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LETTERS

Chiral auxiliaries onto conducting polymers

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Abstract—The synthesis of new chiral auxiliaries was performed onto conducting polythiophene. The electrochemical behaviour of such a matrix was investigated and one of them present a noticeable stability when an adequate spacer is introduced between the redox centre and the chiral unit. © 2001 Elsevier Science Ltd. All rights reserved.

Apart from the large number of asymmetric reactions involving soluble diphosphine–metal complexes,[1] the use of supported catalysts in order to get stereoselective synthesis at a solid interface is a highly developed, yet still evolving, topic.[2] Despite the tremendous activity devoted to this route and in connection with previous studies based on optically-active acetals,[3] we focused our efforts on the development of chiral auxiliaries onto conducting polymers. This would allow the design of a large variety of modified electrodes as well as their potential use in catalytic reactions involving electrogenerated species. To this purpose, different thiophene monomers **1** and **2** linked to a chiral acetal ring were synthesised (Fig. 1). Their further electropolymerisation at a solid anode readily led to the desired polymer without any expensive and time-consuming polystyrene functionalisation.

1 n = 0, 2 **2**

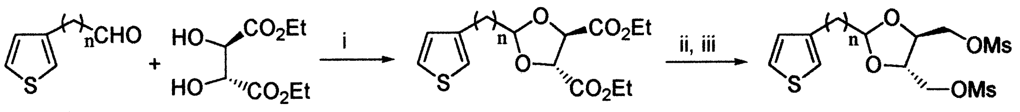
Figure 1.

Compounds **1** and **2** were obtained according to the following sequence (Scheme 1). The first step consisted of a standard acetal formation starting from aldehydes **3a**,**b** and diol **4**. The last step leading to the di-mesylates **2a**,**b** was performed by an ethyl ester reduction followed by mesylation of the subsequent diol.[4]

The electrochemical behaviour of monomers **1a**,**b** and **2a**,**b** was studied as well as their anodic polymerisation. The cyclic voltammetry behaviour of both monomers and polymers was investigated within the range 0 to +2 V in 0.1 M Bu_4NBF_4+CH_2Cl_2. All electrochemical data are summarised in Table 1. At 100 mV s^{-1}, **1a** exhibited a single irreversible oxidation peak at $E_{pa}=1.77$ V, while **1b** presented a less anodic value (Table 1, entry 2). A more noticeable difference present between **2a**

Table 1. Electrochemical data for compounds **1** and **2**

	E_{pa} (V)	E_f (V)
1a	1.77	1.475
1b	1.70	1.40
2a	1.78	1.60
2b	1.57	1.50



3a: n=0
3b: n=2
4
1a,b
2a,b

Scheme 1. (i) $H^+/C_6H_6/\Delta$; (ii) $LiAlH_4/Et_2O$; (iii) $MsCl/Et_3N/CH_2Cl_2$.

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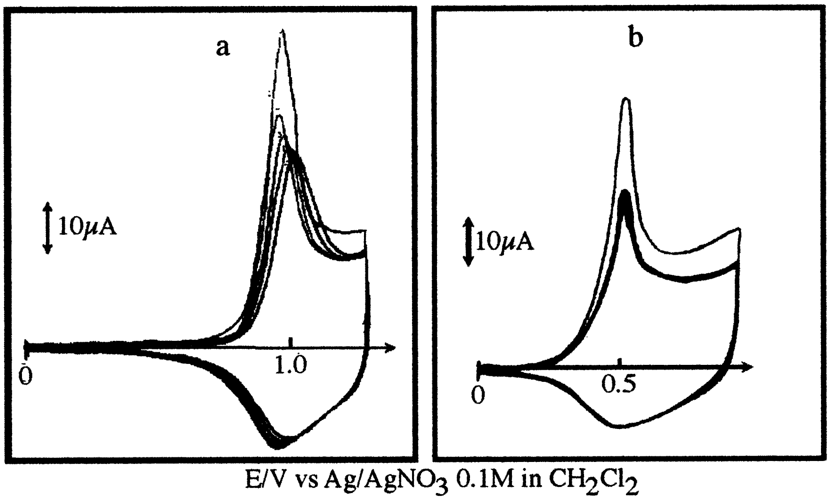
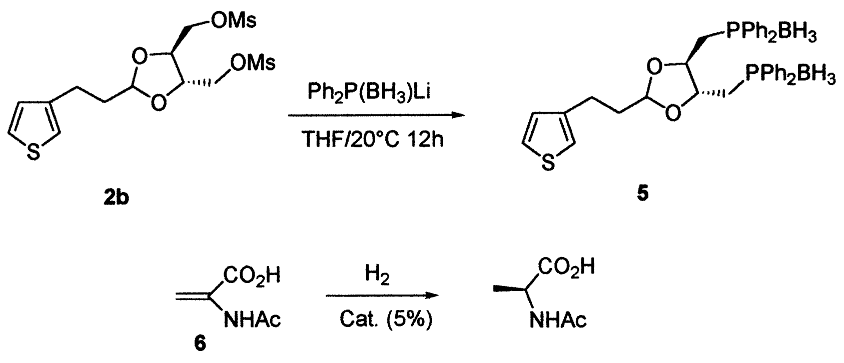


Figure 2.



Scheme 2.

and **2b** indicating the direct influence of the length of the intermediate spacer, which links the acetal ring and the thiophene unit. This observation can be explained by the inductive effect of the two oxygen atoms that, when directly attached to the electroactive thiophene, decrease its electronic density and render the electronic transfer more difficult.[5]

The progressive electrochemical growth (cyclic voltammetry)[6] of poly-(**2**) was performed in CH_2Cl_2+0.1 M Bu_4NBF_4 as inert electrolyte since no polymerisation was found to occur using CH_3CN. Fig. 2 shows a typical response of a conducting phase covering the working electrode. As an example, a resin corresponding to poly-(**2b**) was obtained after six recurrent potential cycles (Fig. 2b). Contrary to poly-(**2a**) (Fig. 2a), it exhibited a noticeable stability without any displacement of potentials during the experiment toward more anodic values.

The potentiostatic growth of the title poly-(**2**) matrix was investigated. Thus, the obtaining of a growing redox system at $E_f = 1.60$ or 1.50 V for poly-(**2a**,**b**), respectively, accounts for the deposition of the polymer layer. The same observations occurred when starting from poly-(**1**).

As measured by chronoamperometry, different experiments conducted at higher potentials led to polymer destruction by over-oxidation. The high electrochemical stability of poly-(**2b**) as well as its easy access allowed us to investigate its properties as a solid-phase asymmetric reagent. For this purpose, the derivatisation of the mesylate groups in phosphine boranes was performed first on the monomer. As demonstrated using monomer **5** obtained from **2b** according to known procedure,[7] a model hydrogenation[8] of alkene **6** led to the desired reduced *S* product in quantitative yield with an enantiomeric excess of 68% (Scheme 2). The efficiency of such a catalyst appeared identical to that of the DIOP complex. First attempts at heterogeneous catalysis on poly-(**5**) modified electrodes gave unsatisfactory results (ee close to 0). On the contrary, the use of a co-polymer between thiophene and **5** led to promising results (57% ee and 20% hydrogenation).

In conclusion, we have developed a new class of conducting polythiophenes bearing chiral auxiliaries. We have found that poly-(**2b**) was stable toward oxidative cycling, and we are currently investigating the improvement of such a process in order to increase the stereoselectivity of the heterogeneous reaction.

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4. Compounds **1a**,**b**, **2a**,**b** and **5** were prepared according standard procedures.[8] Diphosphine borane **5** was purified by column chromatography using cyclohexane/ethylacetate (9:1 v/v) as eluant.

   1a: yield: 88% ^{1}H NMR ($CDCl_3$): δ_{ppm} 7.35 (2H, m, $H_{thiophene}$); 7.55 (1H, m, $H_{thiophene}$); 6.30 (1H, s, O-CH-O), 4.95–4.8 (2H, AB system *J* 3.8, 2×O-CH); 4.25 (4H, 2q, 2×CH_2OCO); 1.30 (6H, 2t, 2×CH_3). **1b**: yield: 70% ^{1}H NMR ($CDCl_3$): δ_{ppm} 7.15 (1H, m, $H_{thiophene}$); 6.80 (2H, m, $H_{thiophene}$); 5.20 (1H, m, O-CH-O); 4.75–4.60 (2H, AB system, *J* 3.9, 2×O-CH); 4.15 (4H, 2q, 2×CH_2OCO); 2.90 (2H, t, CH_2-thiophene); 2.10 (2H, m, CH_2); 1.20 (6H, 2q, 2×CH_3).

   2a: overall yield: 45% ^{1}H NMR ($CDCl_3$): δ_{ppm} 7.45 (1H, m, $H_{thiophene}$); 7.30 (1H, m, $H_{thiophene}$); 7.15 (1H, m, $H_{thiophene}$); 6.10 (1H, s, O-CH-O); 4.35 (6H, m, 2×O-CH and 2×CH_2-O); 3.10 (3H, s, CH_3); 2.99 (3H, s, CH_3).

   2b: overall yield: 30% ^{1}H NMR ($CDCl_3$): δ_{ppm} 7.45 (1H, m, $H_{thiophene}$); 7.10 (2H, m, $H_{thiophene}$); 5.30 (1H, t, O-CH-O); 4.55 (4H, m, 2×CH_2-Oms); 4.40 (2H, m, 2×O-CH); 3.25 (6H, s, 2×CH_3); 2.90 (2H, m, CH_2-thiophene); 2.15 (2H, m, CH_2).

   5: yield: 47% ^{1}H NMR ($CDCl_3$): δ_{ppm} 7.90–7.30 (20H, m, Phenyl); 7.15 (1H, m, $H_{thiophene}$); 6.75 (2H, m, $H_{thiophene}$); 4.75 (1H, t, O-CH-O); 4.20 (2H, m, O-CH); 2.60 (2H, m, CH_2-thiophene); 2.35 (4H, m, CH_2-P); 1.70 (2H, m, CH_2). ^{31}P NMR ($CDCl_3$): δ_{ppm} 13.9 (m).
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6. Electrochemical experiments and instrumentation: Tetra-*n*-butylammonium tetrafluoroborate from Fluka was recrystallised three times from a methanol/water mixture (1/1 v/v) and dried under vacuum for 48 h. Dichloromethane (electrochemical grade) purchased from Merck was used without further purification and stored under a dry argon atmosphere. All electrolytic solutions were dried in situ over neutral alumina (Merck) previously activated at 450°C under vacuum for several hours. They were thoroughly degassed and kept under a positive pressure of argon during each run.

   Cyclic voltammetry measurements were performed in a classical three-electrode cell using a platinum disk (area: 0.8 mm^2) as working electrode and a glassy carbon rod as counter electrode. All potentials were referred to the system Ag/0.1 M $AgNO_3$ in CH_2Cl_2. The cell was connected to an EG&G-PAR model 173 potentiostat monitored with an EG&G-PAR model 175 signal generator. Cyclic voltammograms were plotted on an X-Y SEFRAM type TGM 164 recorder.
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   A mixture of $(RhCODCl)_2$ (0.0014 mmol), diphosphine **3** (5%) and α-acetamidoacrylic acid (1.120 mmol) in methanol (2.6 ml) was stirred in the hydrogenation apparatus under a hydrogen atmosphere for 6 h. After concentration to dryness, the residue was dissolved in water and the catalyst was eliminated by simple filtration. The *N*-acetyl alanine was finally obtained by further evaporation of the title solution.