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Hollow Polymeric Microcapsules Embedding Actuators for Controlled Release of Encapsulants

Abstract:
Microencapsulation of biological and chemical agents and species (e.g., drugs, proteins, vitamins, cells, fragrances, and flavors) is of great importance to many applications ranging from food and pharmaceutical industry to inkless paper. Particularly, liquid core-polymer shell microcapsules have emerged attracting much attention. This is because using polymer shell makes microcapsules more stable and robust, protects sensitive ingredients against denaturing environment, and allows for convenient handling of liquids. More importantly, by controlling thickness, porosity and/or mechanical strength of polymer shell, controlled release of encapsulated ingredient is possible. From the perspective of preparation techniques, a variety of hollow polymeric microcapsules (e.g., polymersomes, multilayered capsules, and hollow microspheres) have been prepared via different methodologies, including colloidosomes by self- assembly, layer-by-layer polyelectrolyte deposition, interfacial polymerization, precipitation by phase separation, surface polymerization, and copolymer vesicles. These techniques often require non-trivial and complex chemical strategies. From the perspective of release mechanisms, four major mechanisms exist for release encapsulated ingredients out of polymeric hollow microcapsules. The first approach involves shell rupture through an applied pressure, where a critical pressure is determined by shell material and thickness. The second method relies on dissolving shell material by melting, enzyme attack, or chemical reaction. The third mechanism allows sustained release over a desired period of time through a free-state diffusion process. But, release profile of a given encapsulant is difficult to change because diffusion rate depends on porosity and thickness of polymer shell. The last mechanism employs a swellable polymer shell that can expand in response to a stimulus such as pH, temperature, and osmotic pressure, tuning porosity and mechanical strength of polymer shell and thus diffusion rate of a given encapsulant. However, due to direct exposure of shell to environment, it is a challenging task to protect stimuli-responsive shell from environmental deteriorating effects such as non- specific stimulus-response reaction, and contamination.

In this report, we report on development of a new type of liquid core-polymer shell microcapsules, capable of tuning flexibly release profile of a given encapsulant. The approach involves embedding miniature actuators within liquid core of microcapsules. The actuators are made of electrically-sensitive hydrogel beads whose physical volume changes with electric field applied. Thus, volumetric change of hydrogel beads allows tuning fluidic pressure within liquid core, regulating diffusion rate and thus release profile of encapsulated ingredients. This release mechanism can not only overcome the limitation of the free-state diffusion process aforementioned, but also avoid direct exposure of control elements to external environments.