

[Electronic Supplementary Information]

**Visibly vapor-responsive structurally colored carbon fibers  
prepared by electrophoretic deposition method**

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## **S1 Experimental section**

### **Materials**

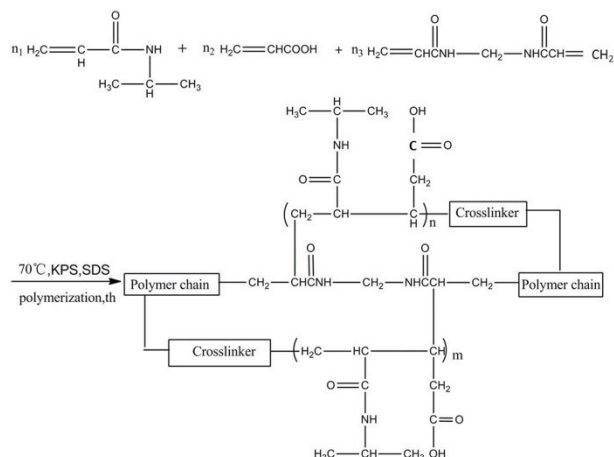
PAN-based carbon fibers with a diameter of 7–8  $\mu\text{m}$  were selected for use in the experiments. The carbon fibers were rinsed with ethanol, acetone, and distilled water in sequence, and then dried in an oven. Monodispersed PNIPAM-co-AAc colloids were synthesized by the emulsion polymerization method. In a typical synthesis, 2 g N-Isopropylacrylamide, 0.15 g acrylic acid, 0.1 g sodium lauryl sulfonate, 0.1 g N, N'-Methylenebisacryl-amide, and 120 mL ultrapure water were mixed in a 250 mL three-necked flask. The mixture was flushed with nitrogen at room temperature for 10 min, after which the flask was sealed and heated to 70  $^{\circ}\text{C}$  for 1 h with stirring. Subsequently, 0.1 g/10 mL potassium peroxydisulphate (KPS) was added as catalyst. The reaction was stopped after 5 h, and the synthesized PNIPAM-co-AAc dispersion was collected, washed, and redispersed in ultrapure water.

For the electrophoretic deposition, 10 mm of carbon fiber was fixed onto a copper plate with conductive silver glue and was placed into a conductive copper cylinder containing the redispersed PNIPAM-Co-AAc colloid. A voltage of 1.8–3.0 V was applied across the two electrodes to form an electric field and cause colloid particles in the copper cylinder to self-assemble on the fiber. After the deposition, the fiber was placed in an oven to dry at 33  $^{\circ}\text{C}$ .

### **Characterization**

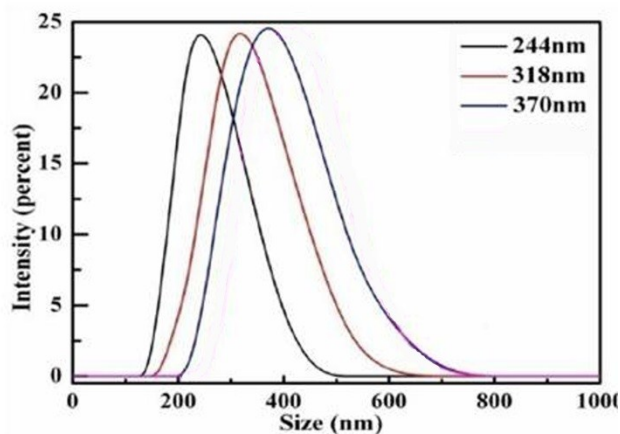
The PNIPAM-Co-AAc microspheres and structurally colored fibers were characterized by field emission scanning electron microscopy (FE-SEM, S-4800, Hitachi), the accelerating voltages used for the SEM was 5KV. Static/dynamic laser light scattering (S/DLLS, BI-200SM, Brookhaven). Particle size and zeta potential analysis (Nano 85, Malvern) at room temperature (about 25  $^{\circ}\text{C}$ ). Optical microscopy (XPF-550, Caikon, with mounted CCD camera, TCC 3.3 ICE). A fiber-optic Uv-Vis spectrometer (PG-2000-Pro-Ex, Ideaoptics Technology Ltd.) was used to measure the reflection spectra of the structurally colored carbon fibers. The incident light was aligned perpendicular to the fiber for all the optical measurements

## **S2 Reaction scheme**



**S2** Synthesis of novel solvent-sensitive PNIPAM-Co-AAc colloidal microspheres.

### S3 Size distribution of PNIPAM-co-AAc nanoparticles

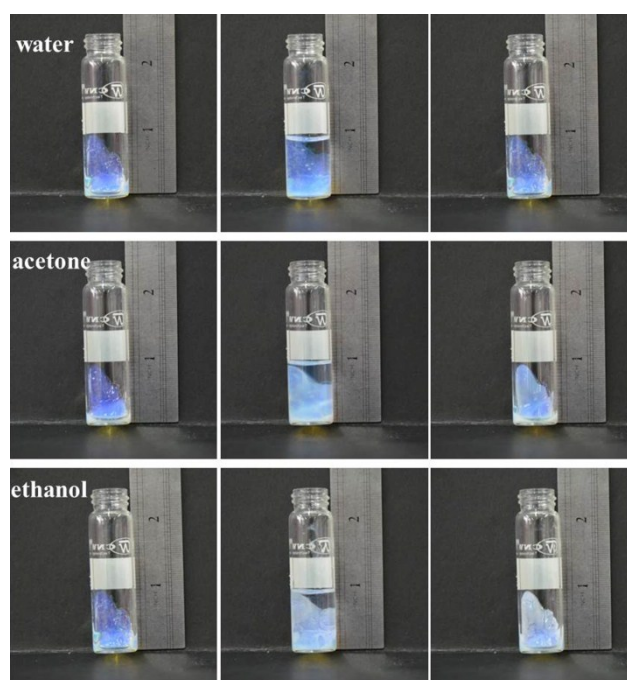


**S3** Size distribution of three kinds of PNIPAM-co-AAc nanoparticles. These microparticles were fabricated by tuning the amount of acrylic acid (0.10g, 0.15g, 0.20g)

S3 shows the size distribution of three kinds of PNIPAM-co-AAc nanoparticles. These microparticles were fabricated by tuning the amount of acrylic acid (0.10g, 0.15g, 0.20g) in the reaction process, and were characterized using particle size and zeta potential analysis (Nano 85, Malvern) at room temperature (about 25 °C). The average sizes of these three different kinds of PNIPAM-co-AAc microparticles were 244 nm, 318 nm, 370 nm, respectively. According to previous work, (ACS Macro Letters, 2013, 2, 116-120; Nanoscale, 2013, 5, 6917-6922), the particles often form to fcc structure on the surface of the fiber under the method of electrophoretic deposition. The PC effect can be explained by the Bragg's law,  $m\lambda = 2nd\sin\theta$ , where  $\lambda$  is the Bragg wavelength,  $m$  is the diffraction order (taken to be 1),  $d$  is the lattice spacing,  $\theta$  is the diffraction angle (90° for normal incidence), and  $n$  is the composite refractive index (taken to be 1.335, this is a reasonable estimate of  $n$ , given the high water content of the component microgels). From Bragg's law, we can calculate the value of  $\lambda$  according to the value of  $d$ . As

shown in Fig. 3, three different colored fibers which assembled nanoparticles with different sizes on the surface of the fibers display different colors from the red to yellow green to green, the nanoparticle sizes are 370nm, 318nm, 244nm respectively. We can estimate the Bragg wavelength  $\lambda=2*n*d=2*1.335*d$  are about 988nm, 849nm, 651.48nm respectively. The Bragg wavelength  $\lambda$  is higher than the diffraction wavelength of the fiber. That is to say the size of the microparticle which was characterized by particle size and zeta potential analysis (Nano 85, Malvern) is bigger in water than it in air.

## S4 Color change of hydrogel



**S4** Swelling of PNIPAM-Co-AAc hydrogel in different solvents; Time of color change: Water: >1 h; Acetone: about 2 min; Ethanol: several seconds.

S4 shows photographs of the visible swelling phenomena of PNIPAM-Co-AAc hydrogel under different stimuli. The photonic crystal hydrogel film was prepared by assembling PNIPAM-Co-AAc spheres on the surface of the glass bottle. When an organic solvent was volatilized onto the surface of the PNIPAM-Co-AAc spheres, the vapor molecules permeated into the air-sphere-pore of the PC by capillary force. The organic vapors easily replaced the air in the pores of the PC. This infiltration of organic vapor changed the effective refractive index of the whole PC film, resulting in a wavelength shift of the PC stopband. As shown in S4, the time taken for the color was different for water, acetone, and ethanol. These results indicate that the effective refractive index is an important factor affecting the tuning of the color of the photonic crystal. According to Bragg's law,  $\lambda=2dn_{\text{eff}}=$

$(8/3)^{1/2} D (0.74 n_p^2 + 0.26 n_m^2 - \sin^2\phi)^{1/2}$ , where  $d$  is the (111) plane spacing,  $n_{\text{eff}}$  is the effective refractive index, and  $D$  is the particle diameter. Swelling of the spheres could result in a shift in the wavelength of the stopband of the PC. In other words, the behavior of the fiber was expected to be similar to that of the film except for the change in the possible viewing angles.

**S5 Video of fiber response to acetone vapor**

**S6 Video of fiber response to ethanol vapor**