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Optical diffusers based on the novel fillers of polysiloxane@boehmite core–shell microspheres

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ABSTRACT

In this study, optical diffusers based on polysiloxane@boehmite microspheres were successfully prepared by solvent-free UV curing process. Polysiloxane@boehmite microspheres had been synthesized via facile hydrothermal synthesis method. The microscope analysis revealed that the size of polysiloxane@boehmite microspheres focused on 6–7 μm in diameter and the shell thickness was about 700–900 nm. The optical properties of the novel diffusers based on polysiloxane@boehmite microspheres were also measured for the first time, and the results proved that the diffusers possessed suitable light transmittance, good diffusion capacity, and low incident angle dependence. When the concentration of polysiloxane@boehmite microspheres was up to 15 wt%, the diffusing properties of novel diffusers can exceed the optical diffusers on market. Thus, the novel microspheres can be widely used for preparing multifunctional diffusion materials such as touch-panel functions, monitors, military projectors, etc.

1. Introduction

There is a requirement for better light diffusion for liquid crystal displays (LCDs) in order to meet the development of them to become larger and thinner [1]. Optical diffuser is the key component in backlight unite (BLU) for LCDs, which plays the role of smoothing the illumination profile behind the LCD and making it more uniform [2,3]. In early studies, the properties of optical diffusers were enhanced through a careful design of the diffusion particles and manufacturing conditions, respectively [4,5]. Quite recently, the development of sophisticated surface patterning techniques has led researchers to explore the feasibility of improving the light diffusing effect of diffusers by patterning optical micro-structures on the upper surface of the film [6,7].

In addition, various researchers have proposed hybrid optical films in which the diffusion and brightness enhancement functions were combined [8,9]. However, there were still drawbacks with the coated optical materials, including controllability of the distribution of the scattered particles due to their tendency to agglomerate and the complex in-line coating process [10]. In particular, since the research progress of optical diffusers was mainly protected in the form of patents, the literatures were very limited and it was needed to be explored and to get up breakthrough earlier [2].

By comparison, the diffuser based on polysiloxane@boehmite was an economical material which can be produced at a much larger scale by the facile hydrothermal method and solvent-free UV process. Polysiloxane@boehmite-based diffusers presented advantages due to their hybrid core–shell structure with special physical and chemical properties [11,12]. In addition, the novel diffusers had low absorption-related losses and therefore high transmission efficiency. Furthermore, the high melting point of boehmite meant that these diffusers can withstand high temperatures [13,14]. Herein, this work described a very simple approach for obtaining novel diffusers with super diffusing properties. Our group first reported that polysiloxane@boehmite microspheres can be used as optical diffusing fillers of diffusers, and the optical properties of the novel diffusers were also measured.

2. Experimental procedures

In a typical synthesis, $Na_2C_4H_4O_6 \cdot 2H_2O$ (0.0003 mol), $CO(NH_2)_2$ (0.007 mol), and $Al(NO_3)_3 \cdot 9H_2O$ (0.0035 mol) powders were dissolved in 70 ml of distilled water. After that, 0.002 mol vinyltrimethoxysilane(VTMS) was added to the above solution, and stirred for 15 min. The solution was placed in a 100 ml

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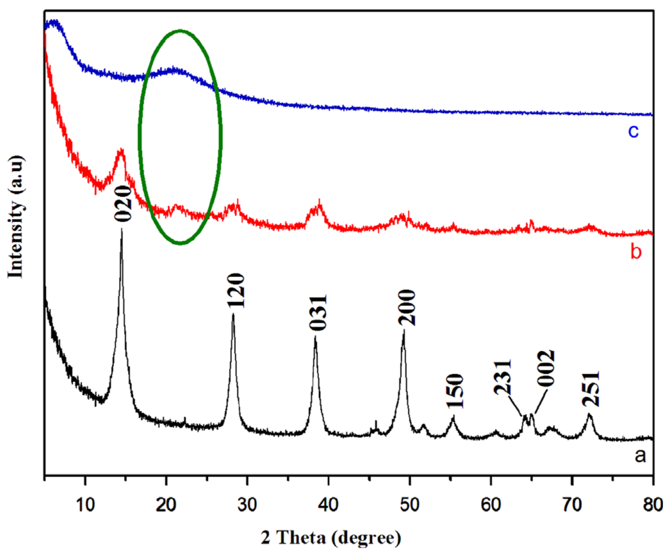

Fig. 1. XRD patterns of (a) boehmite; (b) polysiloxane@boehmite; (c) poly(VTMS).

autoclave with a Teflon liner. The autoclave was maintained at 150 °C for 3 h and then air cooled to room temperature. After reaction, the precipitate was filtered, washed three times with distilled water and one time with anhydrous alcohol, and finally dried in a vacuum oven at 80 °C for 6 h.

Subsequently, the complex films were prepared by solvent-free UV curing process. 5 g Tri(propylene glycol) diacrylate, 0.4 g photoinitiator 184, and 15 g polyurethane acrylate were mixed in dark space. The concentration of relative particles with 2–10 wt% were added to the above. The film samples were obtained by double-sided coating in 50 μm PET. Then, the film was placed in 100 W UV lamp (365 nm) for 10 min each side. Finally, it was placed in an oven at 60 °C for 24 h. The optical diffuser for comparison derived from Dong Xucheng Chemical Co., Ltd. (DXC Diffusion 50-BDN).

The structure and morphology of the multifunctional microspheres were studied by X-ray diffractometer(XRD) equipped with CuKa radiation, powder transmission electron microscopy (TEM) and Scanning Electron Microscopy (SEM). The haze and light transmittance can be measured by transmittance haze meter (WGT-S). Optical diffusing properties were measured by light intensity distribution measuring instrument (HD-4960-LED).

3. Results and discussion

The X-ray diffraction (XRD) patterns of synthesized composites are shown in Fig. 1. It presented the peaks of standard boehmite (JCPDS No. 21-1307), which confirmed that the synthesized products contained boehmite. In addition, it formed a small broad peak in the hydrothermal product (shown in XRD curve b), which was corresponding to the poly(VTMS) XRD pattern (displayed in the circle). Comparing the peak intensities of curve (a) with curve (b), it can be observed that the XRD pattern of hydrothermal product presented weak boehmite peaks and poly(VTMS) peak, which indicated the structure of the product took on the decreasing crystallinity. It suggested the composites of hydrothermal product experienced chemical assembly other than the physical blend of poly(VTMS) microspheres and formed boehmite particles.

Dimensions and morphological features of synthesized particles were observed by SEM and TEM images shown in Fig. 2. Polysiloxane@boehmite particles were prepared via hydrothermal reaction, and the morphology was obtained in Fig. 2(a) and (b). The particles took on smooth regular spherical, and the size of them mainly focused on 6–7 μm. Fig. 2(c) shows TEM image of the hydrothermal product. It revealed obviously the core–shell structure of the microspheres. Moreover, the microscope analysis indicated that the core–shell microspheres were about 6–7 μm in diameter and with a shell thickness of approximately 700–900 nm. Combined with our previous work and vast literature [15–17], it was indicated that the inner layer of final product was boehmite and the outer layer was polysiloxane. Subsequently, the morphology of novel diffusers based on the fillers of

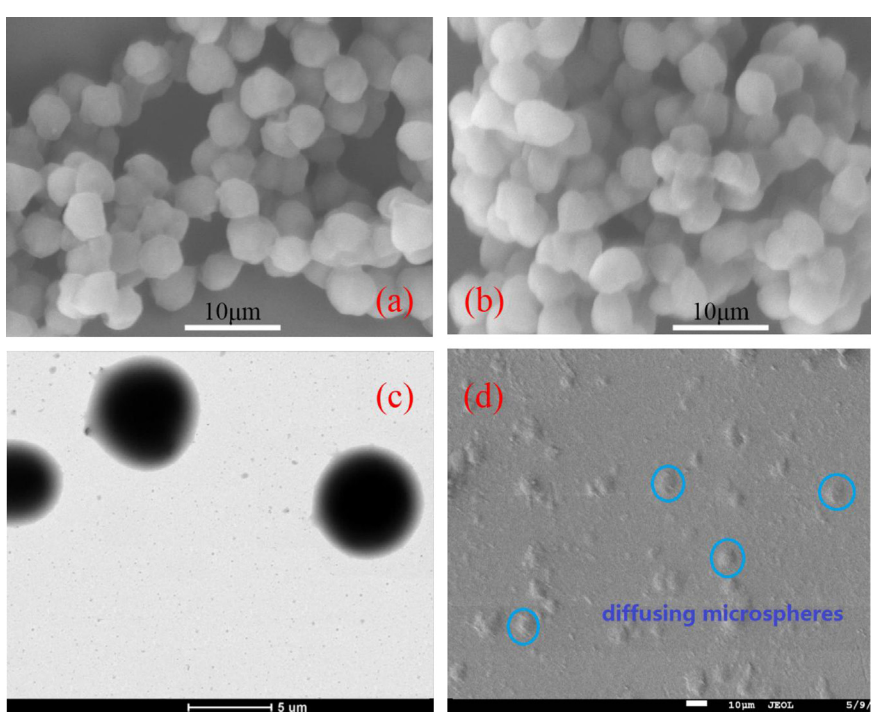

Fig. 2. (a) and (b) SEM photomicrographs of polysiloxane@boehmite; (c) TEM photomicrographs of polysiloxane@boehmite; (d) SEM image of the novel diffusers based on the fillers of polysiloxane@boehmite.