

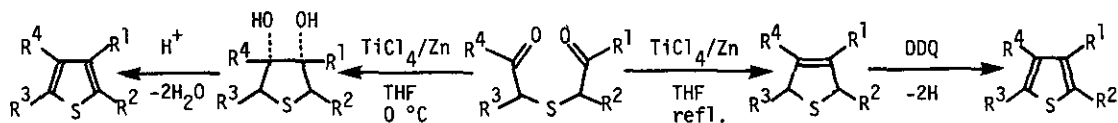
PREPARATION OF AN α,β -TYPE OF TER- AND SEPTITHIOPHENES

Juzo Nakayama,* Shigeru Murabayashi, and Masamatsu Hoshino
 Department of Chemistry, Faculty of Science, Saitama University
 Urawa, Saitama 338, Japan

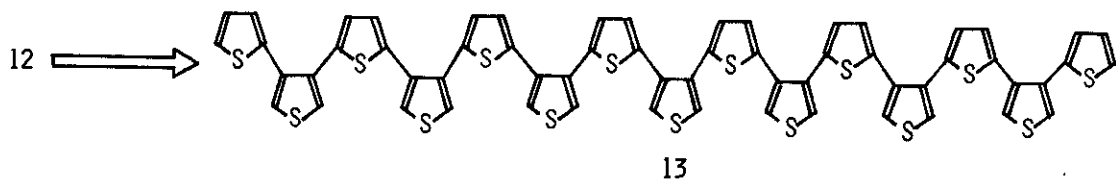
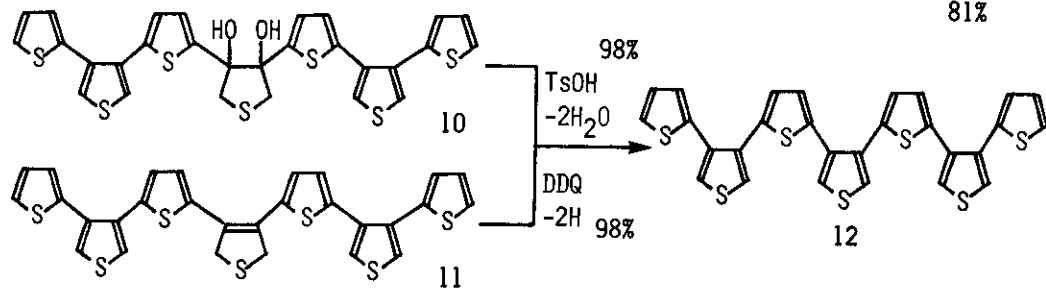
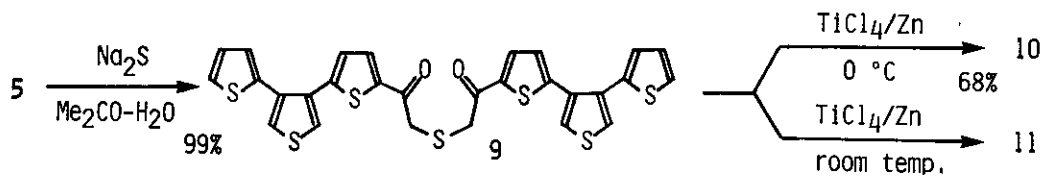
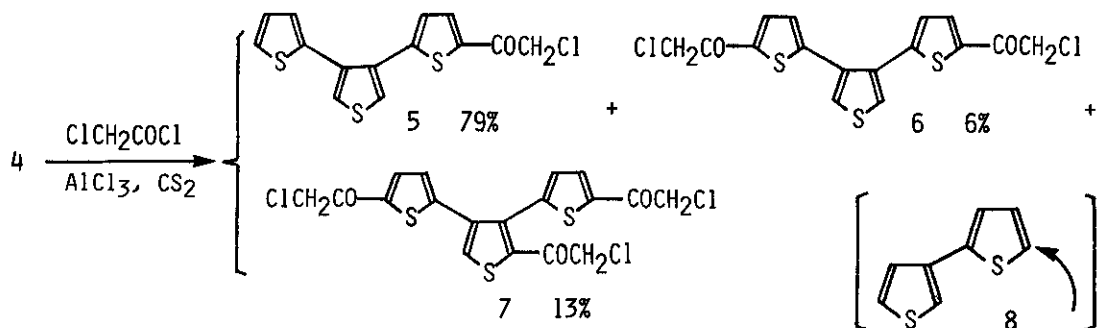
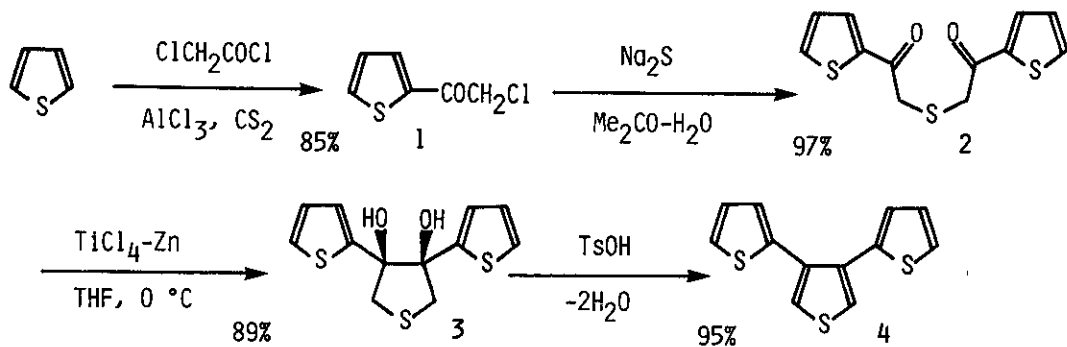
Abstract — An α,β -type of thiophene oligomers, 2,3':4',2''-terthiophene and 2,3':4',2'':5'',3''':4''',2''':5''',3''':4''',2''''-septithiophene, were synthesized through intramolecular reductive coupling reaction of diketo sulfides with a low-valent titanium reagent.

Thiophene oligomers continue to attract much attention because of their unique biological activities¹ and also as starting materials for the preparation of organic conductors. In our continuing synthetic study on thiophene oligomers, we have previously reported the syntheses of a series of an α -type of thiophene oligomers including α -ter-,²⁻⁴ α -quater-,⁵ α -quinque-,⁶ α -sexi-,⁵ α -septi-,⁶ and α -octithiophenes.⁵ Herein we report the preparation of an α,β -type of thiophene oligomers, ter- and septithiophenes (4 and 12).

The synthetic strategy for 4 and 12 stems from our previous thiophene synthesis.^{7,8} The reductive coupling reaction of diketo sulfides by a low-valent titanium reagent in tetrahydrofuran (THF) under controlled conditions affords *cis*-3,4-dihydroxythiolanes in good yields, while the reduction in refluxing THF gives 2,5-dihydrothiophenes in good yields; the formers are converted to the corresponding thiophenes by acid-catalyzed dehydration and the latters by dehydrogenation with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ).



The Friedel-Crafts reaction of thiophene with chloroacetyl chloride catalyzed by aluminum chloride in carbon disulfide affords 2-(chloroacetyl)thiophene (1) in 85% yield. The reaction of 1 with sodium sulfide in an aqueous acetone affords the diketo sulfide (2)⁹ in 97% yield. The intramolecular reductive coupling reaction of 2 with a low-valent titanium reagent, prepared from titanium(IV) chloride and zinc powder in THF,¹⁰ at 0 °C for 4 h afforded *cis*-3,4-dihydroxy-3,4-di(2-thienyl)-thiolane (3),¹¹ mp 107-109 °C, in 89% yield. Treatment of 3 with a catalytic amount of *p*-toluene-



sulfonic acid (TsOH) gave the terthiophene 4, mp 64-66 °C (lit.,¹² mp 64 °C), in 95% yield.¹³

To a stirred mixture of 4 (10 mmol) and chloroacetyl chloride (30 mmol) in carbon disulfide (35 ml) was added aluminum chloride (30 mmol) at 0 °C. The mixture was then warmed to 15 °C and stirred for 1.5 h at this temperature.¹⁴ Usual workup of the mixture followed by column chromatography afforded the expected chloroacetyl compound 5¹⁵ in 79% yield along with the bis(chloroacetyl) derivative 6¹⁵ (6%) and the tris(chloroacetyl) derivative 7¹⁵ (13%) with 2% recovery of 4. The position of the chloroacetyl group of each compound was determined by ¹H-nmr analysis.¹⁶ This assignment is also consistent with the observation that the acetylation of the bithiophene 8 occurs at the position indicated by an arrow.¹⁷ Treatment of 5 with sodium sulfide in an aqueous acetone afforded the diketo sulfide 9 in 99% yield. The reduction of 9 (1 mmol) with the low-valent titanium reagent, prepared from titanium(IV) chloride (6 mmol) and zinc powder (6 mg-atoms) in THF (20 ml), at -18 °C for 1 h and at 0 °C for 2 h afforded the dihydroxythiolane 10¹⁸ in 67% yield, while the reduction at room temperature for 6 h gave the dihydrothiophene 11¹⁸ in 81% yield. Treatment of 10 with a catalytic amount of TsOH in boiling benzene for 10 min afforded the expected septithiophene 12¹⁹ in 98% yield. Treatment of 11 with DDQ in dioxane at room temperature for 10 min also gave 12 in 98% yield.

Structure proof for 12 was mainly based on 400 MHz ¹H-nmr analysis.¹⁹ The thiophene 12 is a white crystalline compound and easily soluble in organic solvents, while its positional isomer, α -septithiophene, is deep red and practically insoluble in organic solvents.^{5,6} The highest absorption maximum of 4 and 12 appears 280 and 284 nm, respectively, in uv-vis spectrum (cyclohexane as solvent), and is comparable of that of 8 which appears at 283 nm in ethanol.¹⁷ The absorption coefficient, incidentally, increases with increasing numbers of thiophene ring. These imply that significant conjugation between each thiophene ring does not occur in this system, and thus 12 exists as the compound in which the unit of 8 is merely repeated.

Finally we challenged the preparation of a pentadecathiophene (13). Application of the above reaction sequence to 12 gave a compound which correctly has a molecular formula of C₆₀H₃₂S₁₅ by ms.²⁰ Currently, however, no conclusive evidence for structure 13 is available.²⁰

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11. cis-Configuration of 3 was established by reductive desulfurization with Raney nickel, which gave meso-5,6-dihydroxy-5,6-dimethyldecane in 71% yield; J. Nakayama, S. Yamaoka, and M. Hoshino, Tetrahedron Lett., 1987, 28, 1799.
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13. The reaction carried out in a 0.1 mol-scale (28.2 g of 2) afforded 4 in 50-65% overall yield without purification of the dihydroxythiolane 3.
14. The reaction is sensitive to the reaction temperature, time, quantities of chloroacetyl chloride and aluminum chloride, and quantity and kind of solvent. The maximum yield of 5 was obtained under the conditions described.
15. 5: mp 68.5-69 °C; $^1\text{H-NMR}$ (CDCl_3) δ 4.50 (2H, s), 6.78-7.43 (6H, m), 7.53 (1H, d, $J=4$ Hz).
6: mp 122-122.5 °C; $^1\text{H-NMR}$ (CDCl_3) δ 4.50 (4H, s), 6.90 (2H, d, $J=4$ Hz), 7.50 (2H, s), 7.63 (2H, d, $J=4$ Hz).
7: mp 214 °C; $^1\text{H-NMR}$ (CDCl_3) δ 4.23 (2H, s), 4.50 (2H, s), 4.67 (2H, s), 6.85 (1H, d, $J=4$ Hz), 7.18 (1H, d, $J=4$ Hz), 7.59 (1H, d, $J=4$ Hz), 7.81 (1H, d, $J=4$ Hz), 7.87 (1H, s).
16. The $^1\text{H-NMR}$ spectrum of 6 shows that it has a symmetrical structure; the methylene protons appear at δ 4.50 as singlet, the protons of the central thiophene ring at δ 7.50, and those of the terminal thiophene rings at δ 6.90 and 7.63 as doublets with $J=4$ Hz. This coupling constant value is harmony with the assigned structure of 6 because the coupling constant values in di-substituted thiophene rings range 3.5-4.3 Hz for $J_{3,4}$, 1-2 Hz for $J_{2,4}$, and ≥ 5.0 Hz for $J_{2,3}$ (W. Brügel, 'Handbook of NMR Spectral Parameters,' Heyden, London, 1979, Vol. 3, p. 662). This in turn means that the first chloroacetylation of 4 occurs to give 5; in $^1\text{H-NMR}$ of 5, the one proton of the thiophene ring carrying chloroacetyl group appears at δ 7.53 as doublet with $J=4$ Hz, though the other doublet is overlapped with signals due to other ring protons.¹⁴
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18. 10: $^1\text{H-NMR}$ (CDCl_3) δ 3.20 (2H, d, $J=12$ Hz, methylene), 3.37 (2H, s, OH), 3.53 (2H, d, $J=12$ Hz, methylene), 6.40-7.35 (14H, m, ring protons).
11: $^1\text{H-NMR}$ (CDCl_3) δ 4.07 (4H, s, methylene), 6.50-7.50 (14H, m, ring protons).
19. 12: mp 126-127 °C (from cyclohexane); $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 6.74 (2H, d, $J=3.7$ Hz), 6.80 (2H, d, $J=3.7$ Hz), 6.91 (2H, dd, $J=4.9$ and 3.5 Hz), 6.92 (2H, dd, $J=3.5$ and 1.5 Hz), 7.19 (2H, dd, $J=4.9$ and 1.5 Hz), 7.33 (2H, s), 7.35 (4H, s); ir (KBr) 3088, 1398, 1230, 1196, 886, 866, 838, 796, 750, 698, 586 cm^{-1} ; ms m/z 576 (M^+ , 100%); uv $\lambda_{\text{max}}^{\text{cyclohexane}}$ (ϵ) 244 (38000), 284 nm (38000). Anal. Calcd for $\text{C}_{28}\text{H}_{16}\text{S}_7$: C, 58.30; H, 2.80; S, 38.90. Found: C, 58.27; H, 2.85; S, 38.59.
20. The compound is a glassy powder which does not show a distinct melting point and has a tendency to form inclusion complexes with organic solvents (detected by $^1\text{H-NMR}$). The uv-vis and ir spectra are similar to those of 12 and the very complex 400 MHz $^1\text{H-NMR}$ spectrum did not give conclusive evidence for structure 13. Uv-vis $\lambda_{\text{max}}^{\text{cyclohexane}}$ (ϵ) 243 (68900), 287 nm (93900) (as $\text{C}_{60}\text{H}_{32}\text{S}_{15}$); ir (KBr) 3096, 1230, 1200, 868, 838, 790, 698 cm^{-1} ; ms (EI) $M^+ m/z$ (relative intensity, %) 1232 (100), 1233 (80), 1234 (99), 1235 (61), 1236 (43), 1237 (22), 1238 (11); m/z (relative intensity, %) 1232 (100), 1068 (5), 986 (5), 904 (50), 616 (M^{2+} , 34), 209 (17).

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