

# Synthesis and Properties of *Ortho*-Linked Aromatic Polyamides Based on 4,4'-(2,3-Naphthalenedioxy)dibenzoic Acid

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**ABSTRACT:** A novel aromatic dicarboxylic acid monomer, 4,4'-(2,3-naphthalenedioxy)-dibenzoic acid (**3**), was prepared by the fluorodisplacement reaction of *p*-fluorobenzonitrile with 2,3-dihydroxynaphthalene in *N,N*-dimethylformamide (DMF) in the presence of potassium carbonate followed by alkaline hydrolysis of the intermediate dinitrile. A series of novel aromatic polyamides containing *ortho*-linked aromatic units in the main chain were synthesized by the direct polycondensation of diacid **3** and a variety of aromatic diamines using triphenyl phosphite and pyridine as condensing agents in the *N*-methyl-2-pyrrolidone (NMP) solution containing dissolved calcium chloride. The resulting polyamides had inherent viscosities higher than 0.74 and up to 2.10 dL/g. All of these polyamides were soluble in polar solvents, such as NMP, DMF, *N,N*-dimethylacetamide (DMAc), and dimethyl sulfoxide. Transparent, flexible, and tough films could be cast from their DMAc or NMP solutions. The solvent-cast films had high tensile strengths and moduli. Extensions to break were relatively low, except for the polymers derived from 2,2-bis[4-(4-aminophenoxy)phenyl]hexafluoropropane and 3,4'-oxydianiline, which had elongations of 82 and 62%, respectively. Except for the polyamide based on *p*-phenylenediamine, all the other polyamides were amorphous in nature. All the polymers are thermally stable to temperatures in excess of 450°C in either air or nitrogen atmosphere. The polymers exhibited glass transition temperatures ranging from 183 to 260°C and decomposition temperatures (10% weight loss) ranging from 462–523°C in air and 468–530°C in nitrogen. © 1997 John Wiley & Sons, Inc. *J Polym Sci A: Polym Chem* **35**: 3385–3391, 1997

**Keywords:** 4,4'-(2,3-naphthalenedioxy)dibenzoic acid; polyamides

## INTRODUCTION

Wholly aromatic polyamides (aramids) have been noted for their high thermal and chemical resistance as well as high strength and high modulus as fibers.<sup>1,2</sup> But they are usually difficult to process due to their high glass-transition or melting temperatures and limited solubility. Several modifications of the chemical structure have been used to lower the transition temperatures and to

improve the solubility of aramids. It is well known that the introduction of appropriate flexible groups<sup>3–6</sup> in the polymer backbone and the incorporation of thermally stable bulky pendent groups<sup>7–14</sup> may enhance the processability of aramids without much sacrificing their outstanding thermal and mechanical properties.

It has been demonstrated that the nucleophilic chlorodisplacement reaction between *p*-chloronitrobenzene with *ortho*-substituted aromatic diols such as catechol and 2,3-dihydroxynaphthalene could successfully proceed to form the *ortho*-linked dinitro compounds that were reduced to the equivalent diamines and used in polyamide

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or polyimide synthesis.<sup>15–17</sup> Eastmond and Pa-  
protny<sup>18,19</sup> recently reported successful nitrodis-  
placement reactions between several substituted  
catechols or 2,3-dihydroxynaphthalene and 3- or  
4-nitrophthalonitrile. The resulting bis(ether di-  
nitrile)s were hydrolyzed to the corresponding bis  
(ether diacid)s and dehydrated to the bis(ether  
anhydride)s. The synthesis and properties of a  
selection of *ortho*-linked poly(ether imide)s from  
these bis(ether anhydride)s were also reported.  
The lateral arrangement of the *ortho*-linked aromatic  
moieties will hinder interchain packing and,  
hence, help to reduce  $T_g$  and increase solubility.  
Very recently we reported<sup>20</sup> that catechol will  
also readily undergo fluoro-displacement with *p*-  
fluorobenzonitrile in DMF to yield a bis(ether ni-  
trile), which is then readily hydrolyzed to the cor-  
responding bis(ether acid). The bis(ether acid)  
was reacted with a variety of diamines to demon-  
strate the synthesis of high molecular weight  
poly(ether amide)s with *ortho*-linked, main-  
chain, aromatic residues. The polymers were evi-  
denced by thermogravimetry (TG) to show good  
thermal stability. As a result, the incorporation of  
*ortho*-linked aromatic residue gave rise to evident  
advantages in solubility as well as thermal stabil-  
ity. Therefore, the present work was undertaken to  
synthesize aromatic polyamides containing pendent  
2,3-naphthyl unit by the direct polyphospho-  
rylation<sup>21</sup> of 4,4'-(2,3-naphthalenedioxy)diben-  
zoic acid with various aromatic diamines. The gen-  
eral properties of these polymers are studied as  
well.

## EXPERIMENTAL

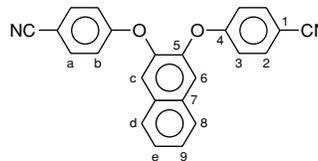
### Materials

2,3-Dihydroxynaphthalene (**1**) (Janssen Chimica)  
and *p*-fluorobenzonitrile (TCI) were used without  
previous purification. *p*-Phenylenediamine (**4a**)  
was purified by sublimation. *m*-Phenylenediamine  
(**4b**) was vacuum distilled prior to use. According  
to a reported method,<sup>22,23</sup> 2,2-bis[4-(4-amino-  
phenoxy)phenyl]propane (**4h**) (m.p. 123–124°C),  
bis[4-(4-aminophenoxy)phenyl] sulfone (**4i**) (m.p.  
185–187°C), 1,1-bis[4-(4-aminophenoxy)phenyl]-  
1-phenylethane (**4j**) (m.p. 72°C), 2,2-bis[4-(4-  
aminophenoxy)phenyl]hexafluoropropane (**4k**)  
(m.p. 162–163°C), and bis[4-(4-aminophenoxy)-  
phenyl]-1,4-diisopropylbenzene (**4l**) (m.p. 187–  
189°C) were prepared by the nucleophilic substitu-  
tion reaction of the corresponding bisphenol precur-

sors and *p*-chloronitrobenzene in the presence of  
potassium carbonate, giving the bis(*p*-nitrophe-  
noxy) compounds and subsequent reduction of the  
intermediate dinitro compounds using hydrazine as  
the reducing agent and palladium as the catalyst.  
The other aromatic diamines were used without  
previous purification. Commercially available cal-  
cium chloride (CaCl<sub>2</sub>) was dried under vacuum at  
180°C for 10 h. *N*-Methyl-2-pyrrolidone (NMP) and  
pyridine were purified by distillation under reduced  
pressure over calcium hydride. Triphenyl phosphite  
(TPP; Fluka) was used as received.

### 4,4'-(2,3-Naphthalenedioxy)dibenzonitrile (**2**)

In a 300-mL flask, 8.01 g (0.05 mol) of 2,3-dihy-  
droxynaphthalene (**1**) and 13.8 g (0.1 mol) of  
K<sub>2</sub>CO<sub>3</sub> were suspended in a 120 mL mixture of  
DMF and toluene (1 : 1 by volume), and the sus-  
pension was heated at reflux temperature using  
a Dean–Stark trap to remove the water azeotropi-  
cally. After complete removal of water, the resid-  
ual toluene was distilled off. Then the reaction  
mixture was cooled to about 60°C, and *p*-fluoro-  
benzonitrile (12.1 g; 0.10 mol) was added and  
heating was continued at 150°C for 6 h. On cool-  
ing, the reaction mixture was poured into 700 mL  
of water, and the precipitated white solid was col-  
lected and washed with water. The yield of the  
product was 17.2 g (95%). The crude product was  
purified by recrystallization from 600 mL of ethan-  
ol to afford **2** as colorless needles. The yield of  
the purified product was 13.1 g (73%); m.p. 138–  
140°C. The IR spectrum (KBr) exhibited absorp-  
tions at 2230 (C≡N) and 1260 cm<sup>-1</sup> (C—O). <sup>1</sup>H-  
NMR (CDCl<sub>3</sub>): δ 7.81 (d, 2H, H<sub>d</sub>), 7.64 (d, 2H,  
H<sub>c</sub>), 7.57 (d, 4H, H<sub>a</sub>), 7.56 (d, 2H, H<sub>e</sub>), 6.88 ppm  
(d, 4H, H<sub>b</sub>). <sup>13</sup>C-NMR (CDCl<sub>3</sub>): δ 160.89 (C<sup>5</sup>),  
144.89 (C<sup>4</sup>), 134.10 (C<sup>2</sup>), 131.59 (C<sup>7</sup>), 127.33  
(C<sup>8</sup>), 126.76 (C<sup>9</sup>), 120.34 (C<sup>6</sup>), 118.61 (cyano car-  
bon), 117.20 (C<sup>3</sup>), 106.46 ppm (C<sup>1</sup>).

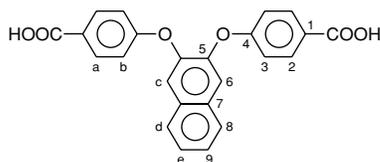


ANAL. Calcd for C<sub>24</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub> (362.39): C, 79.54%; H,  
3.89%; N, 7.73%. Found: C, 79.50%; H, 3.86%; N, 7.69%.

### 4,4'-(2,3-Naphthalenedioxy)dibenzoic Acid (**3**)

In a 1000-mL flask, a suspension of dinitrile **2**  
(13.0 g; 0.036 mol) in an ethanol/water mixture

(250 mL/250 mL) containing dissolved 40.3 g (0.717 mol) of KOH was boiled under reflux. The suspension turned into a clear solution after about 20 h. Reflux was continued for about 1 day until the evolution of ammonia had ceased. The resulting hot, clear solution was filtered to remove any possible insoluble impurities. The hot filtrate was allowed to cool and acidified by conc. HCl to  $\text{pH} \approx 3$ . The white precipitated product was filtered off, washed with water, and dried *in vacuo*, to give 14.1 g of diacid **3**. Yield 95%; m.p. 282°C (DSC). IR (KBr): 2400–3500 (O—H), 1685 (C=O), 1420–1600 (arom. C=C), 1260  $\text{cm}^{-1}$  (C—O).  $^1\text{H-NMR}$  (DMSO- $d_6$ ):  $\delta$  7.96 (d, 2H,  $\text{H}_d$ ), 7.93 (d, 4H,  $\text{H}_a$ ), 7.84 (s, 2H,  $\text{H}_c$ ), 7.54 (d, 2H,  $\text{H}_e$ ), 7.01 ppm (d, 4H,  $\text{H}_b$ ).  $^{13}\text{C-NMR}$  (DMSO- $d_6$ ):  $\delta$  166.68 (carbonyl carbon), 160.31 ( $\text{C}^5$ ), 145.34 ( $\text{C}^4$ ), 131.44 ( $\text{C}^2$ ), 130.94 ( $\text{C}^7$ ), 127.16 ( $\text{C}^8$ ), 126.08 ( $\text{C}^1$ ), 126.02 ( $\text{C}^9$ ), 119.18 ( $\text{C}^6$ ), 116.46 ppm ( $\text{C}^3$ ).



ANAL. Calcd for  $\text{C}_{24}\text{H}_{16}\text{O}_6$  (400.39): C, 71.99%; H, 4.02%. Found: C, 71.90%; H, 4.01%.

### Polymer Synthesis

A typical polymerization procedure is as follows: a mixture of 0.5005 g (1.25 mmol) of 4,4'-(2,3-naphthalenedioxy)dibenzoic acid (**3**), 0.1352 g (1.25 mmol) of *m*-phenylenediamine (**4b**), 0.2 g of  $\text{CaCl}_2$ , 0.9 mL of TPP, 0.8 mL of pyridine, and 2 mL of NMP was heated with stirring at 110°C for 3 h. As polycondensation proceeded, the solution became viscous gradually. The resulting highly viscous polymer solution was trickled into 300 mL of methanol with stirring, giving a fibrous white precipitate that was washed thoroughly with methanol and hot water, collected by filtration, and dried. The yield was quantitative and the inherent viscosity of the polymer (**5b**) in DMAc + 5 wt % LiCl was 0.93 dL/g. IR (film): 3300 (N—H), 1660 (C=O), 1420–1600 (arom. C=C), 1260  $\text{cm}^{-1}$  (C—O).

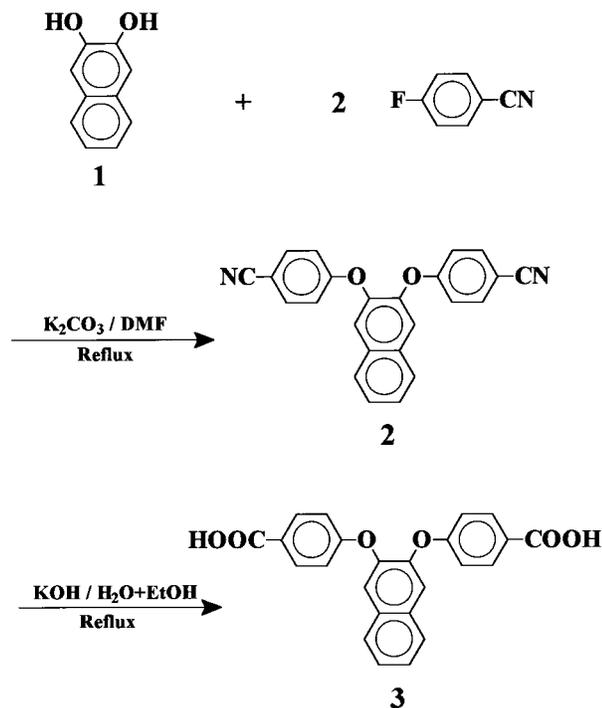
All other polymers were synthesized by a similar procedure.

### Preparation of Polyamide Films

A solution of polymer was made by dissolving about 0.8 g of the polymer in 8 mL of hot DMAc or NMP to afford an approximate 10 wt % solution. The clear solution was poured into a  $\phi = 9$ -cm glass culture dish, which was placed in a 80°C oven overnight to remove the solvent. The semi-dried polyamide film was stripped off from the glass surface and further dried *in vacuo* at 100°C for 6 h. The obtained films had about 0.1 mm in thickness and were ready for X-ray diffraction measurements and tensile tests.

### Measurements

IR spectra were recorded on a Jasco FT/IR-7000 Fourier transform infrared spectrometer at 4  $\text{cm}^{-1}$  resolution and 16 scans.  $^1\text{H}$ - and  $^{13}\text{C}$ -NMR spectra were measured on a JEOL EX-400 NMR spectrometer with perdeuterodimethyl sulfoxide (DMSO- $d_6$ ) as an external reference, working at 400 and 100 MHz, respectively. Elemental analyses were run in a Perkin–Elmer Model 2400 C, H, N analyzer. The inherent viscosities of the polymers were determined at 30°C for solutions having the concentration of 0.5 g polymer/100 mL DMAc-5 wt % LiCl, using a Cannon–Fenske viscometer. The DSC traces were measured on a DuPont 910 differential scanning calorimeter coupled to a DuPont 1090 thermal analyzer at a heating rate of 20°C/min in flowing nitrogen (50  $\text{cm}^3/\text{min}$ ). Glass transition temperatures ( $T_g$ s) of the polymers were taken as the midpoint of the change in slope of the baseline. Thermogravimetry (TG) was conducted with a Rigaku thermoflex TG 8110 coupled to a Rigaku TAS-100 thermal analysis station. Experiments were carried out on 9–11 mg samples heated in flowing nitrogen or air (50  $\text{cm}^3/\text{min}$ ) at a heating rate of 20°C/min. Wide-angle X-ray diffraction patterns were recorded at room temperature (about 25°C) on a Siemens Kristalloflex D5000 X-ray diffractometer, using Ni-filtered  $\text{CuK}_\alpha$  radiation (1.5418 Å) (40 kV, 15 mA). The scanning rate was 2°/min over a range of  $2\theta = 5$ –40°. An Instron universal tester Model 1130 with a load cell 5 kg was used to study the stress–strain behavior of the samples. A gauge of 2 cm and a strain rate of 5 cm/min were used for this study. Measurements were performed at room temperature with film specimens (6 cm long, 0.5 cm wide, and about 0.1 mm thick), and an average of at least five individual determinations was used.



## RESULTS AND DISCUSSION

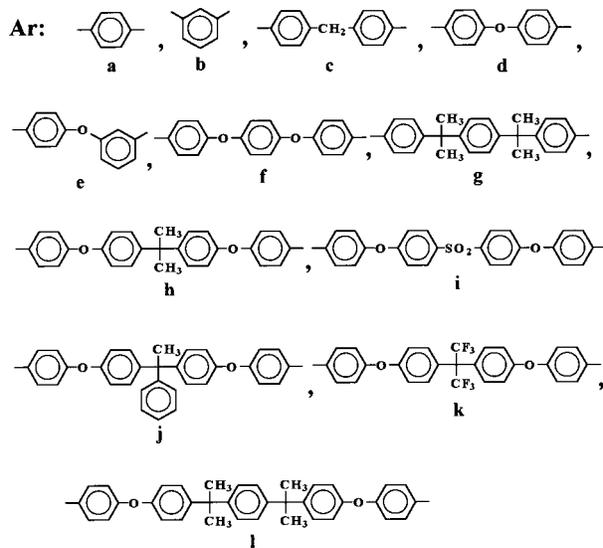
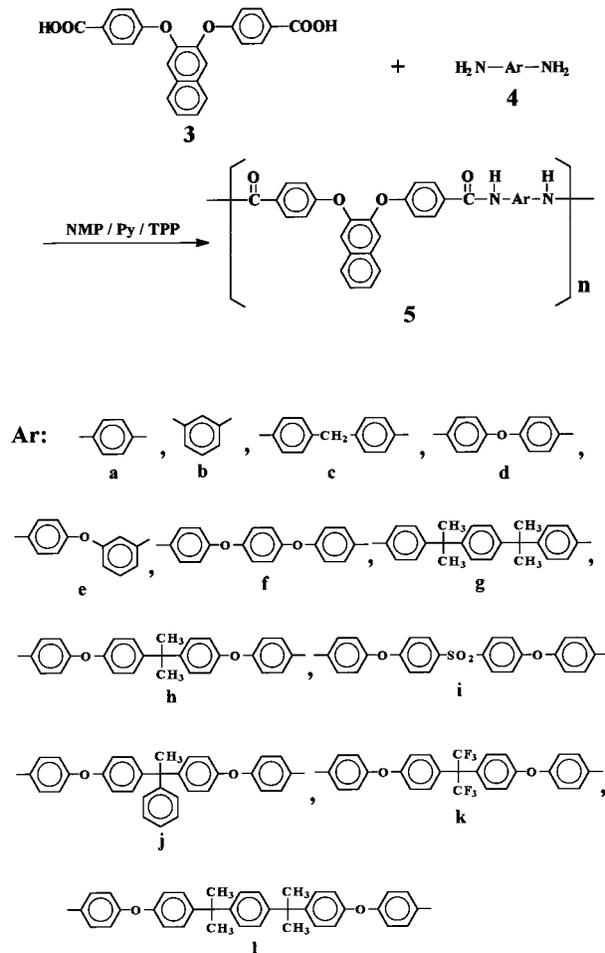
### Monomer Synthesis

The *ortho*-disubstituted naphthalene unit containing bis(ether carboxylic acid) **3** was prepared using a two-stage procedure from 2,3-dihydroxynaphthalene (**1**) and *p*-fluorobenzonitrile (Scheme 1). First, bis(ether nitrile) **2** was prepared by the nucleophilic fluorodisplacement reaction of diol **1** and two equivalent amounts of *p*-fluorobenzonitrile in DMF in the presence of  $K_2CO_3$ . The yield was high, with 73% after recrystallization. Then, the intermediate dinitrile **2** was readily converted into diacid **3** by alkaline hydrolysis in excellent yields. The structures of dinitrile **2** and diacid **3** were confirmed by element analysis, FTIR, and NMR spectroscopy. The purity of diacid **3** was high enough for the preparation of high-molecular-weight polymers.

### Polymer Synthesis

A series of polyamides **5a–l** was prepared by the direct polycondensation of diacid **3** and diamines **4a–l** using TPP and pyridine as condensing agents in NMP containing  $CaCl_2$  at 110°C for 3 h

(Scheme 2). By using the reaction conditions listed in Table I, all the resulting polymers remained in the reaction solutions throughout the reaction due to high solubility, and all the resulting polymer solutions became highly viscous, indicating the formation of high molecular weights. As shown in Table I, the inherent viscosities of the polyamides obtained ranged from 0.74 to 2.10 dL/g. In general, the molecular weight of the polymers obtained from the phosphorylation reaction is highly dependent upon the reactant concentration. Higher molecular weights of these polymers could be obtained by using a higher initial reactant concentration and adding the proper amount of supplemental NMP before the formation of the swollen gel. Take the preparation of polyamide **5d** as an example. A higher inherent viscosity could be obtained by using this technique. The molecular weights of these polyamides were high enough to permit the casting of flexible and tough films from DMAc or NMP. The high



**Table I.** Synthesis Conditions and Inherent Viscosities of Polyamides Based on 4,4'-(2,3-Naphthalenedioxy)dibenzoic Acid

Polymer Code	Amount of Reagent Used <sup>a</sup>			$\eta_{inh}^c$ (dL/g)
	NMP (mL)	Pyridine (mL)	CaCl <sub>2</sub> (g)	
<b>5a</b>	3	1	0.4	1.12
<b>5b</b>	2	0.8	0.2	0.93
<b>5c</b>	2	0.8	0.2	1.15
<b>5d</b>	3	0.8	0.3	1.21
	2 + 0.5 <sup>b</sup>	0.8	0.4	1.33
<b>5e</b>	2	0.8	0.2	1.27
<b>5f</b>	2 + 3	0.8	0.25	2.10
<b>5g</b>	2 + 4	0.8	0.25	1.07
<b>5h</b>	2.5 + 3.5	0.8	0.25	1.64
<b>5i</b>	2.5	0.8	0.25	0.93
<b>5j</b>	2.5 + 0.5	0.8	0.25	0.97
<b>5k</b>	2 + 4	0.8	0.25	1.28
<b>5l</b>	2.5	0.8	0.25	0.74

<sup>a</sup> Amount of each diacid and diamine monomer = 1.25 mmol; TPP = 0.9 mL (2.5 mmol); reaction temperature = 110°C; reaction time = 3 h.

<sup>b</sup> "2 + 0.5" means that an initial amount of 2 mL NMP was used and an additional 0.5 mL of NMP were added when the reaction solution was too viscous to stir.

<sup>c</sup> Measured in DMAc containing 5 wt % LiCl on 0.5 g/dL at 30°C by a Cannon–Fenske viscometer.

molecular weights of the polymers confirm that the monomer synthesis was successful in producing pure material.

The structures of polyamides can be ascertained by IR spectroscopy. The characteristic absorptions of amide group were observed near 3300 cm<sup>-1</sup> (N—H str.) and 1660 cm<sup>-1</sup> (C=O str.), and that of aryl ether stretching appeared near 1260 cm<sup>-1</sup>.

### Properties of Polymers

The solubility of polyamides was studied qualitatively. All of the polyamides exhibited high solubility in polar aprotic solvents such as DMF, DMSO, DMAc, and NMP. Except for polyamide **5a** based on *p*-phenylenediamine, the other polyamides also readily dissolved in *m*-cresol. Some of polyamides obtained from flexibilizing group-linked "multiring" diamines such as **4g**, **4h**, and **4j-1**, dissolved even in less polar solvents like THF. The excellent solubility presented by these polyamides is apparently due to the fact that the *ortho*-oriented, bulky 2,3-substituted naphthalene rings are displaced laterally from the main

chain and interfere with the interchain attractions and packing.

As mentioned earlier, all the polyamides could be cast into flexible and tough films, which all, except for polyamide **5a**, showed an amorphous X-ray diffraction pattern. These films were subjected to tensile test, and the results are given in Table II. Most polyamides showed yield points on their stress–strain curves. The yield strengths, tensile strengths, and initial moduli of these films were in the ranges of 71–83 MPa, 54–84 MPa, and 1.3–2.0 GPa, respectively. Polyamides **5e** and **5k** had larger elongations (62 and 82%) at break point, and belonged to tough materials. The other polymers showed smaller elongations to break and the values were recorded in the range of 2–20%.

Thermal properties of all the polyamides were evaluated by thermogravimetry (TG) and differential scanning calorimetry (DSC). The representative TG curves of polyamide **5a** measured in air and in nitrogen are shown in Figure 1. All the other polyamides showed similar patterns of decomposition with no significant weight loss below 450°C in air or nitrogen, but with more than 54.4 wt % and up to 69.6% residue remaining when heated to 800°C in nitrogen. The data reported in Table III show that the 10% weight loss temperatures of these polyamides were recorded in the range of 462–523°C in air and 468–530°C in nitrogen. Among these polymers, polyamide **5g** revealed the relatively lower decomposition temperature and the lowest char yield, possibly can be related to the highest density of the aliphatic segment in the repeating unit of polymer chain. All the polymers showed distinct baseline shifts on their DSC heating traces. Glass transition temperatures ( $T_g$ s), defined by the midpoint of baseline shift, of the new polymers were in the 183–260°C range, depending on the diamine residue. The polyamide **5a** derived from *p*-phenylenediamine exhibited the highest  $T_g$ , 260°C, probably associated with its semicrystalline characteristics, as evidenced by the X-ray diffraction pattern. Polyamide **5i** also revealed a relatively high  $T_g$  at 241°C, owing to an enhanced intermolecular attraction caused by the presence of polar sulfonyl groups. In general, the introduction of flexible ether groups and *m*-phenylene units leads to a decrease in  $T_g$ . For example, polymer **5e** derived from 3,4'-oxydianiline had the lowest  $T_g$  of 183°C among this series polyamides. Polyamide **5l** also had a lower  $T_g$ , 189°C, which may be attributed to the high amount of flexible linkages, isopropyl-

**Table II.** Tensile Properties of Polyamide Films<sup>a</sup>

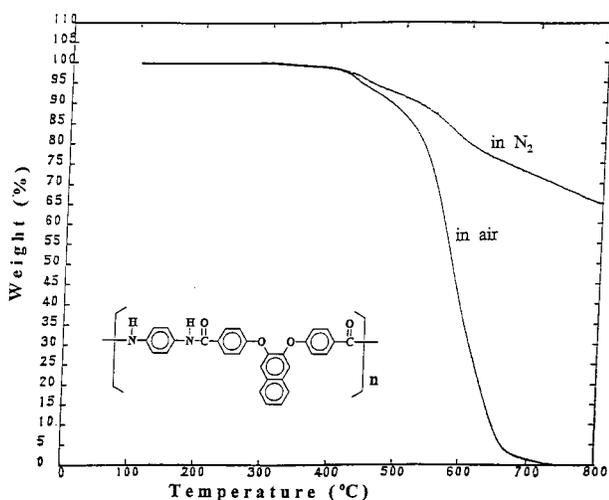
Polymer Code	Strength at Yield Point (MPa)	Strength at Break Point (MPa)	Elongation at Break Point (%)	Initial Modulus (GPa)
<b>5a</b>	—	57	2	2.0
<b>5b</b>	—	84	6	2.0
<b>5c</b>	79	67	6	1.8
<b>5d</b>	65	58	16	1.8
<b>5e</b>	83	61	62	1.9
<b>5f</b>	62	56	20	1.3
<b>5g</b>	—	75	6	2.1
<b>5h</b>	79	56	16	2.0
<b>5i</b>	73	57	9	1.6
<b>5j</b>	—	81	6	2.0
<b>5k</b>	75	60	82	1.8
<b>5l</b>	—	78	6	1.7

<sup>a</sup> Films were cast from slow evaporation of the polymer solutions in DMAc, except for those of **5a**, **5d**, and **5f** cast from NMP.

dene and ether groups, per repeated unit of the polymer backbone. The lower  $T_g$ , also around 189°C, for polymer **5j** can be explained by the fact that the bulky, pendent phenyl group in the diamine moiety disrupts the chain packing and results in an increased free volume leading to a decrease in  $T_g$ , although it may increase intermolecular barriers to rotation. The large window between  $T_g$  and the decomposition temperature makes these polymers attractive for practical processing.

## CONCLUSIONS

4,4'-(2,3-Naphthalenedioxy)dibenzoic acid, as a new dicarboxylic acid monomer containing both a



**Figure 1.** TG curves of polyamide **5a** at a heating rate of 20°C/min.

naphthalene ring and ether group, was prepared in high yield and high purity starting from the fluorodisplacement reaction of 2,3-dihydronaphthalene and *p*-fluorobenzonitrile in the presence of potassium carbonate. High molecular weight polyamides having an *ortho*-substituted naphthalene unit in the backbone could be synthesized

**Table III.** Thermal Properties of Polyamides Based on 4,4'-(2,3-Naphthalenedioxy)dibenzoic Acid

Polymer Code	$T_g^a$ (°C)	Decomposition Temperature <sup>b</sup> (°C)		Char Yield <sup>c</sup> (%)
		In N <sub>2</sub>	In Air	
<b>5a</b>	260	526	486	64.8
<b>5b</b>	221	489	515	60.0
<b>5c</b>	202	512	514	69.6
<b>5d</b>	231	510	509	66.9
<b>5e</b>	183	497	518	56.4
<b>5f</b>	213	519	523	63.2
<b>5g</b>	231	468	462	54.2
<b>5h</b>	200	515	518	59.2
<b>5i</b>	241	525	510	62.5
<b>5j</b>	189	517	516	63.6
<b>5k</b>	205	530	518	60.7
<b>5l</b>	189	528	523	61.8

<sup>a</sup> The samples were heated to 350°C with a heating rate of 20°C/min and rapidly cooled to room temperature. The mid-point of baseline shift on the subsequent second DSC heating trace was defined as  $T_g$ .

<sup>b</sup> Temperature at which 10% weight loss were recorded by thermogravimetry at a heating rate of 20°C/min.

<sup>c</sup> Residual wt % at 800°C in nitrogen.

from the direct polycondensation of this diacid monomer with various aromatic diamines by means of triphenyl phosphite and pyridine. The molecular weights of these polyamides are sufficiently high to permit casting flexible and tough films with good tensile properties. Except for the polyamide derived from *p*-phenylenediamine, all other polyamides are amorphous in nature and all the polyamides reveal excellent solubility in a variety of organic solvents. The present polymers also show high thermal stability and a large window between decomposition and glass transition temperature. All these properties make these polymers potential candidates for high-performance applications.

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