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Chiral recognition system orchestrated by self-assembly: A cascade of molecular chirality — self-assembly morphology — fluorescence response

Takao Noguchi,*[a,b,c] Bappaditya Roy,[a] Daisuke Yoshihara,[c] Junji Sakamoto,[c] Tatsuhiro Yamamoto,[c] and Seiji Shinkai*[a,c]

Abstract: The newly developed oligophenylenevinylene (OPV)-based fluorescent (FL) chiral chemosensor (OPV-Me) for the representative enantiomeric guest, 1,2-cyclohexanedicarboxylic acid (1,2-CHDA: *RR*- and *SS*-form) showed the high chiral discrimination ability, resulting in the different aggregation modes of OPV-Me self-assembly: *RR*-CHDA directed the fibrous supramolecular aggregate, whereas *SS*-CHDA directed the finite aggregate. The consequent FL intensity toward *RR*-CHDA was maximum 30 times larger than that toward *SS*-CHDA. Accordingly, highly enantioselective recognition was achieved. The application to the chirality sensing was also possible: OPV-Me exhibited a linear relationship between the FL intensity and the enantiomeric excess through the morphological development of stereocomplex aggregates. These results clearly offer a novel mechanistic view that the chiral recognition ability is manifested by the amplification cascade of the chirality difference through self-assembly.

Development of methodologies to detect and discriminate chiral compounds is of pivotal importance not only in biomedical sciences but also in industrial applications.[1] One of the fundamental challenges underlying the chirality sensing has been focused on the development of chemosensory systems utilizing optical spectroscopic methods because of their feasibility and accessibility.[2–5] Many molecular chemosensors to access chirality information have been demonstrated so far by applying the traditional technique of lock-and-key molecular recognition.[6] Therein, the chemosensors translate the chirality information on a target, through the formation of a lock-and-key-type complex, into the detectable signals such as colorimetric, circular dichroic, and fluorescence (FL) ones, thus visualizing the information on the molecular chirality and the enantiomeric excess (ee).[7–12] In these systems, when a chemosensor for the chirality sensing exhibits an optical response more preferentially toward one of the enantiomers, enantioselective recognition is achieved. Although a number of chiral chemosensors bearing chiral *locks* for targeted enantiomeric *keys* have been reported so far,[13] there still exist many targets for which satisfactory enantioselectivity is not achieved. It is undoubted, therefore, that to develop a novel chiral recognition method that is different from the traditional lock-and-key binding mechanisms,[14] and can overcome these low enantioselectivity problems is a challenging research target.

Recently, we demonstrated a novel molecular recognition system through aggregation-induced FL signaling[15] coupled with a self-assembly mechanism. The underlying concept stems from the specific self-assembly properties. Therein, a small change in a molecular structure could dramatically alter the macroscopic self-assembly morphology and consequently lead to the characteristic materials properties through self-assembly.[16,17] By applying this principle to molecular recognition, we demonstrated that the difference in guest structural information at a molecular level directs the different self-assembly modes (J- or H-type) of the oligophenylenevinylene (OPV)-based FL chemosensor and leads to the distinct macroscopic self-assembly morphologies and the FL outputs characteristic of the initial guest information.[17,18] One may regard, therefore, that self-assembly can function as a system to amplify the difference in molecular information into the macroscopic outputs. In this case, selectivity for a targeted guest is attained by the mode of self-assembly and the consequent relative FL intensity. Taking advantage of self-assembly as an amplification system for molecular recognition, we assumed that the self-assembly system could be applicable to a chiral recognition purpose.

In this study, we demonstrate a novel chiral recognition system coupled with an emerging self-assembly-based FL sensory system. A newly developed OPV chemosensor bearing two chiral spacers (OPV-Me with *R*-configuration, Figure 1a)[19] showed the high chiral discrimination ability for the representative enantiomeric guest, 1,2-cyclohexanedicarboxylic acid (1,2-CHDA: *RR*- and *SS*-form in Figure 1b)[20] through self-assembly. Moreover, its application to the chirality sensing revealed that the FL intensities obtained under the mixed enantiomer conditions of *RR*- and *SS*-CHDA are linearly correlated to the enantiomer fractions, indicating that this system is useful as a FL sensing system for the estimation of the ee. Here, we emphasize that such a unique chiral discrimination ability is achieved when the amplification cascade of molecular information through self-assembly is integrated in a chiral recognition system.

While OPV-Me was virtually nonfluorescent in water containing methanol (MeOH) (Figure S1 in the Supporting

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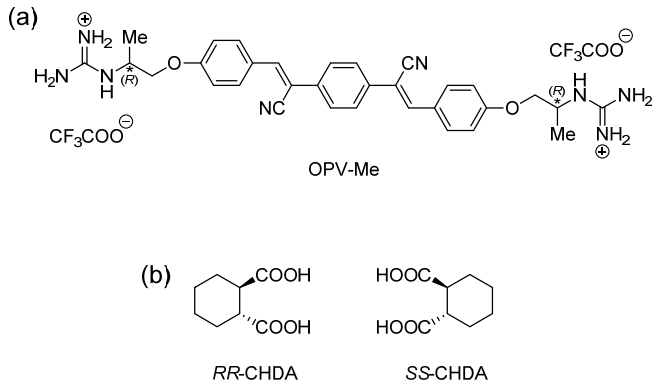

Figure 1. Chemical structures of OPV-Me (a) and enantiomeric *RR*- and *SS*-CHDA (b).

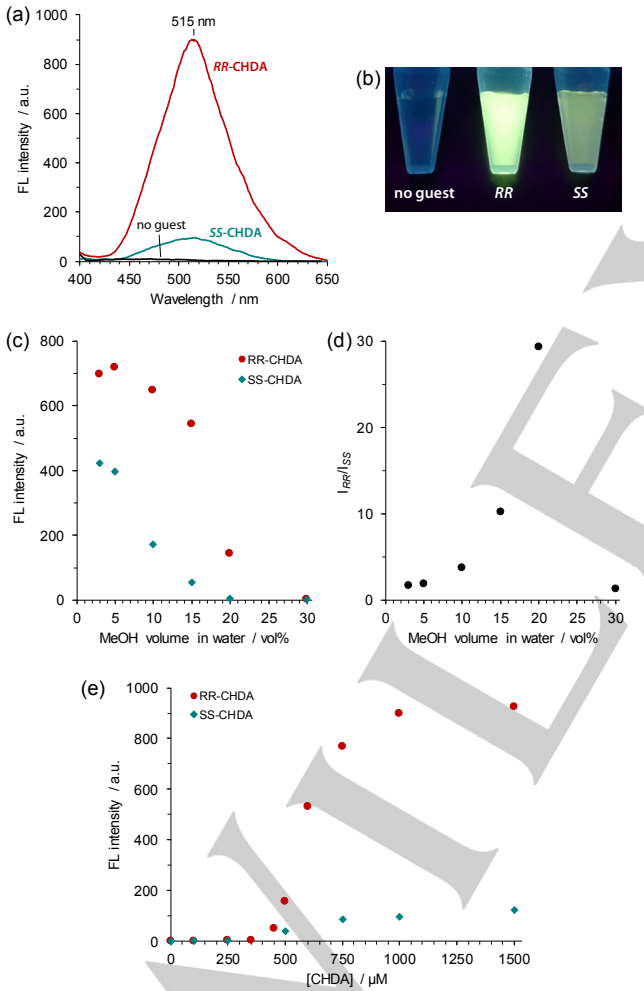

Figure 2. (a) Fluorescence spectra of OPV-Me in the presence of *RR*- and *SS*-CHDA (1.0 mM for both) and (b) the corresponding photograph. (c) Plots of the fluorescence intensities of OPV-Me/CHDA (1.0 mM, fixed) at 515 nm against the MeOH volume, and (d) the corresponding change in the relative fluorescence intensity of OPV-Me for *RR*-CHDA over *SS*-CHDA (I_{RR}/I_{SS}). (e) Changes in the FL intensity of OPV-Me at 515 nm upon increasing concentrations of *RR*- and *SS*-CHDA. Conditions: [OPV-Me] = 10 μM, [HEPES] = 10 mM (pH 7.4), MeOH/water 15:85 (v/v), 25 °C, λ_{ex} = 390 nm.

Information (SI)), the addition of the *RR*- or *SS*-CHDA made its FL turn-on. We found that the FL intensity maximum of OPV-Me (10 μM) toward *RR*-CHDA (1.0 mM) at 515 nm is ca. 10 times larger than that toward *SS*-CHDA (1.0 mM) in HEPES buffered water containing 15 vol% MeOH, its difference being clearly distinguishable by our naked eyes (Figures 2a,b and S2 in the SI). This result guarantees that enantioselective recognition of *RR*-CHDA over *SS*-CHDA is basically possible. Next, we evaluated the performance level of OPV-Me for the enantioselectivity under the optimal conditions. We previously reported that in the self-assembly-based FL sensory system, the selectivity for a targeted analyte can be modified by the competitive binding interference (e.g., by medium pH, salts, etc.) operating in the self-assembly process.[18] In the present study, we examined the effect of the MeOH volume in water on the enantioselectivity in order to directly perturb the self-assembly behavior of OPV-Me. Upon increasing the MeOH volume in water from 3.0 vol% to 30 vol%, the FL intensities of OPV-Me (10 μM) toward *RR*- and *SS*-CHDA (1.0 mM, fixed) were both reduced but the degree of its reduction appeared differently (Figures 2c and S3 in the SI). While the FL intensity of OPV-Me toward *RR*-CHDA remained strong enough, the FL intensity toward *SS*-CHDA decreased more steeply and eventually reached the background level. Indeed, the selectivity evaluated from the relative FL intensity of OPV-Me for *RR*-CHDA over *SS*-CHDA (I_{RR}/I_{SS}) was most enlarged at 20 vol% MeOH (I_{RR}/I_{SS} = ca 30, Figure 2d), where the FL intensity toward *SS*-CHDA was the background level (Figure 2c). In order to evaluate the relationship between the FL intensity and the ee, however, it is necessary to allow *SS*-CHDA to have some FL intensity (vide post). Therefore, we selected the solvent condition of 15 vol% MeOH (MeOH/water 15:85, v/v) for the following experiments, because at 15 vol% MeOH the FL intensity of OPV-Me toward *RR*-CHDA remained strong while the FL intensity toward *SS*-CHDA was weak but still precisely detectable as supported by Figure 2a.

To understand the FL behavior of OPV-Me, a FL titration experiment was performed (Figures 2e and S4 in the SI). Upon addition of *RR*-CHDA a steep nonlinear FL increase characteristic of the self-assembly phenomena[21] was observed whereas upon addition of *SS*-CHDA a weak FL increase was observed. Accordingly, highly enantioselective recognition of *RR*-CHDA was achieved. Here, one important question arises: what is the predominant factors operating for the chiral recognition event?

To address the question, we also studied the self-assembly behavior of OPV-Me. In a UV-Vis titration experiment, OPV-Me showed different spectral changes toward *RR*- and *SS*-CHDA. When the concentration of *RR*-CHDA was increased, the original absorption band of OPV-Me at 370 nm was decreased, concomitantly giving a significant increase in a shoulder band at 425 nm (Figure 3a). This spectral change is in good agreement with that reported previously, attributable to a slip-stacked arrangement of the OPV skeletons with respect to the direction of the molecular long axis.[22] Herein, we classify this mode of arrangement as J-type. In contrast, addition of *SS*-CHDA only showed a decrease in the absorption band at 370 nm without

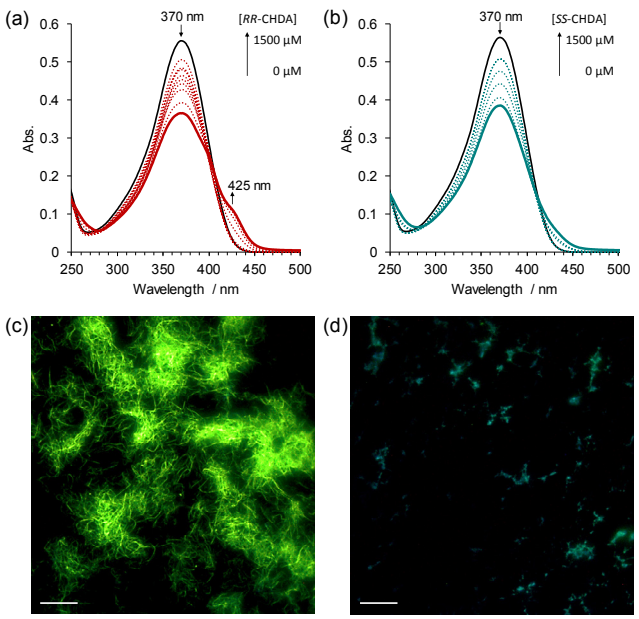

Figure 3. (a,b) Changes in the UV/Vis spectrum of OPV-Me upon increasing concentrations of *RR*-CHDA (a) and *SS*-CHDA (b). Conditions: [OPV-Me] = 10 μM, [HEPES] = 10 mM (pH 7.4), MeOH/water 15:85 (v/v), 25 °C. (c,d) Fluorescence microscopic images of the dispersions of OPV-Me/*RR*-CHDA (c) and OPV-Me/*SS*-CHDA (d). Conditions: [OPV-Me] = 50 μM (to visualize morphologies clearly), [CHDA] = 1.0 mM. Scale bar: 10 μm.

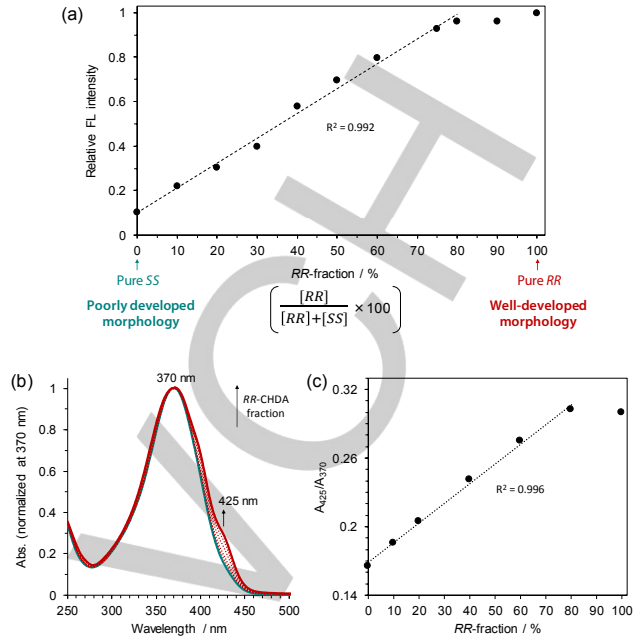

Figure 4. (a) Plot of the FL intensity (λ_{ex} = 390 nm) of OPV-Me at 515 nm against *RR*-CHDA fraction. (b,c) Changes in the relative absorbance of OPV-Me at 425 nm (A_{425}/A_{370}) upon increasing *RR*-CHDA fraction. Conditions: [OPV-Me] = 10 μM, [*RR*-CHDA] + [*SS*-CHDA] = 1.0 mM, [HEPES] = 10 mM (pH 7.4), MeOH/water 15:85 (v/v), 25 °C.

clear appearance of the shoulder band (Figure 3b). To gain more insights into the self-assembly behavior, the effect of the MeOH volume in water was examined. At 5 vol% MeOH a shoulder band at 425 nm which could be ascribable to a slip-stacked arrangement of OPV-Me was clearly observed and this shoulder band disappeared upon increasing MeOH volume from 5 vol% to 15 vol% (Figure S5a in the SI). This is correlated well with reduction of the degree of aggregation and with the consequent FL decrease (Figure 2c, *SS*-CHDA). Thus, the decrease in the absorbance (Figure 3b) is attributed in origin to a slip-stacked arrangement of OPV-Me. It should be taken into consideration that the inherent self-assembly and the FL properties of OPV-Me attained by *SS*-CHDA are different from those attained by *RR*-CHDA as supported by Figure 2c. Here, we tentatively classify the mode of the OPV arrangement attained by *RR*-CHDA as J_{RR}-type and that attained by *SS*-CHDA as J_{SS}-type.

The difference in the self-assembly modes is further supported by the appearance of their macroscopic self-assembly morphologies. The FL microscopic observation for the aqueous dispersions revealed that J_{RR}-type aggregates of OPV-Me (50 μM) associated with *RR*-CHDA (1.0 mM) afforded a well-developed fibrous morphology (Figure 3c).[23] In contrast, J_{SS}-type aggregates of OPV-Me (50 μM) associated with *SS*-CHDA (1.0 mM) afforded a poorly developed morphology (Figure 3d), which is less affected by the MeOH addition (Figure S5b in the SI). Such a macroscopic difference in the self-assembly morphologies is undoubtedly originated from the chirality difference in the enantiomeric *RR*- and *SS*-CHDA. Obviously, sterically favorable *RR*-CHDA for OPV-Me self-assembly achieved a well-developed fibrous morphology, whereas sterically less favored *SS*-CHDA for OPV-Me self-assembly afforded a poorly developed morphology. Therefore, the UV-Vis and the morphological studies provided a clear view that the chirality difference between *RR*- and *SS*-CHDA is amplified into the different modes of OPV-Me self-assembly through the aggregation process. A scenario of the enantioselective chiral recognition can be summarized on the basis of the molecular chirality – self-assembly – FL response cascade: OPV-Me associated with *RR*-CHDA self-assembles favorably in a J_{RR}-type stacked fashion to form a well-developed fibrous morphology and accordingly leads to an intense FL emission, whereas OPV-Me associated with sterically demanding *SS*-CHDA self-assembles in a J_{SS}-type stacked fashion to form a poorly developed morphology affording a much weaker FL emission. As supported by the evaluation of the performance level for the enantioselective recognition (Figure 2c), the enantioselectivity is tunable by skillfully utilizing the difference in the self-assembly properties in a solvent medium.[24]

Since highly enantioselective recognition of *RR*-CHDA over *SS*-CHDA was achieved as shown in Figure 2e, we next studied the FL response of OPV-Me under the mixed enantiomer conditions of *RR*- and *SS*-CHDA toward the chirality sensing. Here, the FL titration experiment was conducted with a continuous variation method about the mole fractions of *RR*- and *SS*-CHDA ([*RR*-CHDA] + [*SS*-CHDA] = 1.0 mM). Interestingly, we found that changes in the FL intensity of OPV-Me exhibit a linear relationship against the *RR*-CHDA fraction from 0% to 80% and reach the plateau (Figures 4a and S6 in the SI). It is worthy to mention that the sensitivity of OPV-Me toward *RR*-

CHDA is enhanced: for example, OPV-Me can sense 10% fraction of *RR*-CHDA ([*RR*-CHDA] = 100 μM and [*SS*-CHDA] = 900 μM) although OPV-Me exhibits virtually no FL response to 100 μM of *RR*-CHDA in a single *RR*-CHDA condition (Figure 2e). The notable points to understand this result are associated with the linearity and the plateau: that is, if OPV-Me could form a J-type aggregate preferentially with *RR*-CHDA under the mixed *RR*- and *SS*-CHDA conditions, then changes in the FL intensity of OPV-Me could show a sigmoidal nonlinear relationship as shown in Figure 2e. Thus, the linear FL change (Figure 4a) strongly supports the view that OPV-Me forms a stereocomplex (co-aggregate) with *RR*-CHDA and *SS*-CHDA. Taking into consideration the fact that OPV-Me forms a poorly developed finite morphology with *SS*-CHDA (0% fraction of *RR*-CHDA in this case) and a well-developed fibrous morphology with *RR*-CHDA (100% fraction of *RR*-CHDA), the linear FL change provides a rationale to explain the FL sensing mechanism: that is, the linearity in the FL changes stems from a continuous change in the self-assembly morphologies from a finite one to a fibrous one. This is also supported by the UV/Vis titration result and the FL microscopic observation. Therein, the increase in the relative absorbance at 425 nm indicative of the well-developed fiber formation exhibits a linear relationship against the increasing *RR*-fraction (Figure 4b,c), correlating well with the morphological development (Figure S7 in the SI). Such a sensing mechanism through the stereocomplex formation can be realized only when the chirality difference in enantiomeric *RR*- and *SS*-CHDA is distinguishable by the self-assembly modes and the consequent FL intensities. This result affords an application prospect that full characterization of the ee with a single chiral FL chemosensor will be possible by manipulating the self-assembly properties (Figure S8 in the SI).

In conclusion, we have developed a novel chiral recognition system coupled with the amplification cascade of molecular information through self-assembly. The chirality difference in enantiomeric *RR*- and *SS*-CHDA is manifested successfully in the self-assembly properties of OPV-Me, which can be visualized as the distinct FL properties and accordingly leads to the enantioselective recognition. By virtue of the enantioselectivity based on self-assembly, a crucial mechanism toward the determination of the ee has been unveiled: that is, the linear correlation between the FL intensity and the ee can be obtained through the morphological development of the stereocomplex aggregates. These results exemplify the emergent property of self-assembly[18b,25] for the application to chiral recognition, which can be regarded as the striking feature realized by the self-assembly-based chemosensory system. We therefore propose an unconventional chiral recognition system emerging through self-assembly: that is, a chirality difference at a molecular level orchestrates self-assembly modes and accordingly leads to a macroscopic output reflecting the initial difference in the chirality information.

Acknowledgements

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Keywords: Chirality • Molecular recognition • Self-assembly • Fluorescent probes • Supramolecular chemistry

[1] V. Schurig, *Differentiation of Enantiomers*, Springer, Heidelberg, **2013**.
[2] L. Pu, *Chem. Rev.* **2004**, *104*, 1687–1716.
[3] G. A. Hembury, V. V. Borovkov, Y. Inoue, *Chem. Rev.* **2008**, *108*, 1–73.
[4] D. Leung, S. O. Kang, E. V. Anslyn, *Chem. Soc. Rev.* **2012**, *41*, 448–479.
[5] C. Wolf, K. W. Bentley, *Chem. Soc. Rev.* **2013**, *42*, 5408–5424.
[6] J.-M. Lehn, *Supramolecular Chemistry: Concepts and Perspectives*, VCH, New York, **1995**.
[7] Colorimetric sensing: Y. Kubo, S. Maeda, S. Tokita, M. Kubo, *Nature* **1996**, *382*, 522–524.
[8] Circular dichroic sensing: a) K. Konishi, K. Yahara, H. Toshishige, T. Aida, S. Inoue, *J. Am. Chem. Soc.* **1994**, *116*, 1337–1344; b) M. Takeuchi, T. Mizuno, S. Shinkai, S. Shirakami, T. Itoh, *Tetrahedron Asymmetry*, **2000**, *11*, 3311–3322; c) L. You, J. S. Berman, E. V. Anslyn, *Nat. Chem.* **2011**, *3*, 943–948; d) M. Anyika, H. Gholami, K. D. Ashtekar, R. Acho, B. Borhan, *J. Am. Chem. Soc.* **2014**, *136*, 550–553; e) F. Biedermann, W. M. Nau, *Angew. Chem. Int. Ed.* **2014**, *53*, 5694–5699; f) S. L. Pilicer, P. R. Bakhshi, K. W. Bentley, C. Wolf, *J. Am. Chem. Soc.* **2017**, *139*, 1758–1761.
[9] Fluorescence sensing: a) L. Pu, *Acc. Chem. Res.* **2012**, *45*, 150–163; b) W.-L. Wong, K.-H. Huang, P.-F. Teng, C.-S. Lee, H.-L. Kwong, *Chem. Commun.* **2004**, 384–385; c) X. Mei, C. Wolf, *J. Am. Chem. Soc.* **2004**, *126*, 14736–14737; d) A. Bencini, C. Coluccini, A. Garau, C. Giorgi, V. Lippolis, L. Messori, D. Pasini, S. Puccioni, *Chem. Commun.* **2012**, *48*, 10428–10430.
[10] Chirality sensing with molecular aggregates: S. Arimori, M. Takeuchi, S. Shinkai, *J. Am. Chem. Soc.* **1996**, *118*, 245–246; b) X. Chen, Z. Huang, S.-Y. Chen, K. Li, X.-Q. Yu, L. Pu, *J. Am. Chem. Soc.* **2010**, *132*, 7297–7299; c) X. Wu, X. –X. Chen, B.-N. Song, Y.-J.Huang, Z. Li, Z. Chen, T. D. James, Y.-B. Jiang, *Chem. Eur. J.* **2014**, *20*, 11793–11799; d) B. Roy, T. Noguchi, Y. Tsuchiya, D. Yoshihara, T. Yamamoto, S. Shinkai, *J. Mater. Chem. C* **2015**, *3*, 2310–2318.
[11] Chirality sensing with polymer systems: E. Yashima, K. Maeda, T. Nishimura, *Chem. Eur. J.* **2004**, *10*, 42–51; b) M. Inoue, M. Waki, H. Abe, *J. Am. Chem. Soc.* **2004**, *126*, 2022–2027; c) G. Fukuhara, Y. Inoue, *Chem. Eur. J.* **2010**, *16*, 7859–7864; d) T. Shiraki, A. Dawn, Y. Tsuchiya, T. Yamamoto, S. Shinkai, *Chem. Commun.* **2012**, *48*, 7091–7093; e) Q. Zhang, Y. Hong, N. Chen, D.-D. Tao, Z. Li, Y.-B. Jiang, *Chem. Commun.* **2015**, *51*, 8017–8019.
[12] Pattern recognition for chirality sensing: a) H. H. Jo, C.-Y. Lin, E. V. Anslyn, *Acc. Chem. Res.* **2014**, *47*, 2212–2221; b) E. G. Shcherbakova, T. Minami, V. Brega, T. D. James, P. Anzenbacher, Jr., *Angew. Chem. Int. Ed.* **2015**, *54*, 7130–7133; *Angew. Chem.* **2015**, *127*, 7236–7239.
[13] X. Zhang, J. Yin, J. Yoon, *Chem. Rev.* **2014**, *114*, 4918–4959.
[14] One example of the improved system for enantioselective recognition: T. Ikeda, O. Hirata, M. Takeuchi, S. Shinkai, *J. Am. Chem. Soc.* **2006**, *128*, 16008–16009.
[15] Y. Hong, J. W. Y. Lam, B. Z. Tang, *Chem. Soc. Rev.* **2011**, *40*, 5361–5388.
[16] M. Yamauchi, B. Adhikari, D. D. Prabhu, X. Lin, T. Karatsu, T. Ohba, N. Shimizu, H. Takagi, R. Haruki, S. Adachi, T. Kajitani, T. Fukushima, S. Yagai, *Chem. Eur. J.* **2017**, *23*, 5270–5280.

[17] T. Noguchi, B. Roy, D. Yoshihara, Y. Tsuchiya, T. Yamamoto, S. Shinkai, *Chem. Eur. J.* **2014**, *20*, 13938–13944, and references cited therein.

[18] a) T. Noguchi, B. Roy, D. Yoshihara, Y. Tsuchiya, T. Yamamoto, S. Shinkai, *Chem. Sci.* **2015**, *6*, 3863–3867; b) T. Noguchi, B. Roy, D. Yoshihara, J. Sakamoto, T. Yamamoto, S. Shinkai, *Angew. Chem. Int. Ed.* **2016**, *55*, 5708–5712; *Angew. Chem.* **2016**, *128*, 5802–5806.

[19] The chiral OPV chemosensors with the branched substituents in the spacer (Me, sec-Bu, tert-Bu, and Bn in Figure 1a) were designed. Among them, OPV-Me showed the highest chiral discrimination ability through self-assembly because the smallest volume of the side-chain substituent is advantageous for the OPV self-assembly.

[20] The enantiomeric CHDA is suitable to demonstrate our concept and sensing mechanism clearly. The applicability of this system to other chiral acids was also confirmed.

[21] a) T. Noguchi, T. Shiraki, A. Dawn, Y. Tsuchiya, L. T. N. Lien, T. Yamamoto, S. Shinkai, *Chem. Commun.* **2012**, *48*, 8090–8092; b) T. Noguchi, A. Dawn, D. Yoshihara, Y. Tsuchiya, T. Yamamoto, S. Shinkai, *Macromol. Rapid Commun.* **2013**, *34*, 779–784.

[22] S.-J. Yoon, S. Y. Park, *J. Mater. Chem.* **2011**, *21*, 8338 –8346.

[23] This correlation between the J-type aggregation mode and the fibrous supramolecular polymer is in good agreement with our previous result (ref. 17).

[24] In other words, the enantioselectivity is controllable by the solubility difference between the diastereomer aggregates (OPV-Me/*RR*-CHDA vs OPV-Me/*SS*-CHDA) in a solvent medium.

[25] Q.-F. Sun, J. Iwasa, D. Ogawa, Y. Ishido, S. Sato, T. Ozeki, Y. Sei, K. Yamaguchi, M. Fujita, *Science* **2010**, *328*, 1144–1147, and references cited therein.

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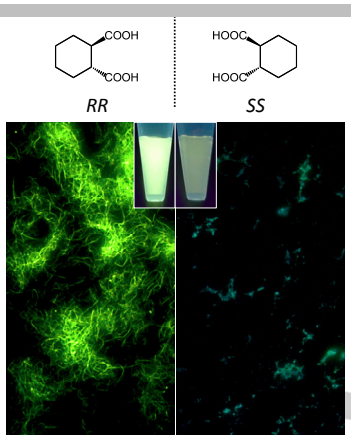
Entry for the Table of Contents

Chiral recognition

Chiral recognition of a guest enantiomer has been achieved by self-assembly of a fluorescent (FL) chiral chemosensor. The highly enantioselective recognition is due to the amplification of the small steric difference through self-assembly into the macroscopic aggregation properties (see graphic). This molecular assembly system possesses a great advantage for chiral discrimination by the FL sensing technique.



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