

Highly efficient, stoichiometric radical exchange reactions using isoindoline profluorescent nitroxides

James P. Blinco,* Kathryn E. Fairfull-Smith, Aaron S. Micallef and Steven E. Bottle*

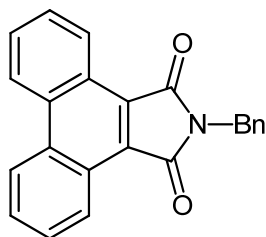
SUPPORTING INFORMATION

General procedures

All air-sensitive reactions were carried out under an atmosphere of ultra-high purity argon. Diethyl ether and toluene were both dried over sodium wire. Styrene (Aldrich 99%, 10-15 ppm 4-*tert*-butyl catechol inhibitor) was purified from inhibitor by passing through a column of activated basic alumina. Phenanthro[9,10-*c*]-1,3-anhydride was synthesized from phenylacetic acid and potassium benzoylformate using established literature procedures. All other reagents were purchased from commercial suppliers and used without further purification. ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance 400 spectrometer and referenced to the relevant solvent peak. Low and high resolution mass spectra were recorded at the Central Science Laboratory, University of Tasmania, on a Kratos Concept ISQ mass spectrometer, utilizing a direct insertion probe and operating at 70 eV, 5.3 KV accelerating voltage and a source temperature of 200 °C. High resolution spectra were referenced against perfluorokerosene internal mass reference. Elemental analyses were carried out by the University of Queensland Microanalytical Service. Melting points were measured on a Gallenkamp Variable Temperature Apparatus by the capillary method and are uncorrected. Spectrofluorimetry was undertaken on a Horiba Jobin-Yvon Fluoromax 4 spectrofluorometer. Ultraviolet-Visible spectra, with a spectral range of 250-500 nm were acquired using a Varian Cary 3000 UV-Visible spectrophotometer. Size Exclusion Chromatography (SEC) was carried out on a chromatographic system consisting of a 1515 Isocratic pump (Waters), a 717 autosampler (Waters), Styragel HT 6E and Styragel HT 3 columns (Waters) run in series, a light scattering detector DAWN 8+ (Wyatt Technology Corp.) and a 2414 differential refractive index detector (Waters). Tetrahydrofuran (THF) was used as the mobile phase at a flow rate of 1mL/min. ASTRA (Wyatt Technology Corp.) and Empower 2 (Waters) were used for data collection and processing. For the

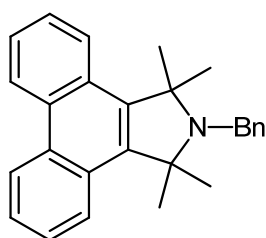
determination of molar mass by SEC, the columns were calibrated by polystyrene standards (Waters) covering the molar mass range of 1 060–1 320 000 g/mol.

Synthesis of 2-Benzylidibenzo[*e,g*]isoindolin-1,3-dione



Phenanthro[9,10-*c*]-1,3-anhydride (1.0 g, 4 mmol) and benzylamine (2 cm³, 18 mmol, 4.5 equiv.) were combined in glacial acetic acid (50 cm³) and refluxed for 4 hours. The mixture was then allowed to cool to room temperature upon which crystals began to form. This yielded fluorescent yellow crystals of 2-benzylidibenzo[*e,g*]isoindoline-1,3-dione (1.15 g, 85%). Mp 236-238 °C; ¹H NMR (400 MHz, *d*₆-DMSO) δ 4.87 (2H, s, CH₂), 7.35 (5H, m), 7.90 (4H, m), 9.00 (4H, d, *J* ca. 12 Hz); ¹³C NMR (100 MHz, *d*₆-DMSO) δ 31.5, 124.4, 125.3, 125.7, 127.5, 127.7, 128.9, 129.2, 130.2, 133.3, 137.2, 169.5

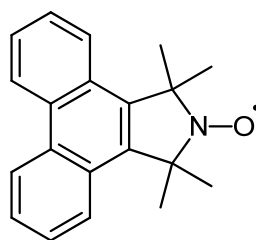
Synthesis of 2-Benzyl-1,1,3,3-tetramethyldibenzo[*e,g*]isoindoline



2-benzylidibenzo[*e,g*]isoindoline-1,3-dione (5.0 g, 15 mmol) was suspended in dry xylene (100 cm³) and stirred with a mechanical stirrer under Ar. To this was added *via* cannulation an ethereal solution of MeMgI, made from magnesium (1 g, 41 mmol, 13.2 equiv.) and MeI (2.2 cm³, 35 mmol, 11.3 equiv.) in dry Et₂O (20 cm³). The mixture was heated to reflux and the Et₂O removed with the aid of a Dean-Stark adaptor and the remaining mixture refluxed for 8 hours. The mixture was allowed to cool to room temperature then cooled in an ice bath. With the vessel immersed in the ice bath, 30% NH₄Cl (50 cm³) was added slowly, with constant stirring, followed by

water (50 cm³) and saturated NaHCO₃ (60 cm³). The resulting suspension was then stirred until the majority of solids had dissolved. The layers were separated and the aqueous phase was extracted with toluene (3 × 50 cm³). The combined organic phase was evaporated and allowed to stand over night exposed to the air, giving a blue/purple solid. This was dissolved in hot acetone and subjected to flash chromatography (SiO₂; 98% CHCl₃, 2% MeOH), This yielded 2-benzyl-1,1,3,3-tetramethyldibenzo[*e,g*]isoindoline as an off white crystalline solid (498 mg, 45%). Mp 190-195 °C; ¹H NMR (400 MHz, CDCl₃) δ 1.70 (12H, s, CH₃), 4.22 (2H, s, CH₂), 7.25 (1H, m), 7.33 (2H, m), 7.56/7.62 (6H, m, overlapping), 8.27 (2H, m), 8.79 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ 27.5, 44.9, 66.8, 123.3, 124.5, 125.5, 126.0, 126.2, 127.4, 127.9, 128.1, 131.0, 139.4, 143.9.

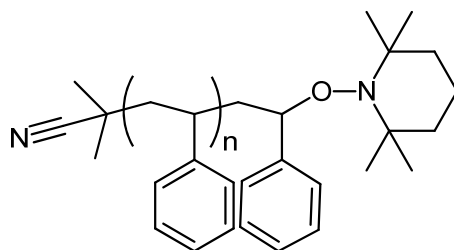
Synthesis of 1,1,3,3-Tetramethyldibenzo[*e,g*]isoindolin-2-yloxy (TMDBIO)



2-Benzyl-1,1,3,3-tetramethyldibenzo[*e,g*]isoindoline (500 mg, 1.7 mmol) was dissolved in acetic acid (100 cm³) containing 10% Pd/C (150 mg) and the suspension agitated under H₂ (50 psi) in a Parr hydrogenator. The progress of the reaction was monitored by thin layer chromatography. After 7 hours, TLC indicated that the hydrogenolysis was complete and that a single new product had formed. The suspension was filtered through celite and evaporated to dryness, giving a colourless solid. This was dissolved in DCM (100 cm³), 3-chloroperbenzoic acid (57%, 885 mg, 2.9 mmol) added and the mixture stirred for 72 hours at room temperature. The DCM solution was washed with saturated NaHCO₃ (2 × 50 cm³) followed by brine (1 × 50 cm³) then dried with Na₂SO₄. The DCM was evaporated to dryness and the residue dissolved in benzene (20 cm³). DDQ (150 mg, 0.68 mmol) was added and the mixture stirred for 2 hours. The solution was then passed through a plug column (neutral Al₂O₃, benzene). The eluent was evaporated to dryness yielding 1,1,3,3-tetramethyldibenzo[*e,g*]isoindolin-2-yloxy as a yellow crystalline solid (312 mg,

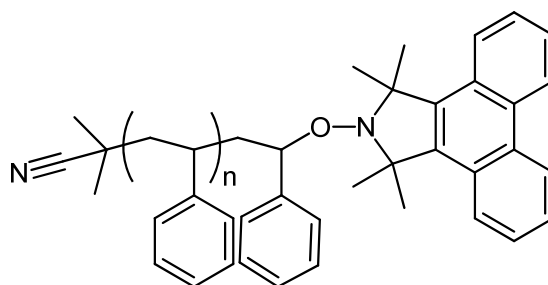
63%). Mp 186-189 °C (dec.) m/z (EI⁺) 290 (M⁺, 62%), 275 (100%), 260 (43%), 245 (18%), 229 (24%), 215 (28%), 202 (31%), 189 (15%); EI⁺ HRMS found M⁺ 290.154596 (0.4 ppm from calc. mass for C₂₀H₂₀NO); Anal. calc. for C₂₀H₂₀NO: C 82.72, H 6.94, N 4.82. Found: C 82.51, H 7.21, N 4.57

Synthesis of PSTY-TEMPO



In a Schlenk flask styrene (2 ml, 1.818 g, 17.46 mmol), TEMPO (27 mg, 0.175 mmol, 0.01 equiv.) and AIBN (29 mg, 0.175 mmol, 0.01 equiv.) were degassed by argon bubbling, stirred at room temperature for 10 min and then placed in a thermostatted oil bath at 120 °C to start the reaction. After 180 minutes time, the reaction was cooled to room temperature, opened to atmosphere and diluted with DCM. The product was then precipitated into a 10× volume of cold methanol, collected, redissolved in DCM and precipitated a further time. The purified product was then collected and dried *in vacuo* to a constant weight yielding PSTY-TEMPO (M_n = 34 400 , PDI = 1.10)

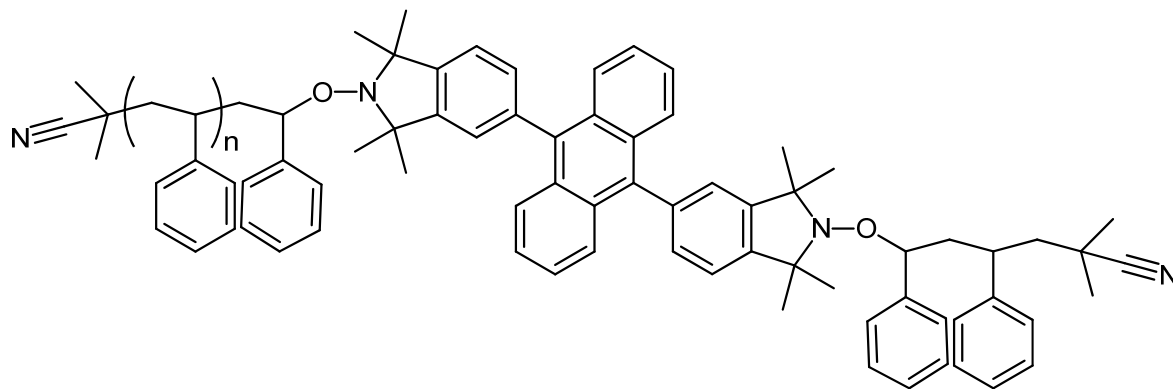
Synthesis of PSTY-TMDBIO



To a degassed solution of PSTY-TEMPO (M_n = 34 400, PDI = 1.10, 500 mg) in bromobenzene (5 cm³), TMDBIO (4.5 mg, 0.016 mmol, 1.1 equiv.) was added and the mixture was then bubbled with argon for a further 20 minutes. After this the vessel was sealed and the reaction mixture was stirred at 80 °C for 240 minutes with

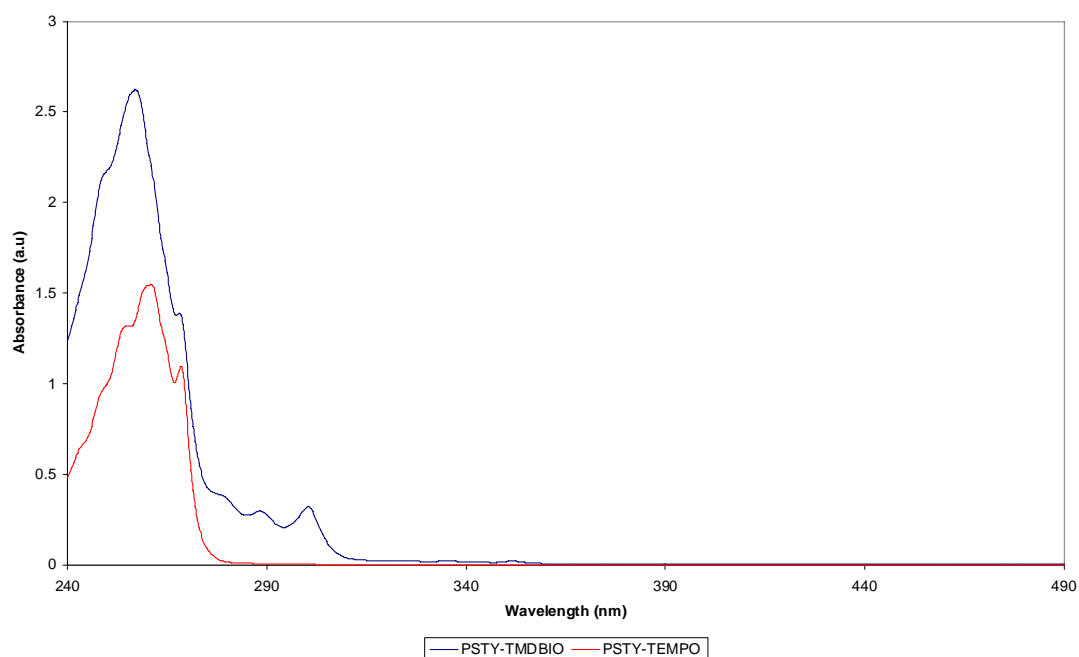
samples taken *via* syringe periodically. The polymer was then cooled to room temperature and precipitated into 10× volume of cold methanol. The polymer was collected, redissolved and precipitated a further time into methanol. The polymer was then collected and dried under vacuum yielding the TMDBIO capped polymer ($M_n = 34\ 800$, PDI = 1.12)

Synthesis of PSTY-DTMIOA-PSTY



DTMIOA (4 mg, 0.007 mmol, 0.5 equiv.) was added to a stirring, degassed solution of PSTY-TEMPO ($M_n = 34\ 400$, PDI = 1.10, 500 mg) in bromobenzene (5 cm³) which was then bubbled with argon for a further 20 minutes. After this the vessel was sealed and the reaction mixture was stirred at 80 °C for 300 minutes with samples taken *via* syringe periodically. The reaction mixture was then cooled to room temperature and precipitated into 10× volume of cold methanol. The polymer was collected, redissolved and precipitated a further time into methanol. The polymer was then collected and dried under vacuum yielding the DTMIO linked copolymer ($M_n = 70\ 400$, PDI = 1.26)

UV-Vis absorbance spectra comparison of re-precipitated PSTY-TEMPO and PSTY-TMDBIO (solvent cyclohexane)



Fluorescence spectra comparison of TMDBIO, re-precipitated PSTY-TEMPO and PSTY-TMDBIO (solvent cyclohexane, excitation = 300 nm)

