



A Copper Ion Sensitive Hydrogel Photonic Crystal Film

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Introduction

Photonic crystals have a unique photonic band gap (PBG) property. Hydrogel is a 3D polymer matrix with large amount of water that can undergo a volume phase transition when stimulated by the external environment. By combining the optical characteristics of photonic crystals with the stimulatory response of hydrogels enables the conversion of chemical signals to optical signals and the detection of ions.

Preparation of Photonic Crystals

In this work, polystyrene (PS) nano-spheres were utilized to prepare photonic crystal templates with bright structural color by vertical deposition, and the mixture of hydroxyethyl methacrylate (HEMA) and vinyl imidazole (VIM) was injected into the photonic crystal templates and the hydrogel films were obtained by photopolymerization under UV 365 nm exposure for 30 min.

Characterization of PS

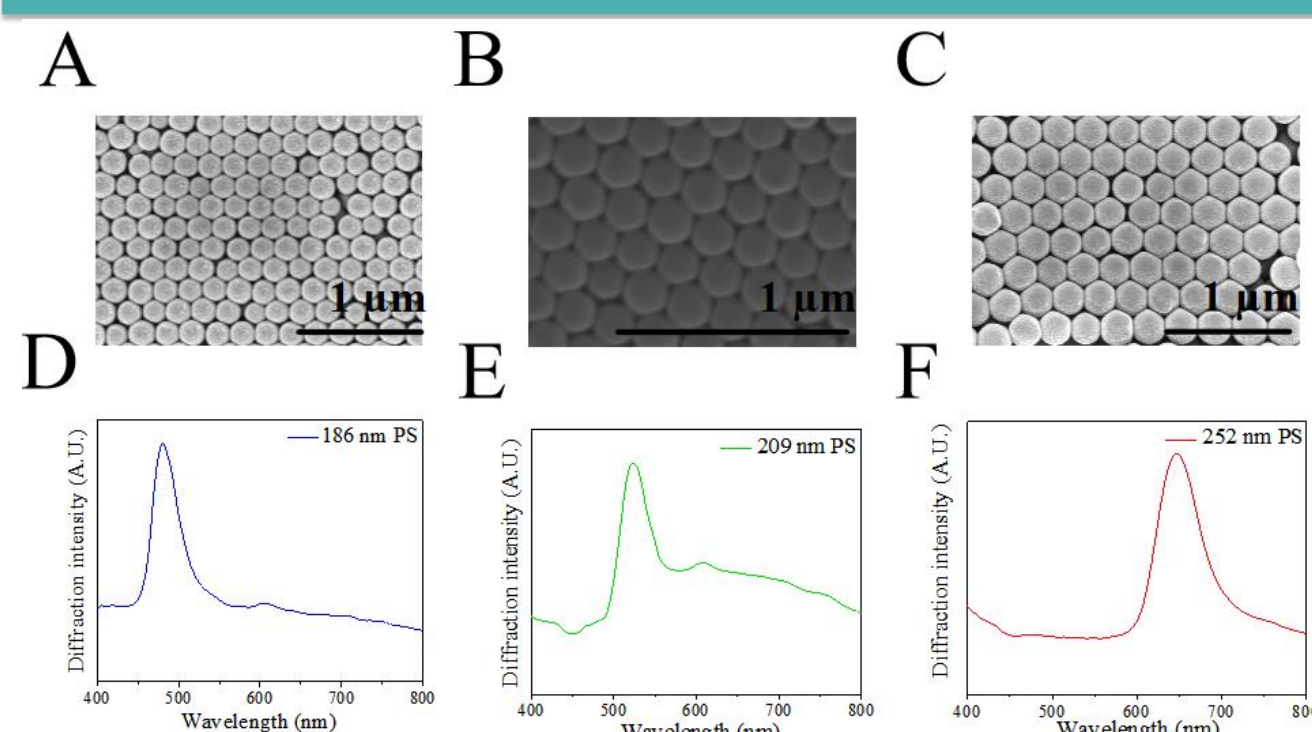


Fig. 1. (A, B, C) Scanning electron microscopy of PS nano-spheres with sizes of 186, 209 and 252 nm, respectively, and (D, E, F) reflectance spectra of PS nano-spheres with sizes of 186, 209 and 252 nm, respectively.

We prepared three types of PS nano-spheres with particle sizes of 186, 209, and 252 nm, respectively, using soapless emulsion polymerization, and it can be seen that the PS microspheres retained a monolayer regular hexagonal close-packed structure, and photonic crystal templates with bright structural coloration were obtained after self-assembly by vertical deposition.

Cu²⁺ Response of PC Films

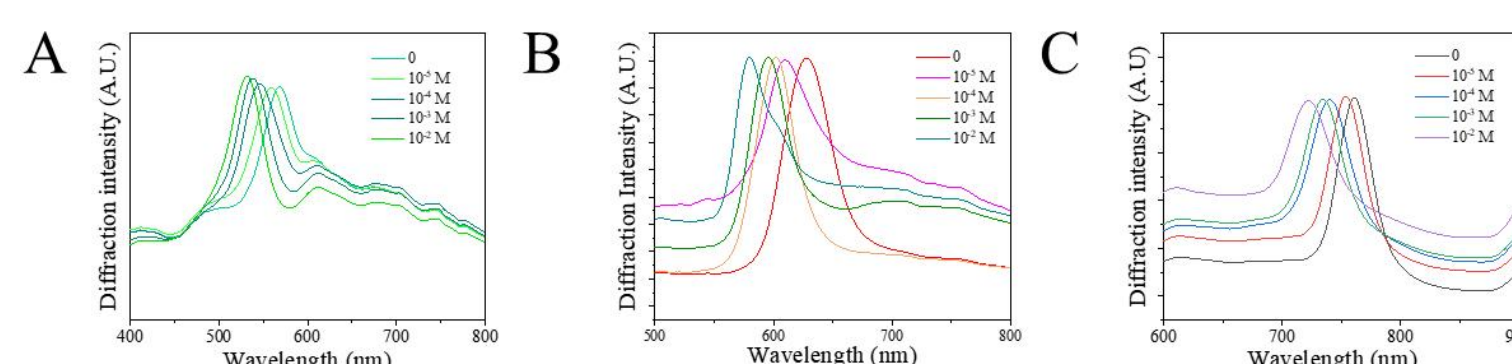


Fig. 2. (A, B, C) Particle sizes of 186, 209 and 252 nm P(HEMA-NVI)/PS responsiveness in different concentrations of Cu²⁺ solutions, respectively.

The P(HEMA-NVI)/PS films were immersed in 10⁻² M-10⁻⁵ M pH = 6 aqueous Cu²⁺ solution, and we found that although the films prepared from nanorods of different particle sizes showed different degrees of blueshift in the aqueous Cu²⁺ solution, the blueshift patterns of the films were similar as the concentration of Cu²⁺ increased.

Cu²⁺ Response Linearity of PC Films

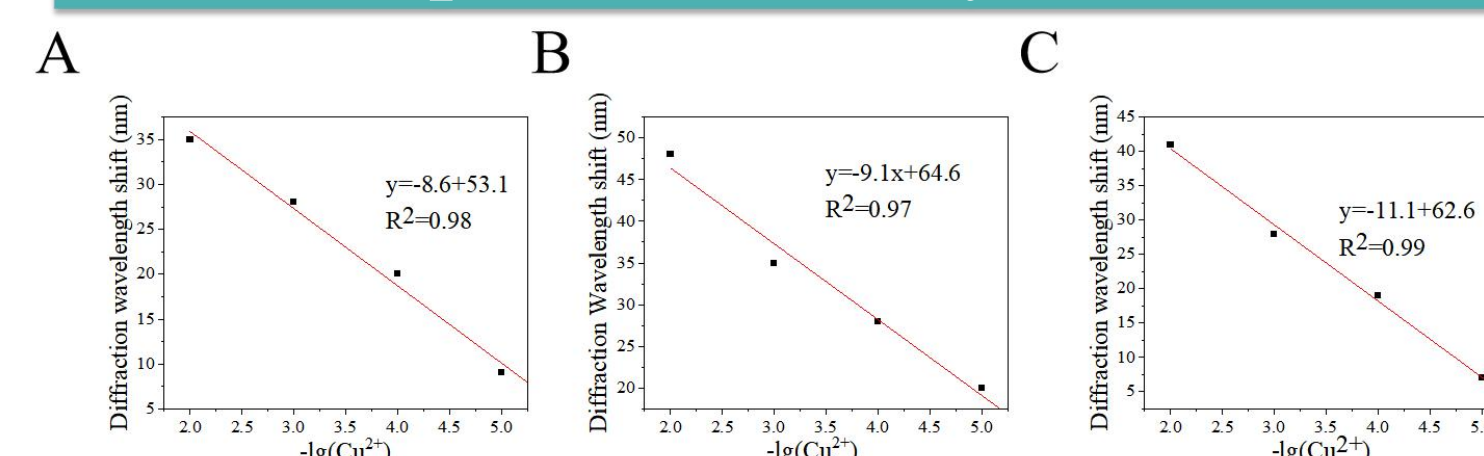


Fig. 3. (A, B, C) Linear fits of the maximum reflected wavelengths of PS nano-spheres films with particle sizes of 186, 209, and 252 nm, respectively, to the concentration of Cu²⁺.

The maximum reflectance wavelengths of P(HEMA-NVI)/PS films in aqueous solutions of copper ions with pH equal to 6 are all blue-shifted to varying degrees with the increase of copper ion concentration, and show a good linear relationship with the Cu²⁺ concentration.

Sensing Repeatability

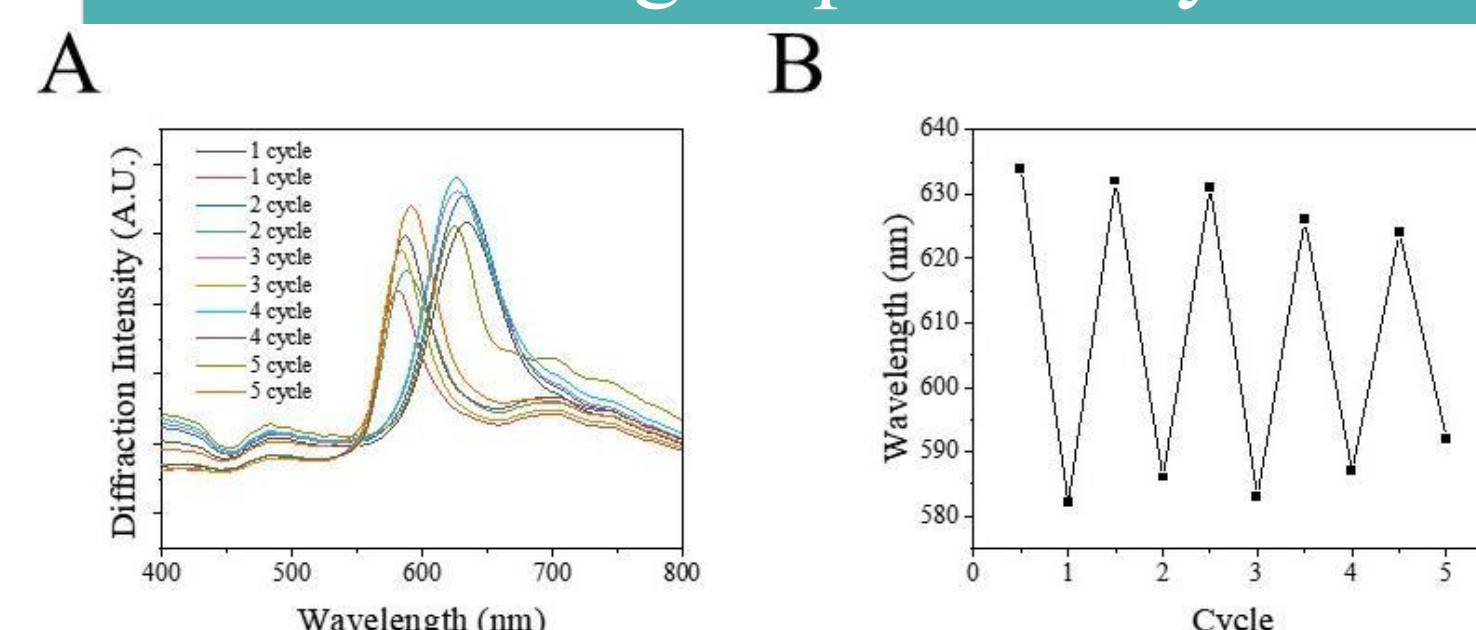


Fig. 4. (A,B) Repeatability testing of P(HEMA-NVI)/PS films for responsiveness to Cu²⁺.

P(HEMA-NVI)/PS films can be reversibly reused for at least 5 cycles.

Sensing Specificity

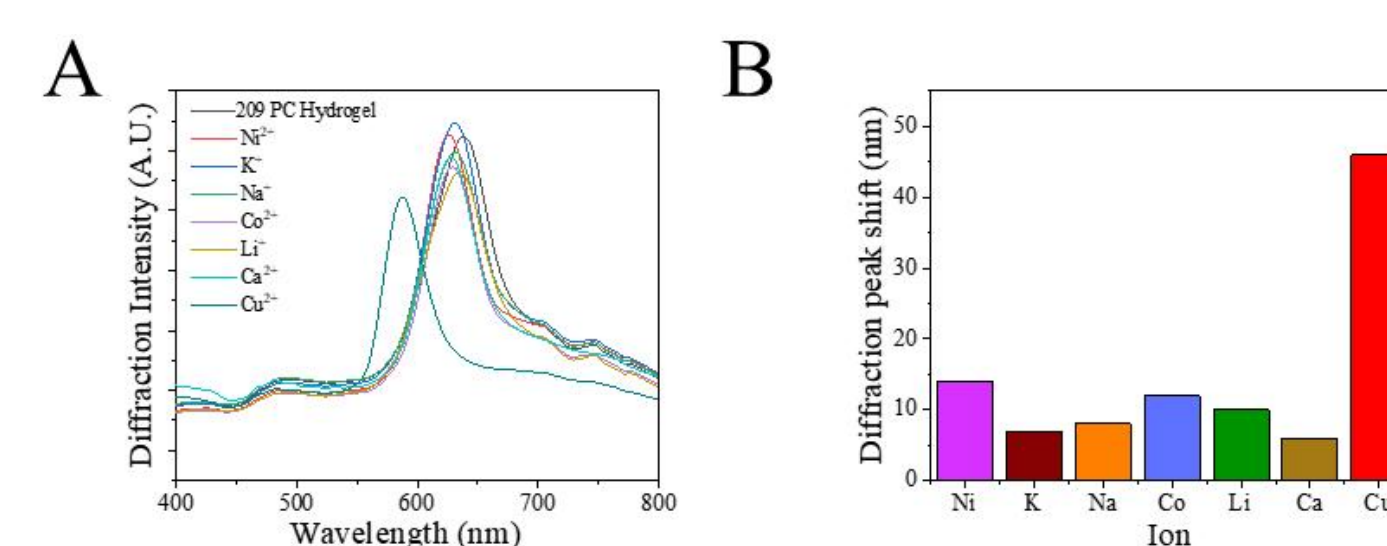


Fig. 5. (A,B) Comparison of detection ability of P(HEMA-NVI)/PS-209 for various metal ions.

We take the P(HEMA-NVI)/PS-209 film as an example, as shown in Fig. 5 (A,B) we put the film into the aqueous solution with the concentration of 10⁻² M different metal ions, we can see that the diffraction wavelength shifts of the film to the different metal ions are smaller than that of the film to the diffraction wavelength shifts of the film to Cu²⁺, which proves that the film has the ability to respond to the specificity of Cu²⁺.

Conclusions

Three kinds of PS nano-spheres with different particle sizes were synthesized by soapless emulsion polymerization, and then photonic crystal templates with bright structural colors were obtained by vertical deposition of self-assembled PS nano-spheres, and finally hydrogel prepolymerization solution composed of HEMA and NVI was injected into three kinds of different particle-size-assembled photonic crystal templates by colloidal crystal templating method, and photonic crystal films were obtained by irradiation with a 365 nm UV lamp. The photonic crystal hydrogel films were irradiated by 365 nm UV light. The three films showed good response to Cu²⁺.

References

Chen C ,Dong Z ,Shen J , et al.2D Photonic Crystal Hydrogel Sensor for Tear Glucose Monitoring. ACS Omega, 2018,3(3):3211-3217