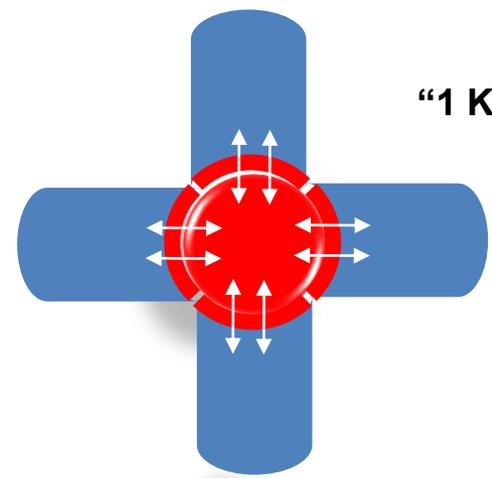
“Sedimentation”



Ground state

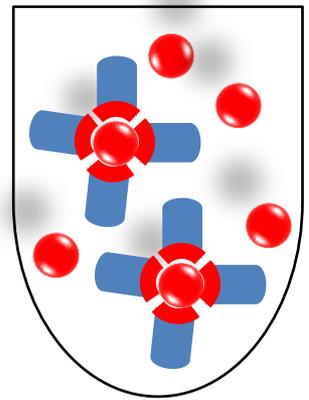
Low probability of assembly under the ground state

Programmed assembly
(analogy Multivalent ligand)



“1 Key + N Locks”

“Self-assembly”

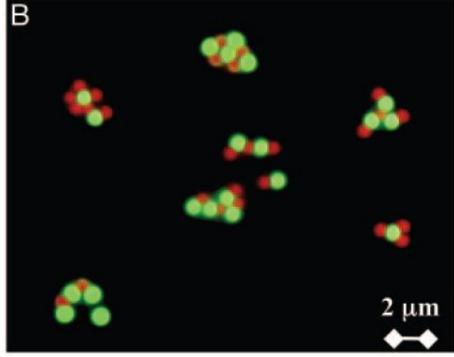
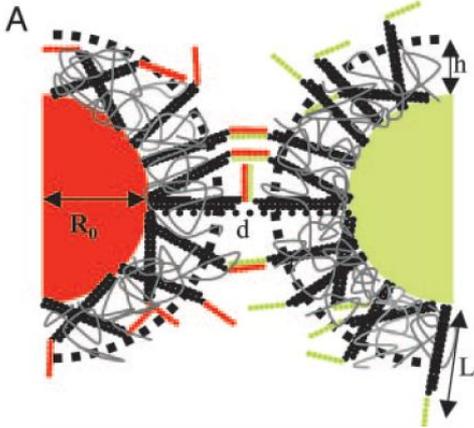


Microgravity

Brief science overview

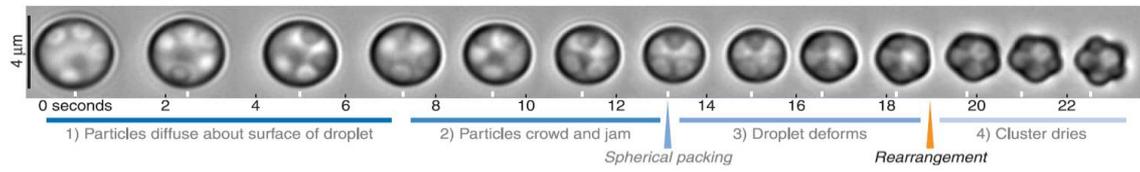
: Colloidal Assembly (< 1 μ m)

DNA-DNA interaction
(Chaikin et al., PNAS 2005)

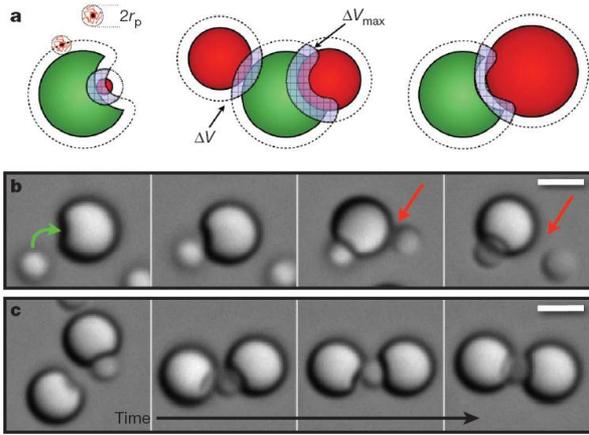


-DNA hybridization

Droplet evaporation : Optimal packing
(Pine et al., Science, 2003)

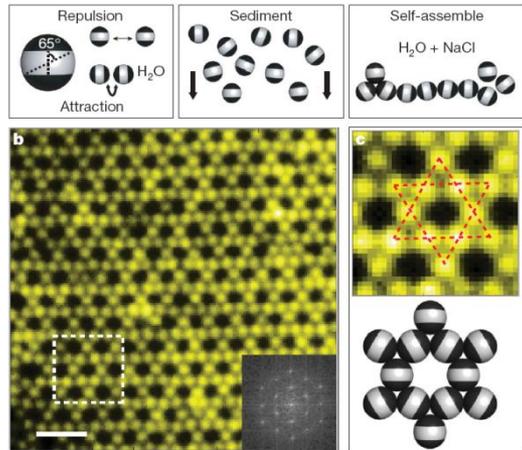


Lock and key principle
(Pine et al., Nature 2010)



-Depletion interaction
-Temperature
-Solution composition

Patchy particle
(Granick et al., Nature 2011)



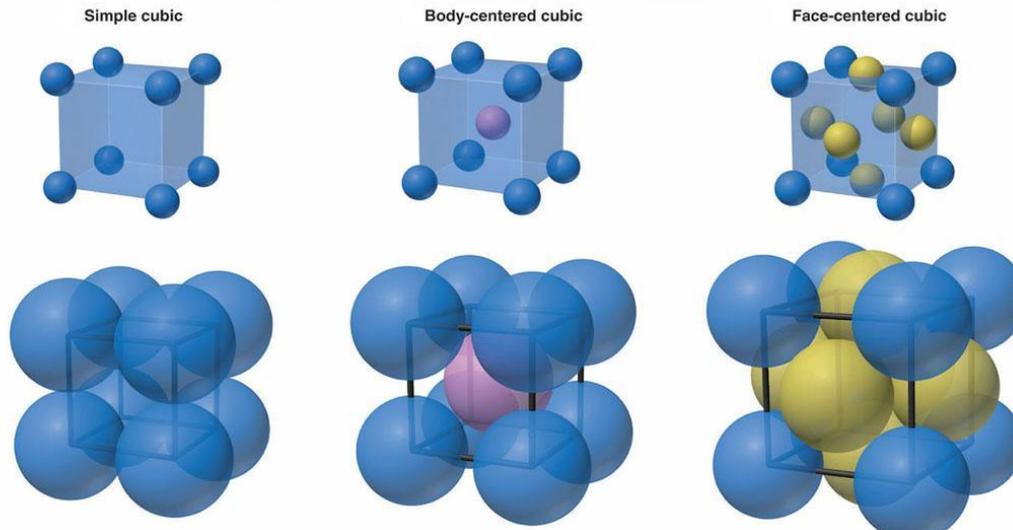
-Hydrophobic attraction
-Electrostatic repulsion
(addition of salt)

Affirm Scientific and Technical Merit

Problem : “Conventional assembly using colloidal particle”

- Sphere particles
- Brownian motion ($< 1\mu\text{m}$)
- Limitation of materials (e.g., PS, PMMA, Silica)

→ commonly yield phases of **simple symmetry**
(face-centered cubic, hexagonal close-packed and body-centered cubic)

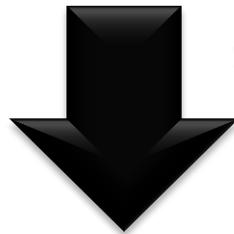


Complexity of materials = **Functionality**

“Microparticles”

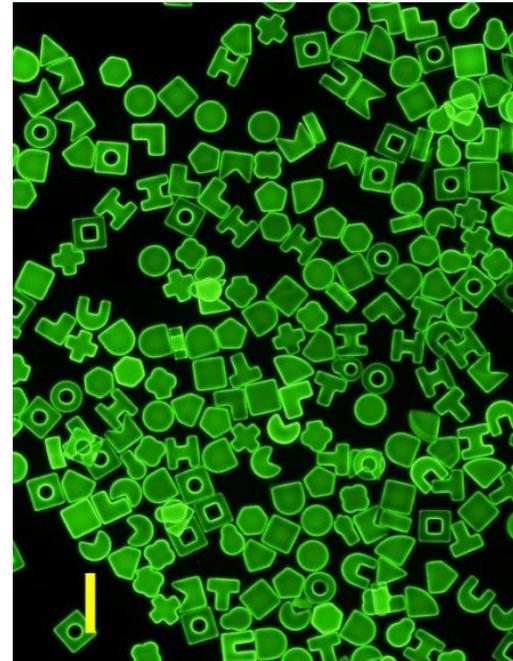
Versatility to control **shapes (highly complex building blocks)**

Wide ranges for choosing **materials**



Self-assembly

Novel functional materials



Scale bar: 100 μ m

Anisotropic particle assembly

Complexity of materials = **Functionality**

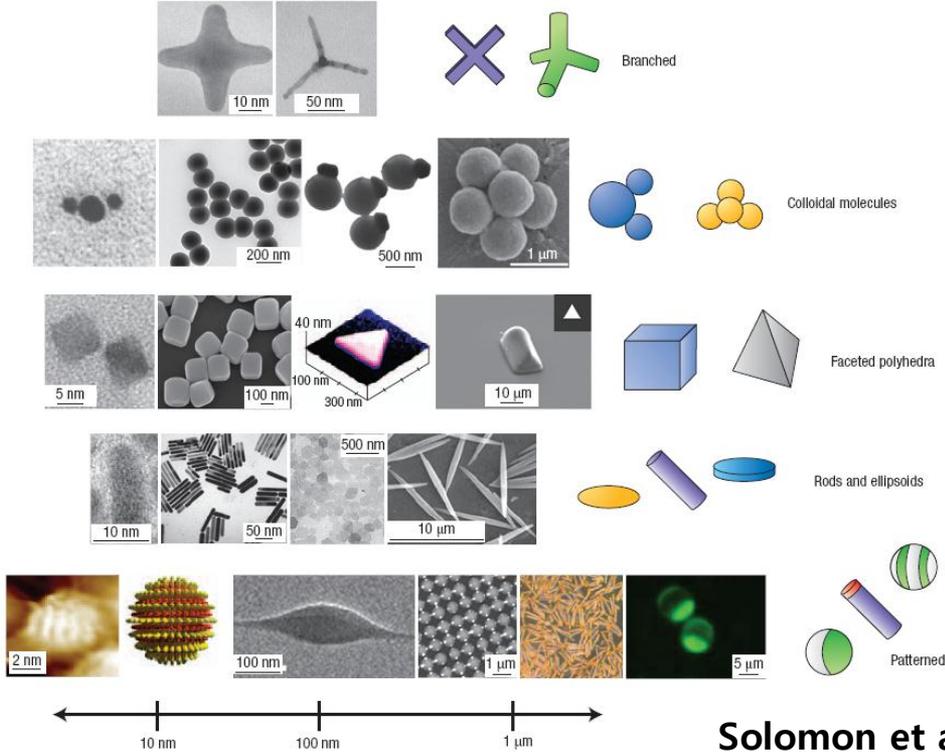
“shape and interaction anisotropy”



Structural complexity
(future applications require)



Molecular analogue
(e.g., liquid crystal, surfactants block copolymer)



Solomon et al. Nature (2007)

Why microparticle ?

Flexibility to control shapes

“**complexity** makes **complexity**”

Less limitation for
choosing **materials**



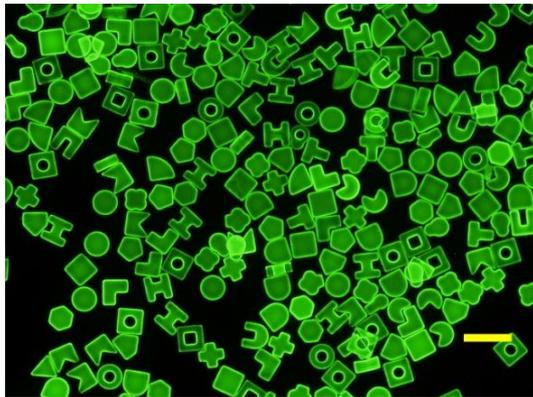
“Microparticles”

Self-assembly



**Easy to observe physical
phenomena**

using general microscope with low magnification



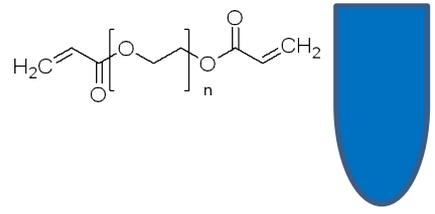
Scale bar: 100µm

Presentation for relevant ground-based work

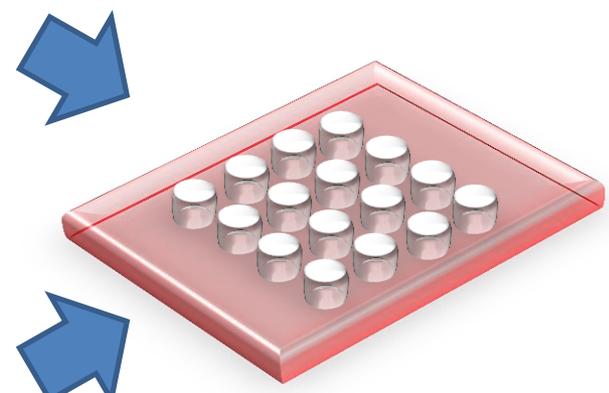
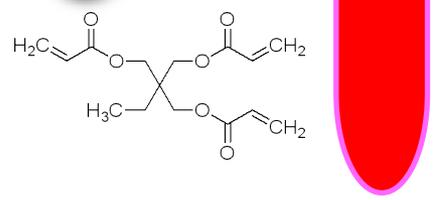
1. Synthesis of anisotropic microparticles
2. Preliminary data for self-assembly on ground state

Fabrication of Janus anisotropic particles

1 Hydrophilic monomer



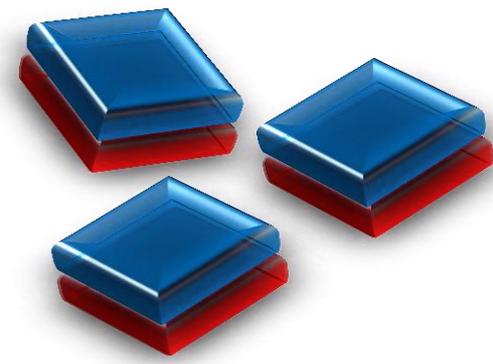
2 Hydrophobic monomer



microwells

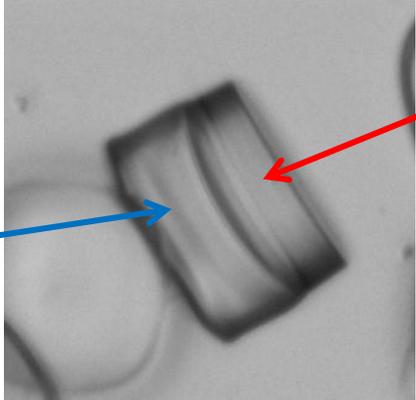
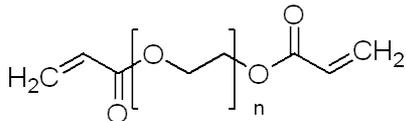


Janus particles



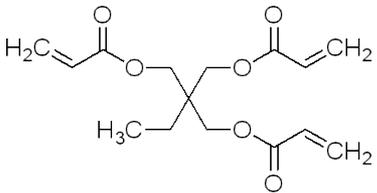
Fabrication of Janus anisotropic particles

PEG-DA Hydrophilic

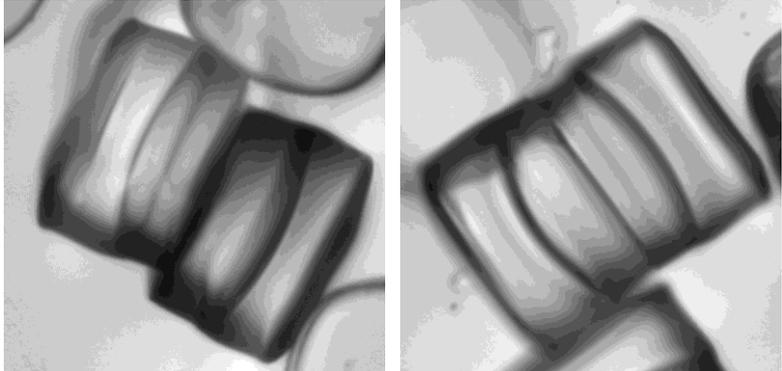


Hydrophobic

TMPTA

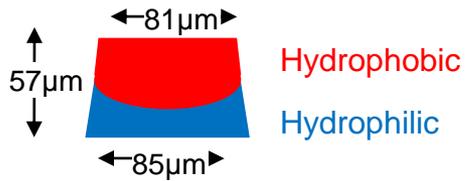


Assembly on hydrophobic domain : Dimer

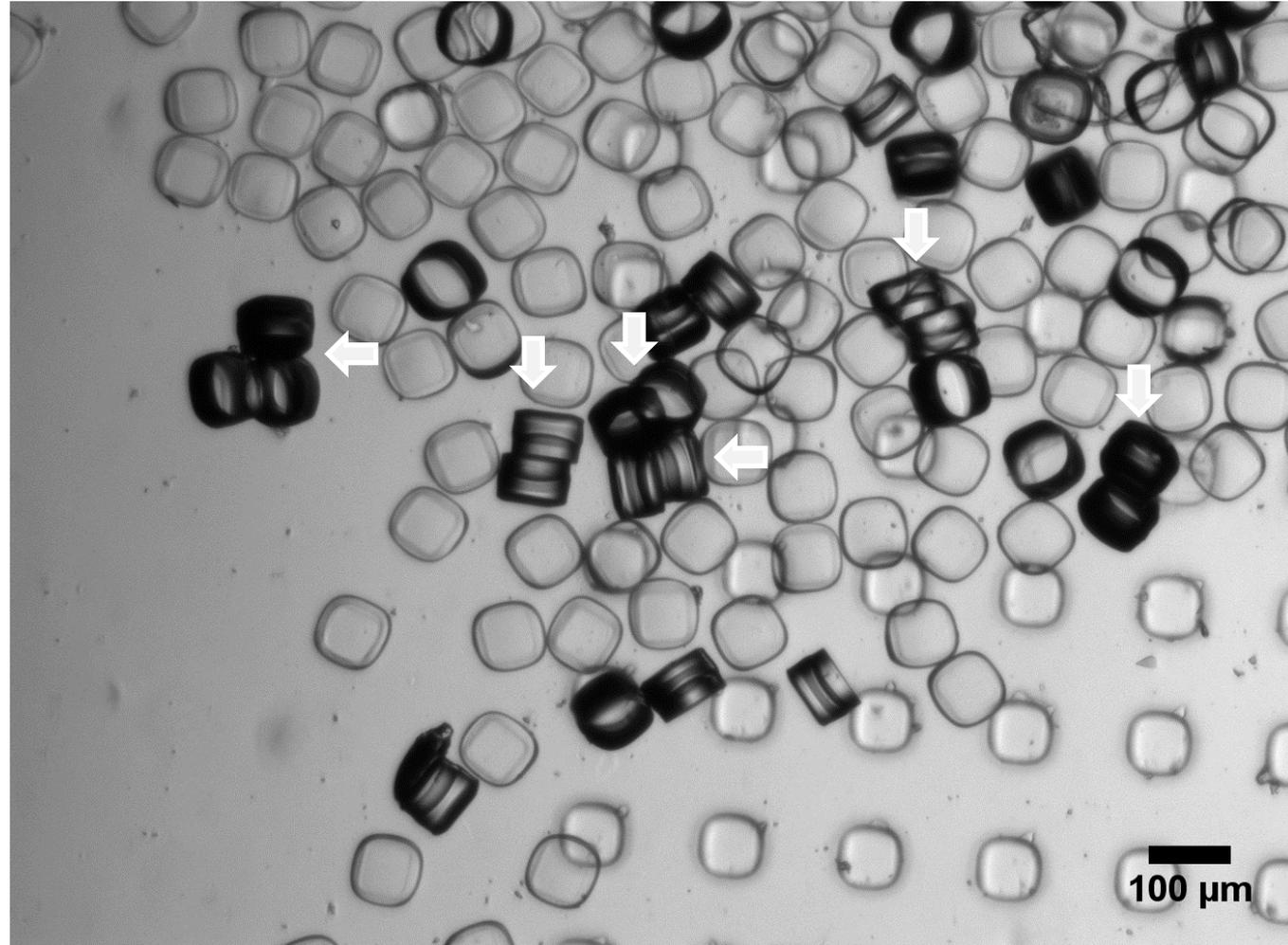


Fabrication of Janus anisotropic particles

Building block



trapezoid

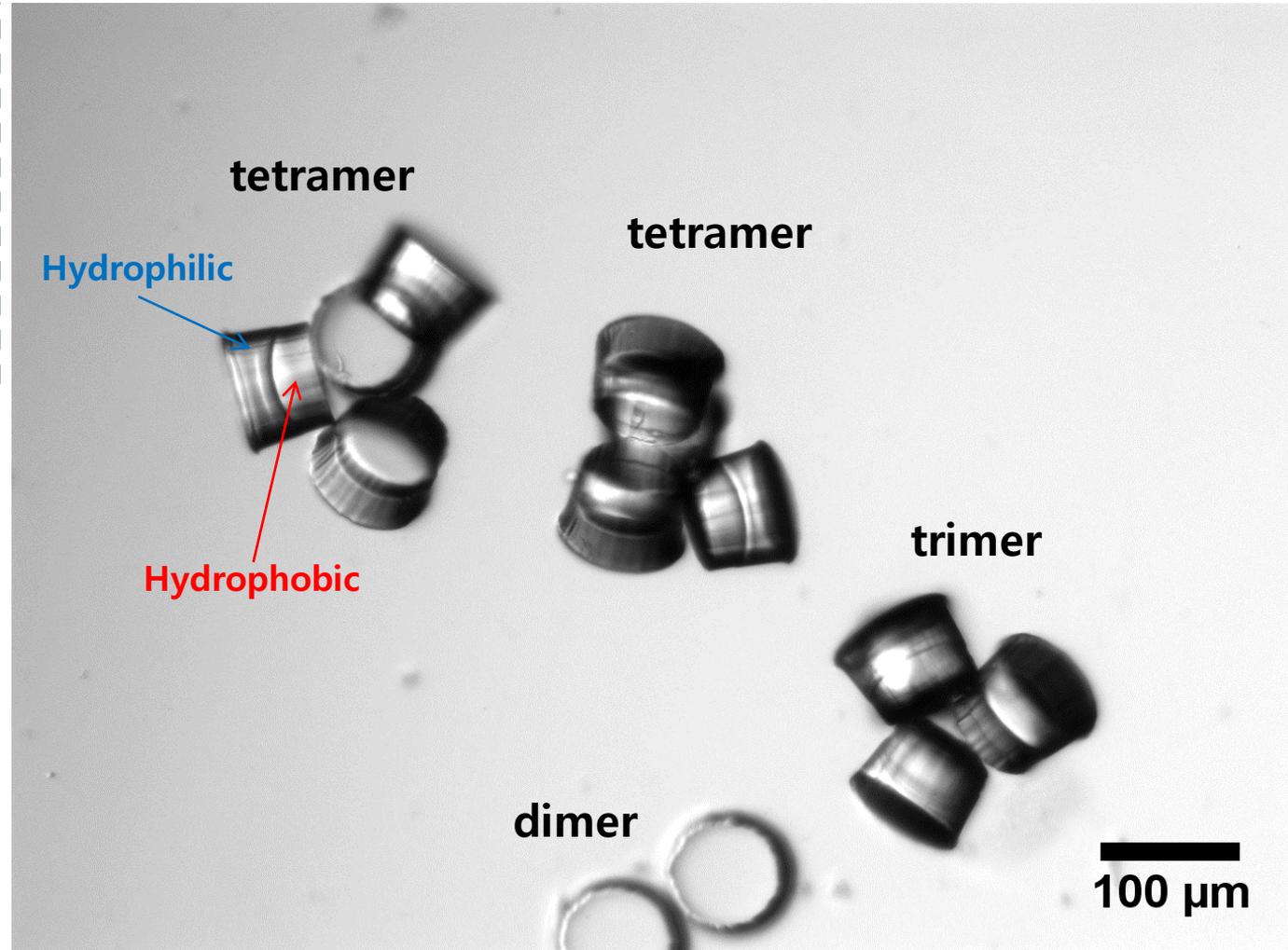
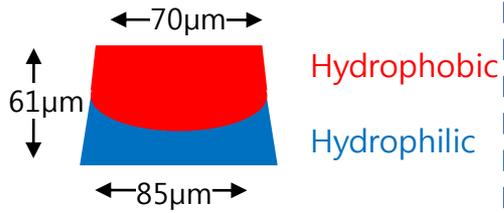


However, **probability** for assembled structures is quite **low**
→ Increase of Hydrophobicity of the particles.

Janus anisotropic particles : < 10 min

Increase in hydrophobicity

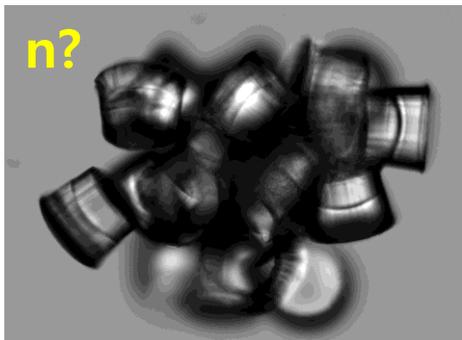
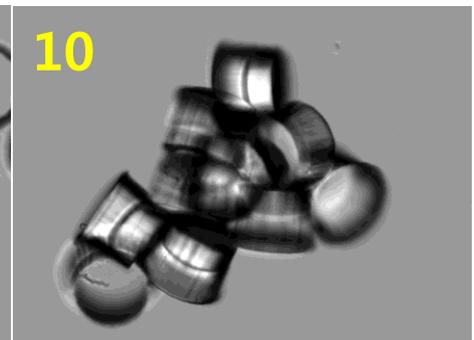
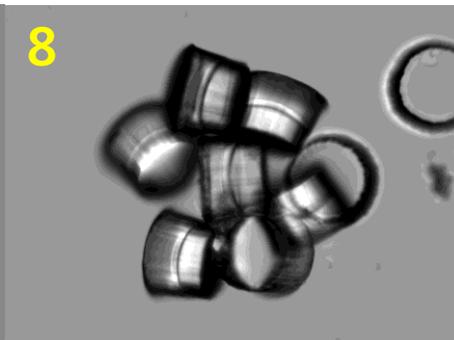
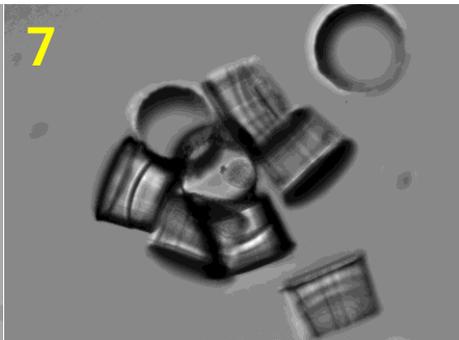
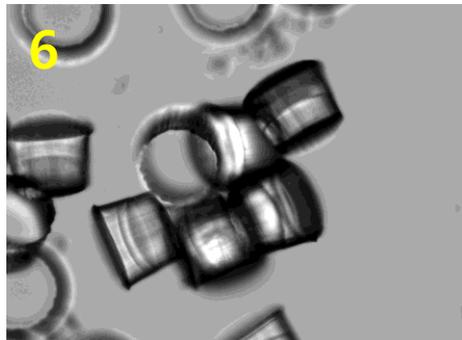
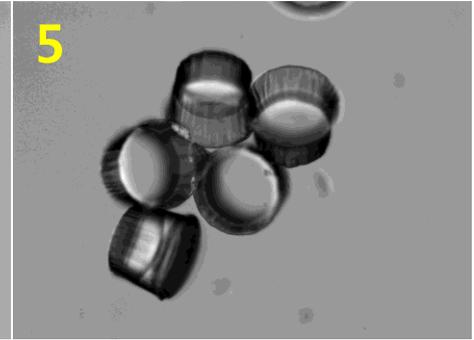
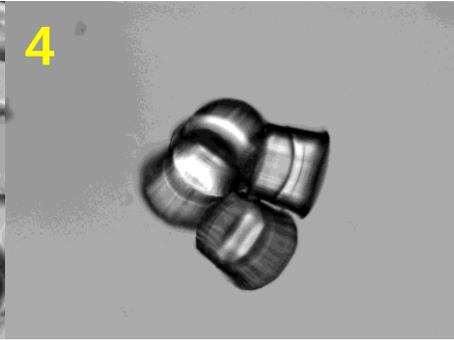
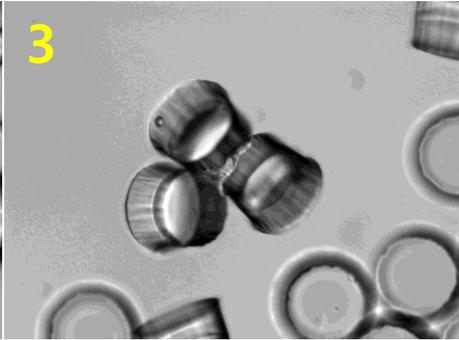
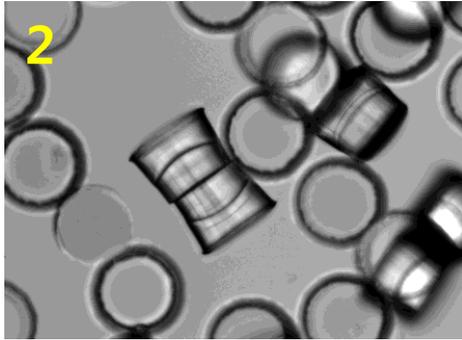
Building block



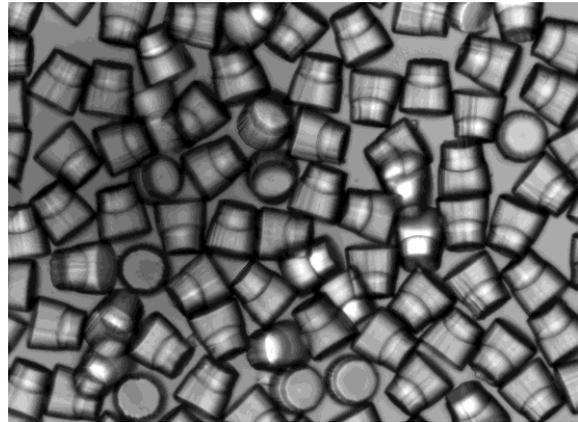
Dispersed in **water** (0.5% tween20 aq.)

Janus anisotropic particle assembly / cluster

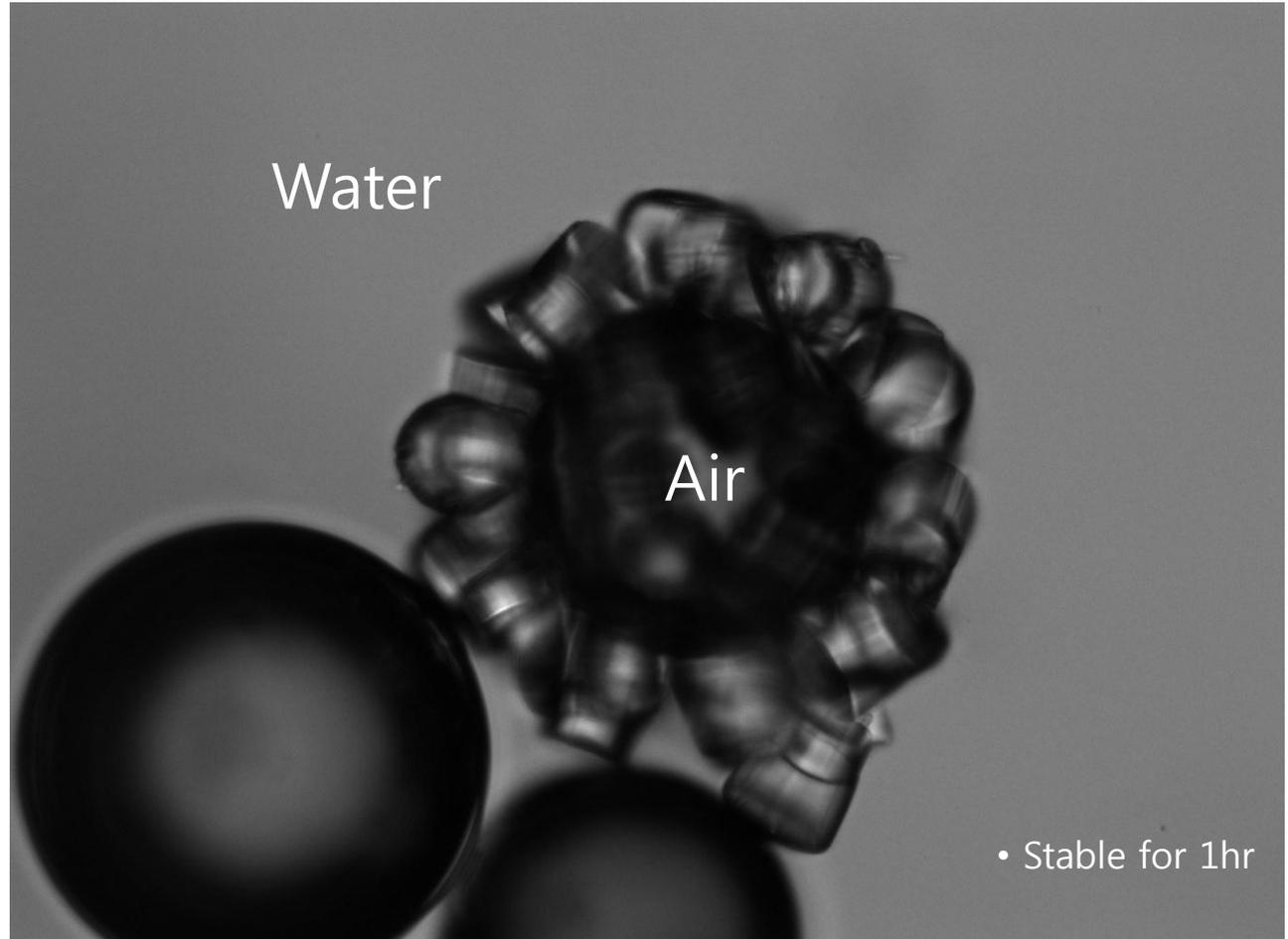
: growing clusters with Janus particle



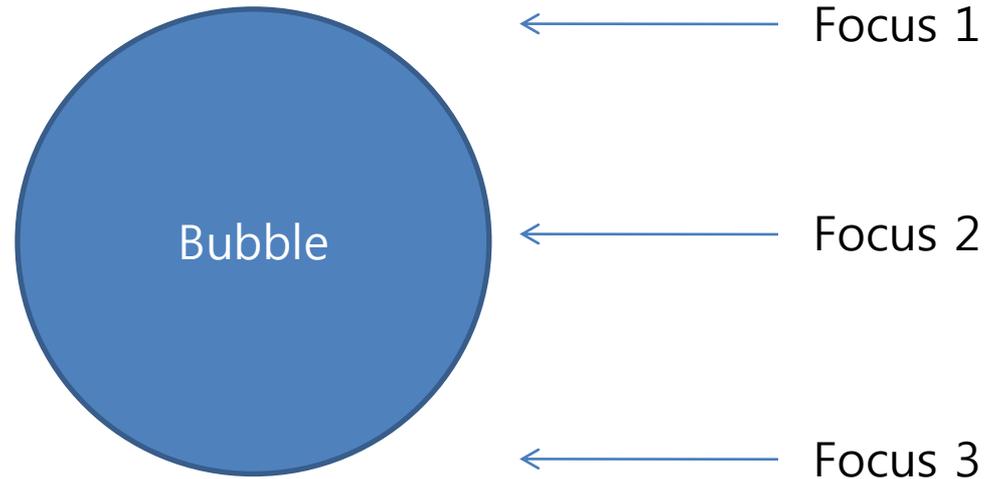
Micelle formation at Air/ Water interface



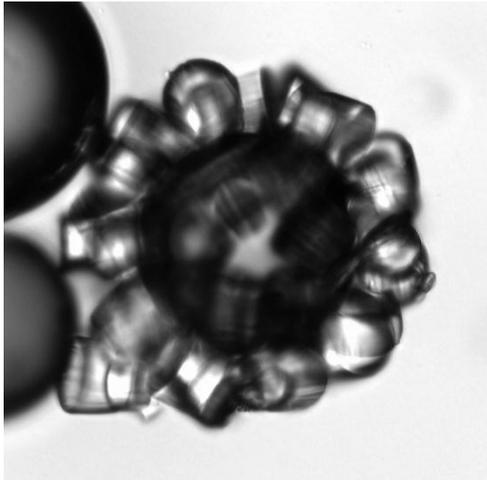
PEGDA-TMPTA, 40um



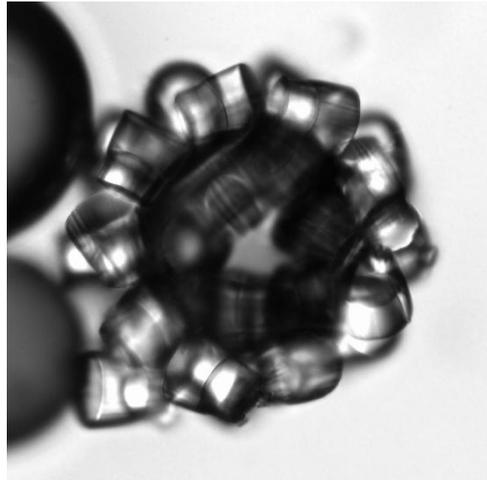
Micelle formation at Air/ Water interface



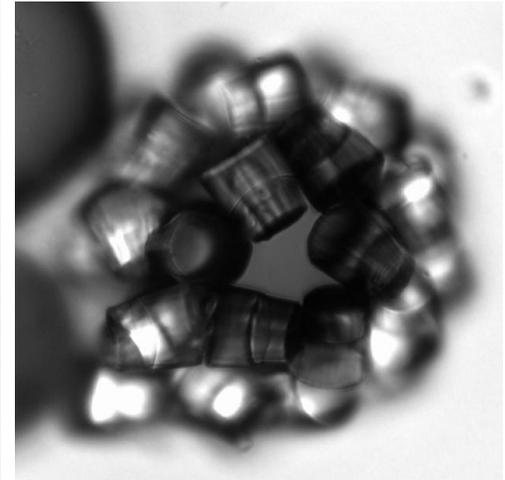
Focus 1



Focus 2



Focus 3

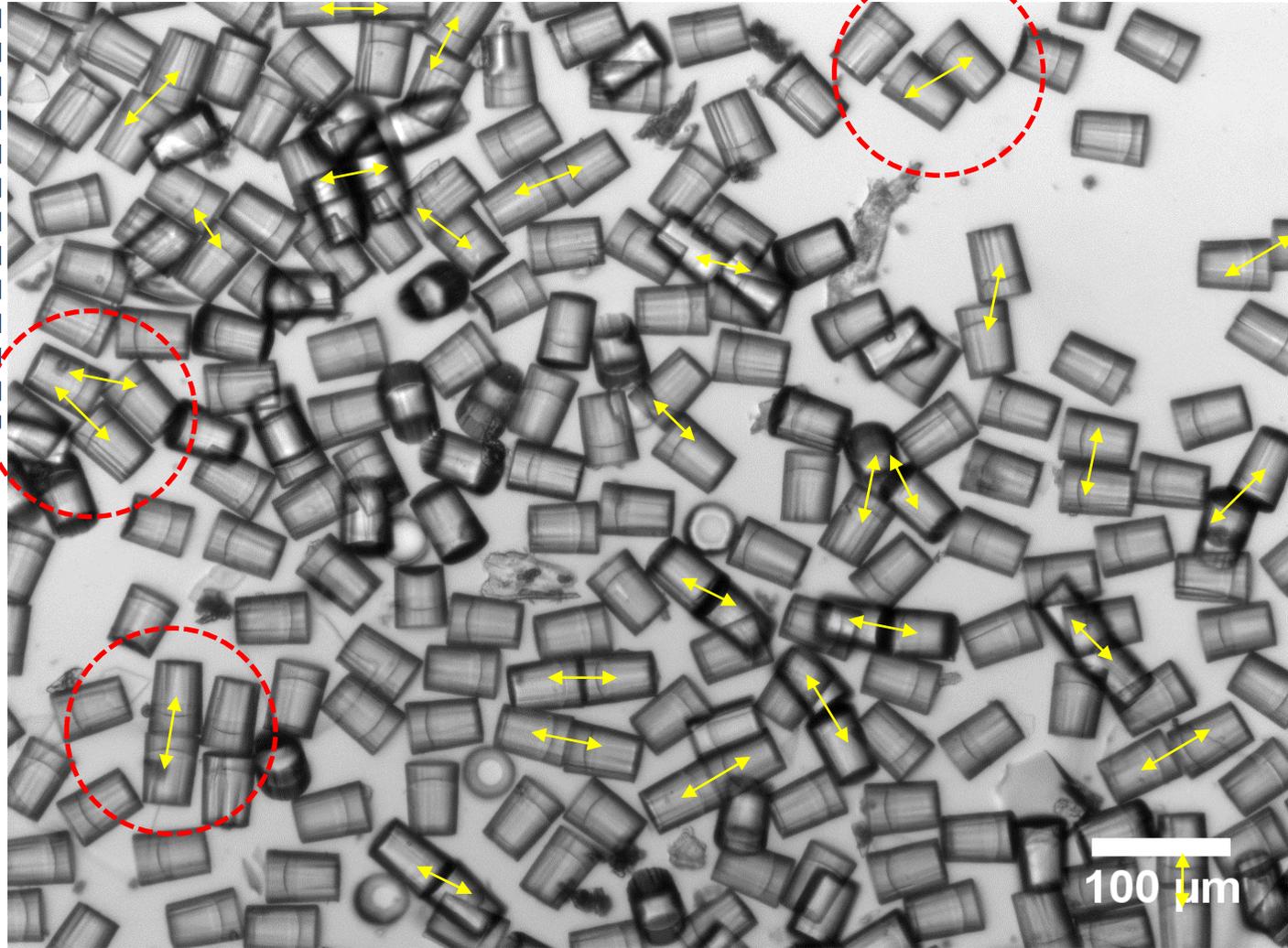
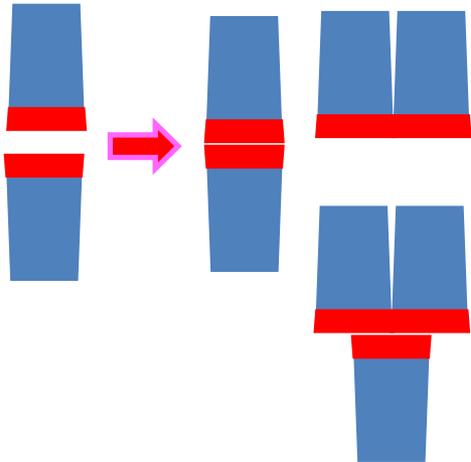
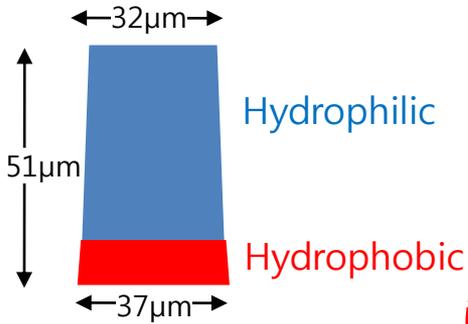


Smaller Janus particles for assembly

: Programmed assembly for Dimers

"Smaller microparticle"

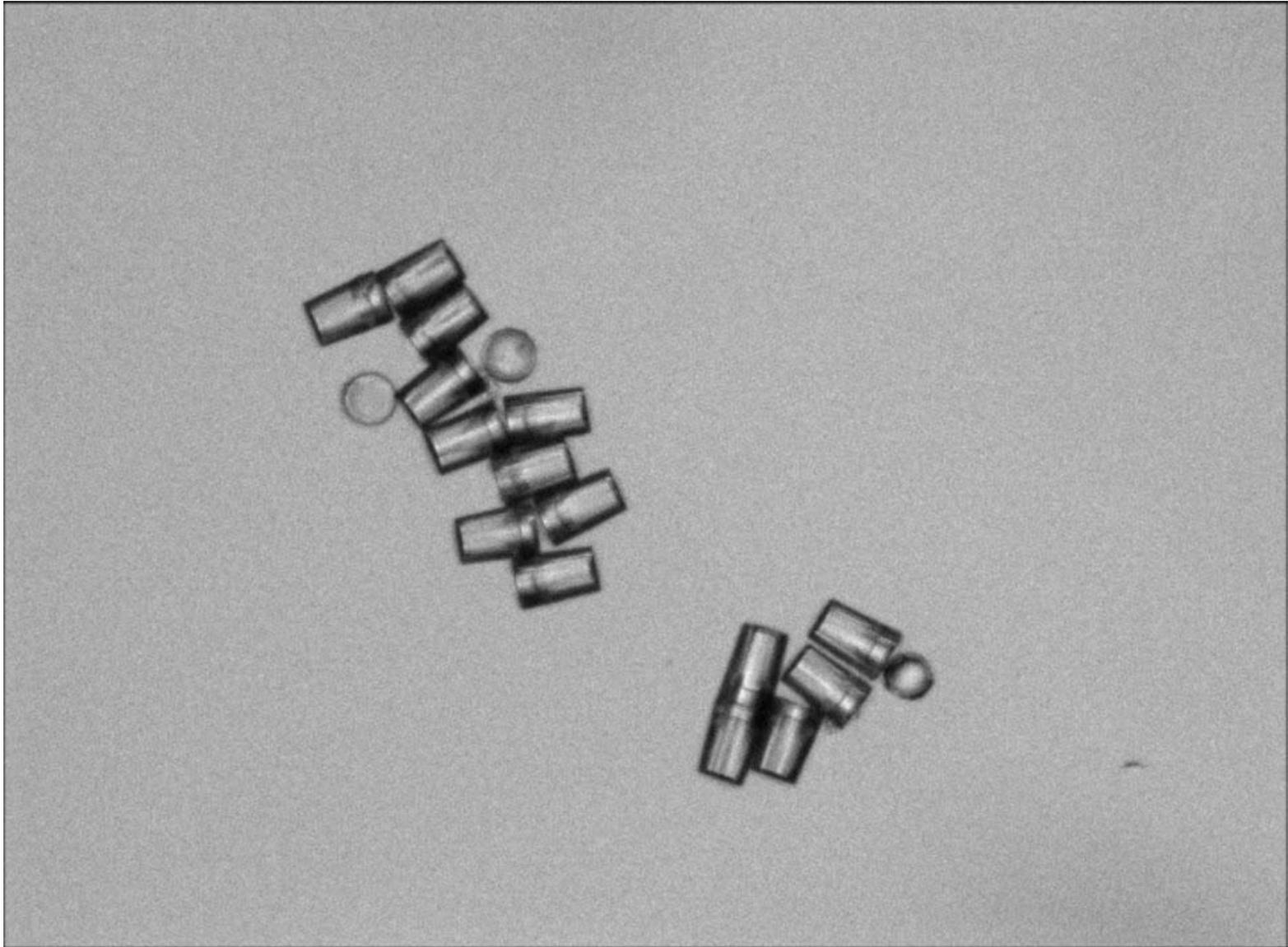
Building block



Dispersed in **water** (0.5% tween20 aq.)

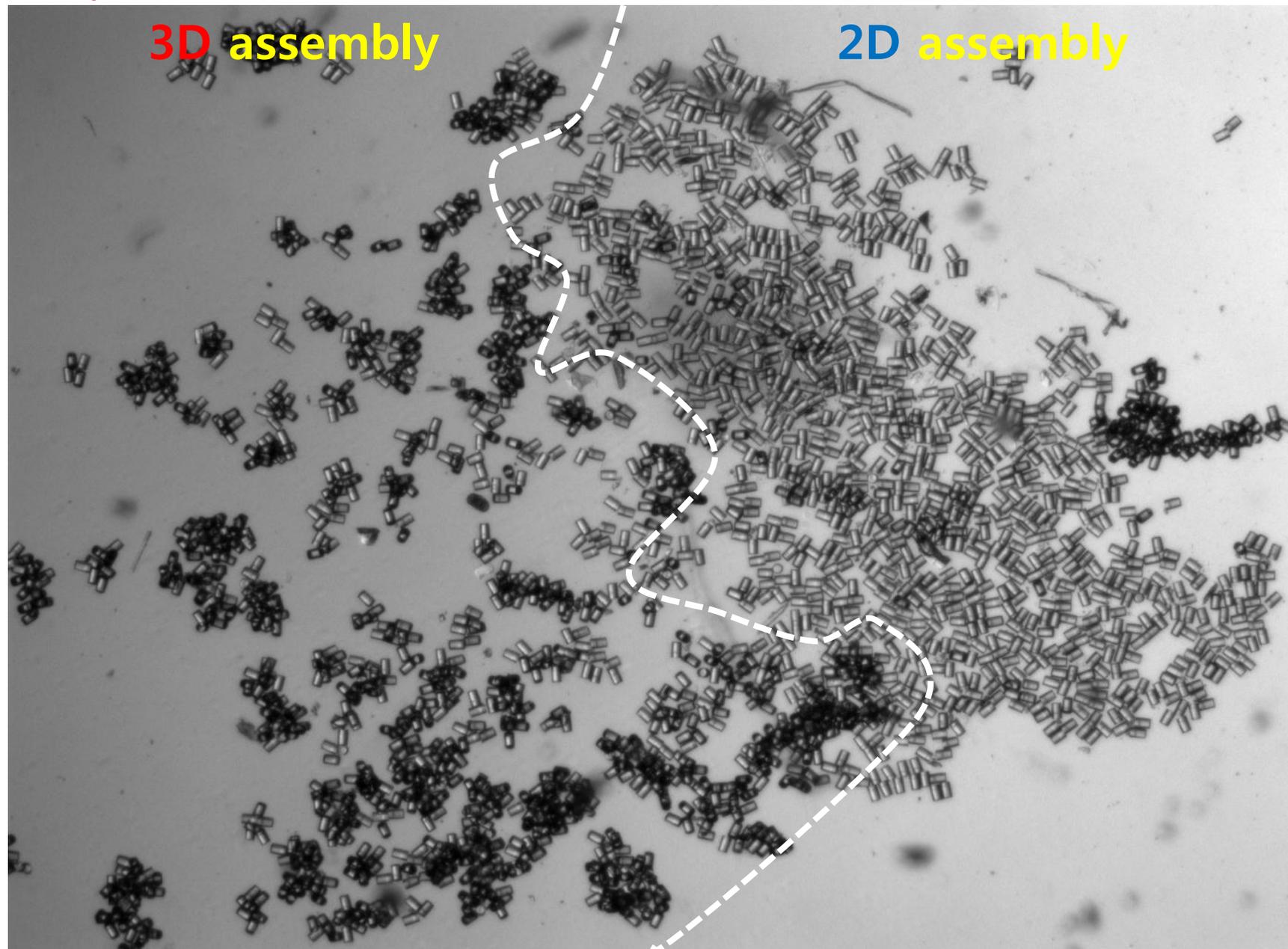
Movie for assembled cluster : Pseudo-bilayer

: Programmed assembly for Mimic of membrane



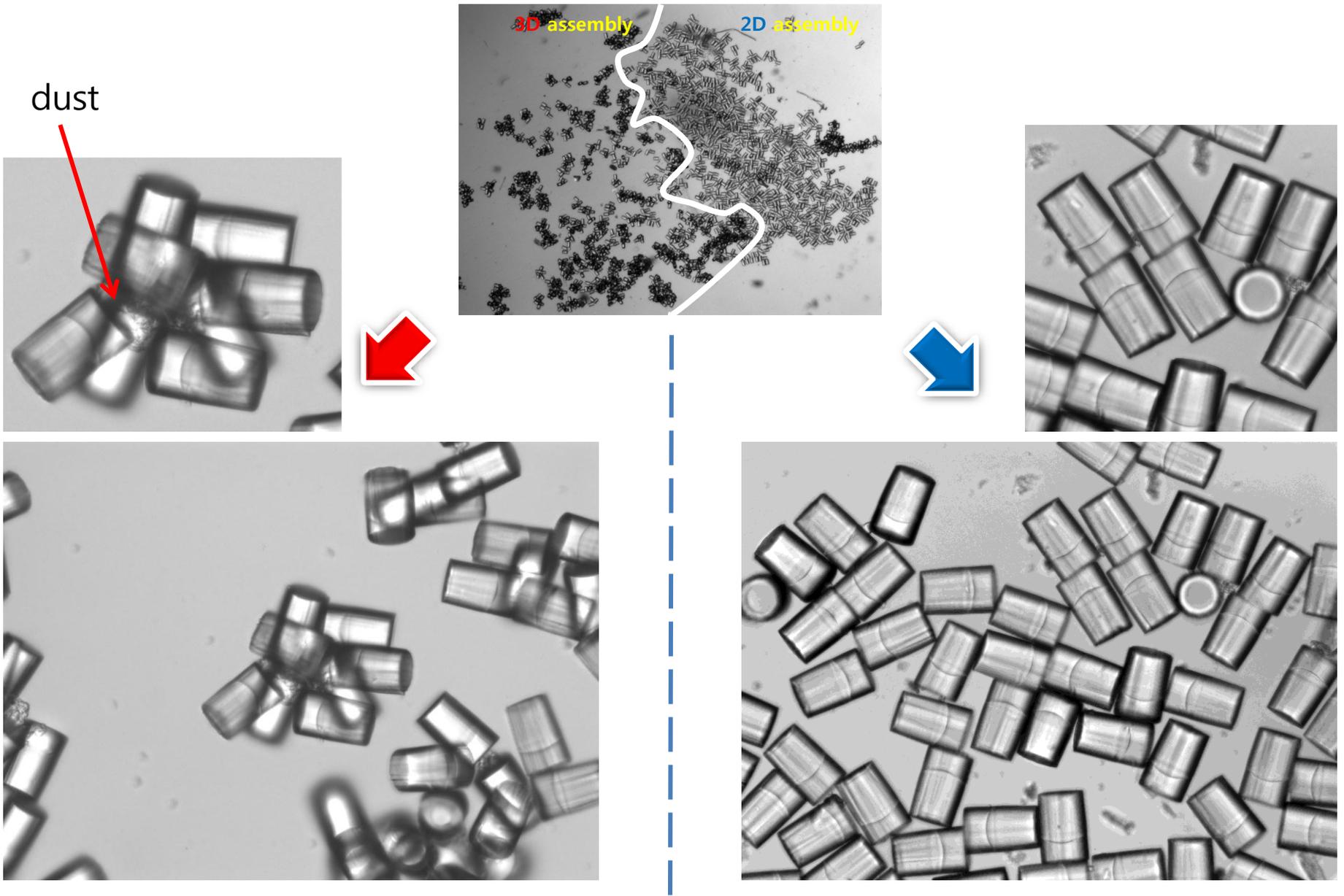
Experimental condition

: assembly of Janus particles



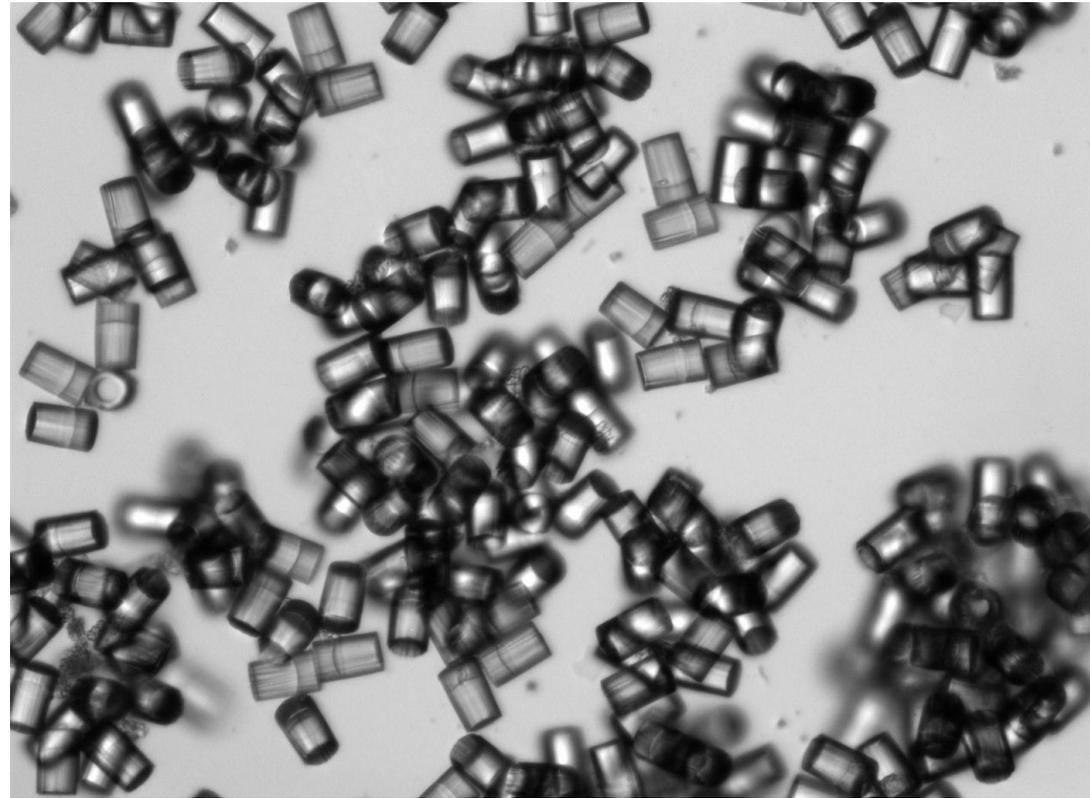
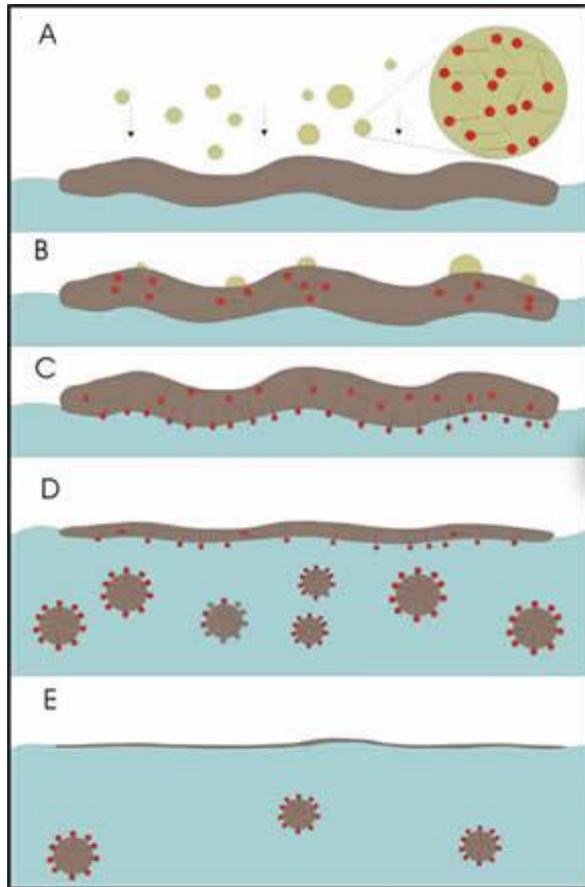
Experimental condition

:chemical composition



Particle based self-cleaning system

:analogy of micelle

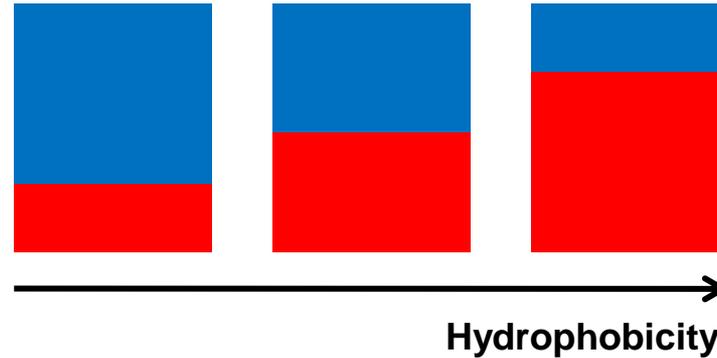


“Analogy of micelle consisting of surfactant molecules”
(particle-based self cleaning, new functional materials)

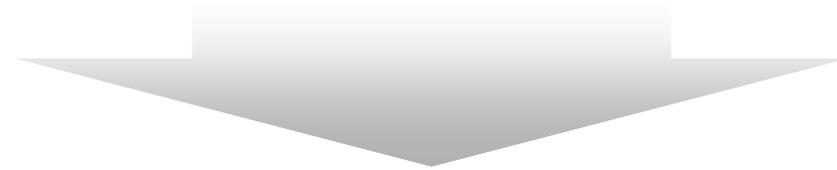
Micelle: self-assembly of surfactant molecule”

Ongoing work for assembly of Janus particle

 Hydrophilic
 Hydrophobic



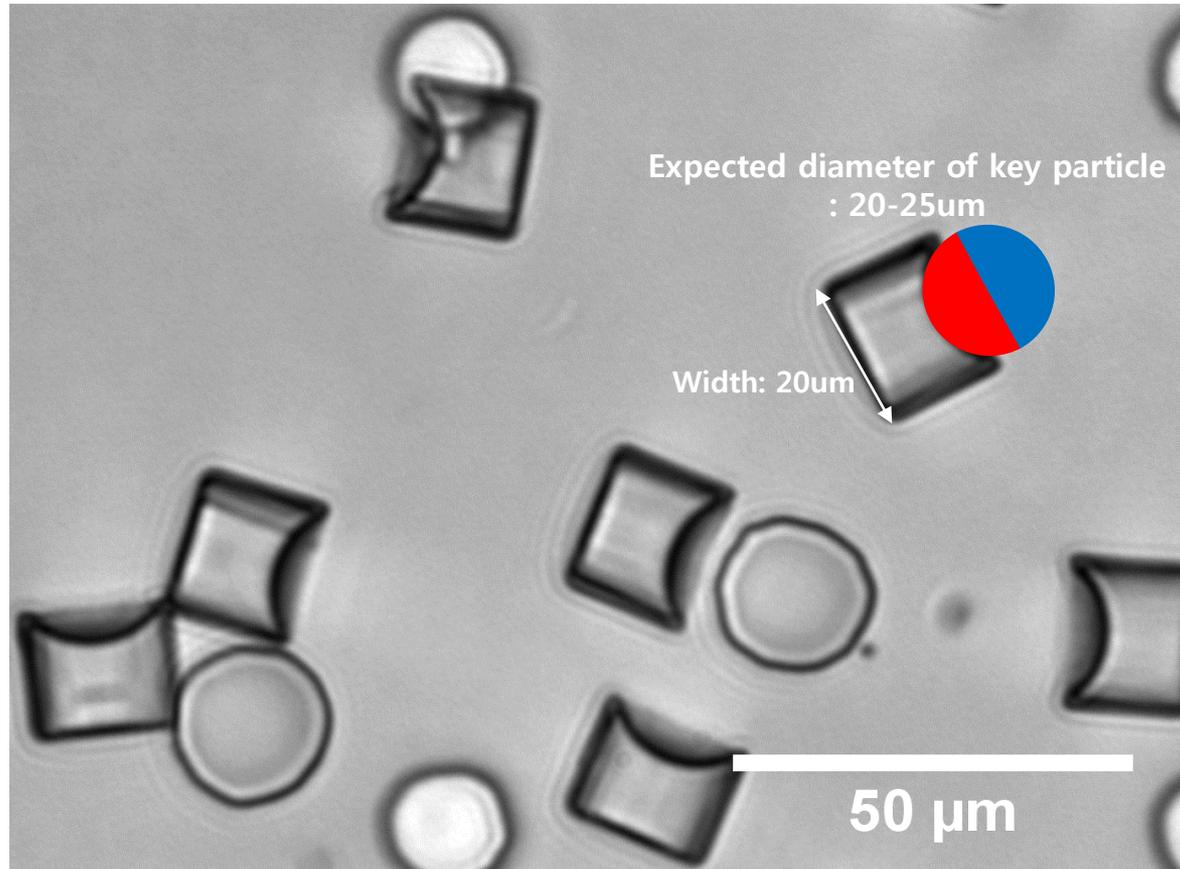
“Manipulation of hydrophobicity of the particles”



Control of configurations of self-assembly

Ongoing work for Lock and Key format

:Fabrication of Lock particle



Particle with Janus lock format fabrication will be setting up soon !!

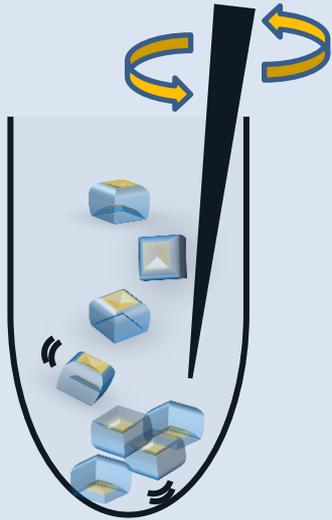
Justification for ISS

Justification for ISS

:Why microgravity?

Advantages of microparticles as building block

(e.g., Increase in complexity and anisotropy, easy to observe dynamics of assembly)



However,

In ground condition,

Mechanical agitation must be required

Estimated settling time for microparticle: < 10 sec (in water)

- Frequency of particle contact



“Microgravity environment” (ISS)

It supply the best conditions for self-assembly using only chemical/physical interaction without any external force.

→ Great challenging to find new way to synthesis novel functional materials

Proposed Experiment

Does the proposed hardware meet your science needs?

“simple observation, minimal involvement of astronaut”

1

Loading samples (particle suspension) into cells
(e.g., different volume fraction and various complex particles)

2

Initialization of samples
– Homogenization (well-dispersion)

3

Observe the sample using microscope with low magnification
(20X or 40x is enough to see dynamics of particles)

Requirement summary

- Sample description

Parameter	Requirement	Reference
Samples (materials)	- Microparticles made of TMPTA as hydrophobic monomer and PEG-DA as hydrophilic monomer, dispersed in water. Isooctyl acrylate and PETA also be used as co-monomer to increase in hydrophobicity of particles and crosslinker, respectively.	TMPTA: trimethylolpropane triacrylate PEG-DA: Polyethyleneglycol diacrylate PETA: Pentaerythritol tetracrylate
	- Janus particles with different properties (i.e., hydrophobic and hydrophilic), dispersed in water (i.e., disk shaped particle with two compartments having different functionality). (plan 1)	
	-A lock particles have single cavity, the other is spherical particle having region well-interacted with the cavity. Both are mixed together (particle cocktail), and used for self-assembly into lock and key format. (plan 2)	
	- A lock particles have single cavity, the other is spherical particle having regions well-interacted with a lock particles. Both are mixed together (particle cocktail), and used for self-assembly into lock and key format (analogy of multivalent ligand). (plan 3)	
Particle size	- Sizes between 5 μm and 50 μm .	
Volume fraction	- Between 0.3 and 0.7 -The particles should be closed as much as possible for effective assembly by attraction force	

Requirement summary

- Optical imaging

Parameter	Requirement	Reference
Visual camera images	- High magnification, high-resolution color visual images for showing motion of particles and steps of assembly.	
	- Field of view ranging from 100 μm x 100 μm up to 1 mm x 1 mm for small sample cells.	
	- Video recorded (5 fps)	
Bright field	-illumination to monitor behavior of the microparticles	
Objective lenses	- Chosen to allow range of field of views, from about 100 μm to 2 mm.	
	- Recommended choice: 10x, 20x, 40x, 50x, and 63x	

- Homogenizer

Parameter	Requirement	Reference
Homogenizer	Be able to homogenize samples one at a time.	
	The particle should be dispersed (separated).	

Requirement summary

- Sample Cell Requirements

Parameter	Requirement	Reference
Cell	- Prefer to use of supplying quartz cell	
Number	-About 20 samples with different conditions (2 launches of an 1 disk for the S. Korea PI).	
Volume	-About 0.5cc in each well in a disk (prefer use of supplying quartz cell).	

- Data (Storage) Requirements

Parameter	Requirement	Reference
Data (Storage) Requirements	<p>Behavior of microparticle should be monitored by time-lapse as follows.</p> <ol style="list-style-type: none">1. Evenly distributed particles, initially2. Particles become closed for attractions,3. Assembled particles4. Behavior of assembled particles	

Requirement data/ Test matrix

Sample no.	Sample type	Day no.	General description of test	Manipulation, diagnostics, and acquisition rate	Test procedure: Sequence and approx. time taken	Acquisition frequency
#1 - #3	Janus particles with different functionality (i.e., hydrophobic and hydrophilic), dispersed in water volume fraction 0.3-0.7 (sequentially numbering sample from #1 to #3) -Plan 1	1	Homogenize samples first Record the step of self-assembly. (time lapse)	Each sample is individually homogenized and observed with 10x lens to assure that particles are evenly distributed. Samples no. from #1 to #10 (at different volume fraction) are allowed to assemble for a day Time-lapse imaging of samples during self-assembly.	1) Each sample (particle suspension) is individually homogenized and observed with 10x lens to identify whether they are evenly distributed. [5min/sample, until the particles are fully separated] 2) Observe the steps for assembly procedures. 3) Estimate the rate of assembled particles after 1day. [non-assembled particles will be counted] Total time: 1day/experiment	5 min/sample
#4 - #10	One is particles having single hemispherical cavity, the other is Janus spheres or solid spheres (Mixture of two types of particle) -Plan 2 and 3 volume fraction 0.3-0.7 (#4 to #10)	1	Homogenize samples first Record the step of self-assembly. (time lapse)			5 min/sample

Success criteria

5.11.1 Complete Success Criteria :

Complete success is that chemically programmed microparticles as building block would be assembled by attraction force. (Probability of assembly is **above 70%**) It means that highly complex microparticles would be made by various assembly regimes we suggested (e.g., dimer, lock and key formation). We could find and establish a new assembly configurations using microparticle with anisotropic shapes in microgravity environment.

5.11.2 Significant Success Criteria

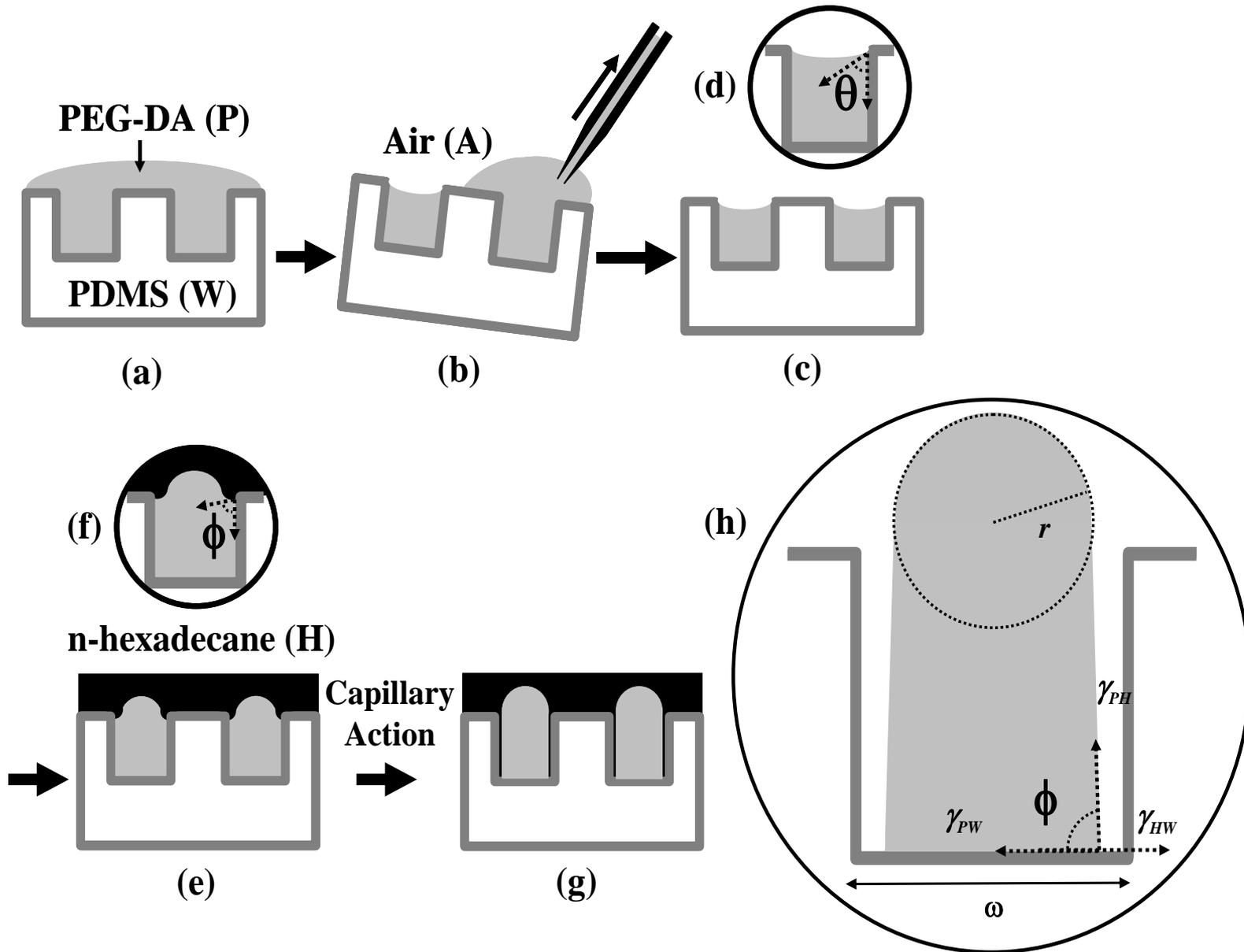
Significant success would be realized if all plans were showing possibility, but not fully accomplished. (Probability of assembly is relatively **around <50%**) Half of assembly was observed, while extra particles are moving solely because of lack of attraction forces (i.e., hydrophobic interaction).

5.11.2 Minimal Success Criteria

While all plan were accomplished, the success rate of assembly is **around 30-50%**.

Supplementary information

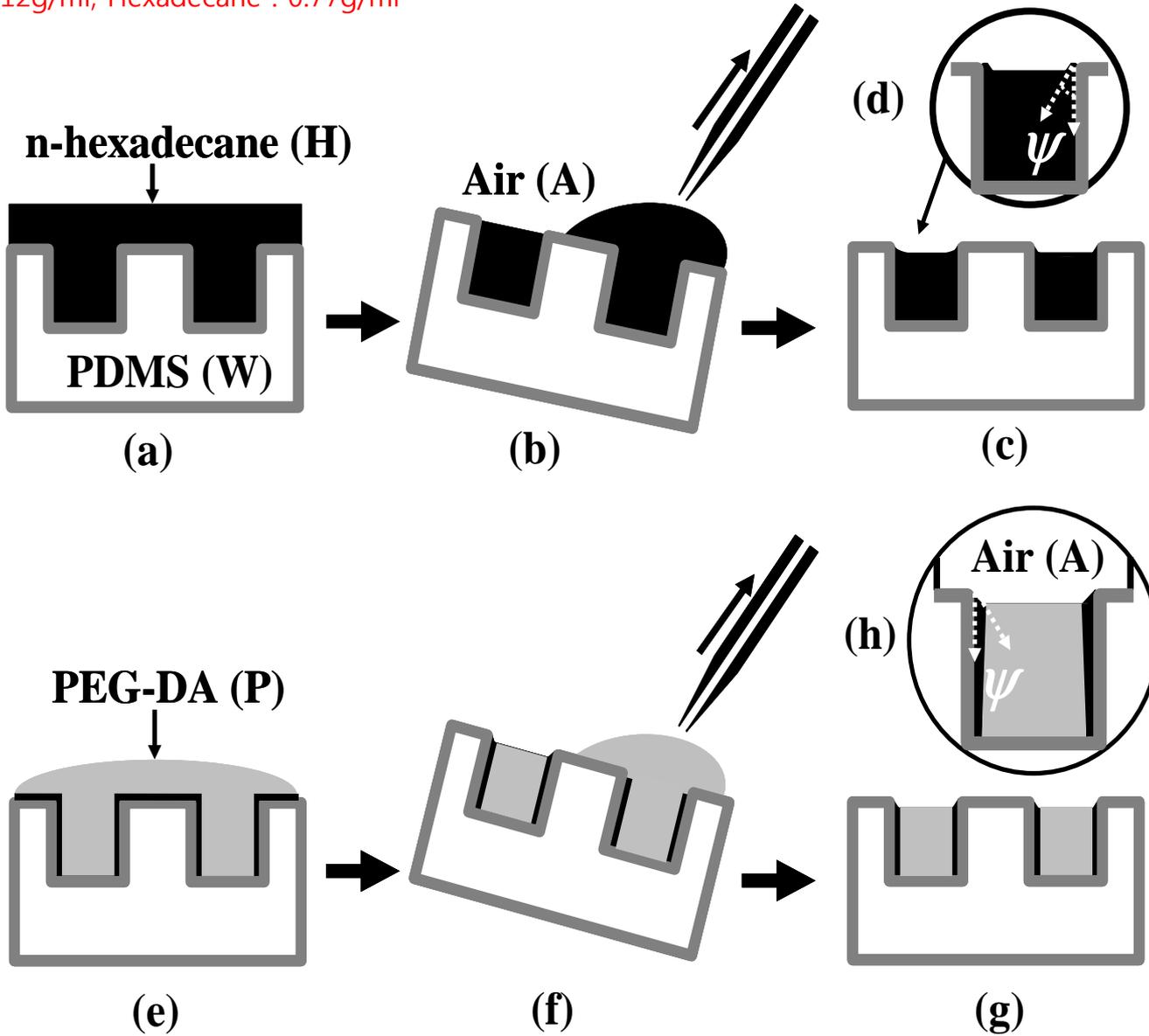
Schematics (Sequence A) : *PEGDA first, Hexadecane later*



Schematics (Sequence B) : *Hexadecane first, PEGDA later*

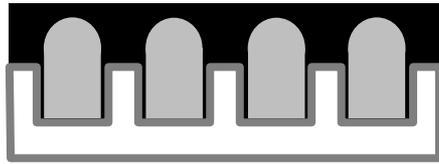
Density

PEGDA : 1.12g/ml, Hexadecane : 0.77g/ml



SEM image : particle array

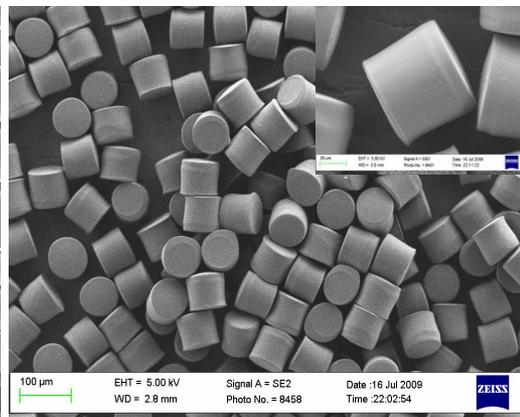
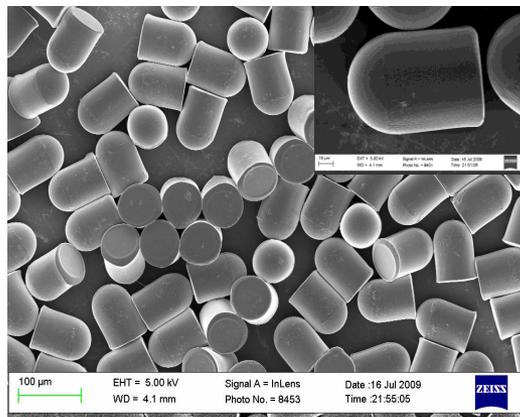
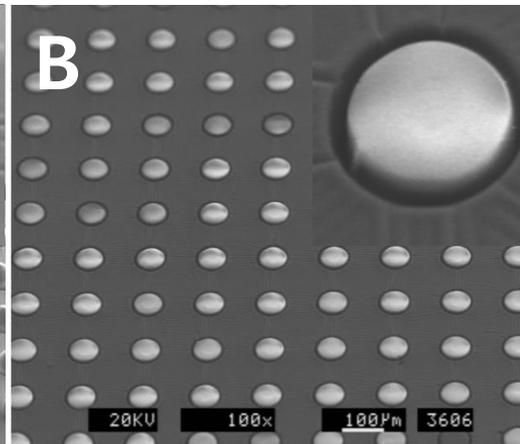
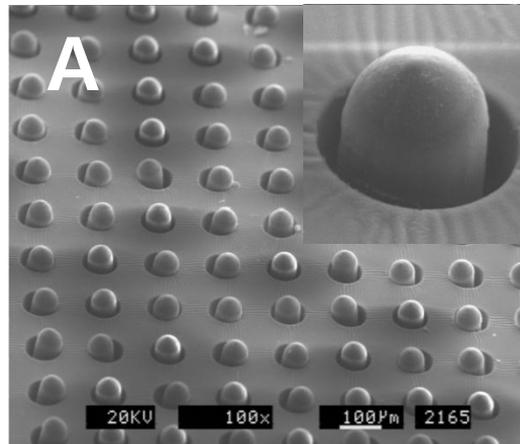
"Monomer first, Hexadecane later" / "Hexadecane first, Monomer later"



Sequence A



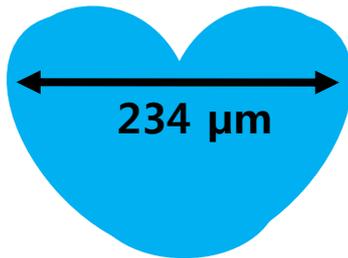
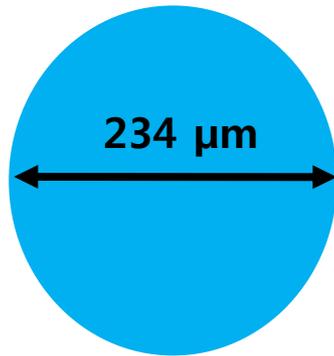
Sequence B



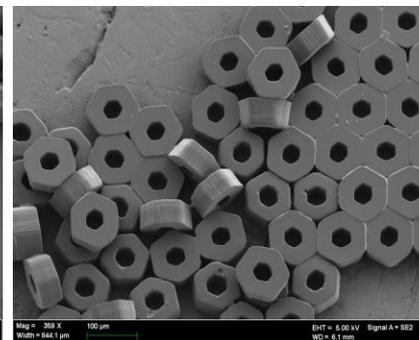
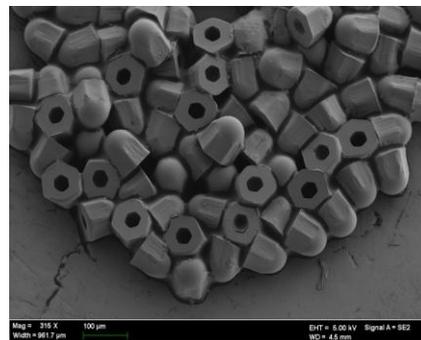
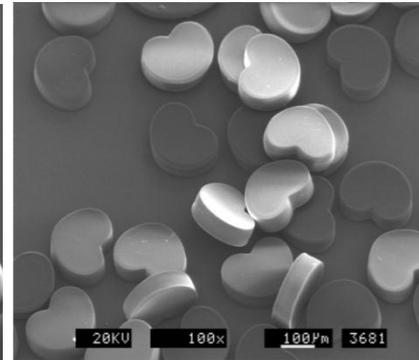
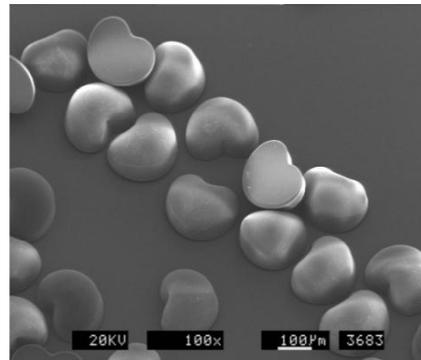
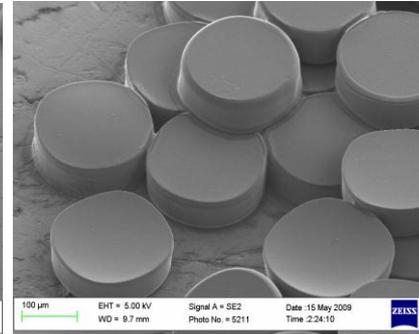
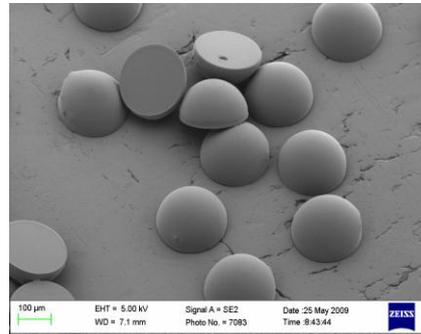
SEM image : complex particles

Sequence A

Sequence B



100 μm



SEM image : complex particles

Sequence A

Sequence B

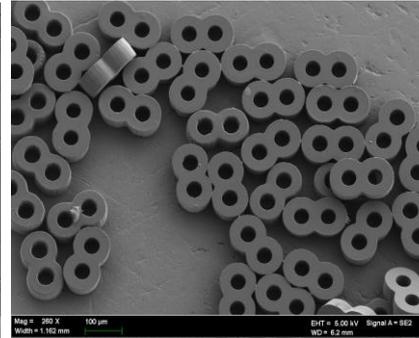
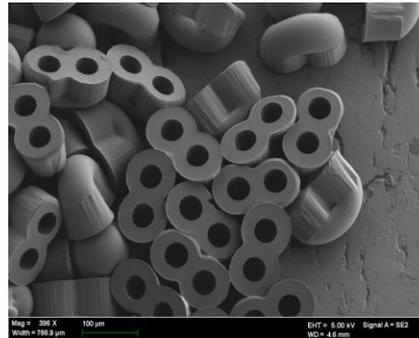
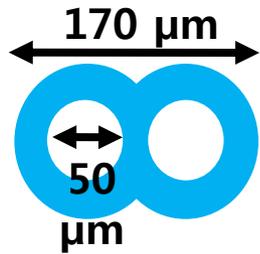
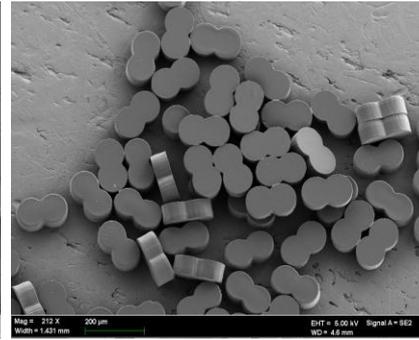
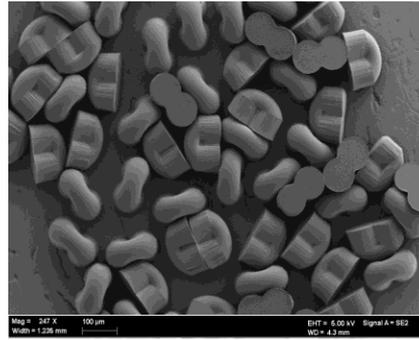
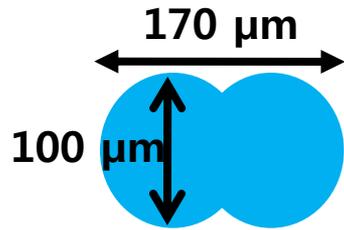
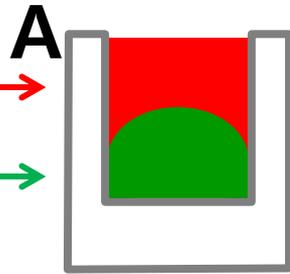


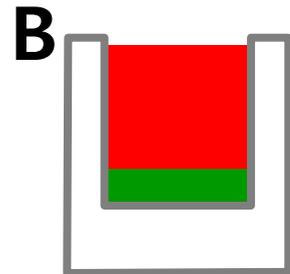
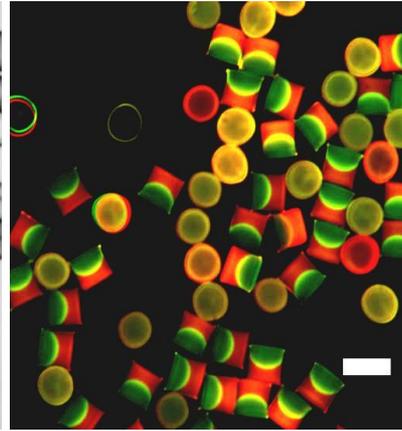
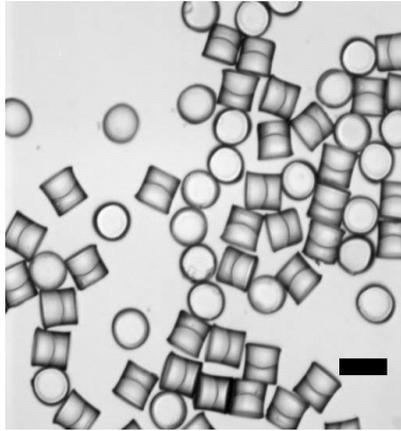
Illustration Optical image Fluorescence image

100% TMPTA
(Hydrophobic)

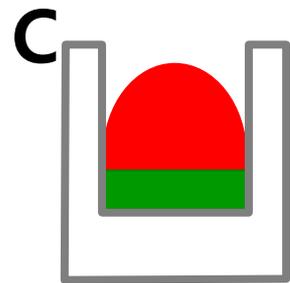
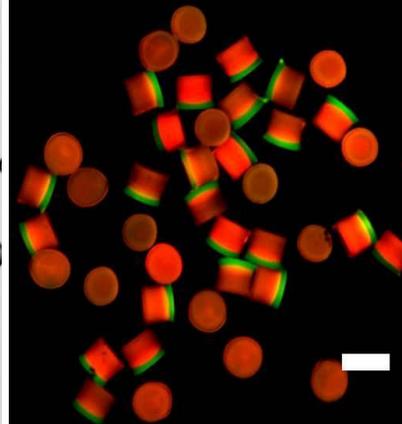
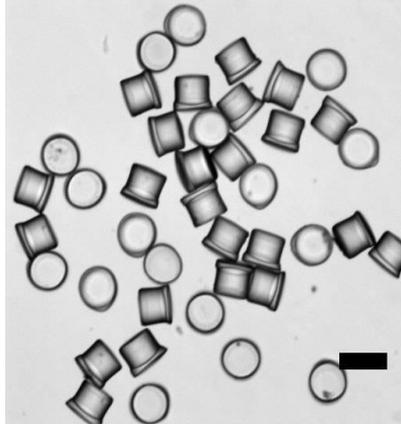
50% PEGDA
:50% MeOH
(Hydrophilic)



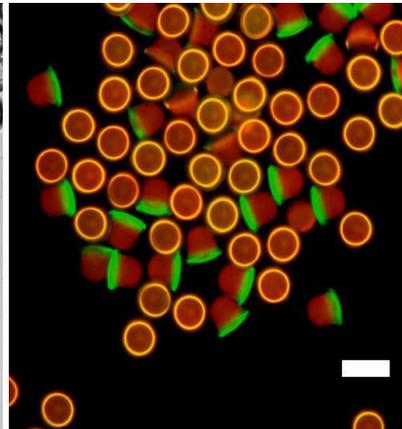
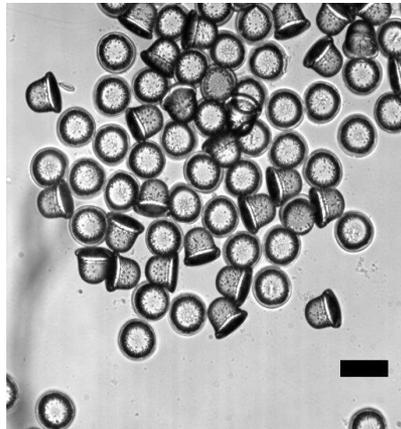
$S_A + S_B$



$S_B + S_B$



$S_B + S_A$



Scale bar :50 μ m