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Preparation of micelle-encapsulated single-wall and multi-wall carbon nanotubes with amphiphilic hyperbranched polymer

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Abstract

The hyperbranched polyester (Boltorn^{TM} H20) was modified by maleic anhydride and then polystyrene (H20-MAh-PSt) to form amphiphilic micelles in water. The single-wall and multi-wall carbon nanotubes (SWCNTs and MWCNTs, respectively) were encapsulated in the formed micelles through non-covalent interactions. The formed structures were confirmed by FTIR, NMR, GPC, and XPS analysis. The dispersion and aggregation behaviors were observed by TEM and UV–vis and Raman spectroscopic analysis. The results showed that the dispersion performance of the obtained micelle-encapsulated carbon nanotubes in water was greatly improved compared to the pure carbon nanotubes. From the TEM observation, the individual SWCNT structure and the uniform polymer coating around the surface of SWCNT were seen after crosslinking. The Raman spectroscopic measurements also demonstrated that for the crosslinked samples, no effect occurred associated with concentration-dependent carbon nanotube aggregation.

Keywords: Carbon nanotube; Hyperbranch; Micelle; Raman spectroscopy; TEM (transmission electron microscopy)

1. Introduction

Carbon nanotubes (CNTs) exhibit remarkable mechanical, thermal, and electrical properties due to their unique one-dimensional all-carbon structure [1,2]. However, some disadvantages, such as poor solubility and processibility restrict their applications. To prepare stable aggregation-free CNT dispersions, lots of work has been done by wrapping them with polymer chains through covalent and non-covalent functionalization. The modified nanotube suspensions in water or water/organic mixtures have shown potential applications in biology and material fields [3].

Using the covalent modification approach, the electronic conjugation will be disrupted by introducing new covalent bonds to the graphene sheet, resulting in the inevitable alteration of CNT properties [4]. The modification of CNTs can also be preformed through the non-covalent interaction between the π-system of CNT and the functional group comprising the polymer. Several studies have been reported on non-covalent adsorption of hydrophilic polymers and amphiphilic block copolymers

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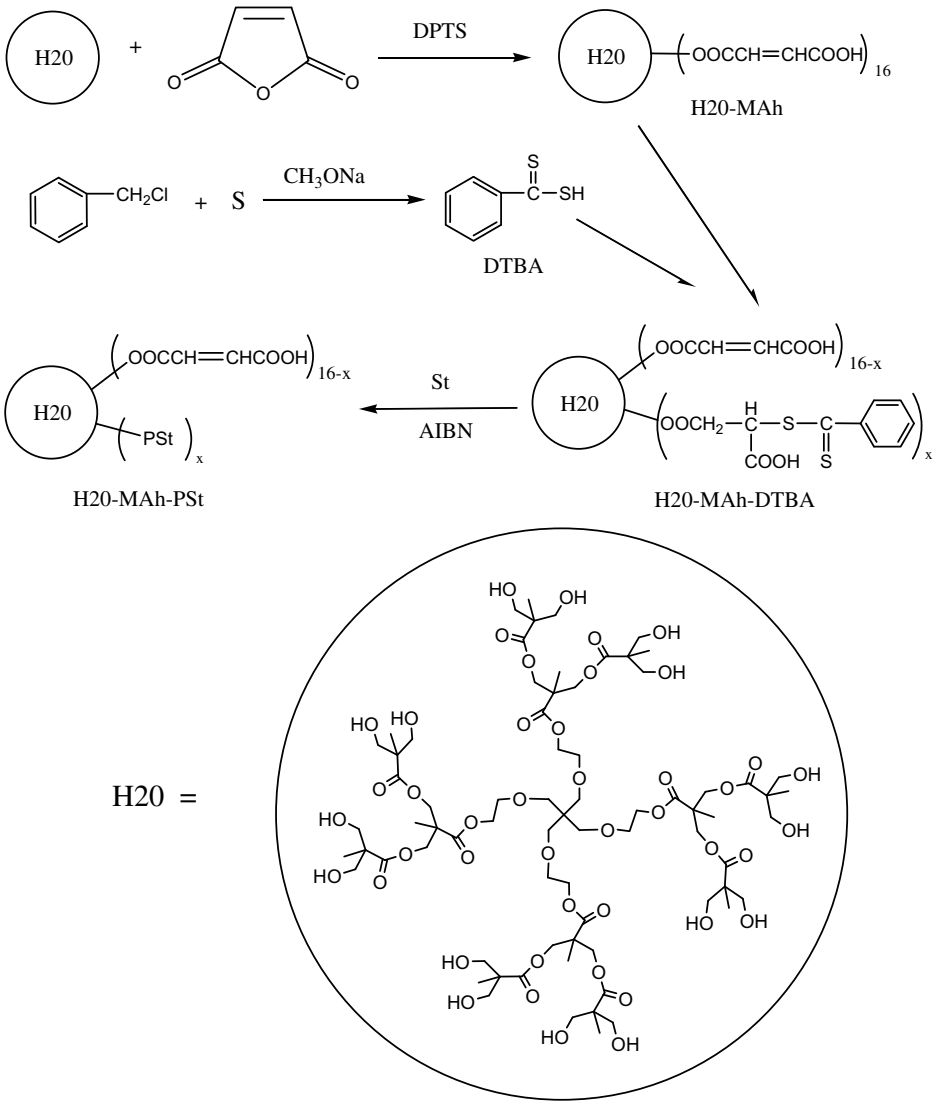
on CNTs [5,6]. Kang and Taton reported a non-covalent approach of packing nanotubes within the crosslinked amphiphilic poly(styrene)-*block*-poly(acrylic acid) copolymer micelles [7]. The assumption that the weak interaction between polymers and CNTs would not interfere with the electronic structure of tubes was proposed [8].

Hyperbranched polymers are characterized by the spherical molecular shape and a large number of functional end-groups, which makes them easy to be tailored for various end-user's purposes with different routes. Moreover, several unique properties such as high reactivity, good compatibility with other polymers, high solubility and low viscosity as melt and solution compared with their linear counterparts have been discovered [9,10]. Thus, it is assumed that the wrapping hyperbranched polymers around CNTs may enhance the dispersion of CNTs in water and a wide variety of solvents.

In this paper, we report an approach by encapsulating the CNTs into crosslinked amphiphilic hyperbranched polyester micelles. The molecular structure of the formed micelle-encapsulated CNTs was characterized by FTIR, NMR, GPC, and XPS analysis. The thermal performance, dispersion and aggregation behaviors were investigated by TGA, TEM observation, and UV–vis and Raman spectroscopy.



Scheme 1. Synthesis routes of H20-MAh-PSt.