Design of Pickering Emulsion Templated Colloidosomes and Fundamentals of Emulsification with Nanoparticles

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April 10, 2012
Research Overview

Dual research

- Design microcapsules
  - Design pH responsive composite microcapsules for controlled release of antimicrobial cargoes

- Fundamentals of Pickering emulsions
  - Investigate effects of particle charge on Pickering emulsions that are neglected in conventional theory
Design colloidosomes: motivation and objective

- Colloidosomes are semi-permeable microcapsules whose external shell is formed by colloid particles.

- Colloidosomes represent a promising encapsulation technology with good controllable permeability, mechanical properties and bio-compatibility.

- Aim to design composite pH responsive colloidosomes for controlled release.

Pickering emulsions

Phase I

Phase II

\[ \Delta E \gg kT \]

Adsorption energy

Irreversible adsorption

\( \theta < 90^\circ \rightarrow \text{hydrophilic} \quad \text{o/w} \)

\( \theta > 90^\circ \rightarrow \text{hydrophobic} \quad \text{w/o} \)


Design Protocol

- Explore double Pickering emulsion as template
Experimental observation

The water phase is labeled with FITC-dextran (10 kDa) encapsulated (green zone), while the oil phase is not labeled (black zone).

By rational design of the shell composition, we are able to generate colloidosome capsules with different release properties.
pH responsive colloidosomes

FITC-dextran (10KDa) was encapsulated inside

Fast release: ~3s

My research focus: Composite colloidosomes with a sustainable release fashion

Stepwise release: ~30s
Composite pH responsive colloidosomes

Hybrid pH responsive colloidosomes with a long-lasting release profile are generated by the inclusion of inorganic particles and polymeric particles.

- The shell permeability can be controlled by adjusting the shell thickness and adding polymer matrix.

![](image1.png)

- Thin shell
- Thick shell
- Incorporate polymer matrix

- The size range of colloidosomes is $20 - 60 \, \mu m$
Permeability Evaluation

- The permeability of hybrid colloidosomes for 10 kDa FITC-dextran is evaluated by fluorescence recovery after photo bleaching (FRAP).

http://en.wikipedia.org/wiki/Fluorescence_recovery_after_photobleaching
Envisioned applications

Antimicrobial colloidosomes

Encapsulate antimicrobial inside

Stimulus trigger

Sustainable antimicrobial protection
Fundamentals of emulsification with polymeric nanoparticles
Motivation and objective

Motivation: Current fundamental understanding is far from satisfactory, which limits the applications!

Objective: Explore the important factors affecting Pickering emulsions that are neglected in conventional theory by investigating emulsification with charged latex particles

\[
\text{Carboxyl} -\text{COOH} \quad \xrightarrow{\text{pH}^+} \quad -\text{COO}^- + \text{H}^+ \\
\text{Amidine} -\text{C(=NH)}\text{NH}_2 + \text{H}^+ \quad \xrightarrow{\text{pH}^-} \quad -\text{C(=NH}_2)\text{NH}_2^+ 
\]
Our experimental findings

No emulsions form when polymer particles are highly charged under low salt concentration.

Particles with macroscopic contact angle greater than 90° should stabilize w/o emulsions.

[Graph showing relationship between electrolyte concentration and pH, with markers indicating increased screening and no emulsion formation.]
Hypothesis and supporting evidence

Electrical repulsive force including double layer force and image force can impede adsorption of particle to the interface to stabilize emulsions. The repulsive force are expected to cause a deformation when the interface is very close to the particle.
Hypothesis and supporting evidence

Self energy of particle counter-ion dipole causes shift in equilibrium particle position and leads to a different contact angle in the interface from macroscopic contact angle.
Conclusions

- We explore double Pickering emulsions as precursors for composite pH-responsive colloidosome for customizable release control.
- We propose the electrostatic interaction between the particle and interface, including electrical double layer force and image force, can impede the particle adsorption and therefore affect the emulsion formation.
- The self-energy of the particle-counterion dipole can shift the particle’s equilibrium position toward the water phase and yield a modified contact angle and emulsion type not predicted from macroscopic contact angle measurements.
Acknowledgements

• Funding from IPST through a PSE fellowship and from the National Science Foundation
• Professors Toan Nguyen, Professors Jennifer Curtis
• Dr. Jan Scrimgeour, Dan Kovari
Thank you!