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Brief notes

Electrorheological properties of poly (linear *trans*-quinacridone)-based suspensions

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Abstract

Ladder-like polymer poly(linear *trans*-quinacridine) (polyquin (2,3-*b*) acridine-7,14(5,12) dione, PTQA) was synthesized and identified. Anhydrous electrorheological fluid (ER fluid, ERF) with PTQA as dispersed particle and bromodiphenylmethane (BDPM) as dispersing medium were prepared; the electrorheological properties were studied. The temperature effect of PTQA suspensions was also discussed. The results showed that PTQA suspensions in BDPM performed excellent ER activity; at room temperature, the yield stress of the suspension with 30 wt.% of particles was up to 6.0 kPa (3.0 kV/mm). The shear stress increased with the rise in temperature, and the temperature effect was enhanced at higher temperature range. The differences of electrorheological properties between PTQA-based ERF and polyquin(2,3-*b*) acridine-12,14(5,7) dione-based ERF were attributed to the molecular structural regularity of the polymer.

Keywords: Poly(linear *trans*-quinacridine); Electrorheological fluid

1. Introduction

In general, an electrorheological fluid (ERF) is made from an insulating liquid medium embodying either a semi-conductive particulate material or a semi-conductive liquid material (usually a liquid crystal material) [1]. ERFs are suspensions whose rheological properties, such as viscosity, yield stress, shear modulus, etc., can adjustably, reversibly and rapidly change upon the application of an external electric field [2,3]. Those excellent mechanical properties have made ERF one of the most promising “smart materials” [4–7], and the subject of intense theoretical [8–10] and experimental [11–13] research due to its emerging technological applications [14–16]. However, large-scale utilization of ERF has not been achieved yet for the lack of ERFs with a sufficiently high performance [17,18]. Thus, the challenge is to design and prepare high-performance ER materials [19,20].

It’s well-known that the chemical natures including molecular and crystal structure of materials are critically important to the dielectric and polarization properties. Thus, it is possible to modify the dielectric and polarization properties to increase ER activity by designing the molecular and crystal structure of ER materials [21].

Linear *trans*-quinacridone (quin (2,3-*b*) acridine-7,14 (5,12) dione) is an isomer of linear *cis*-quinacridone (quin (2,3-*b*) acridine-12,14 (5,7) dione) with the differences in the positions of two group, i.e. amino (NH) and carbonyl (CO). Those structural differences make them very different properties, for example, linear *trans*-quinacridone shows deep red color with very high stability to light, weather and temperature, and insolubility in common solvent, which make it widely used as a top grade pigment [22,23] and presented well optical properties with good prospects in the optical instruments [24,25]. We report here the synthesis, characterizations and the ER properties of poly (linear *trans*-quinacridine) (PTQA, see Fig. 1), which should be some helpful for chemists to design and synthesis polymers with different molecular structure to modify the polymeric corresponding properties.

2. Experimental

2.1. Synthesis and characterizations of PTQA

The synthetic route for PTQA is presented in Scheme 1.

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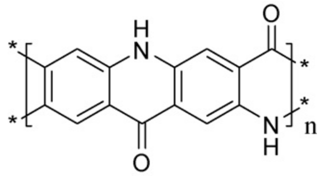


Fig. 1. The chemical structure of PTQA.

The synthesis of PTQA was performed exactly according to the synthesis of polyquin (2,3-*b*) acridine-12,14(5,7) dione (PQA) [26], starting from *p*-phenylenediamine but not *m*-phenylenediamine.

The black powders of PTQA are insoluble in general solvent and also infusible. The structure of polymer, thermal characteristics and crystal structure, were characterized using: Fourier transform infrared spectroscopy (FT-IR, Perkin-Elmer, Spectrum One, USA) with KBr disk method at room temperature, Elemental analysis (Perkin-Elmer 2400-||CHN, USA), Thermal gravity analysis (WRT-3P, China) at the heating rate of 10 °C/min under nitrogen atmosphere, Scanning electron microscopy (SEM, S-570, Hitachi, Japan).

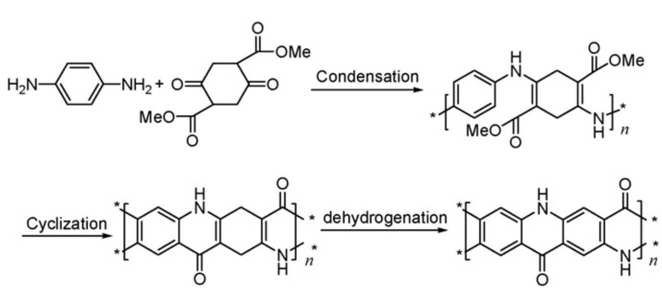
2.2. Preparation of ER suspensions and rheological measurements

The preparation of PTQA-based suspensions and the rheological measurements were performed as our previous work [26]. The weight percentage was used to present the concentration of the suspensions. The temperature effects on the ERF were measured by using an oil bath attached to the coaxial cylinder rotational viscometer for temperature control in the range of 25–120 °C.

3. Results and discussion

3.1. PTQA structural characterization results

The FT-IR spectrum of PTQA is analyzed as follows (see Fig. 2): the single peak at 3409.90 cm^{-1} and the peak at 1384.35 cm^{-1} are $\nu_{\text{N–H}}$ and $\nu_{\text{N–C}}$ of second amine, respectively, the peaks at 2922.53 and 1510.78 cm^{-1} are $\nu_{\text{C–H}}$ and $\nu_{\text{C–C}}$ of benzene ring, the peak at 816.24 cm^{-1} is the two isolated $\delta_{\text{C–H}}$ of benzene ring. The peak at 1599.00 cm^{-1} is the carbonyl stretch absorption; due to the large conjugated molecular structure it is strongly red shift to long wavelength. This suggests that PTQA is more regular than PQA synthesized in our previous work.



Scheme 1. The synthetic route for PTQA.

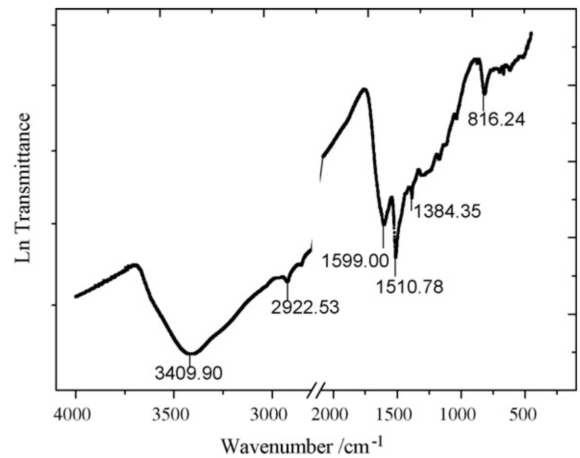


Fig. 2. The FT-IR spectrum of PTQA.

Elemental analysis shows that the polymer contains C, H and N with percentage of 72.00, 2.63 and 11.94%, respectively, which agrees well with the targeted $(C_{14}H_6N_2O_2)_n$ of C 71.79%, H 2.58%, N 11.96%.

The density of dried polyquinacridone particles was also measured to be 1.41 g/cm^3 using Archimedes method.

The thermal gravity result shows clearly that this polymer possesses excellent stability under 300 °C. The decomposed temperature reaches up to 327 °C.

As shown in Fig. 3, the SEM photograph shows that the PTQA particles display lamellar crystal with average diameter of approximately 5–15 μm.

3.2. Electrorheological properties

Figs. 4 and 5 show respectively the shear stress as functions of shear rates and electric field, the apparent viscosity as functions of shear stress and electric field for the PTQA suspension in BDPM at 30 wt.% of particle under 25 °C.

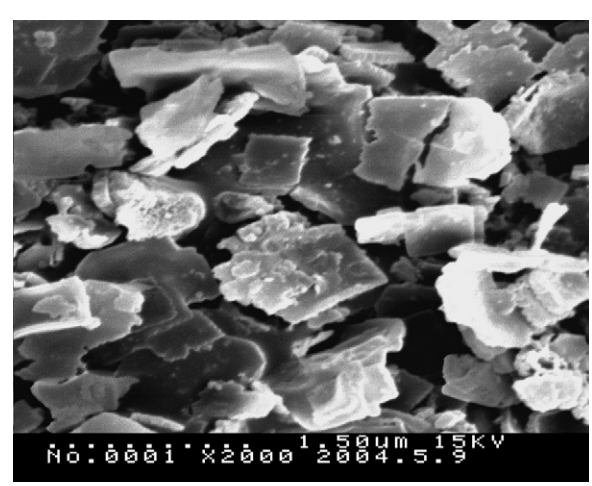


Fig. 3. The SEM photograph of PTQA.