Modeling physico-mechanical properties of an individual photopolymerization-induced urethane-based microgel particle

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ARTICLE INFO

Article history:
Received 8 May 2015
Received in revised form 31 July 2015
Accepted 1 August 2015
Available online 6 August 2015

Keywords:
Photopolymerization-induced microgel particle
Nano-indentation hardness
Apparent diffusion coefficient
Cooperative properties
Dynamic fragility
Cross-link density

ABSTRACT

In this work, an individual microgel particle dispersed in a viscous-like matrix was synthesized through the in-situ photopolymerization process. The actual size of the individual microgel particle was calculated based on the microscopic techniques. The cooperative relaxation properties of the individual microgel particle were studied using dynamic mechanical analysis technique. A value of 18 of dynamic fragility index for the microgel network was obtained. The size of cooperatively rearranging region (CRR) at the glass transition temperature for the microgel particle was estimated to be 6. A value of 0.041 mol/cm³ of cross-link density of the individual microgel particle was predicted based on the atomic force microscopy results and stress-strain data. The microgel hardness was measured by a nano-indentation instrument with an indenter diameter of 150 nm. The value of the hardness of the microgel particle was found to be in a suitable agreement with the results obtained from the atomic force microscopy technique. On the basis of a proposed model, the apparent diffusion coefficient of Cl⁻ through the photopolymerization-induced microgel particle was calculated to be about 10 μm²/sec.

1. Introduction

Highly cross-linked materials have been used in different industries in order to design engineering products with high degree of quality. One of the most special types of these materials is a class of materials so called microgel particles. The crucial role of these polymeric materials in different high-tech applications such as drug delivery, wave attenuation, anticorrosive properties and electronic devices has been studied [1–4]. The microgel particles suspended in a liquid has been considered to assess polymer dispersions. From the viewpoint of surface chemistry, the stabilization and the rheological properties of the microgel-based polymer dispersions are very significant to design the stimuli-responsive materials in recent years. Different procedures for the microgel formation have been reported in literature [5,6]. In situ-photopolymerization-induced microgelation process is one of the most attractive approaches to generate the microgel particles dispersed in a viscous-like matrix. This procedure has not been reported in this way to form the microgel particles. However, the recognition of the microgel domains driven by the intermolecular cyclization has been demonstrated for the first time by Kannurpatti et al. [7]. They found that by using the photopolymerization process two dynamically extreme regions are formed namely microgel domain and pool of unreacted monomers. Several scientists have intended to study these two dynamically extreme regions on the basis of different techniques like dynamic mechanical thermal analysis and dielectric relaxation spectroscopy techniques [8–10]. Meanwhile, the separate characterization of these two dynamically extreme regions is lacking in literature. This may be because of the fact that the photopolymerization process is very complicated. In fact, the control of morphology through the photopolymerization process is not easy. Recently, Shukutani et al. [11], have reported a wide variety of morphologies with changing the monomer content and light intensity in ternary photo-curable mixture. On the other hand, characterization of an individual microgel particle dispersed in a viscous-like matrix can be so helpful to generate the products with different physical and mechanical properties. In our previous work [12], the importance of the microgel particle dispersed in a viscous-like matrix in control of the anticorrosion properties of the organic coatings has been investigated. We showed that the anticorrosive coatings containing microgel particles...