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Thiophene Analogues of Fluorene

III. On the Synthesis of Methylated Cyclopentadithiophenes

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The synthesis of four of the six isomeric tetramethyl cyclopentadithiophenes is described. 2,3,4,5-Tetramethyl-7H-cyclopenta[1,2-b:4,3-b′]dithiophene (II), 2,3,4,6-tetramethyl-7H-cyclopenta[1,2-b:3,4-c′]dithiophene (IV) and 2,3,5,6-tetramethyl-4H-cyclopenta[2,1-b:3,4-b′]dithiophene (III) were prepared in nearly similar reaction paths, in which an Ullmann coupling of appropriate substituted diiododithienyl ketones to tetramethyl cyclopentadithiophenones was the key-step (*cf.* Schemes 3, 6, 5). 1,3,4,6-Tetramethyl-7H-cyclopenta-[1,2-c:3,4-c′]dithiophene (V) was obtained by a classical fluorenone synthesis, with an electrophilic ring closure reaction of 4-carboxy-2,2′,5,5′-tetramethyl-3,3′-dithienyl as key-step (*cf.* Scheme 7). Attempts to prepare II and III in a similar way failed (*cf.* Schemes 1 and 4). The reduction of the tetramethyl cyclopentadithiophenones with lithium aluminium hydride and aluminium chloride is discussed.

The shorter route to II and III *via* ring closure of appropriate dilithiated dithienyl methane derivatives with cupric chloride, was less useful (*cf.* Schemes 3 and 5).

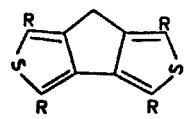
In order to shed light on the effect of the mode of annelation of different ring systems onto the 2,3- and 3,4-positions of thiophene on physical properties and reactivity, Gronowitz and co-workers have studied borazarothienopyridines,[1] thienopyridines,[2] cyclopentathiophenes,[3,4] and cyclopentadithiophenes.[5] For the last mentioned systems we are especially interested in studying the effect of the mode of annelation on the acidity of the fluorenic CH_2 group.

In a series of elegant papers, Wynberg and co-workers [6,7] reported the synthesis of all six isomers of cyclopentadithiophene. They were interested in these compounds as model substances for the study of the conformation of the three isomeric bithienyls and for the study of charge-transfer interaction with 1,3,5-trinitrobenzene.[8] In recent work Wynberg *et al.*[9] describe the synthesis of the six isomeric cyclopentadithiophenes.* Some thiophene analogues of

* We are grateful to Professor Wynberg for providing us with a copy of this manuscript prior to publication.

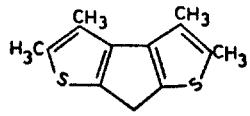
fluorene in which only one benzene ring has been replaced by a thiophene ring have also been prepared.[10,11]

In our earlier work, we found a very convenient method for the synthesis of 1,3,4,6-tetraalkyl-7H-cyclopenta[1,2-c:3,4-c']dithiophenes (I) by cyclisation of 4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'bithienyl, 4,4'-dicarboxy-2,2',5,5'-tetraethyl-3,3'-bithienyl, and 4-carboxy-2,2',5,5'-tetraethyl-3,3'-bithienyl, followed by reduction of the ketones formed with aluminium chloride-lithium aluminium hydride. As these approaches seemed more convenient than the first methods of synthesis published by Wynberg *et al.*,[6,7] and as blocking of the thiophene position with methyl groups should be of no disadvantage in the study of fluorenic acidity, but instead be useful in avoiding complications from metalation of the acidic α-positions of thiophene, we decided to approach the synthesis of the methylated thiophene analogues II – III in the same way as that of I.

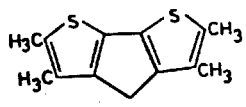


I a R = CH_3

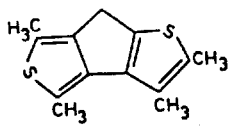
b R = C_2H_5



II



III



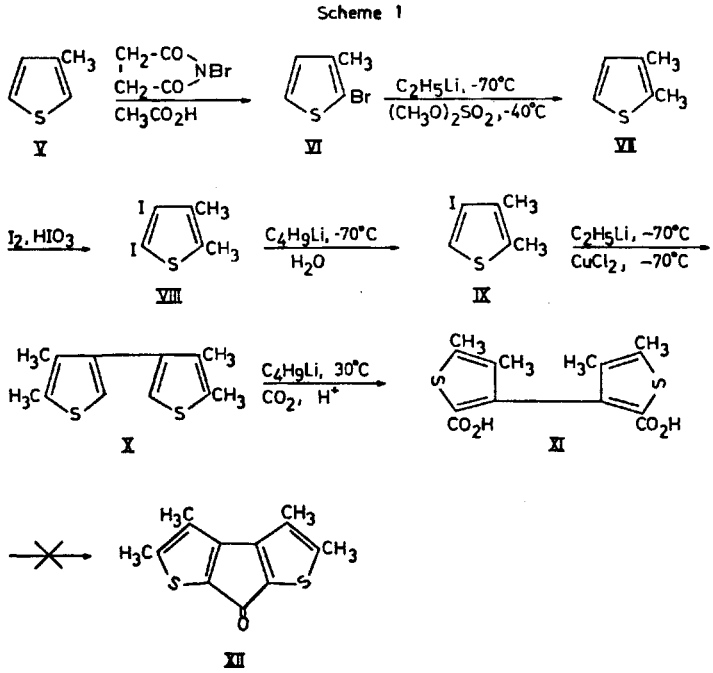
IV

It will be shown below that this approach was not successful and that other routes for the synthesis of II and III had to be used. Besides the synthesis of II and III and a modified synthesis of Ia, the preparation of the analogue with a "cyclopentene" ring (IV) will be described in the present paper. In a following paper the acidity of I-IV and their spectral properties, as well as those of some derivatives, will be discussed.

2,3,4,5-Tetramethyl-7H-cyclopenta[1,2-b:4,3-b']dithiophene (II). The synthesis of 2,2'-dicarboxy-4,4',5,5'-tetramethyl-3,3'-bithienyl, which is the key intermediate for the ring closure, is summarised in Scheme 1.

2,3-Dimethylthiophene (VII) would be a key intermediate not only for the synthesis of II but also of III and IV. It has previously been prepared in low yield through the reaction of β-methyl levulinic acid with phosphorus pentasulphide.[12] Gronowitz and co-workers [13] prepared VII in a three-step synthesis from 3-methylthiophene (V) *via* 2-bromo-3-methylthiophene (VI) and 3-methyl-2-thiophene aldehyde (XVI). We found, however, a more convenient two-step synthesis of VII in the reaction of 3-methyl-2-thienyl lithium, obtained *via* halogen-metal interconversion between VI and butyl lithium, with dimethyl sulphate according to the general method of Levine *et al.*[14]

Scheme 1



Direct metalation of V with butyl lithium can of course not be used as this has been shown to occur predominantly in the 5-position.[13]

The synthesis of VI has been described by several authors. Steinkopf and Jacob [15] obtained it in 50 % yield by brominating V with aqueous bromine, which is very inconvenient for large scale synthesis. Dittmer and co-workers [16] obtained VI in low yield by the reaction of V with *N*-bromosuccinimide (NBS) in refluxing carbon tetrachloride. We found a very satisfactory method in the bromination of V with NBS in acetic acid, which yielded VII in 85 % yield. Minute amounts of hydroquinone were added to the reaction mixture in order to suppress radical reactions. Recently Wynberg *et al.*[17] reported the use of a mixture of chloroform and acetic acid as solvent for the bromination of several 2- and 3-substituted thiophenes. Care has to be exercised in the bromination of activated thiophenes, as it has been found that this reaction is reversible and that the products of kinetic and thermodynamic control are not always the same.[17–19]

Gronowitz and Vilks [20] have demonstrated that the iodination with iodine and iodic acid, with sulphuric acid as catalyst (introduced by Wirth *et al.*[21]), is the most convenient method for the introduction of iodine in thiophene derivatives.

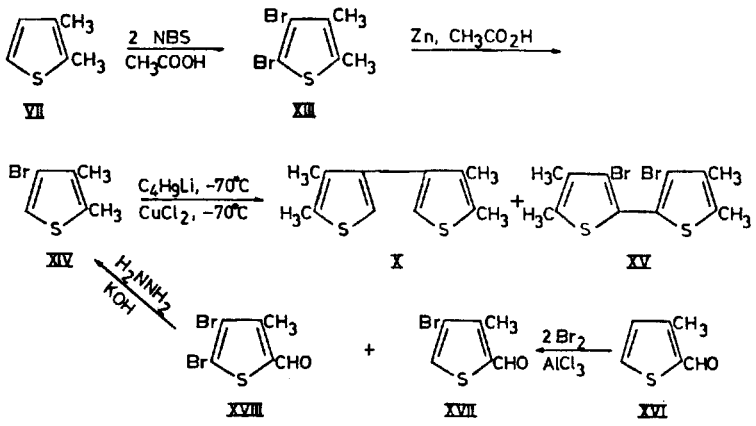
Applying this method to VII gave 2,3-diiodo-4,5-dimethylthiophene (VIII) in 81 % yield. Reduction of VIII with zinc in acetic acid was not selective enough and yielded mostly VII. However, treatment of VIII with butyl lithium at −70°C followed by hydrolysis gave 2,3-dimethyl-4-iodo-

thiophene (IX) in 76 % yield. While this research was in progress a paper dealing with the NMR spectra of iodomethylthiophenes including VIII and IX appeared,[22] but contained no information about the methods of synthesis.*

2,2',3,3'-Tetramethyl-4,4'-bithienyl (X) was prepared from IX in 47 % yield by halogen-metal interconversion with ethyl lithium at −70°C followed by coupling with cupric chloride. This method has been used extensively in recent years for the preparation of symmetrical 3,3'-bithienyls, *e.g.* for the study of atropisomerism in this system.[23–28]

Attempts to use the route *via* the bromo derivatives shown in Scheme 2 to reach X was not so successful.

Scheme 2



2,3-Dibromo-4,5-dimethylthiophene (XIII) has previously been obtained by the bromination of VI with bromine in carbon disulphide.[29,30] We found that XIII could also be prepared by the bromination of VI with 2 equiv. of NBS, although only a yield of 49 % was obtained. The α-bromine of XIII could easily be removed by the general method first used by one of us [31,32] for the preparation of 3-bromothiophene from 2,3,5-tribromothiophene by reduction with zinc dust in acetic acid. After 5 h reflux a 71 % yield of 4-bromo-2,3-dimethylthiophene (XIV) was obtained. An alternative synthesis of XIV was based on two observations. The first was that bromination of thiophene aldehydes with molecular bromine, with aluminium chloride as swamping catalyst, gives "*meta*" orientation for the first entering bromine atom.[33] Gol'dfarb and co-workers [33] obtained 4-bromo-2-thiophene aldehyde in 91 % yield from 2-thiophene aldehyde by this method. The second observation was that during the reduction of formyl groups to methyl groups by the Wolff-Kishner reaction, β-positioned bromine atoms are not removed, while α-positioned are replaced by hydrogen.[25] When XVI was treated with a large

* In a letter Dr. Matsuki has kindly informed us that VIII and IX were prepared *via* mercury derivatives.

excess of $AlCl_3$ and 1 equiv. of bromine, much starting material was recovered. Using 2 equiv. of bromine gave, besides some starting material, 18 % of 4-bromo-3-methyl-2-thiophene aldehyde (XVII) and 59 % of 4,5-dibromo-3-methyl-2-thiophene aldehyde (XVIII), as determined by NMR spectroscopy. XVII and XVIII could be separated by fractional crystallization. Our expectations concerning the outcome of the Wolff-Kishner reduction were fulfilled. Reduction of the mixture of XVII and XVIII according to the modification of King and Nord [34] yielded 47 % of XIV.

The coupling of XIV to X, however, gave rise to difficulties. Halogen-metal exchange between XIV and ethyl lithium at $-70°C$ followed by reaction with cupric chloride yielded only 21 % of X, accompanied by 9 % of a by-product and much starting material. On the basis of elementary analysis, PMR and IR spectra it was concluded that this by-product was 4,4'-dibromo-2,2',3,3'-tetramethyl-5,5'-bithienyl (XV). The structure was confirmed by synthesis of an authentic sample (*cf.* below). If the mixture after halogen-metal interconversion was reacted with carbon dioxide, a mixture consisting of 70 % of 2,3-dimethyl-4-thiophenecarboxylic acid and 30 % of 3-bromo-4,5-dimethyl-2-thiophenecarboxylic acid was obtained, as shown by NMR analysis. Authentic samples of these acids were obtained by reaction between IX and XIII [30] and ethyl lithium at $-70°C$ followed by reaction with carbon dioxide. Moses and Gronowitz [35] have shown that although several thienyl lithium and bromothienyl lithium derivatives, in which the lithium atom was not situated at the thermodynamically most stable position, rearrange by a series of halogen-metal exchanges and transmetalations, it is possible under appropriate conditions to obtain only the product derived from the primary halogen-metal interconversion. The rapid rearrangement of 2,3-dimethyl-4-thienyl lithium, under conditions where 3-thienyl lithium does not rearrange, is therefore somewhat unexpected. It could perhaps be due to the fact that the halogen-metal exchange is so slow due to the deactivating influence of the methyl groups, that the primarily formed 2,3-dimethyl-4-thienyl lithium has an opportunity to metalate unreacted XIV. It has previously been demonstrated that aromatic lithium compounds metalate faster than they undergo halogen-metal exchange.[36] The fact that no rearranged products are found in the halogen-metal exchange between IX and ethyl lithium strengthens this hypothesis, as it is well-known that iodides undergo halogen-metal exchange much faster than bromides.[37]

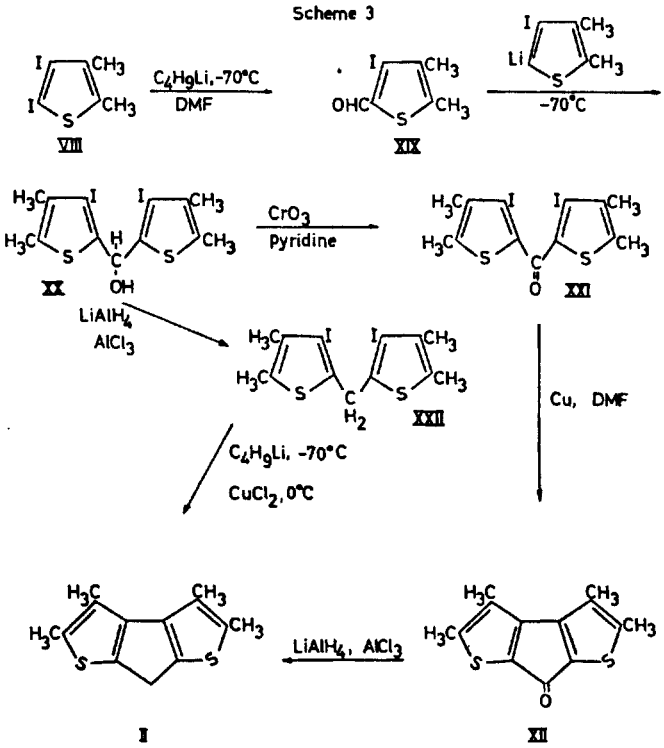
By means of metalation of X with excess butyl lithium in refluxing ether followed by reaction with carbon dioxide, 2,2'-dicarboxy-4,4',5,5'-tetramethyl-3,3'-bithienyl (XI) was obtained in 84 % yield.

All attempts to cyclize XI to XII with PPA, analogous to the cyclization of 4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'-bithienyl,[5] failed. Although different conditions were tried, no other definite products, besides starting material, could be isolated. At this point the route of Wynberg *et al.*[9] came to our knowledge and was used in our further attempts to reach XII.

The key-step in this reaction sequence is an Ullman coupling on a diiodo dithienyl ketone, as is evident from Scheme 3.

2,3-Dimethyl-4-iodo-5-thiophene aldehyde (XIX) was prepared in 73 % yield from VIII by halogen-metal exchange with butyl lithium followed by

Scheme 3



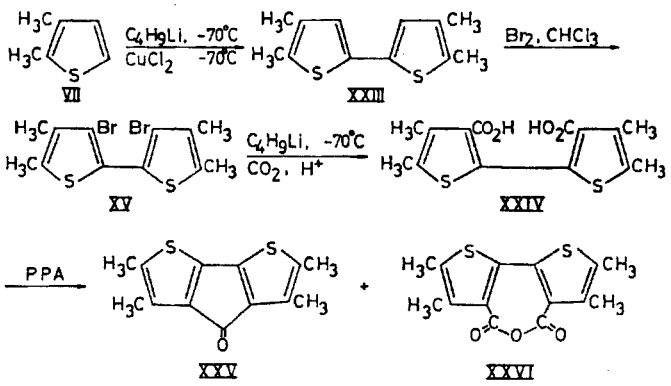
reaction with *N*,*N*-dimethylformamide (DMF). Reaction of XIX with 4,5-dimethyl-3-iodo-2-thienyl lithium, obtained through halogen-metal exchange at −70°C between VIII and butyl lithium, gave 4,4′-diiodo-2,2′,3,3′-tetramethyl-5,5′-dithienylcarbinol (XX) in 80 % yield. Care has to be exercised during the work-up, since under acidic conditions or upon application of heat, dithienylcarbinols easily lose water and form ethers.[38,39] Mild oxidation of XX with chromic trioxide in pyridine containing some water [40] gave 4,4′-diiodo-2,2′-3,3′-tetramethyl-5,5′-dithienyl ketone (XXI) in 87 % yield. The Ullmann coupling of XXI, following the method of Wynberg *et al.*,[9] proceeded smoothly to give the red 2,3,4,5-tetramethyl-7H-cyclopenta[1,2-b:4,3-b′]dithiophene-7-one (XXII) in 75 % yield. The reductions of cyclopentadithiophenones to cyclopentadithiophenes have caused some difficulties. It was found that 1,3,4,6-tetramethyl-7H-cyclopenta[1,2-c:3,4-c′]dithiophene-7-one (XLIII) could not be reduced by either the Wolff-Kishner or the Clemmensen method.[5] Also McDowell and Patrick [11] report low yields for the Wolff-Kishner reduction of their indenothiophenones. Wynberg *et al.*,[9] however, report a 40 % yield in the reduction of 7H-cyclopenta[1,2-c:3,4-c′]dithiophene-7-one by the Wolff-Kishner method. Gronowitz and co-workers [5] found that the convenient reduction method of Brown and White [41] utilizing LAH and $AlCl_3$ gave excellent yields of I when applied to XLIII. However, when this method was

applied to XII, a large excess of the reduction mixture had to be used. Still the best yield of II was not better than 65 %.

We therefore investigated the alternative route consisting of reduction of XX to 4,4′-diiodo-2,2′,3,3′-tetramethyl-5,5′-dithienyl methane (XXII) with the LAH-$AlCl_3$ reagent, which proceeded smoothly in 92 % yield. However, the next step, halogen-metal interconversion with butyl lithium, followed by coupling with cupric chloride, yielded after extensive purifications only a 10 % yield of II. It is therefore clear that the route *via* the Ullmann coupling is to be preferred.

2,3,5,6-Tetramethyl-4H-cyclopenta[2,1-b:3,4-b′]dithiophene (III). Also for the synthesis of III the route *via* ring closure of 4,4′-dicarboxy-2,2′,3,3′-tetramethyl-5,5′-bithienyl (XXIV) was first attempted. The path used to reach XXIV is shown in Scheme 4.

Scheme 4

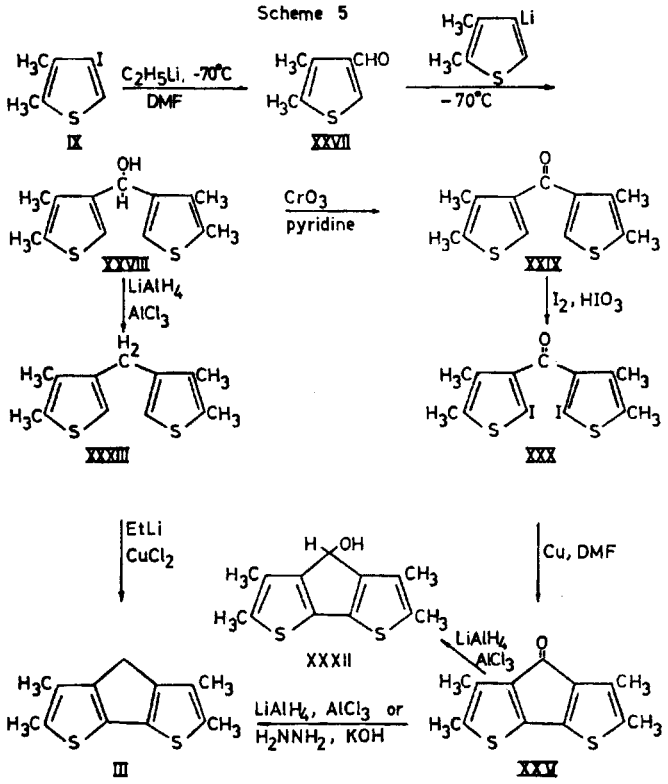


2,2′,3,3′-Tetramethyl-5,5′-bithienyl (XXIII) was prepared in 68 % yield in the usual way, by cupric chloride coupling of 4,5-dimethyl-2-thienyl lithium, obtained upon metalation of VII. Bromination of XXIII with bromine in chloroform yielded XV in 88 % yield, with the same physical properties as the sample obtained as a by-product in the coupling reaction of XIV (*cf.* Scheme 2). Iodination of XXIII with iodine-iodic acid under the same conditions as described for the isomeric 2,2′,5,5′-tetramethyl-3,3′-bithienyl [26] was less successful. On mixing the reagents at room temperature, tarification occurred and only some starting material was isolated. It is possible that by modifying the reaction conditions greater success can be achieved. However, it was possible to prepare 4,4′-diiodo-2,2′,3,3′-tetramethyl-5,5′-bithienyl in 44 % yield by cupric chloride coupling of 3-iodo-4,5-dimethyl-2-thienyl lithium, obtained by halogen-metal interconversion of VIII. The acid XXIV was obtained from XV *via* halogen-metal interconversion followed by reaction with carbon dioxide.

Attempts to cyclise XXIV to XXV with PPA were disappointing. Only in one case was the desired ketone XXV obtained, but in very low yield. The product was difficult to purify, as the anhydride of 4,4′-dicarboxy-2,2′,3,3′-

tetramethyl-5,5′-bithienyl (XXVI) was also formed. Besides starting material decarboxylated product (*i.e.* XXIII) was isolated in some experiments. We therefore utilized the Ullmann route as summarised in Scheme 5.

Scheme 5



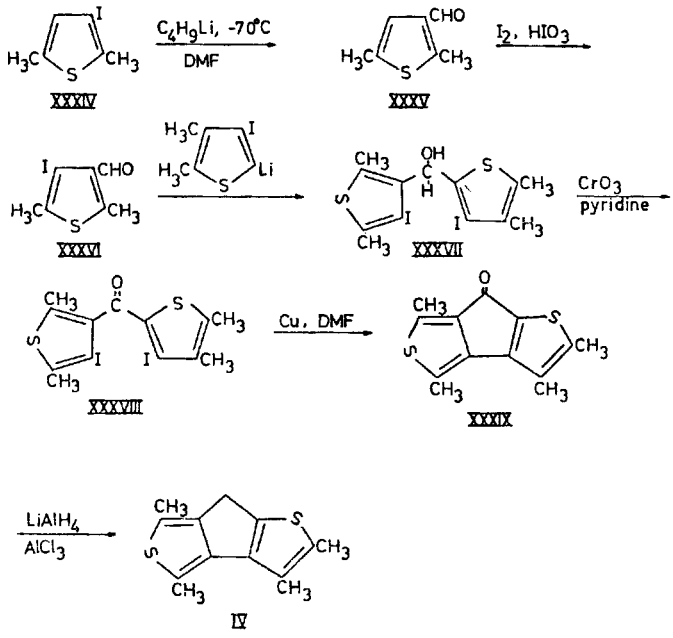
2,3-Dimethyl-4-thiophene aldehyde (XXVII) was prepared in 80 % yield from IX *via* iodine-lithium exchange and reaction with DMF. Reaction of XXVII with 2,3-dimethyl-4-thienyl lithium yielded 2,2′,3,3′-tetramethyl-4,4′-dithienyl carbinol (XXVIII) in 91 % yield. Due to the acid-sensitivity of XXVIII, it was first oxidized to 2,2′,3,3′-tetramethyl-4,4′-dithienyl ketone (XXIX) with chromic trioxide in pyridine and then iodinated with iodine-iodic acid to 5,5′-diiodo-2,2′,3,3′-tetramethyl-4,4′-dithienyl ketone (XXX). In spite of the electron-attracting carbonyl group in the 3-position, the free 2-position is smoothly iodinated. It has earlier been pointed out by one of us that a $-I-M$ substituent in the 3-position in a 4,5-blocked thiophene does not hinder electrophilic substitution in the 2-position, while attempts to substitute a 4,5-blocked thiophene with a $-I-M$ substituent in the 2-position results, if reaction occurs, in the expulsion of one of the α-substituents.[42,43]

Ring closure of XXX with copper bronze in DMF gave smoothly the deeply violet 2,3,5,6-tetramethyl-4H-cyclopenta[2,1-b:3,4-b′]dithiophene-4-one

(XXV) in 89 % yield. The reduction of XXV to III, however, caused difficulties. When a small excess of LAH and $AlCl_3$ was used, 4-hydroxy-2,3,5,6-tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene was obtained in 82 % yield. Using a large excess of LAH and $AlCl_3$ or the Wolff-Kishner method for this reduction yielded XII. However, the yields were very low, 10 % and 15 %, respectively. We were therefore interested in determining whether the alternative route *via* 2,2',3,3'-tetramethyl-4,4'-dithienyl methane (XXXIII) was to be preferred. This, however, was not the case. Although XXVIII was in high yield reduced to XXXIII, the coupling step failed, and only 1 % of III could be obtained.

2,3,4,6-Tetramethyl-7H-cyclopenta[1,2-b:3,4-c']dithiophene (IV). The synthesis of IV is summarised in Scheme 6.

Scheme 6

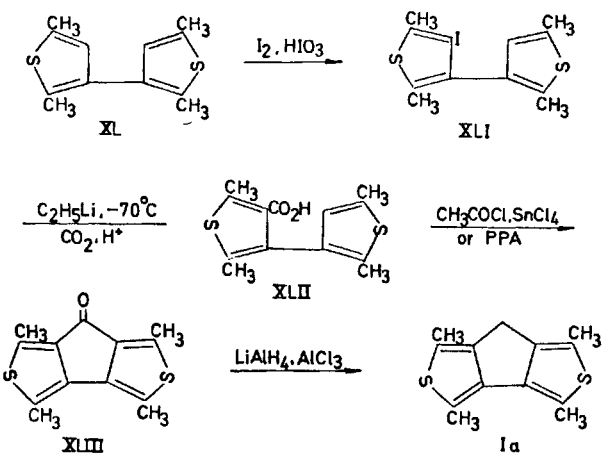


2,5-Dimethyl-3-iodo-4-thiophene aldehyde could not be conveniently prepared by treating 3,4-diiodo-2,5-dimethylthiophene [26] with 1 equiv. of an alkyl lithium followed by DMF, since along with starting material and the expected XXXVI, 2,5-dimethyl-3,4-thiophene dialdehyde was formed. The mixture thus obtained was difficult to separate. Difficulties in achieving selective monolithiation of 2,5-dimethyl-3,4-diiodothiophene have previously been observed by Gronowitz and Beselin in their attempts to prepare 4,4'-diiodo-2,2',5,5'-tetramethyl-3,3'-bithienyl.[26] With excess alkyl lithium derivatives smooth exchange of both iodine atoms of diiodothiophenes occurs.[20,29,44,45] Thus we iodinated 2,5-dimethyl-3-thiophene aldehyde (XXXV)

with iodine-iodic acid, which with the use of excess iodic acid gave an excellent yield of XXXVI. The aldehyde XXXV was obtained in 84 % yield through halogen-metal interconversion between 2,5-dimethyl-3-iodothiophene (XXXIV) followed by reaction with DMF. XXXIV has also been prepared in 40 % yield by direct Vilsmeier formylation.[34] Reacting XXXVI with the lithium reagent derived from VIII yielded 3,3′-diiodo-2′,4,5,5′-tetramethyl-2,4′-dithienyl carbinol XXXVII in 58 % yield, which in the usual manner was oxidised in 90 % yield with chromic trioxide in pyridine to 3,3′-diiodo-2′,4,5,5′-tetramethyl-2,4′-dithienyl ketone (XXXVIII). The Ullmann coupling of XXXVIII went smoothly and gave a 92 % yield of the yellow 2,3,4,6-tetramethyl-7H-cyclopenta[1,2-b:3,4-c′]dithiophene-7-one (XXXIX). In contrast to XII and XXII, but in the same way as XLIII, XXXIX was easily reduced with LAH-$AlCl_3$. No large excess of reagent was necessary and IV was obtained in 86 % yield.

1,3,4,6-Tetramethyl-7H-cyclopenta[1,2-c:3,4-c′]dithiophene (I). The synthesis of I has already been described.[5] Instead of cyclising a dicarboxylic acid, a monocarboxylic acid was now used in analogy with the preparation of the tetraethyl derivative, since a higher yield could be expected. The reactions are summarised in Scheme 7.

Scheme 7



The monoiodination of XL was carried out under slightly different conditions from those used in the monoiodination of the tetraethyl analogue,[5] giving 4-iodo-2,2′,5,5′-tetramethyl-3,3′-bithienyl (XLI) in 81 % yield. Iodine-lithium exchange with butyl lithium at −70°C followed by reaction with carbon dioxide gave 4-carboxy-2,2′,5,5′-tetramethyl-3,3′-bithienyl (XLII) in 83 % yield. The cyclization of XLII to 1,3,4,6-tetramethyl-7H-cyclopenta[1,2-c:3,4-c′]dithiophene-7-one (XLIII) could be easily achieved either by reaction with acetyl chloride and tin tetrachloride or by heating in PPA. The yields were 65 % and 77 %, respectively. Reduction of XVIII with LAH-$AlCl_3$ gave I in almost quantitative yield.

DISCUSSION

The structures of all new compounds were evident from the mode of synthesis and from IR, NMR and mass spectral data. Expected long-range couplings between methyl and ring hydrogens [46] and 2,5- and 2,3-positioned methyl groups [30,47] were observed although they could not always be resolved.

It is obvious from the results described above that the classical fluorenone synthesis, consisting of electrophilic ring closure of biphenyl carboxylic acids, was useful only for the synthesis of I. For the other three isomers the route which involves ring closure of iodinated dithienyl ketones through the Ullmann reaction is the most useful, even when low yields are obtained in the reduction of the cyclopentadithiophenones. The reason for this was the low yield obtained in the intramolecular coupling of appropriate dilithiated dithienyl methane derivatives with cupric chloride, which in some other cases has been shown to be a useful route.[7]

The different behaviour of the ketones XXXIX and XLIII on the one hand and the ketones XII and XXV on the other on reduction with the LAH-$AlCl_3$ reagent is a good example of the annelation effect. Brown and White [41] have proposed a mechanism, which involves carbonium ions of some stability as intermediates. Thus, 2,4-dimethylacetophenone is reduced to 2,4-dimethylethyl benzene in 96 % yield while acetophenone is reduced to methylphenyl carbinol [48] which might be due to the stabilising hyperconjugative effect of the methyl groups. Nystrom and Berger [48] found that 9-fluorenone only yielded 9-fluorenol in 90 % yield with the LAH-$AlCl_3$ reagent. We could confirm this result and found that even the use of a large excess of the reducing agent did not lead to fluorene. We suggest that this is connected with the low stability of the fluorenyl cation, for which a pK_R value of -14.0 has been obtained.[49,50] It is thus less stable than the diphenylmethyl cation ($pK_R = -13.1$ [51]). It seems therefore understandable to us why the "fluorenone-like" ketones XII and XXV are reduced with such difficulty, while XXXIX and XLIII react smoothly. The easy reduction of the latter two ketones and also of the dithienyl carbinols XX and XXVIII is not only due to the presence of the methyl groups, but also to the fact that the thiophene ring stabilises positive charges better than benzene. Petitt and co-workers [51] found that the phenyl 2-thienyl methyl cation ($pK_a = -9.9$) and still more the di-(2-thienyl)-methyl cation ($pK_R = -4.1$) were much more stable than the diphenylmethyl cation ($pK_R = -13.1$). A similar increase in stability was also observed when the phenyl groups of triphenylmethyl cation were replaced by 2-thienyl groups. A quantitative investigation of the stability of the various thiophene analogues of the fluorenyl cation should therefore be of great interest.

EXPERIMENTAL

2-Bromo-3-methylthiophene (VI). To a suspension of 98.0 g (0.55 mole) of NBS and 10 mg of hydroquinone in 250 ml of acetic acid, 54.0 g (0.55 mole) of V was added rapidly with vigorous stirring and ice-cooling. The reaction mixture was poured out in water. The organic layer was taken up in ether. The ether phase was washed with sodium bicarbonate solution and water, dried ($MgSO_4$) and fractionated to yield 83.2 g (85 %) of

VI, b.p. 63–73°C/15 mm Hg, $n_D^{20}=1.5720$. Literature value:[16] b.p. 57–60°C/4 mm Hg, $n_D^{20}=1.5714$.

2,3-Dimethylthiophene (VII). To a solution of 141.6 g (0.80 mole) of 2-bromo-3-methylthiophene cooled to −70°C, 1000 ml of 0.8 N ethyl lithium was added under nitrogen with stirring. After 40 min the temperature was raised to −40°C and 126 g (1.00 mole) of freshly distilled dimethyl sulphate was added at such a rate that the temperature did not rise above −30°C. The reaction mixture was hydrolysed with 4 N sodium hydroxide solution and stirred for 1 h. The ether phase was washed with water and dried ($MgSO_4$). The ether was removed *in vacuo*, and the residue distilled from sodium, yielding 79.4 g (89 %) of VII, b.p. 142–144°C. Literature value:[13] b.p. 141–142°C.

2,3-Diiodo-4,5-dimethylthiophene (VIII). A well stirred mixture of 15.0 g (0.135 mole) of VII, 37 ml of acetic acid, 14.0 ml of water, 14.0 ml of carbon tetrachloride, 1.5 ml of conc. sulphuric acid, 24.3 g (0.095 mole) of iodine, and 10.8 g (0.061 mole) of iodic acid was heated for 45 min at 80°C. The reaction mixture was diluted with 300 ml of chloroform. The organic layer was washed with a saturated sodium thiosulphate solution, sodium bicarbonate solution and with water. After drying ($MgSO_4$), the solvents were removed *in vacuo*, and the residue recrystallised from hexane, yielding 39.9 g (81 %) of VIII, m.p. 56.5–57.5°C. Literature value:[22] m.p. 58°C. NMR (CCl_4): $\tau_{CH_3}=7.60$ and 7.77. (Found: C 20.0; H 1.64; S 8.99. Calc. for $C_6H_6I_2S$ (364.0): C 19.80; H 1.66; S 8.81).

4-Iodo-2,3-dimethylthiophene (IX). To a stirred solution of 23.0 g (0.063 mole) of VIII in 250 ml of ether at −70°C, 100 ml of 0.90 N ethereal butyl lithium was added under nitrogen. The solution was stirred at −70°C for 2 h and poured into water. The ether phase was washed with water and dried ($MgSO_4$). Fractionation yielded 11.4 g (76 %) of IX, b.p. 94–100°C/9 mm Hg, $n_D^{20}=1.6192$. The product solidified and was recrystallised from methanol to give an analytically pure sample, m.p. 35–35.5°C. Literature value:[22] m.p. 38°C. NMR (CCl_4): $\tau_5=2.96$, $\tau_{CH_3}=7.67$ and 7.92. (Found: C 30.4; H 3.07; S 13.8. Calc. for C_6H_7IS (238.09): C 30.27; H 2.96; S 13.47).

2,3-Dimethyl-4-thiophenecarboxylic acid. A solution of 2.0 g (8.4 mmole) of IX in 5 ml of anhydrous ether was added under nitrogen to 20 ml of a stirred ethereal solution of 0.75 N ethyl lithium at −70°C. After 10 min, the solution was poured onto carbon dioxide covered with dry ether. The usual work-up and crystallization from 50 % aqueous acetic acid, gave 0.9 g (69 %) of 2,3-dimethyl-4-thiophenecarboxylic acid, m.p. 143.5–144.5°C. Literature value:[29] m.p. 144–145°C. NMR ($CDCl_3$): $\tau_{COOH}=-1.60$, $\tau_5=2.04$, $\tau_{CH_3}=7.68$. In pyridine solution the methyl group resonances occur at 7.50 τ and 7.77 τ. (Found: C 53.7; H 5.26; S 20.5. Calc. for $C_7H_8O_2S$ (156.2): C 53.83; H 5.16; S 20.53).

2,2',3,3'-Tetramethyl-4,4'-bithienyl (X). A solution of 17.8 g (0.075 mole) of IX in 60 ml of dry ether was added with stirring and under nitrogen to 100 ml of 0.90 N ethereal butyl lithium cooled to −70°C. After 1 h at −70°C, 12.1 g (0.090 mole) of anhydrous cupric chloride was added rapidly. Stirring was continued for 4 h at −70°C, the cooling bath was removed, and when the temperature of the reaction mixture had reached 0°C, the mixture was hydrolysed with dilute hydrochloric acid. The ether phase was washed several times with dilute hydrochloric acid and water and dried ($MgSO_4$). The ether was removed *in vacuo*. Crystallization from ethanol yielded 3.9 g (47 %) of X, m.p. 71–72°C. NMR (CCl_4): $\tau_{5,5'}=3.34$, $\tau_{CH_3}=7.67$ and 8.10. (Found: C 64.6; H 6.44. Calc. for $C_{12}H_{14}S_2$ (222.4): C 64.81; H 6.35).

2,3-Dibromo-4,5-dimethylthiophene (XIII). XIII was prepared from VII as described for VI, using 2 equiv. of NBS. Distillation of the crude product yielded a main fraction, b.p. 130–140°C/16 mm Hg (7.6 g, $n_D^{20}=1.6060$). This fraction was dissolved in hexane and chromatographed on neutral alumina with hexane as eluent. 6.0 g (49 %) of XIII, $n_D^{20}=1.6040$ was obtained. Literature value:[30] b.p. 129–130°C/15 mm Hg, $n_D^{20}=1.6030$.

4-Bromo-2,3-dimethylthiophene (XIV). (Method 1). A mixture of 600 ml of water, 29 g (0.44 mole) of zinc powder and 25 ml of acetic acid was heated to reflux with vigorous stirring, and 40.0 g (0.148 mole) of 2,3-dibromo-4,5-dimethylthiophene was added. After refluxing for 5 h, the reaction mixture was steam-distilled. The organic layer was taken up in ether and washed with sodium bicarbonate solution and water, dried ($MgSO_4$) and fractionated to yield 20.0 g (71 %) of XIV, b.p. 88–92°C/15 mm Hg, $n_D^{20}=1.5695$. NMR ($CDCl_3$): $\tau_5=3.02$, $\tau_{CH_3}=7.64$ and 7.91. (Found: C 37.7; H 3.66. Calc. for C_6H_7BrS (191.10): C 37.71; H 3.64).

Bromination of 3-methyl-2-thiophene aldehyde in aluminium chloride. To 111.6 g (0.836 mole) of pulverised aluminium chloride, 42.0 g (0.334 mole) of 3-methyl-2-thiophene

aldehyde[13] was added with stirring. 128 g (0.80 mole) of bromine was added. When all of the bromine had been added, stirring became impossible. After 1 h the mixture was poured into a mixture of ice and conc. hydrochloric acid. The precipitate was taken up in ether and the ether phase was washed with sodium bicarbonate solution and water, and dried ($MgSO_4$). After evaporation of the ether the residue was recrystallised from petroleum ether (b.p. 60—75°C), yielding 68.7 g of a mixture of XVII and XVIII in the ratio 1:3.2 (according to NMR analysis). Pure compounds were obtained by fractional crystallisation from hexane.

4-Bromo-3-methyl-2-thiophene aldehyde (XVII) has a m.p. of 73.5—74.5°C. NMR (CCl_4): $\tau_5 = 2.45$, $\tau_{CHO} = 0.08$, $\tau_{CH_3} = 7.49$. $J_{CHO-5} = 1.2$ c/s. (Found: C 35.2; H 2.57; S 15.5. Calc. for C_6H_5BrOS (205.1): C 35.14; H 2.46; S 15.63). *Semicarbazone:* m.p. 246.5—247.5°C (Found: N 15.8. Calc. for $C_7H_8BrN_3OS$ (262.1): N 16.03).

4,5-Dibromo-3-methyl-2-thiophene aldehyde (XVIII) has a m.p. of 124—125°C. NMR (CCl_4): $\tau_{CHO} = 0.10$, $\tau_{CH_3} = 7.41$. (Found: C 25.8; H 1.53; S 11.2. Calc. for C_6H_4BrOS (284.0): C 25.38; H 1.42; S 11.29). *Semicarbazone:* m.p. 289—290°C (decomp.). (Found: N 12.3. Calc. for $C_7H_7Br_2N_3OS$ (341.1): N 12.32).

4-Bromo-2,3-dimethylthiophene (XIV). (Method 2). A mixture consisting of about 29 g (0.14 mole) of XVII and about 131 g (0.46 mole) of XVIII (obtained as described above), 700 ml of ethylene glycol and 320 ml hydrazine hydrate was heated with stirring. The water formed and the excess of hydrazine hydrate were distilled off. The mixture was allowed to cool until the temperature had sunk to 75°C. 192 g of potassium hydroxide was added, and when the resulting vigorous reaction had subsided, the mixture was heated again. When no more nitrogen was evolved, the mixture was heated to reflux for 15 min, and was steam-distilled. Further work-up as described for XIV (method 1), yielded 54.6 g (47 %) of XIV, b.p. 70—90°C/9 mm Hg.

Coupling experiments with 4-bromo-2,3-dimethylthiophene. A solution of 30.0 g (0.156 mole) of XIV in 30 ml of anhydrous ether was added dropwise with stirring to 160 ml of 0.5 N butyl lithium at —70°C under nitrogen. When the addition was complete, stirring was continued for 20 min at —70°C, and 22.8 g (0.170 mole) of cupric chloride was added rapidly with vigorous stirring. The procedure as described for X yielded 23 g of a red-brown oil. From this a white substance crystallised (3.3 g) and was filtered off. Recrystallization from hexane and sublimation yielded pure XV, m.p. 181—182°C. NMR (CCl_4): $\tau_{CH_3} = 7.60$ and 7.85. It had the same properties (IR spectrum, mixed m.p.) as an authentic sample described below. (Found: C 38.0; H 3.20; S 17.1. Calc. for $C_{12}H_{12}Br_2S_2$ (380.2): C 37.91; H 3.18; S 16.87).

The filtrate was distilled at reduced pressure. Fractions I and II (10.6 g) consisted mainly of starting material. Fraction III was collected at 120—185°C/12 mm Hg. It solidified and was recrystallised from methanol to yield 5.0 g of X, m.p. 71—72°C, with the same spectral data (IR, NMR) as the sample described above.

Reaction of 4-bromo-2,3-dimethylthiophene with ethyl lithium and carbon dioxide. A solution of 10.0 g (0.051 mole) of XIV in 20 ml of anhydrous ether was added slowly to 180 ml 0.30 N ethereal ethyl lithium at —70°C. After 1.25 h at —70°C, the reaction mixture was poured onto carbon dioxide covered with ether. The usual work-up gave 8.0 g of crude acid. Analysis by NMR spectroscopy of a pyridine solution showed the mixture to consist of 70 % of 2,3-dimethyl-4-thiophenecarboxylic acid and 30 % of 3-bromo-4,5-dimethyl-2-thiophenecarboxylic acid.[30] For the analysis the methyl resonances at 7.50 and 7.96 τ, respectively, were used.

2,2'-Dicarboxy-4,4',5,5'-tetramethyl-3,3'-bithienyl (XI). To a stirred solution of 5.6 g (0.025 mole) of X in 50 ml of anhydrous ether, 90 ml of 0.70 N butyl lithium was added under nitrogen. The solution was refluxed for 2 h and after cooling to —70°C, the reaction mixture was poured onto carbon dioxide covered with ether. The usual work-up and crystallization from acetic acid yielded 6.6 g (84 %) of XI, m.p. 286—287°C (decomp.). NMR ($(CD_3)_2SO$): $\tau_{CH_3} = 7.61$ and 8.28. (Found: C 54.5; H 4.59; S 20.5. Calc. for $C_{14}H_{14}O_4S_2$ (310.4): C 54.17; H 4.55; S 20.66).

Cyclisation experiments with 2,2'-dicarboxy-4,4',5,5'-tetramethyl-3,3'-bithienyl. A mixture of 2.0 g (6.4 mmole) of XI and 70 g of PPA was heated at 80°C for 3 h. The reaction mixture was poured into water and the solid material was dissolved in ether. The ether solution was extracted with sodium bicarbonate solution. Acidification of the alkaline solution yielded starting material. The ethereal solution was dried and the ether removed

in vacuo, leaving a brown substance. This showed no characteristic carbonyl frequencies in its IR spectrum and was not further investigated.

4-Iodo-2,3-dimethyl-5-thiophene aldehyde (XIX). To a stirred solution of 72.8 g (0.20 mole) of VIII in 750 ml of anhydrous ether, 200 ml of 0.75 N ethyl lithium was added under nitrogen. After stirring for 1 h at −70°C, a solution of 22 g (0.30 mole) of DMF in 25 ml of anhydrous ether was added. The cooling bath was removed and when the temperature of the reaction mixture had risen to 0°C, dilute hydrochloric acid was slowly added. The ether phase was washed with dilute hydrochloric acid, 10 % sodium bicarbonate solution and water, and dried ($MgSO_4$). The ether was removed *in vacuo* and the residue recrystallised from hexane, yielding 47.4 g (89 %) of XIX, m.p. 107.5−109°C after sublimation and recrystallization from hexane. NMR ($CDCl_3$): $\tau_{CHO}=0.22$, $\tau_{CH_3}=7.49$ and 7.78. (Found: C 31.6; H 2.61; I 47.5; S 11.9. Calc. for C_7H_7IOS (266.10): C 31.60; H 2.65; I 47.69; H 12.05). *Semicarbazone:* m.p. 268°C (decomp.). (Found. C 29.8; H 3.09; N 12.8. Calc. for $C_8H_{10}IN_3OS$ (323.2): C 29.73; H 3.12; N 13.00).

4,4'-Diiodo-2,2',3,3'-tetramethyl-5,5'-dithienyl carbinol (XX). To a stirred solution of 51.0 g (0.140 mole) of VIII in 400 ml of anhydrous ether, 200 ml of 0.70 N butyl lithium was added at −70°C under nitrogen. After 45 min, 35.9 g (0.135 mole) of XIX in 900 ml of anhydrous ether was added and stirring continued for 1 h at −70°C. The cooling-bath was removed, and at −10°C water was added. The ether phase was washed with water and dried ($MgSO_4$). Evaporation of the ether and one recrystallization from hexane gave 54.5 g (80 %) of XX as nearly white crystals. M.p. 125°C (decomp.) after recrystallization from hexane. NMR (CS_2): $\tau_{OH}=4.02$, $\tau_{CH}=7.38$, $\tau_{CH_3}=7.67$ and 7.92. (Found: C 31.3; H 2.65; I 50.7; S 12.6. Calc. for $C_{13}H_{14}I_2OS$ (504.2): C 30.97; H 2.80; I 50.34; S 12.72).

4,4'-Diiodo-2,2',3,3'-tetramethyl-5,5'-dithienyl ketone (XXI). A solution of 40.0 g (0.40 mole) of CrO_3 in 25 ml of water was added slowly to 1000 ml of ice-cooled pyridine. A solution of 65.0 g (0.129 mole) of XXI in 40 ml pyridine was added. After three days at room temperature the reaction mixture was poured into water. The precipitate was filtered, dried and extracted with ether in a Soxhlet apparatus for five days. The ether solution from which the product had partly crystallised was evaporated to dryness *in vacuo*. The yellow residue was recrystallised from ethanol, yielding 59.5 g (92 %) of XXI, m.p. 198−199.5°C after additional recrystallization from ethanol. NMR ($CDCl_3$): $\tau_{CH_3}=7.49$ and 7.75. (Found: C 31.2; H 2.43; I 50.3; S 13.0. Calc. for $C_{13}H_{12}I_2OS_2$ (502.2): C 31.09; H 2.41; I 50.54; S 12.77).

2,4-Dinitrophenylhydrazone, m.p. 252−253°C. (Found: C 33.9; H 2.64; N 8.13. Calc. for $C_{19}H_{16}I_2N_4O_4S_2$ (682.3): C 33.45; H 2.36; N 8.21).

2,3,4,5-Tetramethyl-7H-cyclopenta[1,2-b:4,3-b']dithiophene-7-one (XII). A mixture of 8.0 g (16.0 mmole) of XXI, 4.0 g (63.0 mmole) of copper bronze and 100 ml of anhydrous DMF was refluxed with stirring for 7 h. The red reaction mixture was poured into water and the precipitate filtered off and extracted with chloroform. The chloroform extracts were washed once with water, dried ($MgSO_4$) and the solvent removed *in vacuo*. Recrystallization of the red crystals from hexane yielded 3.0 g (76 %) of the title compound, m.p. 166−167°C after further recrystallization from hexane. NMR ($CDCl_3$): $\tau_{CH_3}=7.78$ and 7.95. (Found: C 62.6; H 4.72; S 25.7. Calc. for $C_{13}H_{12}OS_2$ (284.4): C 62.87; H 4.87; S 25.82).

2,3,4,5-Tetramethyl-7H-cyclopenta[1,2-b:4,3-b']dithiophene (II). (Method 1). A solution of 3.0 g (12.1 mmole) of XII in 1000 ml of anhydrous ether was added to a mixture of 8.1 g (0.21 mole) of LAH and 9.5 g (0.071 mole) of $AlCl_3$ in 25 ml of anhydrous ether. After the addition was complete water was carefully added and the layers separated. The aqueous phase was extracted twice with ether and the combined ether phases washed with water and dried ($MgSO_4$). The ether was removed *in vacuo* and the residue dissolved in a mixture of carbon tetrachloride and petroleum ether (b.p. 60−75°C) 10:1 (v/v). This was chromatographed on a neutral alumina column using the same solvent mixture as eluent. After evaporation of the solvents the residue was sublimed and then recrystallized from ethanol to yield 1.85 g (65 %) of the title compound, m.p. 176−177°C. NMR (CS_2): $\tau_{CH_3}=6.60$, $\tau_{CH_3}=7.70$ and 7.75. (Found: C 66.4; H 6.21; S 27.4. Calc. for $C_{13}H_{14}S_2$ (234.4): C 66.62; H 6.02; S 27.36).

4,4'-Diiodo-2,2',3,3'-tetramethyl-5,5'-dithienyl methane (XXII). A solution of 23.5 g (175 mmole) of $AlCl_3$ in 100 ml of anhydrous ether was added with stirring to 3.5 g (87.5 mmole) of LAH. To this mixture, a solution of 25.0 g (49.5 mmole) of XX in 300 ml of anhydrous ether was added. When the addition was complete, the reaction mixture was

refluxed for 15 min. The excess of LAH was destroyed and the reaction mixture was poured into dilute sulphuric acid. The ether phase was washed with bicarbonate solution and water, and dried ($MgSO_4$). The solvent was removed *in vacuo* and the crude product recrystallized from methanol, yielding 22.2 g (92 %) of the title compound, m.p. 109—110°C. NMR ($CDCl_3$): $\tau_{CH_3}=5.82$, $\tau_{CH_3}=7.64$ and 7.85. (Found: C 32.1 H 2.86; S 13.1. Calc. for $C_{13}H_{14}I_2S_2$ (504.2): C 31.98; H 2.89; S 13.14).

2,3,4,5-Tetramethyl-7H-cyclopenta[1,2-b:4,3-b']dithiophene (II). (Method 2). To 30 ml 0.75 N ethereal butyl lithium at —70°C, 4.1 g (8.4 mmole) of XXII in 150 ml of anhydrous ether was added. After stirring at —70°C for 1.5 h, the solution was transferred under nitrogen to a dropping funnel and in 15 min added with rapid stirring to an ice-cooled suspension of 3.4 g (25 mmole) of cupric chloride in 25 ml of anhydrous ether. Stirring at 0°C was continued for 4 h. The work-up as described for X gave a dark oil which was taken up in chloroform and chromatographed on a silica column with the same solvent as eluent. After evaporating the chloroform, the remaining red oil was sublimed, yielding after recrystallization from methanol 200 mg (10 %) of the title compound, m.p. 171—173°C.

2,2',3,3'-Tetramethyl-5,5'-bithienyl (XXIII). To 320 ml of ethereal 1.03 N butyl lithium a solution of 33.6 g (0.30 mole) of VII in 100 ml of anhydrous ether was added slowly with stirring. The reaction mixture was refluxed for 2 h and cooled to —70°C. With vigorous stirring, 47.1 g (0.35 mole) of anhydrous cupric chloride was added rapidly and stirring continued for 4 h at —70°C. The work-up as described for X gave a light-brown residue, which was recrystallized from petroleum ether (b.p. 80—120°C) to yield 22.7 g (68 %) of XXIII which could be further purified by sublimation and recrystallization from hexane, m.p. 123.5—124.5°C. NMR ($CDCl_3$): $\tau_{4,4'}=3.29$, $\tau_{CH_3}=7.74$ and 7.95. (Found: C 65.1; H 6.33. Calc. for $C_{12}H_{14}S_2$ (222.4): C 64.81; H 6.35).

4,4'-Dibromo-2,2',3,3'-tetramethyl-5,5'-bithienyl (XV). To a solution of 11.0 g (0.050 mole) of XXIII in 200 ml of chloroform, 16.0 g (0.10 mole) of bromine in 150 ml of chloroform was added slowly with stirring. The reaction mixture was stirred for 15 min after the addition was complete and the chloroform solution washed with water, 10 % sodium bicarbonate solution and again with water. After drying ($MgSO_4$) the solvent was evaporated *in vacuo* and the residue recrystallized from petroleum ether (b.p. 80—120°C) to yield 16.9 g (88 %) of XV, m.p. 181—182°C.

4,4'-Diiodo-2,2',3,3'-tetramethyl-5,5'-bithienyl. To a solution of 36.4 g (0.10 mole) of VIII in 500 ml of anhydrous ether, 160 ml of 0.7 N ethyl lithium was added at —70°C under nitrogen and stirring was continued for half an hour at —70°C. 20.0 g (0.15 mole) of anhydrous cupric chloride was then rapidly added with vigorous stirring. The procedure as described for X gave a solid residue, which was suspended in some ether, filtered off and recrystallized from hexane, yielding 10.3 g (44 %) of the title compound, m.p. 179—180°C (decomp.) after additional recrystallization from hexane. NMR ($CDCl_3$): $\tau_{CH_3}=7.57$ and 7.80. (Found: C 30.5; H 2.69; S 13.6. Calc. for $C_{12}H_{12}I_2S_2$ (474.2): C 30.40; H 2.55; S 13.52).

4,4'-Dicarboxy-2,2',3,3'-tetramethyl-5,5'-bithienyl (XXIV). To a solution of 11.0 g (0.029 mole) of XV in 1000 ml of anhydrous ether, 150 ml 0.90 N butyl lithium was added at —70°C under nitrogen. After stirring for 2 h at —70°C, the reaction mixture was poured onto carbon dioxide covered with ether. The usual work-up and recrystallization from acetic acid yielded 6.2 g (69 %) of the title compound, m.p. 293.5—295°C (decomp.). NMR ($(CD_3)_2SO$): $\tau_{CH_3}=7.70$ and 7.82. (Found: C 54.5; H 4.60; S 20.9. Calc. for $C_{14}H_{14}O_4S_2$ (310.4): C 54.17; H 4.55; S 20.66).

Cyclization experiments with 4,4'-dicarboxy-2,2',3,3'-tetramethyl-5,5'-bithienyl. A mixture of 2.0 g (6.4 mmole) of XXIV and 60 g of PPA were heated under rapid stirring for 5 h at 80°C. The reaction mixture was poured into water. Extraction with much ether left 200 mg of XXVI, m.p. 251—252°C, after recrystallization from acetic acid. (Found: C 57.3; H 3.99; S 22.0. Calc. for $C_{10}H_{12}O_3S_2$ (292.4): C 57.51; H 4.13; S 21.93). Evaporation of the ether extracts yielded some solid material, which partly dissolved in ethanol. Upon evaporation of the alcohol extract a solid separated which was chromatographed on silica with carbon tetrachloride as eluent, yielding one fraction consisting of 100 mg of XXIII and another dark-violet fraction containing 80 mg of somewhat impure XXV, m.p. 211—214°C, as was evident from IR spectral comparison with the pure sample described below.

2,3-Dimethyl-4-thiophene aldehyde (XXVII). XXVII was prepared from IX, in the same way as described for XIX, in 80 % yield. B.p. 103–110°C/12 mm Hg. Upon redistillation the boiling point was 103–106°C/12 mm Hg, $n_D^{20}=1.5627$. NMR ($CDCl_3$): $\tau_{CHO}=0.23$, $\tau_5=2.25$, $\tau_{CH_3}=7.70$. (Found: C 59.7; H 5.89; S 22.5. Calc. for C_7H_8OS (140.2): C 59.97; H 5.75; S 22.87). *2,4-Dinitrophenylhydrazone*, m.p. 274–275°C (decomp.). (Found: C 48.0; H 3.75; N 17.1. Calc. for $C_{13}H_{12}N_4O_4S$ (320.4): C 48.74; H 3.78; N 17.49).

2,2',3,3'-Tetramethyl-4,4'-dithienyl carbinol (XXVIII). XXVIII was prepared from XXVII and IX as described for XX in 92 % yield. M.p. 114–115°C, after additional crystallization from hexane. NMR ($CDCl_3$): $\tau_{5,5'}=3.32$, $\tau_{OH}=4.53$, $\tau_{CH}=7.43$, $\tau_{CH_3}=7.73$ and 8.08. (Found: C 61.8; H 6.39; S 25.3. Calc. for $C_{13}H_{16}OS_2$ (252.4): C 61.86; H 6.39; S 25.41).

2,2',3,3'-Tetramethyl-4,4'-dithienyl ketone (XXIX). A solution of 20.0 g (0.20 mole) of chromic trioxide in 20 ml water was added slowly to 400 ml of ice-cooled pyridine. After 5 min, a solution of 15.5 g (0.061 mole) of XXVIII in 30 ml of pyridine was added. The reaction mixture was set aside for three days at room temperature, after which the precipitate was filtered off and the filtrate poured into much water. The solid that precipitated was filtered off, giving 12.5 g of nearly pure XXIX, m.p. 74–75°C. The first precipitate was extracted for one day with chloroform in a Soxhlet apparatus. After removing the solvent *in vacuo*, the residue was recrystallized from 50 % aqueous methanol, yielding 1.3 g of the title ketone, thus giving a total yield of 13.8 g (90 %). Recrystallization from 50 % aqueous methanol yielded the analytically pure ketone, m.p. 75–76°C. NMR ($CDCl_3$): $\tau_{5,5'}=2.58$, $\tau_{CH_3}=7.67$ and 7.71. (Found: C 62.4; H 5.74; S 25.3. Calc. for $C_{13}H_{14}OS_2$ (250.4): C 62.36; H 5.64; S 25.61).

2,2'-Diiodo-4,4',5,5'-tetramethyl-3,3'-dithienyl ketone (XXX). A mixture of 10.0 g (40.0 mmole) of XXIX, 68 ml of acetic acid, 10 ml of water 10 ml of carbon tetrachloride, 0.8 ml of conc. sulphuric acid, 9.0 g (35.4 mmole) of iodine and 3.2 g (18.7 mmole) of iodic acid was stirred vigorously for 1.5 h at 50°C and 2 h at room temperature. The solid material was filtered off and recrystallized from ethanol to yield 18.4 g (91 %) of the title compound as light yellow needles. The analytical sample was obtained after further recrystallization from ethanol, m.p. 100°C (decomp.), rapid heating 170°C (decomp.). NMR ($CDCl_3$): $\tau_{CH_3}=7.65$ and 7.86. (Found: C 31.7; H 2.49; S 12.7. Calc. for $C_{13}H_{12}I_2OS$ (502.2): C 31.09; H 2.41; S 12.77).

2,3,5,6-Tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene-4-one (XXV). XXV was prepared from XXX as described for XII in 90 % yield. The reaction time was 16 h. M.p. 217–218°C after recrystallization from methanol. NMR ($CDCl_3$): $\tau_{CH_3}=7.77$ and 7.88. (Found: C 63.1; H 4.98; S 25.7. Calc. for $C_{13}H_{12}OS_2$ (248.4): C 62.87; H 4.87; S 25.82).

4-Hydroxy-2,3,5,6-tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene (XXXII). A solution of 1.54 g (12.0 mmole) of $AlCl_3$ was added slowly to 0.22 g (6.0 mmole) of LAH. To the resulting suspension a solution of 1.0 g (4.0 mmole) of XXV in 500 ml of anhydrous ether was added. When the addition was complete, stirring was continued for 5 min and excess LAH was destroyed with ethyl acetate and water. The ether phase was washed with water and dried ($MgSO_4$). The solvents were removed *in vacuo* and the crude product was recrystallized from ethanol, yielding 830 mg (83 %) of the title compound, m.p. 182–183°C (decomp.). NMR ($CDCl_3$): $\tau_{OH}=4.88$, $\tau_{CH_3}=7.66$ and 7.83. (Found: C 62.2; H 5.70; S 25.4. Calc. for $C_{13}H_{14}OS_2$ (250.4): C 62.36; H 5.64; S 25.61).

2,3,5,6-Tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene (III). (Method 1). A mixture of 1.0 g (4.0 mmole) of XXV, 25 ml of ethylene glycol, 10 ml of hydrazine hydrate and 10 g of potassium hydroxide was heated to 210°C, whereupon the reaction mixture was cooled and poured into water. The resulting solid material was taken up in benzene and ethyl acetate. The combined organic phases were washed with water and dried ($MgSO_4$). After removing the solvents, the residue was dissolved in benzene and chromatographed on an alumina (neutral) column, using benzene as eluent. The first fraction gave 140 mg (15 %) of the title compound, m.p. 158–159°C, after recrystallization from ethanol. NMR (CS_2): $\tau_{CH_3}=6.93$, $\tau_{CH_3}=7.63$ and 7.92. (Found: C 66.5; H 6.14; S 27.1. Calc. for $C_{13}H_{14}S_2$ (234.4): C 66.62; H 6.02; S 27.36).

2,3,5,6-Tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene (III). (Method 2). 1.0 g (4.0 mmole) of XXV was reduced with 15.4 g (0.120 mole) of $AlCl_3$ and 2.2 g (0.060 mole) of LAH as described for method 1. After removing the solvents *in vacuo*, the residue was dissolved in carbon tetrachloride and chromatographed on a neutral alumina column.

Carbon tetrachloride and then benzene were used as eluents. After recrystallization from ethanol 100 mg (11 %) of the title compound was obtained, m.p. 155–156°C.

2,2',3,3'-Tetramethyl-4,4'-dithienyl methane (XXXIII). XXXIII was prepared from XXXVIII as described for XXII in 91 % yield, m.p. 59.5–61°C. NMR ($CDCl_3$): $\tau_{\alpha,\alpha'}=3.50$, $\tau_{CH_3}=6.37$, $\tau_{CH_3}=7.67$ and 8.00. (Found: C 65.7; H 6.81. Calc. for $C_{13}H_{16}S_2$ (236.4): C 66.05; H 6.82).

2,3,5,6-Tetramethyl-4H-cyclopenta[2,1-b:3,4-b']dithiophene (III). (Method 3). To a solution of 1.50 g (6.3 mmole) of XXXIII in 25 ml of anhydrous ether, 25 ml 0.65 N ethereal butyl lithium was added. The mixture was boiled under reflux for one hour and transferred under nitrogen to a dropping funnel, from which it was dropped into a rapidly stirred suspension of 2.0 g (15 mmole) of cupric chloride in 50 ml of anhydrous ether, cooled to −20°C. Stirring at −20°C was continued for 1 h and then the reaction mixture was stirred for 3 h at 0°C. The work-up as described for X gave a residue which was washed with a small amount of petroleum ether (b.p. 60–75°C). The undissolved part was filtered by suction and sublimed. After recrystallization from ethanol, 15 mg (1 %) of the title compound was obtained, m.p. 155–158°C. Mixed m.p. 155–157°C.

2,5-Dimethyl-3-thiophene aldehyde (XXXV). XXXV was obtained from *3*-iodo-2,5-dimethylthiophene [26] as described for XIX in 85 % yield, b.p. 97–99°C/11 mm Hg, $n_D^{20}=1.5631$. Literature value:[34] b.p. 77–82°C/4 mm Hg, $n_D^{20}=1.5620$.

Attempted preparation of 3-iodo-2,5-dimethyl-4-thiophenealdehyde from 3,4-diiodo-2,5-dimethylthiophene. A solution of 90.0 g (0.247 mole) of 3,4-diiodo-2,5-dimethylthiophene [26] in 700 ml of anhydrous ether was added with stirring to 260 ml of 1.05 N butyl lithium at −70°C. After stirring for 15 min, this solution was transferred by nitrogen pressure into a stirred ice-cold solution of 29.2 g (0.40 mole) of DMF in 100 ml of anhydrous ether. The work-up as described for XIX and crystallization from petroleum ether (b.p. 60–75°C) yielded 39.6 g of a mixture containing 3,4-diiodo-2,5-dimethylthiophene, 3-iodo-2,5-dimethyl-4-thiophene aldehyde and 2,5-dimethyl-3,4-thiophene dialdehyde. Further crystallization from hexane yielded pure 2,5-dimethyl-3,4-thiophene dialdehyde, m.p. 93.5–95°C. Literature value:[46] m.p. 95–96°C. NMR ($CDCl_3$): $\tau_{CHO}=-0.34$, $\tau_{CH_3}=7.29$. (Found: C 56.8; H 4.63; S 19.1. Calc. for $C_8H_8O_2S$ (266.1): C 57.15; H 4.79; S 19.05).

3-Iodo-2,5-dimethyl-4-thiophene aldehyde (XXXVI). A mixture of 19.6 g (0.141 mole) of XXXV, 60 ml of acetic acid, 22.5 ml of water, 30 ml of carbon tetrachloride, 0.9 ml of conc. sulphuric acid, 14.4 g (0.057 mole) of iodine and 10.6 g (0.060 mole) of iodic acid was stirred vigorously for 5 h at 80°C. The work-up as described for VIII gave 31.1 g (83 %) of XXXVI, m.p. 52–55°C. Recrystallization from hexane raised the m.p. to 59–60°C. NMR ($CDCl_3$): $\tau_{CHO}=0.12$, $\tau_{CH_3}=7.33$ and 7.66. (Found: C 31.5; H 2.41; S 12.1. Calc. for C_7H_7IOS (266.1): C 31.60; H 2.65; S 12.05). *2,4-Dinitrophenylhydrazone*, m.p. 255.5–256.5°C (decomp.). (Found: C 35.0; H 2.66; N 12.8. Calc. for $C_{13}H_{11}IN_4O_4S$ (447.2): C 34.91; H 2.70; N 12.53).

3,3'-Diiodo-2',4,5,5'-tetramethyl-2,4'-dithienyl carbinol (XXXVII). XXXVII was prepared from VIII and XXXVI as described for XX in 58 % yield, m.p. 119.5–121°C. NMR (CS_2): $\tau_{OH}=4.09$, $\tau_{CH}=7.73$, $\tau_{CH_3}=7.58$, 7.67 and 7.89. (Found: C 30.9; H 2.96; S 12.7. Calc. for $C_{13}H_{14}I_2OS_2$ (504.2): C 30.97; H 2.80; S 12.72).

3,3'-Diiodo-2',4,5,5'-tetramethyl-2,4'-dithienyl ketone (XXXVIII). XXXVIII was obtained from XXXVII as described for XXI in 90 % yield, m.p. 188.5–190°C after recrystallization from ethanol. NMR ($CDCl_3$): $\tau_{CH_3}=7.49$, 7.62, 7.65, and 7.75. (Found: C 31.1; H 2.62; I 50.8; S 12.8. Calc. for $C_{13}H_{12}I_2OS_2$ (502.2): C 31.09; H 2.41; I 50.54; S 12.77).

2,3,4,6-Tetramethyl-7H-cyclopenta[2,1-b:3,4-c']dithiophene-7-one (XXXIX). XXXIX was prepared from XXXVIII as described for XII in 93 % yield. The reaction time was 20 h. M.p. 139.5–141°C after recrystallization from ethanol. NMR ($CDCl_3$): $\tau_{CH_3}=7.56$, 7.64, 7.68, and 7.81. (Found: C 62.5; H 4.73; S 25.7. Calc. for $C_{13}H_{12}OS_2$ (248.4): C 62.87; H 4.87; S 25.82).

2,3,4,6-Tetramethyl-7H-cyclopenta[1,2-b:3,4-c']dithiophene (IV). 6.0 g (24.2 mmole) of XXXIX was reduced with $AlCl_3$ and 1.8 g (0.047 mole) of LAH as described for II (method 1). The crude product was recrystallized from ethanol, yielding 4.9 g (87 %) of the title compound. M.p. 131–132°C, after sublimation and recrystallization from ethanol. NMR (CS_2): $\tau_{CH_3}=6.79$, $\tau_{CH_3}=7.54$ and 7.75. (Found: C 66.5; H 6.13; S 27.3. Calc. for $C_{13}H_{14}S_2$ (234.4): C 66.62; H 6.02; S 27.36).

4-Iodo-2,2',5,5'-tetramethyl-3,3'-bithienyl (XLI). A mixture of 12.0 g (0.054 mole) of 2,2',5,5'-tetramethyl-3,3'-bithienyl,[26] 93 ml of acetic acid, 15 ml of water, 15 ml of carbon tetrachloride, 0.9 ml of conc. sulphuric acid, 2.2 g (0.012 mole) of iodic acid and 6.5 g (0.025 mole) of iodine were heated at 80°C for 1.5 h with vigorous stirring. The reaction mixture was poured onto ice and the precipitate filtered off. Recrystallization from ethanol yielded 15.2 g (81 %) of XLI, m.p. 117–119.5°C after additional crystallization from ethanol. NMR ($CDCl_3$): $\tau_{4'}=3.58$, $\tau_{CH_3}=7.60$, 7.77 and 7.85. $J_{4'\text{-}CH_3(5')}=1.0$ c/s. (Found: C 41.2; H 3.90; S 18.6. Calc. for $C_{13}H_{13}IS_2$ (348.3): C 41.39; H 3.76; S 18.41).

4-Carboxy-2,2',5,5'-tetramethyl-3,3'-bithienyl (XLII). To 350 ml 0.70 N ethereal ethyl lithium cooled to −70°C, 80.0 g (0.230 mole) of XLI was added at such a rate that the temperature did not rise above −60°C. After 1 h stirring at −70°C, the reaction mixture was poured onto carbon dioxide covered with anhydrous ether. The usual work-up and recrystallization from acetic acid-water (60:40) yielded 51.5 g (84 %) of the title compound, m.p. 143.5–144.5°C. NMR (CS_2): $\tau_{COOH}=-2.11$, $\tau_{4'}=3.75$, $\tau_{CH_3}=7.40$, 7.64, and 7.77. (Found: C 58.2; H 5.29; S 24.0. Calc. for $C_{13}H_{14}O_2S$ (234.3): C 58.62; H 5.30; S 24.07).

1,3,4,6-Tetramethyl-7H-cyclopenta[1,2-c:3,4-c']dithiophene-7-one (XLIII). (Method 1). A mixture of 5.0 g (18.8 mmole) of XLII and 50 g of polyphosphoric acid was heated with stirring at 120–130°C for 20 min and then poured into a mixture of ice and conc. hydrochloric acid. The precipitate was taken up in ether and the ethereal solution was washed with 10 % sodium bicarbonate solution and water, and then dried ($MgSO_4$). Evaporation of the ether and recrystallization of the residue from ethanol yielded 3.5 g (77 %) of the title compound, m.p. 141–142°C. Literature value:[5] m.p. 142–142.5°C.

1,3,4,6-Tetramethyl-7H-cyclopenta[1,2-c:3,4-c']dithiophene-7-one (XLIII). (Method 2). To an ice-cooled solution of 21.0 g (0.075 mole) of XLII and 58.9 g (0.075 mole) of acetyl chloride in 110 ml of anhydrous benzene, 21.6 g (0.083 mole) of tin tetrachloride was added dropwise with stirring. When the addition was complete, stirring was continued for 1.5 h at room temperature and the reaction mixture poured onto a mixture of ice and conc. hydrochloric acid. The precipitate was taken up in a large amount of ether and the ethereal solution was washed with 10 % sodium bicarbonate solution and water. Acidification of the alkaline extracts led to the recovery of 2.7 g of the starting acid. After drying the ethereal solution ($MgSO_4$) the solvent was evaporated and the residue recrystallized from ethanol to yield 12.2 g (66 %) of the title compound, m.p. 139–141°C. Literature value:[5] 142–142.5°C.

1,3,4,6-Tetramethyl-7H-cyclopenta[1,2-c:3,4-c']dithiophene (I). This was prepared from XLIII by reduction with $AlCl_3$-LAH according to Ref. 5, in 97 % yield, m.p. 186.5–187.5°C. Literature value:[5] m.p. 187–188°C.

NMR spectra were recorded on a Varian A 60 NMR spectrometer. Mass spectra were recorded on an LKB A-9000 mass spectrometer and correct molecular weights were obtained for all compounds. IR spectra were recorded on a Perkin-Elmer 257 grating infra-red spectrophotometer. The elementary analyses were carried out at the Analytical Department of the Chemical Institute.

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