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# ENANTIOSELECTIVE SYNTHESIS OF SPIROOXINDOLES VIA DIRECT CATALYTIC ASYMMETRIC ALDOL-TYPE REACTION OF ISOTHIOCYANATO OXINDOLES

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*This paper is dedicated to Professor Victor Snieckus on the occasion of his 77th birthday.*

**Abstract** – Direct catalytic asymmetric aldol-type reaction of aldehydes with isothiocyanato oxindoles is described. A dinuclear (*S*)-$Ni_2$-Schiff base complex (0.1-10 mol %) efficiently catalyzed the addition of isothiocyanato oxindoles to aliphatic aldehydes, giving spirooxindole products in 80-99% ee and 81:19-91:9 dr. A $Sr(O\text{-}iPr)_2$/Schiff base complex (10 mol %) was utilized for aryl aldehydes and spirooxindole products were obtained in 33-78% ee and 96:4-98:2 dr.

## INTRODUCTION

Spirooxindoles are privileged structural motifs found in many alkaloids and unnatural biologically active compounds.[1] Among them, those with a nitrogen atom at the C3'-position of the oxindole core constitute an important class for the design of medicinally important compounds, such as a CRTH2 antagonist with good oral bioavailability,[2] a selective inhibitor of *Mycobacterium tuberculosis* protein tyrosine phosphatase B,[3] a potent anti-malaria agent,[4] and an inhibitor of the interaction between the tumor suppressor p53 and its negative regulator Hdm2 (Figure 1).[5] Inspired by their important biological activities, various synthetic methods for producing chiral spirooxindoles with a nitrogen atom at the C3'-position have actively been investigated.[6,7] For rapid access to the spirooxindole core bearing a nitrogen atom at the C3'-position, the use of isothiocyanato oxindoles **1** as donors in the reaction of electrophiles is an attractive strategy.[8-12] In 2011, Yuan and coworkers were the first to demonstrate the utility of **1** as donors in the catalytic asymmetric addition to ketones, affording spirooxindoles with

vicinal quaternary carbon stereocenters.[8] Several groups have performed organocatalytic Michael reaction/cyclization sequences for the construction of spirocyclic oxindole cores.[9] We, in collaboration with Shibasaki, also utilized isothiocyanato oxindoles in the reaction of aldimines with Sr(O-*i*Pr)$_2$/Schiff base **2** complexes (Figure 2).[10] In this article, we describe the full details of our efforts to further expand the scope of available chiral spirooxindoles via aldol-type addition with aldehydes under metal/Schiff base catalysis.[11]

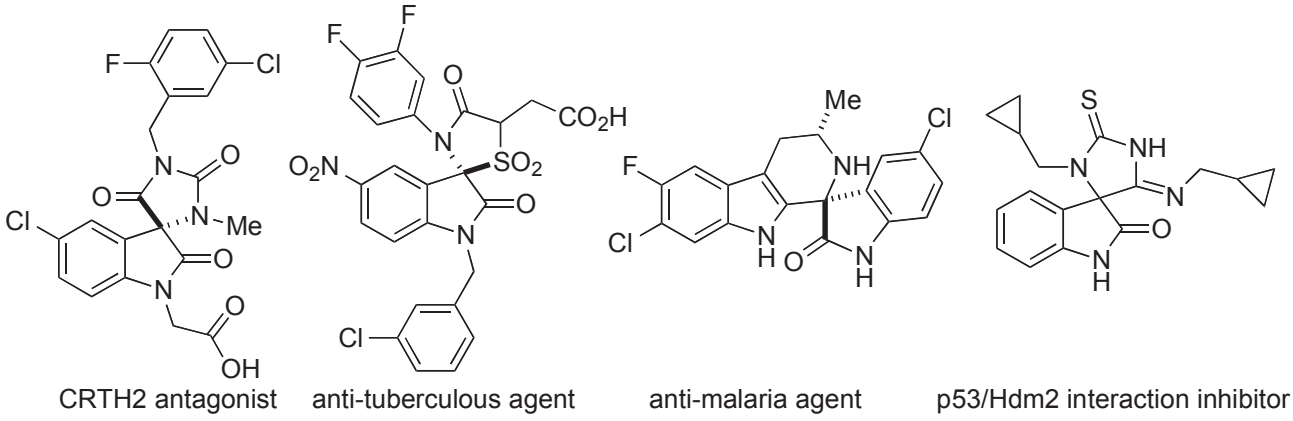



**Figure 1.** Structures of biologically active spirooxindoles bearing a nitrogen atom at the C3'-position

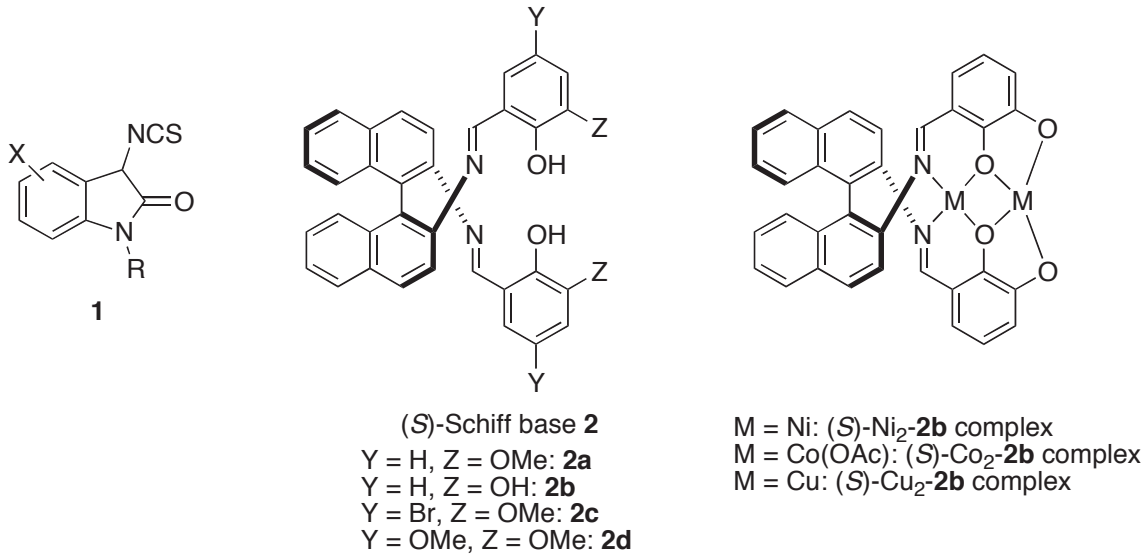


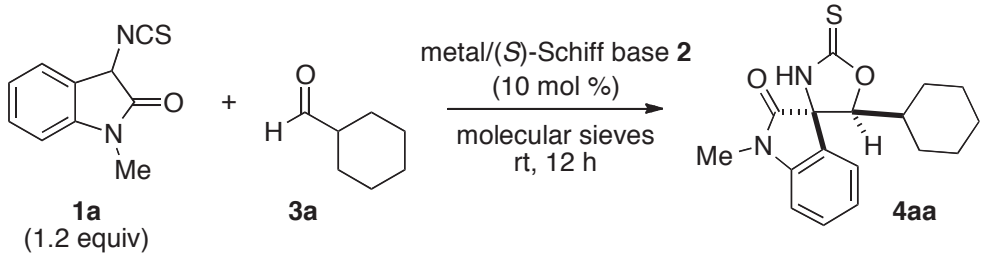

**Figure 2.** Structures of isothiocyanato oxindoles, Schiff bases, and dinuclear transition metal/Schiff base complexes

## RESULTS AND DISCUSSION

Optimization studies using isothiocyanato oxindole **1a** and aliphatic aldehyde **3a** as model substrates are summarized in Table 1. Because we have previously reported the utility of various group 2 metal/Schiff base **2a** complexes as well as dinuclear transition metal/Schiff base **2b** complexes for the enantioselective

reaction with related oxindoles, isoindolinones, and α,β-unsaturated γ-butyrolactam as donors,[13] we screened those metal/Schiff base complexes for the present reaction. Although the Sr(O-*i*Pr)$_2$/Schiff base **2a** (and its biphenyldiamine analogue) = 1:1 complex was suitable for the reaction of **1a** with aldimine,[10] the Sr-**2a** catalyst resulted in poor enantioselectivity for aldehyde **3a** even at low temperature (entry 1, 3% ee). Among other catalysts screened (entries 2-4),[13] the Ni$_2$-**2b** complex[14,15] gave promising results and product **4aa** was obtained in 88:12 dr and 84% ee (entry 3). After further optimization of the solvent (entries 5-9) and molecular sieves (entries 10-11), the best stereoselectivity was achieved in 1,4-dioxane at ambient temperature in the presence of molecular sieves 3Å, and **4aa** was obtained in 91% yield, 89:11 dr, and 91% ee (entry 11).

**Table 1.** Optimization Studies for Aliphatic Aldehyde **3a**



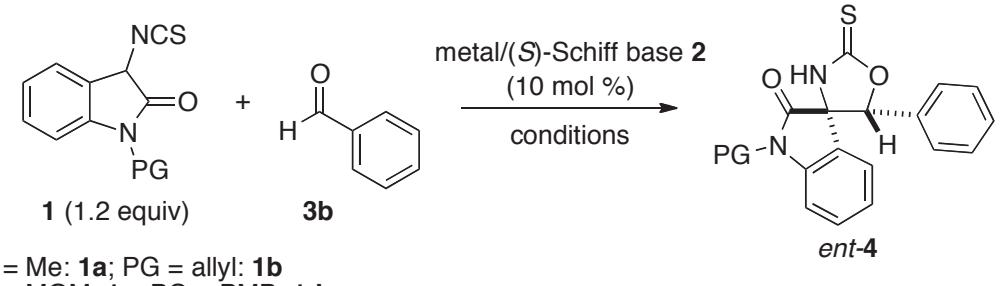

**1a** (1.2 equiv) **3a** **4aa**

| entry | catalyst | solvent | temp (°C) | molecular sieves[a] | % yield[b] | dr[b] | % ee[c] |
|---|---|---|---|---|---|---|---|
| 1 | Sr(O-*i*Pr)$_2$/**2a** | THF | –40 | MS 5Å | >95 | >95:5 | 3[d] |
| 2 | Co$_2$-**2b** | THF | rt | MS 5Å | 94 | 87:13 | 21 |
| 3 | Ni$_2$-**2b** | THF | rt | MS 5Å | >95 | 88:12 | 84 |
| 4 | Cu$_2$-**2b** | THF | rt | MS 5Å | 80 | 59:41 | 2 |
| 5 | Ni$_2$-**2b** | toluene | rt | MS 5Å | >95 | 67:33 | 80 |
| 6 | Ni$_2$-**2b** | $CHCl_3$ | rt | MS 5Å | >95 | 67:33 | 70 |
| 7 | Ni$_2$-**2b** | *t*BuOMe | rt | MS 5Å | >95 | 64:36 | 77 |
| 8 | Ni$_2$-**2b** | DME | rt | MS 5Å | >95 | 74:26 | 80 |
| 9 | Ni$_2$-**2b** | 1,4-dioxane | rt | MS 5Å | >95 | 88:12 | 91 |
| 10 | Ni$_2$-**2b** | 1,4-dioxane | rt | MS 4Å | >95 | 89:11 | 90 |
| 11 | Ni$_2$-**2b** | 1,4-dioxane | rt | MS 3Å | >95(91)[e] | 89:11 | 91 |

Footnote[a] 200 mg molecular sieves per 1 mmol of **3a** was used.[b] Determined by $^1$H NMR analysis of crude mixture with dibenzyl ether as an internal standard.[c] Determined by chiral stationary-phase HPLC analysis using CHIRALPAK IA.[d] *ent*-**4aa** was obtained in major.[e] Number in parenthesis is the combined isolated yield of product **4aa** and its diastereomer after purification by silica gel column chromatography.

Although the $Ni_2$-**2b** complex gave the optimal results for aliphatic aldehyde **3a**, the preliminary survey of substrate scope of aldehydes revealed that the $Ni_2$-**2b** complex was not suitable for aromatic aldehyde **3b** (Table 2, entries 1-2), giving product **4ab** in poor diastereo- and enantioselectivity. Thus, we re-screened several metal/Schiff base complexes using aromatic aldehyde **3b**. As shown in Table 2, entry 3, the Sr-**2a** catalyst gave better diastereoselectivity at -40 °C in THF, albeit in poor enantioselectivity (98:2 dr, 27% ee). Other group 2 metal, $Bu_2Mg$, also gave *ent*-**4ab** in high diastereoselectivity, but enantioselectivity

**Table 2.** Optimization Studies for Aromatic Aldehyde **3b**



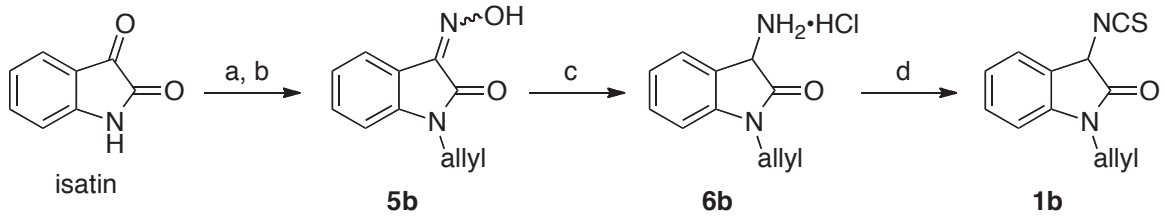

**1** (1.2 equiv) **3b** *ent*-**4**

PG = Me: **1a**; PG = allyl: **1b**
PG = MOM: **1c**; PG = PMB: **1d**

| entry | catalyst | PG | 1 | 4 | solvent | time (h) | temp (°C) | molecular sieves[a] | % yield[b] | dr[b] | % ee[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $Ni_2$-**2b** | Me | **1a** | **4ab** | 1,4-dioxane | 11 | rt | MS 5Å | >95 | 55:45 | 33[d] |
| 2 | $Ni_2$-**2b** | Me | **1a** | **4ab** | THF | 11 | rt | MS 5Å | >95 | 55:45 | 30[d] |
| 3 | Sr(O-*i*Pr)$_2$/**2a** | Me | **1a** | *ent*-**4ab** | THF | 17 | –40 | MS 5Å | >95 | 98:2 | 27 |
| 4 | $Bu_2Mg$/**2a** | Me | **1a** | *ent*-**4ab** | THF | 11 | –40 | MS 5Å | >95 | 98:2 | 3 |
| 5 | Sr(O-*i*Pr)$_2$/**2a** | allyl | **1b** | *ent*-**4bb** | THF | 11 | –40 | MS 5Å | >95 | 98:2 | 27 |
| 6 | Sr(O-*i*Pr)$_2$/**2a** | MOM | **1c** | *ent*-**4cb** | THF | 11 | –40 | MS 5Å | >95 | 98:2 | 20 |
| 7 | Sr(O-*i*Pr)$_2$/**2a** | PMB | **1d** | *ent*-**4db** | THF | 11 | –40 | MS 5Å | >95 | 98:2 | 35 |
| 8 | Sr(O-*i*Pr)$_2$/**2c** | PMB | **1d** | *ent*-**4db** | THF | 17 | –40 | MS 5Å | >95 | 86:14 | 55 |
| 9 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | THF | 12 | –40 | MS 5Å | >95(91)[e] | 98:2 | 78 |
| 10 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | THF | 17 | –60 | MS 5Å | >95 | 97:3 | 75 |
| 11 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | DME | 17 | –40 | MS 5Å | >95 | 71:29 | 5 |
| 12 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | toluene | 17 | –40 | MS 5Å | >95 | 58:42 | 30 |
| 13 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | $CHCl_3$ | 17 | –40 | MS 5Å | >95 | 94:6 | 23 |
| 14 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | THF | 17 | –40 | MS 3Å | >95 | 98:2 | 74 |
| 15 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | THF | 17 | –40 | MS 4Å | >95 | 98:2 | 72 |
| 16 | Sr(O-*i*Pr)$_2$/**2d** | PMB | **1d** | *ent*-**4db** | THF | 17 | –40 | MS 13X | >95 | 93:7 | 70 |

Footnote[a] 200 mg molecular sieves per 1 mmol of **3b** was used.[b] Determined by $^1$H NMR analysis of crude mixture with dibenzyl ether as an internal standard.[c] Determined by chiral stationary-phase HPLC analysis using CHIRALPAK AD-H.[d] **4ab** was obtained in major.[e] Reaction was run using 1.1 equiv of **1d**. Number in parenthesis is the combined isolated yield of *ent*-**4db** and its diastereomer after purification by silica gel column chromatography.

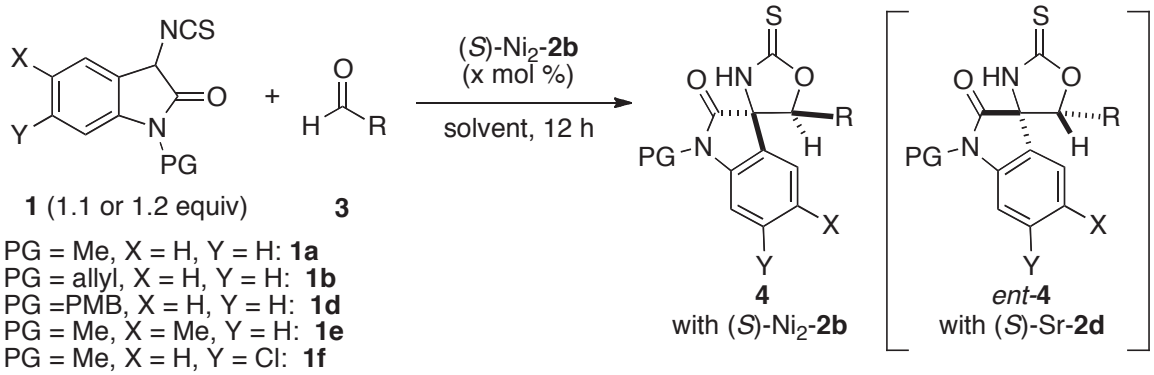
was worse than that with $Sr(O\text{-}iPr)_2$ (entry 3 vs entry 4). The *N*-protecting groups (**1b**-**1d**; entries 5-7) slightly affected enantioselectivity, and *N*-PMB-oxindole **1d** was the best (entry 7, 35% ee). Because the synthetic procedure reported for **1a** was not applicable for *N*-allyl-oxindole **1b**, we modified the synthetic procedure as shown in Scheme 1.[16] Reduction of intermediate **5b** with Zn in AcOH, instead of a Pd/C-catalyzed hydrogenation process used for other derivatives, proceeded smoothly, and 3-amino-oxindole intermediate was isolated as its hydrochloric acid **6b**. Other steps in Scheme 1 were performed by following the reported conditions.[8] Schiff base ligands affected the stereoselectivity (entries 8-9), and Schiff base **2d** bearing additional MeO-units (Figure 2) gave *ent*-**4db** in 78% ee and 98:2 dr (entry 9). Further trials to improve enantioselectiviy by changing reaction temperature, solvent, and/or molecular sieves, however, resulted in less satisfactory selectivity (entries 10-16). Thus, conditions in entry 9 were selected as optimal for aromatic aldehydes.




**Scheme 1.** Synthesis of oxindoles **1b**; reagents and conditions: (a) NaH (1.1 equiv), DMF, 0 °C, 1 h; then allyl iodide (1.1 equiv), rt, 2 h, 81%; (b) $NH_2OH$•HCl (1.5 equiv), $EtOH/H_2O$, rt, 10 h, 94%; (c) Zn (6.0 equiv), AcOH, rt, 3 h; *aq*. $NaHCO_3$ (work-up) and then *aq*. HCl; (d) thiophosgene (1.2 equiv), *aq*. $NaHCO_3$, $CH_2Cl_2$, 0 °C, 30 min, 41% (in 2 steps from **5b**).

The substrate scope of the reaction under the optimized conditions is summarized in Table 3.[17] The results of aliphatic aldehydes under $Ni_2$-**2b** catalysis are summarized in entries 1-13. α-Branched aliphatic aldehydes **3a** and **3c**-**3e** gave spirooxindole products in 83:17-89:11 dr and 80-92% ee (entries 1-4). Linear aliphatic aldehydes **3f**-**3h** showed slightly higher enantioselectivity than the α-branched aldehydes, and products were obtained in 90:10-91:9 dr and 88-99% ee (entries 5-7). Aldehyde **3i**, bearing a silyl ether moiety, also gave product **4ai** with high enantioselectivity and yield, albeit with only moderate diastereoselectivity (81:19 dr, entry 8). In addition to **1a**, oxindole donors with either a Me- (**1e**) or Cl-substituent (**1f**) on the aromatic ring were applicable, and products were obtained in 98% ee and 92% ee, respectively (entries 9-10). Good stereoselectivity was also achieved with oxindole donor **1b**, bearing a removable *N*-allyl protecting group (entry 11, 89% ee). Trials to reduce catalyst loading are summarized in entries 12 and 13. The reaction was promoted by 1 mol % of the $Ni_2$-**2b** catalyst without loss of selectivity, and product **4af** was obtained in 90% yield (TON = 90), 89:11 dr, and 99% *ee* (entry 12).

**Table 3.** Catalytic Asymmetric Aldol Reaction of 3-Isothiocyanato Oxindoles with Aldehydes Under either $Ni_2$ or Sr-Schiff Base Catalysis[a]




**1** (1.1 or 1.2 equiv) **3**

PG = Me, X = H, Y = H: **1a**
PG = allyl, X = H, Y = H: **1b**
PG =PMB, X = H, Y = H: **1d**
PG = Me, X = Me, Y = H: **1e**
PG = Me, X = H, Y = Cl: **1f**

| entry | **1** | R | **3** | (*S*)-cat. (x mol %) | temp (°C) | solvent | molecular sieves | **4** | % yield[b] | dr[c] | % ee[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **1a** | *cyclo*-hexyl | **3a** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4aa** | 91 | 89:11 | 91 |
| 2 | **1a** | *cyclo*-pentyl | **3c** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ac** | 90 | 87:13 | 92 |
| 3 | **1a** | *i*Pr- | **3d** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ad** | 96 | 89:11 | 90 |
| 4 | **1a** | $Et_2CH$- | **3e** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ae** | 92 | 83:17 | 80 |
| 5 | **1a** | *n*-pentyl | **3f** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4af** | 86 | 91:9 | 99 |
| 6 | **1a** | $PhCH_2CH_2$- | **3g** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ag** | 85 | 90:10 | 97 |
| 7 | **1a** | (*E*)-$CH_3(CH_2)_4CH{=}CH(CH_2)_2$- | **3h** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ah** | 82 | 91:9 | 88 |
| 8 | **1a** | $TBSOCH_2CH_2CH_2$- | **3i** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ai** | 99 | 81:19 | 96 |
| 9 | **1e** | *n*-pentyl | **3f** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ef** | 90 | 89:11 | 98 |
| 10 | **1f** | *n*-pentyl | **3f** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4ff** | 84 | 82:18 | 92 |
| 11 | **1b** | *n*-pentyl | **3f** | $Ni_2$-**2b** (10) | rt | 1,4-dioxane | MS 3Å | **4bf** | 96 | 88:12 | 89 |
| 12 | **1a** | *n*-pentyl | **3f** | $Ni_2$-**2b** (1) | rt | 1,4-dioxane | MS 3Å | **4af** | 90 | 89:11 | 99 |
| 13[e] | **1a** | *n*-pentyl | **3f** | $Ni_2$-**2b** (0.1) | rt | 1,4-dioxane | MS 3Å | **4af** | 85 | 71:29 | 98 |
| 14 | **1d** | Ph- | **3b** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4db** | 91 | 98:2 | 78 |
| 15 | **1d** | 3-Me-$C_6H_4$- | **3j** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4dj** | 97 | 98:2 | 68 |
| 16 | **1d** | 4-Me-$C_6H_4$- | **3k** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4dk** | 96 | 96:4 | 45 |
| 17 | **1d** | 4-MeO-$C_6H_4$- | **3l** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4dl** | 97 | 96:4 | 34 |
| 18 | **1d** | 4-F-$C_6H_4$- | **3m** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4dm** | 97 | 98:2 | 60 |
| 19 | **1d** | 2-furyl | **3n** | Sr-**2d** (10) | –40 | THF | MS 5Å | *ent*-**4dn** | 96 | 98:2 | 33 |

Footnote[a] Reaction was run using aldehyde **3** (0.3 mmol in entries 1-11; 0.33 mmol in entry 12; 3.3 mmol in entry 13; 0.2 mmol in entries 14-19), oxindole **1** (1.2 equiv in entries 1-13; 1.1 equiv in entries 14-19), and molecular sieves (200 mg per 1 mmol of **3**). [b] Isolated yield after purification by column chromatography. [c] Determined by $^1H$ NMR analysis of crude mixture. [d] Determined by chiral stationary-phase HPLC analysis using CHIRALPAK IA, IB, ID, AY-H, or AD-H. See experimental section for detail. [e] The reaction was 14 h.

Good yield and enantioselectivity were obtained with as little as 0.1 mol % catalyst loading (TON = 850, 98% ee), although diastereoselectivity decreased to some extent (71:29 dr, entry 13). With aromatic and

heteroaromatic aldehydes **3b** and **3j**-**3n** under the (*S*)-Sr-Schiff base **2d** catalysis (entries 14-19), the reversal of absolute chemistry in products was observed in comparison with (*S*)-$Ni_2$-**2b**. Although the precise reason is not clear, the difference in the structure and dihedral angle of binaphthyl ring might be attributed to the enantiofacial preference of the each catalyst.[18] Although high diastereoselectivity was observed in all cases with aromatic aldehydes, enantioselectivity was significantly affected by a subtle change in the substituent on the aromatic ring, giving products in 33-78% ee (entries 14-19).

The postulated catalytic cycle of the reaction under dinuclear nickel catalysis is shown in Figure 3. Based on previous studies of dinuclear Ni-catalysis,[13,14] we speculate that one of the Ni-O bonds in the outer $O_2O_2$ cavity works as a Brønsted base to deprotonate **1**, generating Ni-enolate *in situ*. The other Ni in the inner $N_2O_2$ cavity functions as a Lewis acid to control the position of aldehyde **3**, similar to conventional metal-salen Lewis acid catalysis. The C-C bond-formation, followed by intramolecular addition to isothiocyanate unit and protonation, affords product **4** and regenerates the $Ni_2$-**2b** catalyst.

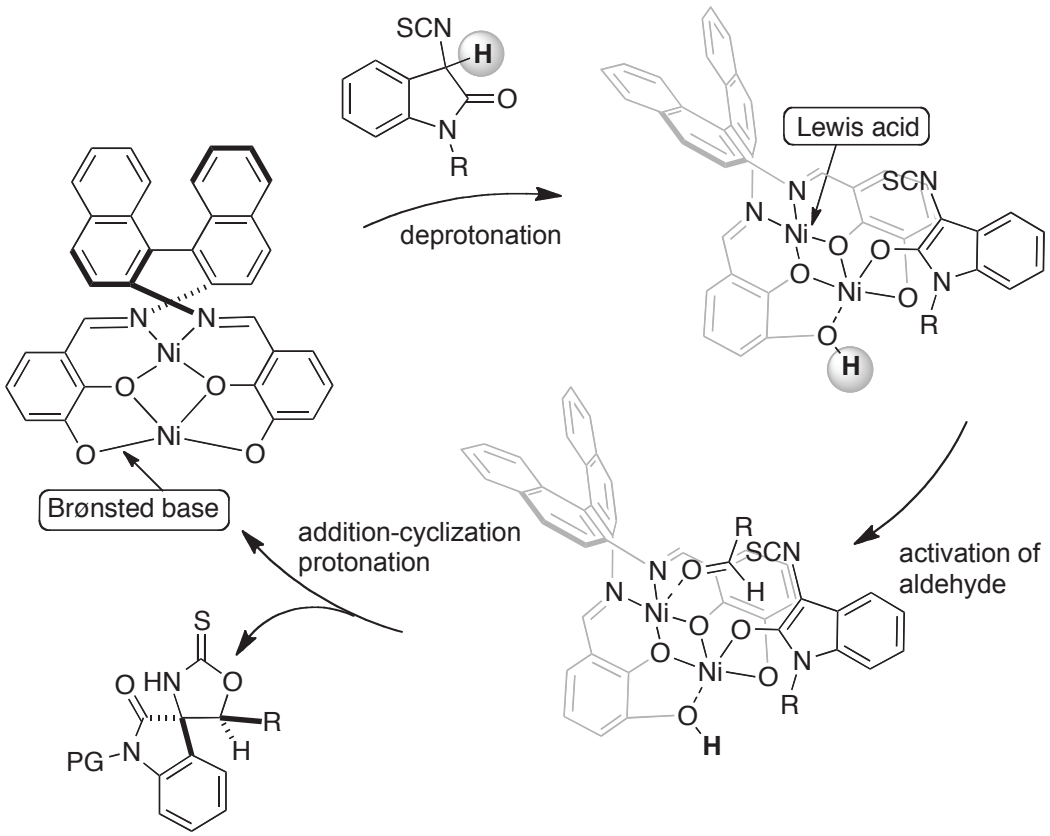



**Figure 3.** Postulated catalytic cycle of the direct aldol-type reaction under dinuclear Schiff base catalysis

In summary, we developed a direct catalytic asymmetric aldol-type reaction of aldehydes with isothiocyanato oxindoles under metal/Schiff base catalysis. A dinuclear $Ni_2$-Schiff base complex efficiently catalyzed the addition of isothiocyanato oxindoles to aliphatic aldehydes, giving spirooxindole

products in 80-99% ee and 81:19-91:9 dr. High TON, up to 850, was observed under dinuclear Ni-catalysis. Because the $Ni_2$-Schiff base complex gave poor selectivity with aromatic aldehydes, a $Sr(O\text{-}iPr)_2$/Schiff base complex (10 mol %) was alternatively utilized for aryl aldehydes, giving products in 33-78% ee and 96:4-98:2 dr.

## EXPERIMENTAL

*General:* Infrared (IR) spectra were recorded on a JASCO FT/IR 410 Fourier transform infrared spectrophotometer. NMR spectra were recorded on JEOL ECX500 spectrometers, operating at 500 MHz for $^1H$ NMR and 125.65 MHz for $^{13}C$ NMR. Chemical shifts in $CDCl_3$ were reported in the scale relative to tetramethylsilane (0 ppm) for $^1H$ NMR. For $^{13}C$ NMR, chemical shifts were reported in the scale relative to $CHCl_3$ (77.0 ppm) as an internal reference. Column chromatography was performed with silica gel Merck 60 (230-400 mesh ASTM). Optical rotations were measured on a JASCO P-1010 polarimeter. ESI mass spectra were measured on Waters micromass ZQ (for LRMS) and ESI mass spectra for HRMS were measured on a JEOL JMS-T100LC AccuTOF spectrometer. The enantiomeric excess (ee) was determined by HPLC analysis. HPLC was performed on JASCO HPLC systems consisting of the following: pump, PU-2080 plus; detector, UV-2075 plus, measured at 254 nm; column, DAICEL CHIRALPAK IA, IB, ID, AY-H, or AD-H; mobile phase, hexane-*i*PrOH. $Sr(O\text{-}iPr)_2$ was purchased from Kojundo Ltd. (Fax: +81-492-84-1351, sales@kojundo.co.jp), and used as received.

### General Procedure for $Ni_2$-Schiff Base-catalyzed Addition to Aliphatic Aldehydes:

A test tube flask charged with MS 3Å (60 mg) was well dried under reduced pressure (around 1.0 kPa) using a heat gun. After cooling to room temperature, argon was re-filled, (*S*)-$Ni_2$-Schiff base **2b** (19.1 mg, 0.030 mmol) and oxindole **1** (0.36 mmol, 1.2 equiv), and anhydrous 1,4-dioxane (1.5 mL) were added to the test tube. To a mixture suspension was added aldehyde **3** (0.30 mmol), and the resulting suspension was stirred at room temperature under Ar atmosphere for 12 h. The reaction was quenched by adding a suspension of silica gel in EtOAc. The mixture was filtered through a filter paper, and sufficiently washed with EtOAc. The diastereomeric ratio of the product was determined at this stage by analysis of crude $^1H$ NMR. After evaporation of the solvent, the crude mixture was purified by flash silica gel column chromatography with $CH_2Cl_2/Et_2O$ (10:1 to 2:1, v:v) to afford product **4**.

**(3*R*,5'*S*)-5'-Cyclohexyl-1-methyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4aa):** a colorless amorphous; IR (KBr) ν 3254, 2928, 2853, 1719, 1613, 1471, 1190 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.57–0.84 (m, 3 H), 1.00–1.20 (m, 3 H), 1.35–1.44 (m, 1 H), 1.60–1.77 (m, 3 H), 2.12–2.25 (m, 1 H), 3.24 (s, 3 H), 4.72 (d, *J* = 10.9 Hz, 1 H), 6.90 (d, *J* = 8.0 Hz, 1 H), 7.15–7.24 (m, 2 H), 7.38–7.50 (m, 2

H); $^{13}$C NMR ($CDCl_3$, 125 MHz) δ 24.6, 24.7, 25.7, 26.7, 27.0, 29.5, 37.7, 68.5, 92.8, 109.1, 123.8, 124.1, 125.5, 131.2, 142.6, 172.1, 189.3; HRMS (ESI): *m/z* calculated for $C_{17}H_{20}N_2NaO_2S^+$ $[M+Na]^+$: 339.1128, found: 339.1124; HPLC (chiral column: CHIRALPAK IA; solvent: hexane/EtOH = 12/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 23.2 min (major) and 36.9 min (minor); $[\alpha]_D^{23.4}$ –105 (*c* 0.76, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-5'-Cyclopentyl-1-methyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ac):** a colorless amorphous; IR (neat) ν 3245, 2956, 2868, 1730, 1613, 1471, 1184 $cm^{-1}$; $^1$H NMR ($CDCl_3$, 500 MHz) δ 0.53–0.81 (m, 2 H), 1.20–1.33 (m, 1 H), 1.39–1.68 (m, 4 H), 1.88–2.09 (m, 2 H), 3.24 (s, 3 H), 4.79 (d, *J* = 10.9 Hz, 1 H), 6.90 (d, *J* = 8.0 Hz, 1 H), 7.09 (s, 1 H), 7.16 (dd, *J* = 7.4, 7.7 Hz, 1 H), 7.37–7.46 (m, 2 H); $^{13}$C NMR ($CDCl_3$, 125 MHz) δ 25.1, 25.2, 26.1, 27.0, 30.9, 39.9, 68.9, 94.1, 109.0, 123.7, 124.6, 125.7, 131.2, 142.8, 172.6, 190.0; HRMS (ESI): *m/z* calculated for $C_{16}H_{18}N_2NaO_2S^+$ $[M+Na]^+$: 325.0981, found: 325.0991; HPLC (chiral column: CHIRALPAK IB; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 10.2 min (minor) and 13.3 min (major); $[\alpha]_D^{23.2}$ –156 (*c* 0.57, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-5'-Isopropyl-1-methyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ad):** a colorless amorphous; IR (KBr) ν 3231, 2967, 1728, 1615, 1472, 1187 $cm^{-1}$; $^1$H NMR ($CDCl_3$, 500 MHz) δ 0.36 (d, *J* = 6.3 Hz, 3 H), 1.13 (d, *J* = 6.9 Hz, 3 H), 1.86–1.96 (m, 1 H), 3.24 (s, 3 H), 4.67 (d, *J* = 10.9 Hz, 1 H ), 6.91 (d, *J* = 8.0 Hz, 1 H ), 6.98 (s, 1 H), 7.17 (dd, *J* = 6.9, 7.4 Hz, 1 H), 7.40 (brd, *J* = 6.9 Hz, 1 H), 7.44 (ddd, *J* = 1.2, 7.4, 8.0 Hz, 1 H); $^{13}$C NMR ($CDCl_3$, 125 MHz) δ 16.8, 20.3, 27.5, 29.4, 69.1, 94.9, 109.6, 124.3, 124.7, 126.1, 131.8, 143.3, 172.6, 190.0; HRMS (ESI): *m/z* calculated for $C_{14}H_{16}N_2NaO_2S^+$ $[M+Na]^+$: 299.0825, found: 299.0834; HPLC (chiral column: CHIRALPAK IA; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 16.7 min (major) and 22.1 min (minor); $[\alpha]_D^{22.9}$ –167 (*c* 0.34, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1-Methyl-5'-(pentan-3-yl)-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ae):** a colorless oil; IR (neat) ν 3254, 2966, 2876, 1731, 1614, 1471, 1188 $cm^{-1}$; $^1$H NMR ($CDCl_3$, 500 MHz) δ 0.47 (dd, *J* = 7.4, 7.4 Hz, 3 H), 0.53–0.64 (m, 1 H), 0.64–0.69 (m, 1 H), 0.86 (dd, *J* = 6.9, 7.2 Hz, 3 H), 1.52–1.75 (m, 3 H), 3.25 (s, 3 H), 4.91 (d, *J* = 10.9 Hz, 1 H), 6.91 (d, *J* = 7.5 Hz, 1 H), 7.00 (brs, 1 H), 7.17 (dd, *J* = 6.9, 7.2 Hz, 1 H), 7.39–7.45 (m, 2 H); $^{13}$C NMR ($CDCl_3$, 125 MHz) δ 9.3, 9.6, 19.2, 20.9, 27.2, 40.0, 68.9, 91.2, 109.4, 124.0, 126.0, 131.5, 143.0, 172.6, 189.6; HRMS (ESI): *m/z* calculated for $C_{16}H_{20}N_2NaO_2S^+$ $[M+Na]^+$: 327.1138, found: 327.1150; HPLC (chiral column: CHIRALPAK IB; solvent: hexane/EtOH = 5/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 6.8 min (minor) and 9.1 min (major); $[\alpha]_D^{22.8}$

–77.4 (*c* 0.50, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1-Methyl-5'-pentyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4af):** a colorless oil; IR (neat) ν 3245, 2954, 1730, 1614, 1471, 1185 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.76 (t, *J* = 6.9 Hz, 3 H), 1.23–1.31 (m, 6 H), 1.31–1.44 (m, 1 H), 1.62–1.76 (m, 1 H), 3.24 (s, 3 H), 4.98 (dd, *J* = 7.2, 9.2 Hz, 1 H), 6.90 (d, *J* = 8.1 Hz, 1 H), 7.16 (dd, *J* = 7.7, 7.7 Hz, 1 H), 7.32 (brs, 1 H), 7.37 (d, *J* = 7.5 Hz, 1 H), 7.43 (dd, *J* = 7.7, 8.1 Hz, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 13.7, 22.1, 24.7, 27.0, 30.1, 31.0, 69.2, 89.4, 109.2, 123.7, 124.0, 125.8, 131.2, 142.7, 172.7, 189.7; HRMS (ESI): *m*/*z* calculated for $C_{16}H_{20}N_2NaO_2S^+$ $[M+Na]^+$: 327.1138 found: 327.1154; HPLC (chiral column: CHIRALPAK ID; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 28.1 min (minor) and 29.4 min (major); $[\alpha]_D^{22.8}$ –102 (*c* 1.29, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1-Methyl-5'-phenethyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ag):** a colorless foam; IR (neat) ν 3252, 2933, 1730, 1614, 1471, 1183 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 1.39–1.51 (m, 1 H), 1.97–2.07 (m, 1 H), 2.38–2.47 (m, 1 H), 2.70–2.80 (m, 1 H), 3.23 (s, 3 H), 5.04 (dd, *J* = 4.6, 9.1 Hz, 1 H), 6.90 (d, *J* = 7.9 Hz, 1 H), 6.95-6.99 (m, 2 H), 7.12–7.23 (m, 4 H), 7.31 (brs, 1 H), 7.36–7.46 (m, 2 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 27.6, 32.1, 32.9, 69.6, 89.1, 109.8, 124.3, 124.3, 126.3, 128.7, 129.0, 131.8, 140.3, 143.3, 173.1, 190.1; HRMS (ESI): *m*/*z* calculated for $C_{19}H_{18}N_2NaO_2S^+$ $[M+Na]^+$: 361.0981, found: 361.0995; HPLC (chiral column: CHIRALPAK AY-H; solvent: hexane/2-propanol = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 46.3 min (major) and 72.1 min (minor); $[\alpha]_D^{23.3}$ –138 (*c* 0.84, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1-Methyl-5'-((*E*)-non-3-en-1-yl)-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ah):** a colorless amorphous; IR (KBr) ν 3250, 2925, 2854, 1732, 1614, 1471, 1186 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.85 (t, *J* = 7.2 Hz, 3 H), 1.07–1.31 (m, 7 H), 1.73–1.93 (m, 4 H), 1.97–2.07 (m, 1 H), 3.24 (s, 3 H), 4.97–5.03 (m, 1 H), 5.09–5.20 (m, 1 H), 5.26–5.35 (m, 1 H), 6.91 (d, *J* = 7.5 Hz, 1 H), 7.17 (dd, *J* = 6.9, 7.6 Hz, 1 H), 7.28 (brs, 1 H), 7.37 (d, *J* = 6.9 Hz, 1 H), 7.43 (dd, *J* = 7.5, 7.6 Hz, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 14.0, 22.4, 27.0, 28.1, 28.9, 30.4, 31.3, 32.3, 69.1, 88.7, 109.2, 123.7, 123.9, 125.8, 126.9, 131.2, 132.7, 142.8, 172,6, 189.7; HRMS (ESI): *m*/*z* calculated for $C_{20}H_{26}N_2NaO_2S^+$ $[M+Na]^+$: 381.1607, found: 381.1615; HPLC (chiral column: CHIRALPAK ID; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 14.6 min (minor) and 15.3 min (major); $[\alpha]_D^{23.0}$ –107 (*c* 0.88, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-5'-(3-((*tert*-Butyldimethylsilyl)oxy)propyl)-1-methyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ai):** a colorless oil; IR (neat) ν 3247, 2954, 2856, 1732, 1614, 1472, 1185 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ –0.08 (s, 6 H), 0.77 (s, 9 H), 1.24–1.36 (m, 2 H), 1.55–1.66 (m, 1 H), 1.70–1.78 (m, 1 H), 3.23 (s, 3 H), 3.41–3.54 (m, 2 H), 5.04 (dd, *J* = 4.6, 7.2 Hz, 1 H), 6.90 (d, *J* = 8.0 Hz, 1 H), 7.11 (brs, 1 H), 7.16 (dd, *J* = 7.7, 7.7 Hz, 1 H), 7.37 (d, *J* = 7.7 Hz, 1 H), 7.42 (dd, *J* = 7.7, 8.0 Hz, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 18.4, 26.0, 27.2, 27.2, 28.3, 61.9, 69.5, 89.6, 109.4, 123.9, 124.2, 126.0, 131.5, 143.0, 172.9, 190.0; HRMS (ESI): *m*/*z* calculated for $C_{20}H_{30}N_2NaO_3SSi^+$ $[M+Na]^+$: 429.1639, found: 429.1640; HPLC (chiral column: CHIRALPAK IA; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 13.5 min (major) and 20.5 min (minor); $[\alpha]_D^{23.1}$ –171 (*c* 0.60, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1,5-Dimethyl-5'-pentyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ef):** a colorless oil; IR (neat) ν 2927, 1717, 1622, 1498, 1362 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.78 (t, *J* = 7.2 Hz, 3 H), 1.01–1.28 (m, 6 H), 1.32–1.46 (m, 1 H), 1.65–1.78 (m, 1 H), 2.35 (s, 3 H), 3.21 (s, 3 H), 4.95–5.05 (m, 1 H), 6.78 (d, *J* = 8.1 Hz, 1 H), 6.99 (brs, 1 H), 7.16–7.23 (m, 2 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 14.2, 21.5, 22.7, 25.2, 27.5, 30.5, 31.5, 69.8, 90.0, 109.4, 124.5, 126.9, 132.0, 134.1, 140.8, 172.9, 190.3 HRMS (ESI): *m*/*z* calculated for $C_{17}H_{22}N_2NaO_2S^+$ $[M+Na]^+$: 341.1300, found: 341.1314; HPLC (chiral column: CHIRALPAK IB; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 14.2 min (minor) and 21.2 min (major); $[\alpha]_D^{22.8}$ –224 (*c* 0.35, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-6-Chloro-1-methyl-5'-pentyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4ff):** a colorless oil; IR (neat) ν 3254, 2955, 2860, 1733, 1611, 1495, 1185 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.79 (t, *J* = 6.9 Hz, 3 H), 1.03–1.26 (m, 6 H), 1.35–1.44 (m, 1 H), 1.60–1.74 (m, 1 H), 3.22 (s, 3 H), 4.97 (dd, *J* = 5.2, 7.2 Hz, 1 H), 6.91 (d, 1.8 Hz, 1 H), 7.16 (dd, *J* = 1.8, 8.0 Hz, 1 H), 7.30 (d, *J* = 8.0 Hz, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 13.9, 22.4, 25.0, 27.4, 30.4, 31.3, 69.1, 89.6, 110.3, 122.5, 123.9, 127.0, 137.5, 144.2, 173.0, 189.8; HRMS (ESI): *m*/*z* calculated for $C_{16}H_{19}ClN_2NaO_2S^+$ $[M+Na]^+$: 361.0748, found: 361.0754; HPLC (chiral column: CHIRALPAK IB; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 17.4 min (minor) and 30.3 min (major); $[\alpha]_D^{22.9}$ –208 (*c* 0.50, $CHCl_3$ for >99% ee sample).

**(3*R*,5'*S*)-1-Allyl-5'-pentyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (4bf):** a colorless oil; IR (neat) ν 3252, 2954, 2860, 1730, 1613, 1469, 1180 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 0.77 (t, *J* = 6.9 Hz, 3 H), 1.25–1.30 (m, 6 H), 1.43–1.51 (m, 1 H), 1.67–1.78 (m, 1 H), 4.18–4.48 (m, 2 H), 4.96–5.07 (m, 1 H), 5.18–5.31 (m, 2 H), 5.72–5.86 (m, 1 H), 6.85–6.94 (m, 1 H), 7.02–7.20 (m, 2 H), 7.33–7.43 (m, 2 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 13.9, 22.3, 24.8, 30.3, 31.3,43.3, 69.4, 89.7, 110.3, 118.9, 123.9, 124.2,

126.1, 130.5, 131.4, 142.4, 172.5, 190.0; HRMS (ESI): *m/z* calculated for $C_{18}H_{22}N_2NaO_2S^+$ $[M+Na]^+$: 353.1294, found: 353.1311; HPLC (chiral column: CHIRALPAK IB; solvent: hexane/EtOH = 7/1; flow rate: 1.0 mL/min; detection: at 254 nm; at rt): $t_R$ = 11.9 min (minor) and 15.6 min (major); $[\alpha]_D^{23.8}$ –184 (*c* 0.42, $CHCl_3$ for >99% ee sample).

**General Procedure for Sr-Schiff Base-catalyzed Addition to Aromatic Aldehydes:**

A test tube flask charged with MS 5Å (40 mg) was well dried under reduced pressure (around 1.0 kPa) using a heat gun. After cooling to room temperature, argon was re-filled, (*S*)-Schiff base **2d** (0.030 mmol) and $Sr(O\text{-}iPr)_2$ (4.12 mg, 0.020 mmol) in 0.60 mL THF was added. After stirring for 1 h at room temperature, aldehyde **3** (0.20 mmol) and THF (0.30 mL) was added to the test tube. The mixture was cooled to –40 ºC, and 3-isothiocyanato oxindole **1** (0.22 mmol, 1.1 equiv) in THF (0.30 mL) was added slowly. The resulting mixture was stirred at –40 ºC under Ar atmosphere for 12 h. The reaction was quenched by adding a suspension of silica gel in EtOAc. The mixture was filtered through a filter paper, and sufficiently washed with EtOAc. The diastereomeric ratio of the product was determined at this stage by analysis of crude $^1H$ NMR. After evaporation of the solvent, the crude mixture was purified by flash silica gel column chromatography with EtOAc/hexane (10:1 to 2:1, v:v) to afford product **4**.

**(3*S*,5'*R*)-1-(4-Methoxybenzyl)-5'-phenyl-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4db):** a colorless solid; IR (KBr) ν 3349, 1726, 1611, 1511, 1467, 1172 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 3.78 (s, 3 H), 4.72 (d, *J* = 14.9 Hz, 1 H), 4.98 (d, *J* = 14.9 Hz, 1 H), 6.15 (s, 1 H), 6.68 (brd, *J* = 7.5 Hz, 1 H), 6.76–6.92 (m, 4 H), 6.96–7.03 (m, 2 H), 7.06–7.18 (m, 4 H), 7.19–7.25 (m, 2 H), 7.56 (brs, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 44.0, 55.2, 70.6, 90.0, 109.6, 114.2, 123.1, 123.6, 125.2, 126.1, 126.8, 128.3, 128.9, 129.0, 130.7, 132.1, 141.7, 159.3, 173.0, 189.9; HRMS (ESI): *m/z* calculated for $C_{24}H_{20}N_2NaO_3S^+$ $[M+Na]^+$: 439.1087, found: 439.1086; HPLC (chiral column: CHIRALPAK AD-H; solvent: hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 18.4 min (minor) and 24.3 min (major); $[\alpha]_D^{28.5}$ +66.6 (*c* 0.73, $CHCl_3$ for >99% ee sample).

**(3*S*,5'*R*)-1-(4-Methoxybenzyl)-2'-thioxo-5'-(*m*-tolyl)spiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4dj):** a colorless solid; IR (KBr) ν 3350, 1728, 1613, 1513, 1468, 1249, 1173 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 2.14 (s, 3 H), 3.78 (s, 3 H), 4.68 (d, *J* = 15.5 Hz, 1 H), 5.03 (d, *J* = 15.5 Hz, 1 H), 6.13 (s, 1 H), 6.67 (d, *J* = 7.6 Hz, 1 H), 6.77–6.87 (m, 5 H), 6.89–6.96 (m, 2 H), 6.97–7.01 (m, 1 H), 7.09 (ddd, *J* = 1.2, 7.6, 7.6 Hz, 1 H), 7.19–7.24 (m, 2 H), 7.47 (brs, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 21.7, 44.6, 55.8, 71.1, 90.6, 110.2, 114.8, 122.9, 123.6, 124.3, 126.3, 126.6, 127.4, 128.7, 129.4, 130.2, 131.2, 132.6, 138.7, 142.3, 159.8, 173.5, 190.5; HRMS (ESI): *m/z* calculated for $C_{25}H_{22}N_2NaO_3S^+$ $[M+Na]^+$: 453.1243, found:

453.1232; HPLC (chiral column: CHIRALPAK AD-H; solvent: hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 15.2 min (minor) and 16.8 min (major); $[\alpha]_D^{24.4}$ +0.10 (*c* 0.64, $CHCl_3$ for 68% ee sample).

**(3*S*,5'*R*)-1-(4-Methoxybenzyl)-2'-thioxo-5'-(*p*-tolyl)spiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4dk):** a colorless solid; IR (KBr) ν 3434, 1725, 1612, 1514, 1468, 1175 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 2.02 (s, 3 H), 3.78 (s, 3 H), 4.72 (d, *J* = 15.5 Hz, 1 H), 4.97 (d, *J* = 15.5 Hz, 1 H), 6.09 (s, 1 H), 6.66 (d, *J* = 7.8 Hz, 1 H), 6.78–6.86 (m, 3 H), 6.88–6.95 (m, 5 H), 7.09 (ddd, *J* = 1.1, 7.8, 7.8 Hz, 1 H), 7.17–7.23 (m, 2 H), 7.71 (brs, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 21.3, 44.2, 55.5, 70.8, 90.4, 109.9, 114.4, 123.4, 123.9, 123.9, 125.5, 126.4, 127.0, 129.1, 129.2, 129.2, 130.9, 139.1, 142.0, 159.5, 173.2, 190.2; HRMS (ESI): *m*/*z* calculated for $C_{25}H_{22}N_2NaO_3S^+$ $[M+Na]^+$: 453.1243, found: 453.1234; HPLC (chiral column: CHIRALPAK AD-H; solvent: hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 16.8 min (minor) and 20.1 min (major); $[\alpha]_D^{23.3}$ –43.5 (*c* 1.2, $CHCl_3$ for 45% ee sample).

**(3*S*,5'*R*)-1-(4-Methoxybenzyl)-5'-(4-methoxyphenyl)-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4dl):** a colorless solid; IR (KBr) ν 3353, 1730, 1612, 1513, 1467, 1251, 1172 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 3.69 (s, 3 H), 3.77 (s, 3 H), 4.69 (d, *J* = 15.5 Hz, 1 H), 4.96 (d, *J* = 15.5 Hz, 1 H), 6.05 (s, 1 H), 6.57–6.65 (m, 3 H), 6.67 (d, *J* = 7.9 Hz, 1 H), 6.78–6.86 (m, 3 H), 6.88–6.96 (m, 3 H), 7.10 (dd, *J* = 7.9, 7.9 Hz, 1 H), 7.14–7.21 (m, 2 H), 7.75 (brs, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 44.1, 55.3, 55.4, 70.9, 90.4, 109.9, 113.9, 114.4, 123.4, 123.9, 123.9, 124.2, 126.3, 127.0, 127.2, 129.1, 130.1, 141.9, 160.1, 173.2, 190.3; HRMS (ESI): *m*/*z* calculated for $C_{25}H_{22}N_2NaO_4S^+$ $[M+Na]^+$: 469.1192, found: 469.1206; HPLC (chiral column: CHIRALPAK AD-H; solvent: hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 24.5 min (minor) and 29.9 min (major); $[\alpha]_D^{25.3}$ +0.74 (*c* 1.2, $CHCl_3$ for 34% ee sample).

**(3*S*,5'*R*)-5'-(4-Fluorophenyl)-1-(4-methoxybenzyl)-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4dm):** a colorless solid; IR (KBr) ν 3347, 1726, 1612, 1513, 1468, 1249, 1173 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 3.79 (s, 3 H), 4.71 (d, *J* = 14.9 Hz, 1 H), 4.96 (d, *J* = 14.9 Hz, 1 H), 6.13 (s, 1 H), 6.72 (d, *J* = 8.0 Hz, 1 H), 6.78–6.88 (m, 5 H), 6.89–7.01 (m, 3 H), 7.14 (ddd, *J* = 1.2, 8.0, 8.0 Hz, 1 H), 7.18–7.25 (m, 2 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 44.9, 55.7, 71.1, 89.9, 110.2, 114.7, 115.9 (d, $^2J_{C\text{-}F}$ = 22.8 Hz), 123.8, 124.0, 126.5, 127.3, 127.7 (d, $^3J_{C\text{-}F}$ = 8.4 Hz), 128.4 (d, $^4J_{C\text{-}F}$ = 3.6 Hz), 129.5, 131.4, 142.2, 159.9, 162.3 (d, $^1J_{C\text{-}F}$ = 248 Hz), 173.2, 190.2; HRMS (ESI): *m*/*z* calculated for $C_{24}H_{19}N_2NaO_3FS^+$ $[M+Na]^+$: 457.0993, found: 457. 0982; HPLC (chiral column: CHIRALPAK AD-H; solvent:

hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 17.8 min (minor) and 20.1 min (major); $[\alpha]_D^{27.8}$ +99.3 (*c* 0.29, $CHCl_3$ for 60% ee sample).

**(3*S*,5'*S*)-5'-(Furan-2-yl)-1-(4-methoxybenzyl)-2'-thioxospiro[indoline-3,4'-oxazolidin]-2-one (*ent*-4dn):** a colorless solid; IR (KBr) ν 3244, 1703, 1612, 1514, 1469, 1176 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) δ 3.77 (s, 3 H), 4.75 (d, *J* = 15.5 Hz, 1 H), 4.94 (d, *J* = 15.5 Hz, 1 H), 6.11 (s, 1 H), 6.22 (dd, *J* = 1.7, 3.4 Hz, 1 H), 6.34 (d, *J* = 1.7 Hz, 1 H), 6.70 (brd, *J* = 7.9 Hz, 1 H), 6.80–6.86 (m, 2 H), 6.94 (dd, *J* = 7.9, 7.9 Hz, 1 H), 7.11–7.23 (m, 5 H), 7.36 (brs, 1 H); $^{13}C$ NMR ($CDCl_3$, 125 MHz) δ 44.1, 55.5, 69.6, 84.1, 110.1, 110.7, 111.1, 114.4, 123.3, 123.6, ,126.2 126.8, 128.8, 131.3, 142.4, 143.9, 145.3, 159.5, 172.9, 189.6; HRMS (ESI): *m*/*z* calculated for $C_{22}H_{18}N_2NaO_4S^+$ $[M+Na]^+$: 429.0879, found: 429.0869; HPLC (chiral column: CHIRALPAK AD-H; solvent: hexane/2-propanol = 4/1; flow rate: 1.0 mL/min; detection: at 254 nm; rt): $t_R$ = 22.8 min (major) and 26.9 min (minor); $[\alpha]_D^{26.5}$ −15.8 (*c* 0.86, $CHCl_3$ for 33% ee sample).

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18. We previously reported that Sr(O-*i*Pr)$_2$-Schiff base **2d** = 1:1 mixture gave a oligomeric complex.

The CD analysis of the Sr-**2d** complex indicated that the dihedral angle of binaphthyl moiety in the Sr-**2d** complex was quite different from **2d** itself and the other metal-**2d** complex. S. Matsunaga and T. Yoshino, *Chem. Rec.*, 2011, **11**, 260.