PREPARATION AND OPTICAL PROPERTIES OF ZnO-QD/SiO_2/EPOXY NANOCOMOSITES

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1 Introduction

ZnO quantum dot (ZnO-QD) emits a broad photoluminescence (PL) emission in the green-yellow region, and it is a potential material for use in white light sources. Many studies have been focused on the superior emitting properties of ZnO-QD filled polymer nanocomposites. The nanocomposites not only inherit the high luminescence of the quantum dots but also possess advantages of polymers such as flexibility, film integrity and conformity [1,2].

Solid ZnO-QD particles often show severe agglomeration. Homogeneous dispersion of the ZnO-QD in a polymer matrix is still a technological challenge. In the present paper, ZnO-QD/SiO_2 composite nanoparticles were synthesized by hydrolyzing TEOS in the ZnO-QD solution. ZnO-QDs were homogeneously dispersed in the silica matrix so that agglomeration of ZnO-QDs was then prohibited. In addition, highly transparent ZnO-QD/SiO_2/epoxy nanocomposites were prepared through controlling the refractive index (RI) of ZnO-QD/SiO_2 nanocomposites. Optical properties of ZnO-QD/SiO_2/epoxy nanocomposites were studied using UV-Vis spectrophotometer and UV fluorescence spectrophotometer.

2 Experimental

2.1 Preparation of ZnO-QD/SiO_2

Initially ZnO colloid was prepared using the modified Spanhel and Anderson method [3]. For preparation of ZnO-QD/SiO_2 composite nanoparticles, calculated amounts of TEOS and ammonia were added to the ZnO-QD solution under stirring at room temperature. After 24h, the resulting ZnO-QD/SiO_2 nanoparticles were harvested by centrifugation. Finally, ZnO-QD/SiO_2 nanoparticles were obtained after calcination of the obtained solids in air at 700℃ for 2 h.

2.2 Preparation of ZnO-QD/SiO_2/epoxy nanocomposites

As-prepared ZnO-QD/SiO_2 nanoparticles were dispersed in anhydride curing agent using the ultrasonic technique for 10 min, the resulting mixture was then mixed with bis-phenol A epoxy. The epoxy and curing agent were well stirred until a homogeneous mixture was obtained. The mixture was poured into a stainless steel mould and heated in an oven for 1 h at 130℃ and 6 h at 100℃. After this curing process, the samples were removed from the mould.

2.3 Characterization

Transmission electron microscopy (TEM) of ZnO-QD/SiO_2 samples was performed with an electron microscope (H-800, Hitachi). The optical properties of the ZnO-QD/SiO_2/epoxy nanocomposites were investigated by UV-Vis spectrophotometer (Lambda 900). Finally, UV fluorescence under the excitation light source of 360 nm and 400 nm was measured by luminescence spectrometer (F4500, Hitachi).

3 Results and Discussion

3.1 Characterization of ZnO-QD/SiO_2

Figure 1 shows a TEM image of ZnO-QD/SiO_2 particles obtained after calcination at 700℃ for 2h. It can be seen that the particle size of ZnO-QD/SiO_2 is smaller than 10 nm with slight aggregation.

3.2 Optical properties of ZnO-QD/SiO_2/epoxy nanocomposites

The UV-Vis transmittance spectra of ZnO-QD/SiO_2/epoxy nanocomposites with 2wt% filler content are shown in Figure 2, where the relative weight percentage of ZnO-QD in the ZnO-QD/SiO_2 composite nanoparticles is 30.6%, 33.5%, 37.0%, 41.4% and 46.9%, respectively. Initially, as the ZnO-QD content increases, the visible light intensity of ZnO-QD/SiO_2/epoxy nanocomposites increased and the optimal transmittance with a value greater than 75% was obtained when the relative content of ZnO-QD was 41.4 wt%. Further increase in the relative weight ratio of ZnO to silica leads to decrease of the transmittance of ZnO-QD/SiO_2/epoxy nanocomposites. The above results show that there is an optimum weight ratio of ZnO to silica, resulting in the optimal RI match between the ZnO-QD/SiO_2 composite nanofiller and epoxy matrix, corresponding to the highest visible light transmittance of QD/SiO_2/epoxy nanocomposites.

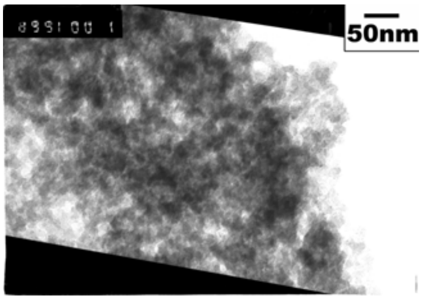

Fig. 1. TEM image of ZnO-QD/SiO_2 composite nanoparticles

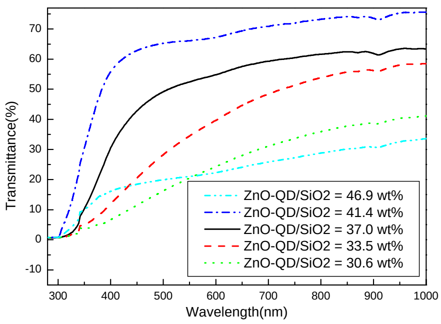

Fig. 2. UV-Vis transmittance spectra of ZnO-QD/SiO_2/epoxy nanocomposites

Figure 3 shows the photoluminescence (PL) spectra of ZnO-QD/SiO_2/epoxy nanocomposites that possess the best visible light transmittance. The excited emission peaks of ZnO-QD/SiO_2/epoxy nanocompostes under 360 nm and 400 nm were similar, corresponding to blue light with a wavelength of around 460 nm. Furthermore, the PL intensity of ZnO-QD/SiO_2/epoxy nanocompostes under 400 nm was higher than under 360 nm. This is because the epoxy matrix absorbed more short (360 nm) wavelength UV light than long (400 nm) wavelength light. Since the emission bands of quantum-sized ZnO nanoparticles depend on the particle size [1], it can thus be inferred that the particle size of ZnO-QD is about 2.2 nm and the annealing process during preparation of ZnO-QD/SiO2 composite nanoparticles didn't significantly influence the growth of ZnO-QD.

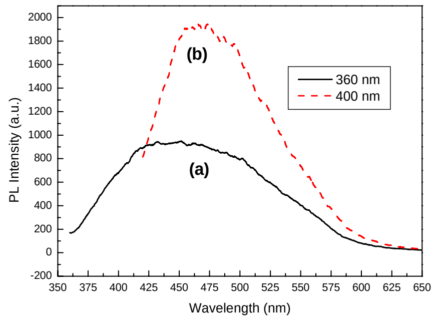

Fig. 3. Fluorescence spectra of ZnO-QD/SiO_2/epoxy nanocomposites under the excitation light source of (a) 360 nm and (b) 400 nm wavelength, respectively

4 Conclusions

In summary, serials of ZnO-QD/SiO_2 nanoparticles have been prepared. The RI was successfully controlled by changing the relative weight ratio of ZnO-QD to silica. Then, the transparent ZnO-QD/SiO_2/epoxy nanocomposites with excellent PL fluorescence properties were prepared by incorporating the as-obtained ZnO-QD/SiO_2 composite nanoparticles into a transparent epoxy matrix.

References

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