

Supporting Information

A Robust and Flexible Thermal-Plasticizing 3D Shaped Composite Films with
Invariable and Brilliant Structure Color

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TABLE S1. The different dosages of surfactant ($C_{\text{surfactant}}$) were used in the preparation of PBMB template. Thus the different diameter of PBMB and PBMB@SiO₂ were obtained via counting 200 individual particles in the TEM images of samples. And corresponding PDI and Zeta potential for PBMB@SiO₂ were measured by Dynamic Light Scattering.

Sample	$C_{\text{Surfactant}}$ (Wt %)	Diameter of PBMB (nm)	Diameter of PBMB@SiO ₂ (nm)	PDI	Zeta potential (mV)
PBMB ₂₃₇ @SiO ₂	0.02	237	319	0.045	-27.2
PBMB ₂₁₅ @SiO ₂	0.06	215	271	0.020	-21.7
PBMB ₁₆₃ @SiO ₂	0.08	163	235	0.033	-15.9

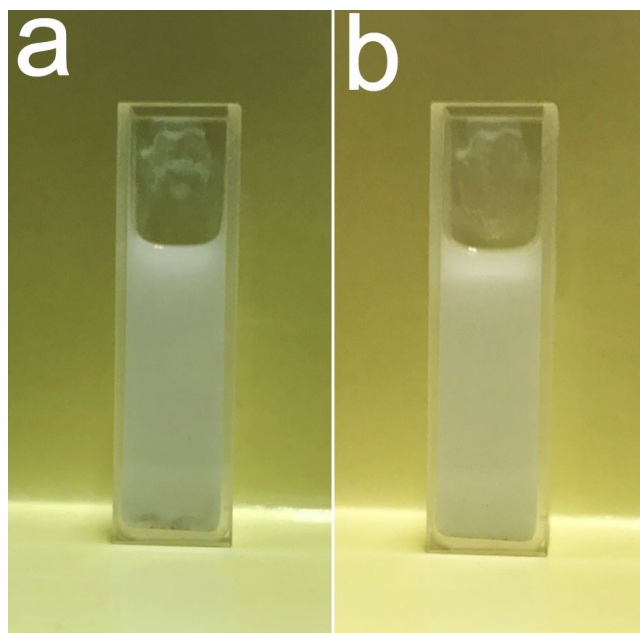


Figure S1. Digital images of PBMB@SiO₂ dispersion in ethanol. (a) just after preparation; (b) stored in ambient environment for 5 days

TABLE S2. Hollow silica spheres obtained. The air core diameter, shell thickness, and diameter for hollow silica PCs obtained by calcination of PBMB@SiO₂ PCs respectively

Sample	Core template	particle	Air diameter (nm)	core thickness (nm)	Shell thickness (nm)	Diameter (nm)
Hollow silica ₂₈₆	PBMB ₂₃₇ @SiO ₂		193	32		286
Hollow silica ₂₄₂	PBMB ₂₁₅ @SiO ₂		174	17		242
Hollow silica ₂₀₅	PBMB ₁₆₃ @SiO ₂		160	28		205

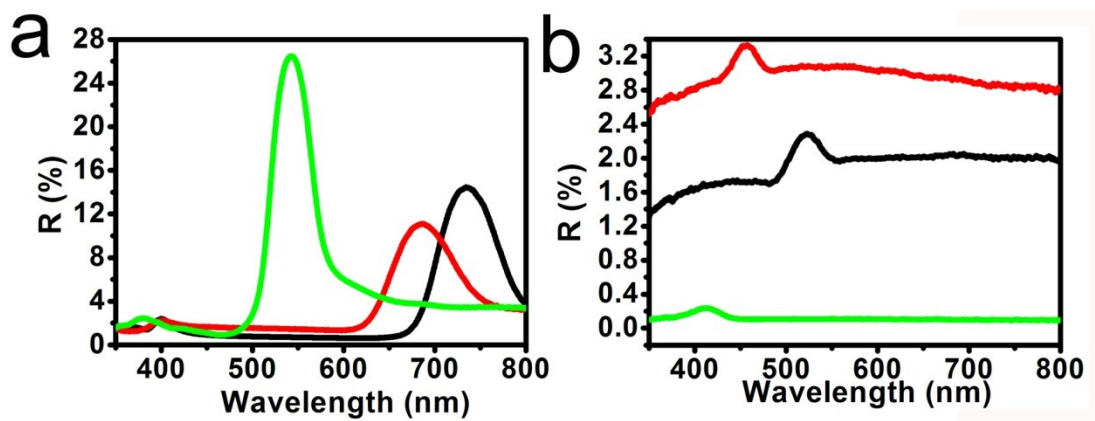


Figure S2. (a) the reflection spectra of the PCs of PBMB@SiO₂ with varying diameters: 319 nm (black), 271 nm (red) and 235 nm (green) respectively. (b) Corresponding reflection spectra of the PCs of hollow silica with varying diameters: 286 nm (black); 242 nm (red); 205 nm (green) respectively.

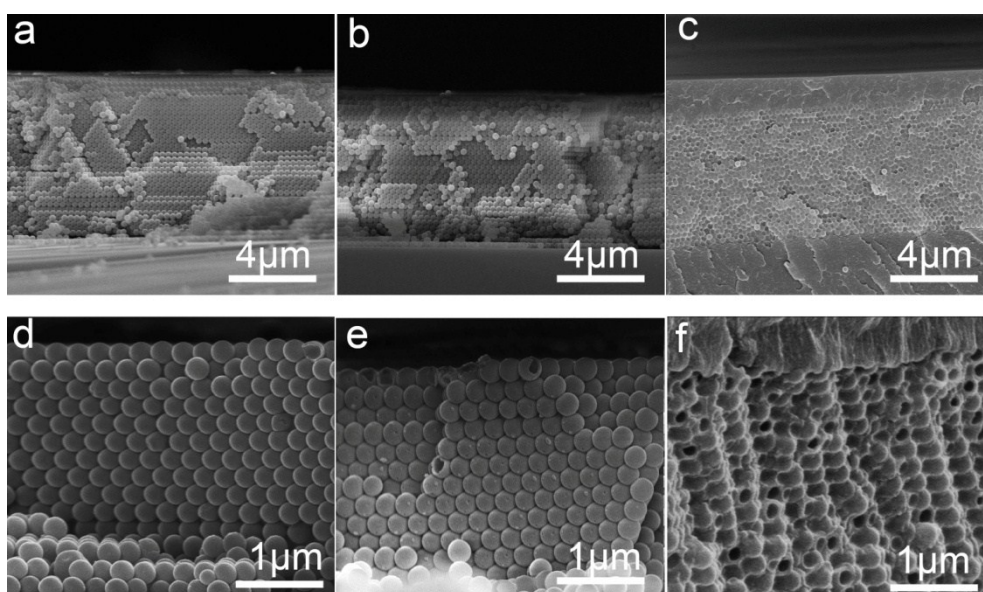


Figure S3. (a, d) Cross-sectional SEM images of the 271 nm PBMB@SiO₂ PCs with the layer of 9 μm. (b, e) Cross-sectional SEM images of the corresponding 242 nm hollow silica PCs with the layer of 7 μm. (c, f) Cross-sectional SEM images of the 242 nm hollow silica/PHMP composite film.

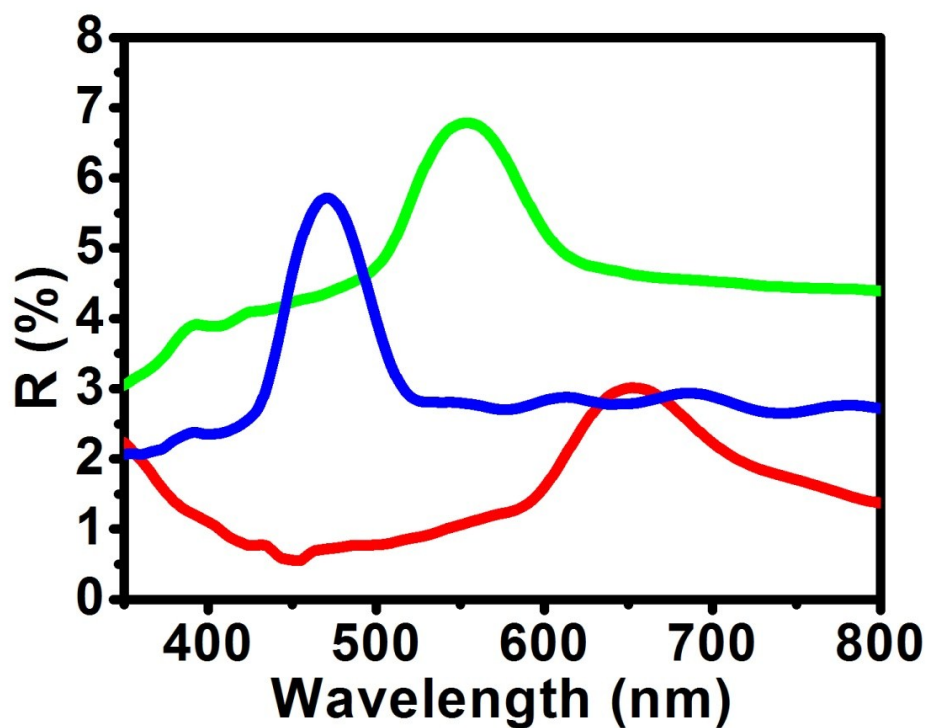


Figure S4. The reflection spectra of the hollow silica/PHMP composite films with varying diameters of hollow silica after storing in the air for 6 months. 286 nm (red line). 242 nm (green line). 205 nm (blue line).

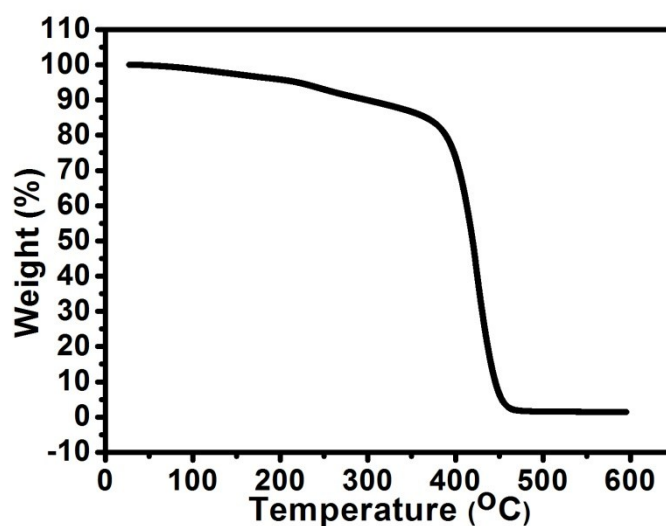


Figure S5 The TGA curve of the pure PHMP polymer.

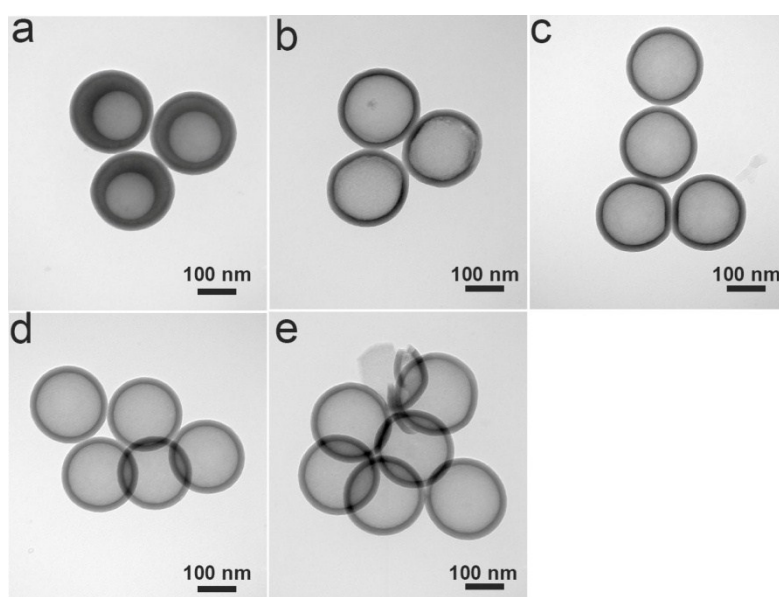


Figure S6. The TEM images of 271 nm PBMB@SiO₂ nanospheres after calcinations at different temperature: (a) 250 °C; (b) 350 °C; (c) 450 °C; (d) 550 °C; (e) 650 °C.

Table S3. Carbon content of hollow silica samples under different calcination temperature.

Calcination temperature (°C)	350	450	550	650
Carbon content (Wt %)	15.1	10.4	7.7	5.8

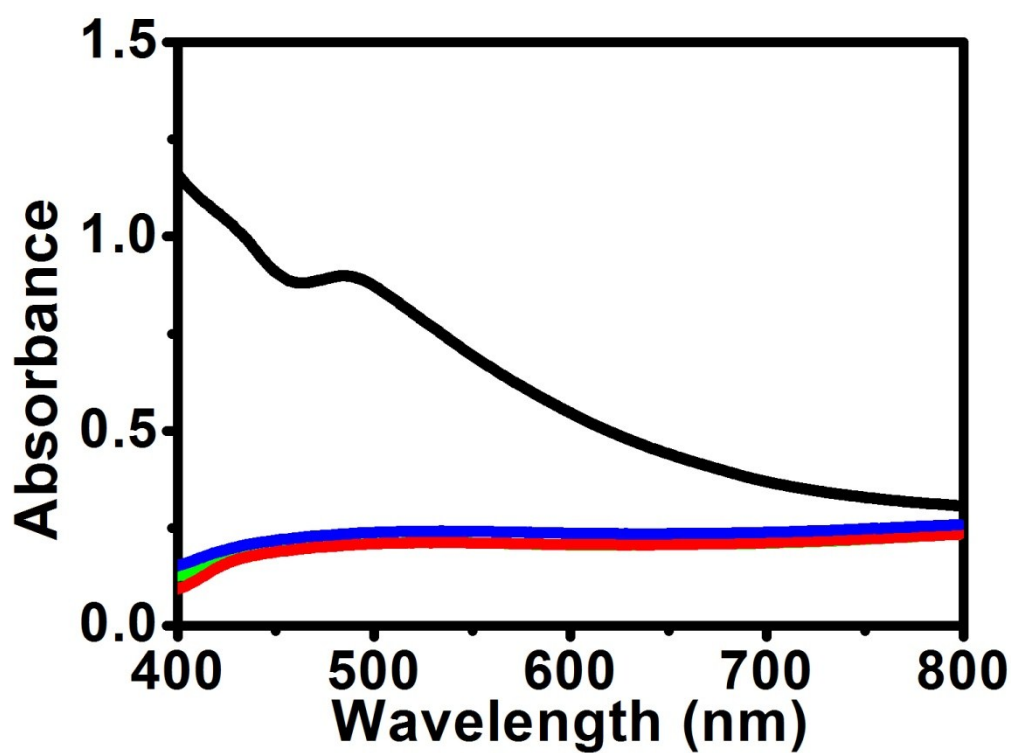


Figure S7. Absorption spectra of the solid powder of hollow silica obtained by

calcination at varying temperature 350 °C(black line); 450 °C(blue line); 550 °C (red line); 650 °C(green line).

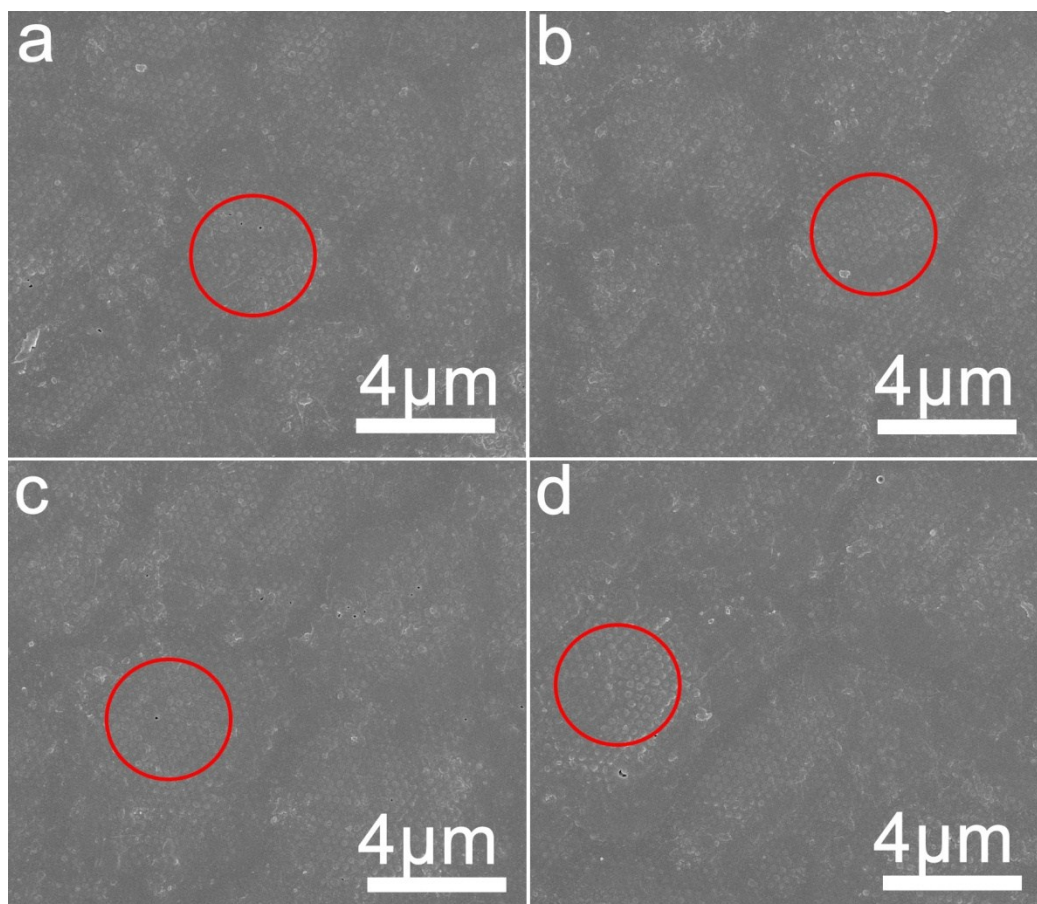


Figure S8. The SEM image of large-scale domains of the green composite film at different state: (a) original 2D flat-sheet. (b) 2D flat-sheet after heating at 80 °C. (c) 3D tubelike state after 80 °C programming and 25 °C fixing of the shape. (d) The initial state of flat-sheet recovered from the tubelike shape by heating at 80 °C. The ordered arrays of hollow silica within the red circle.