Supramolecular microcapsules: directing self assembly

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Supramolecular Microencapsulation

Microencapsulation refers to a very wide range of technologies that encapsulate, protect and release active cargo when needed. The annual global market is estimated at $40 billion in 2015 with applications across a wide range of products; from detergent and perfume, to paints and pesticides. It also has potential in other areas, including: targeted drug delivery, cell encapsulation, catalysis and self-healing concrete.

Directing both the micro-scale accumulation and molecular-scale self-assembly of components at the interface of sub-millimetre aqueous ‘microdroplets’ offers a powerful route to monodisperse ‘microcapsules’ with identical composition, in a single step. These microcapsules are uniquely assembled by dynamic molecular “handcuffs” that can be triggered to dismantle when exposed to a specific stimulus (e.g. light), releasing the protected cargo on demand.

Droplet-based microfluidics

- Droplet-based microfluidics is a rapidly growing field of interdisciplinary research.
- Applications range from fast analytical systems and biological cell assays, to crystallisation and the synthesis of advanced materials.
- Uniform microdroplets are generated in a single step as an aqueous emulsion in oil.
- The microdroplets are used to template microcapsule formation, enveloping the droplet contents.

Polymer-only microcapsules

To expand the versatility of the supramolecular platform it is necessary to generalise microcapsule fabrication away from the need to incorporate nanoparticles.

The assembly of supramolecular microcapsules from aqueous microdroplets is driven by electrostatic interactions, whereby charged polymers are selectively accumulated at the microdroplet interface by a complementary-charged surfactant (patent filed and licensed).

This is both dynamic and reversible, with the location of polymers within the droplet able to be externally manipulated through the carrier oil.

Core-shell capsules

- Control over the location of individual components within the droplet allows for the design of complex structures.
- A mixed solution of oppositely-charged polymers results in the formation of core-shell capsules (left): red polymer forms the outer capsule wall; green polymer forms the solid core.

Capsules-in-Capsules

Electrostatics can be extended to multiple interfaces within a nested microdroplet to form capsules within capsules. Here orthogonal charges allow for distinct compartments.

- Capsule architecture is externally controlled.
- Unique chemistry at each interface (‘bionape’).
- Practise, multi-step or multi-trigger release.
- Segregated cargo of multiple cargos.
- Synergistic delivery with controlled doses.
- Study of chemistry in a controlled environment.

Alternative approach: Interfacial assembly

Complementary polymers self-assemble at the microdroplet interface through the supramolecular “handcuff” (left), forming a polymer microcapsule (right).

REFERENCES