



Highly efficient light-induced reversible micellization of amphiphilic polymer based on photochromism of naphthopyran in aqueous solution



Meiduo Zhang, Dehua Li, Guang Wang*, Jianxin Li, Haizhu Sun*

Faculty of Chemistry, Northeast Normal University, Changchun 130024, PR China

ARTICLE INFO

Article history:

Received 29 November 2013

Received in revised form

7 February 2014

Accepted 17 February 2014

Available online 22 February 2014

Keywords:

Micelles

Nanocarrier

Naphthopyran

Nile Red

Photochemistry

Stimuli-sensitive polymers

ABSTRACT

The photochromic materials of single-molecule naphthopyrans (NP) are first used as hydrophobic and light-responsive group to synthesize amphiphilic polymer with the poly(ethylene glycol) (PEG) via Click-Chemistry. Such an amphiphilic polymer can self-assemble to light-responsive micelles with NP-core and PEG-shell in aqueous solution, as are confirmed by dynamic light scattering and transmission electron microscopy. The photoisomerization of naphthopyrans moieties can fast and reversibly tune the disassembly and re-assembly of the micelle, as are confirmed by UV–Vis spectroscopy. The changes of fluorescent spectra of Nile red (NR) in water solution of polymeric micelle within 60 s demonstrate that the polymeric micelle can be used as nanocarriers to encapsulate, release and re-encapsulate guest solutes on demand controlling of light irradiation. The fast and highly efficient photo-control of polymeric micelles is a potential candidate in biomedical area for drug delivery.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Polymeric micelles are formed in aqueous media by self-assembly of amphiphilic polymers. The stimuli-responsive amphiphilic polymer, which usually have one hydrophilic block and the other stimuli-responsive hydrophobic block, have received considerable attention due to the variety of applications such as controlled drug delivery, nano-reactors, or biomimetics [1,2]. Among the available stimuli, such as pH [3], temperature [4], light, redox or chemical changes, light has attracted more attention and has been used in various areas since reversible control of encapsulation and release of hydrophobic materials incorporated in the interior of polymeric micelles can be achieved by an external light source [5]. Light-sensitive amphiphilic polymer are generally composed of a hydrophilic shell and a responsive hydrophobic core which is controlled by the irradiation [6]. The design of light-responsive amphiphilic polymeric micelles requires that the properties of molecular units change as a result of a chemical or a physical process activated by light [7]. Although there are a few reports on the use of light as an external stimulus for amphiphilic polymeric micelles by incorporating the photochromic molecule

into surfactant molecules, such as azobenzene and spiropyran [6–9]. The use of naphthopyrans as the hydrophobic and the light-responsive block for the preparation of amphiphilic polymeric micelles is less reported. It is well known that naphthopyrans (NP) are an important class of photochromic dyes. They display the ability of reversible color changes and undergo highly efficient photoreversible isomerization which results in the merocyanine (MC) moiety with significant difference in the polarity and the spatial structure of molecule when exposed to UV irradiation [10]. In addition, naphthopyrans have the advantages in commercial application in optical memories, optical and electrical switching, and light-actuated nanovalves due to their special optical properties such as the breadth of color generated, absence of background color, fine control over fading kinetics and good resistance to photochemical fatigue [11]. For these properties, the naphthopyrans were used as the hydrophobic and the light-responsive block for the preparation of amphiphilic polymeric micelles in this work.

The traditional amphiphilic polymeric micelles are usually composed of amphiphilic block copolymers which were synthesized by atom-transfer radical polymerization (ATRP) from a hydrophilic macroinitiator [5]. Besides, as a highly efficient organic reaction, the Cu(I)-catalyzed 1,3-dipolar cycloaddition click reactions [12] between an azide and an alkyne have gained a great deal of attention due to their high specificity and nearly quantitative yields in the presence of many functional groups [13,14]. Click

* Corresponding authors. Tel.: +86 431 85099544; fax: +86 431 85098768.
E-mail address: wangg923@nenu.edu.cn (G. Wang).

reactions have been widely used as a versatile method for synthesis of functional monomers [15,16], functional polymers [17–23], and polymers with different architectures [24–27]. In this paper, we use this method to synthesize amphiphilic polymer by combining the hydrophilic block PEG ($M_n = 5000 \text{ g mol}^{-1}$) and a single-molecule naphthopyran, this is the first time to use the naphthopyrans as the stimuli-responsive part to synthesize the amphiphilic polymer through the click chemistry method.

Herein, we present the synthesis of amphiphilic polymer (Scheme 1a), the morphological aggregation and light-responsive behavior of the polymeric micelles in water, the release and re-encapsulation of Nile Red (NR) in this system. The results demonstrate that the PEG-shell and NP-core micelles can be disrupted by UV irradiation and reversibly regenerated by removing the UV irradiation. And also, the potential application of the micelles as fast and highly efficient light-responsive nanocarriers was investigated by fluorescence spectroscopy of fluorescent dye Nile red.

2. Experimental

2.1. Materials

Methoxypolyethylene glycol 5000 (PEG-5000, Fluka), 3-Bromopropyne (99%, Energy-chemical), N,N,N',N',N''-pentamethyl diethylenetriamine (PMDETA, 99%, Aldrich), Nile Red (99%, J&K Scientific) were all used as received. CuBr (99.5%, Sinopharm Chemical Reagent Co., Ltd.) was purified by washing with glacial acetic acid and dried in a vacuum oven at 100°C . 8-hydroxy-[3,3-diphenyl]-3H-naphtho[2,1-b]pyran (NP-OH), and azido-terminated methoxypolyethylene glycol 5000 (PEG-N₃) was prepared as previously reported [15,28]. All the solvents were distilled before use. Deionized water (Millipore) was used for all experiments.

2.2. Synthesis of NP-alkyne

The synthesis of 8-(prop-2-yn-1-yloxy)-[3,3-diphenyl]-3H-naphtho[2,1-b]pyran (NP-alkyne) is described as follows. NP-OH (0.35 g, 1.0 mmol) and K₂CO₃ (0.21 g, 1.5 mmol) were stirred at room temperature in DMF (10 mL). After 0.5 h, the 3-Bromo-1-propyne (0.12 mL, 1.5 mmol) was added dropwise into the mixture at 0°C . The mixture was stirred at room temperature and the reaction was monitored by TLC. The reaction was quenched with water and extracted with ethyl acetate. The organic solution was dried over anhydrous sodium sulfate. The purified product was obtained by column chromatography on silica gel (ethyl acetate:petroleum ether = 1:5), yellow solid (0.3 g, 86% yield). ¹H NMR (500 MHz, CDCl₃, δ): 7.88 (d, $J = 9.5 \text{ Hz}$, 1H; Ar-H), 7.56 (d,

$J = 9.0 \text{ Hz}$, 1H; -O-C-CH=CH-C), 7.48–7.46 (m, 4H; Ar-H), 7.32–7.27 (m, 4H; Ar-H), 7.25 (s, 1H; Ar-H), 7.24–7.22 (m, 2H; Ar-H), 7.19–7.17 (m, 2H; Ar-H), 7.14 (d, $J = 2.5 \text{ Hz}$, 1H; Ar-H), 6.27 (d, $J = 10 \text{ Hz}$, 1H; -O-C-CH=CH-C), 4.76 (d, $J = 2.5 \text{ Hz}$, 2H; -CH₂-), 2.52 (t, $J = 2.5 \text{ Hz}$, 1H; CH≡C-). ¹³C NMR (125 MHz, CDCl₃, δ): 153.9, 149.2, 144.8, 130.0, 128.6, 128.1, 128.0, 127.5, 127.0, 125.5, 123.0, 119.5, 119.1, 118.9, 114.3, 108.5, 82.3, 78.5, 75.6, 55.8.

2.3. Synthesis of amphiphilic polymer (PEG-NP) by click reactions

Amphiphilic polymer PEG-NP was synthesized by click reaction between PEG-N₃ and NP-alkyne. The reaction is described as follows: PEG-N₃ (2.0 g, 0.4 mmol) and NP-alkyne (0.27 g, 0.6 mmol) were conducted in a 50 mL Schlenk flask in DMF (20 mL) and CuBr (6.0 mg, 0.4 mmol)/PMDETA (0.05 mL, 0.4 mmol) as catalyst. The coupling reaction was carried out at 35°C for 48 h. Copper ions were removed from the polymer solution with neutral alumina column chromatography. The product was isolated by precipitation into cold diethyl ether. After filtration, the polymer was dried under vacuum. ¹H NMR of PEG-NP (500 MHz, CDCl₃, δ): 7.88 (d, $J = 9.5 \text{ Hz}$, 1H; Ar-H), 7.86 (s, 1H; -CH=C), 7.56 (d, $J = 8.5 \text{ Hz}$, 1H; -O-C-CH=CH-C), 7.48 (d, $J = 7.5 \text{ Hz}$, 4H; Ar-H), 7.33–7.30 (m, 5H; Ar-H), 7.26–7.23 (m, 3H; Ar-H), 7.19–7.17 (m, 2H; Ar-H), 6.28 (d, $J = 9.5 \text{ Hz}$, 1H; -O-C-CH=CH-C), 5.28 (s, 2H; -CH₂-), 4.55 (t, $J = 5.0 \text{ Hz}$, 2H; CH₂), 3.86 (t, $J = 5.0 \text{ Hz}$, 2H; CH₂), 3.80–3.50 (m, 482H; O(CH₂CH₂O)_m), 3.39 (s, 3H; CH₃O).

2.4. Preparation of PEG-NP micelles

An aqueous PEG-NP micellar solution was prepared as follows: PEG-NP (1.0 mg) was dissolved in 1 mL THF, and then 10 mL of water was added dropwise overnight to form micelles while THF was allowed to completely evaporate. The solution was filtered through a 0.22 μm filter before use [9].

2.5. Encapsulation of Nile Red

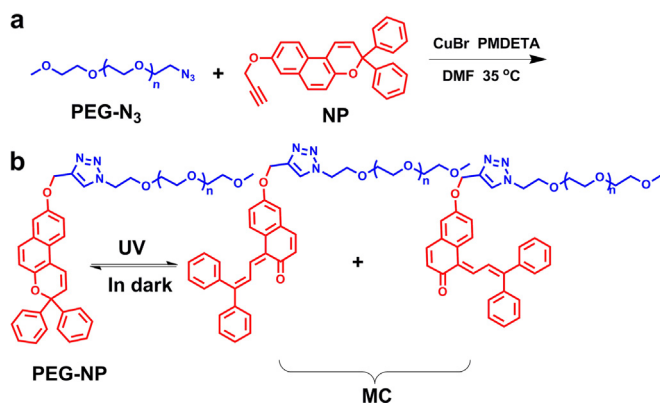
To incorporate Nile Red into the core of the micelles, 2.0 mL Nile Red solution in acetone (0.05 mg mL^{-1}) was added dropwise into 10 mL blank PEG-NP micellar solution under stirring. After ultrasonication for 10 min, the solution was stirred for 24 h in dark [9].

2.6. Turbidity measurements

The turbidity change of polymeric micellar solution was measured alternately after 5 min UV irradiation and thermal fading in dark for 5 min, respectively. The absorbance of the PEG-NP micellar solution at 680 nm was measured by a UV/Vis spectrometer. The turbidity was calculated as $\text{turbidity} = 1 - 10^{-A}$, where A is the UV absorbance at 680 nm of the micellar solution.

2.7. Characterization

The ¹H NMR spectroscopy spectra were recorded on a Varian Unity Inova Spectrometer (500 MHz) at room temperature and dichloroform was used as the solvent. The photochromic properties of the amphiphilic polymer PEG-NP was examined using a Varian Cary 500 UV-Vis spectrophotometer. A CHF-XM35 parallel light system with a 500 W xenon lamp was used as the UV source of irradiation. Transmission Electron Microscopy (TEM) analysis was performed on a JEOL-2011F microscope operating at an accelerating voltage of 200 kV. Samples were prepared by placing a drop of the solutions on a 400-mesh carbon-coated copper grid. Fluorescence emission spectra were recorded from Cary Eclipse Fluorescence Spectrophotometer and the excitation wavelength was



Scheme 1. a) Synthesis of PEG-NP. b) Light-induced isomerization of PEG-NP.

Download English Version:

<https://daneshyari.com/en/article/176261>

Download Persian Version:

<https://daneshyari.com/article/176261>

[Daneshyari.com](https://daneshyari.com)