Synthesis, characterization and thermal decomposition of poly(decamethylene 2,6-naphthalamide)

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Abstract. A novel engineering plastic, poly(decamethylene 2,6-naphthalamide) (PA10N) was prepared via a reaction of 2,6-naphthalene dicarboxylic acid and 1,10-decanediamine. The structure of synthesized PA10N was characterized by elemental analysis, Fourier transform infrared (FT-IR) spectroscopy and proton nuclear magnetic resonance (\textsuperscript{1}H-NMR). The thermal behavior was determined by differential scanning calorimetry (DSC), thermo-gravimetric analysis (TGA) and dynamic mechanical analysis (DMA). Melting temperature ($T_m$), glass transition temperature ($T_g$) and decomposition temperature ($T_d$) of PA10N are 320, 144 and 495°C, respectively. The solubility, water-absorbing capacity, and mechanical properties of PA10N have also been investigated. Pyrolysis products and thermal decomposition mechanism of PA10N were analyzed by flash pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). The results show that the heat resistance and mechanical properties of PA10N are near to those of poly(nonamethylene terephthalamide) (PA9T), and PA10N is a promising heat-resistant and processable engineering plastic.

Keywords: mechanical properties, thermal properties, polyamides, synthesis, decomposition

1. Introduction

Aromatic polyamides and semiaromatic polyamides have been widely used in many industrial and commercial applications, especially in surface-mount technology (SMT) and automobile industries, by virtue of their excellent characteristics such as good thermal stability, chemical resistance, low creep and high modulus [1–3]. The commonly mentioned aromatic and semiaromatic polyamides can not be processed by melting method due to their high melting temperature and relatively lower decomposition temperatures [4–6]. Therefore, several approaches have been made through synthetic modification by the incorporation of flexible linkages [7, 8], bulky pendant groups [9] and noncoplanar biphenylene moieties [10] into the polymer backbones. Poly(nonamethylene terephthalamide) (PA9T) inherits the merits of the heat resistance of aromatic polyamides and the processing ability of aliphatic polyamides [11]. However, the high cost of PA9T limited its applications. In order to increase the processing ability and decrease the cost of semiaromatic polyamides, long flexible aliphatic chains are usually introduced into their backbones [12–14]. It has been reported that diacids with long molecular chains can be prepared from petroleum fermentation process using light wax as raw material [15], and the long chain diamines can be prepared from the corresponding long chain diacids by cyanation and amination process [16]. The cost of obtained long chain diacids and diamines was reduced accordingly. It
was noticeable that naphthalene-ring can be also introduced into the molecular main chain of semi-aromatic polyamides and high thermal stability was retained expectably. However, the semiaromatic polyamides containing naphthalene-ring were presented relatively low molecular weight and unsatisfactory performance which would not meet the requirements for commercialization [17, 18]. Therefore, it is of great significance to synthesize novel, low-cost, high-performance and processability semiaromatic polyamides containing naphthalene-ring.

Semiaromatic polyamides are widely used in many demanding applications where the properties of thermal stability and flame resistant are priorities [19]. Taking into account this high practical interest, it is important to study the thermal decomposition behavior of semiaromatic polyamides [20, 21]. Pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) is well established as a method for the analysis of the thermal decomposition of polymers [22–24]. The investigation of Py-GC/MS can provide unique information on the primary processes of the thermal decomposition of polymers and also important structural information, such as structural identification of homopolymers, differentiation of isomeric structures, copolymer composition, etc.

In this work, the PA10N was successfully synthesized by the polycondensation reaction of 2,6-naphthalene dicarboxylic acid and 1,10-decanediamine through a three-step procedure: salt formation, prepolymerization and solid-state polymerization (Figure 1).

1,10-decanediamine (258 g, 1.5 mol) was dissolved in distilled water (1000 ml) at 80°C. Then the solution was added slowly into 500 ml of distilled water mixture of 2,6-naphthalene dicarboxylic acid (324 g, 1.5 mol) with vigorous stirring and then stirred for 2 h at 80°C. Finally a slight excess of 1,10-decanediamine (2 g, 0.01 mol) was added into the solution with continuous stirring for 1 h at 80°C. The pH value of the solution was adjusted to 7.2. The white 1,10-decanediamine-2,6-naphthalene dicarboxylic acid salt (PA10N salt) precipitated from the solution.

After filtering over a Buchner funnel and drying in a vacuum desiccator for 12 h, the white salt of PA10N (553 g) and distilled water (500 ml) were added into an autoclave. The autoclave was filled with carbon dioxide and then heated to 240°C while increasing the pressure to 2.6 MPa. After 2 h, the pressure of the autoclave was gradually decreased to normal pressure in 2 h by deflating and the reaction temperature of the autoclave was increased to 255°C. After reaction for another 1.5 h, the ivory-white prepolymer of PA10N was obtained (503 g).

The prepolymer of PA10N was ground into particles with diameter of 0.1~2 mm and dried at 90°C in a vacuum oven for 4 h. Then the prepolymer of PA10N was added into a solid-state polymerization kettle, the reaction was carried out at 250°C for 15 h with a vacuum of 10 Pa. Finally, the kettle was cooled to room temperature and straw yellow polymer of PA10N was obtained (478 g).

The prepolymer of PA10N was ground into particles with diameter of 0.1~2 mm and dried at 90°C in a vacuum oven for 4 h. Then the prepolymer of PA10N was added into a solid-state polymerization kettle, the reaction was carried out at 250°C for 15 h with a vacuum of 10 Pa. Finally, the kettle was cooled to room temperature and straw yellow polymer of PA10N was obtained (478 g).

2. Materials and methods

2.1. Materials

2,6-naphthalene dicarboxylic acid was purchased from Mitsubishi Gas Chemical Company, Inc (MGC, Japan). 1,10-decanediamine was provided commercially by Zibo Guangtong Chemical Co. Ltd (China), and purified by vacuum distillation prior to use.

2.2. Synthesis of PA10N

PA10N was prepared from the reaction of 2,6-naphthalene dicarboxylic acid and 1,10-decanediamine through a three-step procedure: salt formation, prepolymerization and solid-state polymerization (Figure 1).

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![Figure 1. The synthetic route of PA10N](image-url)
2.3. Characterization of PA10N

FT-IR, \(^1\)H-NMR and elemental analysis were used to confirm the structure of PA10N. The thermal behavior was determined by DSC, TGA and DMA. Thermal decomposition mechanisms of PA10N were analyzed by Py-GC/MS. The solubility, intrinsic viscosity, inherent viscosity, water-absorbing capacity and mechanical property of PA10N were also studied.

The intrinsic viscosity and inherent viscosity of PA10N dissolved in concentrated sulfuric acid was determined in an Ubbelohde viscometer at 25±0.1°C. The water-absorbing of PA10N was measured according to GB/T 1034 (Chinese standard).

The FT-IR measurement was carried out on a NICOLET 460 spectrometer. \(^1\)H-NMR spectra was recorded with a Bruker DPX-400 (400 MHz), using deuterated trifluoroacetic acid as solvents and tetramethylsilane (TMS) as an internal reference. Elemental analysis was performed on a Perkin-Elmer 2400 CHNS/O elemental analyzer at 975°C under nitrogen.

Thermal analysis (DSC and TGA) was recorded on a NETSCH 204 calorimeter with a heating rate of 10°C·min\(^{-1}\) in a nitrogen stream. DMA was carried out on a NETZSCH DMA-242 apparatus operating in the bending mode at 1 Hz and a heating rate 3°C·min\(^{-1}\) from –170 to 170°C. All samples for mechanical tests were prepared by injection molding. The Izod impact strength was measured according to GB/T 1843 (Chinese standard). Tensile strength and elongation at break were measured according to GB/T 1040 (Chinese standard). Bending strength was measured according to GB/T 9341 (Chinese standard). All tests were carried out at room temperature (23°C). The resulting value of each sample was the average of five parallel experiments.

The samples of PA10N were pyrolyzed with a set-point of 700°C per 5 s using a Chemical Data Systems Pyroprobe 2000. Pyrolyses were carried out in helium using a coil probe. The sample weights used ranged from 0.1 to 1 mg, and no changes in pyrolysis product distribution were observed. Analysis was performed using an Agilent GC/MS(6890A/5973) system with a DB-FFAP (nitroterephthalic acid modified polyethylene glycol) capillary columns from J&W Company (60 m×250 μm×0.25 μm). The oven temperature program was as follows: 40°C, initial time 5 min, heating rate 3°C·min\(^{-1}\), then temperature 200°C holding 10 min, final temperature 230°C for 20 min. Helium was used as the carrier gas. Mass spectra was acquired by a Nist98 Mass Spectra Library data system operating under HP Chemistry Station G1034. The mass spectrometer was scanned repetitively from \(m/z\) 500 to \(m/z\) 20 at a scan rate of 0.7 s/decade; the ionizing conditions were 70 eV.

3. Results and discussion

3.1. Synthesis of PA10N

PA10N was prepared from the reaction of 2,6-naphthalene dicarboxylic acid and 1,10-decanediamine through a three-step procedure: salt formation, prepolymerization and solid-state polymerization. In order to assure an accurate equivalent ratio of 1,10-decanediamine to 2,6-naphthalene dicarboxylic acid, PA10N salt was prepared firstly. Then an slight excess 1,10-decanediamine was added into the salt solution to compensate reaction system for the loss during the prepolymerization reaction. It is noticeable that the solvent for the salt formation reaction is water, which is cheaper and environmental friendly compared with ethanol, usually used in preparing other common polyamides [25]. In order to obtain high vapor pressure, the distilled water was added to reduce volatilization of diamine during the prepolymerization. The prepolymer was ground into small particles, which are convenient for removing water. In order to avoid side reaction and to improve the molecular weight of the polyamide, the high vacuum was maintained during the solid-state polymerization reaction. The molecular weight of the PA10N was characterized by intrinsic viscosity and inherent viscosity. The intrinsic viscosity and inherent viscosity of PA10N are 1.85 dl·g\(^{-1}\) and about 1.78 dl·g\(^{-1}\), respectively. FT-IR spectrum of the PA10N is shown in Figure 2. All the characteristic peaks of amide groups and methylene segments of polyamide are listed as follows: 1632 cm\(^{-1}\) (amide I, C=O stretching vibration), 1534 cm\(^{-1}\) (amide II, C–N stretching and CO–N–H bending vibration), 2922 cm\(^{-1}\) (N–H in-plane bending vibration and CH\(_2\) vibration), 3296 cm\(^{-1}\) (hydrogen-bonded and N–H stretching vibration), 3076 cm\(^{-1}\) (N–H in-plane bending vibration), 348...
912 cm\(^{-1}\) (amide IV, C–CO stretching vibration), 822 cm\(^{-1}\) (CH\(_2\) wagging), 765 cm\(^{-1}\) (C–H of naphthalene ring vibration).

Figure 3 presents the \(^1\)H-NMR spectrum of PA10N in deuterated trifluoroacetic acid. The chemical shifts at 8.50 ppm (2H), 7.96 ppm (2H) and 8.19 ppm (2H) are attributed to the naphthalene ring protons (a, b and c). The chemical shift at 3.83 ppm (4H) originates from the protons at the position d while that at 1.93 ppm (4H) comes from the protons at the position e. The peak at 1.49 ppm (12H) belongs to the other protons of the aliphatic chains (f). The peak at 11.6 ppm was assigned to trifluoroacetic acid.

The elemental analysis data of PA10N are listed in Table 1. The calculated components are presented for comparison. The resulting value of elemental analysis was the average of five parallel experiments. The hydrogen content of PA10N is higher than the theoretical value owing to the absorption of water. The other measurement results are in agreement with the theoretical values.

The water-absorbing of PA10N was measured according to GB/T 1034 (Chinese standard), and the result is 0.14. The low water absorption, close to PA9T (0.17) [26], is conducive to maintain dimensional and mechanical stability of products.

The solubilities (sample 100 mg, solvent 10 ml) of PA10N were tested in different organic solvents. PA10N can easily dissolve in acidic solvents such as concentrated sulfuric acid and trifluoroacetic acid (TFA) at room temperature, while it is insoluble in dimethylsulphoxide (DMSO), N,N’-dimethylformamide (DMF), 1-methyl-2-pyrrolidone (NMP), dimethylacetamide (DMAc), m-cresol, tetrahydrofuran (THF), pyridine, tetrachloroethane, chlorobenzene, methanol, toluene, chloroform, phenol and formic acid. The results show that PA10N exhibits good chemical solvent resistance.

### 3.2. Thermal properties of PA10N

Figure 4 depicts the DSC curves of PA10N. Curve A is the second heating DSC curve, while B is a cooling DSC curve. The heating rate is 10°C·min\(^{-1}\), and the test temperature is 50 to 330°C. PA10N exhibits double-melting endotherms, which is a common phenomenon observed in semicrystalline polymers [27–29]. The melting temperature (\(T_m\)) of PA10N is 320°C based on curve A, and the crystallization

![Figure 2. FT-IR spectra of PA10N](image)

![Figure 3. \(^1\)H-NMR spectra of PA10N](image)

![Figure 4. DSC curves of PA10N](image)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Carbon [%]</th>
<th>Hydrogen [%]</th>
<th>Nitrogen [%]</th>
<th>Oxygen [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>calculated</td>
<td>measured</td>
<td>calculated</td>
<td>measured</td>
</tr>
<tr>
<td>PA10N</td>
<td>75.0</td>
<td>74.9</td>
<td>7.95</td>
<td>8.01</td>
</tr>
</tbody>
</table>
temperature \((T_c)\) of PA10N is 297°C based on curve B.

TGA curves of PA10N are shown in Figure 5. The curve A of PA10N shows a one-stage weight loss process in nitrogen. The decomposition temperature \((T_d)\) of PA10N is approximately 495°C, and the termination temperature of thermal degradation is about 500°C. The maximum degradation temperature \((T_{\text{max}})\) of PA11N is 477°C.

The \(T_m\) of PA10N is far below \(T_d\) of PA10N. Therefore, the melt processing ability of PA10N is excellent. In addition, the \(T_d\) of PA10N is higher than that of aliphatic polyamides \([30, 31]\). The results show that the thermal stability of PA10N has been improved by inserting naphthalene linkage into the polymeric backbone.

DMA was also used to characterize the thermal property of PA10N (Figure 6). Three obvious transition peaks can be observed, and are defined as \(\alpha\), \(\beta\) and \(\gamma\) relaxation, respectively. The glass transition temperature \((T_g)\) of the PA10N is 144°C according to \(\alpha\) relaxation. \(T_g\) of aliphatic polyamides such as poly(\(\varepsilon\)-caprolactam) (nylon6) \((T_g = 60°C)\) and poly(hexamethylene adipamide) (nylon66) \((T_g = 50°C)\) are all below 90°C. The results show that \(T_g\) of PA10N is higher than those of aliphatic polyamides. As expected, the heat-resistance of PA10N was improved by the introduction of naphthalene-ring. The \(\beta\) relaxation reflects the mobility of carbonyl group of amorphous region, and the \(\gamma\) relaxation reflects the co-movement of amido and methane groups. The thermal data of PA10N in this work are listed in Table 2.

3.3. Mechanical properties of PA10N

All dry and standard samples of PA10N for mechanical tests were prepared by injection molding in an injection-molding machine. Based on Table 3, it can be observed that the tensile strength of PA10N is almost as same as that of PA9T at room temperature \([32]\).

3.4. Flash Py-GC/MS analysis

A typical pyrogram of PA10N (total ion chromatogram of the pyrolysates) obtained by flash pyrolysis at 700°C is shown in Figure 7. The pyrolysates were identified by mass spectra and confirmed by comparing their retention times \([33–37]\). The results of identification, the molecular weight and relative intensity of pyrolysis products

<table>
<thead>
<tr>
<th>Sample</th>
<th>(\eta, dLg^{-1})</th>
<th>(T_m, ^\circ C)</th>
<th>(T_c, ^\circ C)</th>
<th>(T_d, ^\circ C)</th>
<th>(T_g, ^\circ C)</th>
<th>Water-absorbing capacity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA10N</td>
<td>1.85</td>
<td>320</td>
<td>297</td>
<td>495</td>
<td>144</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 3. The mechanical property of PA10N compared with PA9T

<table>
<thead>
<tr>
<th>Samples</th>
<th>Tensile strength [MPa]</th>
<th>Tensile modulus [GPa]</th>
<th>Breaking elongation [%]</th>
<th>Bending strength [MPa]</th>
<th>Bending modulus [GPa]</th>
<th>Izod impact strength [kJ·m^{-2}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA10N</td>
<td>94</td>
<td>1.7</td>
<td>40</td>
<td>92</td>
<td>1.9</td>
<td>5.2</td>
</tr>
<tr>
<td>PA9T</td>
<td>92</td>
<td>–</td>
<td>20</td>
<td>120</td>
<td>2.6</td>
<td>4.9</td>
</tr>
</tbody>
</table>
are reported in Table 4. The relative intensity is a ratio of integral shadow area among them. The weight of each sample used in the analysis is 0.1, 0.2, 0.5 and 1 mg. Four parallel experiments were carried out for each sample with different sample weight, and no changes in relative intensity of pyrolysis product were observed. The resulting value was the average of four parallel experiments.

### Table 4. Analysis results of PA10N by Py-GC/MS

<table>
<thead>
<tr>
<th>No.</th>
<th>Tentative compounds</th>
<th>Molecular weight</th>
<th>Retention time [min]</th>
<th>Formula</th>
<th>Relative intensity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carbon dioxide</td>
<td>44</td>
<td>1.57</td>
<td>CO₂</td>
<td>16.39</td>
</tr>
<tr>
<td>2</td>
<td>Pentanenitrile</td>
<td>83</td>
<td>1.65</td>
<td>C₅H₉N</td>
<td>3.47</td>
</tr>
<tr>
<td>3</td>
<td>1-Pentene</td>
<td>70</td>
<td>1.77</td>
<td>C₅H₁₀</td>
<td>2.95</td>
</tr>
<tr>
<td>4</td>
<td>1-Hexene</td>
<td>84</td>
<td>2.06</td>
<td>C₆H₁₂</td>
<td>6.27</td>
</tr>
<tr>
<td>5</td>
<td>1-Heptene</td>
<td>98</td>
<td>2.77</td>
<td>C₇H₁₄</td>
<td>2.66</td>
</tr>
<tr>
<td>6</td>
<td>Heptane</td>
<td>100</td>
<td>2.89</td>
<td>C₇H₁₆</td>
<td>2.81</td>
</tr>
<tr>
<td>7</td>
<td>1-Octene</td>
<td>112</td>
<td>4.21</td>
<td>C₈H₁₆</td>
<td>2.15</td>
</tr>
<tr>
<td>8</td>
<td>Octane</td>
<td>114</td>
<td>4.42</td>
<td>C₈H₁₈</td>
<td>2.14</td>
</tr>
<tr>
<td>9</td>
<td>1,8-Nonadiene</td>
<td>124</td>
<td>5.86</td>
<td>C₉H₁₈</td>
<td>2.57</td>
</tr>
<tr>
<td>10</td>
<td>1-Nonene</td>
<td>126</td>
<td>6.09</td>
<td>C₉H₁₈</td>
<td>3.07</td>
</tr>
<tr>
<td>11</td>
<td>Nonane</td>
<td>128</td>
<td>7.42</td>
<td>C₁₀H₂₀</td>
<td>3.29</td>
</tr>
<tr>
<td>12</td>
<td>1-Decene</td>
<td>140</td>
<td>7.98</td>
<td>C₁₀H₂₀</td>
<td>2.20</td>
</tr>
<tr>
<td>13</td>
<td>Decane</td>
<td>142</td>
<td>9.29</td>
<td>C₁₀H₂₂</td>
<td>2.75</td>
</tr>
<tr>
<td>14</td>
<td>Octanenitrile</td>
<td>125</td>
<td>10.71</td>
<td>C₁₀H₁₅N</td>
<td>2.49</td>
</tr>
<tr>
<td>15</td>
<td>Naphthalene</td>
<td>128</td>
<td>10.88</td>
<td>C₁₀H₈</td>
<td>19.62</td>
</tr>
<tr>
<td>16</td>
<td>Decanenitrile</td>
<td>153</td>
<td>12.26</td>
<td>C₁₀H₁₅N</td>
<td>2.56</td>
</tr>
<tr>
<td>17</td>
<td>1-Methylnaphthalene</td>
<td>142</td>
<td>12.57</td>
<td>C₁₁H₁₈</td>
<td>4.57</td>
</tr>
<tr>
<td>18</td>
<td>2,6-Dimethylnaphthalene</td>
<td>156</td>
<td>14.10</td>
<td>C₁₂H₁₈</td>
<td>2.92</td>
</tr>
<tr>
<td>19</td>
<td>2-Vinylnaphthalene</td>
<td>154</td>
<td>14.38</td>
<td>C₁₂H₁₈</td>
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</tr>
<tr>
<td>20</td>
<td>1-Naphthalenecarbonitrile</td>
<td>153</td>
<td>15.28</td>
<td>C₁₁H₁₇N</td>
<td>9.57</td>
</tr>
<tr>
<td>21</td>
<td>2,6-Naphthalenedicarbonitrile</td>
<td>178</td>
<td>19.77</td>
<td>C₁₂H₁₇N₂</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Figure 7. Py-GC/MS chromatogram of PA10N at 700°C

3.5. **The inferred thermal decomposition processes**

The bond strength of C–N is 305 kJ·mol⁻¹, which is less than the value of 346 kJ·mol⁻¹ for a C–C bond [38], so many evidences suggested that the primary polyamide chain scission occurs either at the peptide C–N or at adjacent bonds [39]. Homolytic scission, hydrolysis, intramolecular C–H transfer and
cis-elimination (a particular case of C–H transfer) are all suggested as possible primary chains-scission mechanisms [39]. Naphthalene rings are stabilized in the process of pyrolysis of PA10N, the cleavage of the C–N amide bond and the homolytic scission of C_naphthalene–C_amido bond were the primary pyrolysis pathways. According to the pyrolysis products, the possible pyrolysis pathways are illustrated in Figure 8–11 (Marked as route A, B, C and D respectively). The four possible routes happen randomly at the same time.

Route A indicated that PA10N was decomposed via a β-CH hydrogen transfer process with formation of amide and olefin end-groups [40]. The products containing amide end-groups could further undergo thermal decompositions and produce the compounds with nitrile end-group, such as 2,6-naphthalene dicarbonitrile.

Route B showed homolytic cleavage occurred at one side of the C_naphthalene–C_amido bonds which form naphthalene amide and alkylamide radicals. Then, naphthalene amide radical reacted with hydrogen radical, alkyl radical and eliminating water. Finally, 1-naphthalene carbonitrile was obtained.

Route C presented the bonds cleavage occurred at the two sides of C_naphthalene–C_amido bonds forming the compounds containing naphthalene and alkylamide radicals. Naphthalene radical reacted with hydrogen radical, alkyl radical, and ethene radical, and then formatted naphthalene compounds.

Route D presented the amide bond leaded to hydrolysis in the presence of water which formed the –NH₂ and –COOH end-groups [41], –COOH end-groups were further degraded to form CO₂.

Alkenes and diolefines are easy to take part in homolytic radical scission of the C–C bonds at high temperature to form smaller fragments. These fragments might react with benzene and benzonitrile free radical, so the alkenes and diolefines were not detected in the pyrolysis products.

4. Conclusions

PA10N was prepared from the reaction of 2,6-naphthalene dicarboxylic acid and 1,10-decanediamine. The characterization of FT-IR, ¹H-NMR
spectroscopy and elemental analysis confirmed that the obtained product has the expected chemical structure and composition. \( T_m, T_g \) and \( T_d \) of PA10N are 320, 144 and 495°C, respectively. The intrinsic viscosity and inherent viscosity of PA10N are 1.85 dl·g⁻¹ and about 1.78 dl·g⁻², respectively. The results show that PA10N has better thermal stability than aliphatic polyamides. Py-GC/MS was used to study the pyrolysis products and thermal decomposition mechanisms of PA10N. The pyrolysis products of PA10N were mainly composed of forty-two kinds of compounds, and the major products of PA10N were mainly composed of aromatic and aliphatic polyamides. Py-GC/MS was used to study the pyrolysis products and thermal decomposition processes, main chain random scission and hydrolytic decomposition. Compared with PA9T, the low cost and good performance of PA10N demonstrate it can be a promising, heat-resisting and well processable engineering plastic and it can be a candidate nylon for the industrial production.

References


