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Supporting Information

Mechanochromic Photonic-Crystal Fibers Based on Continuous Sheets of Aligned Carbon Nanotubes**

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Supporting Information

Experimental Section

Materials. Monodispersed PS microspheres with diameters of 200, 220, 240 and 260 nm were obtained from Duke Scientific Corporation. PS microspheres with diameters of 280 nm were ordered from Bangs Laboratories, Incorporated. All microspheres were received as aqueous dispersions (10% w/w). Ethanol (99.5 vol %) was obtained from Shanghai Zhenxing No. 1 Chemical Plant. Silicone liquid (0.65 cSt) and vinyl terminated silicone liquid (2-3 cSt, DMS-V03) were purchased from Aladdin Reagent Inc. and Yuheng Medical Science Center respectively. The poly(dimethylsiloxane) (PDMS) elastomer was obtained from Dow Corning (Sylgard 184). Randomly dispersed CNTs (diameter of 8-15 nm and length of ~2 μm) were ordered from Chengdu Organic Chemicals Co. Ltd., Chinese Academy of Sciences. Graphene oxide was synthesized by a modified Hummer's method and could be reduced by using hydroiodic acid (40%).[1]

Methods. Elastic PDMS fibers were first fabricated by injecting the mixed precursor of elastomer prepolymer and curing agent (10:1) into plastic tubes (diameter of ~1.5 mm) and cured at 80 ℃ for 2 h. Aligned CNT sheets were continuously drawn from the CNT array, which was synthesized by chemical vapor deposition, and then were wrapped onto PDMS fibers to obtain the conductive elastic fiber, using the previously reported rotating translation method.[2-3] Electrophoretic deposition of PS microspheres was carried out to prepare the colloidal crystal. PS microspheres were dispersed in ethanol with a concentration of 2.5 mg/mL to form a stable suspension. The zeta potentials for the 200 and 240 nm PS microsphere dispersions were –63.4 and –68.1 mV, respectively. A stainless steel (1.5×9 cm) and a conductive elastic fiber were employed as counter (cathode) and working (anode) electrodes, respectively. Both electrodes were vertically immersed and fixed with a distance of ~1.0 cm in the PS microsphere dispersion. Then a voltage of 30 V was applied between them to form an electric field for 3 min. PS microspheres were electrophoretically deposited onto the surface of the elastic fiber to form colloidal crystal structures. Afterwards, the fiber was taken out and immersed into PDMS precursor which was diluted by silicon liquid (0.65 cSt, 1:1) for 2 min to completely fill the voids of PS microspheres

through capillary action. The PDMS was then cured at 80 ℃ for 2 h. Finally, the elastic photonic crystal fiber was obtained by thermal grafting with vinyl terminated silicon liquid (DMS-V03) at 80 ℃ for 2 h. Elastic fibers based on randomly dispersed CNTs were obtained by dip-coating a CNT dispersion in N-cyclohexyl-2-pyrrolidone (1 wt%) onto PDMS fiber. Elastic fibers based on graphene were prepared by dip-coating a graphene oxide dispersion in water (8 mg/mL) onto PDMS fiber, followed by reduction in hydriodic acid.[1]

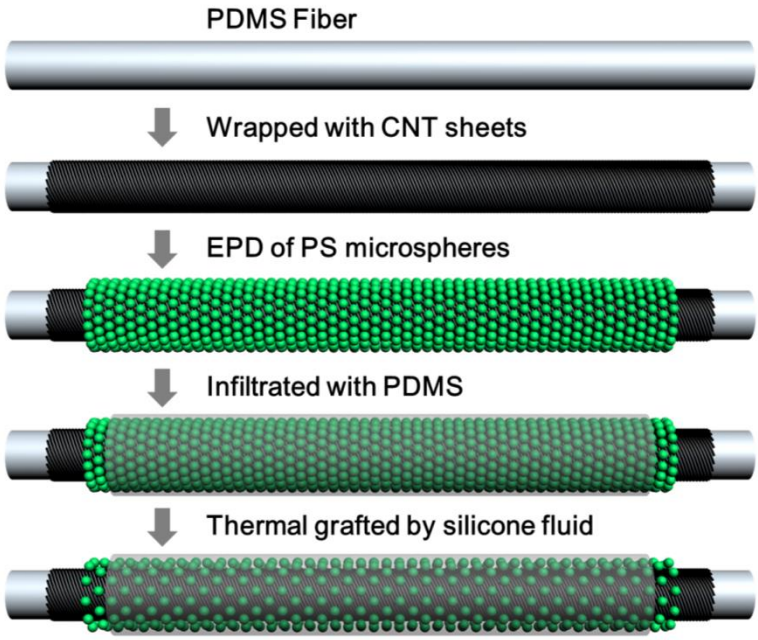
Characterization. Photographs were taken using a digital camera (Nikon J1, Tokyo, Japan). Scanning electron microscope (SEM) images were recorded using a field emission microscope (Hitachi S-4800, Japan), operated at 1 kV. The outer cladding of PDMS was carefully peeled off for observation of the surface layer of photonic crystal fiber. All samples for SEM studies were coated with a thin layer of gold before observation. The fiber was cut into ultrathin slices by a Low Temperature Sectioning System (Leica FC7-UC7, Germany) for transmission electron microscopy (TEM) (JEOL JEM-2100 F, Japan) observation. The stress and strain in the stretch and release cycles were measured from a Hengyi Table-Top universal testing instrument. Reflection spectra were obtained using a miniature fiber optic spectrometer (Idealoptics PG2000-pro, China) installed in an optical microscopy (Olympus BX51, Japan). During the spectra acquisition process, the incident and reflected light was parallel and in the radial direction of the elastic photonic crystal fiber.

References

[1] Z. Yang, H. Sun, T. Chen, L. Qiu, Y. Luo, H. Peng, *Angew. Chem.* **2013**, *125*, 7693.

[2] Z. Yang, J. Deng, X. Sun, H. Li, H. Peng, *Adv. Mater.* **2014**, *26*, 2643.

[3] Z. Yang, J. Deng, X. Chen, J. Ren, H. Peng, *Angew. Chem. Int. Ed.* **2013**, *52*, 13453.



Scheme S1. Schematic illustration to the preparation of the mechanochromic photonic crystal fiber.

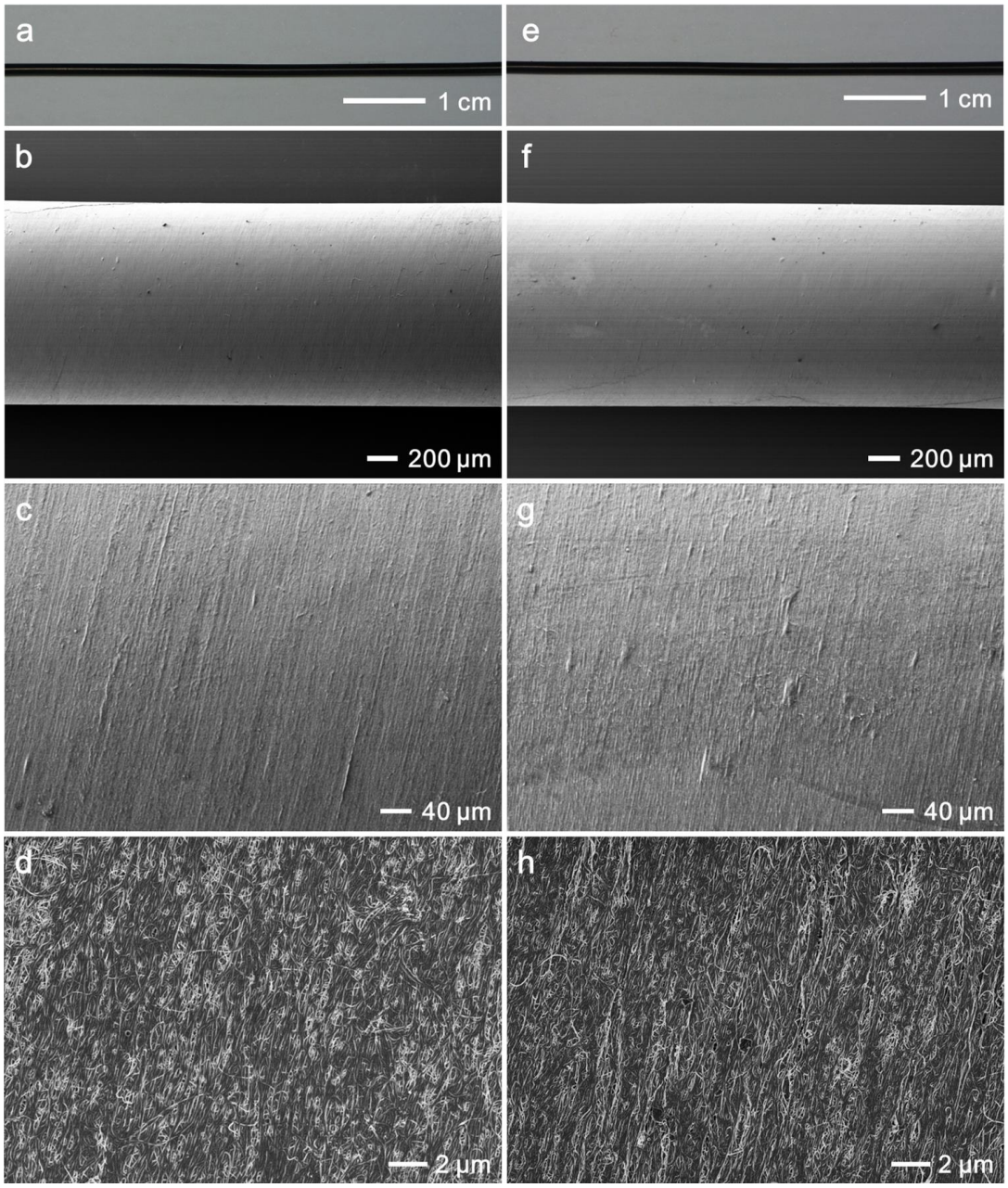


Figure S1. Photographs and scanning electron microscopic (SEM) images of elastic conducting fibers made by winding aligned CNT sheet on the surface of PDMS fibers at different magnifications before (**a**, **b**, **c** and **d**) and after (**e**, **f**, **g** and **h**) stretching.

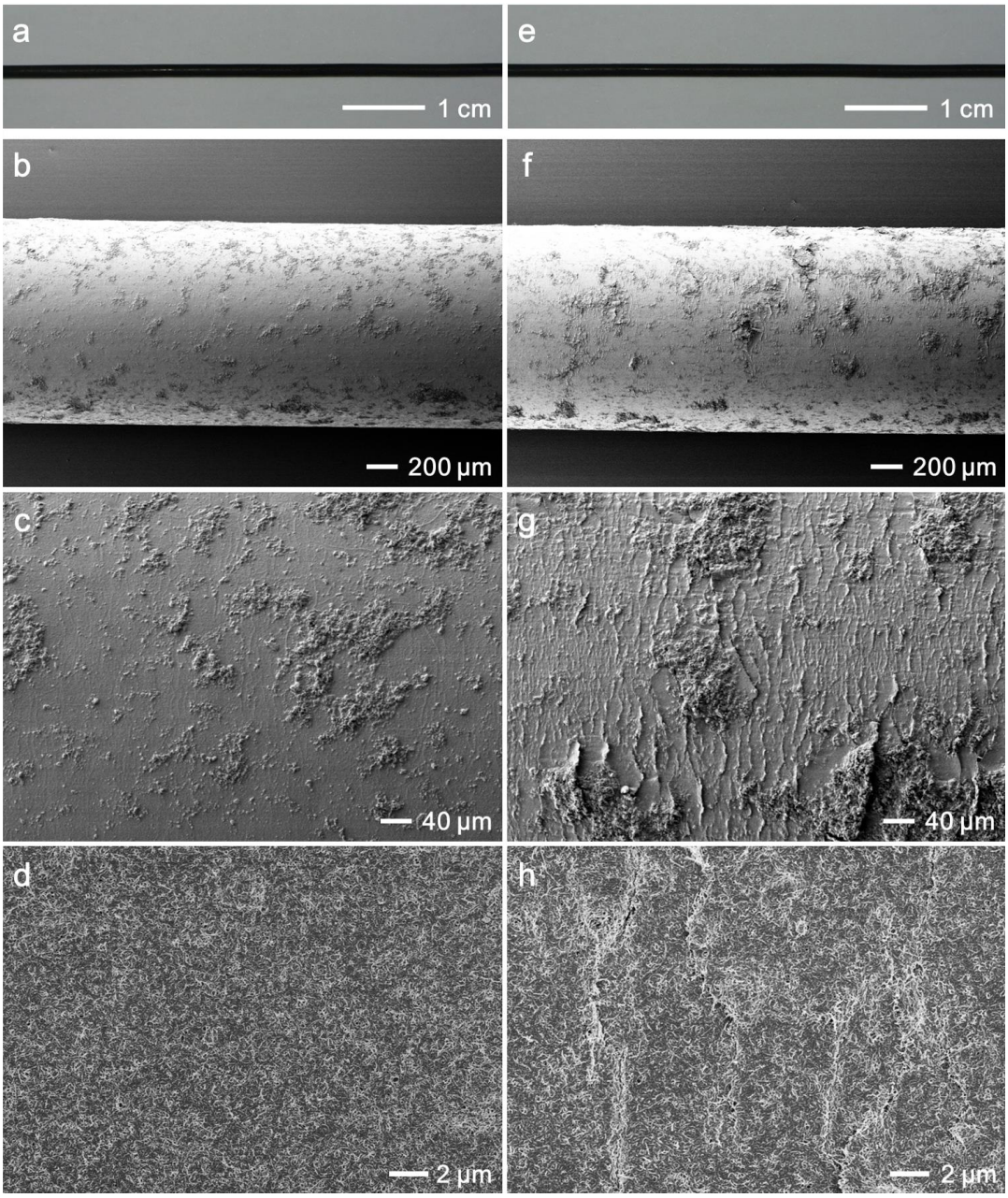


Figure S2. Photographs and SEM images of elastic fibers made by coating randomly dispersed CNTs on the surface of PDMS fibers at different magnifications before (**a**, **b**, **c** and **d**) and after (**e**, **f**, **g** and **h**) stretching.

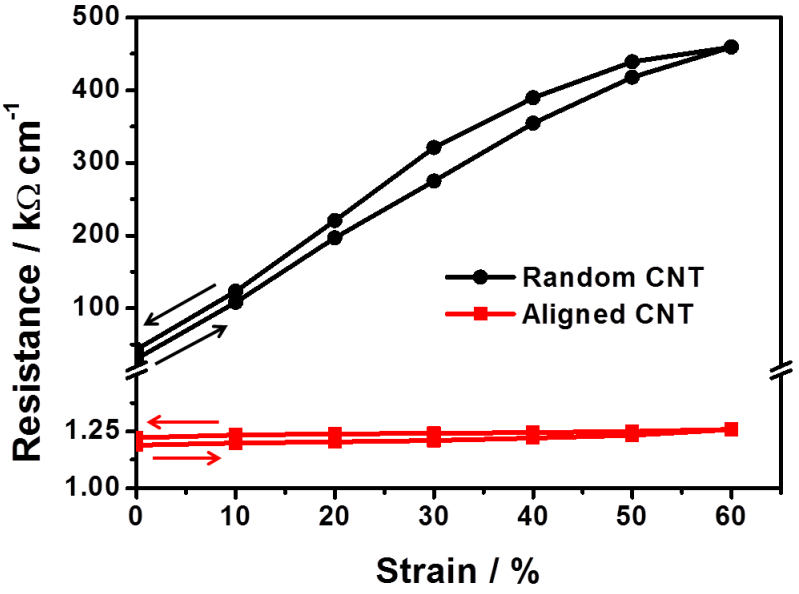


Figure S3. Dependence of the electrical resistance on the strain in a stretching and releasing cycle of the elastic fibers based on aligned and randomly dispersed CNTs, respectively.

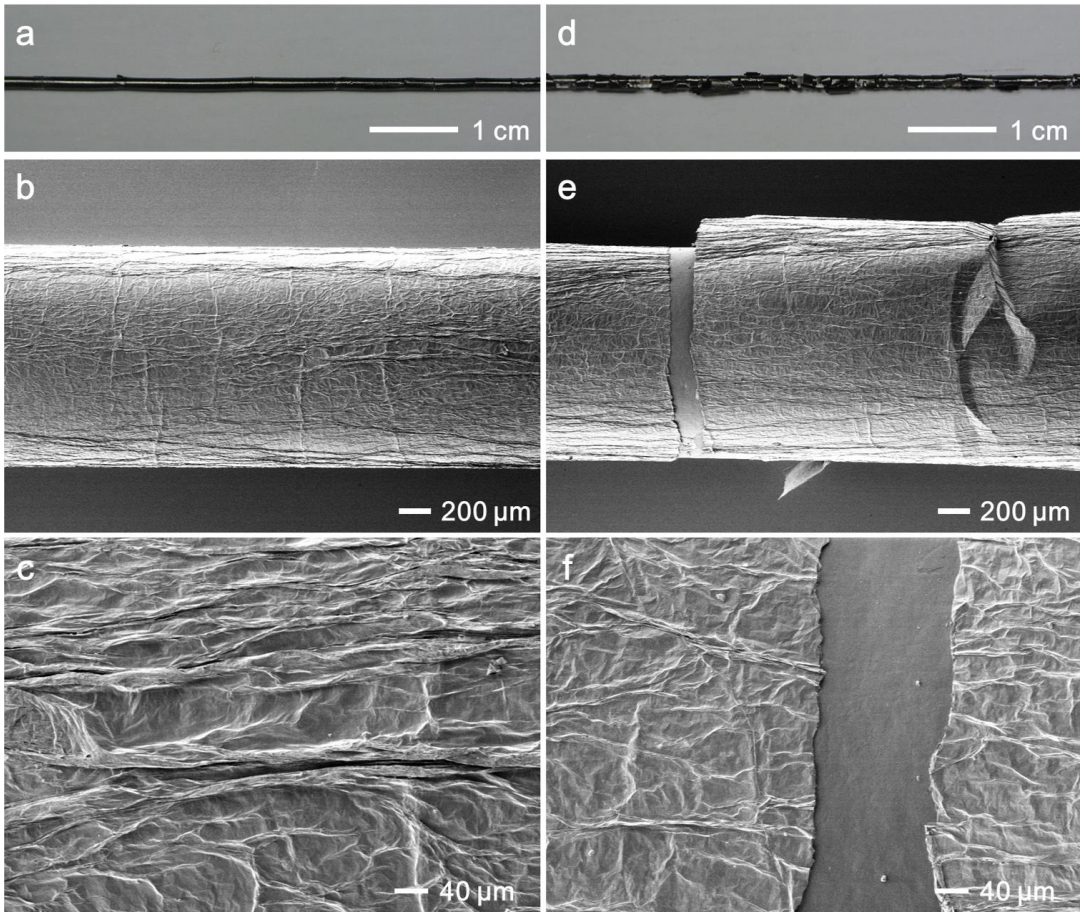


Figure S4. Photographs and SEM images of elastic fibers made by coating graphene on the surface of PDMS fibers at different magnifications before (**a**, **b** and **c**) and after (**d**, **e** and **f**) stretching.

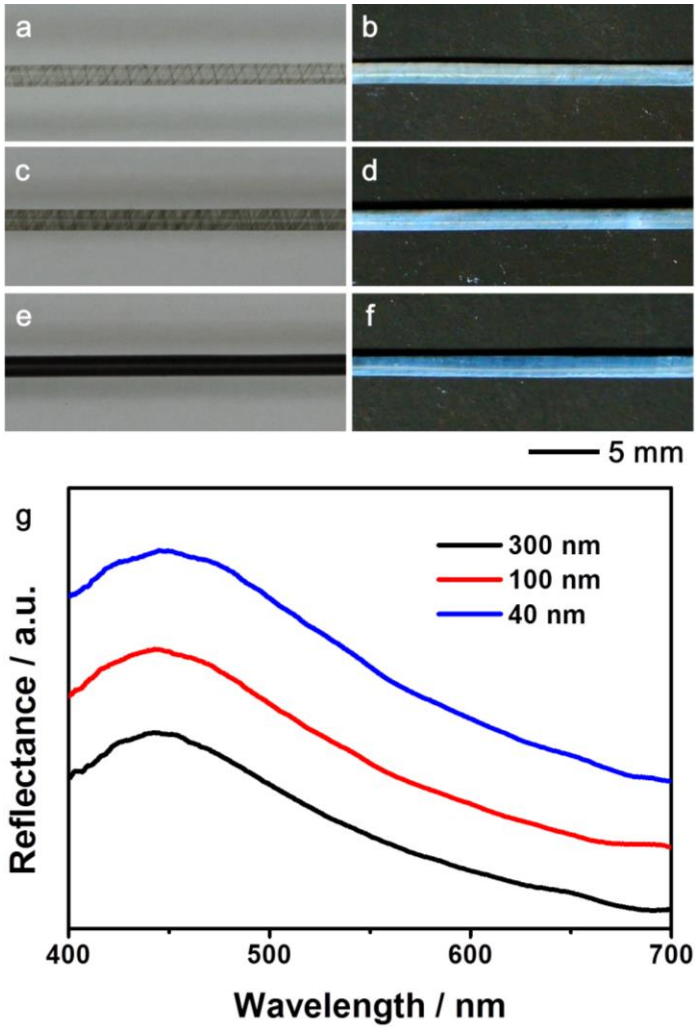


Figure S5. **a-f.** Photographs of fibers before and after deposition of 200 nm PS microspheres with aligned CNT sheet thicknesses of ~40 nm (**a** and **b**), ~100 nm (**c** and **d**) and ~300 nm (**e** and **f**). **g.** Reflection spectra of **b**, **d** and **f**.

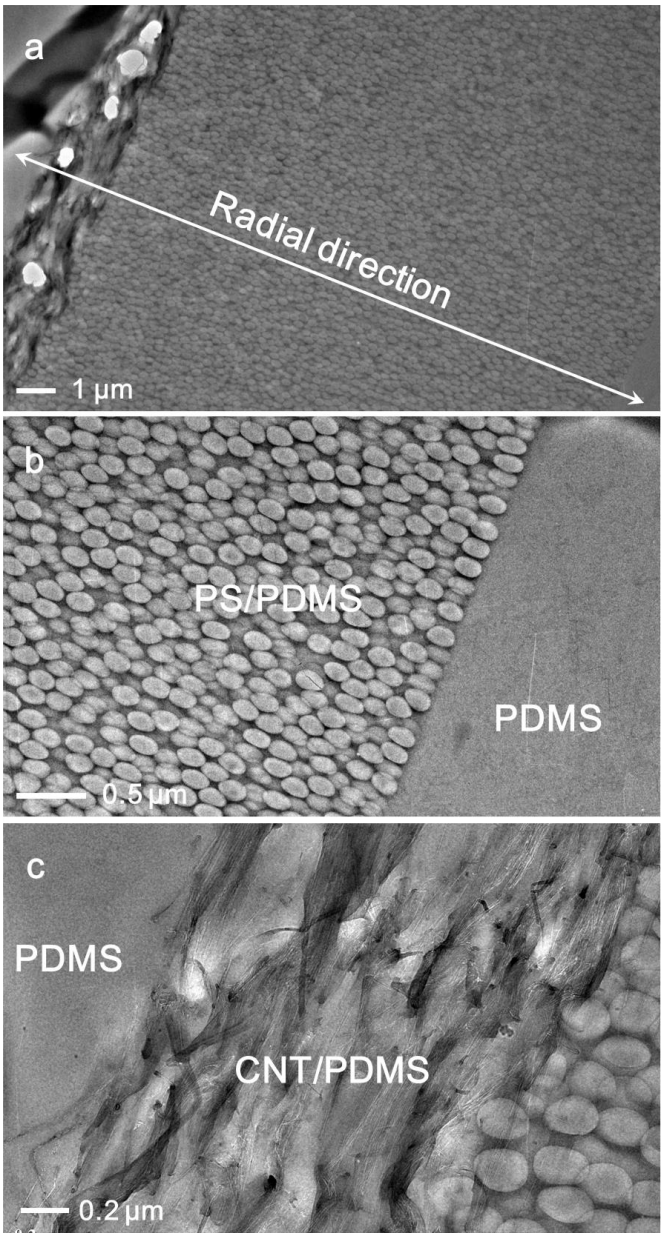


Figure S6. Cross-sectional transmission electron microscopic (TEM) images of a mechanochromic fiber from 200 nm PS microspheres.

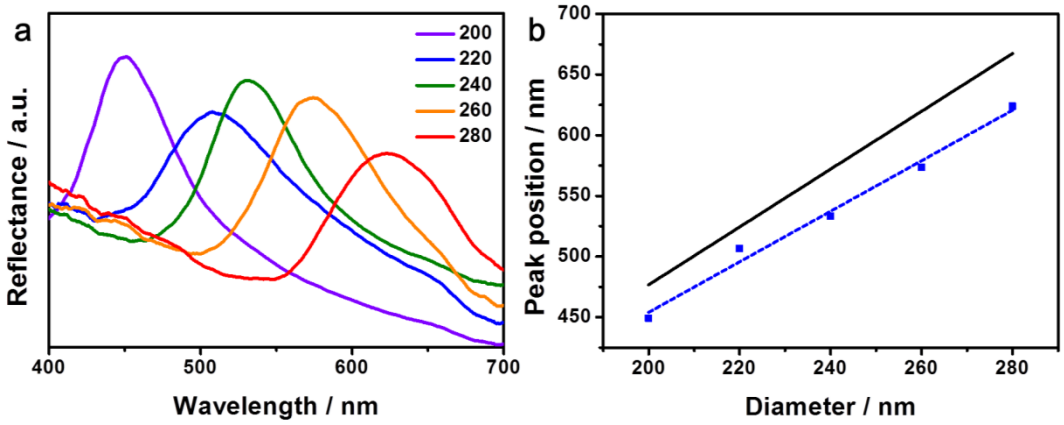


Figure S7. a. Reflection spectra of the preliminary fiber comprising PS microspheres with different diameters, before embedding in PDMS. **b.** Theoretical (black solid line) and experimental (blue square and fitted dash line) correlations between the peak position and microsphere diameter.

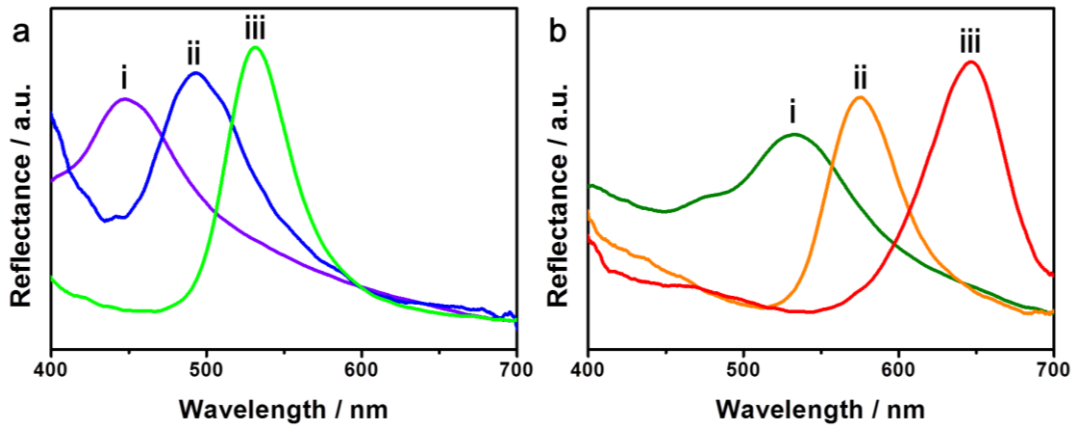


Figure S8. Reflection spectra of photonic crystal fibers fabricated from PS microspheres with different diameters of 200 nm (**a**) and 240 nm (**b**). Graph **i** corresponds to the fibers prepared by only electrophoretic deposition. Graph **ii** corresponds to the fibers prepared by both electrophoretic deposition and infiltrating PDMS. Graph **iii** corresponds to the fibers prepared by electrophoretic deposition, infiltrating PDMS and thermal grafting with vinyl terminated silicone liquid.

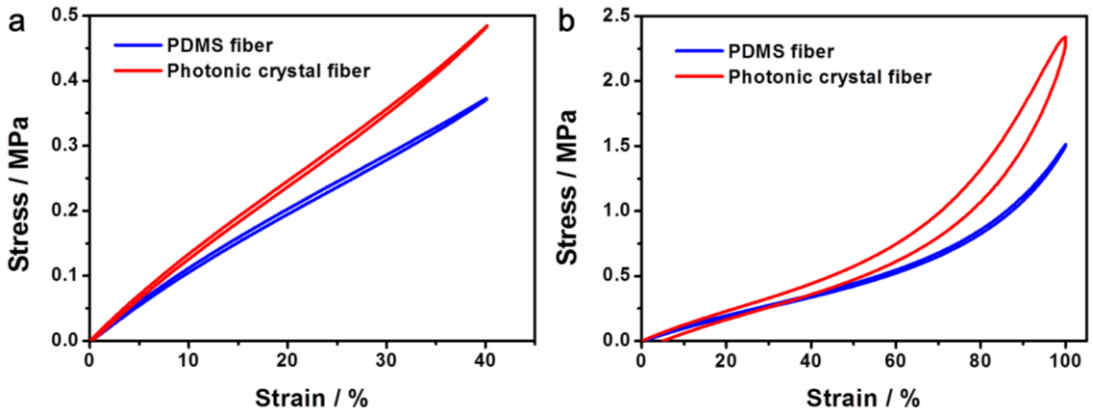


Figure S9. Stress-strain curves in the stretching and releasing cycle for bare PDMS and photonic crystal fibers with strains of 40% (**a**) and100% (**b**).

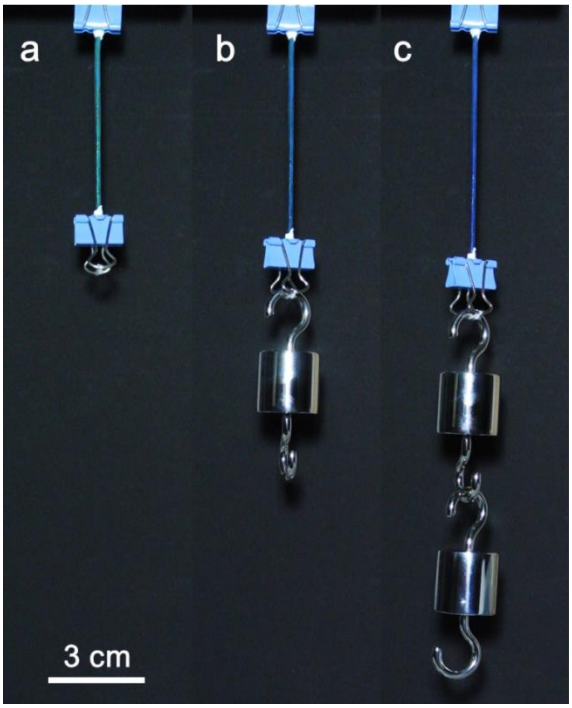


Figure S10. The mechanochromic photonic crystal fiber being used as a load sensor to visualize different weights. **a**. 1.2 g. **b.** 51.2 g. **c.** 101.2 g.

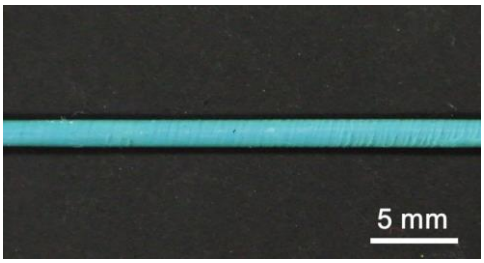


Figure S11. A photonic crystal fiber made from a mixture of 200 and 240 nm PS microspheres.