Supporting Information

Structural Effect of Ditopic Azoprobe-Cyclodextrin Complexes upon the Selectivity of Guest-induced Supramolecular Chirality

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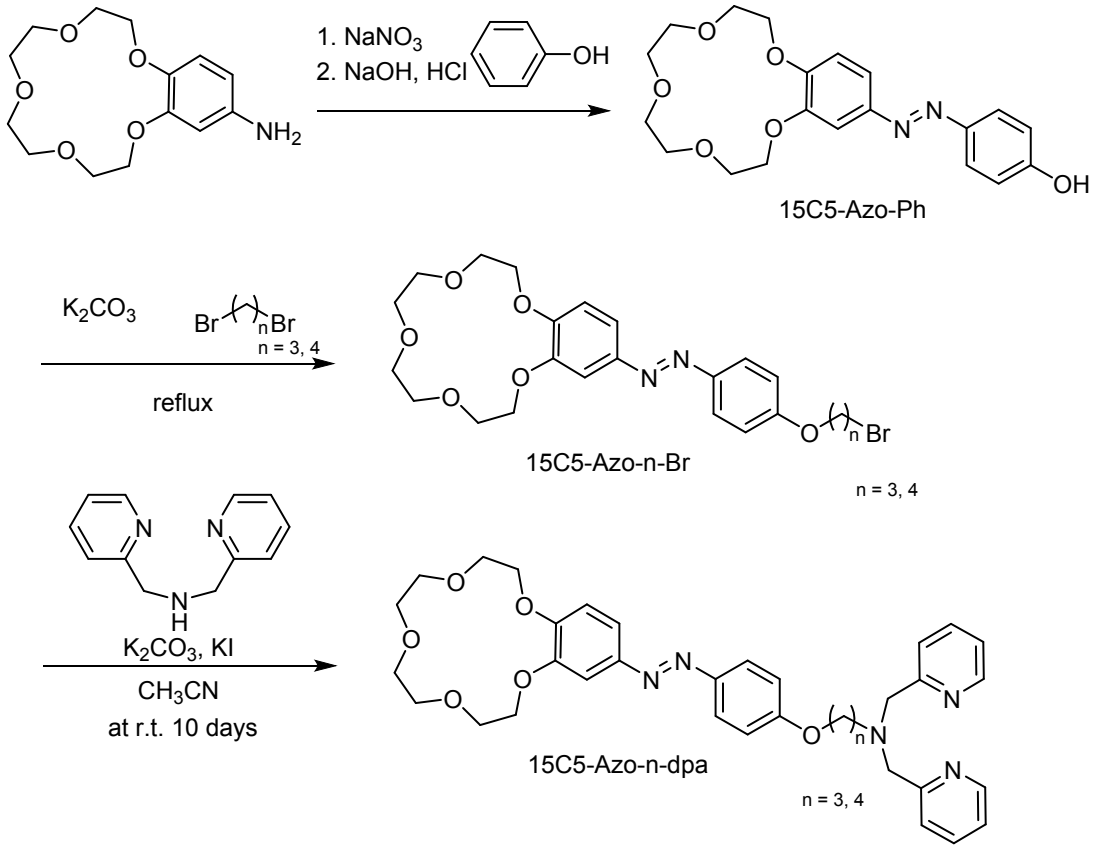
Experimental Procedures

1. Materials and Measurements.

All chemicals were obtained as special-grade reagents from Wako Pure Chemical Industries Ltd. and used as received. Water was doubly distilled and deionized by a Mill-Q water system (WG222, Yamato Sci. Co. Ltd. and Autopure WR-600G, Millipore). ^{1}H NMR spectra were obtained with a JMN-ECX300 (JEOL Ltd.). UV-Vis spectra were recorded with a HITACHI U-3900 spectrometer (HITACHI Corp.) at room temperature (298 K). Quarts cuvette with a 1-cm path length was used. The ICD spectra were obtained with a J-820 spectrophotometer (JASCO Corp.) using a 1.0-cm quartz cell. The scan speed was 120 nm min^{-1}.

2. Synthesis of azoprobes.



Scheme S1. Synthesis route of **15C5-Azo-n-dpa**.

2.1. *N*-(2,3,5,6,8,9,11,12-octahydro-1,4,7,10,13-benzopentaoxacyclopentadecin-15-yl)-azo-4-phenylbromopropylether (**15C5-Azo-3-Br**).

15C5-Azo-3-Br was prepared by procedure[1], with some modifications 1,3-dibromopropane (0.184 g, 1.62 mmol) was slowly added (rate: about 3 seconds per one drop) and refluxed for 48 h. The yield of **15C5-Azo-3-Br** was 20.3 % (0.207 g, 0.330 mmol).

2.2. *N*-(2,3,5,6,8,9,11,12-octahydro-1,4,7,10,13-benzopentaoxacyclopentadecin-15-yl)-azo-4-phenylbromobutylether (**15C5-Azo-4-Br**).

15C5-Azo-4-Br was prepared by procedure[1], with some modifications 1,4-dibromobutane (3.150 g, 16.9 mmol) was slowly added (rate: about 3 seconds per one drop) and refluxed for 48 h. The yield of **15C5-Azo-4-Br** was 57.1 % (0.665 g, 1.29 mmol).

2.3. (E)-2-(4-((2,3,5,6,8,9,11,12-octahydrobenzo[b][1,4,7,10,13]pentaoxacyclopentadecin-15-yl)diazenyl)phenoxy)-N,N-bis(pyridin-2-ylmethyl)ethan-1-amine (**15C5-Azo-3-dpa**).

The mixture, 0.814 g of **15C5-Azo-3-Br** (1.62 mmol), 3.660 g (26.5 mmol) of K_2CO_3 and 0.391 g (2.36 mmol) of KI were dissolved in 70 cm^3 acetonitrile with stirring. Then, 0.466 g of bis(2-pyridylmethyl)amine (2.34 mmol) added. After stirring for 10 days, the solution was filtrated and the solvent was removed under vacuo to obtain orange solid product. The product was purified by column chromatography (silica gel/dichloromethane : methanol = 9 : 1). The product was obtained from the third fraction after removing the eluent under vacuo. The yield of **15C5-Azo-3-dpa** was 20.3 % (0.207 g, 0.330 mmol). ^{1}H NMR ($CDCl_3$, 300 MHz) δ8.52 (dd, J_{ab} = 5.0 Hz, J_{ac} = 5.0 Hz, 2H, ArHa), 7.86 (d, J_{fe} = 10.0 Hz, 2H, ArHf), 7.59-7.55 (m, 3H, ArHi, c), 7.50-7.47 (m, 3H, ArHg, d), 7.12 (td, J_{ba} = 5.0 Hz, J_{bc} = 5.0 Hz, J_{bd} = 5.0 Hz, 2H, ArHb), 6.97 (d, J_{hg} = 5.0 Hz, 2H, ArHh), 6.89 (d, J_{ef} = 9.9 Hz, 2H, ArHe), 4.07(t, J_{ml} = 14.0, 2H, Hm), 3.95-3.79 (m, 16H, Hn, o, p), 3.79 (s, 4H, Hj), 2.77 (t, J_{kl} = 16.0 Hz, 2H, Hk), 2.03 (t, 2H, J_{lk} = 14.0 Hz, Hl), positive FAB-MS (*m/z*): Calcd. for $C_{35}H_{42}N_5O_6$ (M^+): 628.31, Found: 628. Anal. Calcd. for $C_{35}H_{41}N_5O_6 \cdot 0.17CHCl_3$: C, 65.22; H, 6.41; N, 10.81%. Found: C, 65.49; H, 6.26; N, 10.19%.

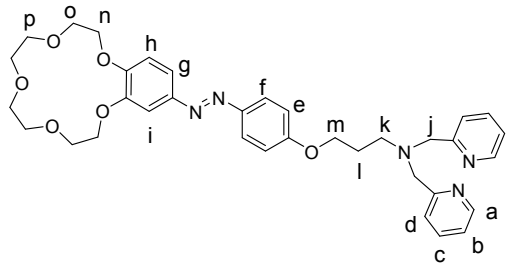


Figure S2. Structure of **15C5-Azo-3-dpa**.

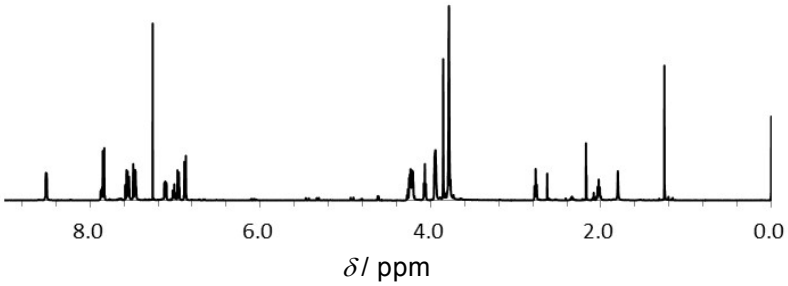


Figure S3. ^{1}H NMR spectrum of **15C5-Azo-3-dpa** (300 MHz in $CDCl_3$).

2.4. (E)-2-(4-((2,3,5,6,8,9,11,12-octahydrobenzo[b][1,4,7,10,13]pentaoxacyclopentadecin-15-yl)diazenyl)phenoxy)-N,N-bis(pyridin-2-ylmethyl)ethan-1-amine (**15C5-Azo-4-dpa**).

The mixture, 0.665 g of **15C5-Azo-4-Br** (1.29 mmol), 3.660 g (26.5 mmol) of K_2CO_3 and 0.391 g (2.36 mmol) of KI were dissolved in 70 cm^3 acetonitrile with stirring. Then, 0.466 g of bis(2-pyridylmethyl)amine (2.34 mmol) added. After stirring for 10 days, the solution was filtrated and the solvent was removed under vacuo to obtain orange solid product. The product was purified by column chromatography (silica gel/dichloromethane : methanol = 9 : 1). The product was obtained from the third fraction after removing the eluent under vacuo. The yield of **15C5-Azo-4-dpa** was 21.9 % (0.181 g, 0.282 mmol). ^{1}H NMR ($CDCl_3$, 300 MHz) δ8.53 (dd, J_{ab} = 3.0 Hz, J_{ac} = 3.0 Hz, 2H, ArHa), 7.75 (d, J_{fe} = 9.0 Hz, 2H, ArHf), 7.64 (td, J_{ca} = 1.8 Hz, J_{cb} = 1.8 Hz, J_{cd} = 1.8 Hz, 2H, ArHc), 7.56-7.52 (m, 3H, ArHi, d), 7.45 (d, J_{gh} = 2.1 Hz, 1H, ArHg), 7.14 (td, J_{ba} = 1.2 Hz, J_{bc} = 1.8 Hz, J_{bd} = 1.2 Hz, 2H, ArHb), 6.97-6.91 (m, 3H, ArHe, h), 4.22 (s, 4H, Hj), 3.97-3.73 (m, 18H, Hn, o, p, q), 2.64 (t, J_{kl} = 1.2 Hz, 2H, Hk), 1.81-1.74 (m, 4H, Hm, l), 3.84-3.77 (m, 4H, Hm), 3.67-3.54 (m, 8H, Ho,p), 2.93 (t, 2H, Hg), positive ESI-MS (*m/z*): Calcd. for $C_{36}H_{44}N_5O_6$ (M^+): 642.3, Found: 642.3. Anal. Calcd. for $C_{36}H_{43}N_5O_6 \cdot 0.1CHCl_3$: C, 66.33; H, 6.65; N, 10.71%. Found: C, 66.35; H, 6.71; N, 10.66%.

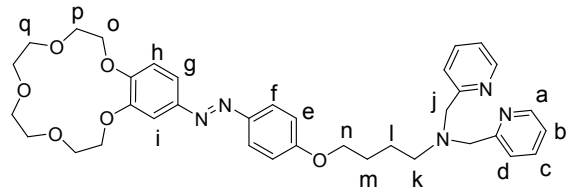


Figure S4. Structure of **15C5-Azo-4-dpa**.

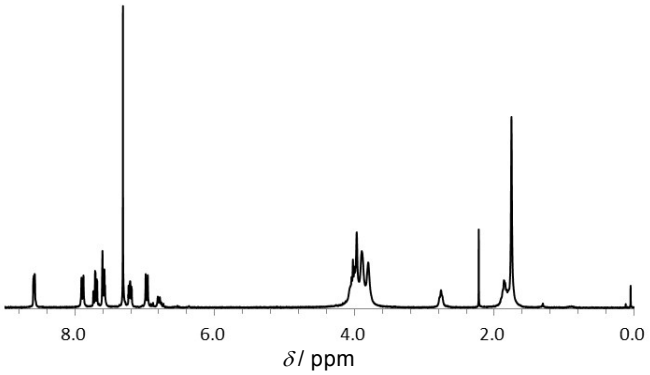


Figure S5. ^{1}H NMR spectrum of **15C5-Azo-4-dpa** (300 MHz in $CDCl_3$).

3. Job's plot analysis for **15C5-Azo-n-dpa**/γ-CyD complex.

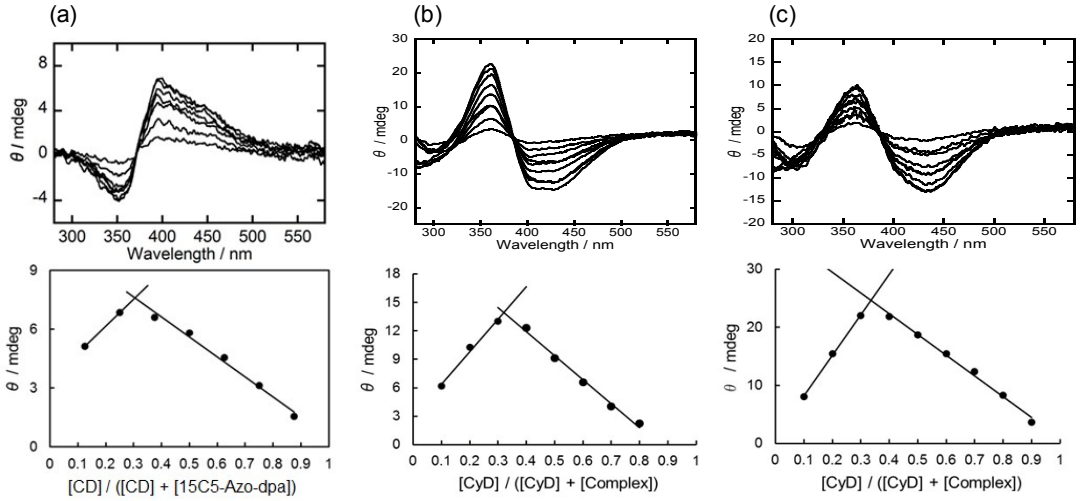


Figure S6. ICD spectra of **15C5-Azo-n-dpa**/γ-CyD sensors (upper), (a) n=2, (b) n=3, (c) n=4, [**15C5-Azo-n-dpa**] = 10-70 μM, [γ-CyD] = 10-70 μM, [Zn^{2+}] = 100 μM, [K_2CO_3] = 50 mM, in 4% DMSO aq., pH = 11.0 at 25°C; (M = mol dm^{-3}). Job's plot calculated with the ICD spectra at 395 nm (a), 360 nm (b), 430 nm (c) (bottom).

4. Selectivity of (**15C5-Azo-n-dpa**)$_2$/γ-CyD complexes (n = 3, 4) for both CO_3^{2-} and OH^- in Figure 5.

As we reported in the previous paper (K. Nonaka et al., *Chem. Commun.*, 2014, **50**, 10059), 1:1 anion binding constants of (**15C5-Azo-2-dpa-Zn^{2+}**)$_2$-γ-CyD were not so high: 84 M^{-1} for CO_3^{2-} and 180 M^{-1} for $CH_3CO_2^-$. In the 50 mM K_2CO_3 solution, pH was 11.0 and thus the concentration of OH^- was ca. 1 mM, which was 50 times lower concentration than that of CO_3^{2-}. Thus we consider by estimating the binding constant of OH^- for (**15C5-Azo-n-dpa-Cu^{2+}**)$_2$-γ-CyD (n = 3, 4) to be ca. 200 M^{-1} as maximum, the concentration of 1 mM OH^- should not be enough to induce a significant ICD response: we can compare the ICD intensities in Fig. 5 between 50 mM OH^- and 50 mM CO_3^{2-}, their intensities were mostly comparable. If only OH^- contributed the ICD response of (**15C5-Azo-n-dpa-Cu^{2+}**)$_2$-γ-CyD system, a large intensity difference in ICD should be noted between 1 mM and 50 mM of OH^- response. This is a clear evidence that the interaction of CO_3^{2-} is involved for ICD response of (**15C5-Azo-n-dpa-Cu^{2+}**)$_2$-γ-CyD complexes (n = 3, 4) in Fig. 5.

5. ^{1}H NMR analysis of **15C5-Azo-3-dpa**/γ-CyD complex with NOESY.

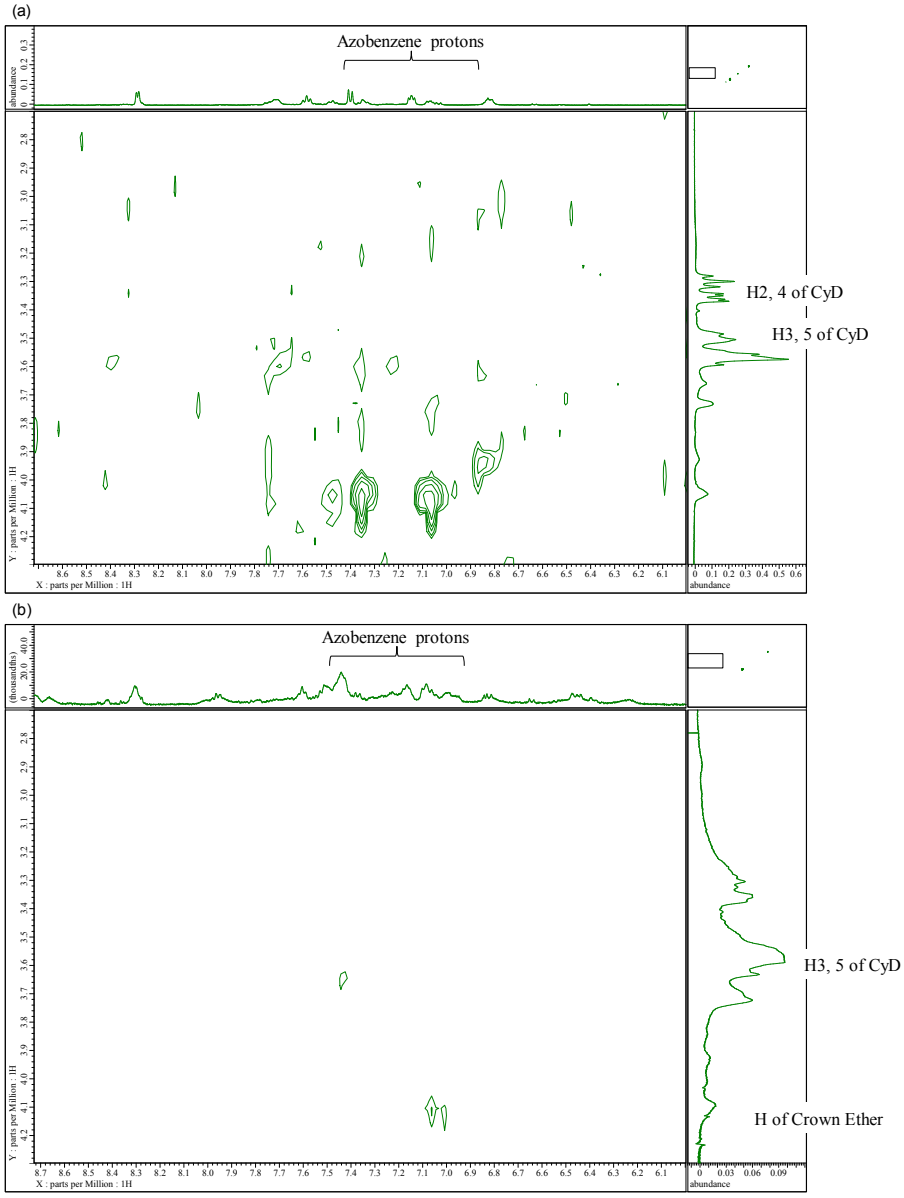


Figure S7. NOESY spectra of **15C5-Azo-3-dpa**/γ-CyD sensors, (a) none, (b) adding Zn^{2+}, K^{+}, CO_3^{2-} at 24°C, 500 MHz, scans:160, acquisition time; 0.1422 sec, relaxation delay; 1 sec, mixing time; 500 msec.

6. Location of **15C5-Azo-2-dpa** dimer inside γ-CyD.

As we reported in the previous paper (K. Nonaka et al., *Chem. Commun.*, 2014, **50**, 10059), when the twisted structure of dimer was strongly induced inside γ-CyD, the benzene protons of crown ether side showed the correlations for the external protons of H2 in γ-CyD (Figure S8 (c)). This may be attributed to that the positioning of crown ether moieties in **15C5-Azo-2-dpa** located relatively the outside of γ-CyD (secondary hydroxyl rim side). In fact, correlations were observed between **15C5-Azo-dpa** and the external protons of H2 in γ-CyD. However, it was found from H-H COSY analysis that there was H3' peak shifted from internal proton of H3 due to the ring current effect of **15C5-Azo-2-dpa** inside γ-CyD, and the observed correlations in NOESY spectra were ascribed to the correlations of benzene proton in 15C5 moiety with H3' and the external H2 located at the secondary hydroxyl rim of γ-CyD (Figure S9). When the twisted structure of dimer was induced inside γ-CyD, the benzene proton h of crown ether side showed the correlations with the crown ether protons in another probe (Figure S7). In addition, only the benzene protons of crown ether side exhibited the peak broadening, indicating the enhanced rigidity due to the twisted structure of bulky benzocrown ether moietis inside γ-CyD. These results indicated that the twisted structure of dimer was induced inside γ-CyD. The twisted structure of dimer is also supported by the ICD responses. Thus we confirmed that the crown ether moiety of **15C5-Azo-2-dpa** located at the secondary hydroxyl rim side of γ-CyD.

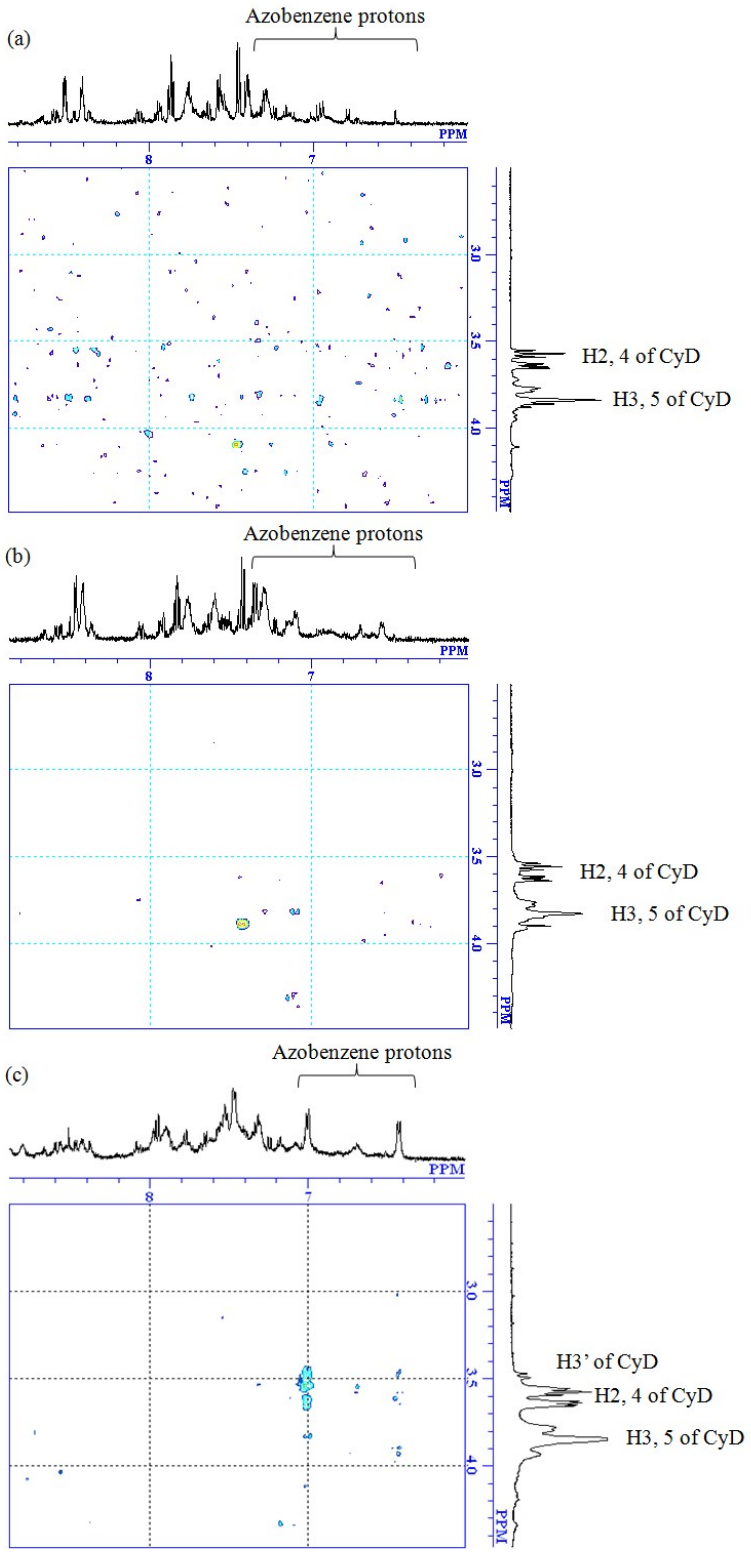


Figure S8. NOESY spectra of **15C5-Azo-2-dpa**/γ-CyD sensors, (a) none, (b) adding Zn^{2+}, (c) adding Zn^{2+}, K^{+}, CO_3^{2-} at 22.8℃, 500 MHz, scans:128, acquisition time; 0.1422 sec, relaxation delay; 1 sec, mixing time; 500 msec. This figure was already reported in ESI of the previous paper (K. Nonaka et al., *Chem. Commun.*, 2014, 50, 10059).

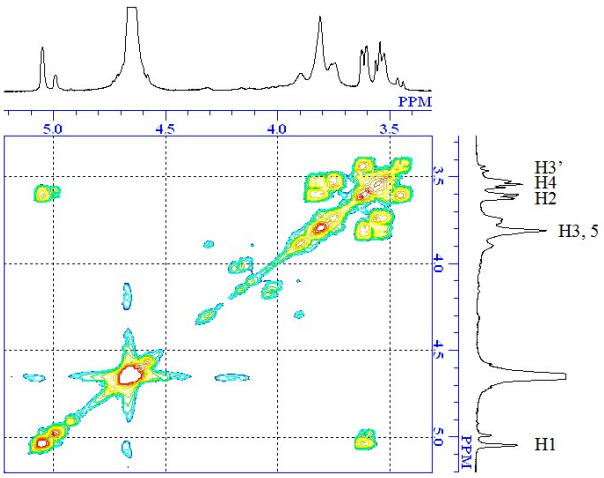


Figure S9. H-H cosy spectrum of **15C5-Azo-2-dpa**/γ-CyD sensors, adding Zn^{2+}, K^{+}, CO_3^{2-} at 22.8℃, 500 MHz, scans:64, acquisition time; 0.1422 sec, relaxation delay; 1 sec, mixing time; 500 msec. This figure was already reported in ESI of the previous paper (K. Nonaka et al., *Chem. Commun.*, 2014, 50, 10059).

7. References

[1] F. Sato, K. Sakamoto, W. Umemoto, T. Hashimoto, and T. Hayashita, Chem. Lett., 2007, 36(7), 880.

[2] F. Sato, M. Tsukano, K. Sakamoto, W. Umemoto, T. Hashimoto, and T. Hayashita, Bull. Chem. Soc. Jpn., 2008, 81, 1589.