IFSCC Mexico Conference 2021

Shiseido

NT-218

Nanodisc emulsion: Broadening the horizon of cosmetics.
— Unique oil-water interface from dynamic transformation of vesicles into nanodiscs—

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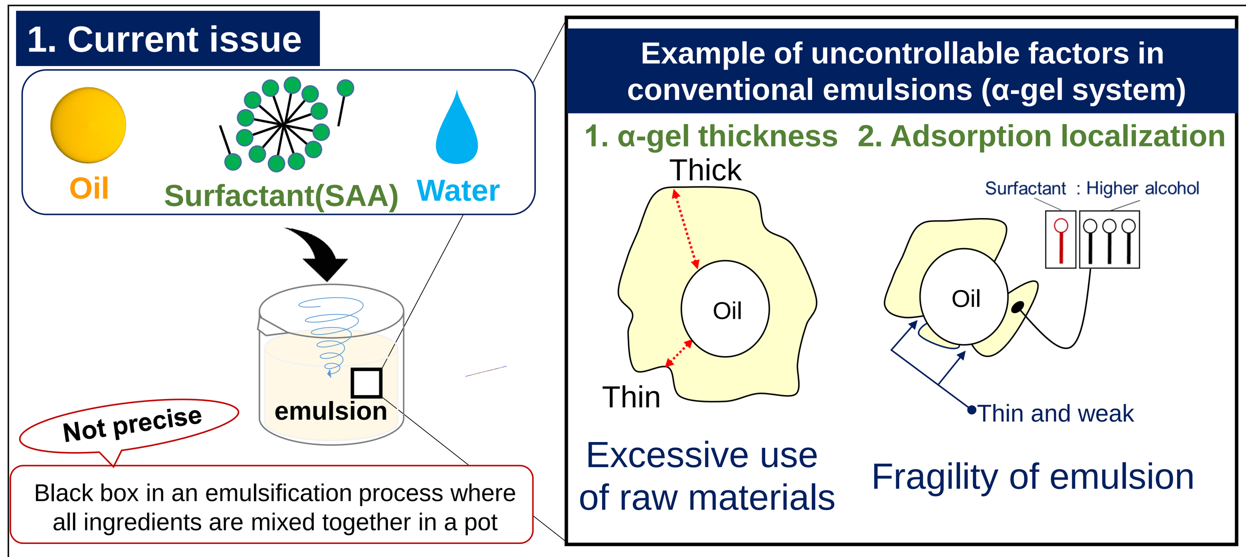
Introduction:

Our Goal is

Simultaneously developing an *eco-conscious* and *high functional* emulsion

R&D in eco-conscious cosmetics always faces restrictions when it comes to ingredients. This can impact functionality, a major issue in the cosmetics industry. We have succeeded to solve this problem by precisely controlling the emulsion with a novel interfacial membrane.

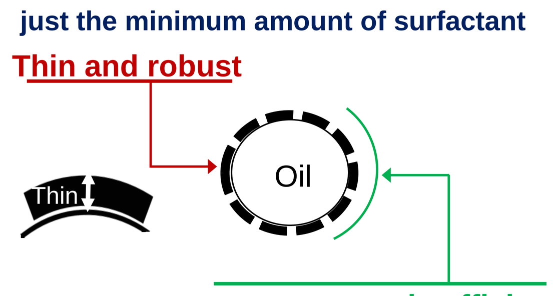
1. Current issue



Causing excessive use of raw materials and fragility of emulsion leads to hindering achieving both eco-consciousness and high function.

2. An ideal emulsification?

Thin and robust interfacial membrane with just the minimum amount of surfactant

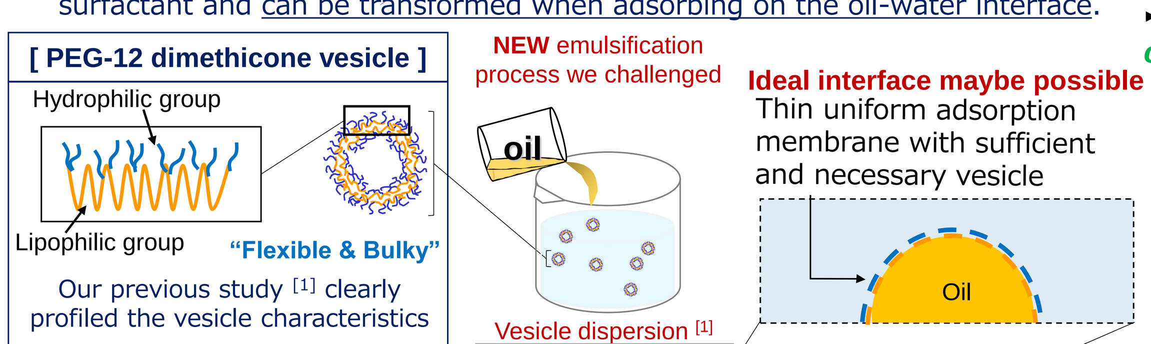


Eco-consciousness
- **Minimizes the amount of emulsifier needed**

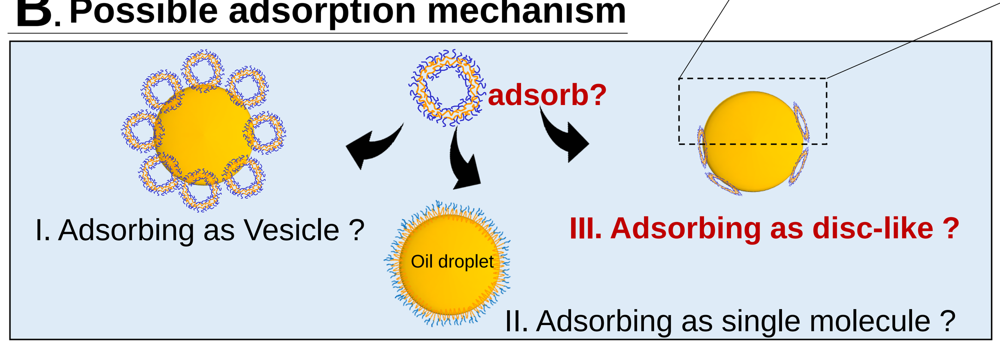
High function
- **High internal phase ratio**
- **Texture may be drastically improved, especially oiliness and stickiness**

3.We focused on lamellar liquid crystalline phase as an interfacial membrane having a thin and robust feature.

A. As a source of lamella liquid crystalline, it is desirable to use a flexible material that has a bulky structure with a smaller amount than general surfactant and can be transformed when adsorbing on the oil-water interface.



B. Possible adsorption mechanism



C. Our Focus Points

- How silicone vesicle behave around oil-water interface?
- How our new system contribute to ***eco-consciousness*** and ***functionality*** of cosmetics?

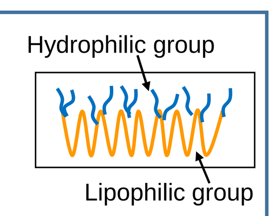
D. Benefits for cosmetics industry

1. **Pioneering eco-conscious products development**
   - reduce consumption of SAA usage
   - all non-heating process
2. **Non-oily texture for all oil-rich-required products**
   - most of Sunscreen (UV absorber)
   - vitamin-A included cosmetics
3. **Additionally, various formulae can be reduced in viscosity by vesicle coalescence stability**
   - effective **BUT** too rich texture - Only for night skincare -
   - effective **AND** refreshing texture - *Whenever I want use!!* -

Materials & Methods:

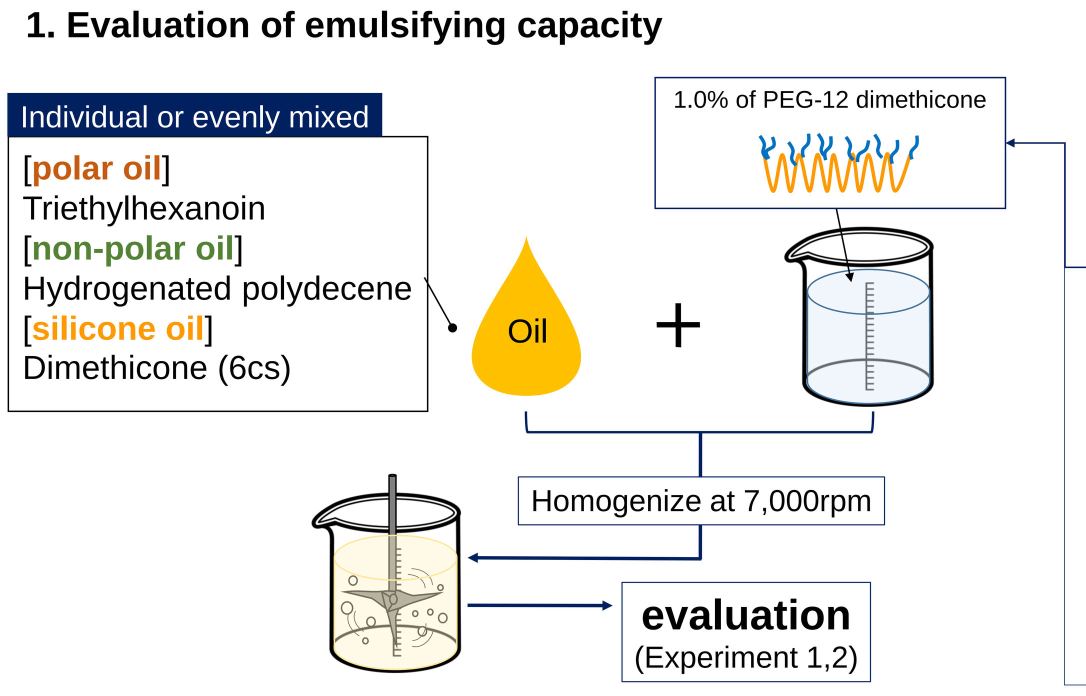
Materials

PEG-12 dimethicone, HLB (hydrophile lipophile balance) = (5, 8, and 13) (Dow Toray Co.,Ltd., Tokyo, Japan).



Methods

1. Evaluation of emulsifying capacity



*All processes are performed without heating

Experiment 1. *See Results 1.

Emulsification Capacity (maximum internal ratio)

Vesicle (HLB 8) × 5~70% of.. Triethylhexanoin, Hydrogenated polydecene, Dimethicone (6cs)

Experiment 2. *See Results 2.

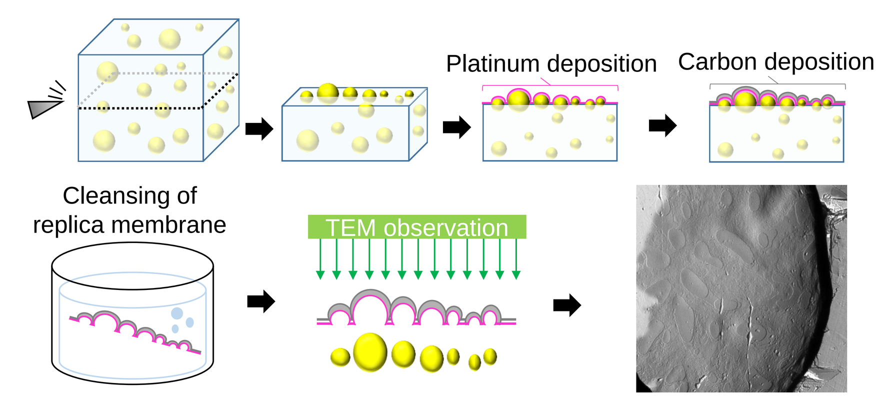
Effect of self-assembly on stability & texture

a. Insoluble gel (HLB 5) b. Micelle (HLB 13) c. Vesicle (HLB 8)

× 30% of evenly mixed oils (non-polar, polar and silicone)

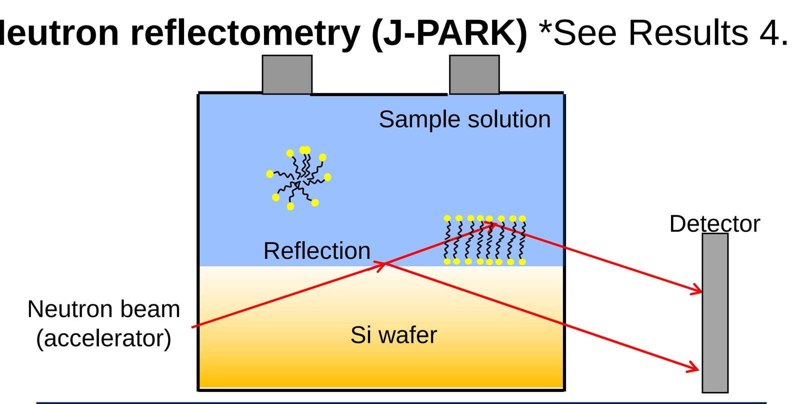
Ultracentrifuge (40,000rpm / 60min)

2. Freeze Fracture TEM *See Results 2.



Observation of actual behavior of vesicles on the oil-water interface

3. Neutron reflectometry (J-PARK) *See Results 4.



Analysis of the structure of the coating film by this emulsification

Results & Discussion:

1. Evaluation of emulsifying capacity

The maximum emulsifying capacity (at a concentration of 1.0% Vesicle).

Emulsified oil	Non-polar (Hydrogenated polydecene)	Silicon (Dimethicone (6cs))	Polar (Triethylhexanoin)	Conventional tech. (α-gel) Polar
Maximum conc.	60%	20%	60%	20-30%

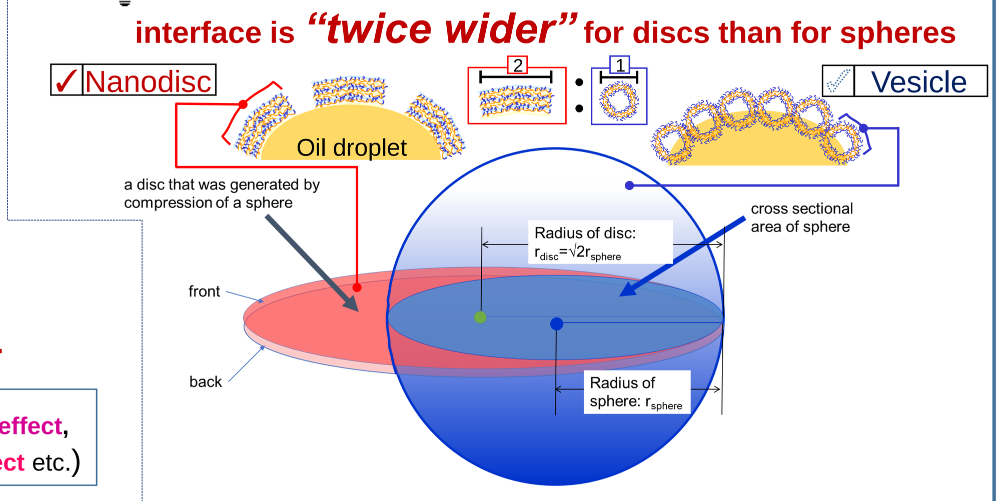
(The present study: Non-polar, Silicon, Polar) At least double efficiency !!

Surprisingly, vesicle emulsified as much as 60% polar oil at only 1.0%, which drastically surpass any conventional emulsification.

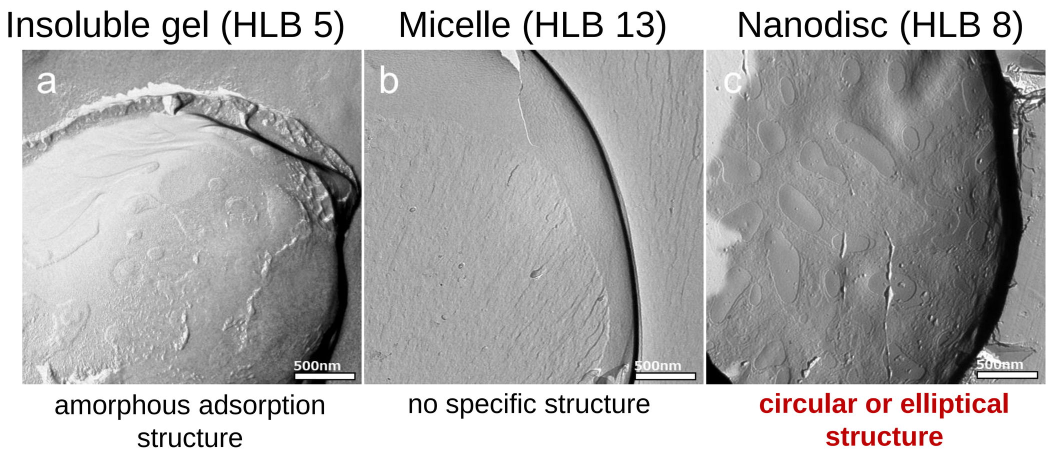
What's benefit?

Polar oils are strongly linked to cosmetics function (*e.g.* **skin-barrier effect**, **Ultraviolet absorbing effect**, **stabilizing oil-soluble active ingredients effect** etc.)

By transforming into nanodisc,
The interfacial area that can be obtained at the oil-water interface is *"twice wider"* for discs than for spheres

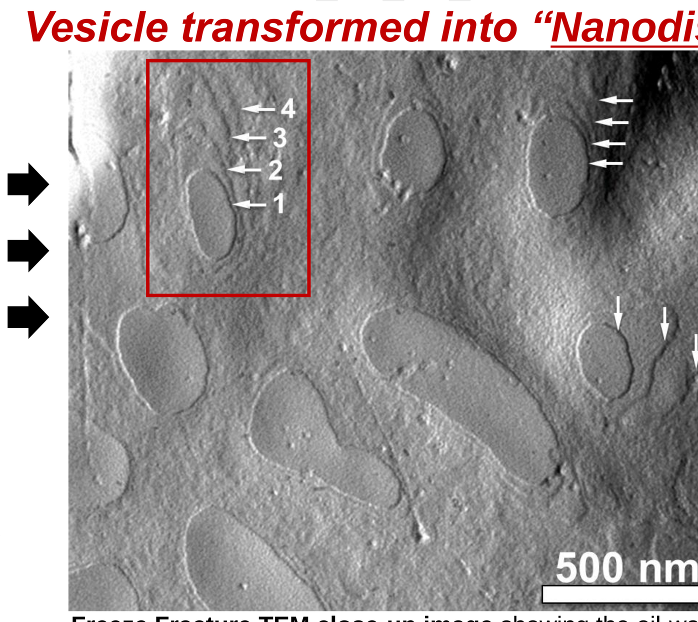


2. Freeze Fracture TEM Images depends on structure



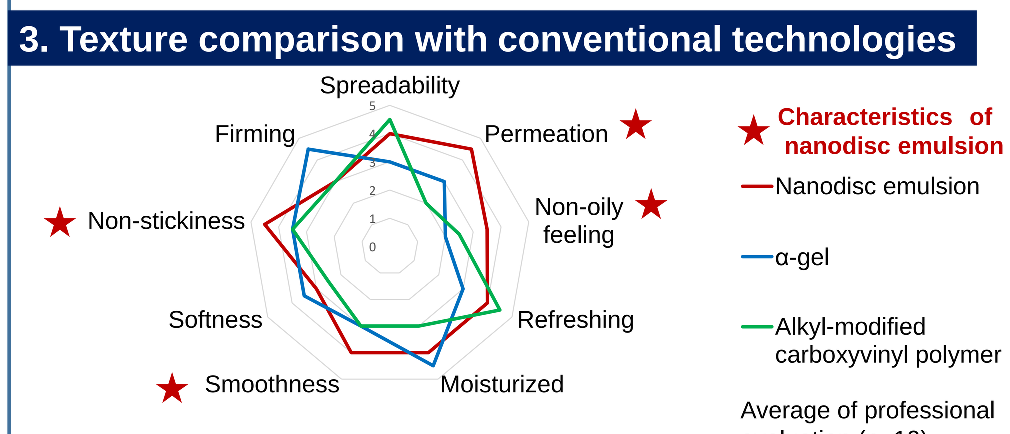
	Insoluble gel (HLB 5)	Micelle (HLB 13)	Nanodisc (HLB 8)
Coalescence stability (30% of mixed oil emulsion, Ultracentrifuge 40,000rpm 60min)	− (separated)	− (separated)	+ (stable)
Difference of texture depends on each self-assembly	− (oiliness)	− (stickiness)	+ (non-oiliness) (non-stickiness)

Vesicle transformed into "Nanodisc"



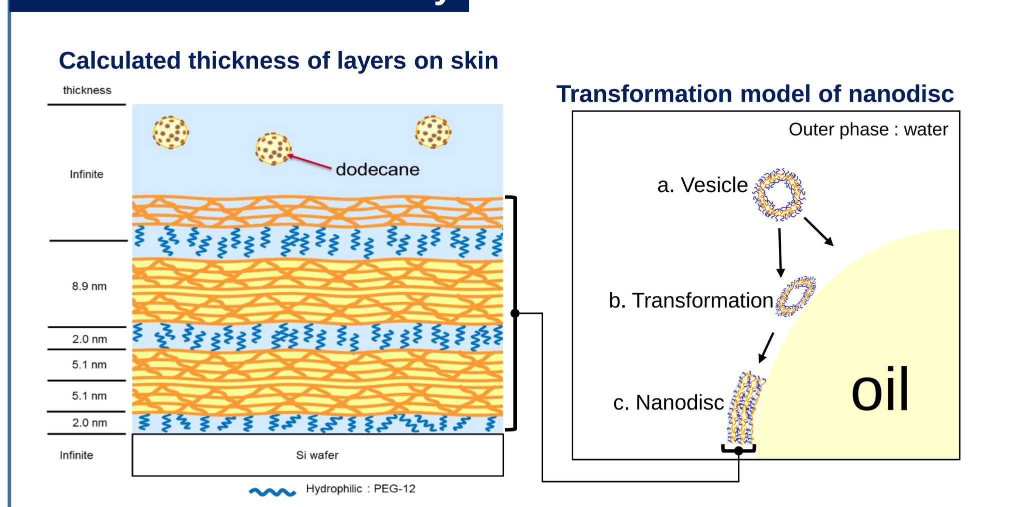
Freeze Fracture TEM close-up image showing the oil-water interface of emulsion stabilized with nanodiscs. Four white arrows show that lamellar layers of vesicle transformed into nanodiscs when adsorbing to the oil-water interface.

3. Texture comparison with conventional technologies



Nanodisc emulsion shows drastic improvement in *oiliness, stickiness* compared to conventional emulsion.

4. Neutron Reflectometry



Regular lamellar membrane structures were thinly laminated. Combining with all results, we achieved *thin and robust interfacial membrane with just the minimum amount of surfactant*. Plus, the reason of non-oily and non-sticky texture was demonstrated!

Nanodisc emulsion expands the horizon of cosmetics.

Eco-consciousness

- **Eco-conscious manufacturing**
  - Minimize consumption of required SAA for oil emulsification (***one thirds of α-gel emulsification***)
  - Non-heating process
- **Opportunity of Biomass ingredients**
  - The superior emulsification capacity maximize opportunity of welcoming and utilizing ***naturally derived materials*** which occasionally fluctuate in quality (*e.g.* vegetable biomass), leading to the ***new standard of eco-consciousness*** for cosmetics industry.

High function

- **Evolution of sunscreen & Vitamin-A cosmetics**
  - Issue that UV absorber and vitamin-A needs much ***polar oil which show oiliness for the stability of themselves*** will be solved and refreshing feeling formula is possible.
- **Super strong coalescence stability**
  - Any formulation could be reduced in viscosity in which consumer can enjoy ***high function*** and ***superior feeling*** even in the morning

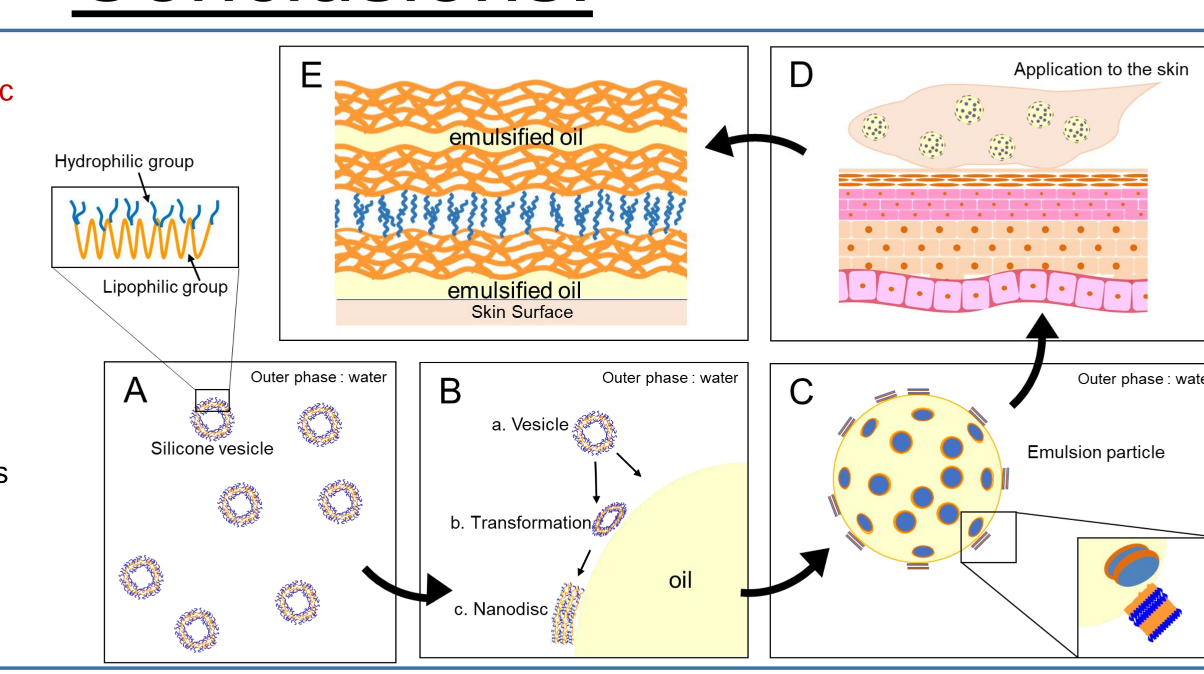
- Wide applicability & High inclusivity -

Nanodisc powerfully emulsify large amount of oil regardless of oil type ***in eco-conscious way***. Therefore, all researchers can apply this technology to any cosmetics, ***makeup, sunscreen and of course skincare***.

" The possibilities are infinite "

Conclusions:

- The present study discovered that nanodisc emulsification using vesicle aqueous dispersion as the outer phase consisting of PEG-12 dimethicone shows extremely high emulsifying capacity.
- The oil-water interface captured as an actual image ***for the first time in the world*** showed the vesicles undergo a structural transformation into nanodiscs.
- This world first emulsification technology is an ideal silver bullet that can be considered as the next-generation of emulsions, ***break the traditional limitations*** and ***make many impossibilities possible***.



Acknowledgments:

The NR measurement was performed on a BL16 (Program No. 2018A0008) beamline at MLF, J-PARC. For the allocation of the beamtime, we would like to thank the MLF, J-PARC.

References:

3. Watanabe K, Nishida M, Nishimura K, et al. (2018) High Skin Hydration and Comfortable Texture of a Moisturizing Lotion Fulfilled by Controlling the Phase Sequence of a Vesicle-Micelle Complex. J Soc Cosmet Chem Jpn 52:260–268.