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9. Synthesis and Characterization of Poly (Ether-Amide) S Containing Triptycene Moiety

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Abstract

Aromatic polyamides are famous high performance polymeric materials for their excellent thermal and mechanical properties. Which now a days became a dominant platform for modern polymer chemistry area and used in advanced technologies that have been transformed into high-strength and flame resistant fibers and coatings, with applications in the aerospace and armors industry, protective clothing wear, sport fabrics, electrical insulation, asbestos substitutes, and industrial filters, as well as gas membrane system. Triptycene unit like structures as a pendent group in polymer directly affects the physiochemical properties of polymer, thus polyamides especially with triptycene unit and ether linkage in their backbone with aryl ether linkage imparts combination of properties such as excellent solubility, melts processing characteristics, and elevated toughness in contrast with those of polymers without an aryl-ether linkage. Therefore, in order to possess similar properties, new triptycene-containing bis(ether amine), 1,4-bis(4-aminophenoxy)-2,3-benzotriptycene (BAPB) (4a) was synthesized by nucleophilic displacement reactions of p-fluoronitrobenzene with 1,4-dihydroxytriptycene results dinitro intermediates, which on reduction by Hydrazine monohydrate and Pd/C. New diamine monomer was elucidated by FTIR, ^1H and ^{13}C NMR spectroscopy. A series of new polymers



containing cardo triptycene group and flexible ether linkage was synthesized by polycondensation of diamine with commercially available five different aromatic diacids by Yamazaki's Phosphorylation method. All the poly(ether amide)s were found soluble in common polar aprotic solvents such as DMF, DMAc, DMSO, NMP, O-Cresol and conc. Sulphuric acid etc. and which could be cast into films too. Inherent viscosities of polyamides were in the range 0.50 to 0.56 dL/g in DMAc, indicating its moderate to high molecular weight buildup. Polymers exhibited 10% wt loss (t_d) in the range of 409 to 486 °C, which is determined from thermogravimetric analysis indicating its better thermal stability and glass transition temperature were in the range of 200 to 248 °C.

Keywords: Polyamides, Structure-property relationship, Triptycene, Solubility, Inherent viscosity.

1] Introduction

Aromatic polyamides are gorgeous high performance polymers due to their excellent mechanical strength and high thermal stability [1-5]. However, their high softening or melting temperatures and poor solubility in organic solvents due to high crystallinity and high rigidity of the polymer backbone limit their processability and applications [6,7]. Numerous approaches have been outlined to enhance the solubility and processability of aromatic polyamides with retaining of their high thermal stability. These approaches include integration of non-coplanar groups in the main chain [8-11], molecular asymmetry [12-23], the use of meta-oriented monomers [24,25], flexible linkages [26-31], and bulky pendent [32-55] or cardo groups [56-61]. These alterations work by breaking chain symmetry and regularity and by terminating hydrogen bonding, usually leading to better solubility and processability.

The objective of the present work was to synthesize a series of poly(ether-amide)s which contains cardo triptycene group and ether linkage to investigate the effect of the insertion of cardo group on the polymer properties such as solubility and thermal behavior. Thus, a series of poly(ether-amide)s was produced by solution polycondensation of 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (BAPB) with commercially available diacids, viz., 4,4'-Oxybis(benzoic acid); 4,4'-Hexafluoroisopropylidene bis(benzoic acid); 4,4'-Sulfonyl dibenzoic acid and Biphenyl 4,4' dicarboxylic acid. The synthesized polyamides were characterized by inherent viscosity measurements, solubility tests, FT-IR spectroscopy, X-ray diffraction pattern, thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) studies.

2] Materials

All the reagents such as terephthalyl chloride (TPC); isophthalyl chloride (IPC), 1, 4-naphthanaptaquinone, anthracene, P-fluoronitrobenzene, hydrazine monohydrate $\text{NH}_2\text{-NH}_2\cdot\text{H}_2\text{O}$, 10% Pd/C were purchased from Sigma Aldrich and used as received. N, N-Dimethylformamide (DMF), anhydrous potassium carbonate (K_2CO_3) were purchased from Fluka. N, N-dimethyl acetamide (DMAc) was purified by distillation under reduced pressure over calcium hydride and stored over 4 Å molecular sieves. N-methyl- 2-pyrrolidone (NMP; Fluka), dimethyl sulfoxide (DMSO; Acros), tetrahydrofuran (THF; Acros), and pyridine (Py; Wako) were used as received from commercial sources. 4, 4'-Oxybis(benzoic acid), 4, 4'-Hexafluoroisopropylidene bis(benzoic acid), 4,4'-Sulfonyldibenzoic acid and Biphenyl 4, 4' dicarboxylic acid were purchased from Sigma Aldrich (USA) and used as received.

2.1] Instruments

Viscosity measurements were carried out with a 0.5% (w/v) polymer solution in N, N-dimethyl acetamide (DMAc) at 30 °C with an Ubbelohde suspended level viscometer. Thermo Nicolet iS-10 Mid Fourier transform infrared (FTIR) spectrometer in the 500–4000 cm^{-1} frequency range, ^1H NMR and ^{13}C NMR (400-MHz) were performed using D_6 DMSO as solvent. A spectrum of monomer was obtained with a Bruker spectrophotometer. Chemical shifts (delta values) are given as parts per million with tetramethyl silane (TMS) as an internal standard.

^1H NMR (400-MHz) of Polymers was performed using D_6 DMSO as solvent. X-ray diffraction (XRD) of polymers was recorded on Rigaku X-ray Diffraction System Ultima IV with ULTIMA IV Goniometer. Thermogravimetric analysis (TGA) was performed on a Mettler Toledo Thermal Analysis system under a nitrogen atmosphere with a scan rate of $100^\circ\text{C min}^{-1}$. Differential scanning calorimetry was performed on a Mettler Toledo DSC at a heating rate of $10^\circ\text{C min}^{-1}$. UV-Vis Spectroscopy (UV-Vis) spectra were recorded on a Beckman DU-640 spectrometer. The mass spectra were recorded on II MS 30, double beam mass spectrometer.

3] Synthesis

3.1] Synthesis of triptycene-1,4-naphthanaptaquinone (1a) and triptycene-1,4-hydronaphthanaptaquinone (2a):

Triptycene-1,4-naptaquinone (1a) and triptycene-1,4-hydronaptaquinone (2a) were prepared according to the published literature with some modifications.[12] A typical reaction is

as follows: anthracene (10.12 g, 56.67 mmol), 1,4 naphthaquinone (10.77g, 68.14 mmol), and (70 mL) toluene were added into a round-bottom flask with a stir bar. The mixture was refluxed at 140 °C under stirring in a nitrogen atmosphere for 8 h. The mixture was allowed to cool to room temperature and then filtered. The obtained solid was then washed three times with hot water (500 mL). The naphthaquinone product (1a) (18.02 g, 80% yield) was collected and dried at 60 °C under vacuum overnight. To synthesize Triptycene hydronaphthaquinone (2a), the quinone product (1a) (15.25 g, 45.4 mmol) and glacial acetic acid (165 mL) were added into a round-bottom flask with a stir bar. The mixture was brought to reflux at 118 °C under a nitrogen atmosphere. Hydrobromic acid (48%) (0.7 mL) was added to the flask drop wise and the mixture was allowed to reflux for an additional 30 minutes. A light tan precipitate was formed. The mixture was allowed to cool to room temperature and then filtered. The resulting hydronaphthaquinone product (2a) was dried under vacuum at 60 °C for 9 h.

Yield =13.72 g, 90%

M.P. = 346-348 °C.

3.2] Synthesis of 1, 4-bis (4-nitrophenoxy)-2, 3-benzotriptycene (3a):

The synthesis of 1, 4-bis (4-nitrophenoxy)-2, 3-benzotriptycene (3a) is used as an example to illustrate the detailed synthetic procedure. The hydronaphthaquinone product (2) (8.23 g, 24.5 mmol), dried potassium carbonate (7.46 g, 53.9 mmol), and DMF (80 mL) were added into a dry round-bottom flask with a stir bar. The mixture was allowed to stir at room temperature for 45 minutes. To the next, 1-fluoro-4-nitrobenzene (6.92 g, 49.0 mmol) was added into the flask and the mixture was allowed to reflux at 153 °C under a nitrogen atmosphere for 8 h. The mixture was cooled to room temperature and then poured into 400 mL of a methanol–water mixture (1:1 v/v) to precipitate an off white solid. The solid was collected via filtration and washed with methanol. The dinitro-para product (3a) was collected (8.15 g, 63% yield) and dried under vacuum at 80 °C 12h.

M.P= 160-164 °C.

IR (KBr): 1594, 1339 cm^{-1} (-NO₂ stretch), 1262, 1191 cm^{-1} (-C-O-C- stretching).

3.3] Synthesis of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a):

The synthesis of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a) is used as an example to illustrate the detailed synthesis procedure. The dinitro-para product (3a) (5.25 g, 9.93 mmol), 10% Pd/C catalyst (0.27 g), and alcohol (210 mL) were added into a 500 mL round-

bottom flask with a stir bar. The mixture was brought to reflux at 80 °C under a nitrogen atmosphere. Hydrazine monohydrate (8.3 mL, 173.1 mmol) was added drop wise and the mixture was allowed to reflux for 8 h. The mixture was cooled to room temperature and the alcohol was removed under reduced pressure. DMF (16 mL) was then added to dissolve the product to facilitate filtration through packed celite to remove the catalyst. The Filtered solution was precipitated in methanol (400 mL) and a fluffy, white solid was obtained. The diamine para (4a) product was dried under vacuum and stored in a desiccator. The schematic reaction steps are shown as in Scheme 1.

Mp = 220-224 °C.

IR (KBr): 3411, 3331 cm^{-1} (N-H stretch)

^1H NMR (400 MHz, DMSO- d_6 , ppm): 4.64 δ (s, 4H, -NH $_2$), 7.8 δ (d, 2H), 7.34 δ (d, 2H), 7.21 δ (d, 2H), 6.51 δ (d, 2H), 5.72 δ (s, 2H).

3.4] Synthesis of Poly(ether-amide)s (PA 1 to 5):

A representative procedure for synthesis of polyamides is described below.

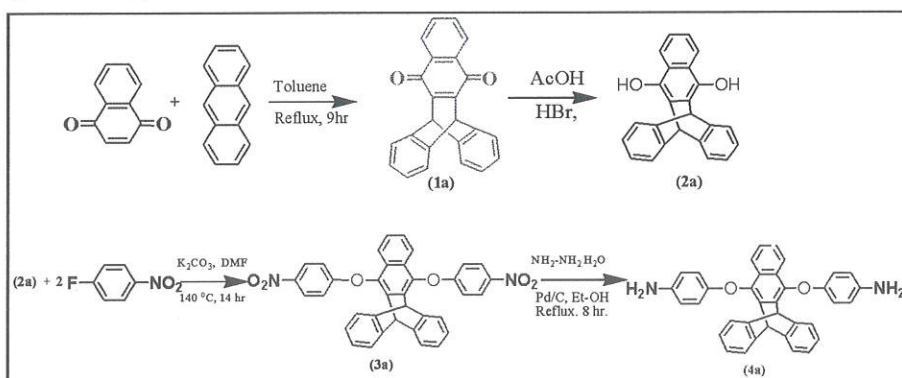
Into a 100 mL three-necked round-bottom flask equipped with a nitrogen gas inlet, a calcium chloride guard tube and a magnetic stirrer were placed 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a) (0.518 g, 1 mmol), in dry 3 mL N, N-dimethyl acetamide (DMAc), 3 mL Triphenyl phosphine (TPP), 0.5 mL Pyridine, and 5 wt % LiCl under nitrogen atmosphere till solution become clear. In that mixture 4,4'-Sulfonyldibenzoic acid (SDA) (0.306 g, 1 mmol) was added. The reaction mixture was later heated at 100 °C for 3 h under nitrogen atmosphere. The formed viscous mass was added to a large excess of rapidly stirring methanol to precipitate. Fibrous polymers were isolated. The polymer was washed several times with methanol as well as hot water, and was dried under vacuum at 80 °C overnight.

4] Results and Discussions

A new diamine monomer with ether linkage, cardo moiety triptycene group viz, 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (4a) (Scheme 1) were utilized. To study the effect of ether linkage, triptycene moiety on solubility behavior a series of polyamides was synthesized by low temperature solution polycondensation of 1, 4-bis (4-aminophenoxy), 2, 3-benzotriptycene (4a) with commercially available five different aromatic diacids (Scheme 2). These poly (ether-amide)s were characterized by IR spectroscopy, inherent viscosity, solubility, thermal analysis and WAXD and UV-Vis Spectroscopy.

4.1] Synthesis of 1, 4-bis (4-aminophenoxy)- 2, 3-benzotriptycene (4a):

The new 1, 4-bis (4-aminophenoxy)- 2, 3-benzotriptycene (4a) was synthesized as outlined in (Scheme 1) by reacting 1,4 naphthaquinone with anthracene to yield triptycene hydronaphthaquinone followed by reduction with Aq. HBr; followed by reaction with p-fluoronitrobenzene in N,N-dimethyl formamide, containing anhydrous potassium carbonate. The ether dinitro which is formed in above step was catalytically reduced by hydrazine monohydrate. The resulting structure of new dietheramine was confirmed by FT-IR and $^1\text{H-NMR}$, $^{13}\text{C-NMR}$ and Mass spectroscopy.



Scheme 1: Synthesis of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a)

The infrared spectrum of 4a (Figure 1) exhibited characteristic absorptions of primary amine Ar-NH_2 at 3338 cm^{-1} and 3408 cm^{-1} . Appearance of band at 1262 cm^{-1} and 1191 cm^{-1} is due to (C-O-C stretching). The absorption band at 824 cm^{-1} is due to para catenation of primary amine group. Absorption peak at 3010 cm^{-1} , 3060 cm^{-1} for allylic Ar(C-H) stretching and aromatic (Ar-H) stretching respectively. 1460 cm^{-1} and 1500 cm^{-1} for aromatic C=C stretching.

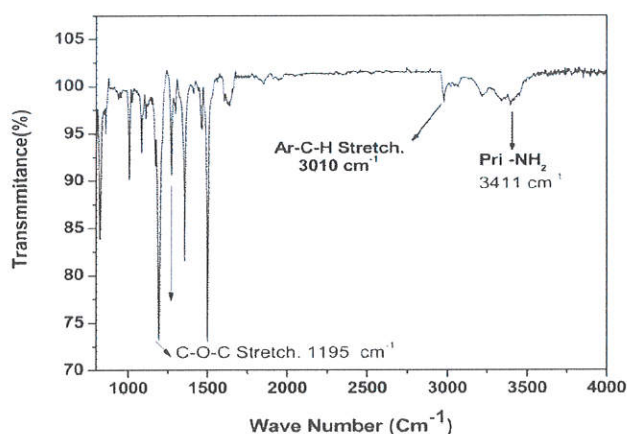


Figure 1: FT-IR spectrum of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (BAPB)

Proton ^1H -NMR spectrum (Figure 2) of (4a) showed singlet at 3.45 δ due to primary- NH_2 protons (Ar-NH_2) and multiplet in the range of 7.90 δ to 6.83 δ due to aromatic protons as expected with desired integration and splitting pattern. Peak at 5.71 δ is due to allylic protons of triptycene moiety.

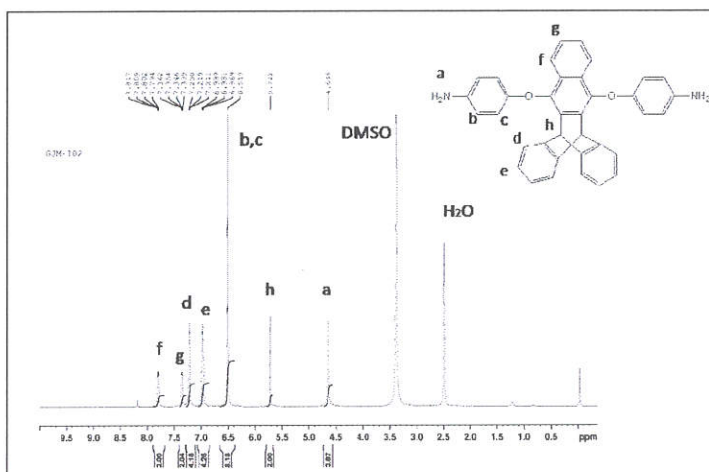


Figure 2: ^1H -NMR spectrum of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (BAPB)

^{13}C -NMR spectrum (Figure 3) of (4a) showed fourteen NMR signals corresponding fourteen types of different carbons of which aniline's carbon (Ar-NH_2) appeared at 144 δ ; whereas aromatic carbons showed signals at 152.70, 144.04, 140.60, 125.40, and 134.16 δ . The CH of aromatic rings appeared at 116, 122.43, 124.21, and 127.6 δ ; whereas allylic CH carbons gave ^{13}C NMR signal at 43.60 δ . Mass spectra (Figure 4) showed molecular ion peak m/e at 519 ($m+1$) of corresponding to molecular weight 518 of (4a).

4.2] Synthesis of poly(ether-amide)s from 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a):

A series of poly(ether-amide)s were synthesized as outlined in (Scheme 2). A series of poly(ether-amide)s were synthesized by Yamazaki's Phosphorylation polycondensation reaction, also known as high temperature solution polymerization of 1, 4-bis (4-aminophenoxy)-2, 3-benzotriptycene (4a) with structurally summarized diacids in NMP/Py. The polymerization preceded forward giving highly viscous solution. The resulting polymers were precipitated by pouring the viscous solutions in stirring methanol. The inherent viscosities of all these polymers were measured in DMAc and ranged from 0.50 to 0.56 dL/g. The data representing the behavior of poly (ether-amide)s are displayed in Table 1.

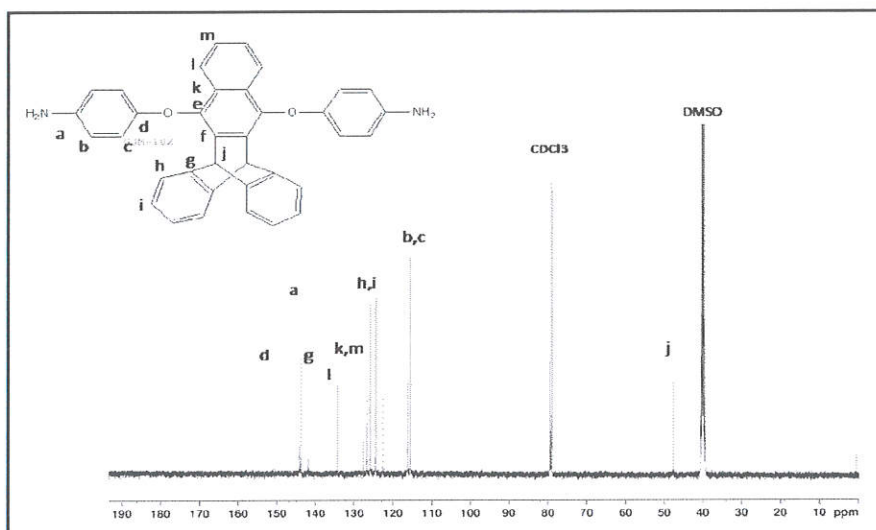


Figure 2: ^{13}C NMR spectrum of 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (BAPB)

Table 1: Yield and Viscosity of Poly(ether-amide)s^a

Polymer	Monomers		Yield %	Inherent Viscosity ^b dL/g
	Diamine	Diacid		
PA 1	BAPB	SDA	99	0.53
PA 2	BAPB	ODA	98	0.54
PA 3	BAPB	HFDA	99	0.50
PA 4	BAPB	BPDA	99	0.56
PA 5	BAPB	NDA	99	0.51

^a :Polymerization was carried out at 1mm each of diamine and diacid.

^b :Inherent viscosities were measured at a concentration of 0.5 % (W/V) in **DMAc** at $30^\circ\text{C} \pm 0.1^\circ\text{C}$

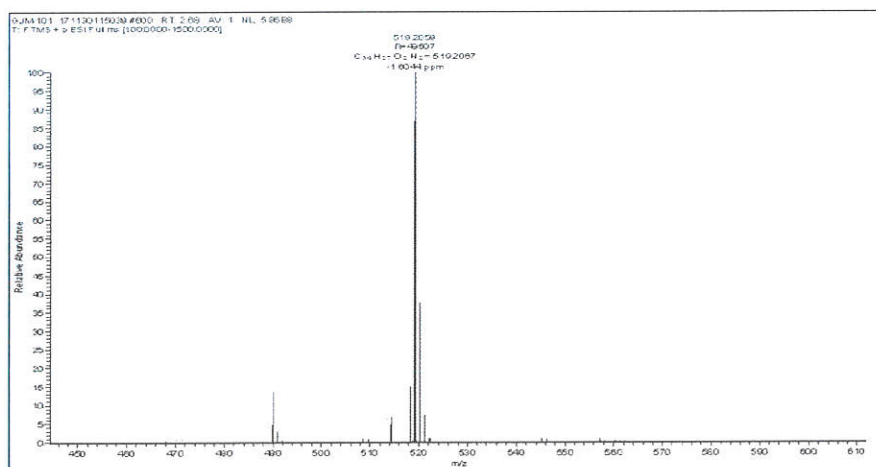
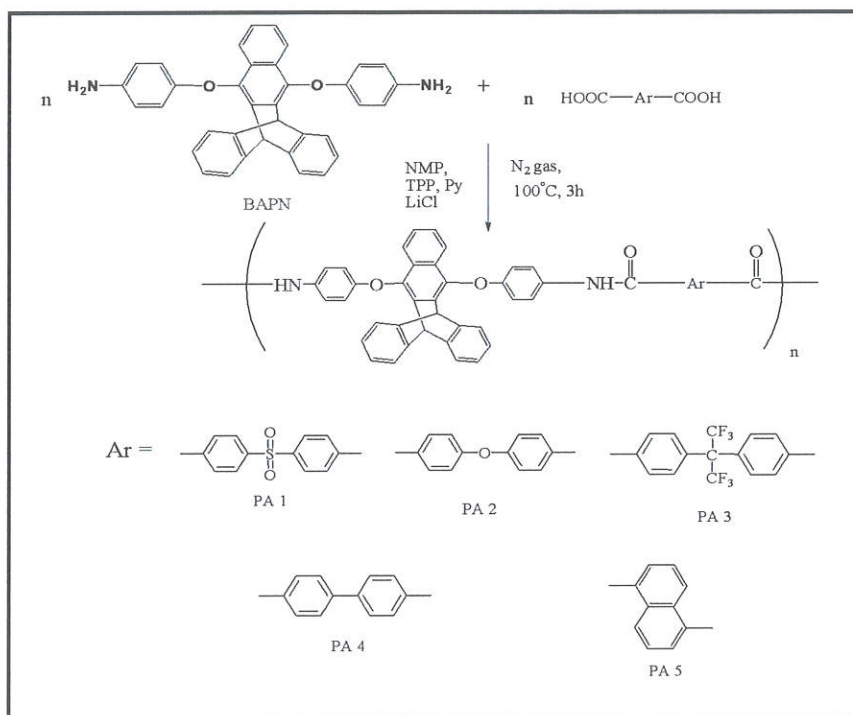


Figure 4: Mass spectrum of 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (BAPB)



Scheme 2: Synthesis of poly(ether-amide)s from 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (4a) PA 1 to PA 5

5] Polymer characterization

5.1] Infrared Spectroscopy

Poly(ether-amide)s were characterized by FT-IR. A representative FT-IR spectrum of polyamide PA 1 based on 1, 4-bis (4-aminophenoxy) 2, 3-benzotriptycene (BAPB) and SDA is shown in (Figure 5). FT-IR spectrum of polyamide showed –NH stretching frequency as a broad band at 3305 cm^{-1} . The amide-I band, associated with stretching vibration of the carbonyl group, appeared at 1649 cm^{-1} . The amide-II band, ascribed to the coupling of the –N-H bending appeared at 1491 cm^{-1} . The polymer PA 3 (Figure 6) showed similar absorption bands at 3301 (N-H stretching), 1508 (N-H bending), 1649 cm^{-1} (amide C=O stretching). FT-IR spectrum of polyamide PA 5 based on 1, 4-bis (4-aminophenoxy)2, 3-benzotriptycene (BAPB) and NDA is shown in (Figure 7) FT-IR spectrum of polyamide showed –NH stretching frequency as a broad band at 3305 cm^{-1} . The amide band, associated with stretching vibration of the carbonyl group, appeared at 1661 cm^{-1} . The amide band, ascribed to the coupling of the –N-H bending appeared at 1502 cm^{-1} .



All other poly (ether-amide)s PA 1, PA 3 and PA 5 also exhibited strong characteristics absorption bands at around 1204, 1205 and 1210 cm^{-1} C–O–C stretching, due to the ether group respectively.

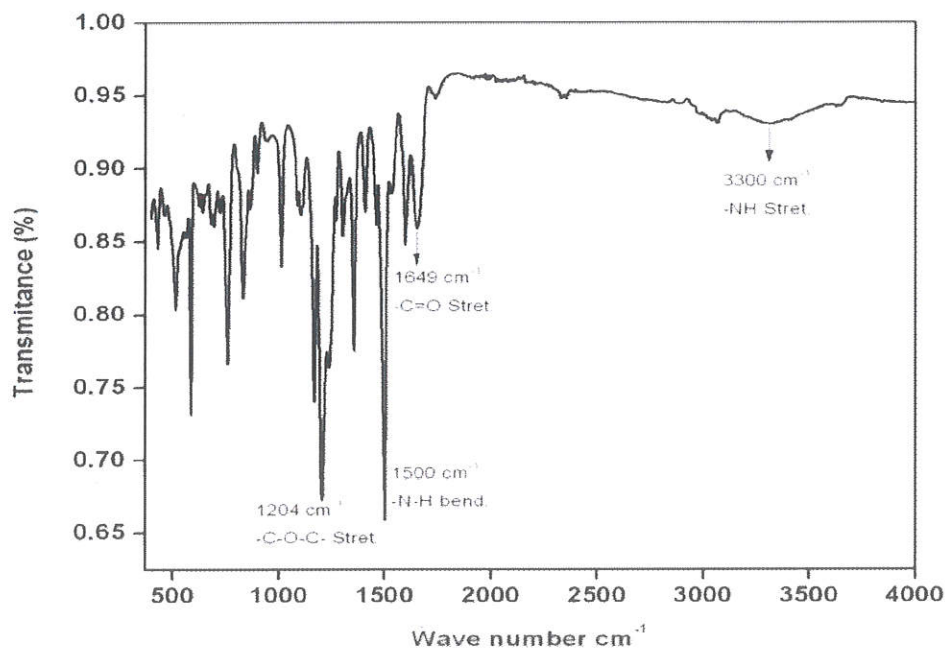


Figure 5: FT-IR spectrum of PA 1.

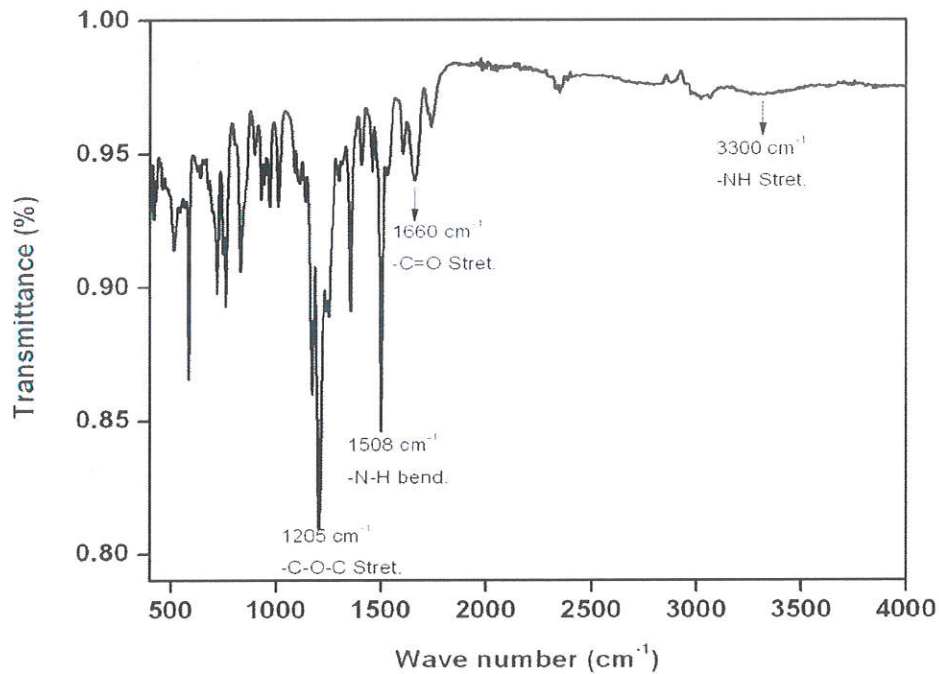


Figure 6: FT-IR spectrum of PA 3.

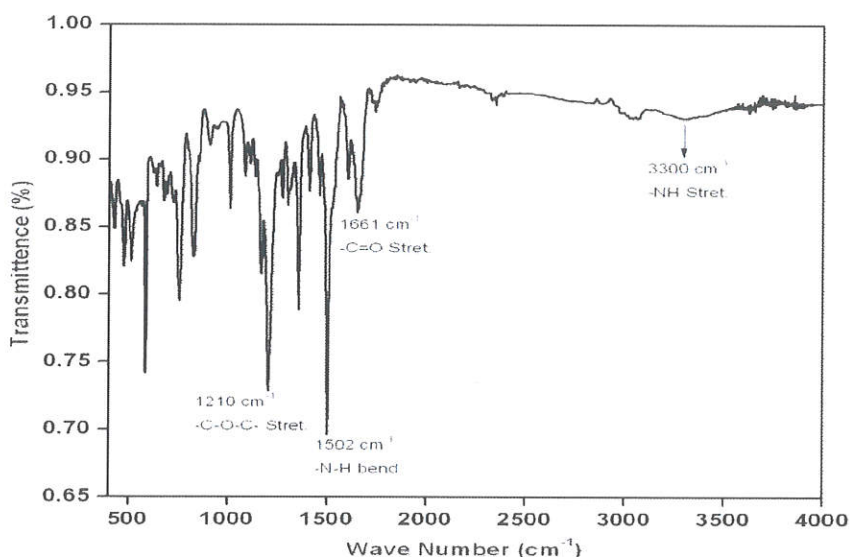


Figure 7: FT-IR spectrum of PA 5.

5.2] Solubility Properties

Solubility characteristics of aromatic poly(ether amide)s are summarized in Table 2. It is observed that PA 1 to PA 5 synthesized exhibited excellent solubility in common organic solvents and also in various polar aprotic solvents such as N-methylpyrrolidone (NMP), N, N-dimethyl sulfoxide (DMSO), N, N-dimethylacetamide (DMAc), tetrahydrofuran (THF) and need moderate heating to get soluble in polar protic solvents such as chloroform (CHCl_3), dichloromethane (CH_2Cl_2) as well as it found completely soluble in formic acid (HCOOH), Conc. H_2SO_4 .

Table 2: Solubility behavior of Poly(ether-amide)s

Polymer Code	Solubility						
	DMF	DMAc	DMSO	NMP	CHCl_3	THF	Conc. H_2SO_4
PA 6	++	++	++	++	+-	++	++
PA 7	++	++	++	++	+-	++	++
PA 8	++	++	++	++	+-	++	++
PA 9	++	++	++	++	+-	++	++
PA 10	+	++	+	+	+-	+	++

++: Soluble; +-: Partly Soluble +: Soluble on heating; --: Insoluble

5.3] Thermal Properties

Thermal behavior of polymers was evaluated by means of thermogravimetry and differential scanning calorimetry under nitrogen atmosphere Table 3 incorporates the thermal

data such as glass transition temperature (T_g), initial decomposition temperature (T_i), 10% decomposition temperature (T_d) and residual weight at 900°C. The thermal stability of triptycene containing poly(ether amide)s outlined in Figure 8 was first dried to high temperature and further studied at a heating rate of 10 °C /min in nitrogen atmosphere by thermogravimetric analysis.

10% decomposition temperature (T_d) values obtained from TG curves for polyamides were in the range 409-486°C, indicating their good thermal stability. The initial decomposition range were in the range of 183-197°C. The weight residue of polyamides when heated to 900°C in nitrogen atmosphere were found in the range of 43-63% as outlined in Figure 9. This good thermal stability of polymers can be attributed to structure of new diamine and diacid monomer.

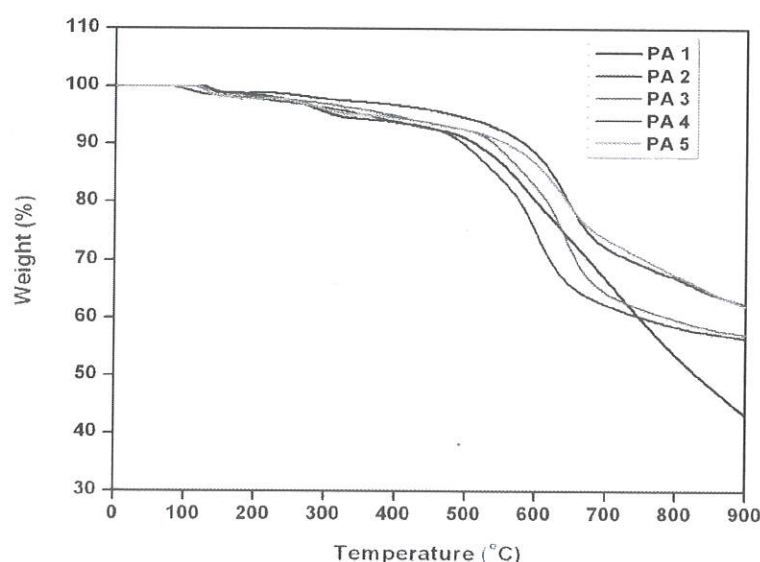


Figure 8: TGA curve of Poly(ether-amide)s PA 1 to PA 5.

Limiting Oxygen Index (LOI)

Fundamentally there are two consecutive chemical processes – decomposition and combustion - connected by ignition and thermal feedback. Primarily the material decomposes (pyrolysis), which requires heat. The decomposition products are combusted, during which heat is generated. This heat is (partly) used to support the decomposition. An ignition mechanism is essential of great importance are the heat effects values, for exchange of heat and matter. To be flame-resistant a material should have a high heat effect value and water formed by pyrolysis may be used as a measure of the non-flammability. This is proved by the fact that there is a significant correlation a between the char residue (CR) and the oxygen index of polymers, as is shown in. This linear relationship can be represented by:

$$LOI = 17.5 + 0.4CR \dots \dots \dots (1)$$

Where CR is the char residue in wt %. In view of this interesting correlation it seemed useful to make an elaborate investigation into the relation between the residue of pyrolysis and the constitution of polymers.

Subsequently, limiting oxygen index (LOI) values of these polyamides PA 1 to PA 5 were calculated because LOI of a material gives us an idea of its flammability. The LOI of a given material can be calculated from its respective char yield by employing the van Krevelen and Hoftyzer equation (1)

$$LOI = 17.5 + 0.4CR \dots \dots \dots (1)$$

Where, CR means Char Yield or the weight percentage of polymer remaining at 900°C. In case of synthesized polyamides reported herein, the LOI values found greater than 28. The LOI of PA 1, PA 2, PA 3, PA 4 and PA 5 found at 31, 39.8, 39.4, 40.6 and 40.2 respectively. **Table 3.** Since materials having LOI greater than 28 are classified as “fire retardants” or “self-extinguishing”, therefore poly(ether-amide)s reported herein may be categorized as ‘fire retardants’ or “self extinguishing” polymer.

The glass transition temperatures of the poly(ether-amide)s containing triptycene moiety in their backbone were in the range of 200 °C to 248 °C. The DSC curves for all the polymers showed similar trend with nearly same values for T_g. The polyamide PA 5 showed higher T_g value due diacid i.e. NDA. The polyamide PA 6 showed lower T_g value, which is attributed to flexible ODA.

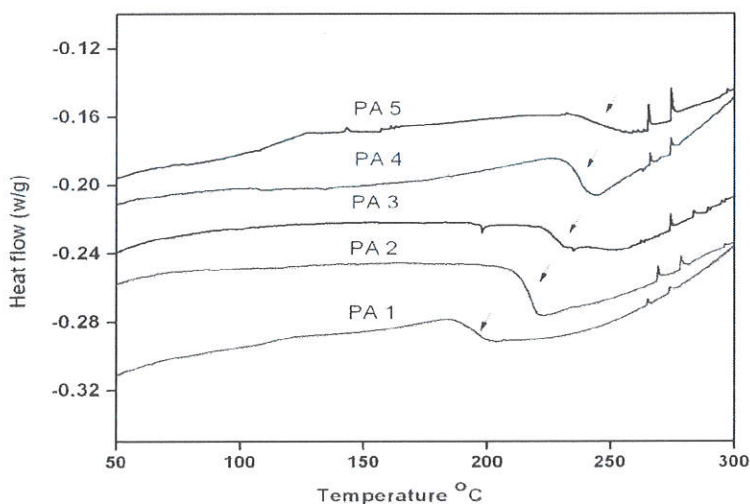
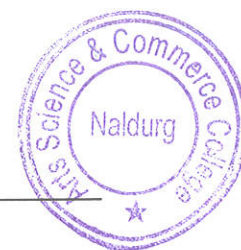


Figure 9: DSC curve of Poly(ether-amide)s PA 1 to PA 5.

**Table 3: Physical properties of Poly(ether-amide)s**

Polymer	Thermal behavior ^a				
	T _i ^b °C	T _d ^c °C	T _g ^d °C	Residual Wt % ^e at 900°C	LOI
PA 1	197	409	200	43	31
PA 2	185	435	217	56	39.8
PA 3	195	455	228	57	39.4
PA 4	183	466	239	62	40.6
PA 5	192	486	248	63	40.2

a: Thermal stability of polyamides determined by thermogravimetric analysis

b: T_i- Initial decomposition temperature

c: T_d – Temperature of 10 % decomposition

d: T_g- Glass transition temperature determined at second heating by DSC at a heating rate of 10°C /min

e: Char yield at 900°C

5.4] X-ray diffraction

The triptycene containing poly(ether-amide)s (PA 1 to PA 5) were also characterized by the wide angle X-ray diffractometer. The wide angle X-ray diffraction pattern of all poly(ether-amide)s is shown in Figure 9. Broad halos without sharp peaks were observed in all WAXD patterns, suggesting a generally amorphous structure of the triptycene-based Poly(ether-azomethine)s. Depending on the monomer structure (i.e., triptycene), quite different diffraction patterns were observed for these poly(ether-amide)s signifying different chain packing structures induced by triptycene moieties. All poly(ether-amide)s shows two diffraction peaks (i.e., A and B) located at $2\theta \approx 15^\circ$, and 20° . These values are likely associated with the main interchain distance disrupted by the rigid triptycene units and π - π stacking of benzene blades rings of triptycene moieties. For the entirely triptycene based poly(ether-amide)s two broad peaks were observed, which represent the main interchain distance disrupted by triptycene units and the average interchain distance of amide backbone.

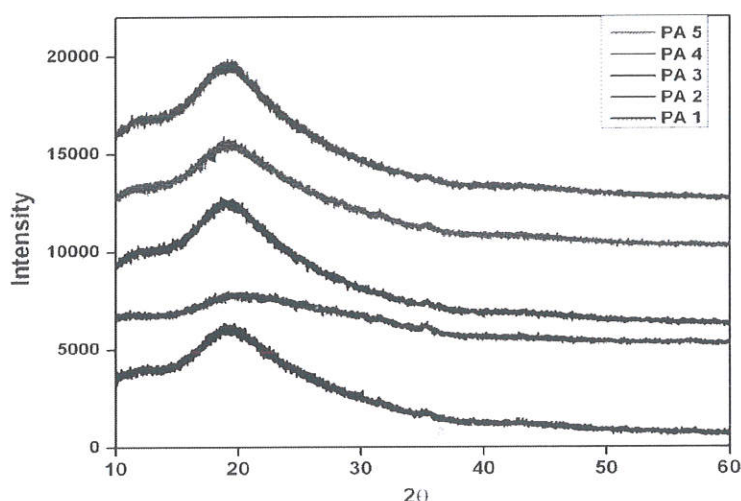


Figure 10: XRD curve of Poly(ether-amide)s PA 1 to PA 5.

Conclusions

A series of new poly(ether-amide)s containing pendant triptycene moiety, flexible ether linkage, was synthesized by elevated temperature solution polycondensation of 1,4-bis(4-aminophenoxy)-2, 3-benzotriptycene and commercial aromatic diacids. Poly(ether-amide)s showed excellent solubility properties which attributes to incorporation of cardo triptycene moiety, and ether linkage which leads to improvement in solubility of polyamides in solvents. Inherent viscosities of polyamides were in the range of 0.50-0.56 dL/g. Inherent viscosities of poly(ether-amide)s indicated the formation of medium to reasonably high molecular weight polymers. Wide angle X-ray diffraction patterns indicated that polyamides were amorphous in nature. (T_d) values were in the range of 587 - 631°C indicating good thermal stability of polyamides and the char yield at 900°C found in the range of 24 % to 54%. (T_i) values of polyamides were in the range 212-311 °C. The noticeable gap in between glass transition temperature and decomposition temperature of polyamides offers a broad processing margin, which could be considered as remarkable advantage that could be helpful in application of polyamides where it is desired.

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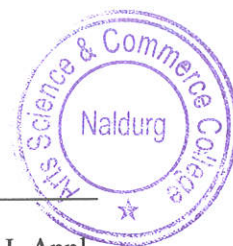
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