

Synthesis of fluorescent dendrimers with aggregation-induced emission features through a one-pot multi-component reaction and their utilization for biological imaging



Weihua Luo^{a,b,1}, Ruming Jiang^{b,1}, Meiying Liu^b, Qing Wan^b, Jianwen Tian^b, Yuanqing Wen^b, Qian-yong Cao^b, Junfeng Hui^{a,*}, Xiaoyong Zhang^{b,*}, Yen Wei^{c,d,*}

^a Shaanxi Key Laboratory of Degradable Biomedical Materials, Shaanxi R&D Center of Biomaterials and Fermentation Engineering, School of Chemical and Engineering, Northwest University, Xi'an 710069, PR China

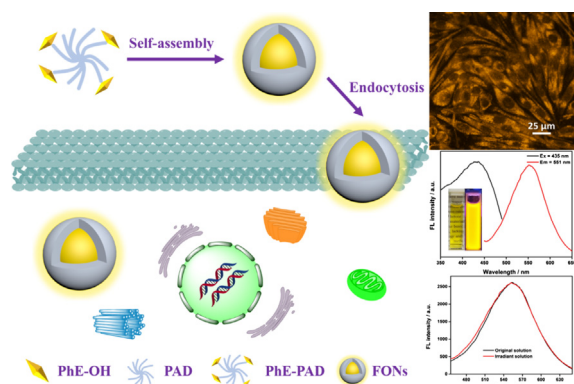
^b Department of Chemistry, Nanchang University, 999 Xuefu Avenue, Nanchang 330031, China

^c Department of Chemistry and the Tsinghua Center for Frontier Polymer Research, Tsinghua University, Beijing 100084, PR China

^d Department of Chemistry and Center for Nanotechnology, Chung-Yuan Christian University, Chung-Li 32023, Taiwan

GRAPHICAL ABSTRACT

The fluorescent hyperbranched dendrimers with aggregation-induced emission feature have been fabricated through a facile one-pot multicomponent reaction and utilized for biological imaging.



ARTICLE INFO

Article history:

Received 8 July 2017

Revised 2 September 2017

Accepted 5 September 2017

Available online 9 September 2017

Keywords:

Fluorescent organic nanoparticles

Aggregated-induced emission

Fluorescent hyperbranched polymers

ABSTRACT

Hyperbranched polymers have attracted wide research attention owing to their unique topological structure, physicochemical properties and great potential for applications such as additives, drug delivery, catalysts and nanotechnology. Among these, the polyamidoamine (PAMAM) dendrimers are some of the most important dendrimers. However, the synthesis and biomedical applications of fluorescent PAMAM dendrimers have received only limited attention. In this work, we present a rather effective and convenient approach for synthesis of fluorescent PAMAM dendrimers with aggregation-induced emission (AIE) properties through a one-pot catalyst-free Mannich reaction under rather mild experimental conditions (e.g., low reaction temperature, air atmosphere in the presence of water). The obtained AIE-active amphiphiles (PhE-PAD) could self-assemble into fluorescent organic nanoparticles (FONS). The

* Corresponding authors.

E-mail address: xiaoyongzhang1980@gmail.com (X. Zhang).

¹ These authors contributed equally to this work.

A one-pot Mannich reaction
Biomedical applications

obtained AIE-active FONs (PhE-PAD FONs) were fully characterized, and their successful construction was confirmed by ^1H NMR spectroscopy, FT-IR spectroscopy and transmission electron microscopy. Fluorescence and UV-Visible absorption spectroscopy results demonstrated that the final PhE-PAD FONs showed strong yellow fluorescence, desirable photostability and good water dispersity. The cell viability evaluation and confocal laser scanning microscope imaging results suggested that PhE-PAD FONs possessed low cytotoxicity and excellent biocompatibility. Taken together, these results demonstrate that we have developed a facile and efficient strategy for the fabrication of AIE-active FONs, which possess many desirable features for biomedical applications.

© 2017 Elsevier Inc. All rights reserved.

1. Introduction

Optical imaging is one of the most important and direct methods for real-time quantitative acquisition of biological information [1–3]. Among these methods, the fluorescent imaging technology play a very important role in the field of optical biological imaging because of its excellent advantages such as minimal damage to the living organisms, absence of harmful electromagnetic radiation and low equipment cost [4,5]. With the rapid development of materials science, fluorescent nanomaterials have been extensively used in biological imaging due to their excellent luminescent properties, high biocompatibility and high sensitivity [6–8]. Currently, fluorescent nanomaterials commonly used in the field of biomedicine include fluorescent proteins [9], fluorescent organic nanoparticles (FONs) [10] and various other fluorescent probes [11] from inorganic nanomaterials and metal-complexes [12]. Nevertheless, the biological imaging applications of fluorescent proteins are restricted by their poor anti-photobleaching properties, infrared absorption and high cost [13]. On the other hand, the poor biodegradability, existence of heavy metals and toxic issues from fluorescent inorganic nanoparticles such as semiconductor quantum dots [14] and metal nanoclusters [15] have also greatly impeded their practical biomedical applications. Compared to the fluorescent proteins and fluorescent inorganic nanoparticles, FONs show many advantages for biomedical applications. The principle for the preparation of FONs is the encapsulation of hydrophobic organic chromophores into amphiphilic copolymers through covalent and non-covalent interactions. The resultant luminescent amphiphilic copolymers will self-assemble into FONs with great water dispersity [16]. However, these FONs based on conventional organic molecules will result in a significant decrease in fluorescence owing to the aggregation-caused quenching (ACQ) effect [17]. Therefore, the development of novel FONs that could avoid the ACQ effect from conventional organic chromophores is still highly desirable.

In 2001, Tang et al. reported an abnormal phenomenon of small organic molecules (siloles) being non-luminescent in dilute solution but showing significantly enhanced fluorescence in the aggregated state [18]. This unique fluorescent phenomenon was obviously different from the ACQ effect and was defined as aggregation-induced emission (AIE) [19–23]. Since its discovery, the AIE phenomenon has aroused great research interest. Various organic molecules with AIE features such as tetraphenylethene, triphenylethene and distyrylanthracene derivatives have been reported [24–26]. Additionally, many AIE-active functional materials have been developed for various applications, especially in the biomedical fields [27–31]. The AIE-active FONs could not only have controllable physicochemical properties and the good design properties of small organic molecules but also display better photostability and multifunctional potential of the final FONs [32]. The basic principle for the preparation of AIE-active FONs relies on the self-assembly of AIE-active dye containing amphiphilic macromolecules in aqueous solution [33]. After self-assembly, the hydrophobic dyes were aggregated and resulted in an enhanced

fluorescence intensity, while the hydrophilic segments served as a protective coating and provided the good water dispersity of the resultant FONs. Therefore, FONs with desirable fluorescent properties and good designability could be obtained. These AIE-active FONs are therefore expected to elegantly overcome the drawbacks of small organic fluorescent molecules, fluorescent inorganic nanoparticles and FONs based on conventional fluorescent organic molecules. Over the past few years, a number of fabrication methods such as the ring-opening reaction [34,35], Schiff base condensation [36] and reversible addition fragmentation chain transfer (RAFT) polymerization [37] have been developed for the synthesis of AIE dyes containing amphiphilic polymers. Although great progress has been made, most of these methods not only require cumbersome steps, harsh conditions and expensive raw materials but also require the participation of a catalyst, which is undesirable in biomaterials. Moreover, the synthesis of AIE-active hyperbranched polymers has received only very limited attention [38,39]. Thus, the development of a simple, green and highly efficient approach for the fabrication of AIE-active hyperbranched polymers is still of great interest.

In this contribution, a novel one-pot multi-component reaction was proposed to prepare AIE-active FONs under rather mild reaction conditions. To obtain the AIE-active PhE-PAD FONs, three reactants including poly(amidoamine) dendrimers (PAD), paraformaldehyde (PF) and phenol hydroxyl-contained AIE dye (PhE-OH) were conjugated through a one-pot Mannich reaction (Scheme 1). Owing to their amphiphilic properties, the final PhE-PAD FONs are expected to display good water dispersity and strong fluorescence. This approach does not require any catalysts, and the one-pot synthesis eliminates the tedious experimental steps. The operational procedure is also very simple and environmentally friendly. Finally, to explore the biological applications of PhE-PAD FONs in biological imaging, their morphology, optical properties, biocompatibility and cell uptake behaviour were evaluated.

2. Experimental procedure

2.1. Materials and characterization

Paraformaldehyde ($M_w = 30.03$ Da, 96%), 4-hydroxyphenylacetonitrile ($M_w = 133.15$ Da, 98%) and tetrabutylammonium hydroxide solution (TBAH, $M_w = 259.47$ Da, 0.8 M in methanol) were purchased from Aladdin and were used as received. Poly(amidoamine) dendrimers (95%) were obtained from Weihai CY Dendrimer Technology CO., LTD (China). All other chemicals were used directly without further purification, except when noted otherwise. Intermediate 10-hexadecyl-10H-phenothiazine-3-carbaldehyde (PhE-CHO) was obtained and characterized according to our previous report [40]. Proton nuclear magnetic resonance (^1H NMR) spectra were measured on a Bruker Avance-400 spectrometer with d_6 -DMSO and CD_3Cl as the solvents and tetramethylsilane (TMS) as the internal standard. The Fourier transform infrared spectroscopy (FT-IR) spectra were measured using the

Download English Version:

<https://daneshyari.com/en/article/4984323>

Download Persian Version:

<https://daneshyari.com/article/4984323>

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