# Activated Photothermal Heating Using Croconaine Dyes

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## Supplementary Information

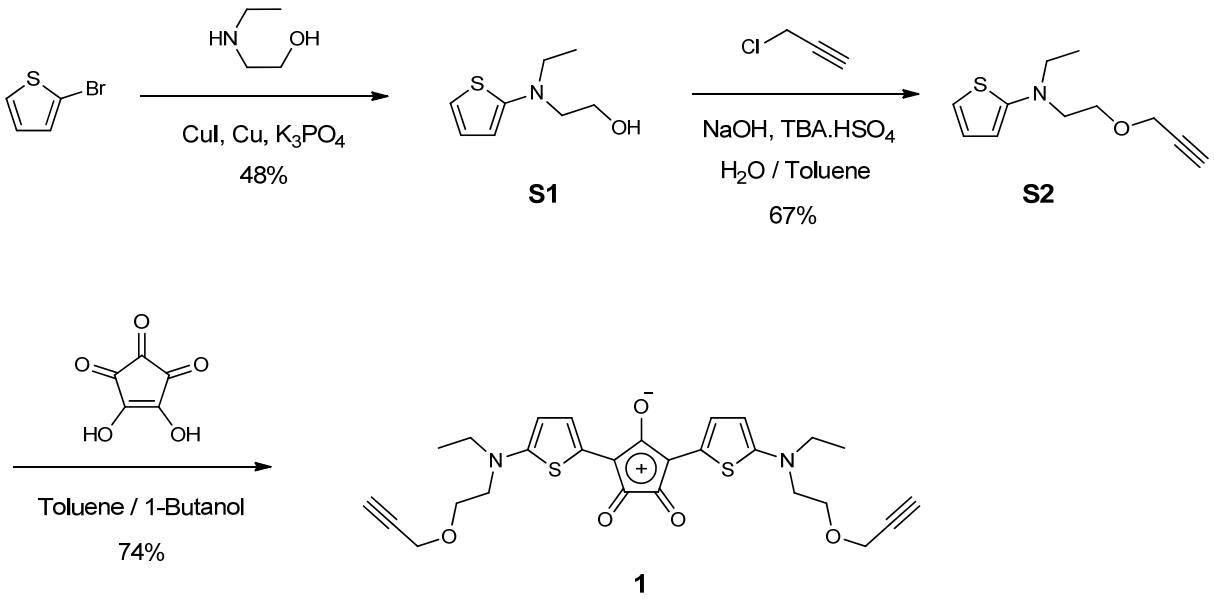
## Section 1: Synthesis and Characterisation

NMR spectra were recorded on Varian INOVA-500 and Varian DirectDrive 600 spectrometers at 295 K. High resolution electrospray ionisation (ESI) mass spectrometry (MS) was performed using a Bruker micrOTOF II spectrometer. Commercially available solvents and chemicals were used without further purification unless otherwise stated. Water was de-ionised and microfiltered. Cu(I)TBTA.Br was synthesized from CuBr and TBTA,[S1] and stored in a desiccator prior to use.

Indocyanine green (ICG) was purchased from Sigma Aldrich, while certified organic soluble gold nanorods (Organic NSol™ Gold Nanorodz™) were purchased from Nanopartz™ (Loveland, Colorado, USA) with the following specifications:

| | |
|---|---|
| **Product Family:** | Organic Gold Nanorodz |
| **Product Number:** | E12-10-808-2.5 |
| **Lot #:** | D1871 |
| **Appearance:** | Gold Colloid |
| **Capping Agent:** | Covalent Polymer |
| **Matrix:** | Short Chained Alkane Alcohol |

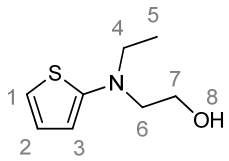
| | | | | |
|---|---|---|---|---|
| **SPR Peak:** | nm | measured | UV/Vis | 808 |
| **Absorption:** | OD @ 1 mL | measured | UV/Vis | 75 |
| **LSPR Peak:** | nm | measured | UV/Vis | 511 |
| **Absorption:** | OD @ 1 mL | measured | UV/Vis | 25 |
| **Diameter:** | nm | measured | TEM | 10 |
| **Length:** | nm | measured | TEM | 41 |
| **Aspect Ratio:** | | calc | | 4.1 |
| **Amount:** | nps | calc | | $4.7 \times 10^{13}$ |
| **Amount:** | mg | measured | ICP | 2.625 |
| **Volume:** | μL | measured | | 150 |
| **Concentration:** | nps/mL | calc | | $3.101 \times 10^{14}$ |




**Scheme S1.** Synthesis of croconaine dye **1**.

Amino-thiophenes are known to be relatively unstable.[S2] Consequently, any purification by column chromatography was undertaken after pre-treating the column with 3% $Et_3N$/hexane solution, and the isolated pure compounds were stored at −20 °C.

**2-(Ethyl(thiophen-2-yl)amino)ethanol (S1)[S2]**




**S1**

2-Bromothiophene (1.19 mL, 12.3 mmol), copper(I) iodide (350 mg, 15 mol%), copper powder (117 mg, 15 mol%) and potassium phosphate tribasic (5.22 g, 24.6 mmol) were suspended in 2-(ethyl-amino)ethanol (12 mL) and heated at 80 °C for 20 h under Ar. After this time, the reaction mixture was allowed to cool to room temperature and water (40 mL) added. The solution was extracted with diethyl ether (3 x 40 mL), and the combined organic fractions washed with brine (1 x 60 mL), dried over $MgSO_4$ and the solvent removed *in vacuo*. Purification was undertaken by silica gel column chromatography (column loaded using 3% $Et_3N$/hexane) using 2:1 hexane/ethyl acetate to elute the product as an orange oil (1.02 g, 5.96 mmol, 48%).

Formation of the product was confirmed by $^1H$ NMR and ESI-MS.

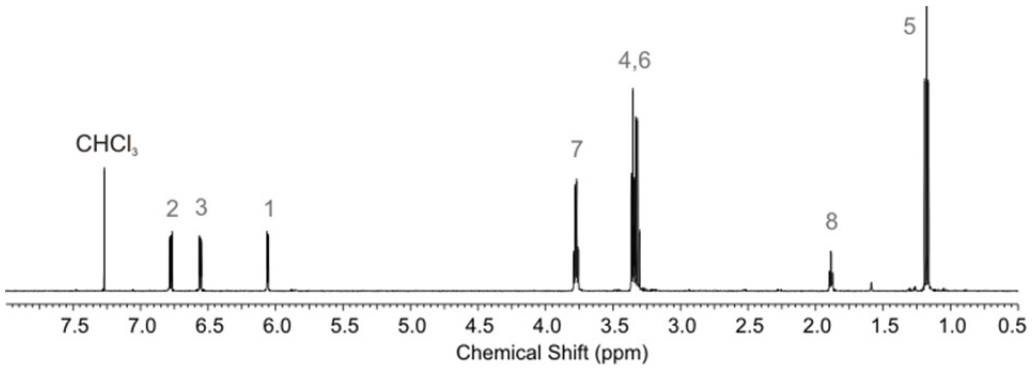
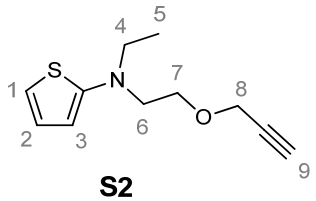



**Figure S1.** $^{1}$H NMR spectrum ($CDCl_3$, 500 MHz, 295 K) of 2-(ethyl(thiophen-2-yl)amino)ethanol (**S1**).

***N*-Ethyl-*N*-(2-(prop-2-yn-1-yloxy)ethyl)thiophen-2-amine (S2)**




**S2**

To a solution of 2-(ethyl(thiophen-2-yl)amino)ethanol (**S1**) (1.01 g, 5.90 mmol) and propargyl chloride (1.54 mL, 21.2 mmol) in toluene (35 mL) was added a solution of tetrabutylammonium bisulfate (200 mg) in 50% sodium hydroxide solution (20 mL) and the reaction mixture was stirred at room temperature for 3 days. The organic layer was separated and the solvent removed *in vacuo*. The resulting residue was dissolved in $CHCl_3$ (100 mL), washed with water (2 x 50 mL), dried over $MgSO_4$ and the solvent removed *in vacuo*. Purification was undertaken by silica gel column chromatography (column loaded using 3% $Et_3N$/hexane) using 5% ethyl acetate/hexane to elute the product as an off-white solid (810 mg, 3.87 mmol, 67%).

**$^{1}$H NMR** (600 MHz, $CDCl_3$) δ (ppm) 6.77 (1H, dd, $^{3}J$ = 5.5 Hz, $^{3}J$ = 3.7 Hz, $H_2$), 6.46 (1H, dd, $^{3}J$ = 5.5 Hz, $^{4}J$ = 1.3 Hz, $H_3$), 5.91 (1H, dd, $^{3}J$ = 3.7 Hz, $^{4}J$ = 1.3 Hz, $H_1$), 4.18 (2H, d, $^{4}J$ = 2.5 Hz, $H_8$), 3.72 (2H, t, $^{3}J$ = 6.0 Hz, $H_7$), 3.45 (2H, t, $^{3}J$ = 6.0 Hz, $H_6$), 3.36 (2H, q, $^{3}J$ = 7.1 Hz, $H_4$), 2.44 (1H, t, $^{4}J$ = 2.5 Hz, $H_9$), 1.19 (3H, t, $^{3}J$ = 7.1 Hz, $H_5$).
**$^{13}$C NMR** (151 MHz, $CDCl_3$) δ (ppm) 157.1, 126.5, 109.4, 102.4, 79.6, 74.5, 67.4, 58.4, 52.8, 49.0, 12.0.
**MS-ESI** *m/z* 210.0934 ($[M + H]^+$, $C_{11}H_{16}NOS$, calc. 210.0947).

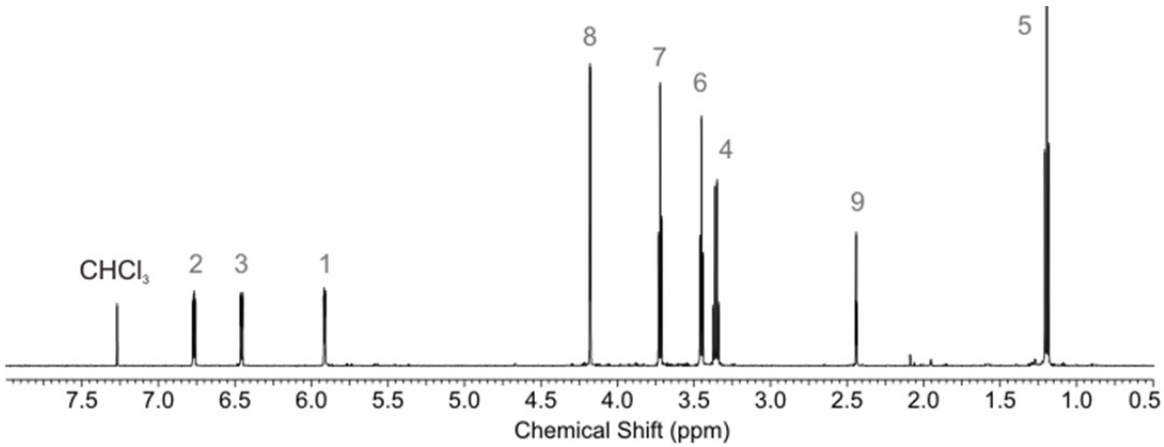



**Figure S2.** $^{1}$H NMR spectrum ($CDCl_3$, 600 MHz, 295 K) of *N*-ethyl-*N*-(2-(prop-2-yn-1-yloxy)ethyl)thiophen-2-amine (**S2**).

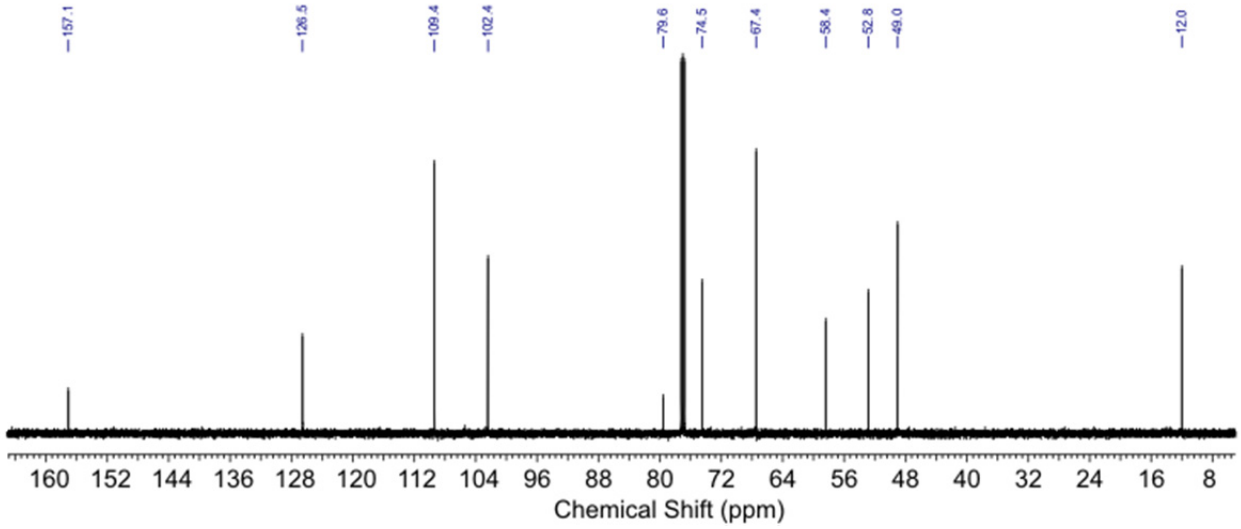
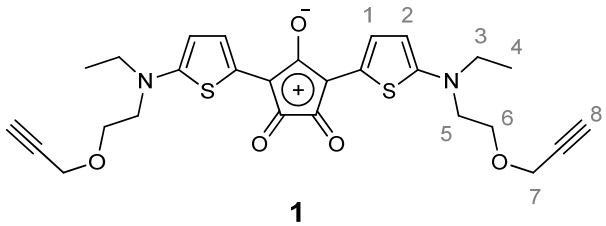



**Figure S3.** $^{13}$C NMR spectrum ($CDCl_3$, 151 MHz, 295 K) of *N*-ethyl-*N*-(2-(prop-2-yn-1-yloxy)ethyl)thiophen-2-amine (**S2**).

**Croconaine Dye 1**



**1**

Croconic acid (136 mg, 0.96 mmol) and *N*-ethyl-*N*-(2-(prop-2-yn-1-yloxy)ethyl)thiophen-2-amine (**S2**) (400 mg, 1.91 mmol) were dissolved in 1:1 anhydrous toluene/1-butanol (30 mL) and heated at reflux for 1 h under Ar. After this time, the solution was allowed to cool to room temperature and the solvent removed *in vacuo*. The crude residue was purified by silica gel column chromatography using 2% MeOH/DCM to elute the product as a black solid (373 mg, 0.71 mmol, 74%).

**$^1$H NMR** (600 MHz, $CDCl_3$) δ (ppm) 8.67-8.85 (2H, m, $H_1$), 6.48-6.57 (2H, m, $H_2$), 4.15-4.18 (4H, m, $H_7$), 3.81-3.86 (4H, m, $H_{5/6}$), 3.76-3.81 (4H, m, $H_{5/6}$), 2.43-2.46 (1H, m, $H_8$), 1.32-1.38 (6H, m, $H_4$).

**$^{13}$C NMR** (151 MHz, $CDCl_3$) δ (ppm) 186.2, 186.0, 185.5, 185.3, 182.9, 182.9, 173.5, 173.0, 173.0, 172.8, 141.8, 141.7, 141.0, 140.6, 137.7, 137.4, 136.4, 136.2, 123.9, 123.7, 123.6, 113.2, 133.1, 133.0, 112.9, 78.8, 78.8, 75.3, 75.2, 67.0, 67.0, 58.6, 53.8, 50.7, 50.6, 12.3, 12.3. [37 out of a theoretical 55 signals].

**MS-ESI** *m/z* 525.1526 ($[M + H]^+$, $C_{27}H_{29}N_2O_5S_5$, calc. 525.1512).

**$\lambda_{abs,max}$** ($CHCl_3$) 795 nm. **ε** ($CHCl_3$, 5.0 μM) 2.24 x $10^5$ $M^{-1}cm^{-1}$. **$\lambda_{em,max}$** ($CHCl_3$) 811 nm. **$\Phi_F$** ($CHCl_3$, 5.0 μM) 0.061.

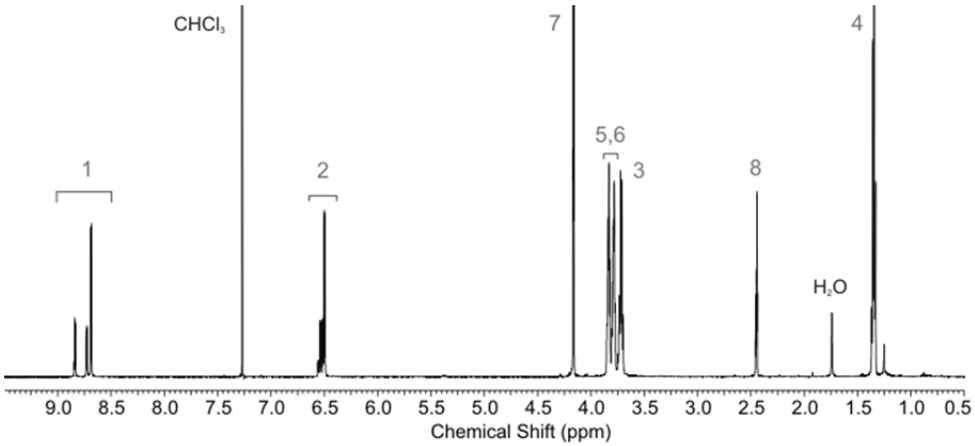



**Figure S4.** $^1$H NMR spectrum ($CDCl_3$, 600 MHz, 295 K) of bis-alkyne croconaine dye **1**.

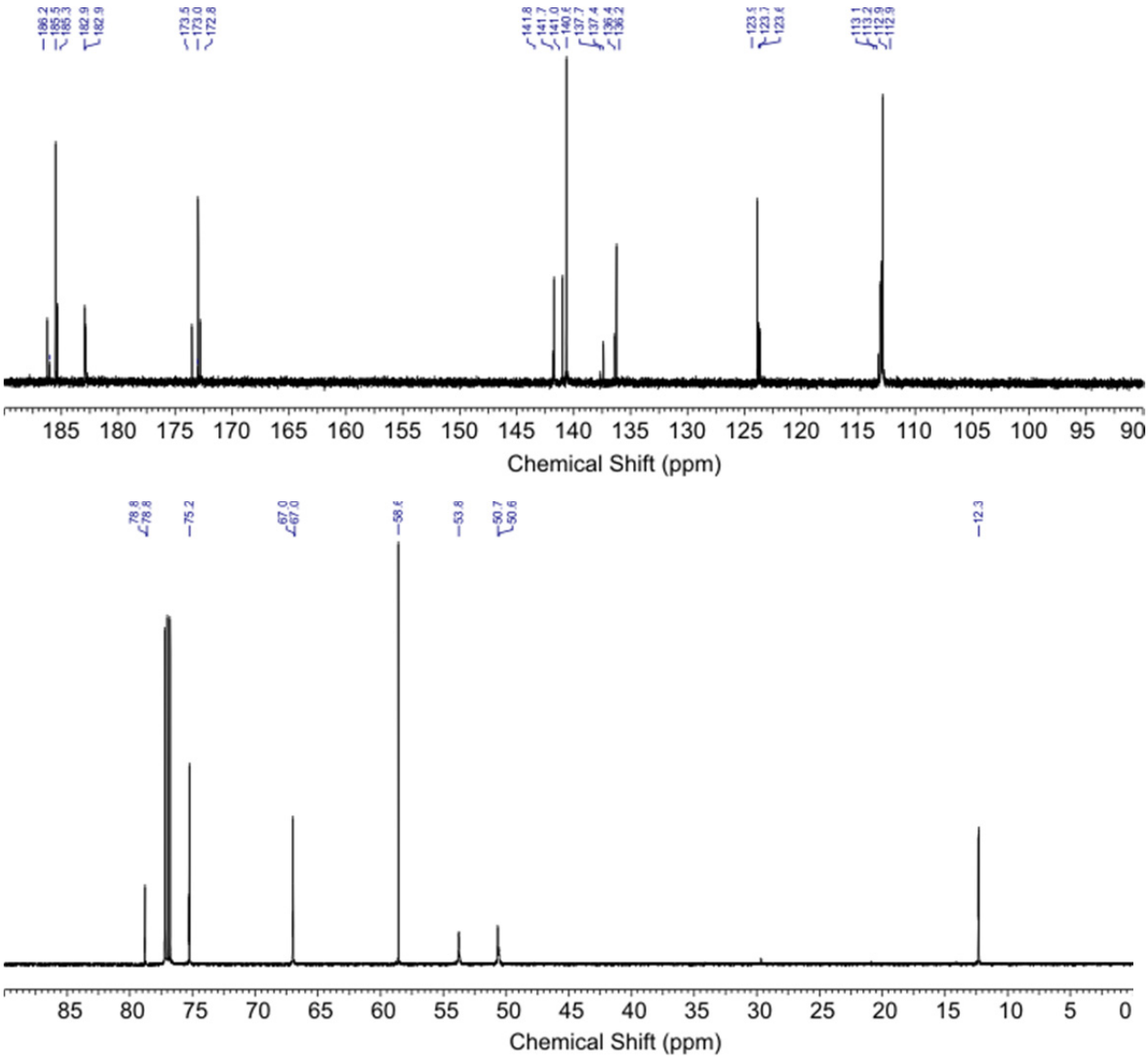



**Figure S5.** $^{13}C$ NMR spectrum ($CDCl_3$, 151 MHz, 295 K) of bis-alkyne croconaine dye **1**. Note: multiple peaks are too close to be marked separately.

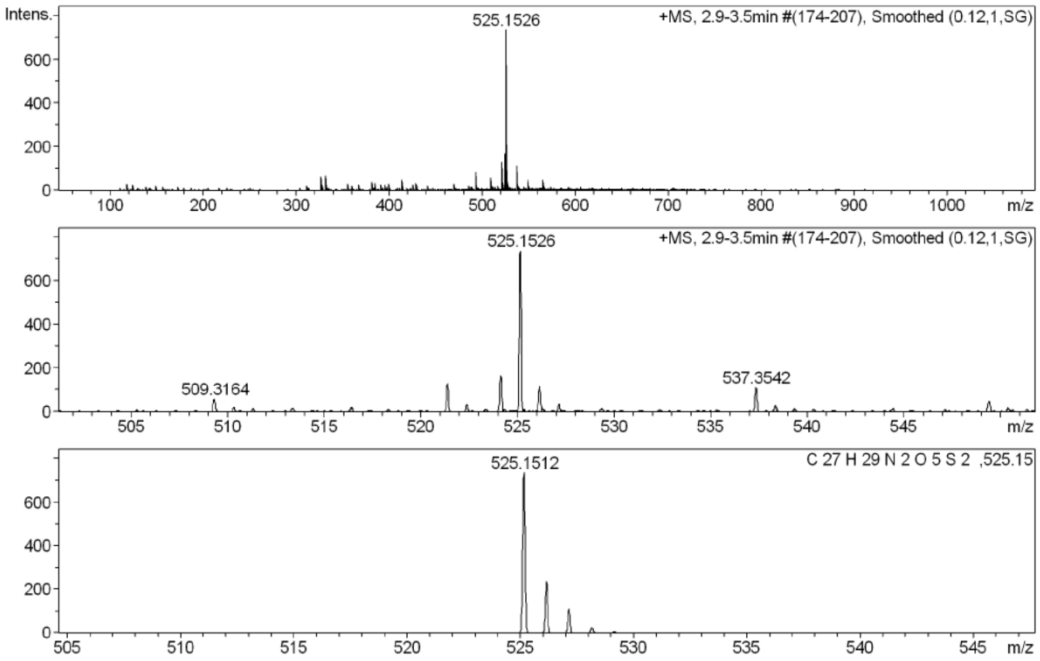
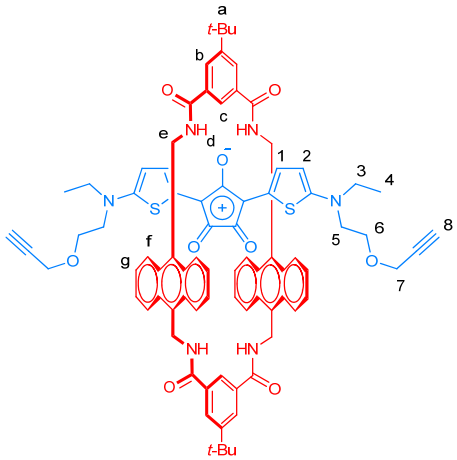



**Figure S6.** Electrospray mass spectrum of bis-alkyne croconaine dye **1** (top and middle) with theoretical isotope model for $[M + H]^+$ (bottom).

## Croconaine Inclusion Complex (2⊃1)




**2⊃1**

Croconaine dye **1** (10 mg, 0.019 mmol) and anthracene macrocycle[S3] (20 mg, 0.024 mmol) were dissolved in $CHCl_3$ (3 mL) and the solution stirred at room temperature for 2 days. After this time, the solvent was removed *in vacuo* and the resulting residue purified by gradient silica gel column

chromatography using 0-10% acetone/DCM to elute the product as a black solid (22 mg, 0.016 mmol, 84%).

**$^1$H NMR** (600 MHz, $CDCl_3$) δ (ppm) 9.23-9.60 (2H, m, $H_c$), 8.44-8.55 (4H, m, $H_b$), 7.66-8.25 (12H, m, $H_d$ & $H_f$), 7.44-7.66 (2H, m, $H_1$), 6.74-7.11 (8H, m, $H_g$), 5.76-5.87 (2H, m, $H_2$), 5.11-5.23 (8H, m, $H_e$), 4.21-4.27 (4H, m, $H_7$), 3.31-3.68 (12H, m, $H_3$ & $H_5$ & $H_6$), 2.56 (2H, m, $H_8$), 1.49-1.57 (18H, m, $H_a$), 1.21-1.30 (6H, m, $H_4$).

**MS-ESI** *m/z* 1391.5486 ($[M + Na]^+$, $C_{83}H_{80}N_6NaO_9S_2$, calc. 1391.5326).

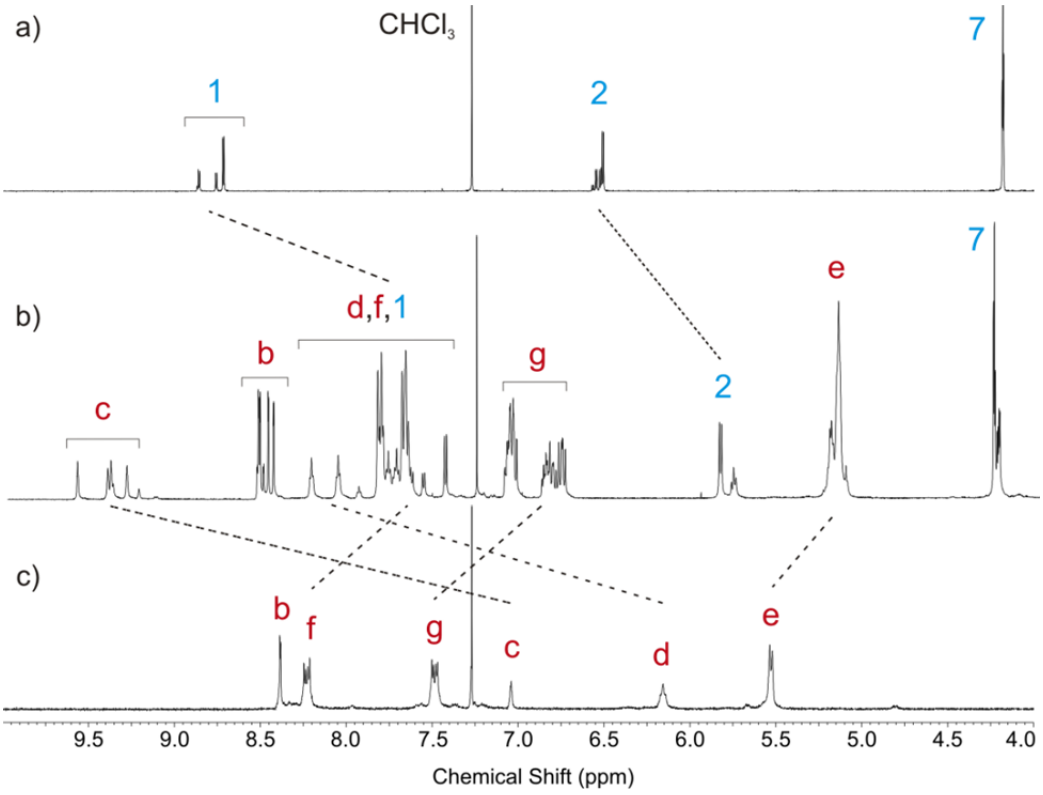



**Figure S7.** Diagnostic region of the $^1$H NMR spectra ($CDCl_3$, 600 MHz, 295 K) of a) croconaine dye **1**, b) croconaine inclusion complex **2**⊃**1**, and c) macrocycle **2**, indicating dye encapsulation.

# Section 2: Croconaine Conformational Isomers

## Croconaine Dye 1

The three possible thiophene-croconaine conformational isomers (Figure S8) are clearly seen from the signals corresponding to these protons in the $^1$H NMR spectrum of **1** (Figure S9). Each signal is composed of four doublets – one each from the two possible '*cis*' isomers (*i* and *iii*), and two of equal size from the '*trans*' isomer (*ii*). Integration indicates that the major *cis* isomer is present in approximately 55%, the *trans* isomer in 40%, and the minor *cis* in 5%.

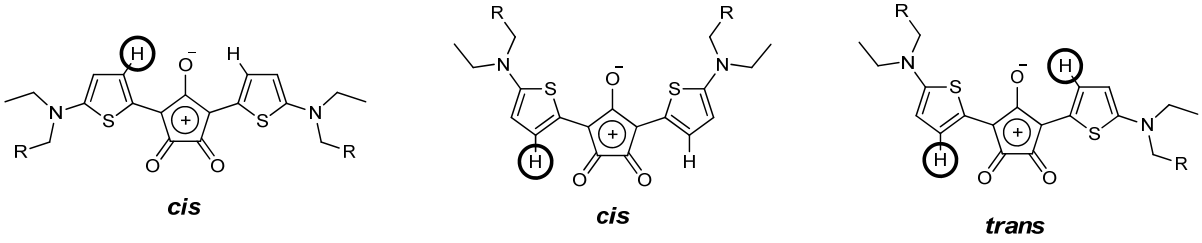



**Figure S8.** Thiophene-croconaine conformational isomers.

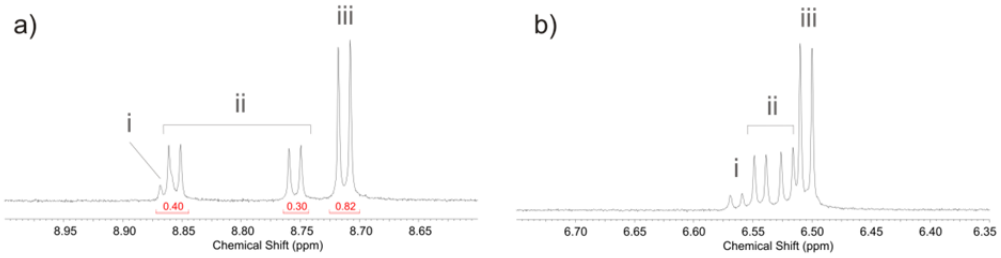



**Figure S9.** Regions of the $^1$H NMR spectrum ($CDCl_3$, 600 MHz, 295 K) of croconaine dye **1** corresponding to a) thiophene protons 1, and b) thiophene protons 2.

## Inclusion Complex 2⊃1

Evidence for the three conformational isomers of croconaine inclusion complex **2⊃1** (Figure S10) is most obviously observed in the $^1$H NMR peaks corresponding to isophthalamide protons b and c (shown in Figure S11). If the conformational isomers are in slow exchange, these protons would be expected to result in two peaks from each isomer due to the five-membered croconaine core imparting asymmetry on the two 'ends' of the macrocycle, and indeed both macrocycle protons b and protons c are split into six

distinct signals (i.e. three pairs of peaks). From peak integration, it appears that, like in croconaine dye **1**, there are two 'major' isomers and one 'minor'.

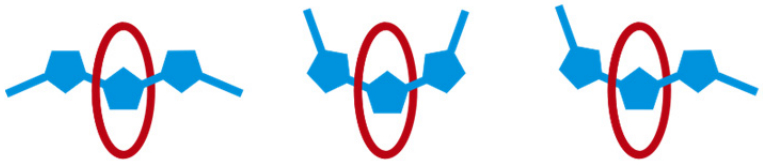


**Figure S10.** Schematic representation of the croconaine inclusion complex conformational isomers.

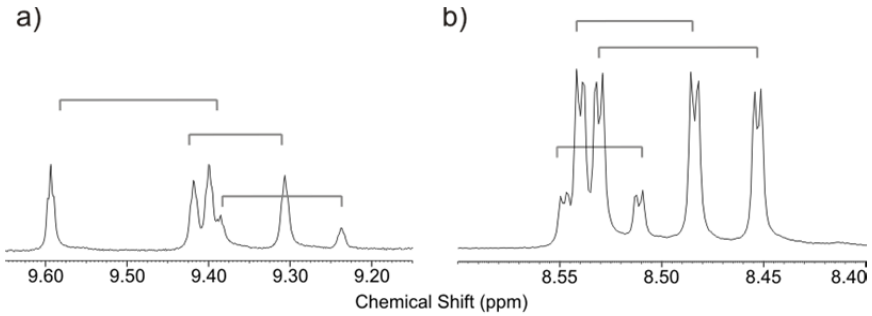



**Figure S11.** Regions of the $^{1}$H NMR spectrum ($CDCl_3$, 600 MHz, 295 K) of croconaine inclusion complex **2⊃1** corresponding to a) macrocycle protons c, and b) macrocycle protons b. Proposed pairing of signals corresponding to the three conformational isomers are marked.

# Section 3: Photophysical Studies

Spectra were obtained using spectrophotometric grade solvents and 1 cm Helma cuvettes. Fluorescence spectra were taken and analysed on a Horiba Fluoromax-4 spectrofluorometer with FluorEssence software, and absorption spectra on a Perkin Elmer Lambda 25 spectrometer with UV-WinLab software.

## Normalised Absorbance and Emission

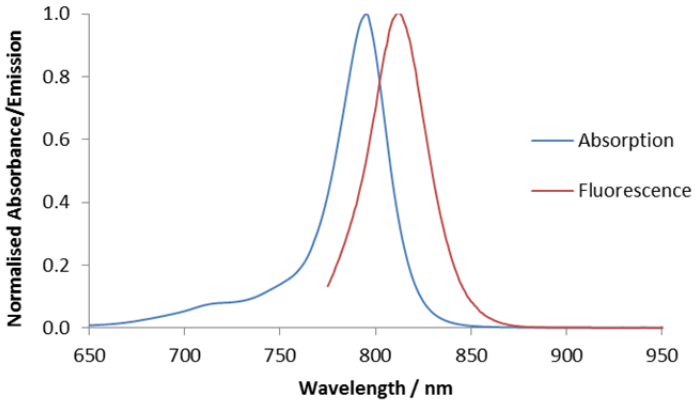



**Figure S12.** Normalised absorption and emission spectra of croconaine dye **1** ($CHCl_3$, $\lambda_{excit}$ = 765 nm).

## Quantum yield calculations

The quantum yield for the near-infrared emission of croconaine dye **1** was calculated in $CHCl_3$ using ICG in EtOH as a standard ($\Phi_f$ = 0.132[S4]). The concentrations of μM solutions of ICG and **1** were adjusted such that their absorbances at 750 nm were equal and <0.1 a.u. (Figure S13a). The fluorescence spectra of these solutions were then obtained ($\lambda_{excit}$ = 750 nm, Figure S13b) and their integrated areas used in the quantum yield calculation (Equation S1 and Table S2). The estimated error of this method is ±10%.

**Equation S1.** Equation used to calculate quantum yields using the comparative method. Note: for solutions with identical absorbance values, the absorbance factor terms cancel.[S5]

$$\Phi_f^i = \Phi_f^s \frac{F_i f_s \eta_i^2}{F_s f_i \eta_s^2}$$

$\Phi_f$ = Quantum yield
F = Integrated fluorescence intensity
$f$ = Absorption factor
$\eta$ = Solvent refractive index

i = Sample
s = Standard

**Table S1.** Refractive index values for the solvents used in quantum yield calculations.[S6]

| | EtOH | $CHCl_3$ |
|---|---|---|
| η | 1.360 | 1.445 |

a) b)

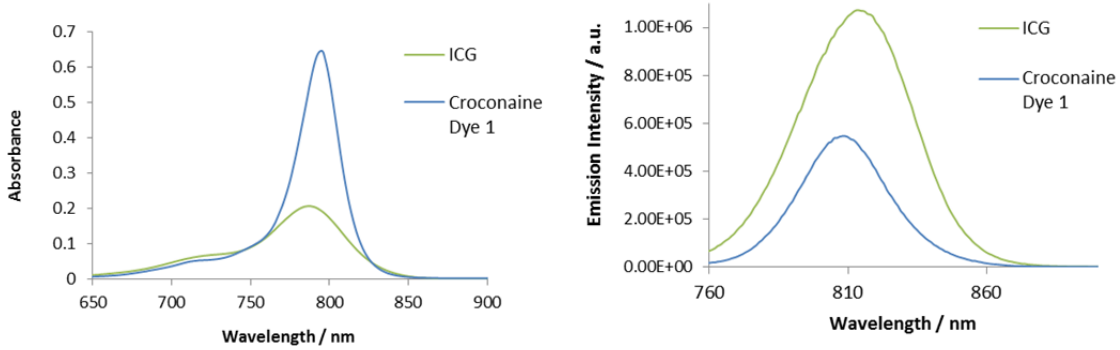



**Figure S13.** a) Absorbance and b) emission spectra of ICG (EtOH) and croconaine dye **1** ($CHCl_3$) for μM solutions adjusted to give identical absorbance values (< 0.1) at 750 nm ($\lambda_{excit}$ = 750 nm).

**Table S2.** Fluorescence integrated areas for the adjusted solutions of ICG and croconaine dye **1** ($\lambda_{excit}$ = 750 nm).

| | ICG | Dye **1** |
|---|---|---|
| Integrated Fluorescence Intensity | $5.521 \times 10^7$ | $2.275 \times 10^7$ |

## Encapsulation Association Constant

The association between croconaine dye **1** and macrocycle **2** at equilibrium is:

$$\text{Dye} + \text{Macrocycle} \underset{}{\overset{K_{eq}}{\rightleftharpoons}} \text{Inclusion Complex}$$

Therefore:

$$K_{eq} = \frac{[\text{Complex}]}{[D] \cdot [M]}$$

Given that at equilibrium:

$$[D] = [D]_0 - [\text{Complex}]$$

$$[M] = [M]_0 - [\text{Complex}]$$

Hence:

$$K_{eq} = \frac{[\text{Complex}]}{\left([D]_0 - [\text{Complex}]\right) \cdot \left([M]_0 - [\text{Complex}]\right)} \quad (1)$$

The absorbance profiles for the free dye ($A_{max}$ = 795 nm) and the inclusion complex ($A_{max}$ = 823 nm) overlap, the contribution of both species to the absorbance at each wavelength can be calculated using Beer's law:

$$A_\lambda = (\varepsilon_{\lambda D} \cdot b \cdot [D]) + (\varepsilon_{\lambda C} \cdot b \cdot [\text{Complex}])$$

Since b = 1 cm, the absorption at a specific wavelength, λ, is:

$$A_\lambda = \varepsilon_{\lambda D} \cdot ([D]_0 - [\text{Complex}]) + \varepsilon_{\lambda C} \cdot [\text{Complex}]$$

$$[\text{Complex}] = \frac{A_\lambda - \varepsilon_{\lambda D} \cdot [D]_0}{\varepsilon_{\lambda C} - \varepsilon_{\lambda D}} \quad (2)$$

To a series of 2.5 mL, 5.0 μM solutions of dye **1** in $CHCl_3$ were added increasing equivalents of macrocycle **2** up to 50 equivalents, such that the concentration of dye remained at 5.0 μM. The solutions were left overnight to ensure equilibration and their absorption spectra obtained (Figure S13).

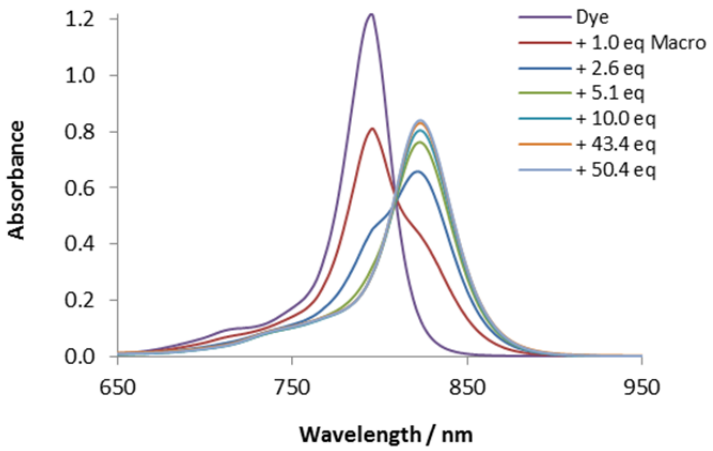



**Figure S14.** Absorption spectra of croconaine dye **1** upon addition of anthracene macrocycle **2** ($CHCl_3$, 5.0 μM). Note: these spectra are from separate solutions left overnight to ensure equilibration.

Due to saturation, the spectrum corresponding to 50 equivalents was considered pure inclusion complex and the following ε values calculated:

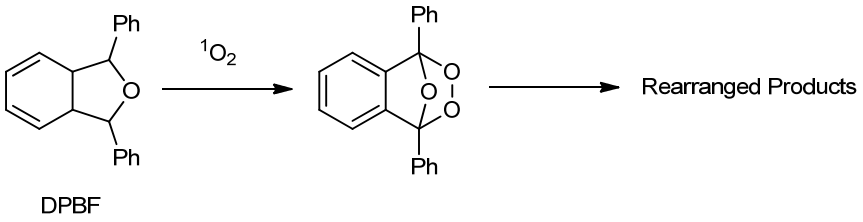
$$\varepsilon_{D,795} = 2.44 \times 10^5\ M^{-1}cm^{-1}$$
$$\varepsilon_{D,823} = 2.67 \times 10^5\ M^{-1}cm^{-1}$$
$$\varepsilon_{C,795} = 5.67 \times 10^4\ M^{-1}cm^{-1}$$
$$\varepsilon_{C,823} = 1.68 \times 10^5\ M^{-1}cm^{-1}$$

Using the absorbance values at 795 nm and 823 nm for the optimum intermediate spectra (1.0 and 2.6 equivalents) and equations (1) and (2), estimates of $K_{eq}$ were obtained. The obtained values were averaged to yield:

$$\mathbf{K_{eq}\ (CHCl_3,\ 295\ K) = (3.4 \pm 0.7) \times 10^5\ M^{-1}}$$

## Singlet oxygen generation and photobleaching

1,3-Diphenylisobenzofuran (DPBF) is a singlet oxygen trap that absorbs at 415 nm, and its corresponding cycloadduct (Scheme S2) only absorbs at lower wavelengths due to the loss of conjugation.[S7, 8]




**Scheme S2.** 1,3-Diphenylisobenzofuran (DPBF) and its corresponding oxygen cycloadduct.

To 2.0 mL solution of dye at 5.0 μM in MeOH was added 0.02 mL of a stock solution of DPBF in $CHCl_3$ corresponding to 20 molar equivalents. This solvent mixture was necessary to allow for the solubility of both DPBF (only soluble in non-polar organic solvents such as $CHCl_3$) and ICG (soluble in polar organic solvents such as MeOH). The solution was irradiated with a Xenon lamp (150 W, 620 nm long-pass filter) at a distance of 15 cm, with absorption spectra taken at 0, 1, 2 and 3 minutes. A reduction in the DPBF absorbance band (~400 nm) corresponds to singlet oxygen generation, whereas a reduction in the ICG/croconaine band (~800 nm) corresponds to photobleaching of the dye.

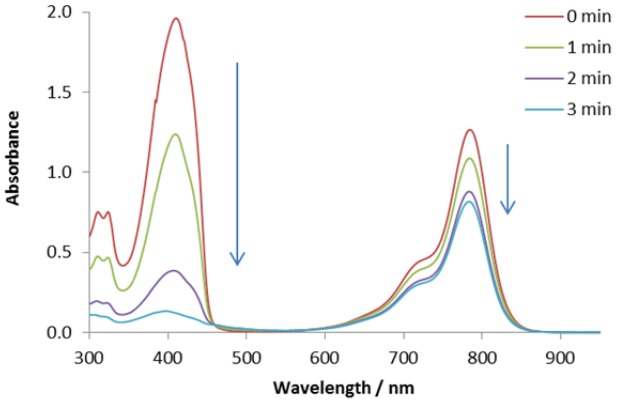



**Figure S15.** Change in the absorption spectra of a solution of ICG (5.0 μM) and DPBF (100 μM) upon Xenon lamp irradiation (> 620 nm) after 0, 1, 2 and 3 minutes (99:1 MeOH/$CHCl_3$).

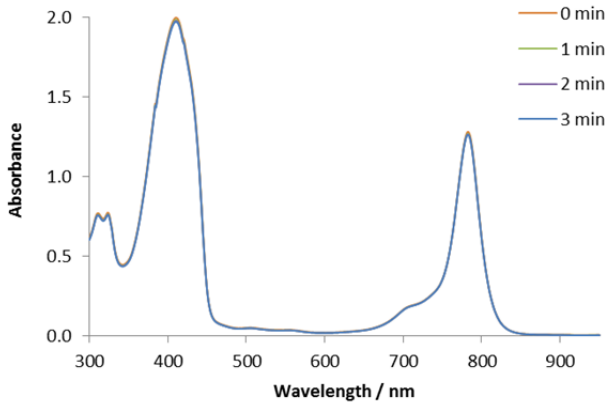



**Figure S16.** Change in the absorption spectra of a solution of croconaine dye **1** (5.0 μM) and DPBF (100 μM) upon Xenon lamp irradiation (> 620 nm) after 0, 1, 2 and 3 minutes (99:1 MeOH/$CHCl_3$). Note: all lines are coincident.

## Chemical Stability

To a 2.5 mL, 5.0 μM solution of croconaine dye **1** in 4:1 MeOH/$H_2O$ was added increasing amounts of L-cysteine up to 100 molar equivalents. No significant change in the absorbance profile was observed (Figure S16). The same result was obtained when repeated at pH 6.2 (using HEPES buffer) and 9.0 (using TRIS buffer).

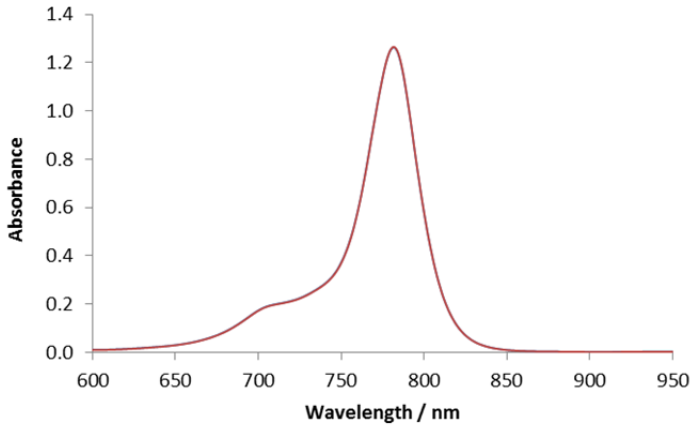



**Figure S17.** Absorption spectra of croconaine dye **1** (4:1 MeOH/$H_2O$, 5.0 μM) in the presence and absence of L-cysteine (100 molar equivalents) indicate no reaction of the dye with the L-cysteine. Note: both lines are coincident.

# Section 4: Laser-induced Heat Generation Studies

## Comparison Studies

A 0.6 mL solution of the photothermal agent in 4:1 MeOH/$H_2O$ at 2.0 or 50.0 μg/mL was stirred using a magnetic stirrer bar in a 1 cm Helma cuvette located in an air-conditioned room maintained at 295 K. An Omega hypodermic thermocouple (HYPO-33-1-T-G-60-SMPW-M) was placed in the solution and the temperature measured using the associated USB converter. The Ti:Sapphire laser beam was aligned to pass through the solution (above the stirrer and avoiding close contact with the thermocouple) in an identical manner in every experiment. The laser wavelength was set at 780 or 808 nm and the power controlled to be 250 mW during all of the experiments, with a beam diameter of 0.3 cm. Hence, the laser power density was 3.5 W/$cm^2$.

**Table S3.** Temperature changes observed for solutions of croconaine dye **1**, ICG and AuNRs (4:1 MeOH/$H_2O$) during laser irradiation (250 mW).

| | Concentration / μg/mL | Wavelength / nm | ΔT / °C |
|---|---|---|---|
| **Croconaine 1** | 2.0 | 780 | 10.6 |
| **ICG** | 2.0 | 780 | 1.5 |
| **AuNRs** | 2.0 | 808 | 0.0 |
| **AuNRs** | 50.0 | 808 | 9.4 |

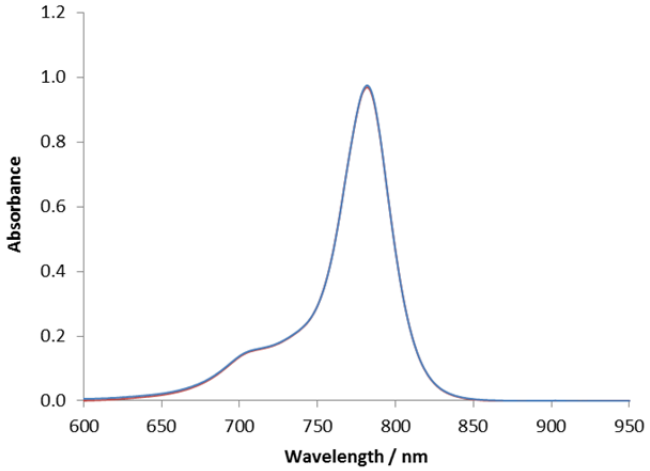



**Figure S18.** Absorption spectra of croconaine dye (4:1 MeOH/$H_2O$, 2.0 μg/mL) before (blue) and after (red) laser irradiation at 780 nm (900 s, 250 mW) indicate no dye decomposition. Note: both lines are coincident.

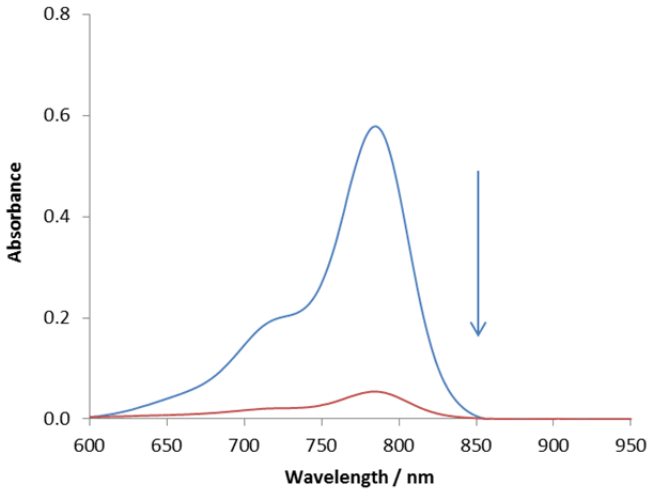



**Figure S19.** Absorption spectra of ICG (4:1 MeOH/$H_2O$, 2.0 μg/mL) before (blue) and after (red) laser irradiation at 780 nm (900 s, 250 mW) indicate substantial dye decomposition.

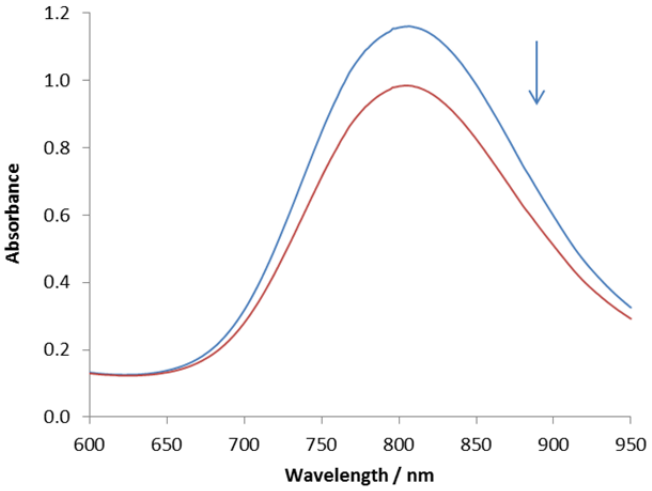



**Figure S20.** Absorption spectra of AuNRs (4:1 MeOH/$H_2O$, 50.0 μg/mL) before (blue) and after (red) laser irradiation at 808 nm (900 s, 250 mW) indicate modest change in AuNRs structure. Note: a similar reduction in AuNR absorbance has been observed in other studies.[S9]

## Beer-Lambert Experiment

The same experimental set-up was used as described above, except the laser wavelength was maintained at 780 nm and solutions of varying concentrations of croconaine dye **1** (0.10 to 50.0 μg/mL) were studied.

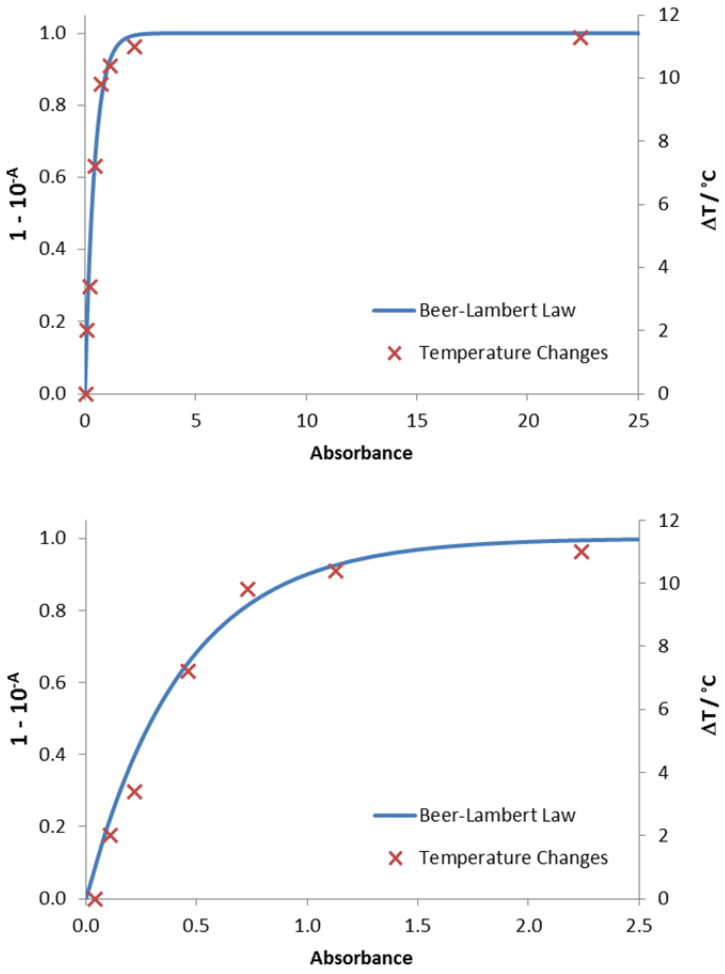



**Figure S21.** Correlation between the Beer-Lambert law ($1 - 10^{-A}$) and the temperature changes (ΔT) observed upon laser irradiation (250 mW) for solutions of croconaine dye **1** of different concentrations (4:1 MeOH/$H_2O$, 780 nm, 250 mW) and b) expansion. Note: bottom graph is an expansion of the top.

**Table S4.** Temperature changes observed for different solutions of croconaine dye **1** (4:1 MeOH/$H_2O$) during laser irradiation (780 nm, 250 mW) and the corresponding absorbance values.

| Concentration / µg/mL | ΔT / °C | A |
|---|---|---|
| **50.0** | 11.3 | 22.4 (est.) |
| **5.00** | 11.0 | 2.24 |
| **2.50** | 10.4 | 1.13 |
| **1.67** | 9.8 | 0.73 |
| **1.00** | 7.2 | 0.46 |
| **0.50** | 3.4 | 0.22 |
| **0.25** | 2.0 | 0.11 |
| **0.10** | 0.1 | 0.04 |

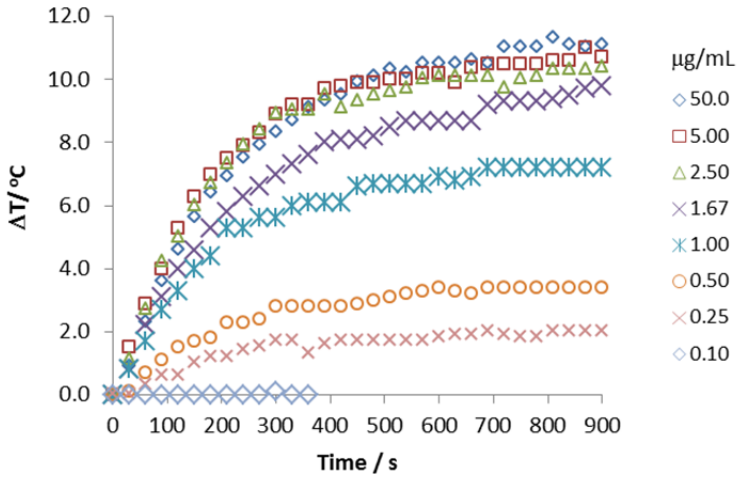



**Figure S22.** Temperature changes observed for different concentrations of croconaine dye **1** (4:1 MeOH/$H_2O$) during laser irradiation (780 nm, 250 mW).

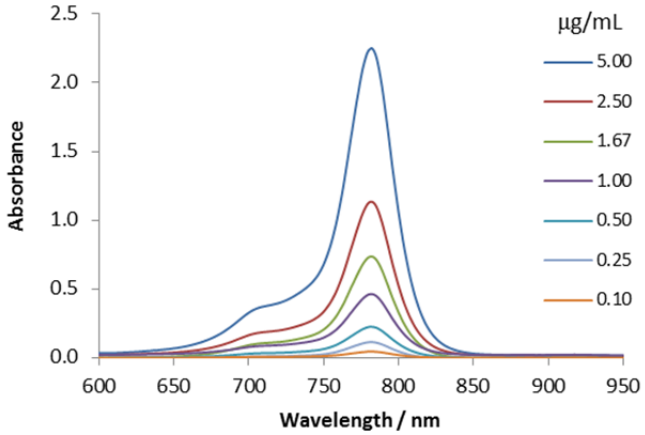



**Figure S23.** Absorption spectra of croconaine dye **1** (4:1 MeOH/$H_2O$) at different concentrations.

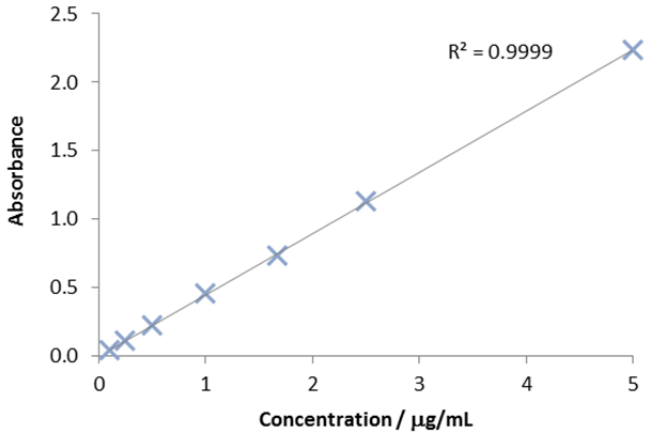



**Figure S24.** Graph of croconaine dye **1** concentration against absorbance at 780 nm, proving a linear relationship obeying the Beer-Lambert Law (A = ε.c.l).

## Activated Photothermal Heating Experiment

The same experimental set-up was used as described above, except a 4.0 µg/mL solution of croconaine dye **1** in $CHCl_3$ was studied, the laser wavelength was set at 830 nm, and after 10 minutes irradiation 50 molar equivalents of macrocycle **2** were added with no increase in sample volume.

**Table S5.** Temperature changes observed before and after addition of macrocycle **2** to croconaine dye **1** (4.0 µg/mL, $CHCl_3$) while undergoing laser irradiation (830 nm, 250 mW).

| Croconaine Species | ΔT / °C |
|---|---|
| 1 | 1.7 |
| 2⊃1 | 10.2 |

## Section 5: Croconaine Encapsulation in Water

Water soluble croconaine dye **S3**[S10] and macrocycle **S4**[S11] are both known literature compounds (Figure S25). We would like to acknowledge Prof. Tony Davis (University of Bristol, UK) for providing us with a sample of macrocycle **S4**.

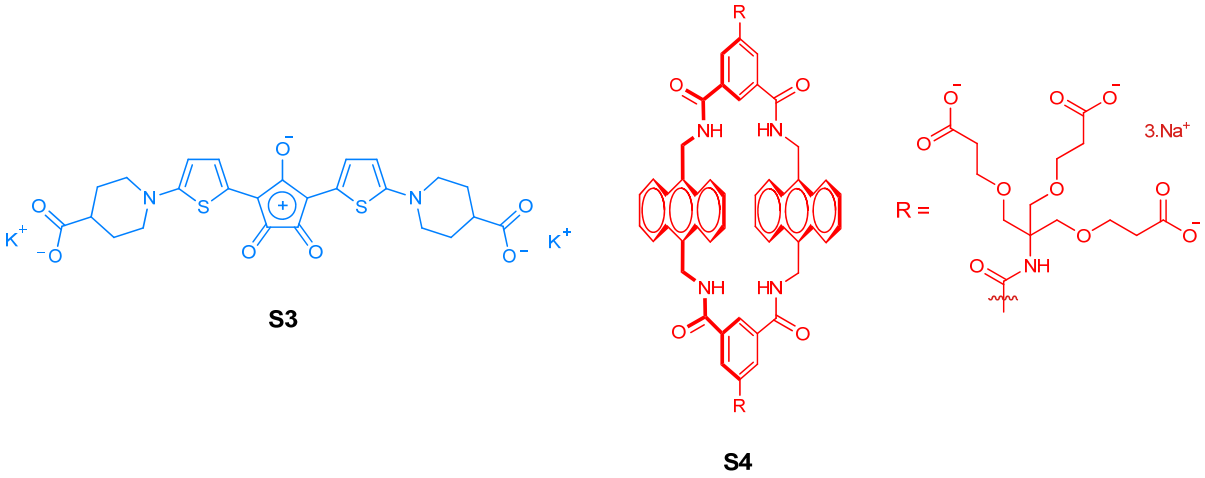



**Figure S25.** Water soluble croconaine dye and anthracene-containing tetra-lactam macrocycle compounds.

To a 2.5 mL, 3 μM (2 μg/mL) solution of croconaine dye **S3** in water was added increasing amounts of macrocycle **S4** (Figure S26).

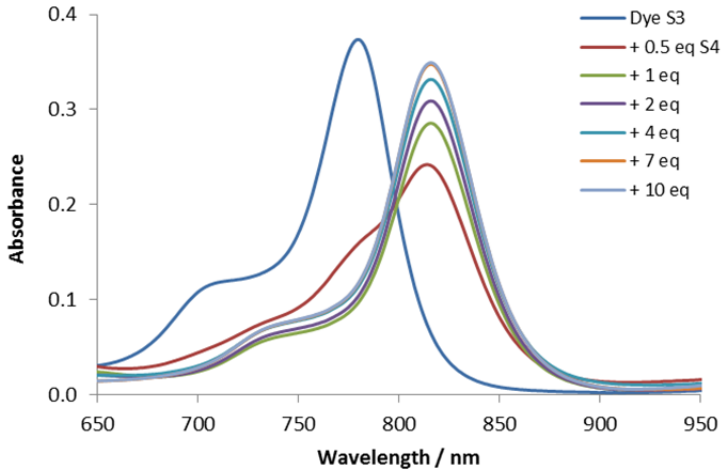



**Figure S26.** Absorption spectra of croconaine dye **S3** upon addition of macrocycle **S4** ($H_2O$, 3 μM). Note: no change in absorbance between samples with 7 and 10 equivalents of added **S4**.

## Section 6: References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