Electronic Supplementary Information for:

High Performance Photosensitizers with Aggregation-Induced Emission for Image-Guided Photodynamic Anticancer Therapy

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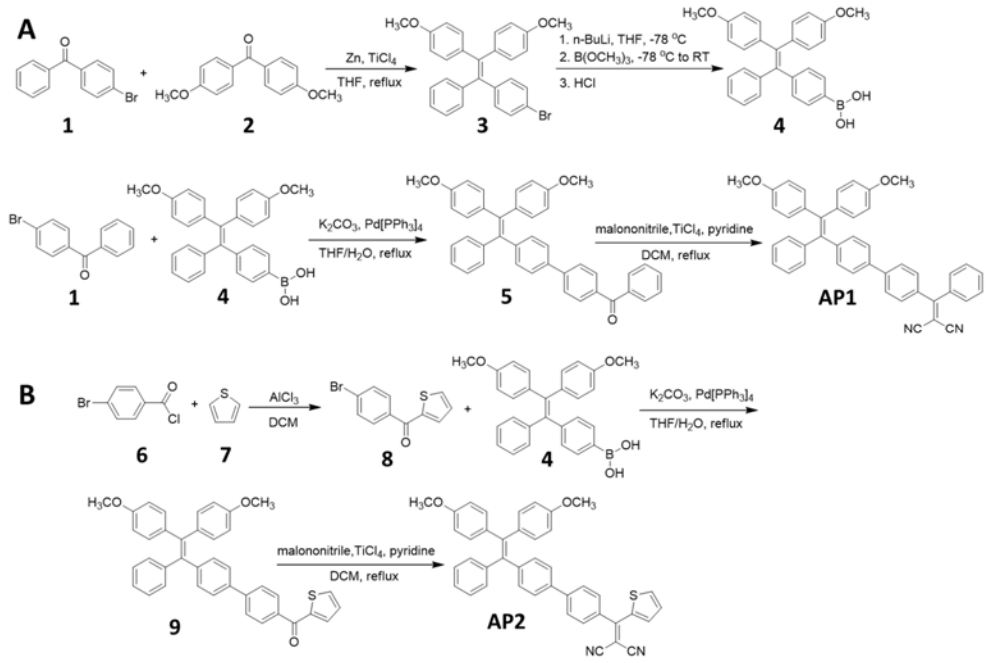
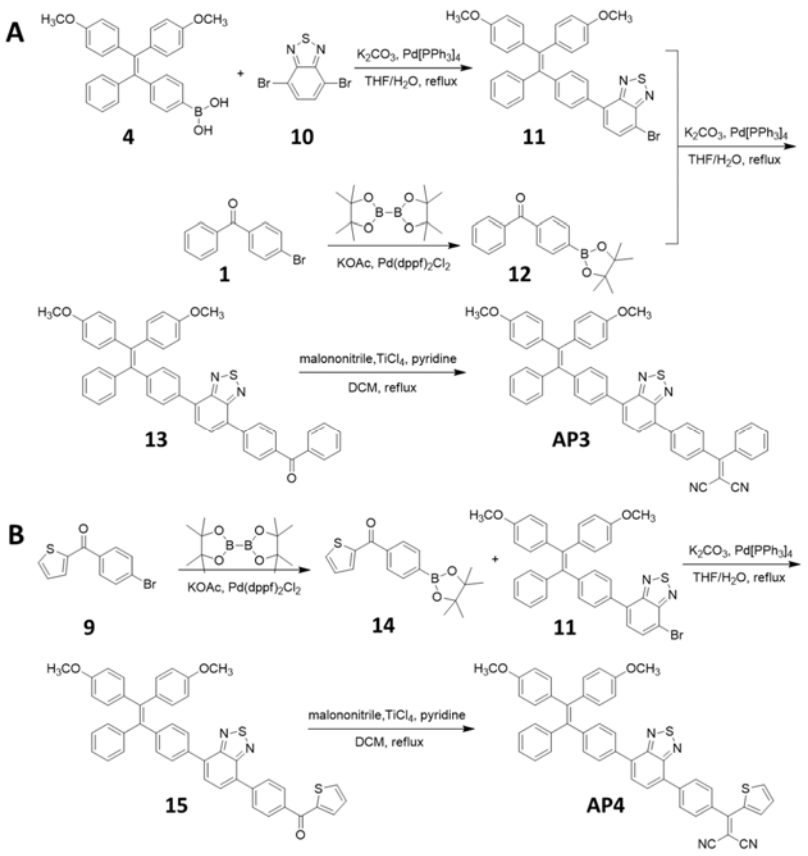


Scheme S1. The synthetic route to **AP1** (A) and **AP2** (B).



Scheme S2. The synthetic route to **AP3** (A) and **AP4** (B).

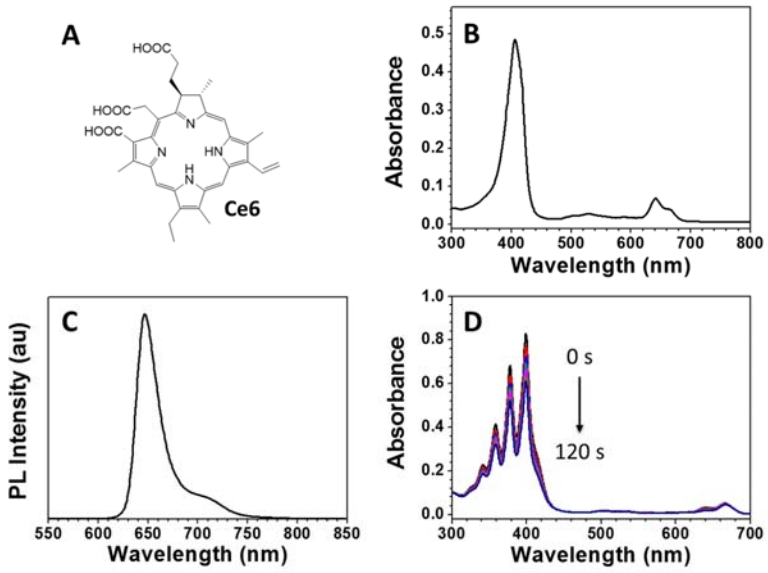


Fig. S1. (A) The chemical structure of traditional PS **Ce6**. (B) UV-vis spectrum of **Ce6** in DMSO/water = 1/99 (v/v). (C) PL spectra (λ_{ex} = 640 nm) of **Ce6** in DMSO/water = 1/99 (v/v). (D) UV-vis spectra of **ABDA** in the presence of **Ce6** NPs under light irradiation (60 mW/cm^2, 400-700 nm) for different time in DMSO/water = 1/99 (v/v). For testing aborpation and emission spectra, [**Ce6**] = 5×10^{-6} M; for testing $^1O_2$ generation, [**Ce6** NPs] = 10 μg/mL based on **Ce6** molecule; [**ABDA**] = 5×10^{-5} M.

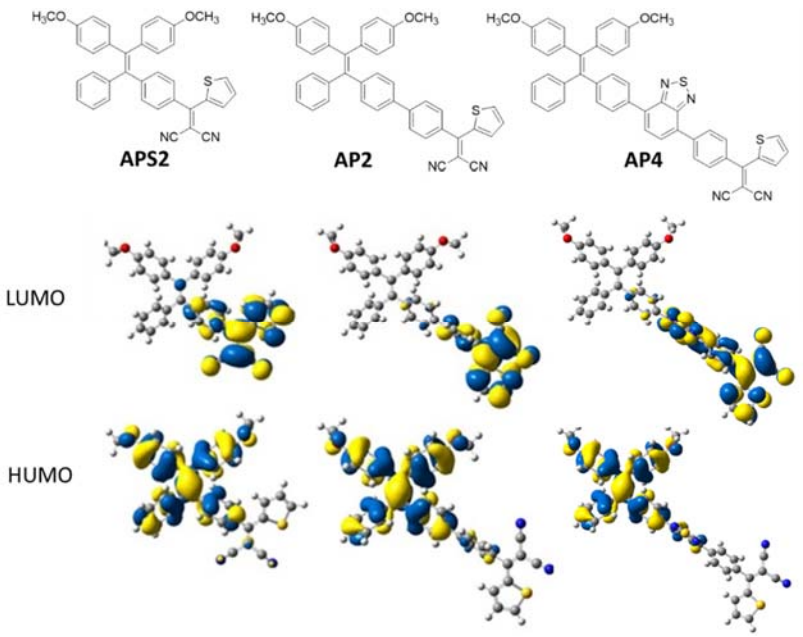


Fig. S2. Chemical structures and HOMO-LUMO distributions of **APS2**, **AP2** and **AP4**, optimized structures of the HOMO and LUMO at S_1 were calculated by TD-DFT (Gaussian 09/B3LYP/6-31G(d)).

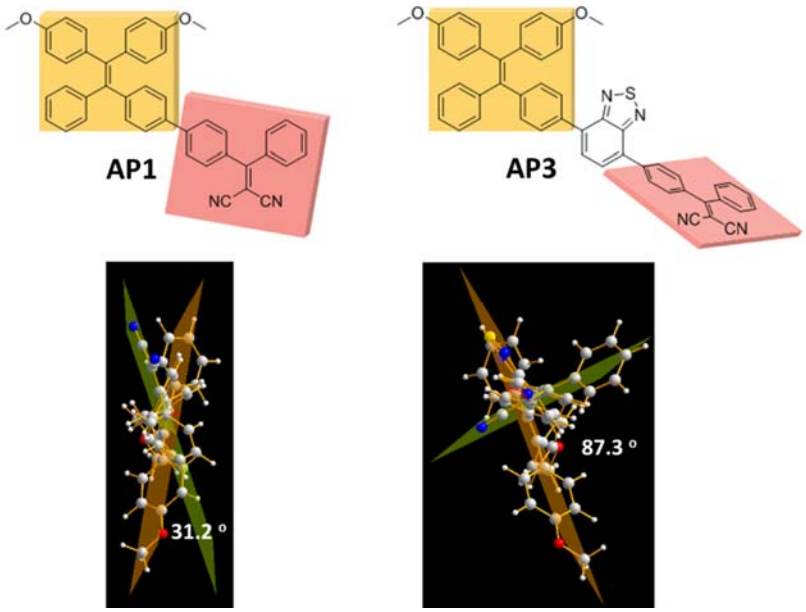


Fig. S3. Chemical structures and the optimized structures of **AP1** and **AP3**, which were calculated by TD-DFT (Gaussian 09/B3LYP/6-31G(d)).

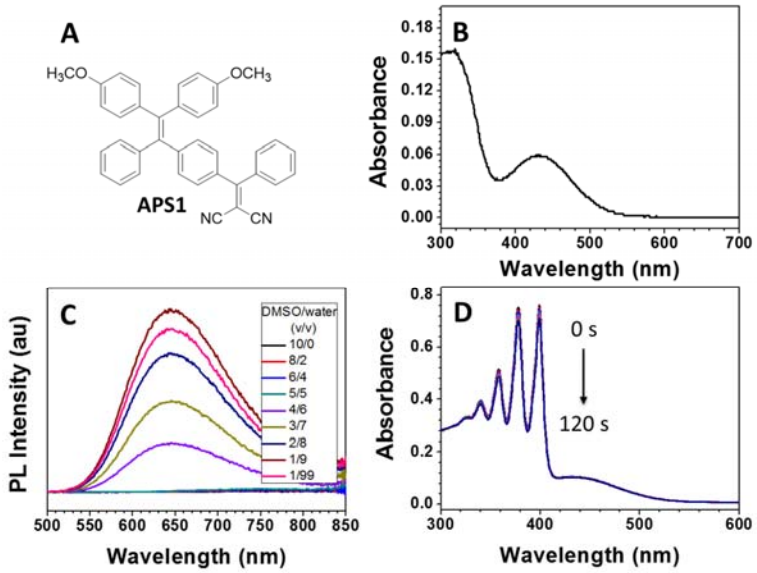


Fig. S4. (A) The chemical structure of AIE PS **APS1**. (B) UV-vis spectrum of **APS1** in DMSO/water = 1/99 (v/v). (C) PL spectra of AIE PS **APS1** (λ_{ex} = 440 nm) in DMSO and DMSO-water mixtures at differernt volume ratios. (D) UV-vis spectra of **ABDA** in the presence of **APS1** NPs under light irradiation (60 mW/cm^2, 400-700 nm) for different time in DMSO/water = 1/99 (v/v). For testing the absorption and emission spectra, [**APS1**] = 5×10^{-6} M; for testing $^1O_2$ generation, [**APS1** NPs] = 10 μg/mL based on **APS1** molecule; [**ABDA**] = 5×10^{-5} M.

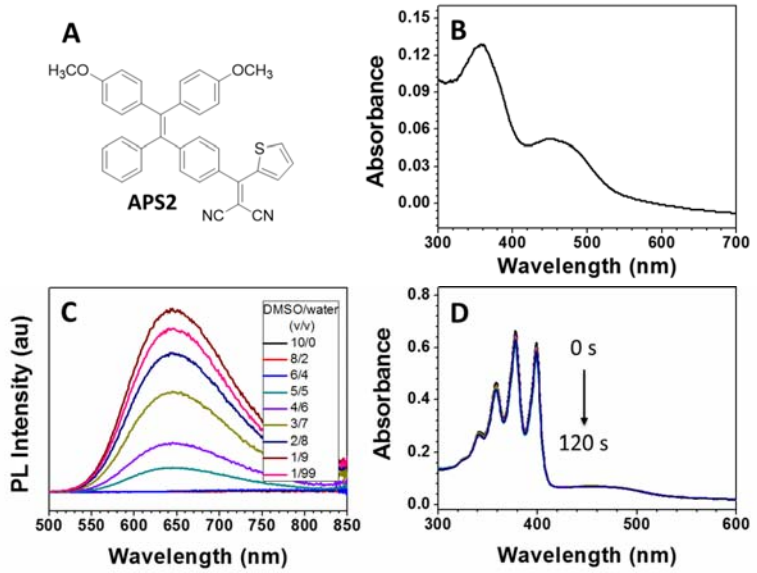


Fig. S5. (A) The chemical structure of AIE PS **APS2**. (B) UV-vis spectrum of **APS2** in DMSO/water = 1/99 (v/v). (C) PL spectra (λ_{ex} = 440 nm) in DMSO and DMSO-water mixtures at differernt volume ratios of AIE PS **APS2**. (D) UV-vis spectra of **ABDA** in the presence of **APS2** NPs under light irradiation (60 mW/cm^2, 400-700 nm) for different time in DMSO/water = 1/99 (v/v). For testing absorption and emission spectra, [**APS2**] = 5×10^{-6} M; for testing $^1O_2$ generation, [**APS2** NPs] = 10 μg/mL based on molecule; [**ABDA**] = 5×10^{-5} M.

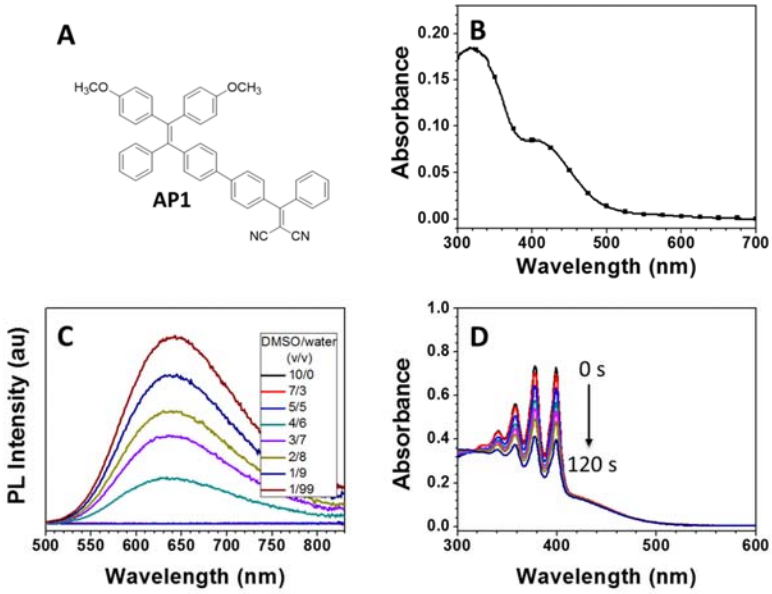


Fig. S6. (A) The chemical structure of AIE PS **AP1**. (B) UV-vis spectrum of **AS1** in DMSO/water = 1/99 (v/v). (C) PL spectra (λ_{ex} = 420 nm) in DMSO and DMSO-water mixtures at differernt volume ratios of AIE PS **AP1**. (D) UV-vis spectra of **ABDA** in the presence of **AP1** NPs under light irradiation (60 mW/cm^2, 400-700 nm) for different time in DMSO/water = 1/99 (v/v). For testing absorption and emission spectra, [**AP1**] = 5×10^{-6} M; for testing $^1O_2$ generation, [**AP1** NPs] = 10 μg/mL based on **AP1** molecule; [**ABDA**] = 5×10^{-5} M.

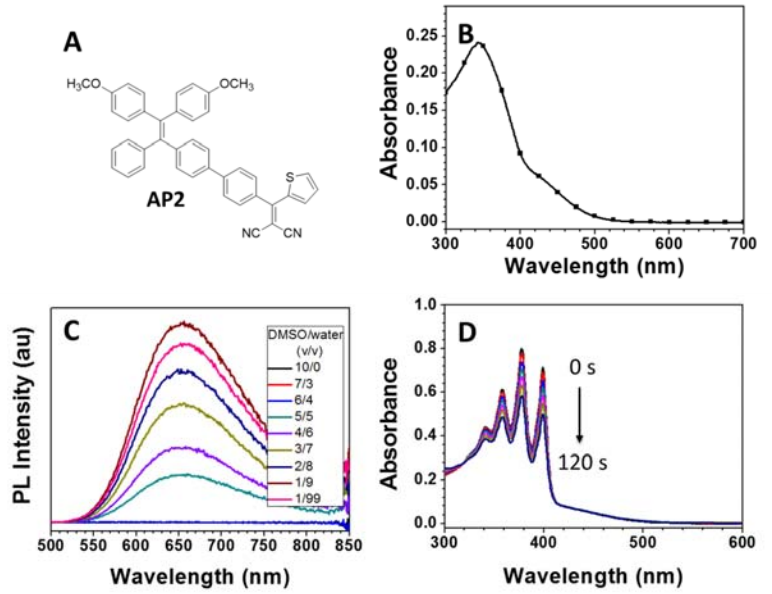


Fig. S7. (A) The chemical structure of AIE PS **AP2**. (B) UV-vis spectrum of **AP2** in DMSO/water = 1/99 (v/v). (C) PL spectra (λ_{ex} = 420 nm) in DMSO and DMSO-water mixtures at differernt volume ratios of AIE PS **AP2**. (D) UV-vis spectra of **ABDA** in the presence of **AP2** NPs under light irradiation (60 mW/cm^2, 400-700 nm) for different time in DMSO/water = 1/99 (v/v). For testing absorption and emission spectra, [**AP2**] = 5×10^{-6} M; for testing $^1O_2$ generation, [**AP2** NPs] = 10 μg/mL based on **AP2** molecule; [**ABDA**] = 5×10^{-5} M.

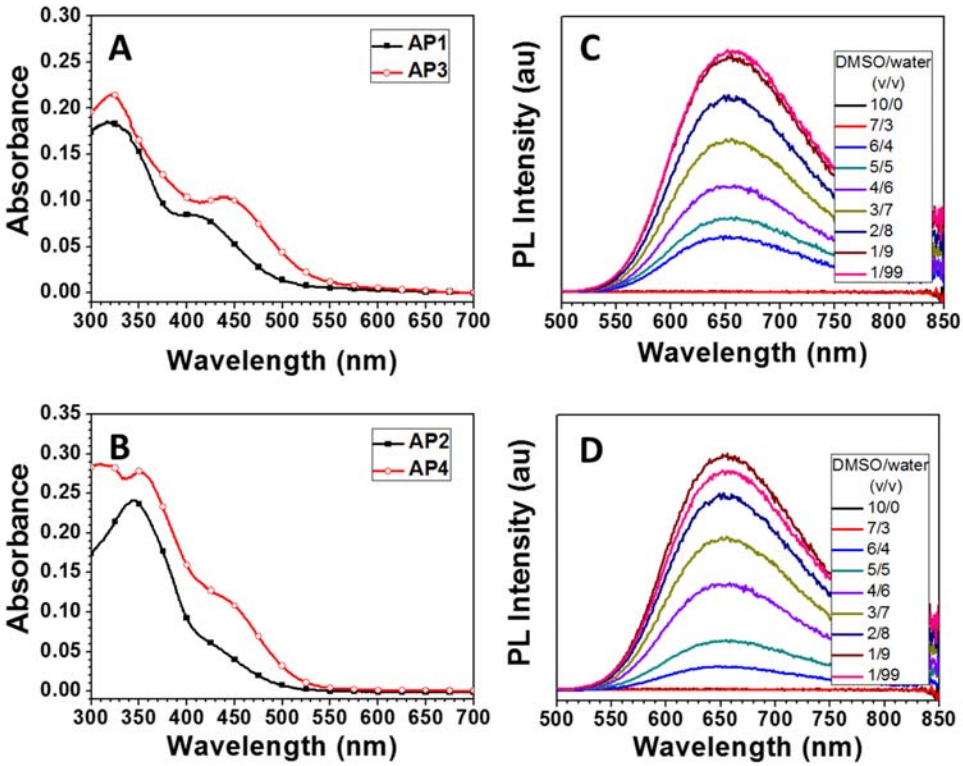


Fig. S8. (A, B) UV-vis spectra of **AP1**, **AP3** (A) and **AP2, AP4** (B) in DMSO/water = 1/99 (v/v). (C, D) PL spectra of **AP3** (C) and **AP4** (D) in DMSO and DMSO-water mixtures at differernt volume ratios (λ_{ex} = 460 nm). [**AP1** or **AP2** or **AP3** or **AP4**] = 5×10^{-6} M.

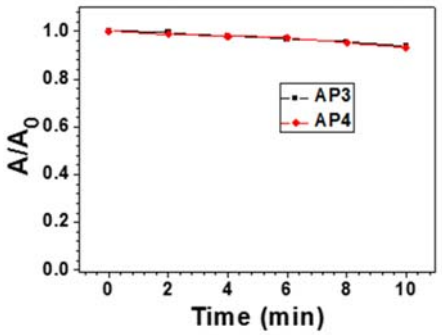


Fig. S9. The degradation rates of **AP3** and **AP4** under light irradiation (60 mW/cm^2, 400-700 nm). A_0 and A are the absorbance of **AP3** or **AP4** at 450 nm before and after light irradiation, respectively. [**AP3** or **AP4**] = 10 μg/mL.

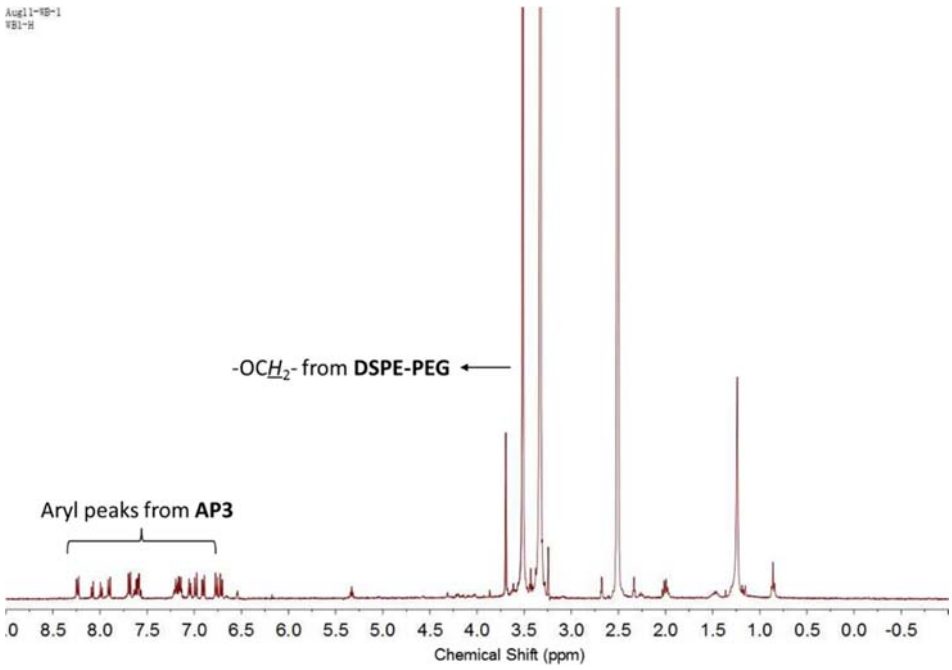


Fig. S10. The ^{1}H NMR spectrum of **AP3** NPs in DMSO-d_6.

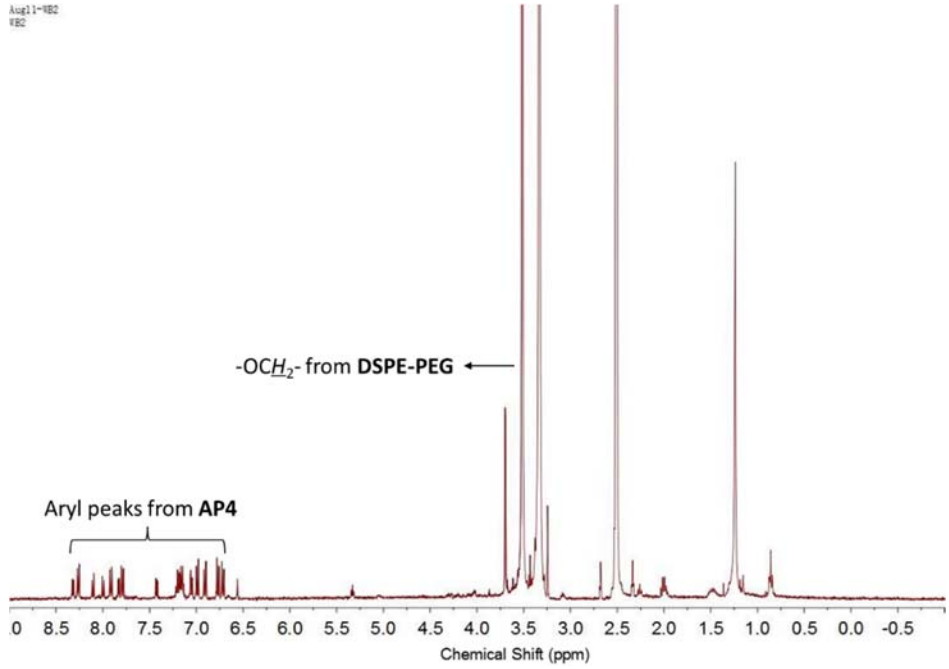


Fig. S11. The ^{1}H NMR spectrum of **AP4** NPs in DMSO-d_6.

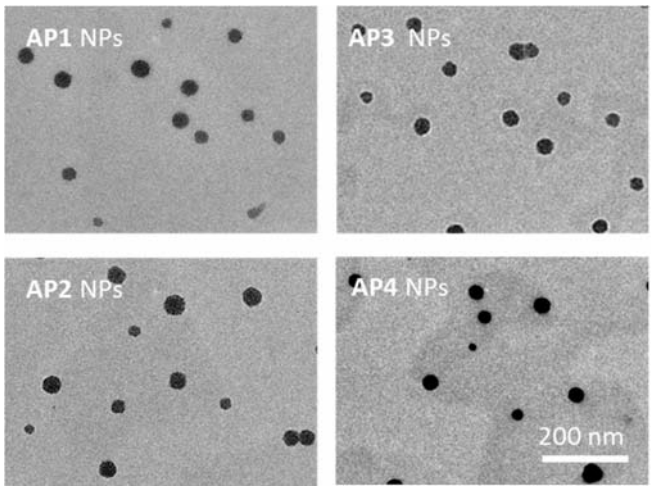


Fig. S12. Transmission electron microscopy (TEM) images of **AP1-AP4** NPs. All the TEM images share the same scale bar of 200 nm.

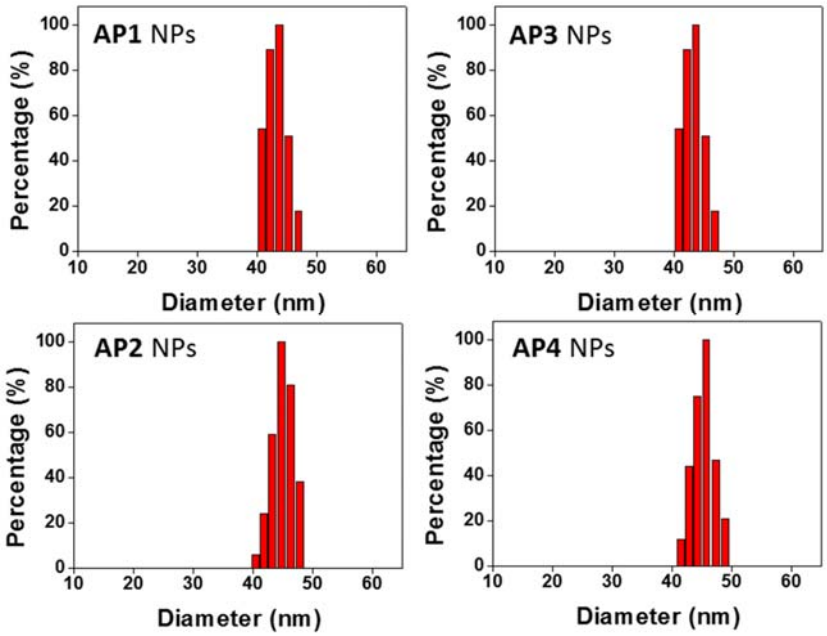


Fig. S13. Dynamic laser scattering (DLS) results of **AP1-AP4** NPs.

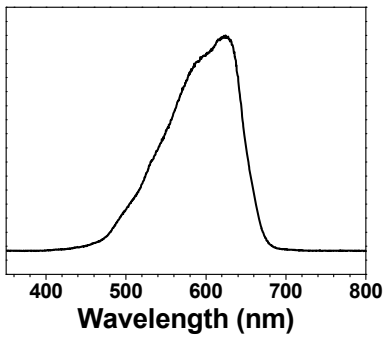


Fig. S14. The emission spectrum of white light source used in this work.

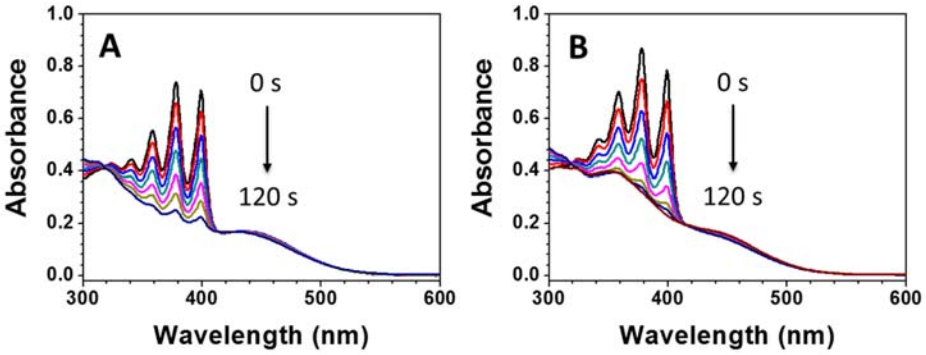


Fig. S15. UV-vis spectra of ABDA in the presence of **AP3** NPs (A) or **AP4** NPs (B) under light irradiation (60 mW/cm^2, 400-700 nm) in water. [**AP3** or **AP4** NPs] = 10 μg/mL based on **AP3** or **AP4** molecule, [**ABDA**] = 5×10^{-5} M.

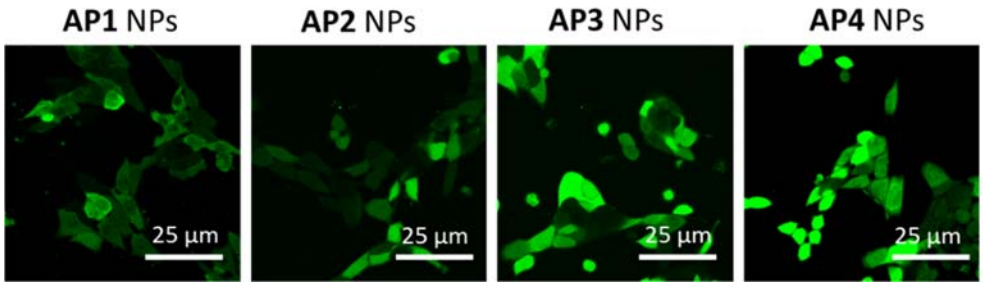


Fig. S16. Detection of $^1O_2$ generation with **AP1-AP4** NPs (5 μg/mL based on molecule) labeled MDA-MB-231 breast cancer cells by dichlorofluorescein diacetate (DCFDA, excitation: 488 nm, collection: 505-525 nm) followed by 2 min light irradiation (60 mW/cm^2, 400-700 nm).

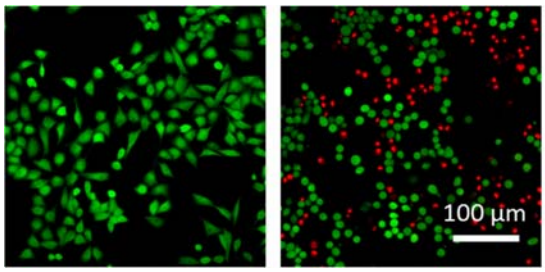


Fig. S17. Live/dead staining of untreated (left) and **Ce6** NPs (5 μg/mL based on **Ce6** molecule, right) treated MDA-MB-231 breast cancer cells after 5 min light irradiation (60 mW/cm^2, 400-700 nm). The live cells were stained by fluorescein diacetate (green, 50 μg/mL for 10 min), while dead cells were stained by propidium iodide (red, 100 μg/mL for 10 min). Both images share the same scale bar of 100 μm.

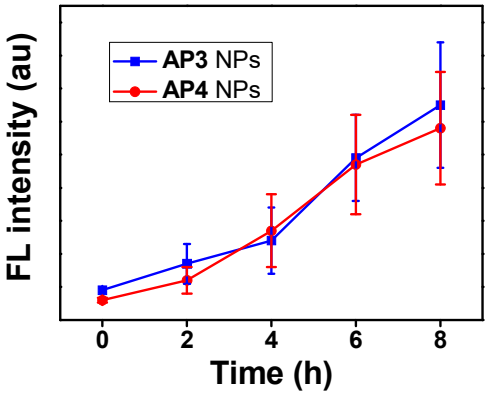


Fig. S18. Average fluorescence intensities for mice tumors over time after the mice were *i.v.* injected with **AP3** NPs and **AP4** NPs, respectively.

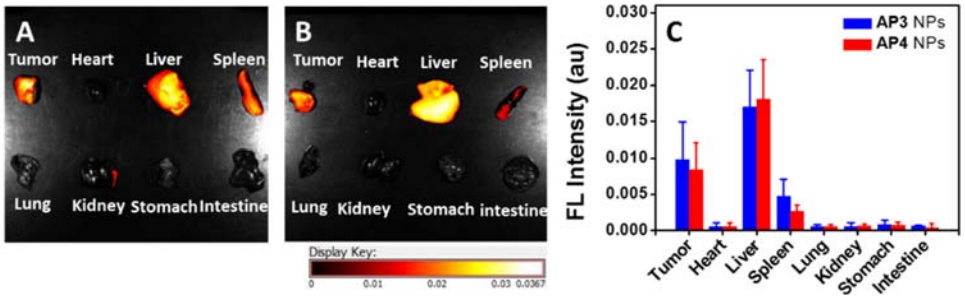


Fig. S19. (A, B) Different mice tissue fluorescence distribution after 8 h post *i.v.* injection of **AP3** (A) and **AP4** (B) NPs to different mice. (C) Fluorescence intensity in various tissues of mice after 8 h post *i.v.* injection with **AP3** and **AP4** NPs.

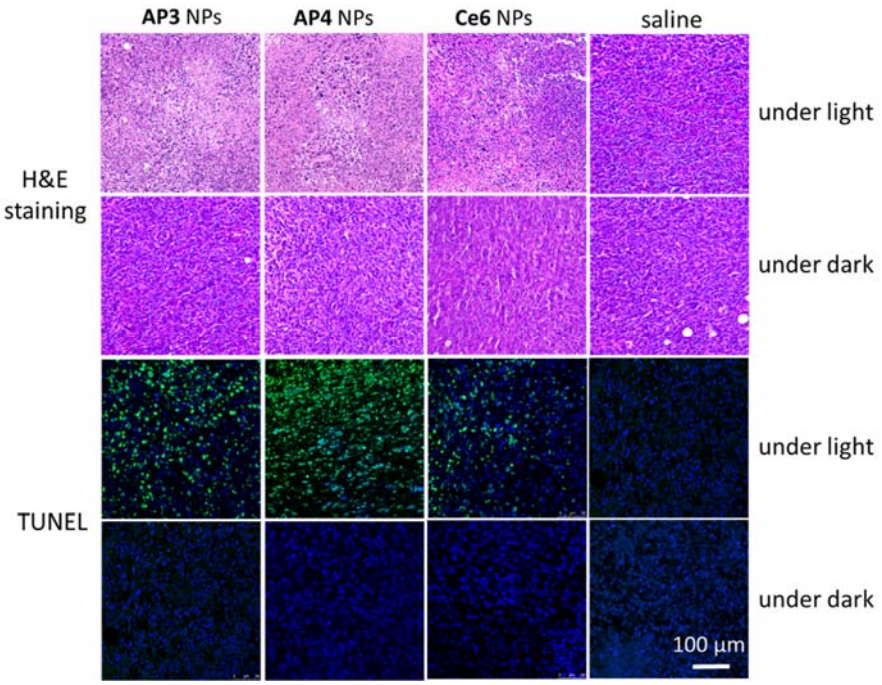


Fig. S20. H&E staining and TUNEL immunostaining for tumor section from mice after 14 days post treatment. The green fluorescence indicates the TUNEL or PCNA signal, and the cell nuclei were stained by DAPI (blue).

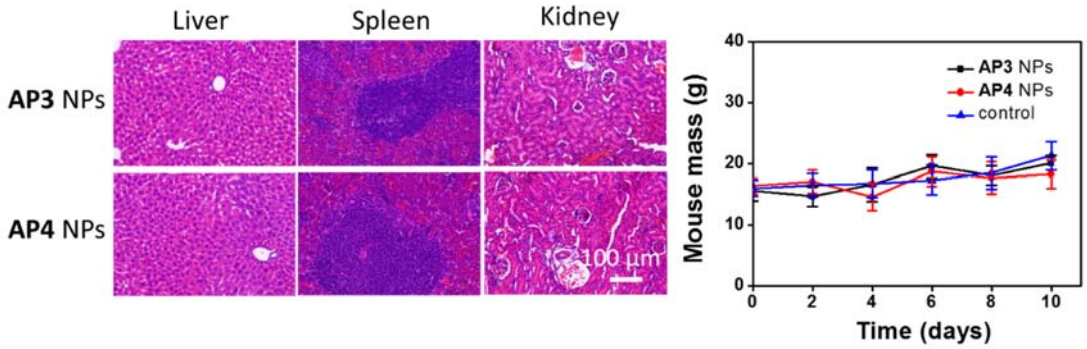


Fig. S21. Typical images of H&E-stained liver, spleen and kidney slices from mice 10 days post different treatments, and body weight changes of mice receiving different treatments (n = 5 mice per group).

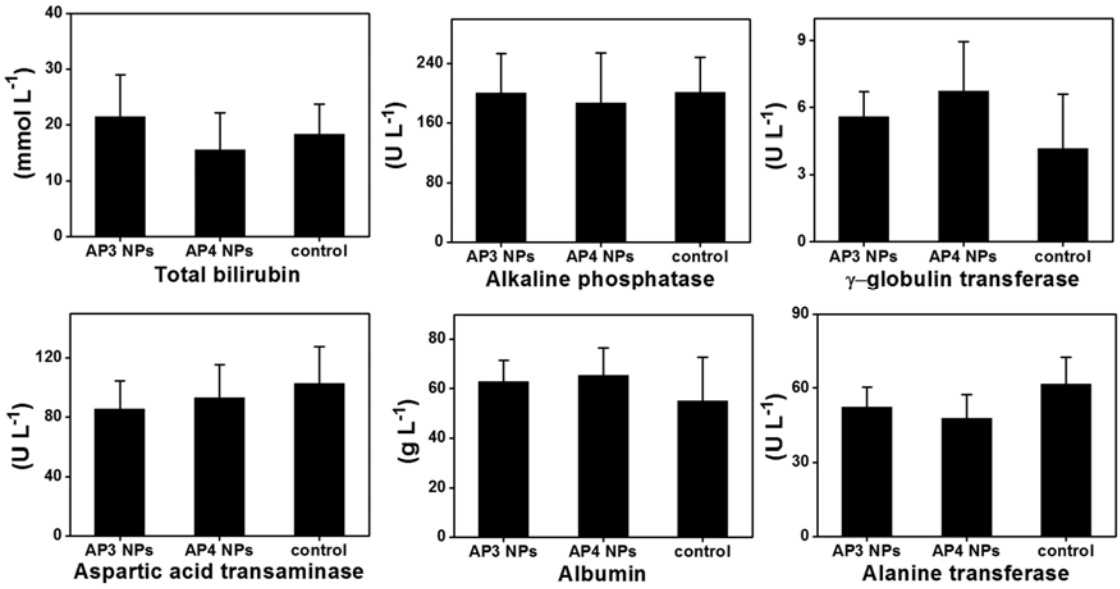


Fig. S22. Blood chemistry data of **AP3** NPs treated mice, **AP4** NPs treated mice and control ones.

Supplementary Experimental Section

Materials and Instrumentation

Compound **4**[S1] and **8**[S2] were prepared by the same procedure, as reported in the literature. All the other materials for organic systhesis were purchased from Sigma-Aldrich. Fetal bovine serum (FBS) and RPMI 1640 medium were purchased from Thermo Fisher Scientific Inc. (Waltham, MA, USA). All antibodies were obtained from Abcam (Cambridge, MA). In Situ Cell Death Detection Kit were purchase from Roche (Applied Science). Tetrahydrofuran (THF) was distilled from sodium benzophenone ketyl under

dry nitrogen immediately prior to use. Ultrapure grade 10×phosphate-buffered saline (PBS) buffer with pH = 7.4 was purchased from 1st BASE Singapore. Milli-Q water was supplied by Milli-Q Plus System (Millipore Corporation, Bedford, USA). All other chemicals and reagents were purchased from Sigma-Aldrich and used as received.

^{1}H and ^{13}C NMR spectra were measured on a Bruker Avance 600 (or 400) spectrometer using tetramethylsilane (TMS; δ = 0 ppm) as internal standard. UV-vis and photoluminescence spectra were recorded using Shimadzu UV-1700 and Perkin-Elmer LS 55 spectrometer, respectively. Hydrodynamic diameter and size distribution were measured by laser light scattering (LLS) with Zetasizer Nano S (Malvern Instruments Ltd, Worcestershire, UK) at room temperature.

Synthesis of compound 5

Compound **4** (130.9 mg, 0.30 mmol), 4-bromobenzophenone (**1**) (86.2 mg, 0.33 mmol), potassium carbonate (414 mg, 3.0 mmol), THF (9 mL)/water (3 mL), and $Pd(PPh_3)_4$ (3 %) were degassed and charged with nitrogen. The reaction mixture was then stirred at 60 ºC for 12 h. After cooling down the reaction mixture to ambient temperature, it was extracted with dichloromethane and washed with water. The dichloromethane layer was separated and dried over $MgSO_4$. After solvent evaporation, the crude product was purified by column chromatography on silica gel using n-hexane/dichloromethane (1/1, v/v) as the eluent to afford **5** as a yellow solid (127.6 mg, 74.3 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) (TMS, ppm): 3.71 (s, 6H, $-OCH_3$), 6.62-6.66 (m, 4H, ArH), 6.95 (d, *J* = 7.8 Hz, 2H, ArH), 6.99 (d, *J* = 7.8 Hz, 2H, ArH), 7.05-7.12 (m, 7H, ArH), 7.40 (d, *J* = 8.4 Hz, 2H, ArH), 7.46 (t, *J* = 7.8 Hz, 2H, ArH), 7.55 (t, *J* = 7.8 Hz, 1H, ArH), 7.64 (t, *J* = 7.8 Hz, 2H, ArH), 7.79 (d, *J* = 8.4 Hz, 2H, ArH), 7.83 (d, *J* = 8.4 Hz, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298K) (ppm): 55.1, 113.0, 113.2, 126.5, 126.6, 128.3, 130.0, 130.7, 132.0, 132.6, 132.7, 136.0, 136.2, 137.1, 137.8, 138.5, 140.8, 144.1, 144.5, 144.8, 196.3.

Synthesis of compound AP1

To the solution of compound **5** (57.2 mg, 0.10 mmol) and malononitrile (19.8 mg, 0.30 mmol) in dichloromethane (10 mL) was added titanium tetrachloride (0.04 mL, 0.35 mmol) slowly at 0 ºC. After the reaction mixture was stirred for 30 min, pyridine (0.03 mL, 0.35 mmol) was injected and stirred for another 30 min. Then the mixture was heated at 40 ºC for 4 h. After the mixture was cooled down to room temperature, the reaction was quenched by water (30 mL) and the mixture was extracted with dichloromethane. The collected organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The desired residue was purified by column chromatography using n-hexane/dichloromethane (1/1 ~ 1/2, v/v) as eluent to give the desired product **AP1** as a red solid (58.2 mg, 93.7 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) (TMS, ppm): 3.73 (s, 6H, -OCH_3), 6.62-6.66 (m, 4H, ArH), 6.94-6.98 (m, 4H, ArH), 7.05-7.15 (m, 7H, ArH), 7.39 (d, *J* = 7.8 Hz, 2H, ArH), 7.44-7.50 (m, 6H, ArH), 7.58 (t, *J* = 7.8 Hz, 1H, ArH), 7.65 (t, *J* = 8.4 Hz, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298K) (ppm): 55.1, 80.7, 109.1, 113.0, 113.2, 126.4, 127.0, 127.8, 128.9, 130.5, 131.1, 131.4, 132.1, 132.6, 136.1, 158.2, 158.3, 174.7.

Synthesis of compound 9

Compound **4** (87.3 mg, 0.20 mmol), compound **8** (53.4 mg, 0.22 mmol), potassium carbonate (276 mg, 2.0 mmol)), THF (6 mL)/water (2 mL), and $Pd(PPh_3)_4$ (3 %) were degassed and charged with nitrogen. The reaction mixture was then stirred at 60 ºC for 12 h. After cooling down the reaction mixture to ambient temperature, it was extracted with dichloromethane and washed with water. The dichloromethane layer was separated and dried over $MgSO_4$. After solvent evaporation, the crude product was purified by column chromatography on silica gel using n-hexane/dichloromethane (1/1, v/v) as the eluent to afford **9** as a yellow solid (107.2 mg, 92.7 % yield). ^{1}H NMR (400 MHz, $CDCl_3$, 298K) (TMS, ppm): 3.73 (s, 6H, -

OCH_3), 6.64 (t, *J* = 8.5 Hz, 4H, ArH), 6.95 (m, 4H, ArH), 7.08 (m, 7H, ArH), 7.22 (d, *J* = 4.8 Hz, 1H, ArH), 7.39 (d, *J* = 8.3 Hz, 2H, ArH), 7.49 (d, *J* = 8.3 Hz, 2H, ArH), 7.68 (d, *J* = 8.8 Hz, 2H, ArH), 7.80 (dd, *J* = 7.7, 4.1 Hz, 2H, ArH). ^{13}C NMR (100 MHz, $CDCl_3$, 298K) (ppm): 55.1, 110.0, 113.0, 113.2, 126.3, 126.4, 126.9, 127.8, 128.9, 130.3, 131.4, 132.1, 132.6, 135.9, 136.2, 136.3, 138.7, 144.1, 144.8, 158.2, 158.3, 164.8

Synthesis of compound AP2

To the solution of compound **9** (57.9 mg, 0.10 mmol) and malononitrile (19.8 mg, 0.30 mmol) in dichloromethane (10 mL) was added titanium tetrachloride (0.04 mL, 0.35 mmol) slowly at 0 ºC. After the reaction mixture was stirred for 30 min, pyridine (0.03 mL, 0.35 mmol) was injected and stirred for another 30 min. Then the mixture was heated at 40 ºC for 4 h. After the mixture was cooled down to room temperature, the reaction was quenched by water (30 mL) and the mixture was extracted with dichloromethane. The collected organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The desired residue was purified by column chromatography using n-hexane/dichloromethane (1/1 ~ 1/2, v/v) as eluent to give the desired product **AP2** as a red solid (48.2 mg, 80.0 % yield). ^{1}H NMR (400 MHz, $CDCl_3$, 298K) (TMS, ppm): 3.73 (s, 6H, -OCH_3), 6.64 (t, *J* = 8.5 Hz, 4H, ArH), 6.95 (dd, *J* = 12.3, 8.7 Hz, 4H, ArH), 7.05 (d, *J* = 7.6 Hz, 2H, ArH), 7.11 (m, 5H, ArH), 7.22 (m, 1H, ArH), 7.40 (d, *J* = 8.3 Hz, 2H, ArH), 7.49 (d, *J* = 8.3 Hz, 2H, ArH), 7.68 (d, *J* = 8.3 Hz, 2H, ArH), 7.80 (dd, *J* = 6.8, 4.5 Hz, 2H, ArH). ^{13}C NMR (100 MHz, $CDCl_3$, 298K) (ppm): 55.1, 113.1, 113.2, 114.0, 114.5, 126.3, 126.4, 126.9, 127.8, 128.9, 130.3, 131.4, 132.1, 132.6, 134.6, 135.9, 136.2, 136.4, 138.5, 138.7, 140.9, 144.1, 144.5, 144.8, 158.2, 158.3, 166.8.

Synthesis of compound 11

Compound **4** (349.1 mg, 0.80 mmol), 4,7-dibromobenzothiadiazole (**10**) (470.4 mg, 1.60 mmol), potassium carbonate (1.10 g, 8.0 mmol), THF(24 mL)/water (8 mL), and $Pd(PPh_3)_4$ (3 %) was carefully degassed and charged with nitrogen. The reaction mixture was then stirred at 60 ºC for 12 h. After cooling down the reaction mixture to ambient temperature, it was extracted with DCM and washed with water. The DCM layer was separated and dried over $MgSO_4$. After evaporation of the solvent, the crude product was purified by column chromatography on silica gel by using n-hexane/DCM (1/1 ~ 1/2, v/v) as the eluent to afford an orange solid **11** (411.0 mg, 84.8 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) δ(TMS, ppm): 3.74 (s, 6H, -OCH_3), 6.63-6.68 (m, 4H, ArH), 6.95 (d, J = 8.4 Hz, 2H, ArH), 7.01 (d, J = 7.8 Hz, 2H, ArH), 7.09-7.19 (m, 7H, ArH), 7.55 (t, J = 7.8 Hz, 1H, ArH), 7.70 (d, J = 8.4 Hz, 1H, ArH), 7.88 (d, J = 7.8 Hz, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298K) δ (ppm): 55.1, 112.7, 113.0, 113.2, 126.2, 127.8, 127.9, 128.4, 131.5, 131.7, 132.2, 132.6, 132.7, 136.2, 138.6, 140.9, 144.1, 144.9, 153.0, 153.9, 158.1, 158.3.

Synthesis of compound 12

Compound **1** (1.04 g, 5.0 mmol), bis(pinacolato)diborane (2.53 g, 10.0 mmol), potassium acetate (1.72 g, 17.5 mmol), $Pd(dppf)Cl_2$ (5 %, dppf = 1,1'-bis (diphenylphosphanyl)ferrocene) and dioxane (20 mL) were mixed together in a 250 mL flask. After degassing, the reaction mixture was kept at 85 ºC for 2 days, and then cooled to room temperature. The organic solvent was distilled out, and the residual solid was dissolved in dichloromethane and washed with water. After removal of the solvents, the crude product was purified on a silica gel column using n-hexane/ethyl acetate (10/1, v/v) as the eluent to afford a white solid **12** (1.42 g, 92.2 % yield). ^{1}H NMR (400 MHz, $CDCl_3$, 298 K), δ(TMS, ppm): 1.37 (s, 12H, -CH_3), 7.48 (t, J = 7.8 Hz, 2H, ArH), 7.59 (t, J = 7.8 Hz, 1H, ArH), 7.76-7.81 (m, 4H, ArH), 7.92 (d, J = 8.6 Hz,

2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298 K), δ (ppm): 25.0, 83.4, 84.1, 128.3, 128.9, 130.1, 132.5, 134.5, 137.5, 139.7, 196.7.

Synthesis of compound 13

Compound **11** (121.1 mg, 0.20 mmol), compound **12** (92.5 mg, 0.30 mmol), potassium carbonate (276.4 mg, 2.0 mmol), THF(6 mL)/water (2 mL), and $Pd(PPh_3)_4$ (3 %) was carefully degassed and charged with nitrogen. The reaction mixture was then stirred at 60 ºC for 12 h. After cooling down the reaction mixture to ambient temperature, it was extracted with DCM and washed with water. The DCM layer was separated and dried over $MgSO_4$. After evaporation of the solvent, the crude product was purified by column chromatography on silica gel by using n-hexane/DCM (1/2, v/v) as the eluent to afford an orange solid **13** (135.6 mg, 95.9 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) δ(TMS, ppm): 3.75 (s, 6H, -OCH_3), 6.64-6.69 (m, 4H, ArH), 6.97 (d, J = 7.8 Hz, 2H, ArH), 7.03 (d, J = 7.8 Hz, 2H, ArH), 7.09-7.21 (m, 7H, ArH), 7.52 (t, J = 7.8 Hz, 2H, ArH), 7.61 (t, J = 7.8 Hz, 1H, ArH), 7.79-7.89 (m, 6H, ArH), 7.90 (d, J = 7.2 Hz, 2H, ArH), 8.10 (d, J = 7.2 Hz, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298K) δ (ppm): 55.1, 113.1, 113.2, 126.3, 127.7, 127.8, 128.3, 128.5, 128.7, 129.1, 130.1, 130.4, 131.6, 131.7, 132.5, 132.6, 132.7, 133.7, 134.6, 136.3, 137.0, 137.6, 138.7, 140.9, 141.4, 144.2, 144.8, 153.9, 158.2, 158.3, 196.1.

Synthesis of compound AP3

To the solution of compound **13** (70.6 mg, 0.10 mmol) and malononitrile (19.8 mg, 0.30 mmol) in dichloromethane (10 mL) was added titanium tetrachloride (0.04 mL, 0.35 mmol) slowly at 0 ºC. After the reaction mixture was stirred for 30 min, pyridine (0.03 mL, 0.35 mmol) was injected and stirred for another 30 min. Then the mixture was heated at 40 ºC for 4 h. After the mixture was cooled down to room temperature, the reaction was quenched by water (30 mL) and the mixture was extracted with dichloromethane. The collected organic layer was washed by brine, dried over $MgSO_4$ and concentrated

under reduced pressure. The desired residue was purified by column chromatography using n-hexane/dichloromethane (1/2 ~ 1/5, v/v) as eluent to give the desired product **AP3** as a red solid (59.9 mg, 79.4 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) δ(TMS, ppm): 3.73 (s, 6H, -OCH_3), 6.63-6.69 (m, 4H, ArH), 6.96 (d, J = 8.4 Hz, 2H, ArH), 7.03 (d, J = 8.4 Hz, 2H, ArH), 7.09-7.15 (m, 5H, ArH), 7.20 (d, J = 8.4 Hz, 2H, ArH), 7.48-7.52 (m, 4H, ArH), 7.58-7.62 (m, 3H, ArH), 7.70-7.83 (m, 4H, ArH), 8.11 (d, J = 8.4 Hz, 2H, ArH). ^{13}C NMR (600 MHz, $CDCl_3$, 298K) δ(ppm): 55.1, 81.5, 113.1, 113.2, 114.0, 126.0, 127.6, 127.8, 128.5, 128.9, 129.4, 130.4, 130.5, 130.8, 130.9, 131.3, 131.5, 131.7, 132.6, 132.7, 132.9, 134.2, 134.5, 135.5, 136.0, 136.3, 138.6, 140.9, 141.8, 144.1, 144.9, 153.7, 153.9, 158.2, 158.3, 174.3.

Synthesis of compound 14

Compound **9** (1.33 g, 5.0 mmol), bis(pinacolato)diborane (2.53 g, 10.0 mmol), potassium acetate (1.72 g, 17.5 mmol), Pd(dppf)Cl_2 (5 %) and dioxane (20 mL) were mixed together in a 250 mL flask. After degassing, the reaction mixture was kept at 85 ^{o}C for 2 days, and then cooled to room temperature. The organic solvent was distilled out, and the residual solid was dissolved in dichloromethane and washed with water. After removal of the solvents, the crude product was purified on a silica gel column using n-hexane/ethyl acetate (10/1, v/v) as the eluent to afford a white solid **14** (1.48 g, 94.3 % yield). ^{1}H NMR (400 MHz, $CDCl_3$, 298 K), δ(TMS, ppm): 1.37 (s, 12H, -CH_3), 7.16 (s, br, 1H, ArH), 7.62 (s, br, 1H, ArH), 7.72 (s, br, 1H, ArH), 7.84 (s, br, 2H, ArH), 7.93 (s, br, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298 K), δ(ppm): 25.0, 83.4, 84.1, 128.0, 128.1, 134.3, 134.7, 134.9, 140.3, 143.2, 188.1

Synthesis of compound 15

Compound **11** (121.1 mg, 0.20 mmol), compound **14** (94.3 mg, 0.30 mmol), potassium carbonate (276.4 mg, 2.0 mmol), THF(6 mL)/water (2 mL), and Pd(PPh_3)$_4$ (3 %) was carefully degassed and charged with nitrogen. The reaction mixture was then stirred at 60 ^{o}C for 12 h. After cooling down the reaction

mixture to ambient temperature, it was extracted with DCM and washed with water. The DCM layer was separated and dried over $MgSO_4$. After evaporation of the solvent, the crude product was purified by column chromatography on silica gel by using n-hexane/DCM (1/2, v/v) as the eluent to afford an orange solid **15** (113.2 mg, 79.4 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) δ(TMS, ppm): 3.70 (s, 6H, -OCH_3), 6.63-6.68 (m, 4H, ArH), 6.96 (d, J = 8.4 Hz, 2H, ArH), 7.04 (d, J = 7.8 Hz, 2H, ArH), 7.09-7.21 (m, 11H, ArH), 7.68-7.82 (m, 6H, ArH), 7.96 (d, J = 7.8 Hz, 1H, ArH), 8.01 (d, J = 7.8 Hz, 2H, ArH), 8.10 (d, J = 8.4 Hz, 2H, ArH). ^{13}C NMR (150 MHz, $CDCl_3$, 298K) δ(ppm): 55.1, 113.1, 113.2, 126.3, 127.3, 127.7, 127.8, 128.1, 128.2, 128.5, 128.7, 129.0, 129.2, 129.5, 129.9, 131.5, 131.7, 132.7, 133.8, 134.3, 134.6, 134.8, 136.3, 137.5, 138.7, 140.9, 141.2, 143.6, 144.2, 144.8, 153.8, 153.9, 158.2, 158.3, 187.6. HRMS (ESI), calcd for ($C_{50}H_{34}N_4O_2S$): m/z $[M+Na]^+$: 777.2295; found: m/z 777.2292.

Synthesis of compound AP4

To the solution of compound **15** (71.2 mg, 0.10 mmol) and malononitrile (19.8 mg, 0.30 mmol) in dichloromethane (10 mL) was added titanium tetrachloride (0.04 mL, 0.35 mmol) slowly at 0 ^{o}C. After the reaction mixture was stirred for 30 min, pyridine (0.03 mL, 0.35 mmol) was injected and stirred for another 30 min. Then the mixture was heated at 40 ^{o}C for 4 h. After the mixture was cooled down to room temperature, the reaction was quenched by water (30 mL) and the mixture was extracted with dichloromethane. The collected organic layer was washed by brine, dried over $MgSO_4$ and concentrated under reduced pressure. The desired residue was purified by column chromatography using n-hexane/dichloromethane (1/2 ~ 1/5, v/v) as eluent to give the desired product **AP4** as a red solid (67.3 mg, 88.4 % yield). ^{1}H NMR (600 MHz, $CDCl_3$, 298K) δ(TMS, ppm): 3.76 (s, 6H, -OCH_3), 6.67-6.72 (m, 4H, ArH), 6.99 (d, J = 8.4 Hz, 2H, ArH), 7.06 (d, J = 8.4 Hz, 2H, ArH), 7.11-7.18 (m, 5H, ArH), 7.23 (d, J = 7.8 Hz, 2H, ArH), 7.28 (m, 1H, ArH), 7.66 (d, J = 7.8 Hz, 2H, ArH), 7.82-7.88 (m, 6H, ArH), 8.18 (d, J

= 8.4 Hz, 2H, ArH). ^{13}C NMR (600 MHz, $CDCl_3$, 298K) δ(ppm): 55.3, 78.1, 113.3, 113.5, 114.2, 114.7, 126.5, 127.9, 128.1, 128.8, 129.1, 129.2, 129.6, 130.3, 131.7, 132.0, 132.8, 132.9, 134.3, 134.7, 135.8, 136.4, 136.5, 137.1, 138.8, 138.9, 141.1, 141.3, 144.4, 145.1, 154.0, 154.2, 158.4, 158.5, 164.9. HRMS (ESI), calcd for ($C_{48}H_{32}N_4O_2S_2$): m/z $[M+Na]^+$: 783.1859; found: m/z 783.1872.

Synthesis of AIE PS NPs

The THF mixture containing 1 mg of **AP1** and 2 mg of **DSPE-PEG$_{2000}$** was poured into water with 10-fold dilution. The THF/water mixture was then sonicated for 2 min using a microtip ultrasound sonicator at 12 W output (XL2000, Misonix Incorporated, NY). After THF evaporation by stirring the obtained suspension in fume hood overnight, the **AP1** NPs was obtained by filtration through a 0.2 μm syringe driven filter. After centrifugation using a centrifugal filter with molecular cut-off of 100,000 KDa, **AP1** NPs (10 mL, 0.1 mg/mL based on AP1) was collected for further study.

AP2-AP4 NPs and **Ce6** NPs were prepared by the same procedure.

Cell culture

MBA-MD-231 human breast cancer cells were cultured in RPMI-1640 medium (GIBCO) supplemented with 10% FBS (GIBCO) and PS (10 U/mL penicillin and 10 mg/mL streptomycin). The cells were maintained in an atmosphere of 5% CO_2 and 95% humidified air at 37 °C.

Cell imaging

MBA-MD-231 cells were seeded and cultured in glass bottom dish for 12 h. **AP1-AP4** NPs were added into medium and incubated with cancer cells for 12h, respectively. The fluorescence signal of **AP1-AP4** NPs within MBA-MD-231 cells were captured by confocal laser scanning microscopy (CLSM, Leica TSC SP8, Germany) with excitation at 405 nm and signal collection from 600 nm to 750 nm.

Cell viability test

MBA-MD-231 cells were seeded in 96 well plates at density of 3000 cells in 200 μL per well for 12 h. **AP1-AP4** NPs at different concentration were added into the cell culture medium separately. Cells were further incubated with different NPs for 12 h, followed by white light irradiation for 5 min. After light treatment, MTT (40 μL, 1 mg/mL) was added into medium for 3 h. The media was removed, and DMSO (100 μL) was added into each well and gently shaken for 10 min at room temperature. The absorbance of MTT at 550 nm was measured by using a SpectraMax M5 Microplate Reader. Cell viability was measured by the ratio of the absorbance of the cells incubated with different nanoparticles to that of the cells incubated with normal culture medium.

***In vitro* cell apoptosis imaging**

The MBA-MD-231 cells were seeded in 8-well chamber. After reaching 80% confluence, **AP1-AP4** NPs were added into the cell culture medium (final concentration, 5 μg/mL based on PS), respectively. After 6 h incubation, the cells were washed and replaced with fresh culture medium. Cells were treated upon light irradiation for 5 min. After light treatment, the cells were then incubated with FDA (50 μg/mL) and PI (100 μg/mL) for 10 min. After washing, the cells were imaged by CLSM.

Breast cancer mouse model

All animal studies were performed in compliance with the guidelines set by Tianjin Committee of Use and Care of Laboratory Animals and the overall project protocols were approved by the Animal Ethics Committee of Nankai University. 6-week-old nude mice (obtained from the Laboratory Animal Center of the Academy of Military Medical Sciences (Beijing, China)) were used to establish breast cancer mouse model. MBA-MD-231 cancer cells (1×106) suspended in 30 μL of saline were injected subcutaneously into the right shoulder of the mouse. Tumors were grown until a single aspect was ~7 mm (approximately two weeks) before used for fluorescence imaging and PDT.

In vivo fluorescence imaging

The Maestro EX fluorescence imaging system (Caliper Life Sciences, Hopkinton, MA) was utilized to image mouse. Nude mice bearing MBA-MD-231 tumors were intravenously injected with **AP3** or **AP4** NPs (30 μL, 1 mg/mL based on PS) (n = 5 per group) and fluorescence signals were captured immediately after NPs administration. Nuance software was used to remove the mouse background fluorescence. At 8h after nanoparticles injection, mice in different groups were sacrificed. Different tissues were collected, imaged and semi-quantified by the Maestro system.

In vivo PDT

Nude mice bearing MBA-MD-231 tumors were exposed to white light for 10 min (0.3 W/cm^2), after intravenous injection of saline (30 μL), **AP3** NPs and **AP4** NPs (100 μL, 1 mg/mL, based on PS) at postinjection time of 30 min (n = 5 per group). The tumor size was measured every other day and calculated as follows: volume = (tumor length) × (tumor width)^2/2.

Histological analysis

At day 14 after PDT, the mice in different groups were sacrificed and tumor tissues were collected and fixed in 4% paraformaldehyde, which were then embedded into paraffin, sliced at thickness of 5 μm. Slices were stained with hematoxylin and eosin (H&E) and imaged by optical microscopy and assessed by 3 independent pathologists. For the apoptosis staining, the tumor sections were stained following manual instruction of In Situ Cell Death Detection Kit (Roche Applied Science) and imaged by CLSM (Leica TSC SP8, Germany).

Statistical Analysis

Quantitative data were expressed as mean standard deviation. ANOVA analysis and Student's t test were utilized for statistical contrast. $P < 0.05$ was Fig.d statistically significant.

***In vivo* toxicity study**

Healthy male BALB/c mice (8 weeks old) were used to evaluate the in vivo toxicity of **AP3** NPs and **AP4** NPs. Mice were divided into 2 groups and each group had 5 mice. On day 0, the mice in one group were intravenously injected with 0.1 mL of 50 nM **AP3** NPs or **AP4** NPs, respectively. The body weights of all the mice were monitored every two days. On day 10, all the mice in two groups were sacrificed and the blood sample was collected for blood chemistry analyses by Tianjin Medical University Cancer Institute and Hospital. Moreover, the organs of mice including liver, spleen and kidney were collected for further histological analysis. The organs were fixed in 4% paraformaldehyde, which were then processed into paraffin, sliced at thickness of 6 μm. Slices were stained with hematoxylin and eosin (H&E) and imaged by optical microscopy and assessed by 3 independent pathologists.

References

[S1] G. Feng, W. Wu, S. Xu and B. Liu, *ACS Appl. Mater. Interfaces* **2016**, *8*, 21193.

[S2] P. Ortiz, A. M. del Hoyo and S. R. Harutyunyan, *Eur. J. Org. Chem.* **2015**, 72.

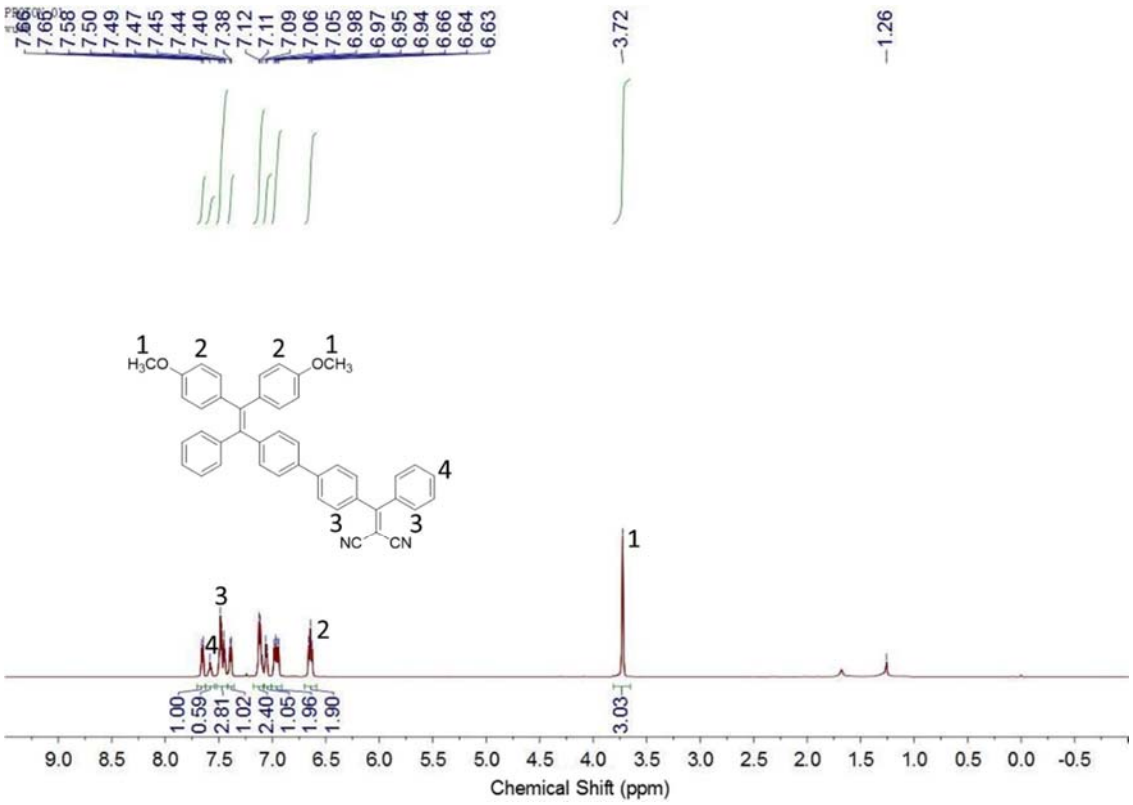


Fig. S23. ^{1}H NMR spectrum of **AP1** in chloroform-*d*.

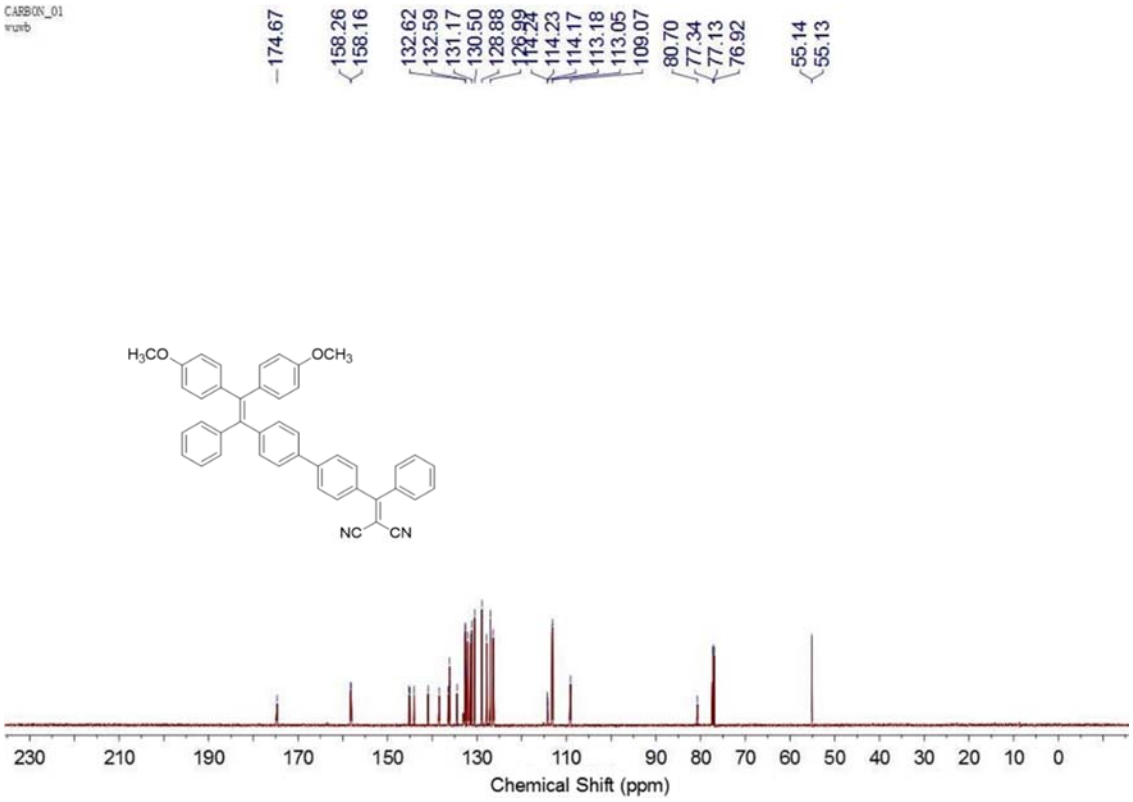


Fig. S24. ^{13}C NMR spectrum of **AP1** in chloroform-*d*.

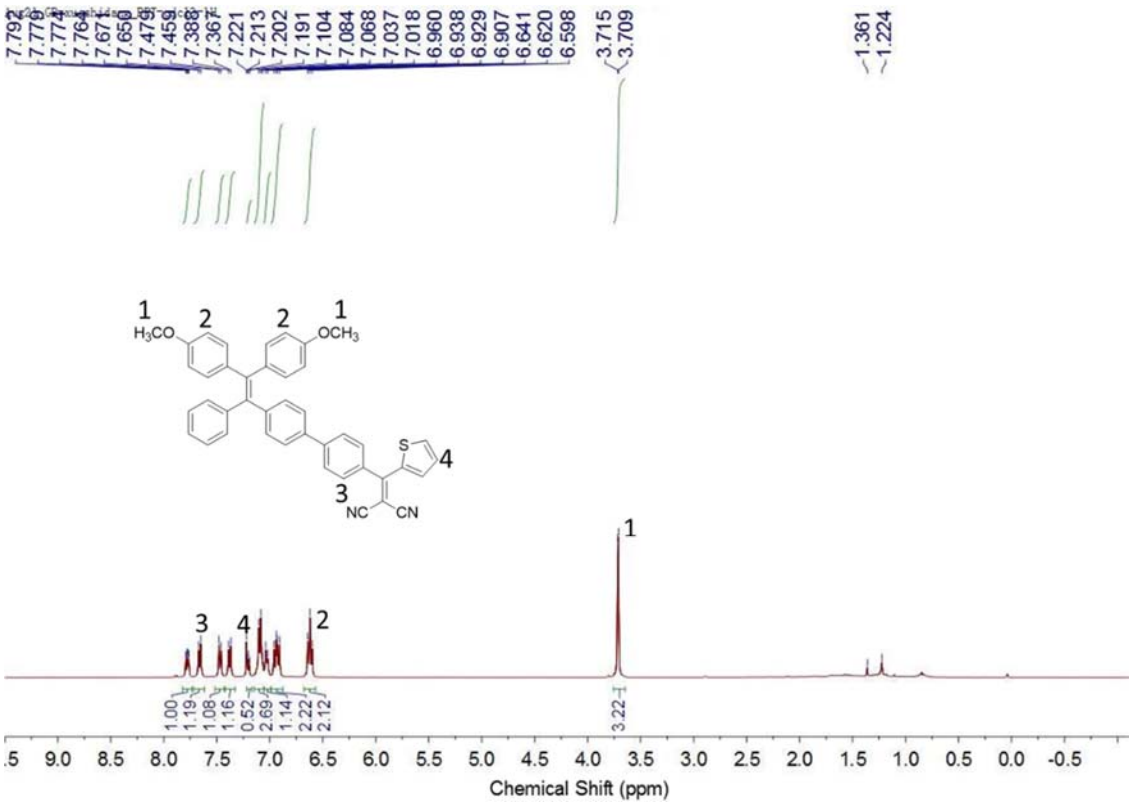


Fig. S25. ^{1}H NMR spectrum of **AP2** in chloroform-*d*.

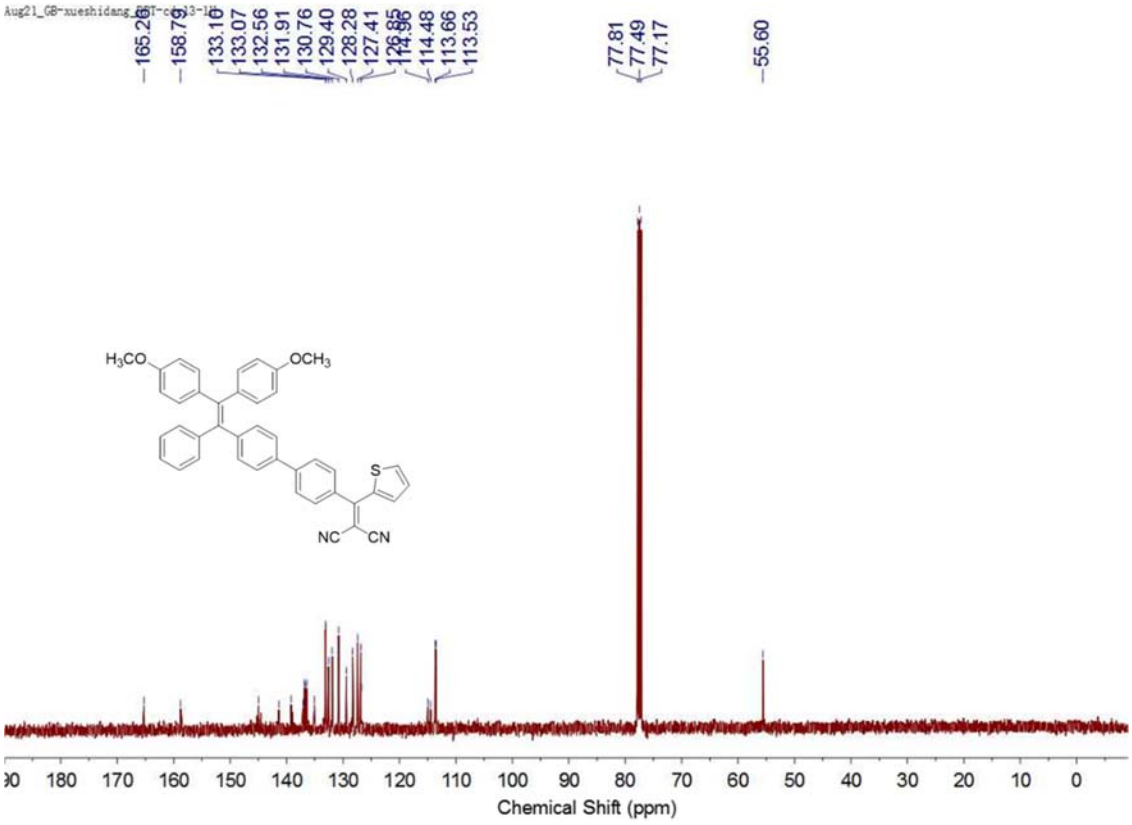


Fig. S26. ^{13}C NMR spectrum of **AP2** in chloroform-*d*.

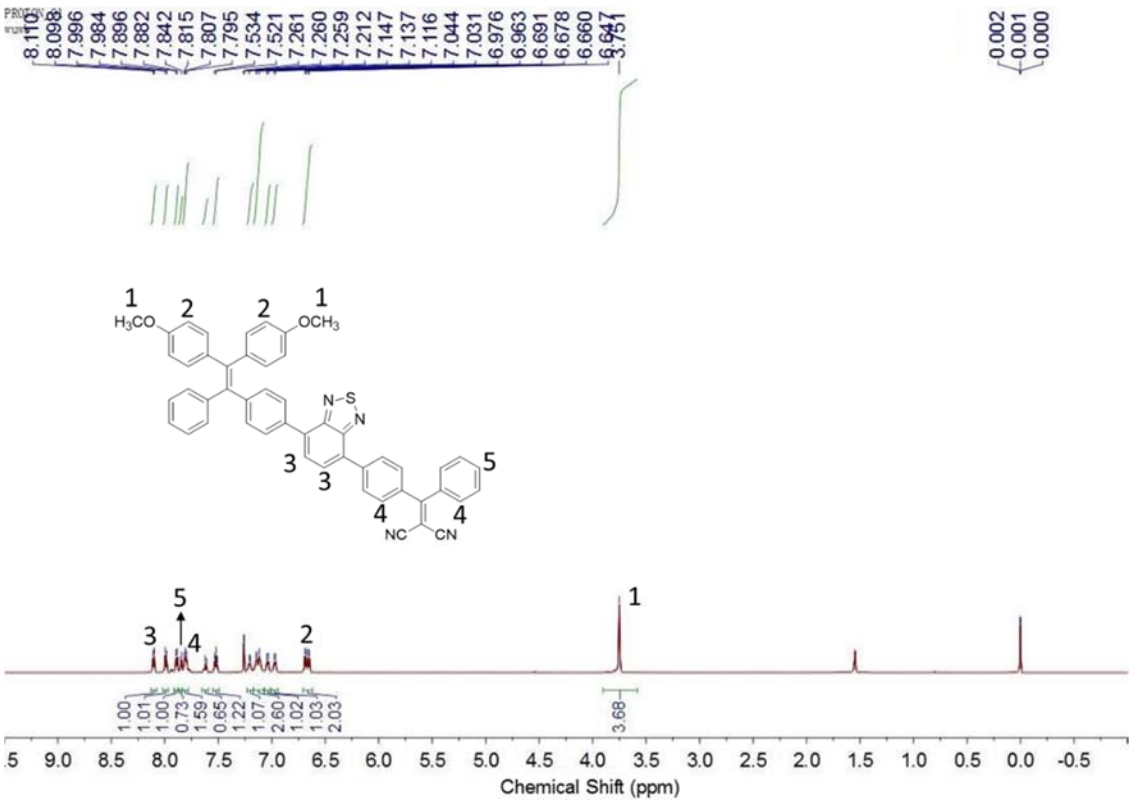


Fig. S27. ^{1}H NMR spectrum of **AP3** in chloroform-*d*.

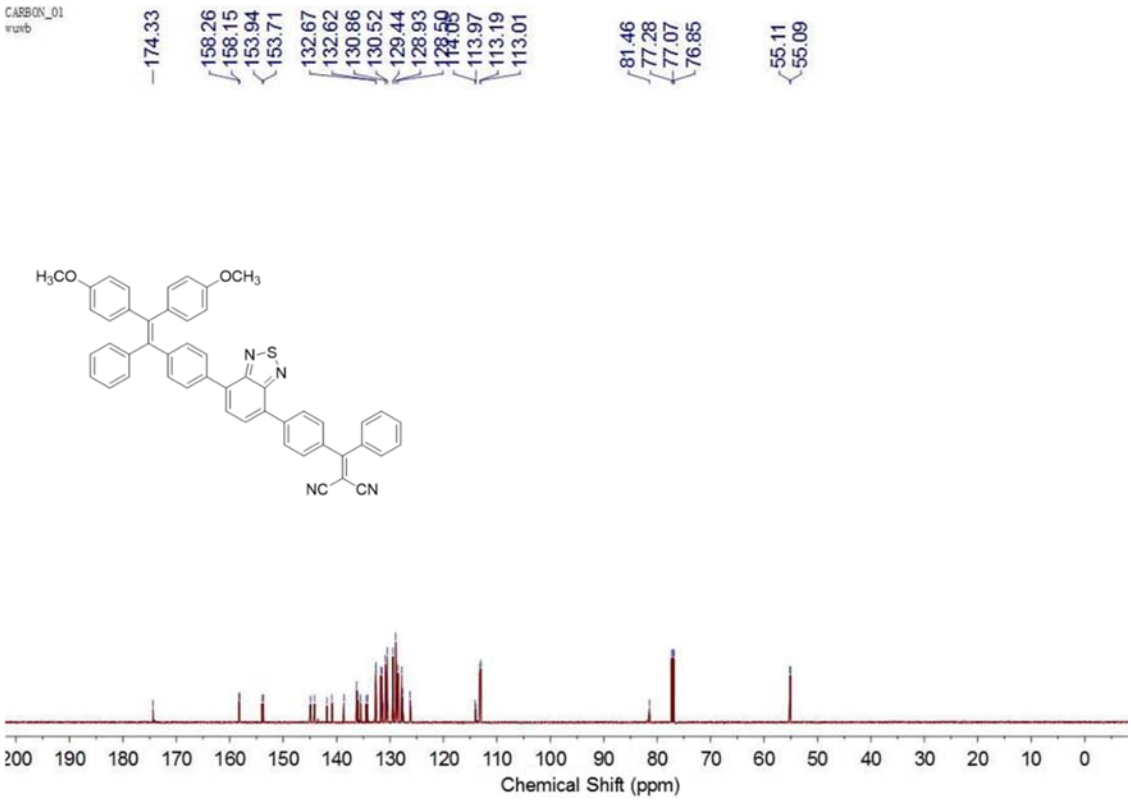


Fig. S28. ^{13}C NMR spectrum of **AP3** in chloroform-*d*.

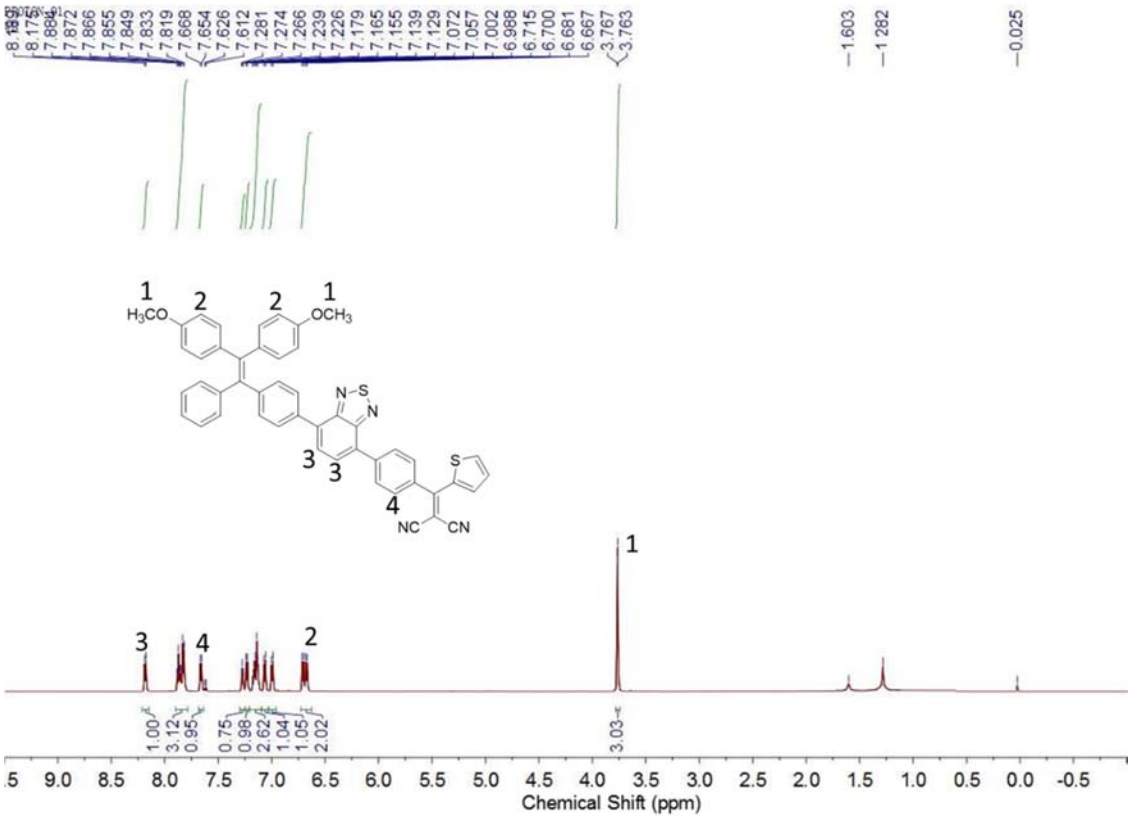


Fig. S29. ^{1}H NMR spectrum of **AP4** in chloroform-*d*.

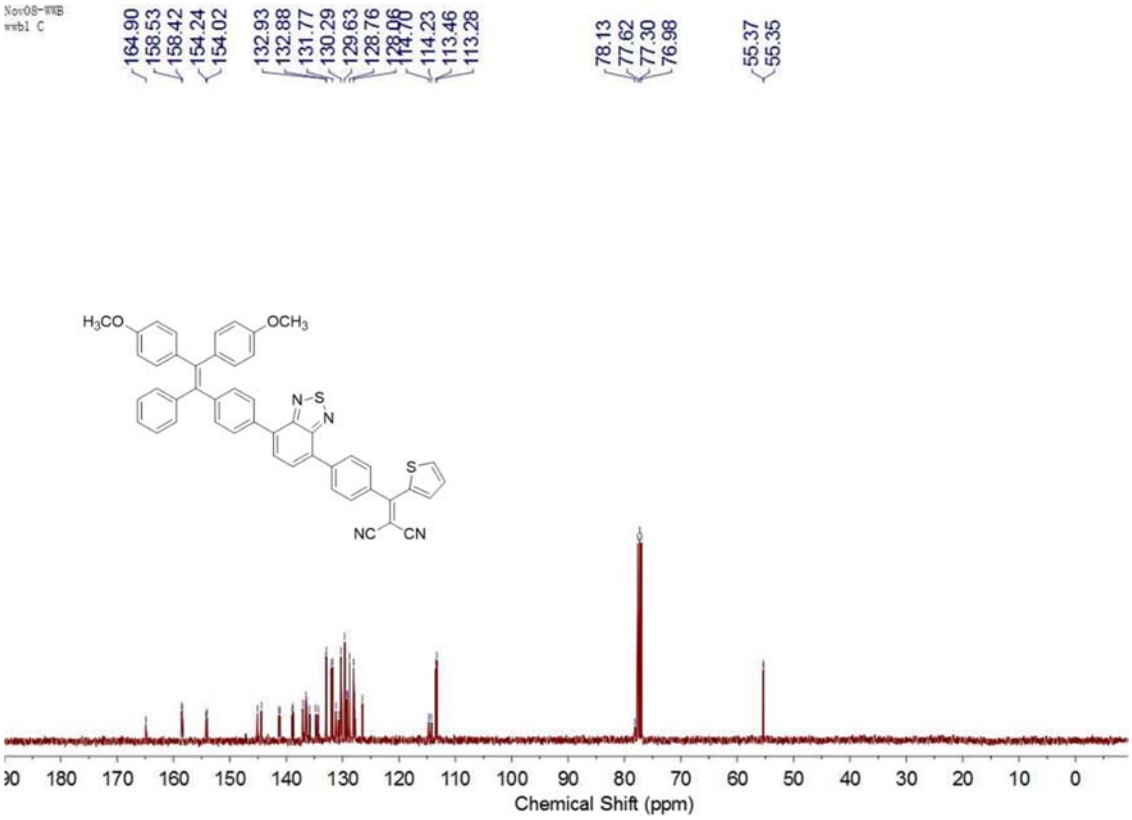


Fig. S30. ^{13}C NMR spectrum of **AP4** in chloroform-*d*.

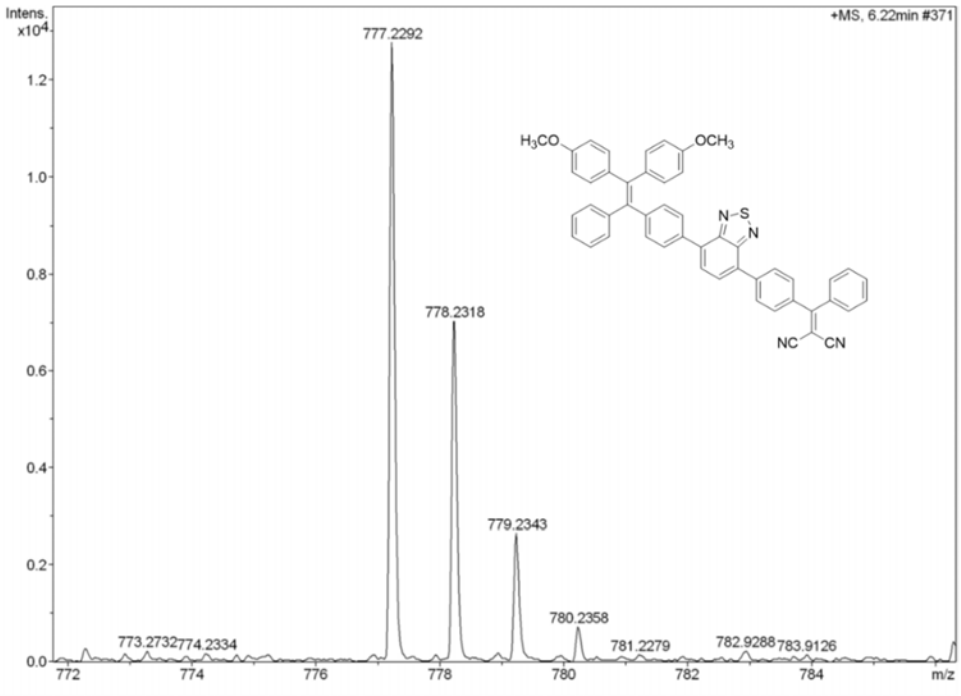


Fig. S31. High resolution mass spectrum of **AP3**. The peak of 777.2292 is the molecular ion peaks ($[M+Na]^+$), while the other peaks are the isotopic ion peak.

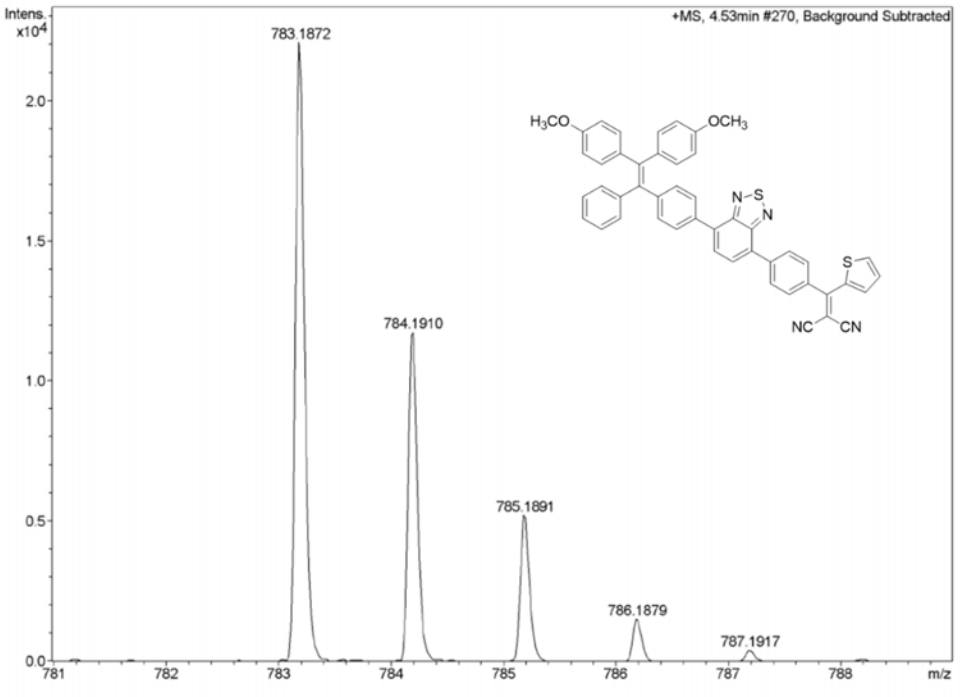


Fig. S32. High resolution mass spectrum of **AP4**. The peak of 783.1872 is the molecular ion peaks ($[M+Na]^+$), while the other peaks are the isotopic ion peak.