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Shear-induced color transition of PDA (polydiacetylene) liposome in polymeric solutions

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Abstract

The polydiacethylene (PDA) is known to change its color by mechanical shear. The shear-induced color transition has been reported with elastomer or film type of PDA. In this paper, we newly investigated the transition with liposome type of PDAs in polymeric solutions. The liposomes were dispersed in Poly(vinyl alcohol) 2% + Sodium borate 1%, Poly(vinyl alcohol) 15% and Hyaluronic acid 1% (PVA/B, PVA, HA). The shear stress was continuously imposed to each solution by stress control type rheometer with coni-cylinder fixture. The degree of color transition was quantified with the characteristic absorbance peak at 540 nm (blue) and 640 nm (red). As a result, PDA liposome in PVA/B solution changed the color from blue to red upon increasing the magnitude of shear (from 0 to 100 Pa) and the duration of shear-imposed time (from 0 to 5400 sec). Meanwhile, PDA liposome in HA or PVA solution did not noticeably change the color, even though the low shear viscosities of the solutions were kept almost constant. This color transition of PDA liposome is expected to measure the magnitude of shear, and to distinguish different responses of polymeric solutions to the applied shear.

Keywords **:** polydiacetylene (PDA), liposome, shear-induced color transition, normal stress difference

1. Introduction

The polydiacethylenes (PDAs) are fascinating materials to detect the perturbation from their surroundings. They exhibit visible color transition from blue to red in response to the perturbations such as temperature (Ahn *et al*., 2003; Lio *et al*., 1997; Rubner, 1986; Yuan *et al*., 2006), binding of specific biological targets (Cheng and Stevens, 1997; Cheng and Stevens, 1998; Jelinek, 2000), pH (Kew and Hall, 2006) and molecule structure (Su *et al*., 2004). The transition is known to originate from the alteration of PDAs' polymeric backbone conformation composed of alternating double and triple bonds. In optimal state, the conjugated polymer absorbs the light at nearly 640 nm, whose wavelength shows a blue color appearance. If the effective conjugation length is changed by perturbation, the maximum peak of absorption shifts to near 540 nm, which corresponds to bright red color appearance. This visible response is simple and fast so that the PDAs are used as a diagnostic sensor for chemical reaction, toxicity and so on.

Mechanical shear can invoke the color transition of PDAs (Carpick *et al*., 2000; Nallicheri and Rubner, 1991; Tomioka *et al*., 1989). Previously, PDAs were prepared as a type of elastomer or Langmuir-Blodgett film for investigation of shear-induced transition. Nallicheri and Rubner (1991) made use of poly(urethane-diacetylene) elastomer to observe the colorimetric difference between stretched state and relaxed state by the tensile strain. Tomioka *et al*. (1989) prepared PDA monolayer in Langmuir-Blodgett trough to investigate the reversible transition by surface pressure. Also, Carpick *et al*. (2000) used PDA molecular tri-layer films to observe the transition by force between AFM tip and PDA film.

Meanwhile, the liposome type PDA has little been paid attention to shear-induced color transition. The liposome is the structure composed of amphiphilic molecular bilayers that enclose a volume. The PDA liposome follows the same mechanism of color transition as we mentioned above, when perturbation is imposed on the liposomes: the color transition occurs from blue to red phase. It has the advantages of 1) being easily dispersed in target materials due to its amphiphilicity and 2) being highly sensitive because the perturbation easily transported to whole connected structures of liposome.

In this study, we attempt to observe the shear-induced color transition of PDA liposome. The liposomes were dispersed in three kinds of polymeric solutions: Poly(vinyl alcohol), Hyaluronic acid and PVA/Sodium borate. Also,

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