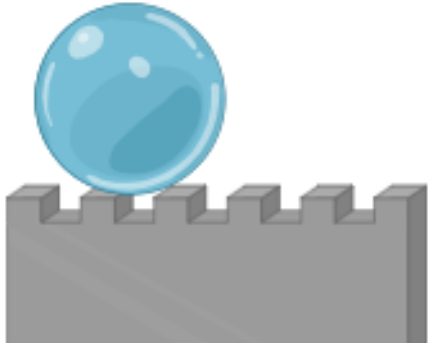
The Petroleum and Petrochemical College, Chulalongkorn University

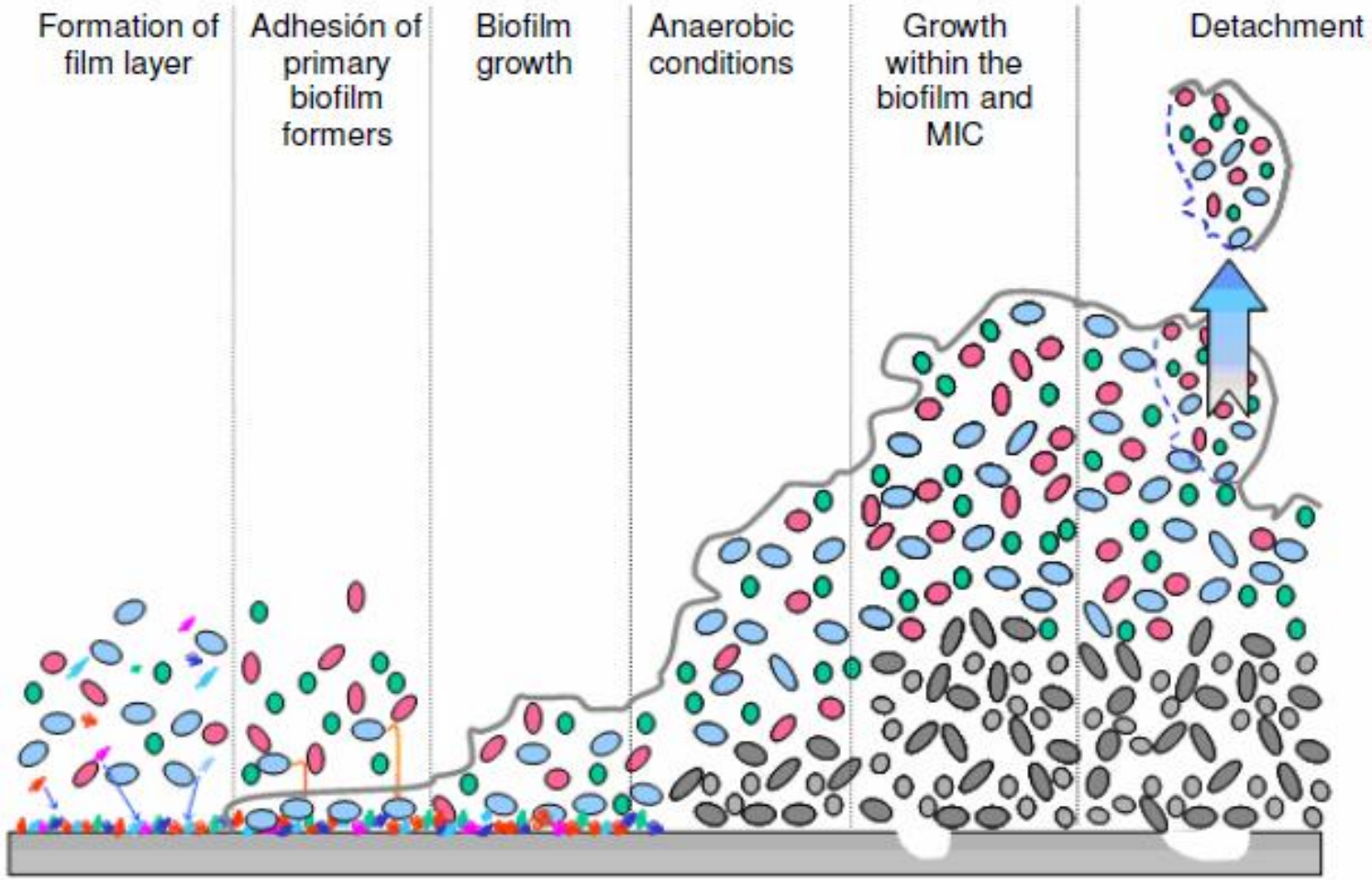
Development of blended PDMS/PU biomimetic microstructure for marine application

Presented by

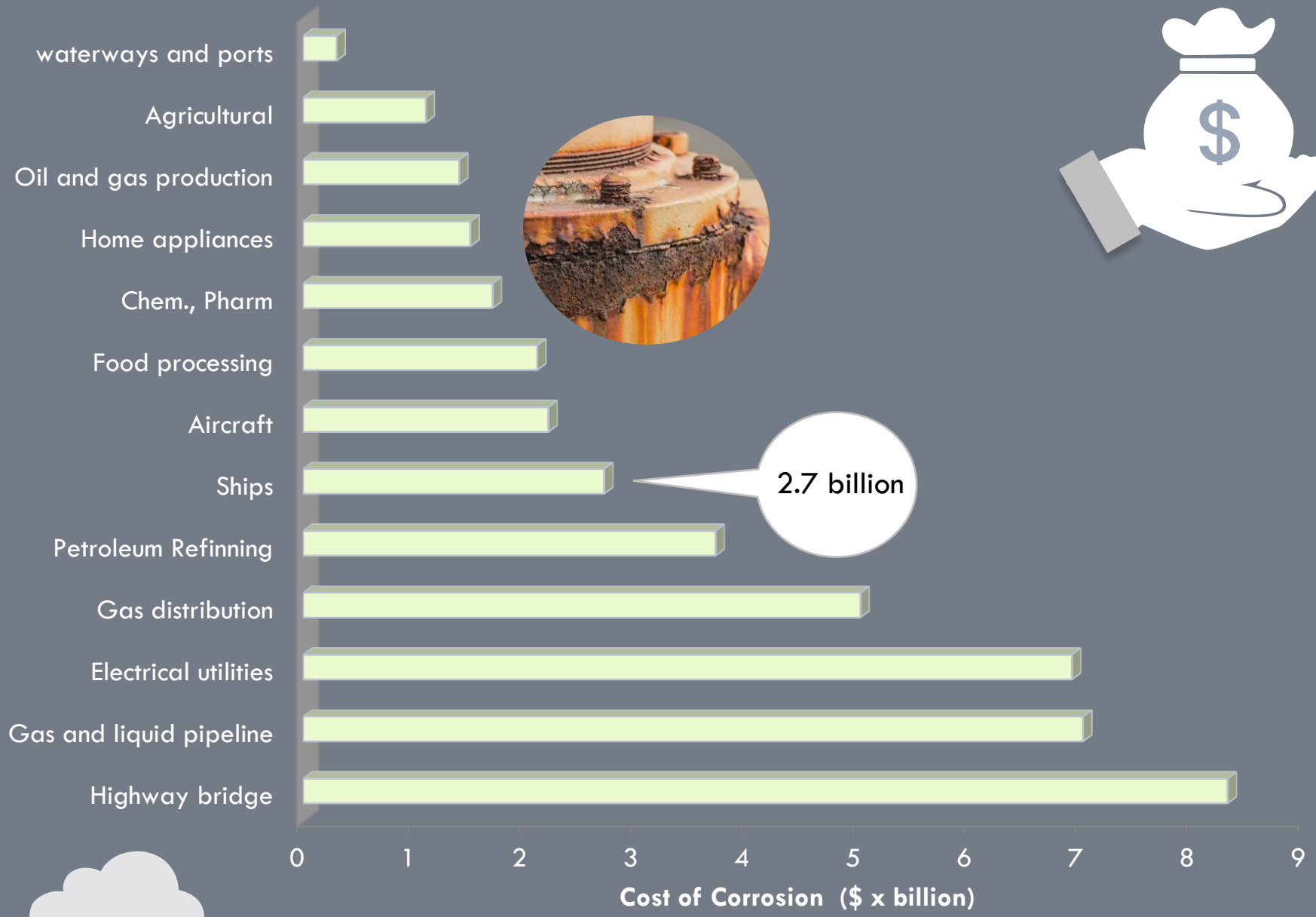
Asst. Prof. Manit Nithitanakul, Ph.D.



Biofouling Process



Ref: Blanco 2003: Charackisand Cooksey 1983



Corrosion costs and preventive strategies in the United States.

The Global Cost of Corrosion

$2.5 trillion

Ships: The total cost of corrosion to the U.S. shipping industry is estimated at $2.7 billion. This cost is divided into costs associated with new construction ($1.1 billion), with maintenance and repairs ($0.8 billion), and with corrosion-related downtime ($0.8 billion).

Biofouling on ship resistance and powering

Loss of
Time, Money and
Energy

Predictions of the change in required shaft power with average coating roughness (Rt_{50}) and fouling conditions at a speed of 15 knots

Ref: Schultz , 2007

Description	Rt_{50} (µm)	Increase in power at 15 kn
Hydraulically smooth surface	0	-
Typical as applied AF coating	150	2%
Deteriorated coating or light slime	300	11%
Heavy slime	600	21%
Small calcareous fouling or weed	1000	35%
Medium calcareous fouling	3000	54%
Heavy calcareous fouling	10000	86%

Anti-fouling:

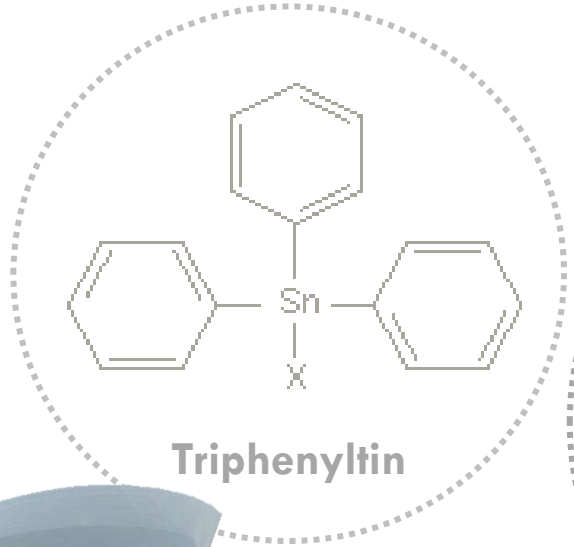
is the process of preventing accumulation from forming

- Biocides
- Non-toxic coating
- Etc.

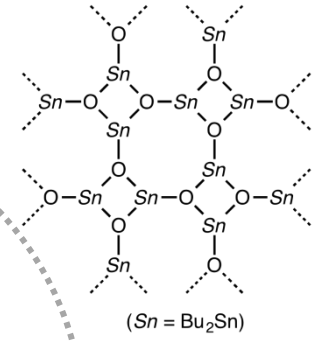
Biocides

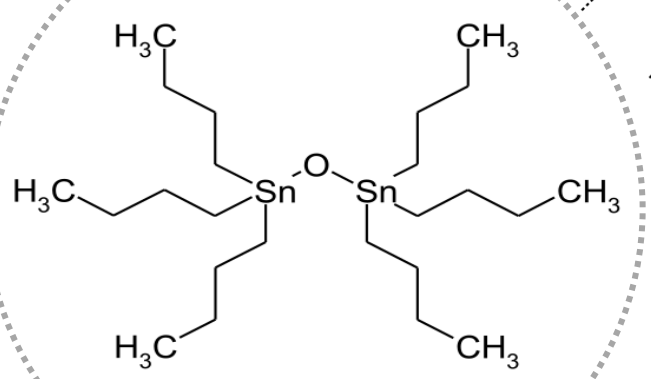
Highly Toxic

to non-targeted aquatic organism



Triphenyltin





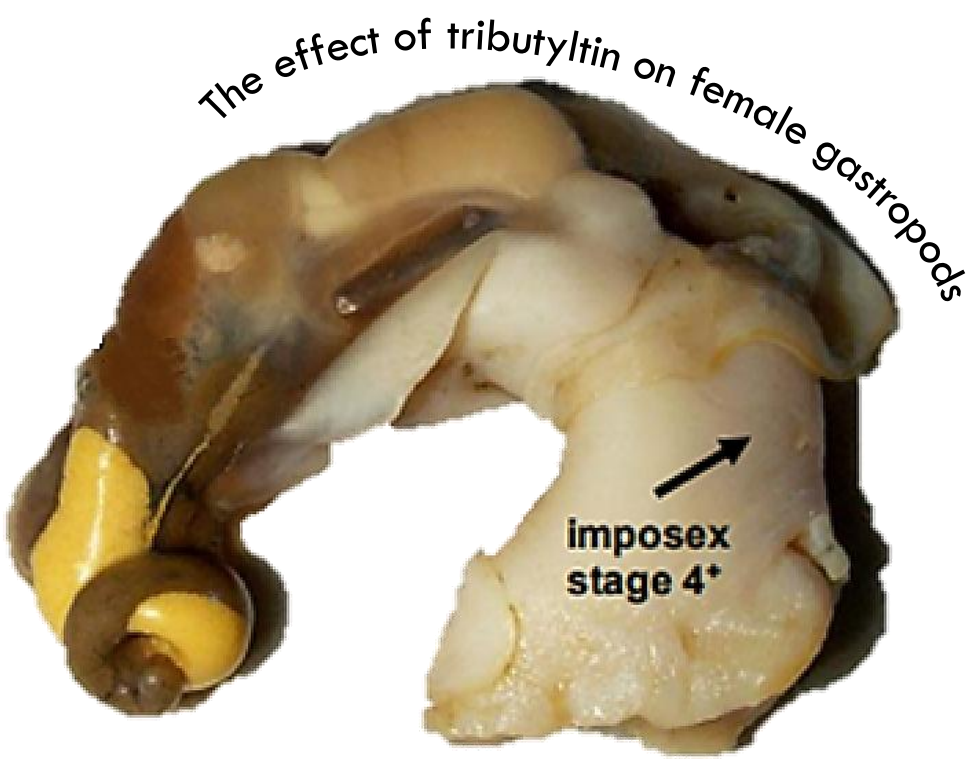
Tributyltin (TBT)

It is able to accumulate in and even contaminate the aquatic environment as well as cultivated land and remain unchanged for year

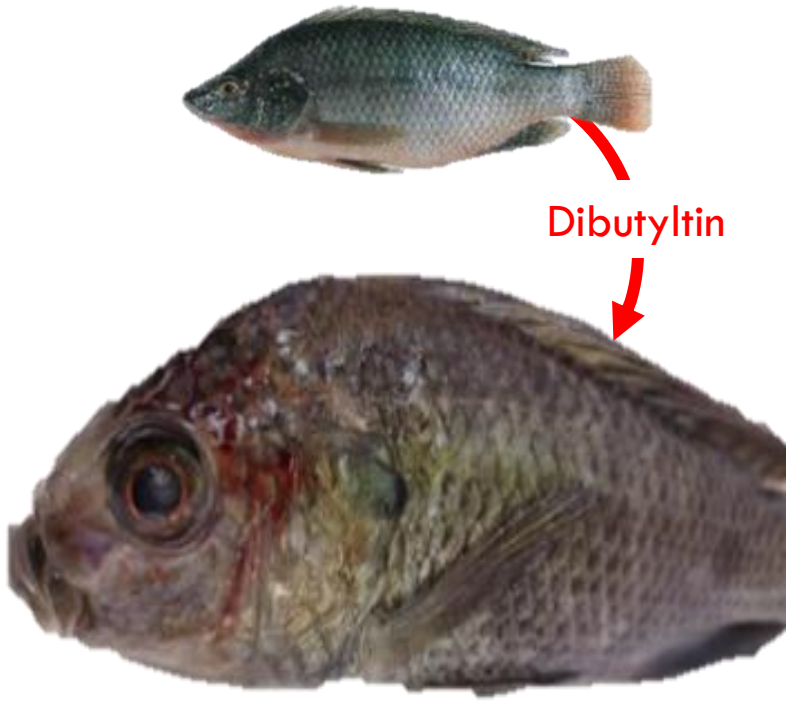
Toxicity

to non-targeted aquatic organism

- Imposex
- Malformations
- Changes in the normal biochemical and physiologic aspects



Ref: Magnusson and Strand, 2017



Ref: Ghais and Bhardwaj, 2019

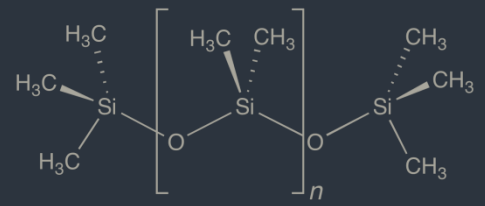
Non-toxic coatings

Nontoxicity

Low surface energy

Good thermal stability

Low cost



PDMS

Polydimethylsiloxane

but

Poor Mechanical properties

How to improve polymer properties

Blending

Processing method

- Easy to process

Processing time

- Less time

Capital cost

- Low cost

Synthesis

Processing method

- Difficult to process

Processing time

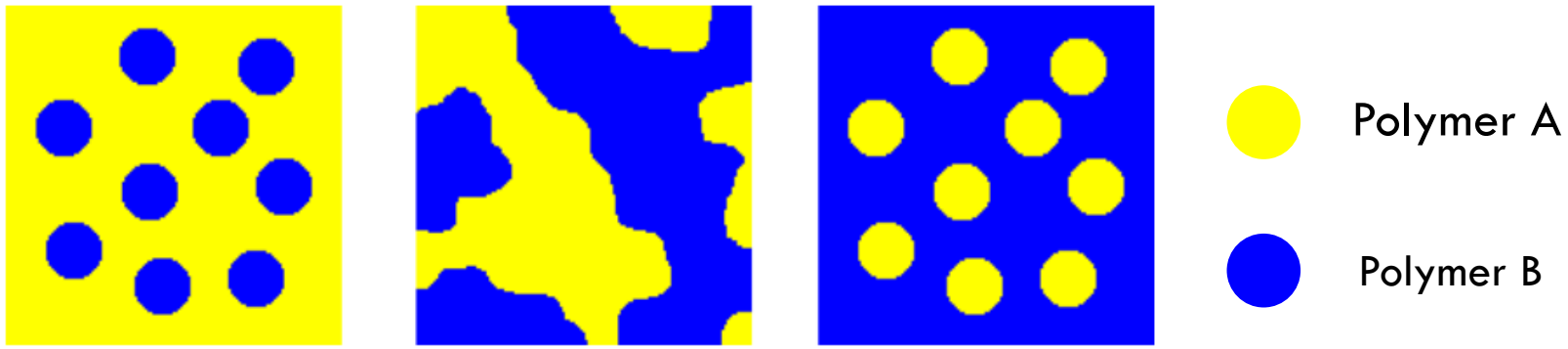
- More time

Capital cost

- High cost

Polymer Blend

Polymer blends are physical mixtures of two or more polymers with/without any chemical bonding between them

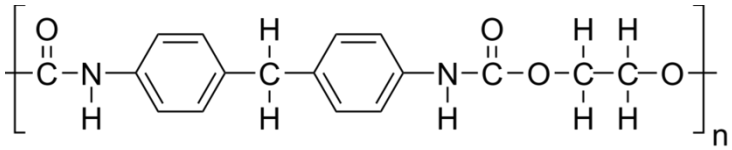


Advantages:

- Low cost
- Improve mechanical properties
- Improve thermal properties
- Processability

How to improve polymer properties

Polymer Blend



Polyurethane: PU

- Good Mechanical properties
- Good Thermal properties
- Nontoxic
- Durability to coating
- Resistance UV radiation

Experimental

Preparation of PDMS/PU Blend

Preparation

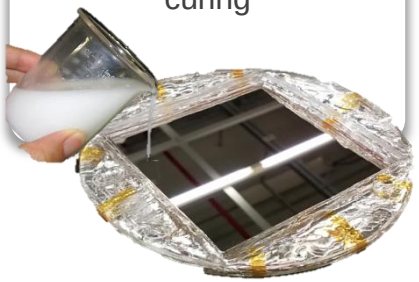
Prepared pure Polydimethysiloxane (PDMS) and pure polyurethane (PU) part A/B using magnetic stirrer at 100 rpm

Blending

PDMS was blended with PU (vary PU content), using magnetic stirrer at 100 rpm

Degasing

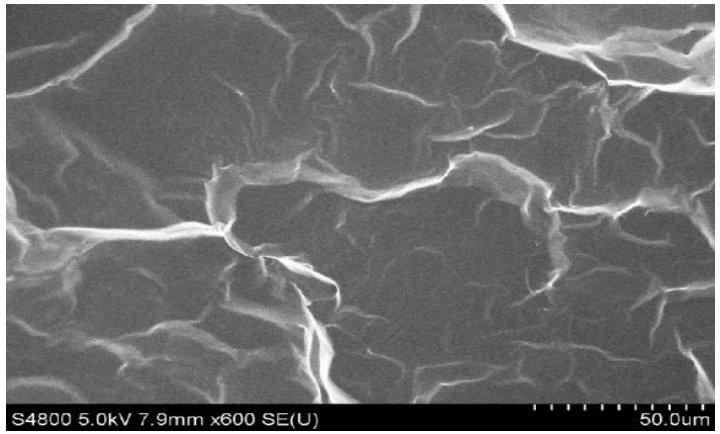
PDMS/PU blend was degassed using a vacuum pump before curing

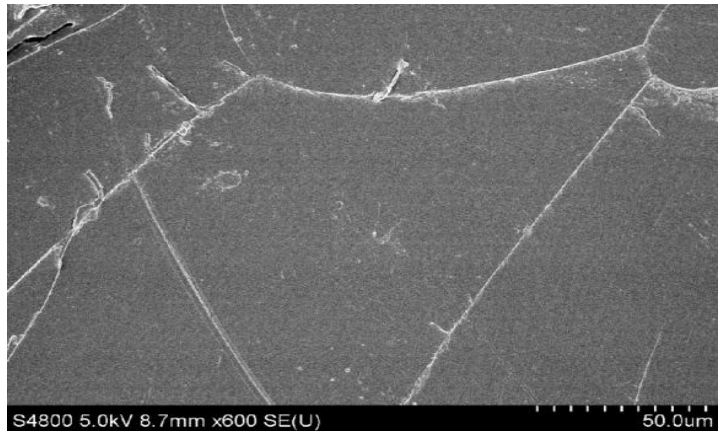


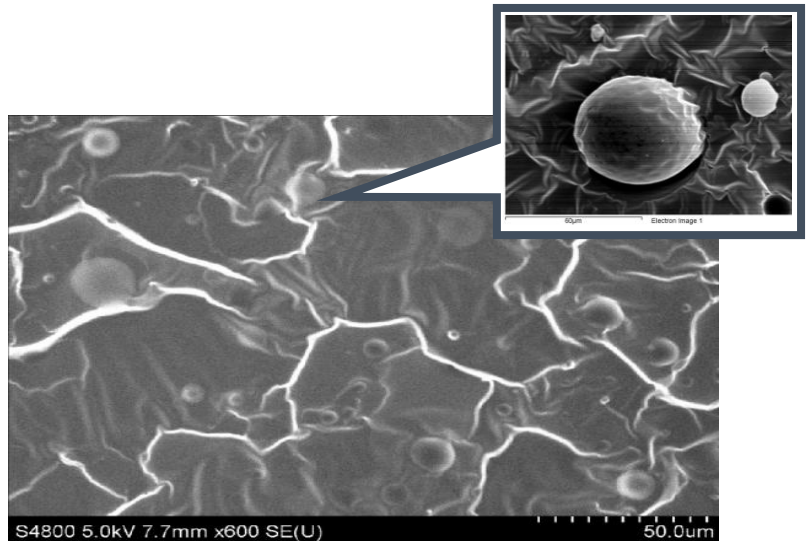
Cured

PDMS/PU blend was cured in an oven at 60°C

SEM-EDX







Element	PDMS		PU		PDMS/PU Blend	
C	24.30	38.82	66.05	72.16	53.47	68.58
O	18.35	22.00	33.95	27.84	14.24	13.72
Si	57.35	39.18	0	0	32.29	17.71
	Weight%	Atomic	Weight%	Atomic	Weight%	Atomic

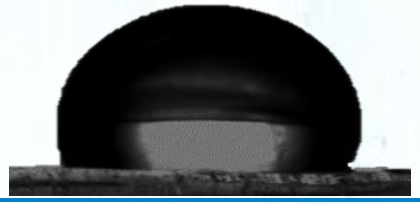
In the minor phase which is PU, it was observed that carbon weight % was decreased from 66.05 to 53.47 and silicon weight % on the surface of the samples increased from 0 to 32.29%. The results indicated that PU was dispersed in the PDMS/PU blend.

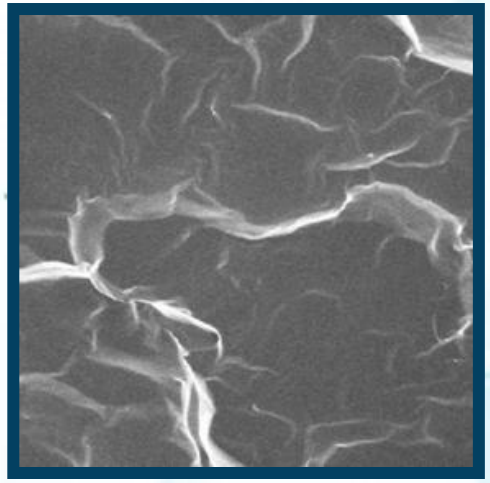
Contact Angle

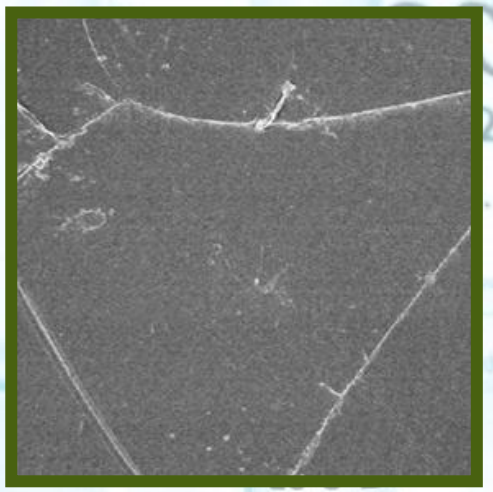
The hydrophobicity of the surface of blend PDMS/PU polymers' film was investigated by water contact angle measurements (WCA > 90°).

PDMS

109.5 ° ± 0.3 °

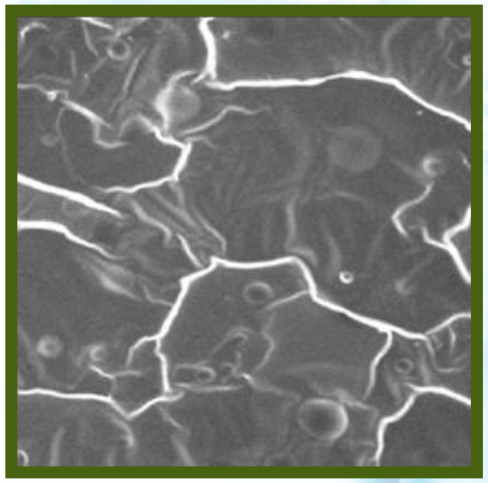






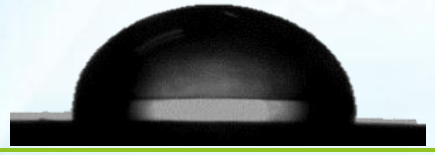
PU

88.1 ° ± 0.7 °



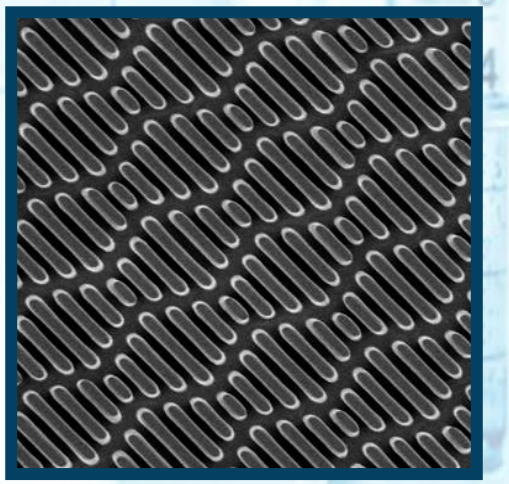
PDMS/PU Blend

95.6 ° ± 0.3 °



PDMS/PU pattern

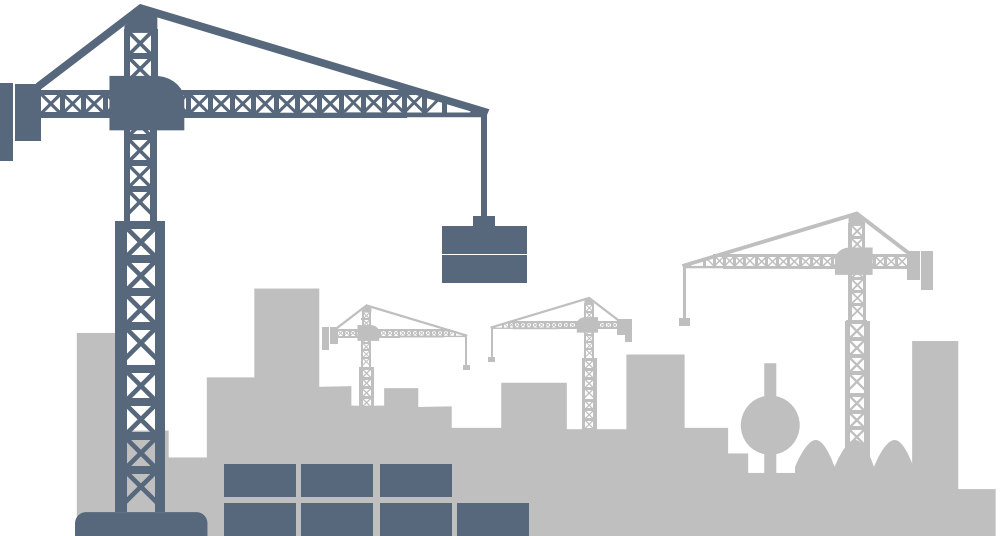
128.8 °± 1.6 °

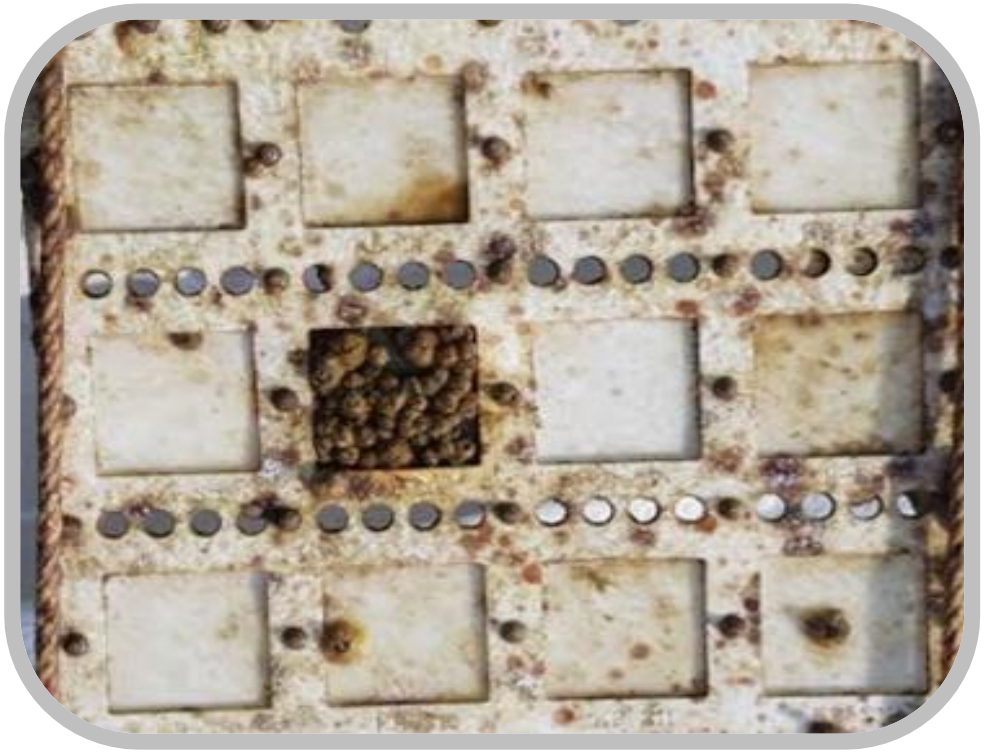


x600

Barnacle Attachment on PDMS/PU

PDMS/PU samples were tested in sea water at Aquatic Resources Research Institute, CU





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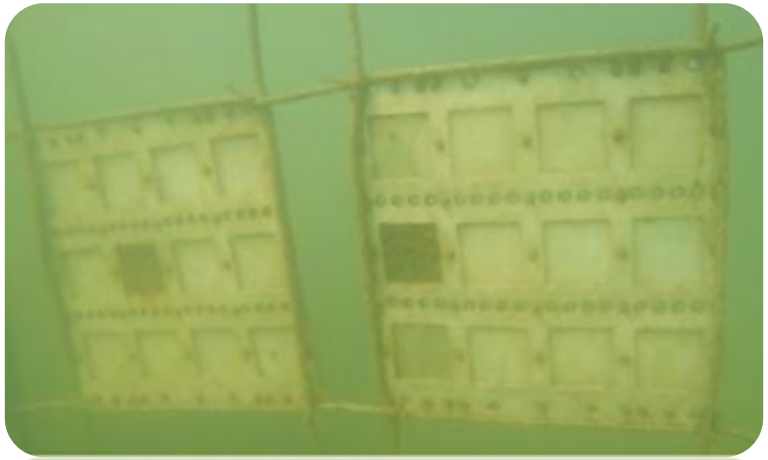
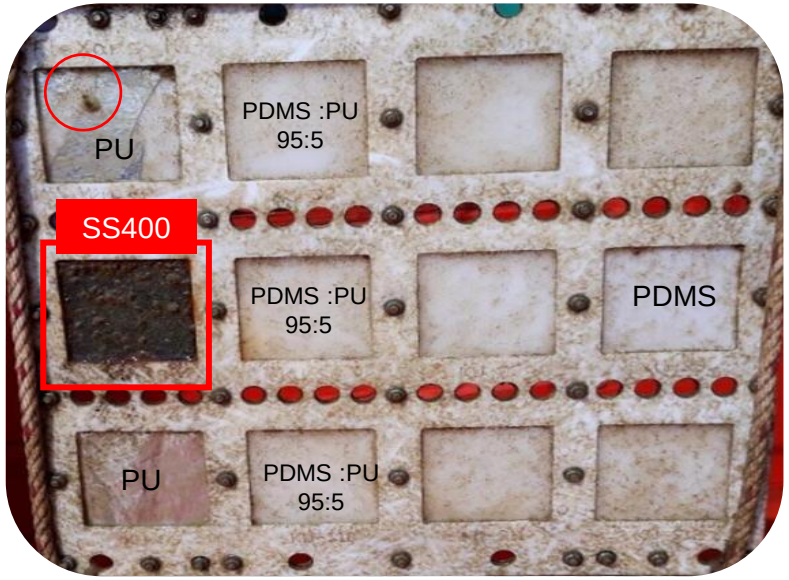


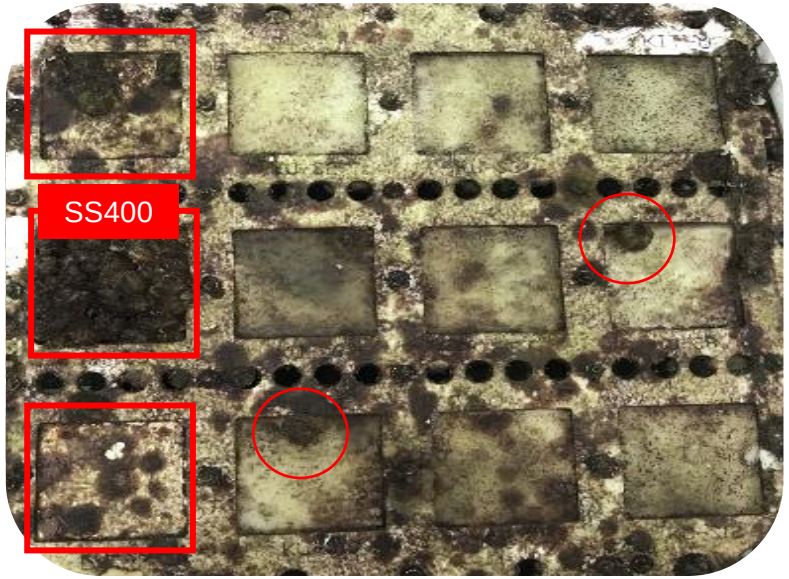
Barnacle attachment on PDMS/PU

2 Week



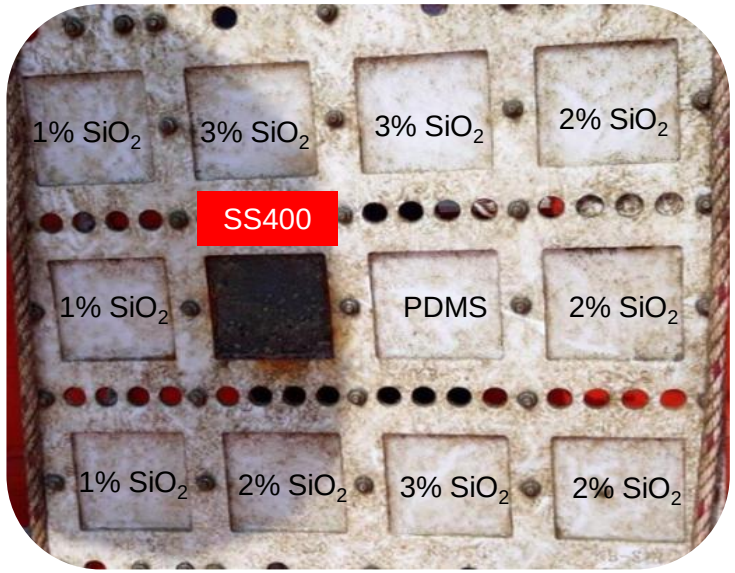
4 Week

8 Week

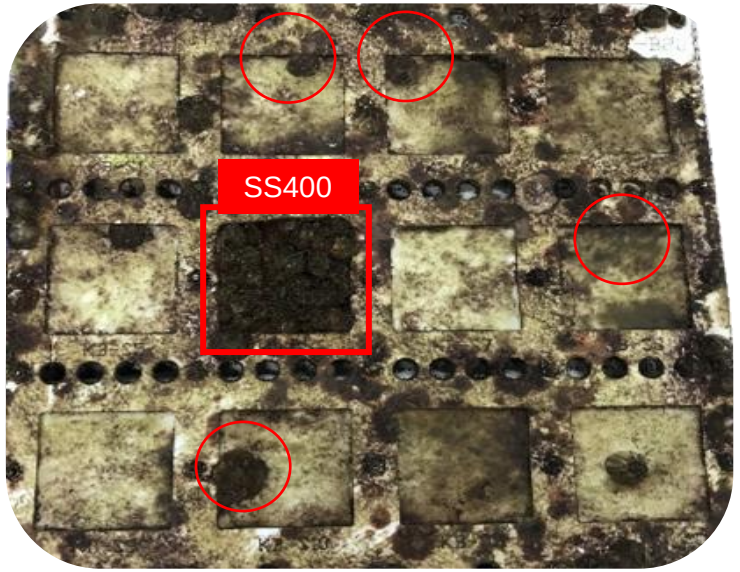


Barnacle attachment on PDMS/PU

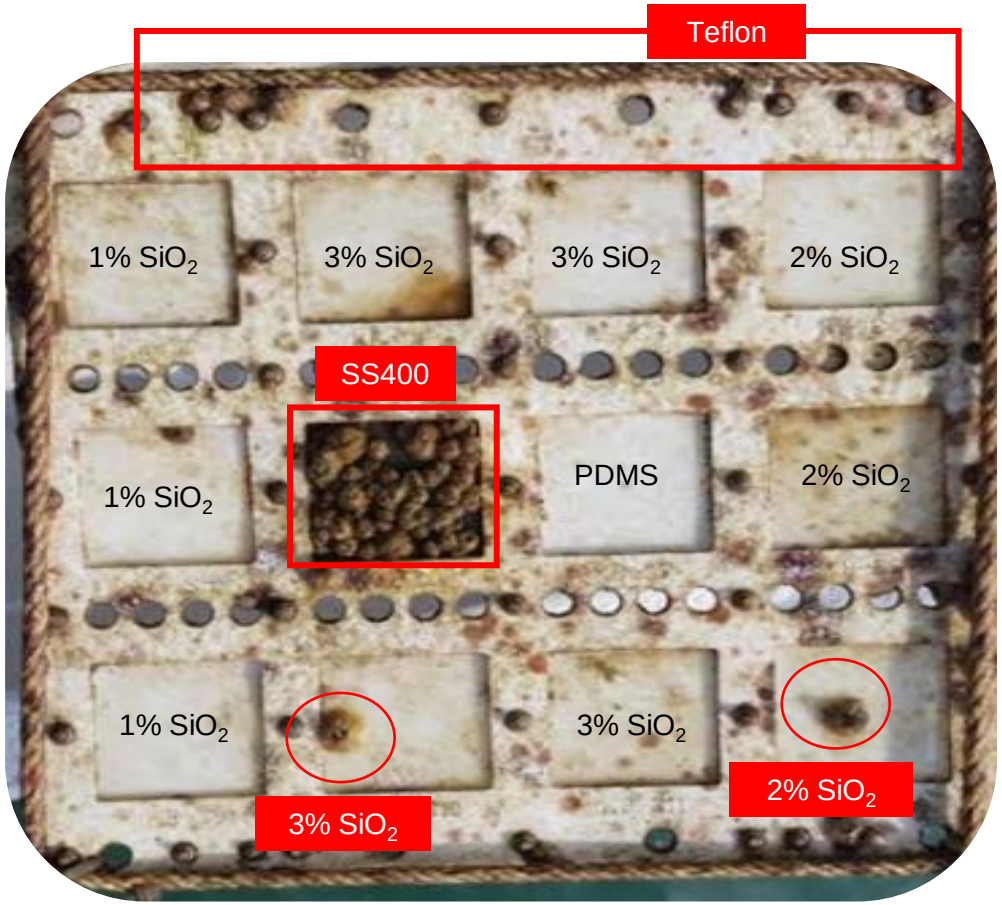
2 Week



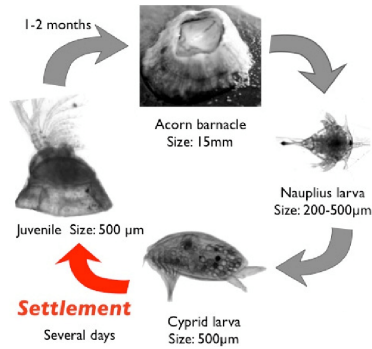
8 Week

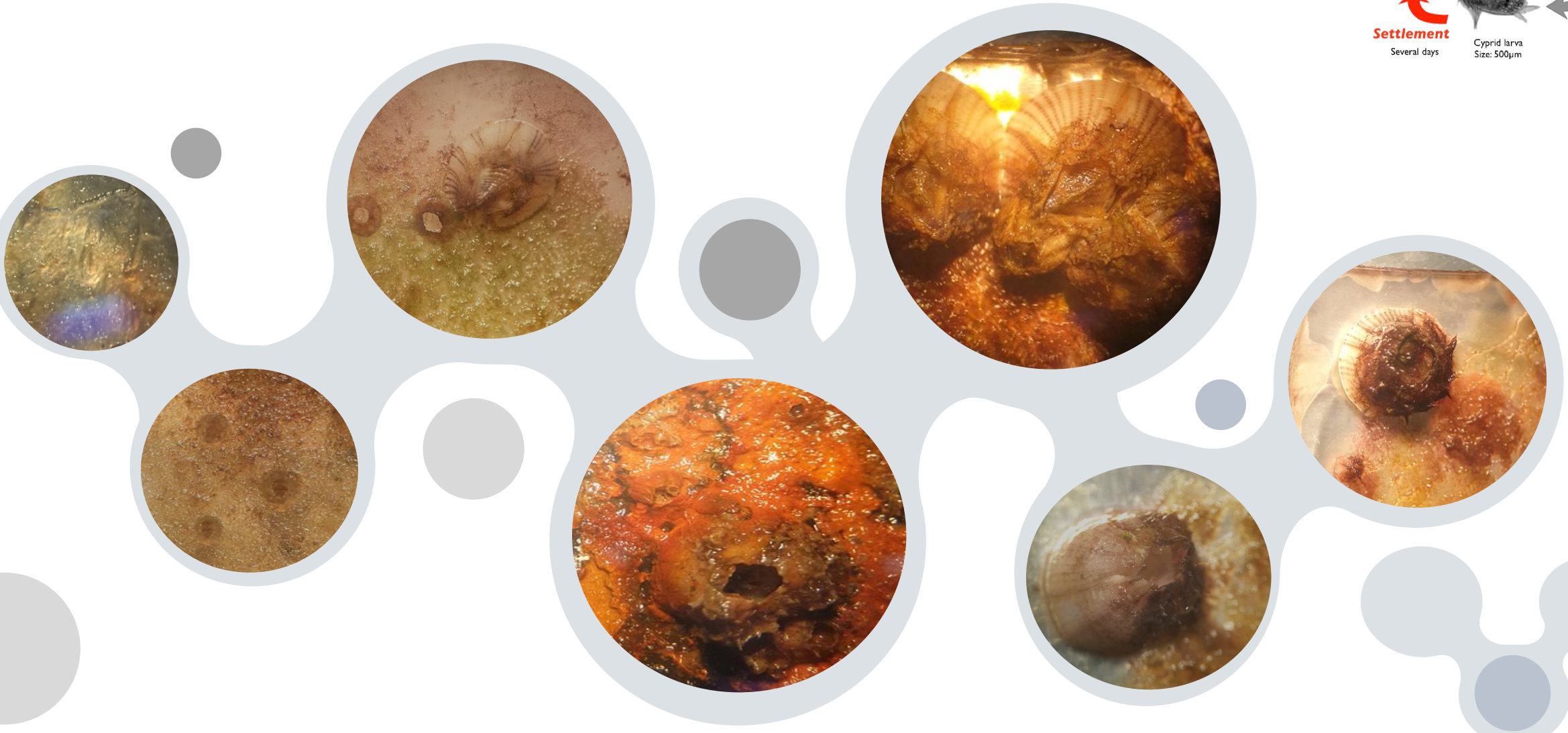


4 Week



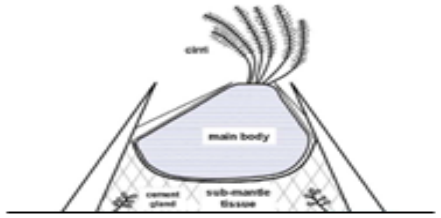
Barnacle attachment on PDMS/PU

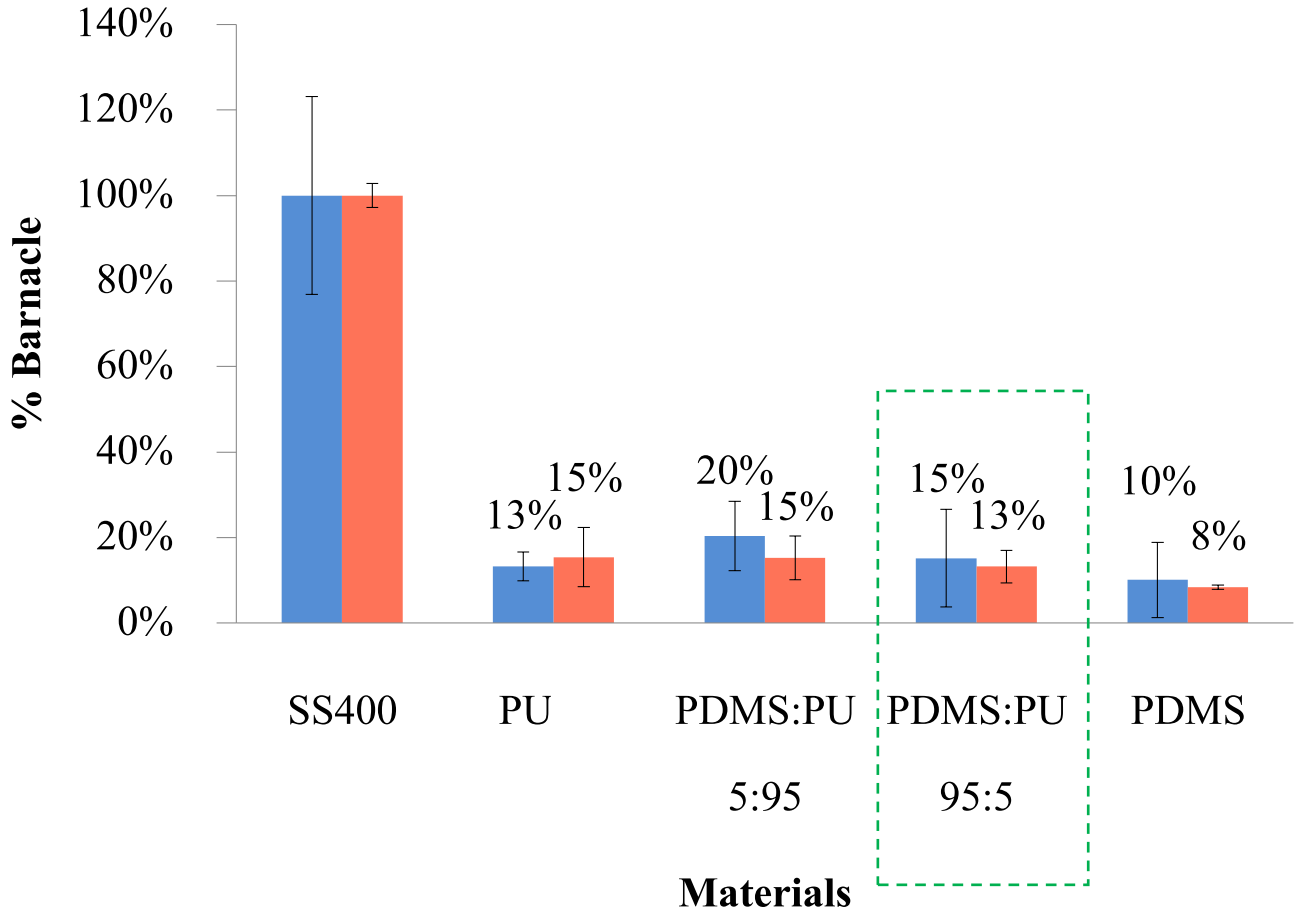




Size and % Barnacle counts on PDMS/PU surface after 4 weeks

Barnacle size	Wide (cm.)	Height (cm.)
Samples		
SS400	0.3	0.6
PU	0.5	0.8
PDMS/PU 95:5	0.3	0.5
PDMS/PU 5:95	0.4	0.9
PDMS	0.3	0.5



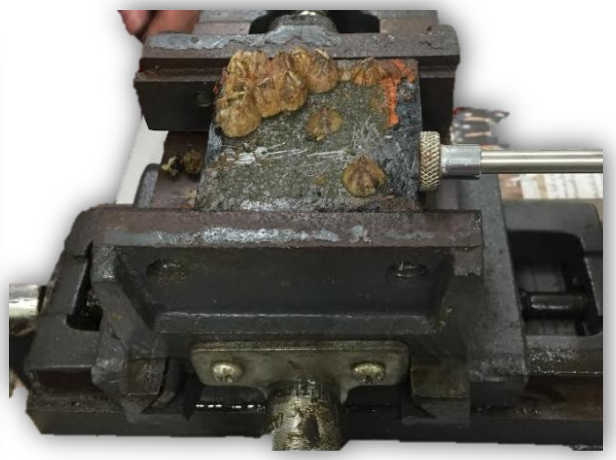


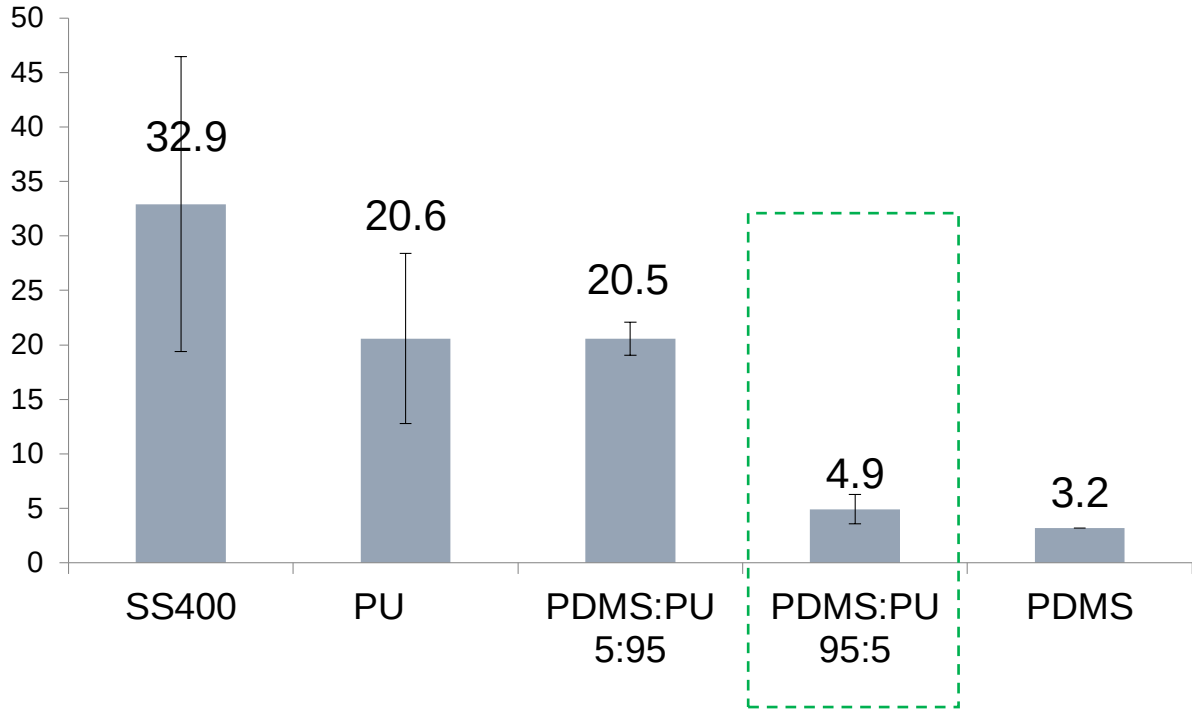
Shore Side: Samples were placed in the sea facing the shore

Sea Side: Samples were placed in the sea facing away from the shore

Adhesive force of barnacle on PDMS/PU surface after 4 weeks

Sample	Force (N)
SS400	32.9
PU	20.6
PDMS/PU 95:5	20.6
PDMS/PU 5:95	4.9
PDMS	3.2

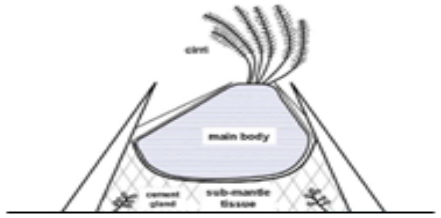


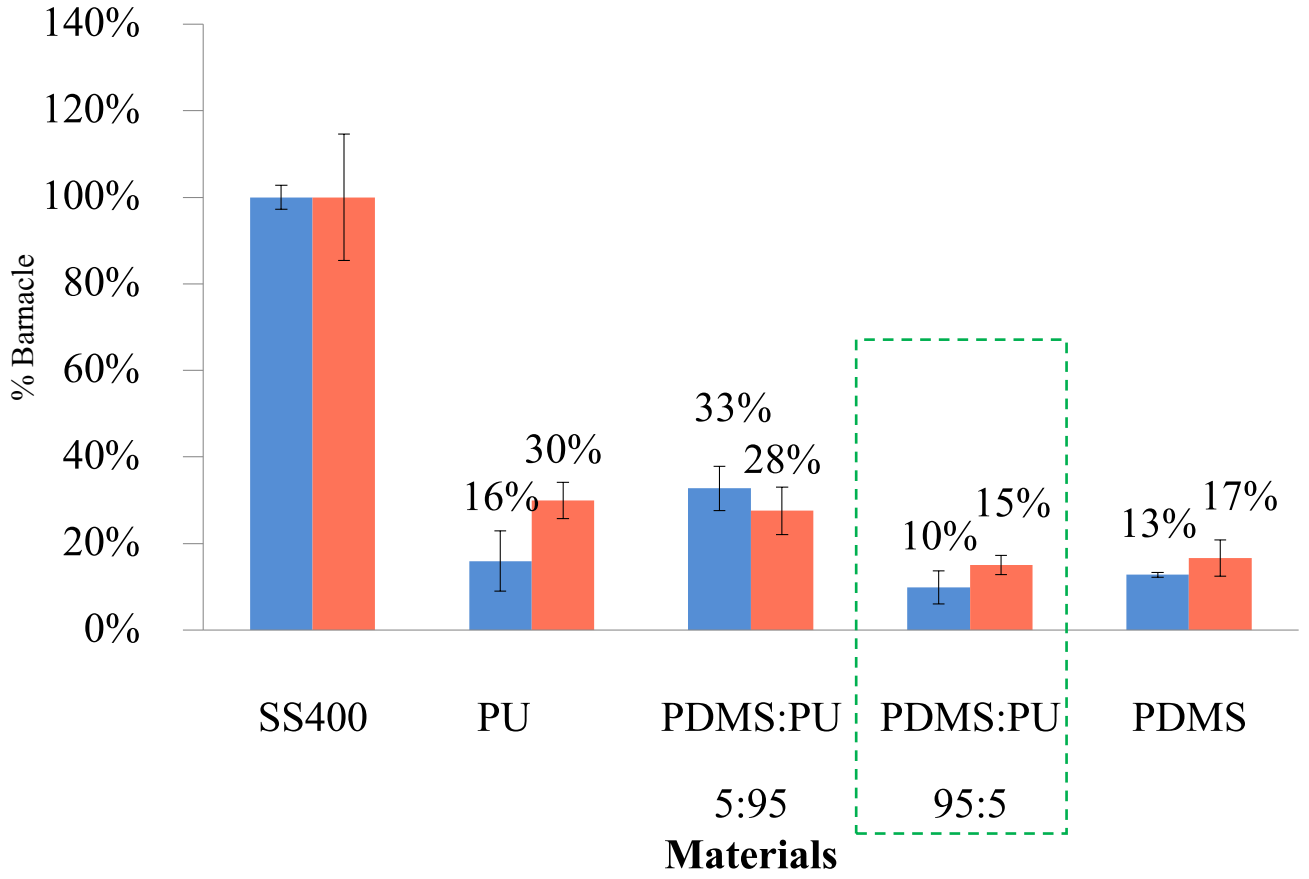


Adhesive force of barnacles attached on surface PDMS/PU samples (after 4 weeks)
Sea Side: Samples were placed in the sea facing the shore

Size and % Barnacle counts on PDMS/PU surface after 8 weeks

Barnacle size	Wide (cm.)	Height (cm.)
Samples		
SS400	0.4	0.7
PU	0.5	0.9
PDMS/PU 95:5	0.7	0.9
PDMS/PU 5:95	0.5	0.8
PDMS	0.5	0.7



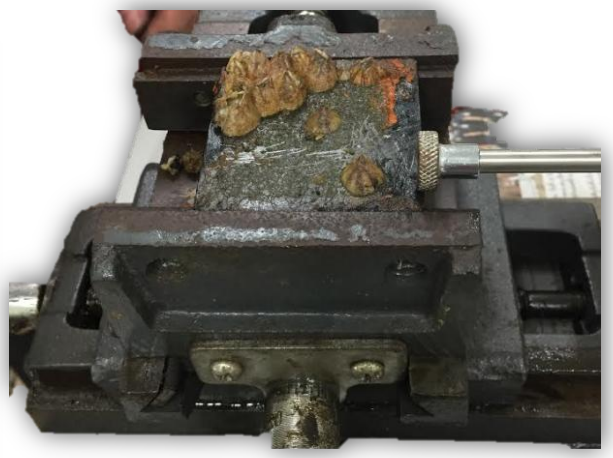


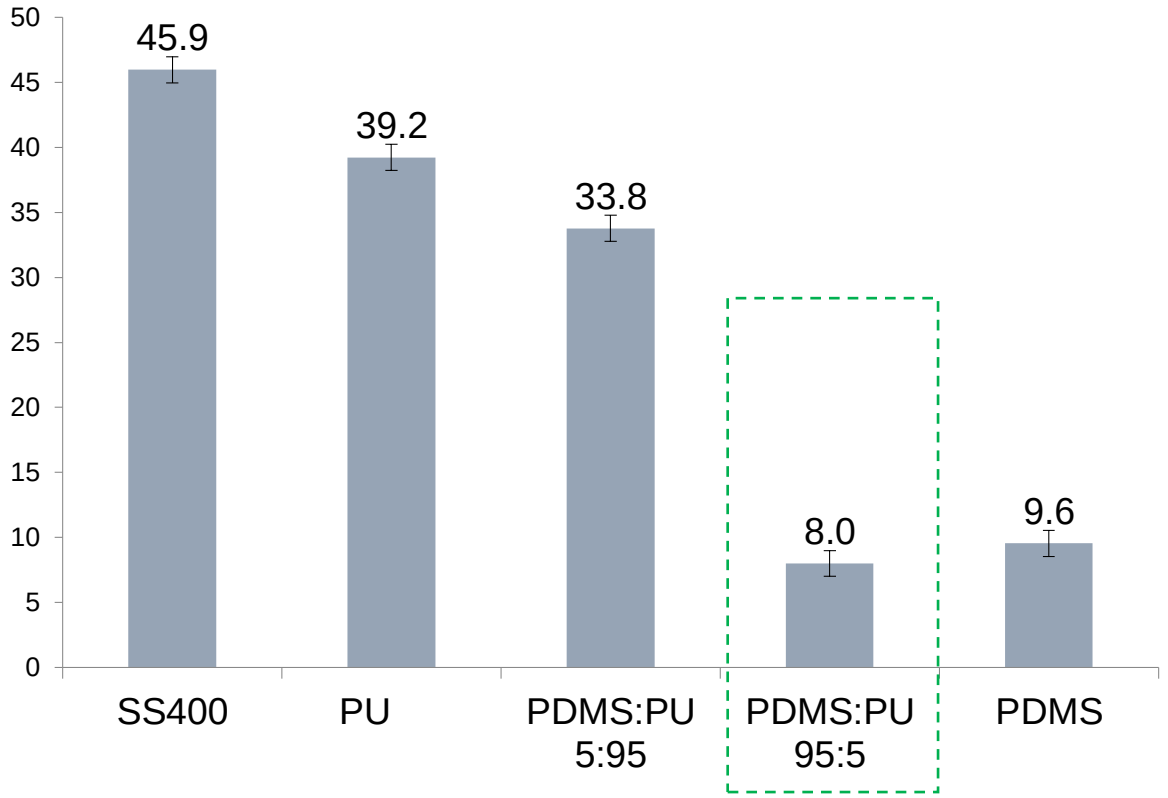
Shore Side: Samples were placed in the sea facing the shore

Sea Side : Samples were placed in the sea facing away from the shore

Adhesive force of barnacles on PDMS/PU surface after 8 weeks

Sample	Force (N)
SS400	45.9
PU	39.2
PDMS/PU 95:5	33.8
PDMS/PU 5:95	8
PDMS	9.6





Adhesive force of barnacles attached on surface PDMS/PU samples (after 8 weeks)
Sea Side: Samples were placed in the sea facing the shore

Conclusions

PDMS/PU blend with soft lithography process gave contact angle up to 128.8°± 1.6°

PDMS/PU blend reduced fouling attraction around 80-90% compared with surface of SS400 metal

PDMS/PU blend has lower barnacle adhesive force than SS400 metal up to 83% in 8 weeks

TMEC
Thai Microelectronics Center

PPC
วิทยาลัยปิโตรเลียมและปิโตรเคมี
The Petroleum and Petrochemical College

The Petroleum and Petrochemical College, Chulalongkorn University

Dr. Nithi Atthi

Mr. Witsaroot Sripumkhai

Asst. Prof. Manit Nithitanakul

Sutep Charoenpongpool

Jirasuta Chungprempree

Punika Ratchachittapong

And TMEC Team

Aquatic Resources Research Institute, CU.

Thank You

FOR
YOUR
ATTENTION !
ANY QUESTIONS?