

# 論文の内容の要旨

論文題目 Study on Organic Synthesis by Olefin Oligomerization Reactions  
(オレフィンのオリゴマー化を用いた有機合成の研究)

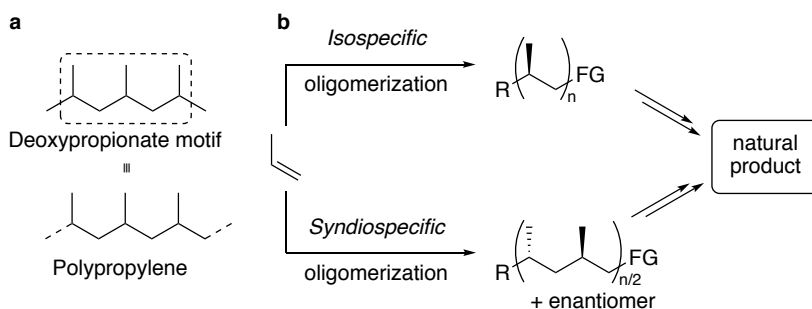
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## 1. General Introduction

Polymer chemistry and total synthesis have previously had little exchange, although they share the same principle of carbon-carbon bond formation. Strategies in polymer chemistry have the potential to boost the field of total synthesis if the reactivity is controlled to selectively afford oligomers. This dissertation consists of two major parts: Firstly, stereospecific propylene oligomerization catalyzed by zirconocenes was explored to synthesize deoxypropionate motif, which is the fully reduced variant of polyketide. Secondly, reactivity of rhodium complex bearing PBP pincer ligands with tetrafluoroethylene (TFE) was investigated towards the selective trimerization of TFE.

## 2. Asymmetric isospecific oligomerization of propylene for the synthesis of *syn*-deoxypropionate motif

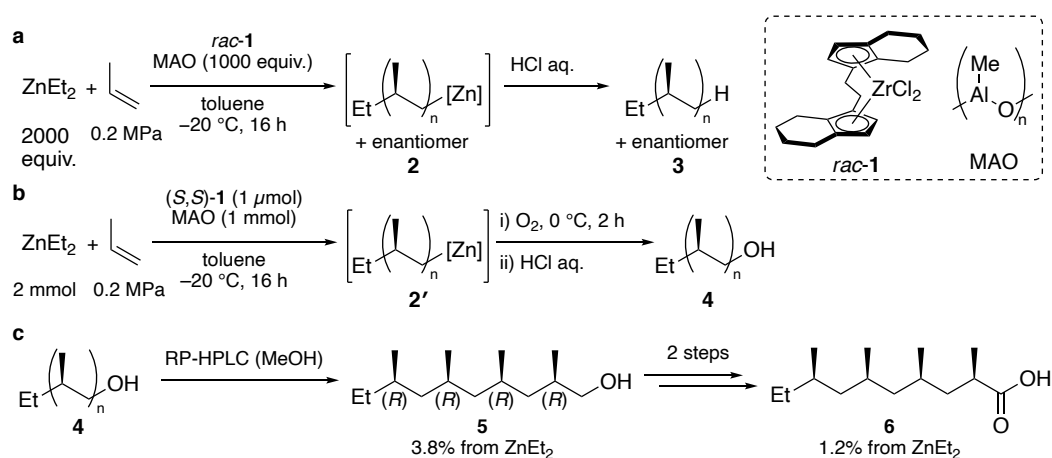
The deoxypropionate motif is common substructure found in natural products (Figure 1a).<sup>[1]</sup> Most of the conventional syntheses of the deoxypropionate motif employ iterative



stereoselective reactions including functional-group interconversions to construct the structures consisting of multiple stereocenters but no functionalities.<sup>[2,3]</sup>

To construct the deoxypropionate motif in a facile manner, the author envisioned using propylene as a building block. Since the deoxypropionate motif is identical to the partial structure of polypropylene, stereospecific oligomerization of propylene would afford the structure in a single step (Figure 1b). In order to control both the chain length and the stereospecificity, the author focused on the polymerization mode called “coordination chain-transfer polymerization”, where excess amount of alkylmetal reagent is added to the reaction system as a chain transfer agent (CTA).<sup>[4]</sup>

The reaction conditions were optimized using highly isospecific propylene polymerization catalyst *rac*-1 because *syn*-deoxypropionate motif is a partial structure of isotactic polypropylene (Figure 2a).

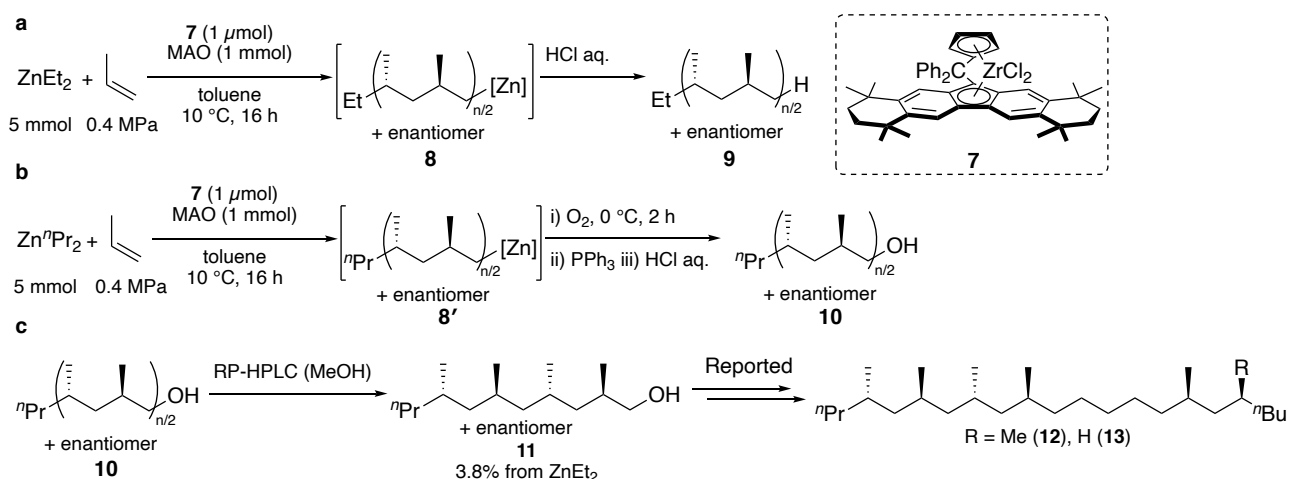


**Figure 2.** (a) Optimized conditions of isospecific propylene oligomerization. (b) Asymmetric isospecific oligomerization of propylene and oxidation to alcohols. (c) Total synthesis of **6**.

After protonation of alkylzinc species **2**, oligomers **3** were obtained with high diastereoselectivity. The process was then expanded to asymmetric reaction. Oligomerization was carried out using (*S,S*)-1 and in-situ oxidation of alkylzinc species **2'** by dioxygen afforded alcohols **4** (Figure 2b). Tetramer alcohol **5** was isolated by chromatography in 3.8% yield, and was oxidized to carboxylic acid **6**, which is a major acid component of preen-gland wax secreted by graylag goose,<sup>[5]</sup> in two steps (Figure 2c). Thus, three-step synthesis of **6** from propylene is the shortest known sequence to date.

### 3. Syndiospecific oligomerization of propylene for the synthesis of *anti*-deoxypropionate motif

In chapter 2, the product was limited to the *syn*-configured deoxypropionate motif owing to the isospecificity provided by  $C_2$ -symmetric zirconocene catalyst. Therefore, the author then explored the construction of *anti*-deoxypropionate motif utilizing a  $C_3$ -symmetric zirconocene catalyst. Highly syndiospecific propylene polymerization catalyst **7** was chosen after brief screening. Under a similar reaction conditions to the isospecific propylene oligomerization, after protonation of alkylzinc species **8**, syndiotactic oligopropylenes **9** were obtained with high stereoregularity (Figure 3a).



**Figure 3.** (a) Optimized conditions of syndiospecific propylene oligomerization. (b)  $n$ Pr-initiated syndiospecific oligomerization of propylene and oxidation to alcohols. (c) Formal total syntheses of **2** and **3**.

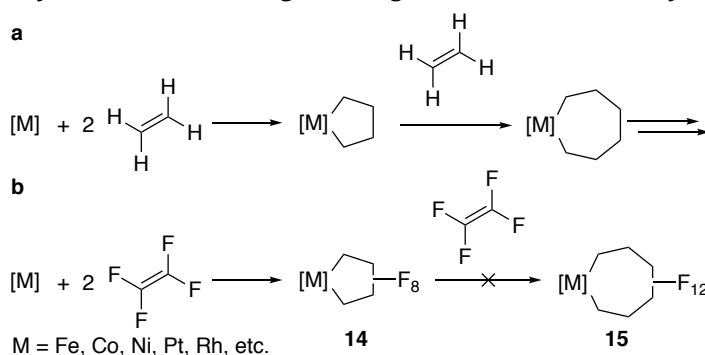
The CTA was then switched to di( $n$ -propyl)zinc, and oligomerization proceeded with the diastereoselectivity comparable to diethylzinc system (Figure 3b). Then oxidation of alkylzinc species **8'** to alcohols **10** was carried out, and tetramer alcohol **11** was isolated in 3.8% yield (Figure 3c). Alcohol **11** is the racemic mixture of the common synthetic intermediate for hydrocarbons **12** and **13**, major cuticular hydrocarbons isolated from the cane beetle *Antitrogus parvulus*.<sup>[6,7]</sup> Thus, the facile formal total syntheses of **12** and **13** were completed.

#### 4. Reactivity of PBP-Rh complexes with tetrafluoroethylene

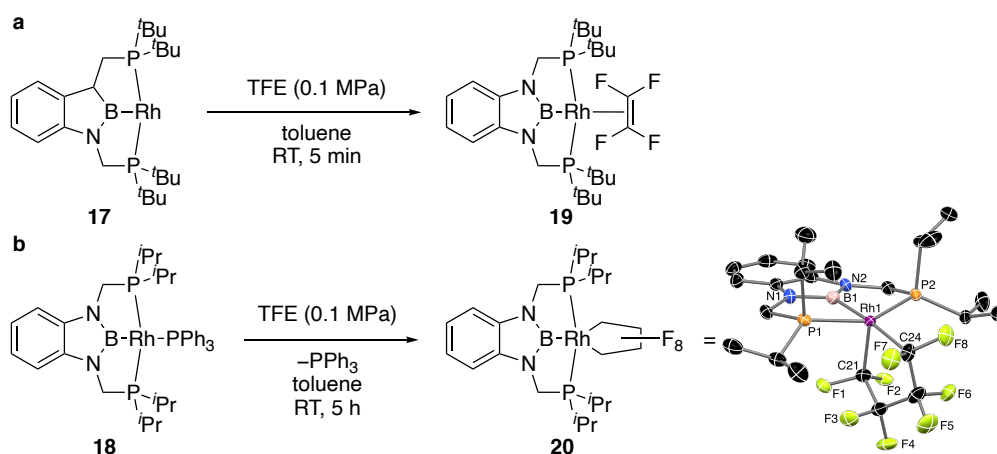
Poly(meth)acrylates bearing perfluoroalkyl chains are good water- and oil-repellants.<sup>[8]</sup> 1-iodoperfluorohexane is the typical perfluoroalkyl source and synthesized by telomerization of tetrafluoroethylene (TFE). However, the telomerization product is a mixture of oligomers and selective trimerization reaction is desired for the effective preparation of 1-iodoperfluorohexane.

Selective oligomerization of olefins via metallacycles is well investigated (Figure 4a). The reactivity of transition metal complexes with TFE have also been reported but is limited to the formation of five-membered rings **14** (Figure 4b). In order to selectively trimerize TFE, another TFE molecule should insert into **14** to form seven-membered ring **15**; however, this reaction is not known.

To destabilize five-membered ring **14**, the author focused on rhodium complexes bearing PBP pincer ligands so that the strongly  $\sigma$ -donating boryl anion will weaken the bond between rhodium and the carbon trans to boron. Reactivity of PBP-Rh complexes **17** and **18** with TFE was investigated (Figure 5). NMR analysis revealed that **17** and **18**



**Figure 4.** (a) Ethylene oligomerization via metallacycles. (b) Formation of octafluorometallacyclopentane.



**Figure 5.** Reactions between PBP-Rh complexes and TFE and molecular structure of **20**. Hydrogen atoms are omitted. Selected bond lengths (Å): Rh1-C21 = 2.170(6), Rh1-C24 = 1.977(4).

were converted to TFE complex **19** and octafluororhodacyclopentane **20** respectively. Single crystal X-ray diffraction analysis showed **20** had square pyramidal geometry. The bond length between rhodium and equatorial carbon was longer than that between rhodium and axial carbon by 0.2 Å.

## 5. Conclusions and Perspectives

In chapters 2 and 3, the author developed the single-step construction of *syn*- and *anti*-deoxypropionate motif by stereospecific propylene oligomerization and demonstrated the facile (formal) total syntheses of natural products. In chapter 4, the author investigated the reactivity of rhodium complexes bearing PBP pincer ligands and obtained octafluororhodacyclopentane complex, which possesses elongated rhodium-carbon bond. This complex possesses elongated rhodium-carbon bond and have possibility to incorporate another TFE molecule to achieve the selective trimerization of TFE. This complex would also incorporate another coupling partners including ethylene, carbon monoxide, and isocyanides, serving as a new scaffold for the synthesis of molecules containing perfluoroalkyl moiety.

## 6. References

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- [7] S. Chow, M. T. Fletcher, L. K. Lambert, O. P. Gallagher, C. J. Moore, B. W. Cribb, P. G. Allsopp, W. Kitching, *J. Org. Chem.* **2005**, *70*, 1808–1827.
- [8] W. Yao, Y. Li, X. Huang, *Polymer* **2014**, *55*, 6197–6211.

## 7. Publications related to this dissertation

- [1] Y. Ota<sup>†</sup>, T. Murayama<sup>†</sup>, K. Nozaki, *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 2857–2861. (<sup>†</sup>Co-first authors)
- [2] T. Murayama, K. Nozaki, *Angew. Chem. Int. Ed.* **2018**, *57*, 11394–11398.