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ORIGINAL RESEARCH

Preparation of multi-responsive amphiphilic particles by one-step soapless emulsion polymerization

Bin Wang[1] · Wenzhong Zhai[1] · Rong-Min Wang[1] · Xuling Wei[1] · Pengfei Song[1] · Yufeng He[1]

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Abstract
A novel multi-responsive amphiphilic copolymer (mRAP) particles with tunable emulsifiability was successfully prepared via one-step soapless emulsion polymerization using common monomers, such as methyl methacrylate, methacrylic acid (MAA), butyl acrylate (BA) and *N*,*N*-diethylacrylamide (DEAA). The obtained monodisperse spherical mRAP particles were characterized by dynamic light scattering, Fourier transform infrared spectroscopy, scanning electron microscope and transmission electron microscope, which provided the information of particle size, components and anisotropic structure. Its multiple responsivities were investigated under the condition of diversified pH values, salinity and temperature. The results showed that the mRAP particles exhibited good dispersivity based on uniform particle size, as well as tunable emulsifiability and anticipated multiple responsiveness. Furthermore, the tunable emulsifiability of oil–water mixtures could be easily achieved by adjusting the mass ratios of MAA to DEAA. Meanwhile, the obtained multi-responsive polymers relying on simple and effective copolymerization can be used in fundamental research and industrial production.

Keywords Multi-responsive particles · Amphiphilic acrylate copolymer · Good dispersivity · Tunable emulsifiabilities · Soapless emulsion polymerization

Introduction

Responsive polymers, also known as environment-sensitive polymers, can quickly respond to external stimulus by reversibly switching their physical and chemical properties [1, 2]. Various responsive polymers have been widely explored both theoretically and technologically over the past few decades due to their special potential applications in different scientific fields [3], such as drug delivery system [4, 5], light-responsive materials [6], smart coatings [7] and solid emulsifiers [8]. Generally, responsive polymers can be synthesized through adding sensitive monomers in polymerization systems by copolymerization or graft polymerization [9], and more and more effective synthetic technologies have also been developed in recent decades. As an example, a thermo-responsive polymer based on poly[*N*-(4-vinylbenzyl)-*N*,*N*-dialkylamine] was prepared by RAFT polymerization, which exhibited phase transition at the lower critical solution temperature (LCST) or the upper critical solution temperature (UCST) [10]. In recent studies, the combination of temperature and pH values has been focused on the response to more complex external stimuli. Typically, dual stimuli-responsive comb polymers have been successfully synthesized by the spontaneous zwitterionic copolymerization of stimuli-responsive monomers [11]. Additionally, some new polymerization processes, such as one-step precipitation polymerization, two-step emulsion polymerization [12, 13], dispersion emulsion polymerization [14], and the direct aqueous self-assembly [15] were investigated, which prepared multi-responsive gel, micelles or three-phase controllable Janus particles (JPs). Compared with traditional responsive polymers with single or dual responsiveness, the preparation of multi-responsive polymers by simple and effective copolymerization are still very limited [16, 17].

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✉ Rong-Min Wang
wangrm@nwnu.edu.cn

✉ Yufeng He
heyufeng@nwnu.edu.cn

[1] Key Lab Eco-Environment-Related Polymer Materials of Ministry of Education, Institute of Polymer, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, China