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Photonic Crystals Enhanced Fluorescence for Sensing and Display Applications

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INTRODUCTION

Photonic crystals, artificial structures with periodic refractive indices and photonic bandgaps, regulate light propagation and are widely used. This study investigates the enhancement effect and mechanism of self-assembled photonic crystal films as Bragg reflectors on the fluorescence intensity of perovskite quantum dots of different colors.

SAMPLE PREPARATION

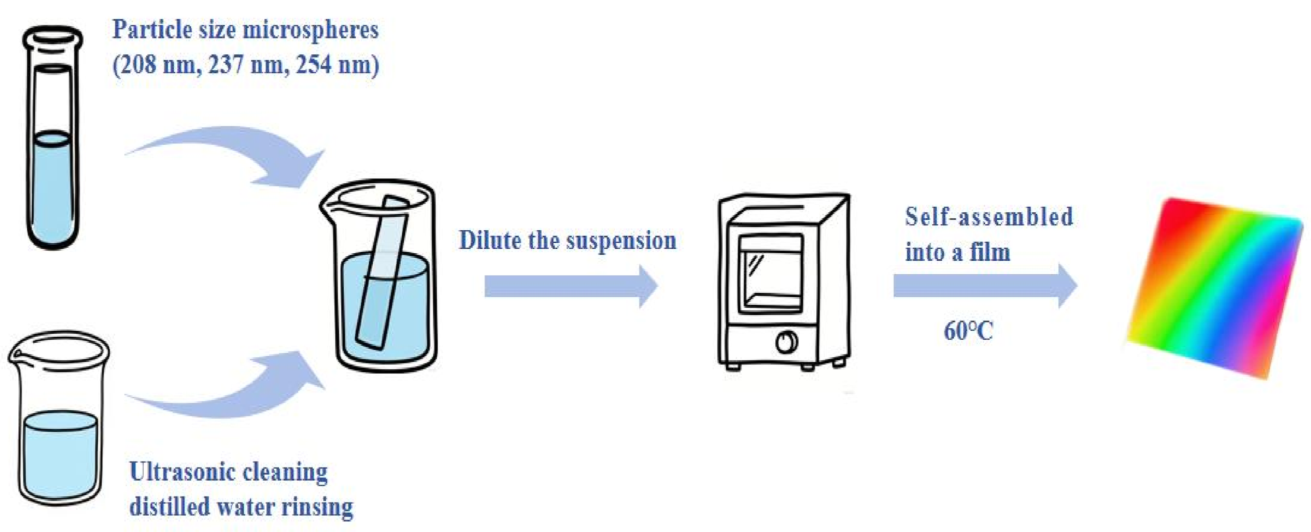

Fig. 1. Self-assemble polystyrene photonic crystal films.

In this work, uniform monodisperse PS spheres (208, 237, 254 nm) were dispersed in 18.2 MΩ·cm water, ultrasonicated 15 min. Then, glass slides were put vertically in the suspension, PS spheres were self-assembled at 60 °C for 2–3 days to get blue, green, and red photonic crystal Bragg films according to different diameters of PS.

STRUCTURAL OF PS ASSEMBLY

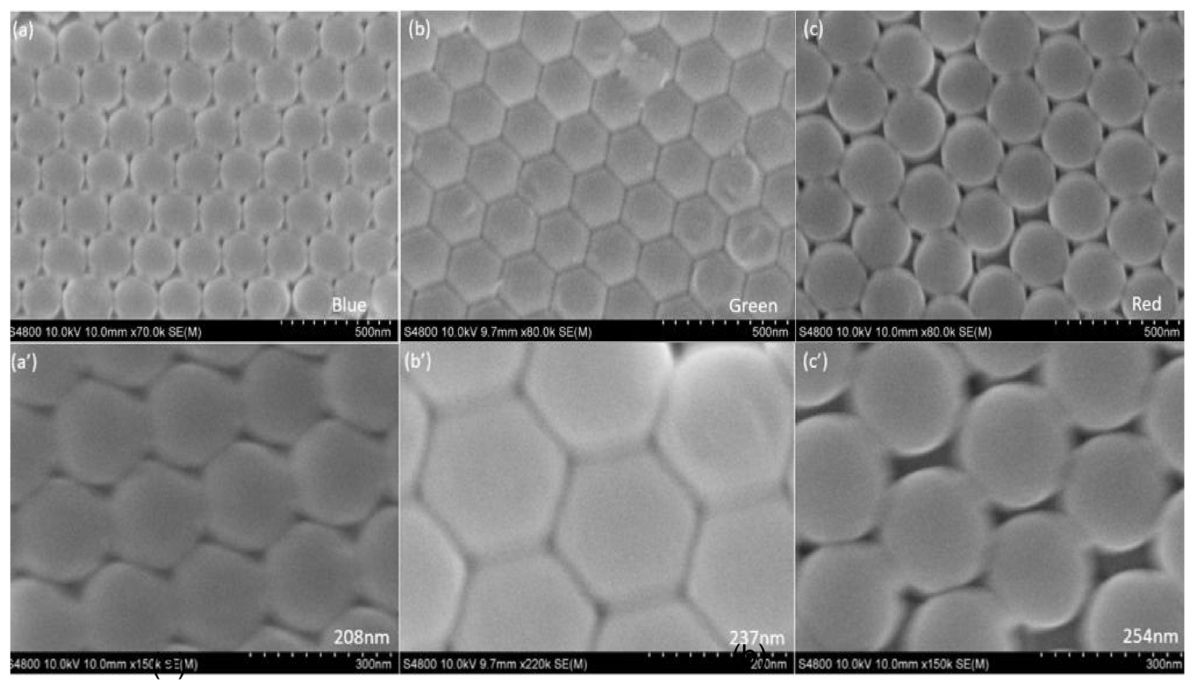

Fig. 2. SEM of PS nanomicrospheres films with particle sizes of 208, 237, and 254 nm.

The particle sizes of PS were 208, 237 and 254 nm, respectively, and it can be seen that the photonic crystal films maintin regular hexagonal close-packed structures.

OPTICAL PROPERTIES

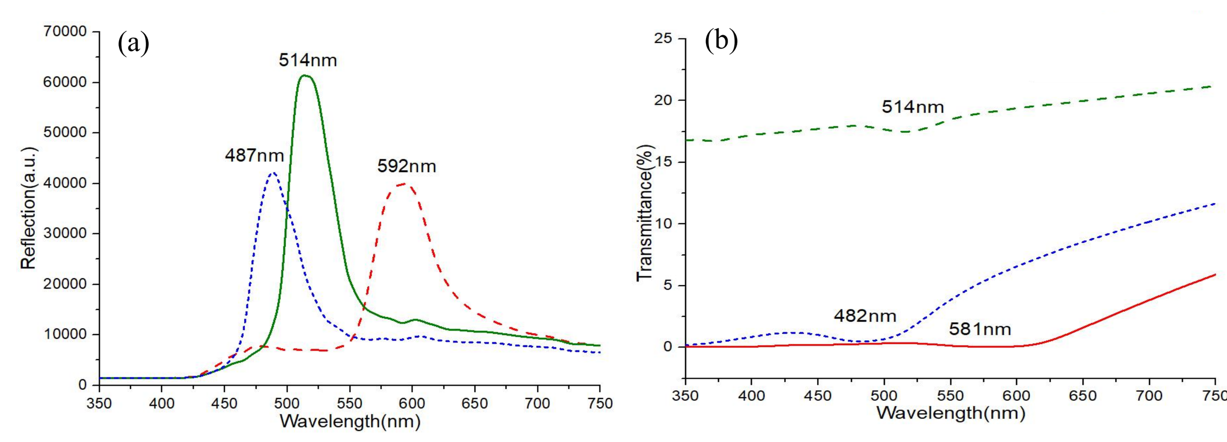

Fig. 3. (a) reflection spectrum and (b) transmittance spectrum of PS PC (208, 237, 254 nm) films.

The reflection peaks of self-assembled photonic crystals (blue, green, and red) are located at 487 nm, 514 nm, and 592 nm, respectively (Fig. 3a).

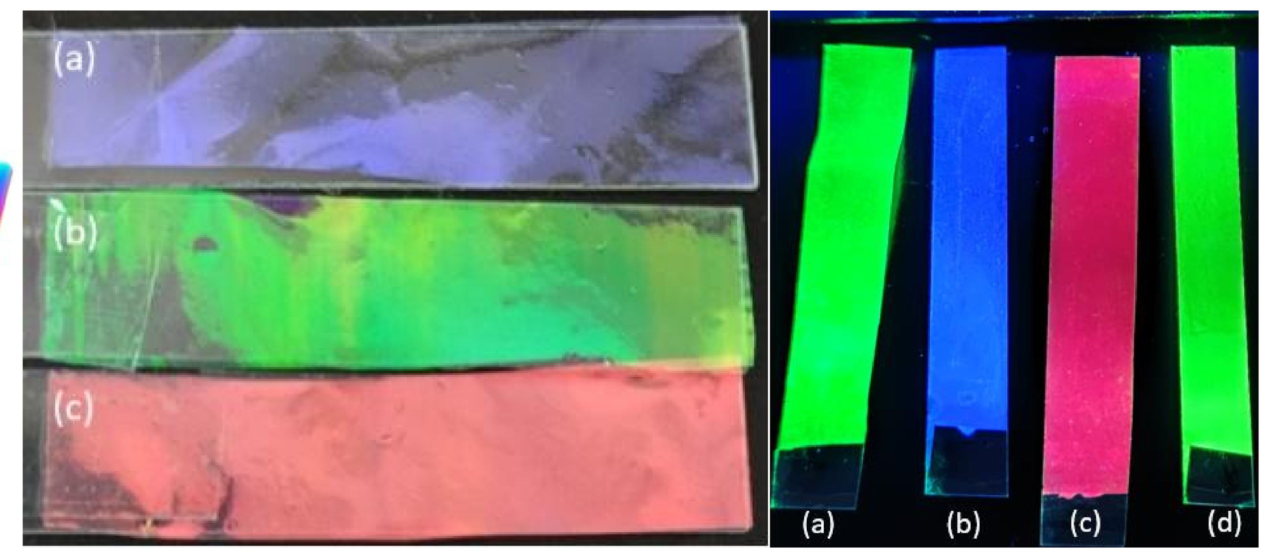

Fig. 4. LEFT: PC (a) 208, (b) 237, (c) 254 films;
RIGHT: $CsPbBr_3$ quantum dots with (a) green, (b) blue, (c) red, (d) yellow color under UV exposure.

FLUORESCENCE ENHANCEMENT

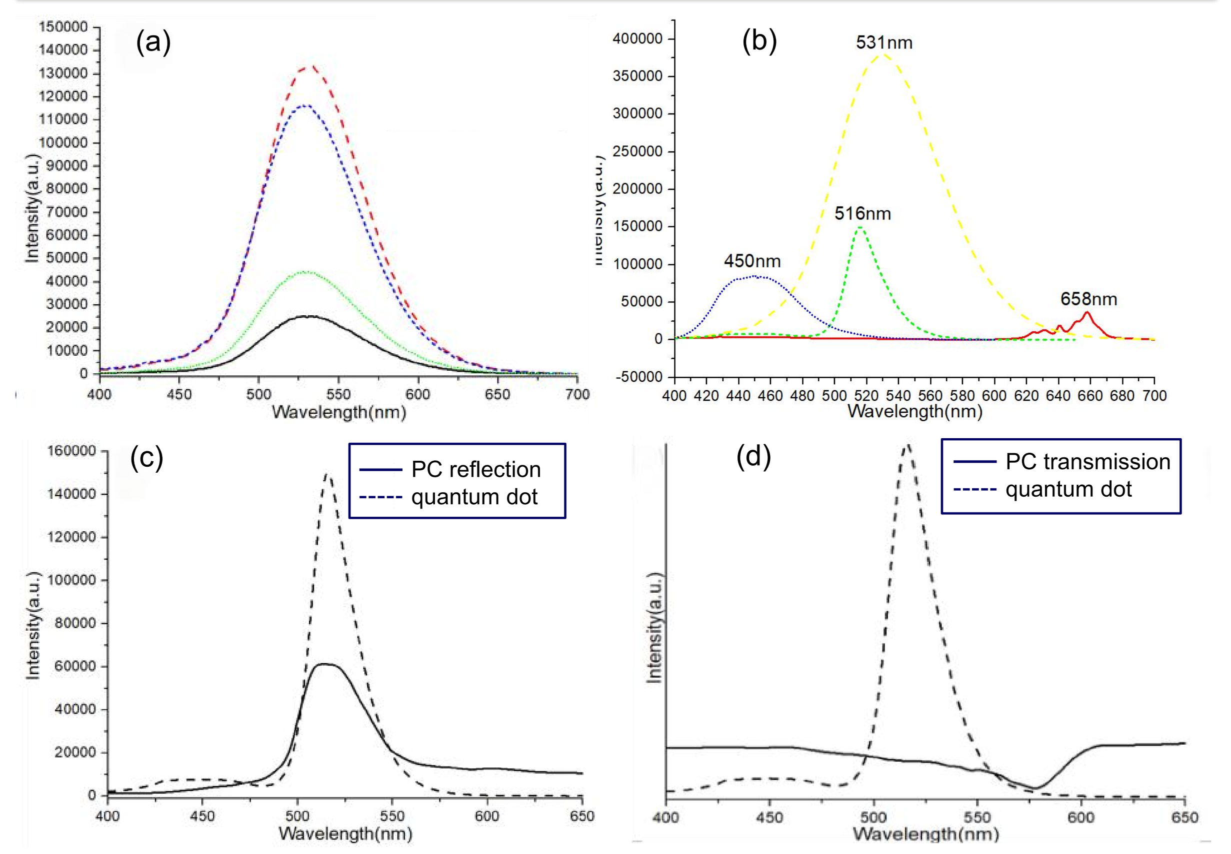

Fig. 5. (a) Photonic crystals enhanced fluorescence spectra with $CsPbBr_3$quantum, (b) fluorescence spectra of $CsPbBr_3$ quantum films. Matching relationship between quantum dot emission spectroscopy and photonic crystal reflection (c) and transmission (d) spectroscopy.

Here, the emission range of yellow quantum dots is 420-680 nm, covering all photonic crystal bandgaps (Fig. 5b), so the enhancement is the most significant. The fluorescence intensity on the blue PC film is 5.68 times that of the glass reference.

Besides, the green quantum dot (516 nm) almost coincides with the green photonic bandgap (514 nm), and the blue quantum dot (450 nm) is an good match with the blue PC film reflection peak (487 nm), confirming that "wavelength-bandgap matching" is the key for the enhancement.

RESULTS & DISCUSSION

The enhancement of quantum dot fluorescence by photonic crystals is related to the fact that the maximum emission wavelength of quantum dots is within the photonic bandgap range, and according to the Bragg's law, the fluorescence echancement is modulated. Photonic crystals composed by different particle sizes can basically enhance quantum dot fluorescence. Experiment results revealed that the yellow quantum dots can be particularly enhanced due to their high fluorescence intensity and wide emission wavelength range.

CONCLUSION

The study proved that self-assembled photonic crystals can enhance the fluorescence of quantum dots with comparable apparent colors, which is related to the match of the photonic band gap. It is anticipated to contribute to the development of novel photonic crystal-quantum dot sensors and high brightness display materials.

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