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Feature Article

Recent progresses in layer-by-layer assembled biogenic capsules and their applications ☆

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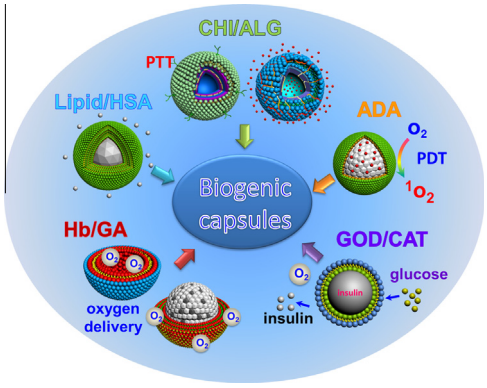
GRAPHICAL ABSTRACT



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ABSTRACT

In this review, we summarize the recent progress made in the fabrication of pure natural materials such as biogenic capsules. Unlike polyelectrolyte capsules, biogenic capsules are primarily prepared with pure natural components using layer-by-layer (LbL) assembly on sacrificial templates. These capsules have been developed as smart materials for guest molecule encapsulation and delivery in the last two decades. With the extreme demands on biodegradability and biocompatibility, biogenic capsules exhibit unique properties that can be integrated with special ligands or conjugated functional groups for the design of intelligent platforms, significantly enriching their functions and applications.

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Contents

1. Introduction

Polyelectrolyte hollow microcapsules have always been of great interest ever since they were first reported by Möhwald's group in 1998 [1–12]. The capsules belong to a class of artificially polymeric hollow structures, specially prepared on sacrificial templates by the layer-by-layer (LbL) assembly technique [13–19]. LbL assembly can provide a moderate approach to conduct the preparation of capsules, fulfilling the "on-demand" assembly process [20–22]. Initially, researchers focused on template fabrication, assembled materials, morphological control, and the regulation of mechanical properties. However, according to the beneficial requirements, many compositions and assembly approaches can be easily adjustable to fabricate the various capsules with versatile physicochemical properties and permeability [23–25]. Biogenic capsules are a type of special hollow polyelectrolyte structure made of pure natural materials such as lipids, proteins, enzymes, and natural polymers [26,27]. The coating modifications and doped molecules can significantly achieve the functionality of these capsules. Due to the biologically friendly components, well-defined biocompatibility enables biogenic capsules to have great potential for applications in biomedicine, catalysis, and microdevices.

Compared with the traditional polymeric capsules, biogenic capsules have extremely less toxicity and notable biodegradability (Fig. 1) and have great potential for applications in the biomedicine, cosmetic, and food industries [28,29]. Biogenic capsules not only serve as prominent organic materials but can also be regarded as a polymer-based encapsulated cargo for guest molecule delivery and release. The inner compartment of capsules can block various molecules with its adjustable permeability and versatile mechanical properties [30,31]. As for small molecules, the capsules can also provide complete encapsulation as before by coating the introduced macromolecules such as lipids, proteins, and hydrophilic or hydrophobic polymers. Based on the favourable biocompatibility, these capsules can be used as a hybrid platform to integrate the diverse natural molecules, providing a desirable three-dimensional, sphere-like substrate to conjugate several biological units such as DNA, RNA, lipids, and biomolecular motors. In addition, biogenic capsules can be simulated as a promising cell with functional membranes, creating a microenvironment to perform biochemical research and physiological investigation at the cellular level [32,33].

In this study, we mainly focus on recent and important work regarding LbL assembled biogenic capsules, their key features, projects concerning functionality, and their applications. First, the component materials, assembly mechanisms, and physicochemical properties will be briefly introduced and explained. Next, we will talk about how biogenic capsules encapsulate and release guest molecules and modify themselves with biological units or inorganic nanoparticles, particularly describing the performance of biogenic capsules in biomedicine such as drug delivery, biocatalysis, bioluminescence, and cancer therapy. In this review, much more promising work will be given as examples and highlighted during this fantastic journey of biogenic capsule development.

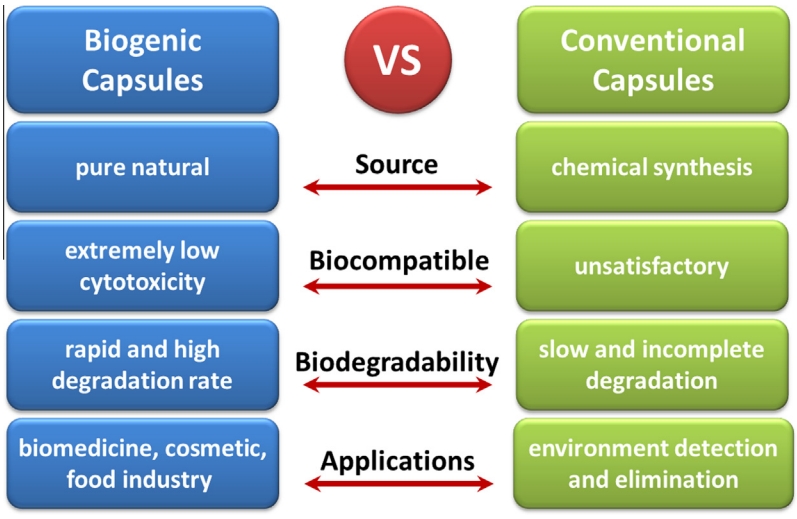

Fig. 1. The characteristic features of biogenic capsules and conventional capsules.