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Synthesis of 4-phenylethynylphthalic anhydride, a useful end-capping agent for polyimides

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Hydrolysis and bromination of phthalic anhydride in water gave a mixture of the monosodium salt of 4-bromophthalic acid. These were reacted with phenylacetylene under Sonogashira coupling reaction conditions in an aqueous medium. Acidification afforded 4-phenylethynylphthalic acid and then dehydration of this gave 4-phenylethynylphthalic anhydride in 76% overall yield. Compared with traditional synthetic methods, this method has the advantage of low cost, convenient manipulation and is environmentally friendly.

Keywords: polyimides, 4-phenylethynylphthalic anhydride, Sonogashira coupling reaction, aqueous medium, synthesis

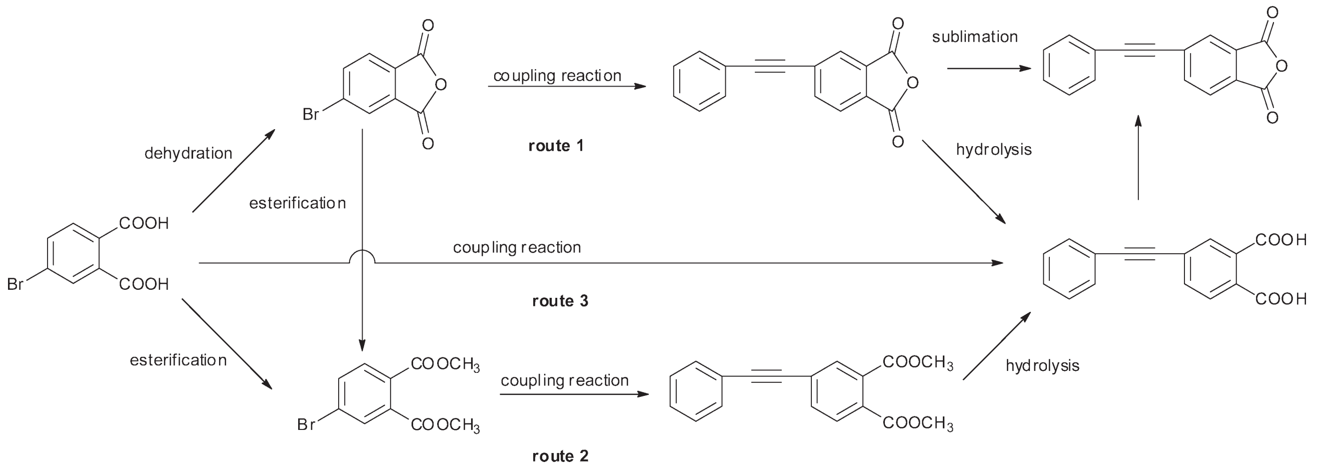
Polyimides are well known for possessing excellent thermal and oxidative stability, as well as excellent mechanical properties.[1,2] 4-Phenylethynylphthalic anhydride (4-PEPA) is a commonly used end-capping agent, which can improve the thermal stability, solvent resistance and processibility of polyimides.[3–5]

The most convenient way of preparing 4-PEPA employs 4-bromophthalic anhydride (4-BPA) as starting material, which is reacted with phenylacetylene under Sonogashira coupling reaction conditions (Scheme 1, route 1).[3–7] The starting material 4-BPA was prepared from 4-bromophthalic acid (4-BPAc) by a process involving fractional distillation[8] or by dehydration with acetic anhydride.[9] However, since 4-PEPA produced by this way was impure, it had to be purified by hydrolysis in basic solution, neutralisation with concentrated HCl and dehydration in acetic anhydride,[5] or by vacuum sublimation.[7] In order to prepare high purity 4-PEPA, Urazoe[10] used dimethyl 4-bromophthalate (4-BDMP) obtained from either 4-BPA[11] or 4-BPAc[12,13] as the starting material which was reacted with phenylacetylene to afford dimethyl 4-phenylethynylphthalate (4-PEDMP). 4-PEPA was then obtained after complete hydrolysis in basic solution and dehydration with acetic anhydride (Scheme 1, route 2).

Application of these methods has been restricted by their tedious manipulations and low atom economy. Recently, we developed a convenient procedure with a high yield for the synthesis of 4-PEPA from 4-BPAc. Thus, 4-BPAc reacted with phenylacetylene by a Sonogashira coupling reaction in THF/EtN_3[14] (Scheme 1, route 3). However, this method was carried out in organic solvents which could pose recyclability problems and add to the environmental burden. In addition, the starting material 4-BPAc was expensive. We now report a more facile method for the synthesis of 4-PEPA with a good yield (Scheme 2).

What is believed to be a mixture of monosodium salt of 4-BPAc (**2**) was prepared from commercially available phthalic anhydride (**1**) by hydrolysis and bromination in an aqueous medium with 85% yield. To the best of our knowledge, there has not been any report using **2** as the substrate in a Sonogashira coupling reaction. As **2** could be dissolved in water and the Sonogashira coupling reaction was carried out under basic conditions, **2** was employed as the substrate directly without acidification and organic solvent extraction to afford 4-BPAc,[13] which simplified the experimental operation. 4-BPAc is believed to be mainly present as its dibasic anion in the basic solution.

The Sonogashira coupling reaction is the key step in the synthesis of 4-PEPA. Generally, $Pd(PPh_3)_2Cl_2$-CuI/PPh_3 was chosen as the catalyst system, when organic solvents were used as the reaction media. The water soluble palladium catalyst prepared *in situ* from $Pd(AcO)_2$ and TPPTS (tris-(3-sulfonatop henyl)phosphine, sodium salt) is a useful and piratical catalytic system for coupling reaction.[15] In our revised method, $Pd(AcO)_2$/TPPTS was employed as catalyst, with water as the reaction solvent. Compared with organic solvents, water is non-toxic, non-flammable, inexpensive and environmentally friendly. After optimisation of the conditions, *e.g.* co-catalysts, phase transfer catalysts (PTC), bases, temperatures, catalyst mole ratios and reaction times, the coupling reaction was catalysed by $Pd(AcO)_2$ (0.25 mol%), TPPTS (0.5 mol%) in the presence of NaOH (2.0 equiv.) and TBAB (tetrabutyl ammonium bromide) (5.0 mol%) at 100 °C for 3h without using CuI



Scheme 1

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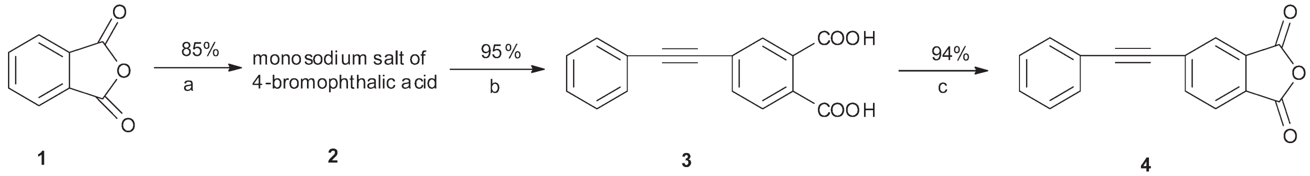

Scheme 2

as co-catalyst, to afford 4-phenylethynylphthalic acid (**3**) in a yield of 95%. The coupling reaction time in water was shortened from 12h (traditional methods) to 3h and the yield was 15%, 22%, and 9% higher than that in organic solvent starting from 4-BPAc,[14] 4-BPA[3] and 4-BDMP,[10] respectively. Diacid **3** was then dehydrated in acetic anhydride at 80 °C for 1h to afford 4-PEPA with a yield of 94%.

In conclusion, a facile synthesis of 4-PEPA in three steps is described in this paper. The new method overcomes some of the shortcomings of traditional synthetic routes to 4-PEPA such as high cost, complex operation, more pollution, *etc*.

Experimental

Melting points were determined on an XRC melting point apparatus and are uncorrected. IR spectra were recorded on a PK1600 FTIR-type spectrophotometer using KBr pellets. ^{1}H-NMR (400 MHz) and ^{13}C-NMR (100 MHz) spectra were measured on a Bruker AV II-400 instrument spectrometer with TMS as an internal standard. TPPTS was synthesised as described in the literature.[16] All the other reagents and chemicals were commercially available and were used without purification.

Monosodium salt mixture of 4-bromophthalic acid (2): To NaOH (120.0 g, 3.0 mol) dissolved in water (1000 mL) was added **1** (222.0 g, 1.5 mol). When the complete solution was obtained, bromine (124.0 g, 1.55 mol) was dropped in slowly. After the addition, the reaction mixture was heated to 90 °C for 4h and was stood at room temperature overnight. The solids that crystallised out of solution were filtered off and recrystallised from water to give a white solids (340.8 g, 85%), which was analysed as a monosodium salt of 4-bromophthalic acid[13] (believed to be a mixture). Product **2** could be acidified with conc. HCl to afford 4-BPAc. m.p. 166–168 °C (lit.[17] 166–167 °C). ^{1}H NMR (DMSO-d_6, 400 MHz) δ (ppm): 13.39 (s, 2H), 7.81 (m, 2H), 7.65 (d, J = 8.0 Hz, 1H).

4-Phenylethynylphthalic acid (**3**): To a stirred solution of **2** (30.0 g, 112.4 mmol), NaOH (9.0 g, 224.8 mmol) in water (200 mL), Pd(OAc)$_2$ (0.06 g, 0.27 mmol), TPPTS (0.31 g, 0.54 mmol) and TBAB (1.8 g, 5.6 mmol) were added under an argon atmosphere. After being stirred at 60 °C for 30 min, phenylacetylene (13.8 g, 134.9 mmol) was dropped in slowly. The mixture was heated under reflux for 3h, and then brought by additions of conc. HCl to pH=2–3, The precipitate was filtered, washed with water and recrystallised from acetic acid to afford **3** as a pale-yellow solid (28.4 g, 95%). m.p. 210–212 °C (lit.[10] 211.0–211.6 °C). IR (KBr, cm^{-1}): 3074 (aromatic C–H) 3012–2525 (COO-H), 2208 (C≡C), 1708 (C=O), 1280 (C–O). ^{1}H NMR (DMSO-d_6, 400 MHz) δ (ppm): 13.40 (s, 2H), 7.81 (s, 1H), 7.75 (s, 2H), 7.62 (dd, J = 3.0, 6.6 Hz, 2H), 7.47 (m, 3H). ^{13}C NMR (DMSO-d_6, 100 MHz) δ (ppm): 168.40, 168.38, 134.2, 133.7, 132.6, 132.1, 131.4, 129.8, 129.6, 129.3, 125.3, 122.1, 92.3, 88.2.

4-Phenylethynylphthalic anhydride (**4**): **3** (20.0 g, 75.2 mmol) and acetic anhydride (100 mL) were placed in a three necked flask. After stirred at 80 °C for 1h, the solvent was removed and the residue was recrystallised from toluene/n-hexane (V:V=1:1) to afford a pale yellow crystals (17.6 g, 94%). m.p. 152–153 °C (lit.[6] 150–152 °C). IR (KBr, cm^{-1}): 3063 (aromatic C–H), 2205 (C≡C), 1843, 1772 (C=O), 1245 (C–O). ^{1}H NMR (CDCl$_3$, 400 MHz) δ (ppm): 8.11(s, 1H), 7.99(s, 2H), 7.58(m, 2H), 7.40(m, 3H). ^{13}C NMR (CDCl$_3$, 100 MHz) δ (ppm):162.2, 138.7, 132.04, 131.99, 131.7, 129.7, 129.6, 128.6, 128.2, 125.6, 121.6, 96.0, 86.9.

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References

1 C. Feger, M.M. Khohasteh and J.E. McGrath, *Polyimides: chemistry, materials, and characterization*, Elsevier, Amsterdam, 1989.
2 M.K. Ghosh and K.L. Mittal, *Polymides: fundamentals and applications*, Marcel Dekker, New York, 1996.
3 P.M. Hergenrother and J.G. Smith Jr, *Polymer*, 1994, **35**, 4857.
4 P.M. Hergenrother and J.G. Smith Jr, *US* 5567800, 1996.
5 T. Takekoshi and J.M. Terry, *Polymer*, 1994, **35**, 4874.
6 J.A. Johnston, F.M. Li and F.W. Harris, *Polymer*, 1994, **35**, 4865.
7 G.W. Meyer, B. Tan and J.E. McGrath, *High Perform. Polym.*, 1994, **6**, 423.
8 J. Oren, *IL* 115814, 1999.
9 K.J. Gould, N.P. Hacker, J.F.W. McOmie and D.H. Perry, *J. Chem. Soc., Perkin Trans. 1*, 1980, **8**, 1834.
10 D. Urazoe, H. Mori and K. Yamakawa, *US* 20050215820, 2005.
11 I. Akira, N.Yoshihiro and U. Osamu, *JP* 2010070527A, 2010.
12 J. Zon, P. Misiak, N. Amrhein and R. Gancarz, *Chem. Biodiversity*, 2005, **2**, 1187.
13 E.T. Sabourin and A. Onopchenko, *J. Org. Chem.*, 1983, **48**, 5135.
14 T.F. Wu, M.J. Yang, Y. Wang, G.W. Gao and J. Men, *Chin. Chem. Lett.*, 2011, **22**, 159.
15 C. Amatore, E. Blart, J.P. Genêt, A. Jutand, S. Lemaire-Audoire and M. Savignac, *J. Org. Chem.*, 1995, **60**, 6829.
16 H. Chen, H.C. Liu and X.J. Li, *J. Mol. Catal. (China)*, 1994, **8**, 124.
17 M.J. Lin, J.D. Wang, N. S Chen and J.H. Huang, *J. Coord. Chem.*, 2006, **59**, 607.