Route Towards New Heteroaromatic Benzo[1,4]dioxine Derivatives

Joachim Storsberg,## Dieter Schollmeyer, and Helmut Ritter*†
Johannes Gutenberg-Universität Mainz, Institut für Organische Chemie, Duesbergweg 10-14, D-55099 Mainz, Germany
†Heinrich-Heine-Universität, Institut für Organische und Makromolekulare Chemie,
Lehrstuhl II, Universitätsstr. 1, D-40225 Düsseldorf, Germany

(Received September 17, 2002; CL-020795)

2*H*-[1,4]benzodioxino[2,3-c]pyrrole- and thieno[3,4-b][1,4]benzodioxine derivatives were synthesized via nucleophilic aromatic substitution reactions of halogenated benzene derivatives with the corresponding 3,4-dihydroxythiophene or pyrrole derivatives.

The discovery in the year 1977, that polyacetylene upon oxidation with halogens becomes electrically conducting,[1] can be regarded as the origin of a tempestuous development in the field of electrical conducting polymers, which was honoured with the Nobel prize in 2000. Nowadays, many of conducting polymers are based on pyrrole- and thiophene-derivatives, whereas 3,4-ethylenedioxythiophene (EDT) and its derivatives are currently extensively used.[2] The search for conducting polymers with improved properties motivates for structure variation of the monomers used in the fabrication of these polymers. In this communication we wish to report for the first time the synthesis of a completely new class of modified pyrrole or thiophene monomers, having benzo[1,4]dioxino structure (Figure 1). They can be polymerised via chemical or electrochemical routes to yield the corresponding poly(heterocycles). The key step toward these new compounds is the formation of the substituted 1,4-dioxane ring, which was performed by a nucleophilic aromatic displacement reaction of the heteroaromatic 3,4-diols[3] with 3,4-difluorobenzonitrile (DFBN) (R^1 = CN, COOH) or 2-chloronitrobenzene (CNB) (R^1 = H).[4] The reaction of **4** with DFBN was carried out in dimethylformamide as solvent in the presence of 2 mol equiv. K_2CO_3 at 130 °C (Scheme 1). After 15 h reaction time, **1a** was isolated in 95% yield. However, trying to synthesize **2a** under these conditions was not yet successful. The only solvent, that was found to be suitable in order to obtain **2a** via the reaction of **3** with DFBN was hexamethylphosphorous triamide (HMPT) at 120 °C. The same observations were made for the reaction of **3** or **4** with CNB. Only in HMPT as solvent, satisfying yields of **2d** or **1g** were achieved. Saponification of the ester- and nitrile-functional group was achieved in aqueous NaOH solution, followed by acidification with aqueous HCl. The tricarboxylic acids **1b**, **1e**, **2b** and the dicarboxylic acids **1i** and **2e** could be isolated by simple filtration. Debenzylation of the N-functional group was achieved in a mixture of trifluoroacetic acid/H_2SO_4 within 30 min at 90 °C. Decarboxylation to yield the heterocycles unprotected in α-position **1d**, **1e**, **1i**, **2c**, and **2f**, was generally performed by heating the carboxylic acids in ethanolamine or dimethylacetamide (DMAA). Using ethanolamine, there was a side reaction, namely the formation of the corresponding amides

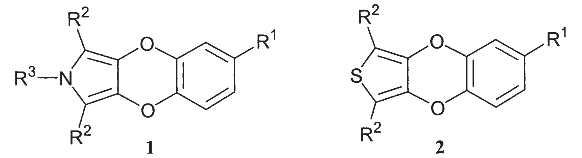
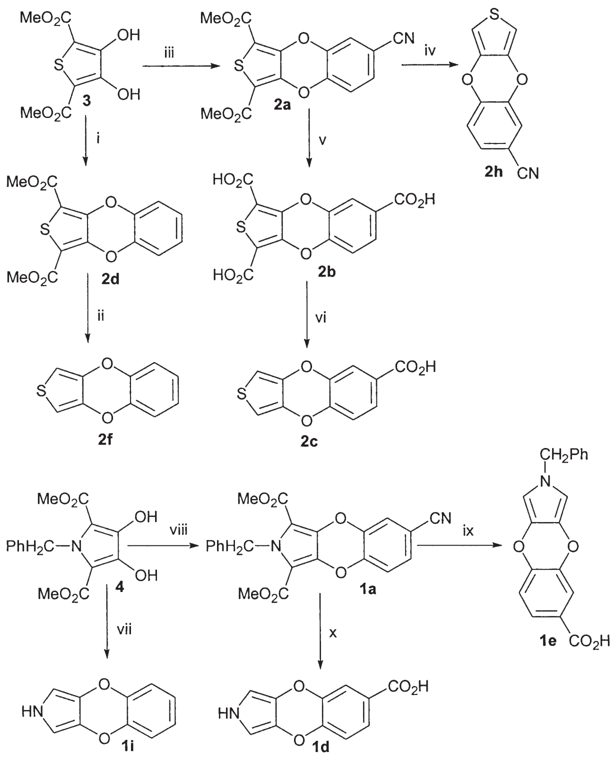


Figure 1. Synthesized new pyrrole- (**1**) and thiophene- (**2**) derivatives. **1a**: R^1 = CN, R^2 = CO_2Me, R^3 = CH_2Ph; **1b**: R^1 = COOH, R^2 = CO_2H, R^3 = CH_2Ph; **1c**: R^1 = COOH, R^2 = CO_2H, R^3 = H; **1d**: R^1 = COOH, R^2 = H, R^3 = H; **1e**: R^1 = COOH, R^2 = H, R^3 = CH_2Ph; **1f**: R^1 = H, R^2 = CO_2Me, R^3 = CH_2Ph; **1g**: R^1 = H, R^2 = CO_2H, R^3 = CH_2Ph; **1h**: R^1 = H, R^2 = CO_2H, R^3 = H; **1i**: R^1 = H, R^2 = H, R^3 = H; **2a**: R^1 = CN, R^2 = CO_2Me; **2b**: R^1 = CO_2H, R^2 = CO_2H; **2c**: R^1 = COOH, R^2 = H; **2d**: R^1 = H, R^2 = CO_2Me; **2e**: R^1 = H, R^2 = CO_2H; **2f**: R^1 = H, R^2 = H; **2g**: R^1 = CN, R^2 = COOH; **2h**: R^1 = CN, R^2 = H.



Scheme 1. Synthetic routes to the new heteroaromatic derivatives. Reagents and conditions: i: CNB, HMPT, 2 mol eq. K_2CO_3, 120 °C, 3 h, 40%; ii: 1. NaOH, H_2O/ethylene glycole, 110 °C, 1 h, 2: DMAA, copper chromite catalyst, quinoline, 160 °C, 30 min, 50%; iii: DFBN, HMPT, 2 mol eq. K_2CO_3, 120 °C, 3 h, 65%; iv: 1. HCl/$CHCl_3$, RT, 7 d, 2. vacuum, 160 °C, 50%; v: 1. NaOH, H_2O/ethylene glycole, 110 °C, 30 min, 2. aqu. HCl, RT, 93%; vi: DMAA, copper chromite catalyst, quinoline, 160 °C, 45 min, 87%; vii: 1. CNB, HMPT, 2 mol eq. K_2CO_3, 120 °C, 2 h, 42%, 2. CF_3COOH/H_2SO_4, 90 °C, 30 min, 3. NaOH, H_2O/ethylene glycole, 110 °C, 1 h, 4. aqu. HCl, 5. DMAA, 160 °C; viii: DFBN, DMF, 130 °C, 15 h, 95%; ix: 1. NaOH, H_2O/ethylene glycole, 110 °C, 1 h, 2. aqu. HCl, 3. DMAA, 160 °C; x: 1. CF_3COOH/H_2SO_4, 90 °C, 30 min, 2. NaOH, H_2O/ethylene glycole, 110 °C, 1 h, 3: aqu. HCl, 4. DMAA, 160 °C, 60 min.

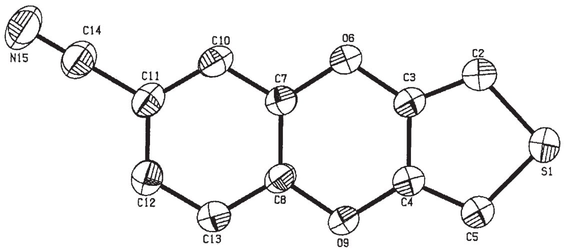


Figure 2. X-ray structure of **2h**.

of **1d**, **1e**, and **2c** observed. **2h** was obtained by ester hydrolysis of **2a** in $CHCl_3$/HCl at room temperature, followed by decarboxylation via vacuum sublimation. Fortunately, single crystals of **2h** were obtained from chloroform (Figure 2).[5]

As displayed in the X-ray structure, **2h** is flat. In comparison to this, the currently most studied monomer EDT (**5**) (Figure 3),[6] used for fabrication of transparent electrical conducting layers, the torsion angle of the ethylene bridge (C2L–O3L–C4L–C4L$^{\#}$) is 14°. According to this fact, the arrangement of polymer chains in the solid state, based on the new heteroaromatic monomers with benzo[1,4]dioxino structure, should be better. As a result of this, the charge transfer form chain to chain should become easier because of closer distance of the polymer chains. These new interesting pyrrole- and thiophene derivatives are expected to have a strong application potential in the area of conducting polymers. Preliminary experiments have shown, that they polymerise easily under oxidative chemical or electrochemical conditions (Figure 4). Further studies to elucidate the full potential are in progress.

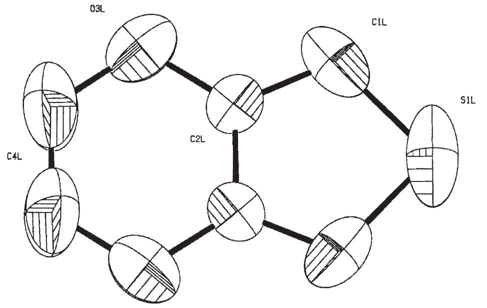


Figure 3. X-ray structure of 3,4-ethylenedioxythiophene (EDT) (**5**).

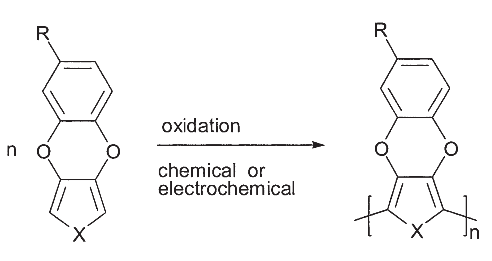


Figure 4. Oxidative polymerisation of the new heteroaromatic monomers via chemical (e.g. with Fe(III)-tosylate) or electrochemical methods. R = H, CN, COOH; X = S, N–H, N–CH_2–Ph.

Financial support of this work by the Bayer AG, Krefeld-Uerdingen, Germany, is gratefully acknowledged.

References and Notes

Present address: University of Potsdam, Institute of Chemistry, Applied Polymer Chemistry, Karl-Liebknecht-Str. 24-25, D-14476 Golm, Germany

1 H. Shirakawa, E. J. Louis, A. G. Mac Diarmid, C. K. Ciang, and A. J. Heeger, *J. Chem. Soc., Chem. Commun.*, **1977**, 579.

2 L. Groenendaal, F. Jonas, D. Freitag, H. Pielartzik, and J. R. Reynolds, *Adv. Mater.*, **12**, 481 (2000).

3 **3** was synthesized according to Q. Pei, G. Zuccarello, M. Ahlskog, and O. Inganäs, *Polymer*, **35**, 1347 (1994), but the esterification of thiodi(acetic acid) with MeOH was performed with $SOCl_2$, resulting in quantitative yield.
4 was prepared following the procedure of A. Merz, R. Schropp, and E. Dötterl, *Synthesis*, **1995**, 795.

4 The synthesis was performed in analogy to a procedure, described for substituted dibenzo[1,4]dioxines by a) G. C. Eastmond and J. Paprotny, *Chem. Lett.*, **1999**, 479. b) H. H. Lee and W. A. Denny, *J. Chem. Soc., Perkin Trans. 1*, **1990**, 1071.

5 Crystal data for **2h** (CCDC-166596): $C_{11}H_5NO_2S$, $M_r = 215.22$, triclinic, space group *P*-1 (No. 2), $a = 5.8472(9)$, $b = 7.506(2)$, $c = 10.452(2)$ Å, $\alpha = 86.33(2)$, $\beta = 88.18(1)$, $\gamma = 79.87(2)°$, $V = 450,5(1)$ Å^3, $Z = 2$, $D_{\mathrm{calcd}} = 1.586\,\mathrm{g\,cm^{-3}}$, μ(Cu Kα) = 2.99 mm^{-1}, numerical absorption correction from crystal shape, transmission $T_{\min} = 0.58$, $T_{\max} = 0.89$. Figure 2: Thermal ellipsoid plot (50% probability level) of **2h**. The molecule is flat. Selected bond lenghts (Å) and bond angles (°):S1–C2 1.706(2), S1–C5 1.712(2), C3–O6 1.377(2), O6–C7 1.381(2), C4–O9 1.376(2), O9–C8 1.376(2), C11–C14 1.438(2), C14–N15 1.140(3), C2–S1–C5 92.73(9), C3–O6–C7 114.3(1), C4–O9–C8 114.7(1), C11–C14–N15 179.8(2).

6 Crystal data for **5** (CCDC-136913): $C_{36}H_{66}O_{30}+C_6H_6O_2S+nH_20$, M_r=1310.16, orthorhombic, space group $P2_12_12$ (No. 18), $a = 16.7507(6)$, $b = 21.7939(15)$, $c = 8.3508(5)$ Å, $V = 3048.6(3)$ Å^3, $Z = 2$, $D_{\mathrm{calcd}} = 1.427\,\mathrm{g\,cm^{-3}}$, μ(Cu Kα) = 1.43 mm^{-1}. Figure 3: Thermal ellipsoid plot (50% probability level) of **5**. The EDT-structure is extracted from the crystal structure of a EDT/α-cyclodextrin complex. The structure of the complex has been previously published by J. Storsberg, H. Ritter, H. Pielartzik, and L. Groenendaal, *Adv. Mater.*, **12**, 567 (2000). C4L and C5L are slighty out of the molecular plane of EDT. Selected bond lenghts (Å), bond angles and torsion angles(°): S1L–C1L 1.701(9), O3L–C4L 1.363(10),C1L–S1L–C1L$^{\#}$92.5(5), C2L–O3L–C4L–C4L$^{\#}$-14(2).

7 All compounds were characterized by ^{1}H NMR (200 and 400 MHz), and ^{13}C NMR (50 and 100 MHz), DEPT, Spin-Echo, and FD-MS analysis. Selected spectroscopic data: **1a**: ^{1}H NMR ($CDCl_3$, 200 MHz) δ 3.84(s, 6H), 5.98 (s, 2H), 6.99–7.04 (m, 5H), 7.20–7.26 (m, 3H). MS (FD, m/z) 404.7 (M^+). **1d**: ^{1}H NMR (DMSO-d_6, 400 MHz) δ 6.28 (d, J = 3.9 Hz, 1H), 6.69 (d, J = 4.7 Hz, 1H), 7.10 (d, J = 8.6 Hz, 1H), 7.42 (d, J = 1.6 Hz, 1H), 7.55 (dd, J = 8.6, 1.9 Hz, 1H), 10.16 (br, 1H), 11.20 (br, 1H). MS (FD, m/z) 217.5 (M^+). Some compounds were also characterized by single crystal X-ray crystallography. The Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre as a supplementary publication. Copies of this data can be obtained free of charge on application to The Director, CCDC, 12 Union Road, Cambridge CB21EZ, UK; fax: (+44)1223 336033; e-mail: deposit@ccdc.cam.ac.uk.