

# Supporting Information

## Photo-powered Stretchable Nano-Containers Based on Well-defined Vesicles Formed by An Overcrowded Alkene Switch

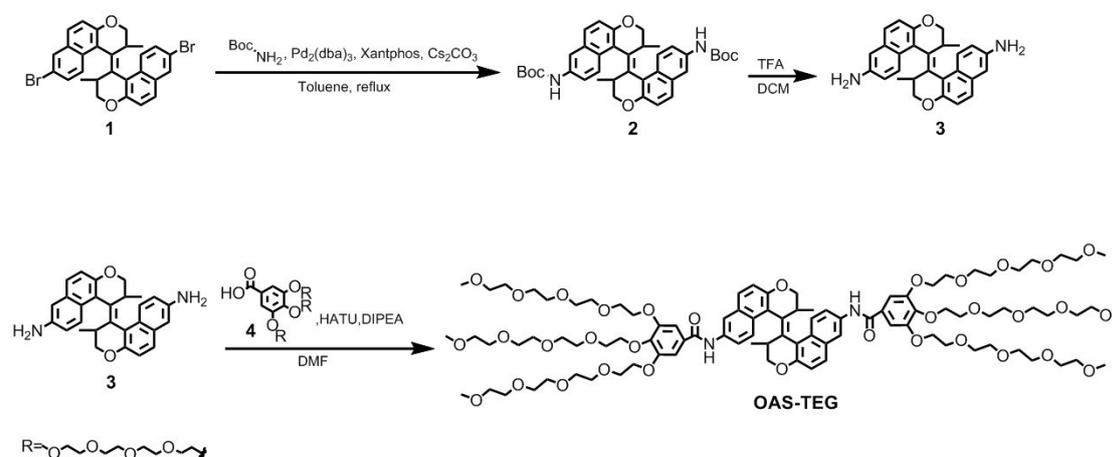
Jing-Jing Yu, Zhan-Qi Cao, Qi Zhang, Shun Yang, Da-Hui Qu\* and He Tian

### 1. Experimental Section

#### 1.1 General Methods and Details

Chemicals were purchased from Acros, Aldrich, Fluka, Adamas, or Merck and used as received unless otherwise stated. Solvents were reagent grade, which were dried and distilled prior to use according to standard procedures. All reactions were carried out under an atmosphere of dry nitrogen unless otherwise stated.  $^1\text{H}$  NMR,  $^{13}\text{C}$  NMR and spectra were measured on a Bruker AV-400 spectrometer. The electronic spray ionization (ESI) mass spectra were tested on a LCT Premier XE mass spectrometer. The UV-vis absorption spectra and fluorescence spectra were also recorded on a Varian Cary 100 spectrometer and a Varian Cary Eclipse (1-cm quartz cell used), respectively. Photo-controlled cleavage experiments were carried out with an UVATA UPF1 UV LED lamp ( $8\text{ W/cm}^2$ ) with a constant wavelength of 365 nm. Surface tension as measured at  $25\text{ }^\circ\text{C}$  by tensiometer DCAT21 (Dataphysics, Germany) using a Wilhelmy small platinum plate of ca. 4 cm perimeter. The plate was first rinsed with deionized water and then burned to red before each measurement. The surface tension of deionized water was measured ( $72 \pm 0.2\text{ mN/m}$ ) at the beginning to check the instrument. Surface tension was measured three times and plotted as a function of concentration. The aggregates of OAS-TEG in water were prepared by dissolving the compound in water directly. DLS were measured on MALV RN, ZETA SIZER, Model ZEN3600, 303K. TEM images were recorded on a JEOL JEM-1400 apparatus, and the samples were prepared by casting dilute solution on copper sheet.

## 1.2. Synthesis

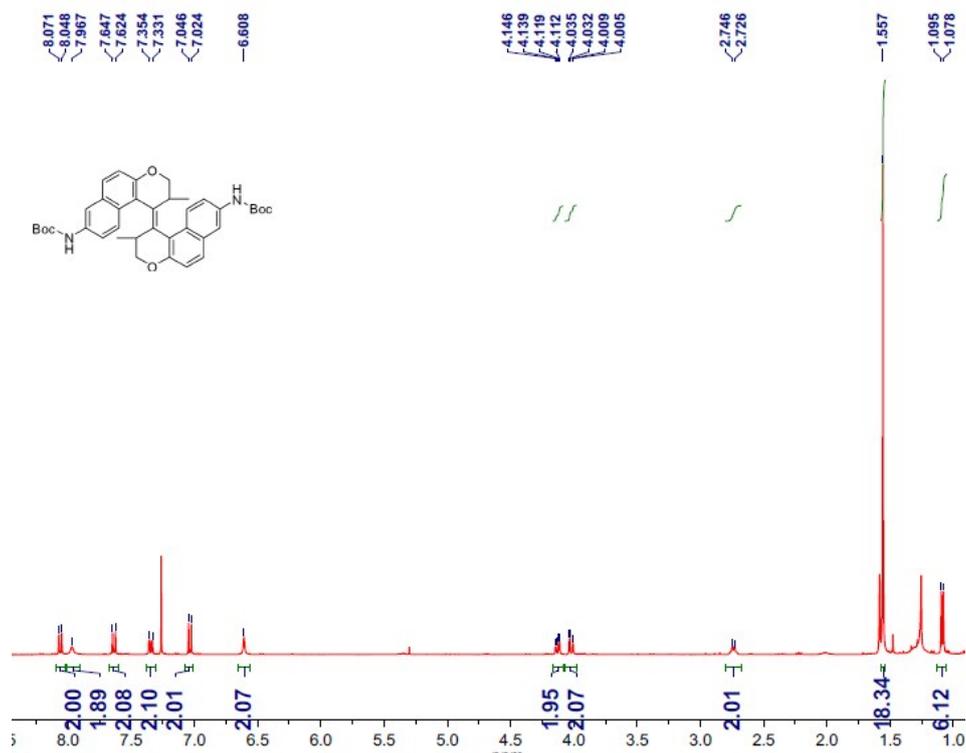


**Scheme S1.** Synthetic route of OAS-TEG.

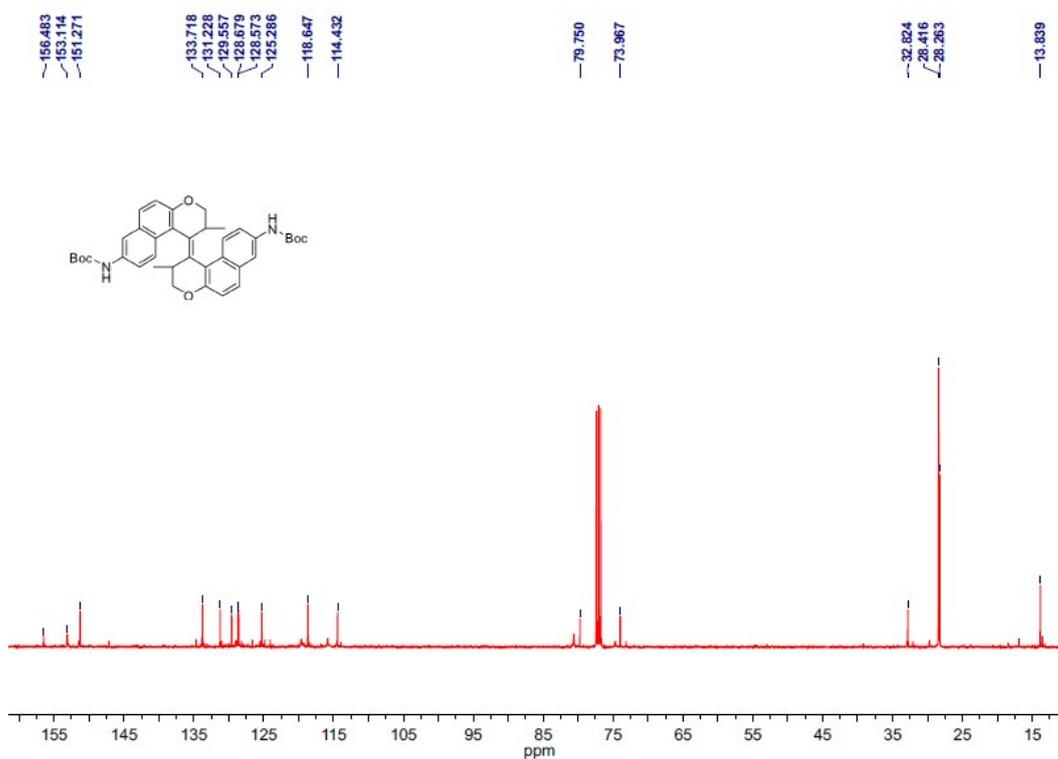
Compound **1** has been synthesized according to the previous procedure as a slightly green solid<sup>1</sup>. Compound **4** was synthesized according to previously reports<sup>2</sup>.

### Synthesis of Compound **2**

To a solution of Compound **1** (200 mg, 0.36 mmol, 1 equiv) in toluene was added tert-butyl carbamate (127 mg, 1.08 mmol, 3 equiv), Pd<sub>2</sub>(dba)<sub>2</sub> (17 mg, 0.018 mmol, 0.05 equiv), Xantphos (32 mg, 0.054 mmol, 0.15 equiv) and Cs<sub>2</sub>CO<sub>3</sub> (127 mg, 326 μmol, 3 equiv). Then the mixture was stirred at 110 °C under Ar for 6 h. After cooling down the reaction solution to room temperature, the mixture was filtered by vacuum filtration, The filtrate was collected, and the solvent was removed under reduced pressure, Subsequent purification by chromatography on silica using PE/EA (20:1) as eluent yielded Compound **2** (170 mg, 75%) as a yellow green solid. <sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>Cl, 298 K) δ (ppm): 8.06 (d, *J* = 9.2, 2H), 7.97 (s, 2H), 7.64 (d, *J* = 9.2, 2H), 7.34 (d, *J* = 9.2, 2H), 7.04 (d, *J* = 8.8, 2H), 6.61 (s, 2H), 4.13 (dd, *J* = 10.8, 2H), 4.13 (dd, *J* = 10.8, 2H), 4.13 (m, 2H), 4.13 (s, 18H), 1.09 (d, *J* = 6.8, 6H). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>, 298 K) δ (ppm): 156.48, 153.11, 151.27, 133.72, 131.23, 129.56, 128.68, 128.87, 125.29, 118.65, 114.43. HRMS (ESI) (*m/z*): [M + Na]<sup>+</sup> calcd for C<sub>38</sub>H<sub>42</sub>N<sub>2</sub>O<sub>6</sub> 645.2935, found 645.2958.



**Figure S1.** <sup>1</sup>H NMR spectrum (400MHz, CDCl<sub>3</sub>) of 2.



**Figure S2.** <sup>13</sup>C NMR spectrum (400MHz, CDCl<sub>3</sub>) of 2.

### Single Mass Analysis

Tolerance = 50.0 PPM / DBE: min = -1.5, max = 100.0

Element prediction: Off

Number of isotope peaks used for i-FIT = 2

Monoisotopic Mass, Even Electron Ions

32 formula(e) evaluated with 1 results within limits (up to 1 closest results for each mass)

Elements Used:

C: 0-38 H: 0-43 N: 0-2 O: 0-6 Na: 0-1

DH-QU

ECUST institute of Fine Chem

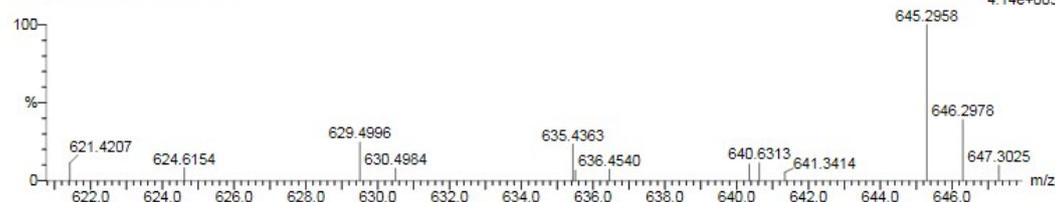
24-Oct-2015

21:36:27

1: TOF MS ES+

4.14e+003

QD-YJJ-002 96 (0.663) Cm (92.98)



Minimum:

Maximum: 300.0 50.0 100.0

Mass	Calc. Mass	mDa	PPM	DBE	i-FIT	i-FIT (Norm)	Formula
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645.2958	645.2941	1.7	2.6	18.5	11.0	0.0	C38 H42 N2 O6 Na
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**Figure S3.** ESI-Mass spectrum of **2**

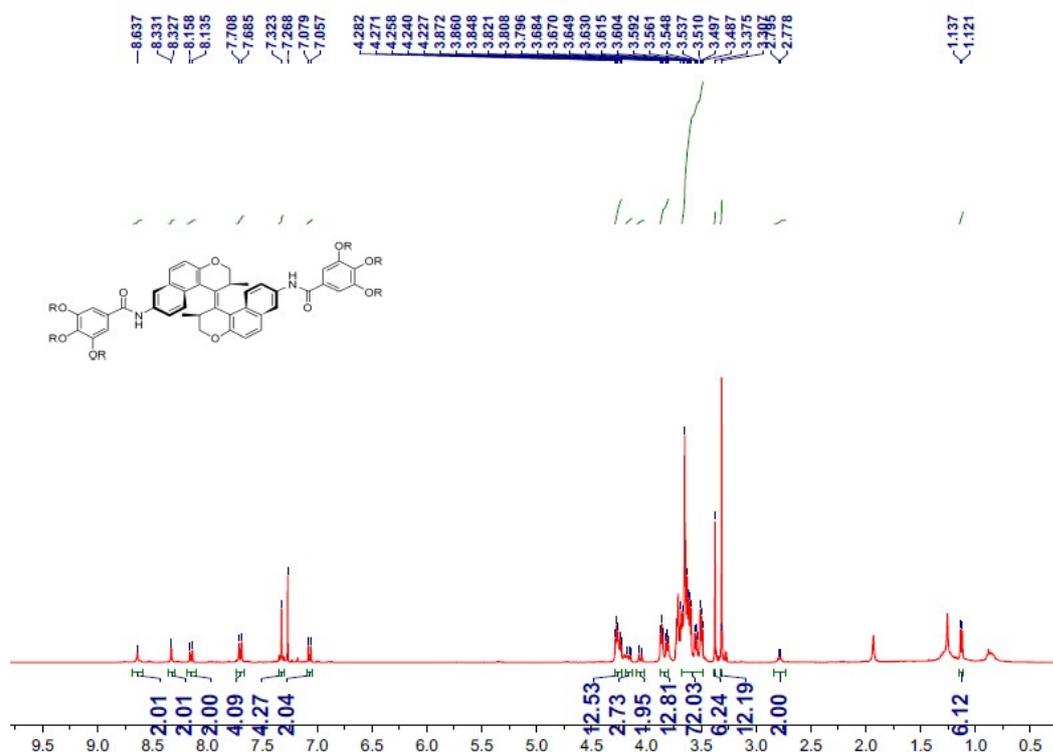
### Synthesis of Compound **3**

To a solution of compound **2** (212 mg, 0.34 mmol, 1 equiv) in DCM was added TFA (776 mg, 6.8 mmol, 20 equiv), then the mixture was stirred at room temperature for 4 h. After that, to the reaction mixture 100 ml of DCM was added and the organic layer was washed with 100 ml saturated NaHCO<sub>3</sub> aqueous followed by 100 ml brine and dried with Na<sub>2</sub>SO<sub>4</sub>. And the solvent was removed under reduced pressure to yield compound **3** (129 mg, 90%) as a light yellow solid. Due to the unstable nature of compound **3**, it was immediately used as starting materials to the next step without subsequent purification.

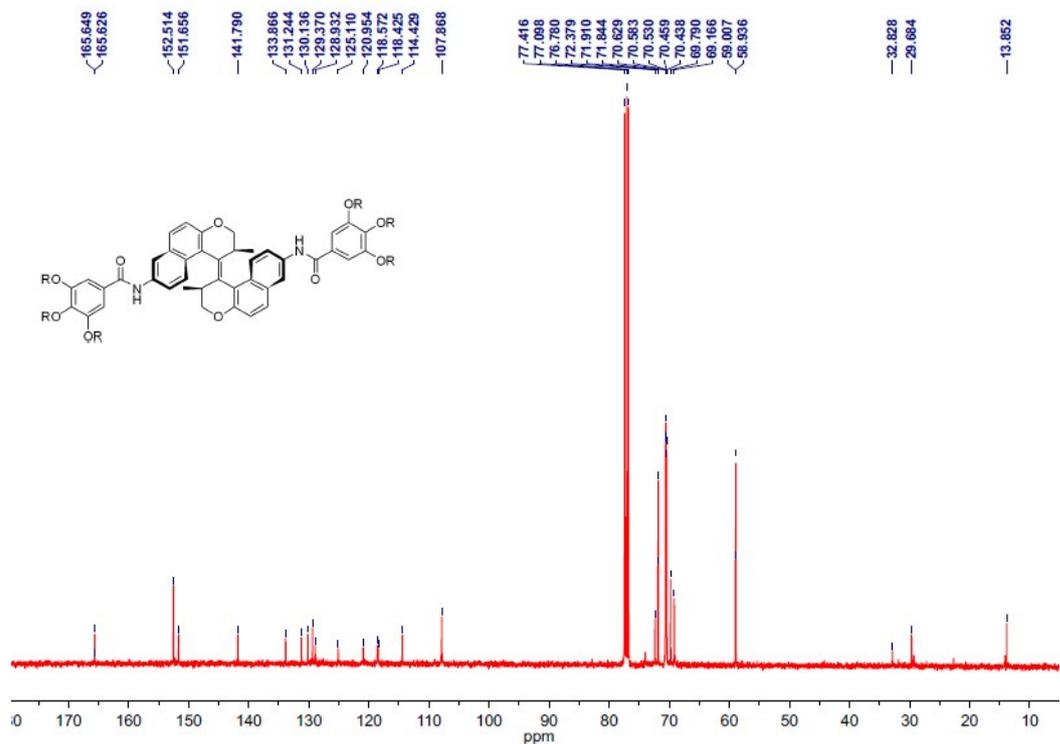
### Synthesis of Compound OAS-TEG

To a solution of compound **3** (100 mg, 0.237 mmol, 1 equiv) in dry DMF was added compound **4** (351 mg, 0.474 mmol, 2 equiv), HATU (360 mg, 0.948 mmol, 4 equiv) and DIPEA (185 mg, 1.422 mmol, 6 equiv), then the mixture was stirred at room temperature under Ar for overnight. After that, the reaction solution was extracted by EtOAc and brine for 6 times, and washed with water for once, then the organic layer was dried by Na<sub>2</sub>SO<sub>4</sub>, and the solvent was removed through reduced pressure to get a crude product, Subsequent purification by chromatography on silica using DCM/MeOH (40:1) as eluent yielded Compound **OAS-TEG** (274 mg, 62%) as a blue

liquid.  $^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{Cl}$ , 298 K)  $\delta$  (ppm): 8.64 (s, 2H), 8.33 (d,  $J=1.6$ , 2H), 8.15 (d,  $J=9.2$ , 2H), 7.70 (d,  $J=9.2$ , 2H), 7.32 (s, 4H), 7.07 (d,  $J=8.8$ , 2H), 4.22-4.28 (m, 12H), 4.16 (dd,  $J=11.2$ , 2H), 4.05 (d,  $J=10.0$ , 2H), 3.78-3.87 (m, 12H), 3.47-3.69 (m, 72H), 3.37 (s, 6H), 3.30 (s, 12H), 2.79 (d,  $J=6.8$ , 2H), 1.13 (d,  $J=6.4$ , 6H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CD}_3\text{Cl}$ , 298 K)  $\delta$  (ppm): 165.64, 152.51, 151.66, 141.79, 133.87, 131.24, 130.14, 129.37, 128.93, 125.11, 120.95, 118.57, 114.43, 107.87, 72.38, 71.87, 70.63, 70.58, 70.53, 70.46, 70.44, 69.79, 58.43, 32.83, 29.68, 13.85. HRMS (ESI) (m/z):  $[\text{M} + \text{Na}]^+$  calcd for  $\text{C}_96\text{H}_{142}\text{N}_2\text{O}_{34}$  1889.9336, found 1889.9338,



**Figure S4.**  $^1\text{H}$  NMR spectrum (400MHz,  $\text{CDCl}_3$ ) of OAS-TEG.



Fig

re S5.  $^{13}\text{HNMR}$  spectrum (400MHz,  $\text{CDCl}_3$ ) of OAS-TEG.

#### Single Mass Analysis

Tolerance = 50.0 PPM / DBE: min = -1.5, max = 100.0

Element prediction: Off

Number of isotope peaks used for i-FIT = 3

Monoisotopic Mass, Even Electron Ions

112 formula(e) evaluated with 1 results within limits (up to 1 closest results for each mass)

Elements Used:

C: 29-96 H: 0-143 N: 1-2 O: 4-34 Na: 0-1

DH-QU

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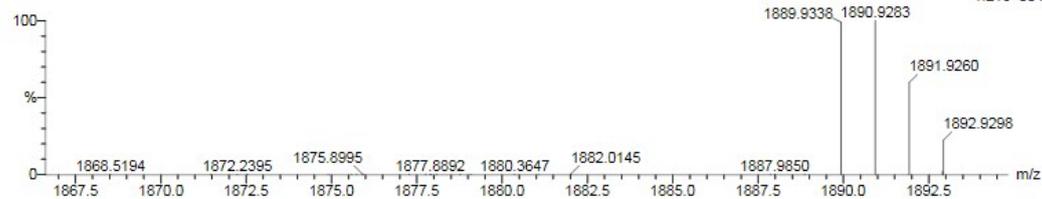
07-Jan-2016

17:05:20

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1.21e+004

QD-YJJ-015 131 (0.896) Cm (129:139)

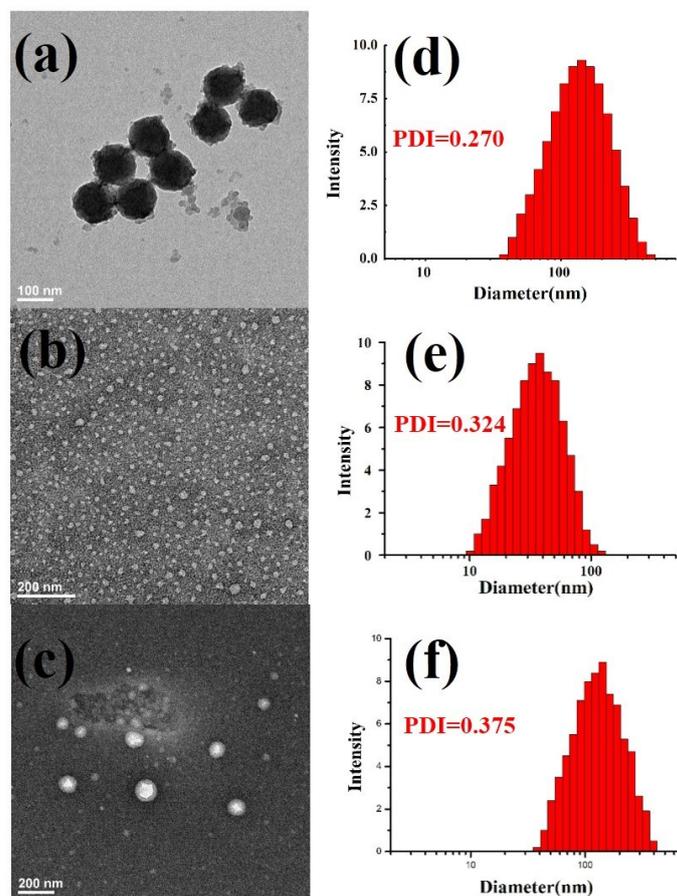


Minimum: -1.5  
Maximum: 300.0 50.0 100.0

Mass	Calc. Mass	mDa	PPM	DBE	i-FIT	i-FIT (Norm)	Formula
1889.9338	1889.9342	-0.4	-0.2	26.5	22.5	0.0	C <sub>96</sub> H <sub>142</sub> N <sub>2</sub> O <sub>34</sub> Na

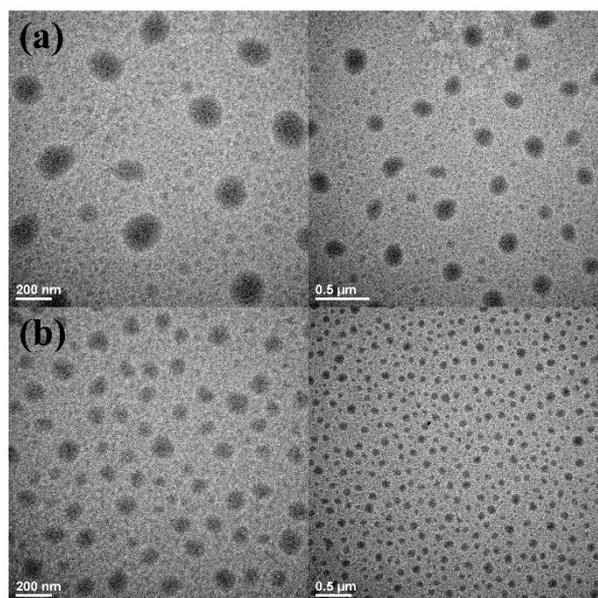
Figure S6. ESI-Mass spectrum of OAS-TEG.

## 2. The reversibility of photo-responsive process in TEM and DLS



**Figure S7.** (a) TEM of OAS-TEG before irradiation of UV light; (b) TEM of OAS-TEG after irradiation of UV light for 15 min; (c) DLS of the irradiated OAS-TEG after standing at 40 °C water bath for 10 min; (d) TEM of OAS-TEG before irradiation of UV light; (e) DLS of OAS-TEG after irradiation of UV light for 15 min; (f) DLS of the irradiated OAS-TEG after standing at 40 °C water bath for 10 min. ( All the samples of TEM were stained by phosphotungstic acid )

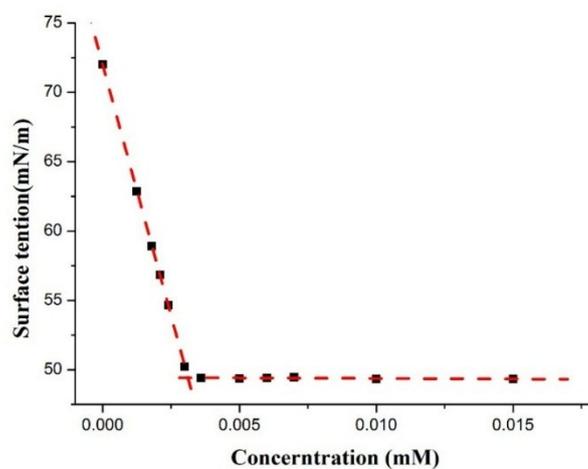
We can observed from the TEM, before irradiation of UV light, OAS-TEG self-assembly formed well-defined and homogeneous vesicles in aqueous solution; After irradiation of UV light, larger vesicles almost disappeared, which have change into smaller vesicles; Then the irradiated OAS-TEG aqueous standing at 40°C water bath for 10 min, the larger vesicles can appeared again. Nevertheless, many smaller vesicles can also be seen. All the size changes of OAS-TEG vesicles are consistent with the corresponding DLS data.



**Figure S8.** (a) TEM images of *trans*-OAS-TEG before irradiation of UV light; (b) TEM images of OAS-TEG after irradiation of UV light for 15 min. (All the samples were not stained).

In order to observe the further morphology of the vesicles, we gained the TEM images from unstained samples. From the TEM figures, we can clearly observe the morphological characteristics of the vesicles whether before or after UV irradiation.

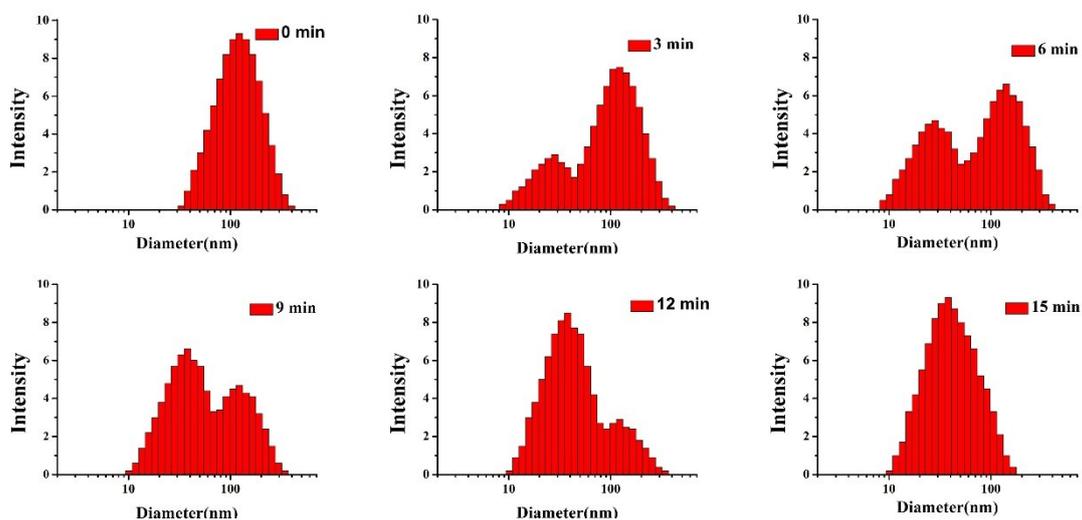
### 3. Critical micelle concentration (CMC) of OAS-TEG in water



**Figure S9.** Surface tension of water as a function of the OAS-TEG concentration. There are two linear segments in the curve and a sudden reduction of the slope, implying that the

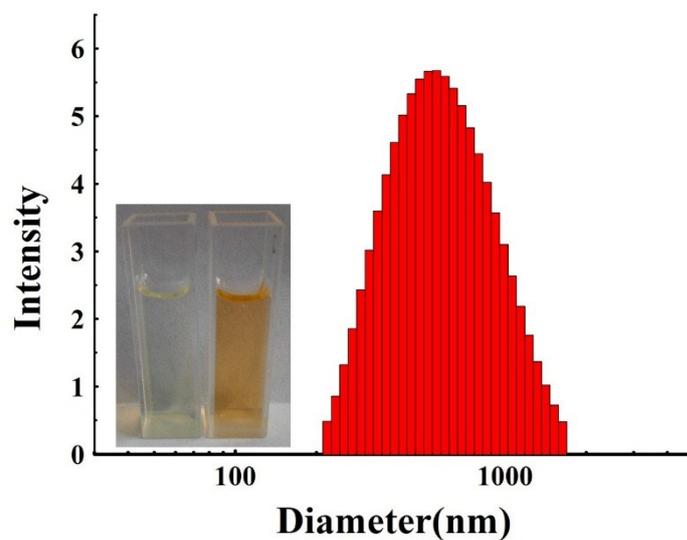
CMC of OAS-TEG is approximately  $3.13 \times 10^{-6}$  M in water.

#### 4. Changeable process of DLS of OAS-TEG



*Figure S10.* Changeable process of DLS of OAS-TEG after irradiation of UV light for 15 min

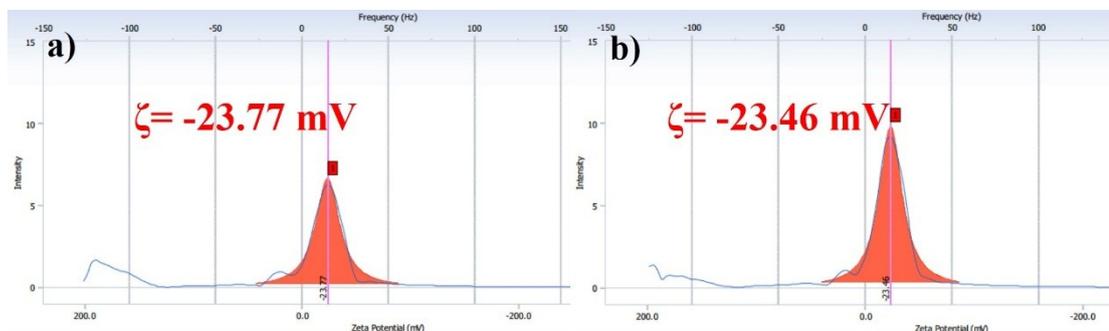
#### 5. The DLS data of calcein-loaded OAS-TEG vesicles



*Figure S11.* DLS data of calcein-loaded OAS-TEG vesicles, Inset Images: unloaded

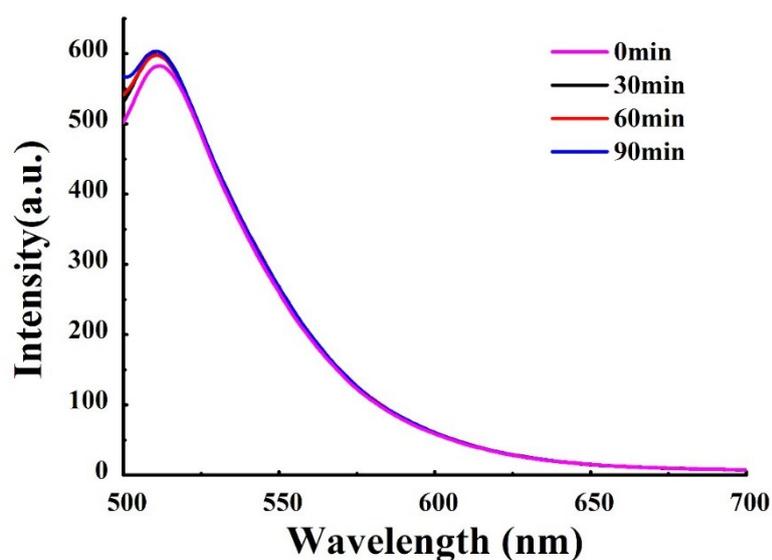
OAS-TEG aqueous (left) and calcein-loaded OAS-TEG aqueous (right)

## 6. $\zeta$ -potential of unloaded and calcein-loaded OAS-TEG vesicles



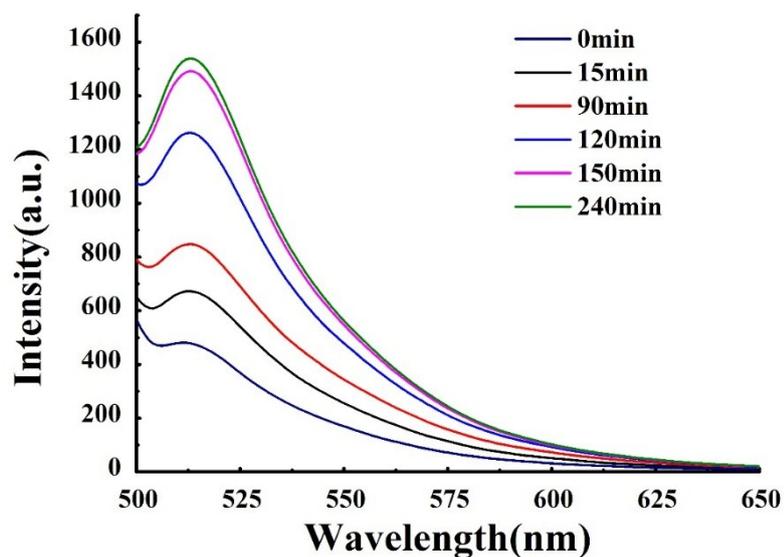
*Figure S12.* (a)  $\zeta$ -potential of unloaded OAS-TEG vesicles; (b)  $\zeta$ -potential of calcein-loaded OAS-TEG vesicles

## 7. The fluorescence intensity change of calcein ( $\lambda_{em}=513$ nm) at different condition

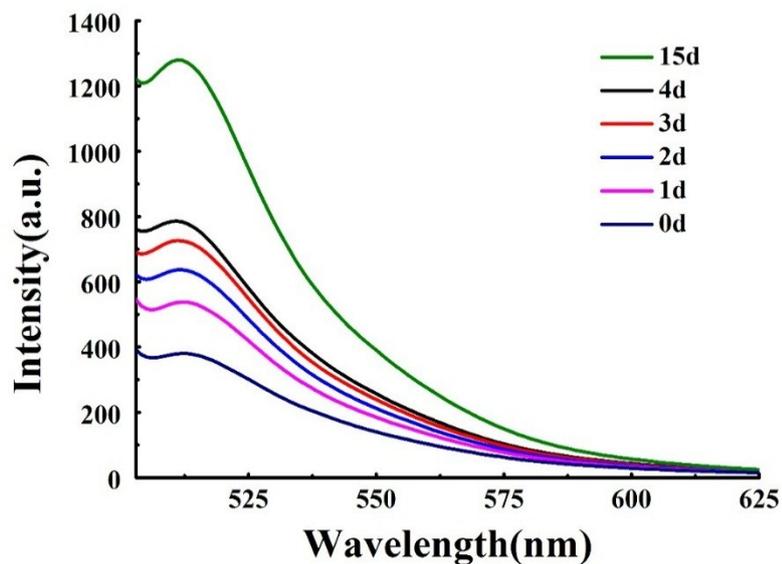


*Figure S13.* Fluorescence intensity change of pure calcein aqueous under irradiation of

UV light over time



*Figure S14.* Fluorescence intensity change of calcein-loaded OAS-TEG aqueous under irradiation of UV light over time



*Figure S15.* Fluorescence intensity change of calcein-loaded OAS-TEG aqueous with no stimulus over time

As can be seen from the contrast experiments, the fluorescence intensity of pure calcein aqueous do not changed under irradiation of UV light, which can prove that calcein was really encapsulated via larger OAS-TEG vesicles. And calcein cannot be released at a short time after irradiation UV light, almost 100% release of calcein need 150 min after irradiation UV light. And calcein can be released from OAS-TEG vesicles spontaneously over time, but only about 15% release after 2days, which would be influenced by UV stimulus from fluorescence spectrophotometer.

### ***References:***

1. W. Zhou, Y. J. Guo and D. H. Qu, *J. Org. Chem.* 2013, **78**, 590-596
2. M. D. Tzirakis, M. N. Alberti, H. Weissman, B. Rybtchinski and F. Diederich, *Chem. Eur. J.* 2014, **20**, 16070-16073