Supplementary Information

for

Soluble conjugated porous organic polymer: efficient white light emission in solution, nanoparticles, gel and transparent thin film

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I. Instrumentation

Nuclear magnetic resonance (NMR) spectroscopy: ¹H NMR and ¹³C NMR spectra were recorded on Bruker Avance III 500 and 700 MHz NMR spectrometers. The residual solvent signal was used as internal standard, and chemical shifts (δ) are reported in parts per million (ppm).

Fourier transform infra-red spectroscopy (FTIR): FTIR measurements were done on Perkin-Elmer Model 2000 FTIR using KBr pellet. Thirty scans were signal-averaged, with a resolution of 8 cm⁻¹ at ambient temperatures.

Electron spray ionization low resolution mass spectrometry (ESI-LRMS): ESI-LRMS was done on Bruker Daltonics MicroTOF-Q-II mass spectrometer using acetonitrile as solvent.

Gel permeation chromatography (GPC): Molecular weight of the soluble polymer was estimated by Gel Permeation Chromatography (GPC, Polymer Laboratories). Polystyrene was used as the calibration standard. The eluent was THF (flow rate of 1 mL/min at 40 °C).

Matrix-assisted laser desorption ionization (MALDI): Matrix-assisted laser desorption ionisation time of flight mass spectrometry was performed with Bruker Daltonics UltrafleXtreme, using software flexControl version 3.4.

Thermogravimetric analysis (TGA): TGA analysis was carried out using Perkin Elmer TGA-6000 instrument. The sample was heated at a rate of 10 °C min⁻¹ under a nitrogen atmosphere to a maximum of 900 °C.

Field emission scanning electron microscopy (FESEM): The morphologies of solution processable polymer (TPDC-BZ), white light emitting nanoparticle and thin film were observed using Carl Zeiss (Ultraplus) field emission scanning electron microscope. Samples for microscopy were prepared by smearing TPDC-BZ polymer (~ 0.5 mg) on aluminum stub coated by an adhesive carbon tape and nanoparticles were drop casted on Si wafer. All samples were coated with a thin layer of sputtered gold before imaging. The accelerating voltage of 5 kV and 10 kV were used.

BET analysis: All the gas adsorption measurements were performed on Quantachrome Autosorb, QUANTACHROMEQUA211011 equipment. Sample was degassed at 80 °C for 12 h under

vacuum before analysis. Isotherms were analyzed using ASiQwin software. The micropore surface area and external surface area were determined by t-plot method.

Dynamic light scattering measurement: The dynamic light scattering measurement was carried out using Beckman Coulter Delso Nano C DLS instrument. The aqueous dispersion of WLE nanoparticles were further diluted with Milli-Q water for the determination of average hydrodynamic diameter.

Steady-state absorption spectroscopy: UV-Visible absorption spectra were recorded on Cary 100 spectrophotometer using 10 mm path length quartz cuvette. To avoid artifacts due to inner-filter effects, the optical density was kept low.

Steady-state fluorescence spectroscopy: All the steady-state fluorescence measurements were carried out on Jobin Yvon Horiba Model Fluorolog-3-21 using 10 mm quartz cuvette. The emission for the gel recorded using front face geometry.

The absolute emission quantum yields for WLE solution, nanoparticles, gel and thin film were measured using Fluorolog-3-21 spectrophotometer equipped with a BaSO₄-coated calibrated integrating sphere, Model F-3029, Quanta-Phi 6 (Jobin Yvon Horiba). The quantum yields were estimated taking the average of three measurements and the reported values are within the error of $\pm 2\%$.

Time-resolved fluorescence measurements: Time-resolved fluorescence measurements were carried out using time-correlated single photon counting (TCSPC) spectrometer (Delta Flex-01-DD/HORIBA). Delta diode laser 340, 510 nm and LED laser 280 nm were used as excitation source. Photomultiplier tube of picosecond photon detection module was used as detector. An aqueous solution of ludox was used to record instrument response function. All decay curves were analyzed by nonlinear least-squares iteration using IBH DAS6 (version 6.8) decay analysis software. The quality of the fit was assessed by the fitting parameters (χ^2) as well as the visual inspection of the residuals.

II. Synthesis and Characterization

(a) Chemicals

1,3-Diphenyl-2-propanone (99%), benzil (98%), potassium hydroxide (99%), lithium aluminum hydride (95%), aluminum chloride (99.9%), 2,1,3-benzothiadiazole-4,7-bis(boronic acid pinacol ester) (96%), tetrakis(triphenylphosphine)palladium (99.9%), dimethyl sulfoxide (99%), toluene (99.8%), diisopropylamine (99%), phenyl acetylene (98%) and 1,4-diethynylbenzene (95%) were received from Sigma-Aldrich. Bromine (99.5%), sodium hydroxide (99%), chloroform and hexane were received from Merck. THF (99%), ethanol (99.8%), extra pure concentrated HCl were received from Spectrochem, 1,2,3,4,5-pentaphenyl-1,3-cyclopentadiene (99%) was purchased from Alfa Aesar.

(b) Synthesis of monomers

(i) Synthesis of 2,3,4,5-tetraphenylcyclopenta-2,4-dien-1-one (TPCPO)



Scheme S1: Synthetic scheme of 2,3,4,5-tetraphenylcyclopenta-2,4-dien-1-one (3).

TPCPO was synthesized according to a literature procedure.¹ In a 50 mL shield tube containing 10 mL of anhydrous ethanol with 1,3-(diphenyl)propan-2-one (1) (500 mg, 2.4 mmol, 1 eq.) and benzyl (2) (500 mg, 2.4 mmol, 1 eq.) were taken. 1 mL of 50% aqueous KOH was added to it and refluxed for 30 minutes and the reaction mixture was cooled to 0 $^{\circ}$ C using ice bath. The solution was filtered and washed with cold methanol to yield (685 mg, 75%) TPCPO (3) as a purple crystalline solid.

¹H NMR (500 MHz, CDCl₃): δ 7.30 – 7.24 (m, 12H), 7.20 (t, *J* = 7.5 Hz, 4H), 6.96 (d, *J* = 7.1 Hz, 4H).

¹³C NMR (126 MHz, CDCl₃): δ 200.35, 154.50, 133.10, 130.78, 130.17, 129.35, 128.51, 128.04, 128.00, 127.47, 125.34.

HRMS calculated for $C_{29}H_{20}O$ 385.16, found 385.15.

(ii) Synthesis of tetraphenylcyclopentadiene (TPCP)



Scheme S2: Synthetic scheme of tetraphenylcyclopentadiene (4).

Tetraphenylcyclopentadiene (TPCP) (4) was synthesized starting from tetraphenylcyclopentadienone (3) following a reported procedure with minor modifications.²

¹H NMR (500 MHz, CDCl₃): δ 7.22 – 7.11 (m, 16H), 7.00 – 6.95 (m, 4H), 4.03 (s, 2H).

¹³C NMR (126 MHz, CDCl₃): δ 144.55, 139.75, 136.60, 136.48, 129.85, 128.15, 128.05, 127.84, 126.69, 126.40, 45.81.

MALDI-TOF calculated for $C_{29}H_{22}$ 370.48 found 370.19.

(iii) Synthesis of (5,5-dioctylcyclopenta-1,3-diene-1,2,3,4-tetrayl)tetrabenzene (TPDC)



Scheme S3: Synthetic scheme of (5,5-dioctylcyclopenta-1,3-diene-1,2,3,4-tetrayl)tetrabenzene (5).

TPCP (4) (1 g, 2.7 mmol) and tetra-n-butylammonium bromide (260 mg, 0.8 mmol) were dissolved in 5 mL DMSO. 1-bromooctane (1 mL, 5.9 mmol) and 1.2 mL 50% aqueous NaOH were added to it. The reaction mixture was stirred at 80-90 °C for 2 h. After cooling down to room temperature, the reaction mixture was poured into 100 mL of water. The reaction mixure was then extracted three times with chloroform. The organic layer was washed with water and brine solution, dried over MgSO₄. After evaporation of the solvent the resulted residue was purified via column chromatography (SiO₂, hexane) and colorless oil was obtained. The colorless oil was then dissolved in ethanol and recrystallized to obtain the pure compound (**5**) as a colorless solid (0.8 g, 50% yield).

¹H NMR (500 MHz, CDCl₃): δ 7.22 (t, *J* = 7.2 Hz, 4H), 7.20 – 7.15 (m, 2H), 7.11 – 7.07 (m, 4H), 7.06 – 7.00 (m, 6H), 6.83 (dd, *J* = 7.7, 1.6 Hz, 4H), 1.78 – 1.67 (m, 4H), 1.39 – 1.13 (m, 24H), 0.87 (t, *J* = 7.1 Hz, 6H).

¹³C NMR (126 MHz, CDCl₃): δ 147.75, 144.06, 137.14, 136.17, 130.31, 129.71, 127.93, 127.36, 126.37, 126.06, 64.57, 35.48, 31.84, 29.77, 29.38, 29.23, 23.17, 22.66, 14.12.

MALDI-TOF calculated for C₄₅H₅₄ 594.91 found 594.37.





Scheme S4: Synthetic scheme of tetrakis(4-bromophenyl)-5,5-dioctylcyclopentadiene (6).

In 50 mL round-bottom flask TPDC (5) (350 mg, 0.6 mmol) was dissolved in 5 mL chloroform. 0.35 mL (7 mmol) of bromine was added to it. The reaction mixture was stirred for 10 h at room temperature under protection from light. Then the reaction mixture was poured into

50 mL of chloroform and washed three times with sodium thiosulfate solution (1 M) and dried over MgSO₄. After evaporating the solvent, the residue was purified via column chromatography (SiO₂, hexane) to get colorless oil. The colorless liquid was dissolved in ethanol and recrystallized to obtain the pure compound (**6**) as a colorless solid (350 mg, 65% yield).

¹H NMR (500 MHz, CDCl₃): δ 7.39 (d, J = 8.5 Hz, 4H), 7.22 (d, J = 8.4 Hz, 4H), 6.91 (d, J = 8.5 Hz, 4H), 6.66 (d, J = 8.4 Hz, 4H), 1.70 (dd, J = 10.2, 5.2 Hz, 4H), 1.33 – 1.13 (m, 24H), 0.89 (t, J = 7.1 Hz, 6H).

¹³C NMR (126 MHz, CDCl₃): δ 147.74, 142.95, 135.18, 134.11, 131.72, 131.52, 131.07, 131.06, 121.05, 120.86, 64.80, 35.35, 31.80, 29.62, 29.30, 29.18, 23.16, 22.64, 14.11.

MALDI-TOF calculated for C₄₅H₅₀Br₄ 910.49 found 910.04.

(c) Synthesis of polymer



Scheme S5: Fabrication of TPDC-BZ polymer.

In 100 mL Schlenk tube, TBDC (6) (136 mg, 0.15 mmol), 2,1,3-benzothiadiazole-4,7bis(boronic acid pinacol ester) (174 mg, 0.45 mmol) and tetrakis(triphenylphosphine)palladium (9 mg, 0.008 mmol) were dissolved in 20 mL of degassed THF and 2 mL of degassed 2 M aqueous potassium hydroxide solution. The reaction mixture was stirred for 48 h at 80 °C under an argon atmosphere and under protection from light. After cooling down the reaction mixture to room temperature, it was diluted with 50 mL of chloroform and 50 mL of water and successively extracted three times with 25 mL of chloroform. The organic phase was continuously washed with 30 mL of 2 M aqueous hydrochloric acid, saturated aqueous solution of sodium bicarbonate, aqueous EDTA solution (30 mL) and 30 mL of water. The solvent was removed by reduced pressure. The residue was dissolved in a very small amount of chloroform and precipitated into cold methanol, the precipitate was washed with methanol and acetone. The precipitate was thoroughly washed by Soxhlet extraction for 24 h, each with methanol and acetone respectively and then dried under vacuum at 70 °C to obtain pure TPDC-BZ polymer (36 mg) as a yellow solid.

(d) Synthesis of (5-octylcyclopenta-1,3-diene-1,2,3,4,5pentayl)pentabenzene (OPCP)



Scheme S6: Synthetic scheme of (5-octylcyclopenta-1,3-diene-1,2,3,4,5-pentayl)pentabenzene (8).

1,2,3,4,5-pentaphenyl-1,3-cyclopentadiene (7) (200 mg, 0.45 mmol) and tetra-nbutylammonium bromide (43 mg, 0.1 mmol) were dissolved in 2 mL DMSO. 1-Bromooctane (120 µL, 0.5 mmol) and 0.5 mL 50% aqueous NaOH were added to it. The reaction mixture was stirred at 80-90 °C for 2 h. After cooling down to room temperature, the reaction mixture was poured into 100 mL of water, and then it was extracted three times with chloroform. The organic layer was washed with water and brine solution, dried over MgSO₄. After evaporation of the solvent the resulted residue was purified via column chromatography (SiO₂, hexane). The colorless oil obtained, was dissolved in ethanol and recrystallized to get the pure compound as a colorless solid (**8**) (0.1 g, 44% yield).

¹H NMR (500 MHz, CDCl₃): δ = 7.39 (d, *J* = 7.7 Hz, 2H), 7.30 (t, *J* = 7.6 Hz, 2H), 7.23 (t, *J* = 7.2 Hz, 1H), 7.16 – 6.98 (m, 16H), 6.76 (d, *J* = 6.7 Hz, 4H), 2.26 – 2.18 (m, 2H), 1.44 (dd, *J* = 9.4 Hz, 5.5 Hz, 2H), 1.27 (m, 10H), 0.91 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃): δ 150.73, 144.04, 140.33, 136.05, 130.17, 129.53, 128.47, 127.57, 127.50, 126.67, 126.42, 126.39, 66.99, 31.84, 30.80, 29.92, 29.37, 29.18, 22.67, 14.13.

MALDI-TOF: calculated for C₄₃H₄₂ 558.81 found 558.30.

(e) Characterization of polymer

(i) Fourier transform infra-red (FTIR) spectroscopy

The FTIR spectra of TPDC-BZ, TPDC and BZ are shown in Fig. S1. The characteristic aliphatic C-H stretching at 2926-2852 cm⁻¹ originating from TPDC building blocks were observed. Aromatic C=C stretching band was observed at 1482 cm⁻¹. Strong band in the region of 832 cm^{-1} can be attributed to C–H bending of para-di-substituted benzene ring.



Figure S1: Comparative account of FTIR spectrum of TPDC-BZ polymer with TPDC and BZ.

(ii) ¹H NMR

¹H NMR spectra of TBDC, BZ and TPDC-BZ polymer are shown in Fig. S2, S3 and S4, respectively. Fig. S4 clearly indicates similar resonances as that of TBDC and BZ in addition to other resonances demonstrating polycondenzation between the monomers.



Figure S2: ¹H NMR spectrum of TBDC.



Figure S3: ¹H NMR spectrum of benzothiadiazole (BZ).



Figure S4: ¹H NMR spectrum (2000 pulses with a standard pulse program) of TPDC-BZ polymer.

(iii)¹³C NMR

¹³C NMR of TPDC-BZ polymer depicts the peaks at $\delta = 153$ and 155 ppm attributed to benzothiadiazole moiety and the peaks at $\delta = 14$ to $\delta = 35$ ppm correspond to the aliphatic carbons of TPDC core (Fig. S5).



Figure S5: ¹³C NMR (5000 pulses with a standard pulse program) spectrum of TPDC-BZ polymer.

(iv) Gel permeation chromatography (GPC) analysis

Molecular weights of the soluble polymers ($M_w \sim 5.4$ and $M_n \sim 3.5$ kg mol⁻¹) were estimated by GPC using polystyrene standard. The universal calibration was used employing refractive index and viscometry detectors. Also, the estimated molecular weights were corroborated with the analysis using triple detectors (refractive index, viscometry and light scattering).



Figure S6: SEC chromatogram of TPDC-BZ polymer.

(v) Thermogravimetric analysis (TGA)

The samples were heated at a rate 10 $^{\circ}$ C min⁻¹ under a nitrogen atmosphere to a maximum of 900 $^{\circ}$ C. TGA showed that the TPDC-BZ polymer was thermally stable without decomposing up to 370 $^{\circ}$ C.



Figure S7: TGA curve of TPDC-BZ polymer.

(vi) FESEM

Solid Polymer (powder) was sprinkled over carbon tape and a thin layer of gold was coated for 120 s. The TPDC-BZ polymer showed globular morphology with rough surfaces.



Figure S8: FESEM image of TPDC-BZ polymer.

(vii) BET analysis

Samples were degassed at 80 °C for 12 h under vacuum before analysis. Nitrogen adsorption isotherms were analyzed using ASiQwin software. Nitrogen and hydrogen sorption isotherms were measured at 77 K. As TPDC-BZ was found to be ultramicroporous, BET analysis for surface area measurement was carried out considering relative pressure (P/P_0) in low pressure regions. The relative pressure ranges used for the analysis are $0.005 < P/P_0 < 0.025$ and $0.01 < P/P_0 < 0.1.^{3,4}$ The estimated surface areas for the above two different pressure range were found to be 610 and 603 m²g⁻¹. The better fit to the BET equation was obtained using P/P_0 0.005 to 0.025 and the corresponding specific surface area plot is shown in Fig. S9a. The pore size distribution was determined using NLDFT method. The details of the specific calculation model are as following: N₂ at 77 K on carbon (slit pore, NLDFT equilibrium model). The zoomed view of the pore size distribution data is shown in Fig. S9b.



Figure S9: (a) BET specific surface area plot of TPDC-BZ with the relative pressure range 0.005 $< P/P_0 < 0.025$. (b) Pore size distribution estimated using NLDFT method (black circles: differential pore volume and blue circles: cumulative pore volume).

t-Plot method: The t-plot method was used for the calculation of external surafce area. Carbonblack was used as a standard in t-plot analysis. The best linear fitting (correlation coefficient, r = 0.99956) for t-plot analysis was obtained considering P/P_0 range 0.2 to 0.5. The t-plot for nitrogen adsorption at 77 K is shown in Fig. S10.



Figure S10: t-plot graph for TPDC-BZ polymer.

Surface area measurements of OPCP impregnated TPDC-BZ: TPDC-BZ was stirred in 1 M OPCP solution in methanol for 24 h. Then the polymer was filtered, washed with methanol and dried in glass oven at 70 °C for 12 h. Subsequently, the nitrogen adsorption isotherms were measured at 77 K. The BET surface area was found to be 103 m²g⁻¹, significantly lower than the native polymer (610 m²g⁻¹). This observation clearly suggests encapsulation of OPCP in the porous framework of TPDC-BZ (Fig. S11). The microporosity is also considerably reduced in OPCP encapsulated TPDC-BZ.



Figure S11: (a) Nitrogen isotherm of OPCP encapsulated TPDC-BZ and (b) BET specific surface area plot of TPDC-BZ with the relative pressure range $0.075 < P/P_0 < 0.15$.

III. Spectroscopic characterization

Fluorescence quantum yield (ϕ_F) **measurement:** The fluorescence quantum yield (ϕ_F) of TPDC-BZ in THF was estimated by comparison with coumarin-102 in ethanol $(\phi_F = 0.76)$.⁵ The quantum yield was calculated using the following equation.⁶ $\phi_{F,x} = \phi_{F,s} \cdot \frac{F_x}{F_s} \cdot \frac{f_s}{f_x} \cdot \frac{n_x^2}{n_s^2}$

Where, subscript *x* denotes unknown sample and subscript *s* refers to standard. *F* denotes integral fluorescence, η refers to refractive index of the solvent used in the measurements and *f* is the absorption factor at the excitation wavelength ($f = 1 - 10^{-\varepsilon(\lambda_{ex})cl} = 1 - 10^{-A(\lambda_{ex})}$), where A is absorbance and ε = molar extinction coefficient in L mol⁻¹ cm⁻¹.

The absolute emission quantum yield for WLE solution, nanoparticles, gel and thin film were measured on a Jobin Yvon Horiba Model Fluorolog-3-21 spectrophotometer equipped with a BaSO₄-coated integrating sphere, Model F-3029, Quanta-Phi 6 (Jobin Yvon Horiba).



Figure S12: TPDC-BZ polymer in THF: (i) absorption, (ii) emission ($\lambda_{ex} = 388$ nm) and (iii) excitation spectra ($\lambda_{em} = 577$ nm).

Table S1: Summary of Reichard's solvent polarity parameters $E_T(30)$, the absorption wavelength (λ_{abs}), emission wavelength (λ_{em}).

Solvent	E _T (30) [kcal mol ⁻¹]	λ _{abs} [nm]	λ _{em} [nm]
Toluene	33.9	387	549
THF	37.4	388	577
Chloroform	39.1	390	586
DCM	40.7	384	601

IV. White light emitting (WLE) systems

(a) Parameters to characterize the quality of white light

The quality of white light is mainly characterized by three parameters as given below:

- (i) The Commission Internationale de l'Eclairage (CIE) chromaticity coordinates (x, y) depicts the emission color in the chromaticity diagram. The perfect white light system has CIE coordinates (x = 0.33, y = 0.33). However, a quite broad region around this point in the diagram can be considered as white light.^{7,8}
- (ii) The color rendering index (CRI) is a numerical value ranging from 0 100, which measures the true color of the object when illuminated by a light source. CRI value for WLE systems are preferably higher than 80.⁹ The quality of the color, which can be distinguishable from one to another, is given by Munsell color system. The different hue of the colors are designated by code (R_n). The general CRI is indicated by symbol R_a which is the average value of R_1 to R_n .
- (iii) Broad band light source is characterized by the correlated color temperature (CCT) and it is defined as the temperature of the black body radiator, which emits same color as that of light source. For lighting application, CCT range is usually 2500-7500 K.^{7,9} The CCT values are calculated using McCamy's formula.¹⁰

The CIE coordinates, CRI and CCT were calculated using ColorCalculator 6.31 from *Osram Sylvania*, Inc. using the corrected emission spectra.

(b) Preparation of WLE solution

1 mg of TPDC-BZ polymer was dissolved in 2 mL of THF. The solution was stirred overnight and then filtered through 0.2 μ m syringe filter. The emission color was tuned by varying the amount of OPCP (0.1 M in THF) in TPDC-BZ polymer solution, keeping the total volume of solution fixed (2.5 mL). The pure white light emission was obtained upon addition of 5 μ M of OPCP in 2.5 mL of TPDC-BZ solution in THF. A broad emission ranging from 400 to 800 nm was obtained when excited at 290 nm. Fig. S13a and b show the absorption and emission spectra of OPCP (i), TPDC-BZ and different concentrations of OPCP (ii, iii, iv) and pure TPDC-BZ in THF (v). Upon addition of OPCP to the polymer solution, apart from the peak at 390 nm

due to the TPDC-BZ, another peak at 340 nm is also present which corresponds to OPCP. Fig. S13c shows the emission spectrum of WLE solution (iii). The CIE chromaticity diagram and the emission color of the corresponding solutions upon excitation with UV light of 265 nm are shown in Fig. S13d. The CRI (*Ra*) value of WLE solution was found to be 79 (Fig. S13e).

(c) Time-resolved fluorescence decay measurement of WLE solution

The detailed photophysics for WLE solution were investigated by time-correlated single photon counting experiments. The decay curves of the WLE solution were monitored at the emission wavelengths of the TPDC-BZ (588 nm) and OPCP (435 nm) exciting at 280 nm using a laser diode (Fig. S13f). The pure TPDC-BZ polymer in THF followed biexponential decay kinetics with an average decay time of 3.5 ns. After addition of OPCP, the weighted average decay time remains same (3.6 ns). No significant decrease in the decay time of OPCP was observed. These observations indicate no significant energy transfer from OPCP to TPDC-BZ in solution (Table S2).

Table S2: Fluorescence decay parameters of TPDC-BZ, OPCP and WLE solution in THF; the decay times $(\tau_1 \text{ and } \tau_2)$ and the fractional contributions $(\alpha_1 \text{ and } \alpha_2)$, the weighted average decay time (τ_{avg}) and the quality of fitting (χ^2) are shown.

System	λ _{ex} [nm]	λ _{em} [nm]	τ1 [ns]	α1	τ 2 [ns]	α2	τ _{avg} [ns]	χ^2
OPCP	340	435	0.4	6	4.7	94	4.4	1.01
TPDC- BZ	340	588	2.1	34	4.3	66	3.5	1.04
		435	0.9	39	4.4	61	3.0	1.10
WLE	280	578	2.4	36	4.4	64	3.6	1.03
solution		588	2.3	35	4.3	65	3.6	1.07



Figure S13: Tuning of emission color to achieve white light by varying the concentration of two components, TPDC-BZ and OPCP in THF: (a) absorption spectra, (b) emission spectra ($\lambda_{ex} = 290$ nm) as a function of TPDC-BZ : OPCP molar ratio (i) 0 : 5, (ii) 4 : 5, (iii) 15 : 5, (iv) 15 : 1.5 and (v) 15 : 0. (c) Emission spectum of the WLE solution (iii). (d) The chromaticity diagram (CIE 1931) of the solutions depicting the gradual shift of emission color from blue to yellow through white (x = 0.34, y = 0.31); (inset: photographs of different solutions illuminated under UV light at 265 nm. (e) CRI of WLE solution at various Munsell codes and (f) The fluorescence decay curves of WLE solution ($\lambda_{ex} = 280$ nm) observed at different emission wavelengths.

(d) Preparation of WLE nanoparticles

The polymer TPDC-BZ (0.5 mg / 1 mL) was dissolved in THF by stirring overnight. The solution then filtered using 0.2 μ m syringe filter. Then the stock solutions of OPCP (0.4 mM) and pyridine red (PR, 0.01 mM) were prepared using THF. The amount of OPCP and PR were varied in the polymer solution to obtain white light emission. 400 μ L of OPCP, 10 μ L of PR and 10 μ L of TPDC-BZ in THF solution were mixed. 100 μ L of this solution was injected into 5 mL of milli-Q water under vigorous sonication to obtain WLE nanoparticles.

The emission spectrum of WLE nanoparticles covers broad region as shown in Fig. S14a. The CRI (*Ra*) value was found to be 93 for WLE nanoparticles (Fig. S14b).



Figure S14: (a) Emission spectrum and (b) CRI at various Munsell codes of WLE Nanoparticles.

(e)The comparative account of photophysical properties of polymer and dyes in THF solution and in aqueous dispersion

The normalized absorption spectra of OPCP, TPDC-BZ and PR in THF are shown in Fig. S15a. The corresponding emission spectra exciting OPCP, TPDC-BZ and PR at 340, 388 and 540 nm respectively are shown in Fig. S15b. Aqueous dispersion of OPCP, TPDC-BZ and PR were prepared by rapidly injecting THF solution of TPDC-BZ (0.5 mg/ mL, 100μ L), OPCP (0.4 mM, 400 μ L) and PR (0.01 mM, 400 μ L) separately into 5 mL of water. The normalized absorption and emission spectra of aqueous dispersion of OPCP, TPDC-BZ and PR were compared with an aqueous dispersion of white light emitting (WLE) nanoparticles (Fig. S15c and d). The emission spectrum of aqueous dispersion of WLE nanoparticles revealed the characteristic emission of OPCP, TPDC-BZ and PR.



Figure S15: (a) The absorption spectra, (b) emission spectra of TPDC-BZ, OPCP and PR in THF. (c) absorption spectra and (d) emission spectra of the same in aqueous dispersion.

For the proof of concept of ensemble composition of OPCP, TPDC-BZ and PR in WLE nanoparticles, further, the aqueous dispersion of WLE nanoparticles were filtered off using nanoporous alumina membrane (average pore diameter 20 nm). Steady state absorption and emission spectra of the filtrate (Fig. S16) showed very low intensity compared to that of the native WLE nanoparticle dispersion (before filtration). This observation suggests hydrophobic OPCP, TPDC-BZ, and PR (present in THF solution, before precipitation) were almost completely ensembled in the form of nanoparticles. The slight intensity of absorption and emission in the filtrate is probably to be due to the leaching of smaller size nanoparticles during filtration. Based on the above discussion, we believe that the composition of the THF solution is likely to be retained in nanoparticles.



Figure S16: (a) Absorption spectra and (b) emission spectra of WLE nanoparticles before filtration and after filtration.

(f) Time-resolved fluorescence decay measurement of WLE nanoparticles

Time-resolved spectroscopy was carried out to understand the decay dynamics of the WLE nanoparticles. Fig. S17 showed the emission decay profiles of the WLE nanoparticles upon excitation at 340 nm and observed at different emission wavelengths. OPCP in aqueous dispersion shows biexponential decay kinetics with an average decay time of 3.1 ns (Table S3). The emission decays of WLE nanoparticles monitored at different wavelengths fit to the three-exponential functions. Multiexponential decay kinetics is quite expected in such a heterogeneous system containing multiple chromophores. In WLE nanoparticles, the average decay time of OPCP is reduced from 3.1 to 2 ns. The reduction in the decay time of OPCP provides a strong evidence of energy transfer from OPCP as a donor. The weighted average decay time monitored at emission wavelength of TPDC-BZ and PR found to increase with respect to the native fluorophores in aqueous dispersion. It indicates the energy transfer processes from OPCP to TPDC-BZ polymer and PR.



Figure S17: (a) Emission decay curves of WLE nanoparticles ($\lambda_{ex} = 340 \text{ nm}$) observed at different emission wavelengths and (b) zoomed view of the decay curves with $\lambda_{em} = 435$, 500 and 600 nm.

Table S3: Fluorescence decay parameters for OPCP, TPDC-BZ and PR in aqueous dispersion and WLE nanoparticles; the decay times (τ_1 , τ_2 , and τ_3) and the respective fractional contributions (α_1 , α_2 and α_3), the weighted average decay time (τ_{avg}) and the quality of fitting (χ^2) are shown.

System	λ _{ex} [nm]	λ_{em} [nm]	$\tau_1[ns]$	α_1	τ_2 [ns]	α_2	τ ₃ [ns]	α3	τ_{avg} [ns]	χ^2
Aqueous dispersion of OPCP	340	435	2.1	57	4.5	42			3.1	1.09
Aqueous dispersion	240	500	0.8	75	3.0	25	-	-	1.3	1.08
of TPDC-BZ	540	560	0.8	68	2.2	32	-	-	1.2	1.02
Aqueous dispersion of PR	510	600	0.2	39	0.6	61	-	-	0.5	1.06
		435	0.4	17	1.3	57	3.6	26	1.7	1.06
		500	0.3	-5	1.7	47	4.8	58	3.6	1.02
WLE nanoparticles	340	560	0.3	-5	2.5	53	6.1	52	4.5	1.09
		580	0.4	-4	4.0	58	9.6	46	6.7	1.09
		600	0.4	-3	6.2	80	15.1	23	8.4	1.2

(g) Time-resolved emission spectra (TRES) measurement of nanoparticles

Time-resolved emission spectra were measured using time-correlated single photon counting (TCSPC) spectrometer (Delta Flex-01-DD/HORIBA).¹¹ The Delta diode laser at 340 nm was used as the excitation source. The instrument response function was carried out using LUDOX solution. The first detected signal was recorded as fluorescence intensity at time zero. TRES was recorded with a wavelength range from 370 to 650 nm at 4 nm interval and at different delay time from 54 ps to 7.8 ns (Fig. S18). At lower gated time the emission peak is centered at 435 nm which corresponds to direct excitation of OPCP. With the evolution of time, emission peaks at red region (500 and 600 nm) were found to increase and subsequently, blue emission at 435 nm decreases (Fig. S18). The dynamic decrease of the peak at blue region and subsequent increment of the peak at red region with the evolution of time, confirms the energy transfer from OPCP to TPDC-BZ and PR.



Figure S18: Time-resolved emission spectra of WLE nanoparticles after excitation at 340 nm.

(h) Preparation of white light emitting gel

The white light emitting gel was prepared using agarose as gelator. 2 mL of 1 wt% of agarose solution was heated at 60 °C and 500 μ L of aqueous dispersion of WLE nanoparticles was added to it with stirring. The mixture was allowed to cool to room temperature. The spectroscopic investigation was carried with the gel. Upon excitation at 340 nm, it shows a broad emission ranging from 400 to 700 nm with peak maxima at 435, 500 and 600 nm corresponding to the characteristic peaks of OPCP, TPDC-BZ and PR, respectively (Fig. S19a). The CIE chromaticity coordinate of gel was found to be 0.31, 0.28 (Fig. S19b). The CRI (*Ra*) value was 84 (Fig. S19c). The excitation spectra monitored at the emission wavelengths of TPDC-BZ and PR revealed a peak at 340 nm relating to absorption maxima of OPCP. This result suggests that the Förster type resonance energy transfer (FRET) from OPCP to TPDC-BZ and PR is retained in the gel (Fig. S19d).



Figure S19: Characteristics of WLE gel: (a) emission ($\lambda_{ex} = 340$ nm) spectrum, (b) the chromaticity diagram (CIE 1931, x = 0.31, y = 0.28), (c) CRI at various Munsell codes and (d) excitation spectra monitored at different emission wavelengths.

(i) Time-resolved emission spectra (TRES) measurement of WLE gel

TRES measurement for WLE gel recorded with gated time from 0.82 ns to 8.3 ns. At lower gated time, major part of the emission comes from OPCP at 435 nm. After 1.3 ns of gated time, we observed a noticeable increase in the emission intensity at 500 and 600 nm, corresponding to TPDC-BZ and PR respectively with a concomitant decrease in intensity at 435 nm. The time-resolved emission spectra of WLE gel are shown in Fig. S20. The result infers that dye encapsulated polymer nanoparticles might have trapped in the gel network and the energy transfer processes are retained.



Figure S20: Time-resolved emission spectra of WLE gel ($\lambda_{ex} = 340$ nm).

(j) Preparation of white light emitting transparent thin film

The transparent thin film was prepared by coating the WLE gel on quartz substrate and allowing it to dry for 24 h. The dried thin film was peeled off the substrate to get transparent freestanding thin film which emits white light under illumination at 365 nm (Fig. 4d). The transmittance spectra of WLE thin film and thin film of agarose gel are shown in Fig. S21. The WLE thin film was highly transparent with a transmittance of 95-97% in 500-800 nm.



Figure S21: Transmittance spectra of WLE thin film (solid black line) and agarose gel thin film (solid red line) on quartz substrate.



Figure S22: The quality of the white light obtained from the free-standing film ($\lambda_{ex} = 340$ nm): (a) CIE chromaticity diagram and (b) CRI at various Munsell codes.

The quality of white light emitted from the transparent thin film, when excited at 340 nm is depicted by chromaticity diagram (CIE 1931, Fig. S22a). The CIE chromaticity coordinates were found to be x = 0.33, y = 0.32, which are very close to pure white light. The CRI (*Ra*) value was found to be 82 which is shown in Fig. S22b.

(k) A comparative account of the quality of white light

The white light emitting systems developed in the present study are turned out to be suitable for optical applications. The quality of the white light characterized by CIE, CRI and CCT is found to be very promising for device applications (Table S4). The CRI value of WLE nanoparticles was found to be 93 and for solution, gel and thin film were found to be close to 80. The CCT values for solution, gel and thin film were found to be close to that of day light (6500 K). The CCT value of WLE nanoparticles can be reduced by increasing the relative percentage of PR.

Table S4: Summary of CIE, CRI and CCT values of white light emitting solution, nanoparticles, gel and transparent thin film.

Parameters	Solution	Nanoparticles	Gel	Thin film
Quantum yield	14	35	14	8
CIE	0.34, 0.31	0.29, 0.32	0.31, 0.28	0.33, 0.32
CRI	84	93	79	82
CCT (K)	5290	7750	6942	5481

C	SPOP (System)	SPOP Surface			Multifur applica		
S. No.		area [m ² g ⁻¹]	size	Fluorescence	H2 uptake [mmol g ⁻¹]	White light emission	Citation
1	TPDC-BZ	610	0.7 nm	$\frac{\text{Yellow / } \phi_{\text{F}}}{46\%} =$	6.4	Yes	Current work
2	Pyrene	505		Green / NA	3.9	No	Angew. Chem. Int. Ed. 2012, 51, 12727 ¹²
3	Polystyrene	724		NA	5.05	No	<i>J. Mater.</i> <i>Chem. A</i> , 2016 , <i>4</i> , 15072. ¹³
4	Pyrene, perylene- diimide	728	< 2 nm	Greenish yellow / NA	3.5	No	<i>Adv. Funct.</i> <i>Mater.</i> 2014 , 24, 5219. ¹⁴

Table S5: Comparison of TPDC-BZ with reported soluble porous organic polymers (SPOP, $S_{BET} > 100 \text{ m}^2 \text{ g}^{-1}$) for multifunctional applications.

S. No.	System	Quantum yield	Commission Internationale de l'Eclairage coordinates	Citation
1	TPDC-BZ based hybrid materials	Solution = 14% Nanoparticles = 35% Gel = 14% Thin film = 8%	(0.34, 0.31) (029, 0.32) (0.31, 0.28) (0.33, 0.32)	Current work
2	Green and red emitting dyes encapsulated In ³⁺ - MOF	17.4%	(0.34, 0.32)	Ref. 9
3	Ir complex doped Cd-MOF	20.4%	(0.31, 0.33)	Ref. 15
4	Ir complex doped triazine based CPOP	5.2%	(0.32, 0.34)	Ref. 16
5	Nile Red incorporated POP nanoparticles	NA	(0.31, 0.31)	Ref. 17
6	CdS embedded Zn ²⁺ -MOF	NA	(0.30, 0.35)	Ref. 18
7	Alq ₃ @ Zn^{2+} -MOF composite	11.4%	(0.29, 0.32)	Ref. 19
8	Eu ³⁺ -MOF	33%	(0.33, 0.34)	Ref. 20
9	Polyphenylene based conjugated microporous polymer	8.8%	(0.25, 0.30)	Ref. 21
10	La ³⁺ , Tb ³⁺ , Sm ³⁺ - MOF	46, 47%	(0.32, 0.33)	Ref. 22
11	Eu ³⁺ , Tb ³⁺ doped Ga ³⁺ - MOF	22%	(0.36, 0.33)	Ref. 23
12	Porous polyuria in DMF	NA	(0.26, 0.38)	Ref. 24
13	Sr ²⁺ -MOF	10%	(0.33, 0.38)	Ref. 25
14	C-153, Nile red and DCM Zn ²⁺ -doped MOF	41%	(0.32, 0.34)	Ref. 26
15	[H ₂ NMe ₂] ₃ Gd _{1-x-y} Eu _x Tb _y (DPA) ₃ based MOF	62%	(0.33, 0.33)	Ref. 27

Table S6: A comparative study on white light emission obtained from TPDC-BZ based materials with other notable WLE system involving porous solids and conjugated polymers.

16	Lanthanide based MOF	-	-	Ref. 28
17	[Zn ₆ (btc) ₄ (tppe) ₂ (sol) ₂] based MOF	90.7%		Ref. 29
17	${[Sr(ntca)(H_2O)_2] \cdot H_2O}_n$ based MOF	10%	(0.32, 0.36)	Ref. 30
18	Eu _{0.045} Tb _{0.955} CPOMBA/La _{0.6} Eu _{0.1} Tb _{0.3} CPOMBA based MOF	15%	(0.32, 0.34)	Ref. 31
19	Conugated polymer-di-ureasils	-	(0.23, 0.33)	Ref. 32
20	2,6-bis(pyrazolyl)pyridine- <i>co</i> -octylated phenylethynyl conjugated polymers coordinated to Eu(tta) ₃	-	(0.33, 0.37) (0.30, 0.35)	Ref. 33
21	Graphene oxide wrapped polyfluorene oxide nanoparticles	3%	-	Ref. 34
22	Oligo-phenylenevinylene based π -conjugated amphiphilic polymer	~ 25%	0.25,0.32	Ref. 35
23	poly[2,7-(9,90-dioctylfluorene)-co-N-phenyl- 1,8-naphthalimide (99:01)] (PFONPN01)	-	0.26, 0.32 0.31, 0.38 0.30, 0.40	Ref. 36

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VI. ¹H NMR and ¹³C NMR spectra



Figure S23: ¹H NMR spectrum of TPCPO (3)



Figure S24: ¹³C NMR spectrum of TPCPO (3)



Figure S25: ¹H NMR spectrum of TPCP (4)



Figure S26: ¹³C NMR spectrum of TPCP (4)



Figure S27: ¹H NMR spectrum of TPDC (5)



Figure S28: ¹³C NMR spectrum of TPDC (5)



Figure S29: ¹H NMR spectrum of TBDC (6)



Figure S30: ¹³C NMR spectrum of TBDC (6)



Figure S31: ¹H NMR spectrum of OPCP (8)



Figure S32: ¹³C NMR spectrum of OPCP (8)