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Microfluidic Encapsulation of Catalysts and Reactive Epoxy Using SBS and Acrylamide Hydrogel Shells for Tailored Release Applications

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Abstract

Encapsulation of functional agents within polymeric microcapsules enables their controlled release and protection from environmental degradation, a capability that is critical for advanced applications such as self-healing materials, responsive adhesives, and deployable repair systems in extreme environments. In this study, we report two complementary encapsulation strategies developed using double emulsions generated in microfluidic devices: (1) encapsulation of the catalyst DABCO (1,4-diazabicyclo[2.2.2]octane) in poly(styrene-butadiene-styrene) (SBS) elastomeric shells, and (2) encapsulation of EPON 825 epoxy resin in ultraviolet (UV)-crosslinked acrylamide hydrogel shells. The SBS capsules provide flexible, solvent-responsive release of aqueous cores, while the acrylamide capsules offer robust, pressure-sensitive delivery of highly viscous hydrophobic cores. Both systems achieve monodisperse capsule populations with tunable shell properties and excellent core retention. We compare the formation dynamics, mechanical behavior, release mechanisms, and application potential of these two encapsulation platforms. The results highlight the versatility of microfluidic double emulsions for designing tailored capsule architectures and provide insights for selecting shell materials based on application-specific performance requirements.