Flow and Thermal Characteristics of Cationic Dyeable Nylon 6/Cationic Dyeable Poly(ethylene terephthalate) Polyblended Polymers and Filaments

Yao-Chi Shu,[1] Kai-Jen Hsiao[2]

[1]Department of Polymer Materials, Vanung University, Chungli City, Taiwan 320, Republic of China
[2]Fiber Technology Division, MCL/ITRI, Hsinchu, Taiwan 300, Republic of China

ABSTRACT: Cationic dyeable nylon 6 (CD-N6) and cationic dyeable poly(ethylene terephthalate) (CD-PET) polymers were extruded (in the proportions of 75/25, 50/50, 25/75) from one melt twin-screw extruders to prepare three CD-N6/CD-PET polyblended polymers and then spin filaments. The molar ratio of 5-sodium sulfonate dimethyl isophthalate (5-SSDMI) for CD-N6 and CD-PET polymers were 2.01% and 2.04%, respectively. This study investigated the flow and thermal characteristics of CD-N6/CD-PET polyblended polymers and filaments using gel permeation chromatography (GPC), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), potentiometer, a rheometer, the density gradient, wide-angle X-ray diffraction (WAXD), and extension stress–strain measurement. Flow behavior of CD-N6/CD-PET polyblended polymers exhibited negative-deviation blends (NDB), and the 50/50 blend of CD-N6/CD-PET showed a minimum value of the melt viscosity. Experimental results of the DSC indicated CD-N6 and CD-PET molecules formed an immiscible system. Particularly, a double endothermic peak was observed from CD-N6, CD-PET and their polyblended filaments. The tenacity of CD-N6/CD-PET polyblended filaments decreased initially and then increased as the CD-PET content increased. Crystallinities and densities of CD-N6/CD-PET polyblended filaments were the linear relation with the blend ratio. The miscibility parameter µ values of CD-N6/CD-PET all samples were less than zero. It indicated the electrostatic repulsion was evident between CD-N6 and CD-PET molecules. From the experimental data, the CD-N6 and CD-PET polymers were identified to be immiscible. © 2006 Wiley Periodicals, Inc. J Appl Polym Sci 103: 2049–2056, 2007

Key words: CD-N6; polyblended filament; NDB; tenacity; CD-PET

INTRODUCTION

The applications of polyblends are important developments of the plastics and synthetic fiber industries. Polyblends are mixtures of two or more polymers that can either mix completely on a molecular scale or form a two-phase structure. Polyblends can exhibit new combinations of properties that depend on the properties of the components and strongly upon the morphology of the blended materials. The morphology resulting from a blending process depends mainly upon the rheological and interfacial properties of the molten components, the blending conditions, and the weight ratio of the polymers blended.[1–5] Polyblends can be characterized by their phase behavior as being either miscible or immiscible. The thermal, mechanical, and rheological properties of a polyblend depend strongly on its state of miscibility.[6] Among the very large number of polymer blends studies, the combination of a partially crystalline and an amorphous polymer is often studied, because their properties are often complementary. Binary blends of two crystalline polymers are, however, less frequent, the main reason being probably the complications that the interactions among the four phases of the blends may involve. Two of the most attractive semicrystalline polymers are nylon 6 (N6) and poly(ethylene terephthalate) (PET). Despite their common semicrystalline nature, they have contrasting properties, as water sorption is very large in N6 and low in PET, and deflection temperature is low in N6 and high in PET.

Samios and Kalfoglou reported that the binary N6/PET blended showed two amorphous phases when observed by dynamic mechanical analysis.[7] Recently, Retolaza et al. studied a reactive processing compatibilization of direct injection-molded N6/PET blends.[8] They found that homogeneous N6/PET blends were obtained by direct injection molded method, with a large interface area at all blend compositions. The blends were composed of a probably pure N6 amorphous phase, and a PET phase that had small amounts of N6 in the N6-rich blends, and was apparently pure in PET-rich blends. The mechanical properties of the blends were advantageous. The ductile nature of both the 75/25 and 25/75

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TABLE I
Characteristics of CD-N6 and CD-PET Polymers

Chip	R.V.[a]	I.V. (dL/g)[b]	5-SSDMI (mol %)	$\overline{M}_w$ (g/mol)	$\overline{M}_w/\overline{M}_n$[c]	R—COOH (meq/kg)	T_m (°C)	T_d (°C)[d]
CD-N6	2.38	–	2.01	28,000	1.97	43.5	207.8	311
CD-PET	–	0.49	2.04	31,000	2.02	46.1	245.2	384

[a] Relative viscosity (R.V.) of CD-N6 polymer was obtained by a solution of 1.0 g/100 mL in 96% H_2SO_4 at 25°C.
[b] Intrinsic viscosity (I.V.) of CD-PET polymer was obtained by a mixed solution of 0.5 g/100ml in phenol/tetrachloroethane (60/40) at 30°C.
[c] Molecular weight distribution (MWD) of polymer. MWDs of CD-N6 and CD-PET polymers were measured in HFIP (1,1,1,3,3,3 hexafluoro-2-propanol) solvent system.
[d] Degradation temperature of polymer.

blends was maintained after annealing at 100°C for half an hour, showing the thermal stability of the obtained morphologies.

Choi et al. studied the effects of interface on the dynamic mechanical properties of N6/PET bicomponent fibers.[9] They found that the storage moduli of N6/PET bicomponent fibers are higher, and the maximum values of loss tangent are low than the values calculated by the Takayanagi parallel model with perfect adhesion assumption. The side-by-side type of N6/PET bicomponent fibers with the smallest interfacial area has the lowest maximum loss tangent and the highest crystallinity among the three types (side-by-side, alternating-radial and island-sea types) of bicomponent fibers at the same composition ratios. With the decrease in interfacial area, the maximum loss tangent decreases and the crystallinity increase at the same composition ratios. It can be concluded that the crystallinity of PET component in the bicomponent fibers is improved, and the degree of improvement is dependent on the interfacial area. Thus, the interface plays an important role in the determination of the dynamic mechanical properties of the bicomponent fibers.

N6 has also been blended with poly(butylene terephthalate) (PBT). N6/PBT blends showed two glass transition temperature.[10] These blends were modified with either an epoxy resin, 4,4′-biphenol, amorphous polyamide, or phenoxy as compatibilizers. When epoxy was used, the copolymers formed hindered the crystallization of both N6 and PBT. Both the impact strength and the ductility increased very large while the modulus did not change.[11] The addition of 4,4′-biphenol to a 40/60 N6/PBT blend led to reactions that increased the tensile and flexural strength, as well as the flexural modulus, and improved the compatibility.[12] The addition of amorphous polyamide to a 30/70 N6/PBT blend led to a domain structure finer than that of the binary blend. The addition of 3 wt % amorphous polyamide led to a higher tensile modulus value, which decreased with increasing amorphous polyamide content.[13] The

addition of phenoxy to a 70/30 N6/PBT blend also led to reactions that increased tensile and impact properties and stabilized the morphology to annealing.[14] Keven and coworkers studied the physical properties of polyblends of N6 with cationic dyeable poly(ethylene terephthalate) (CD-PET). They found that a higher 5-sodium sulfonate dimethyl isophthalate (5-SSDMI; —SO_3Na groups) content in CD-PET polymer could really increase the interfacial adhesion of N6 with CD-PET molecules.[15]

In this study, cationic dyeable nylon 6 (CD-N6) possesses both 5-SSDMI and amide (—NHCO— groups) functional groups. Furthermore, CD-PET also possesses 5-SSDMI functional groups. The interfacial adhesion plays a critical role for CD-N6 and CD-PET polyblended polymers. This study thoroughly investigated the flow behavior, thermal behavior, crystallinity, tenacity, density, and miscibility parameter μ of CD-N6/CD-PET polyblended polymers and filaments.

EXPERIMENTAL

Materials and melting spinning

CD-N6 chips were obtained from the Material and Chemical Research Laboratories/Industrial technology research Institute (MCL/ITRI) in Taiwan (Hsinchu). The CD-N6 chip is a bright grade, crystallized chip, with a normal relative viscosity (R.V.) of 2.38 (at 96% H_2SO_4, 1.0 g/100 mL and 25°C conditions). CD-PET pellets were also produced from the MCL/ITRI in Taiwan (Hsinchu). The CD-PET polymer, a white pellet with an average diameter size of 3–5 mm and a bright grade, is specially designed for the fiber spinning process. Its intrinsic viscosity (I.V.) is 0.49 dL/g. Table I presents the synthetic characteristics of CD-N6 and CD-PET polymers.

CD-N6 and CD-PET polymers were extruded (in the proportions of 75/25, 50/50, 25/75) from one melt twin-screw extruders to prepare three CD-N6/CD-PET polyblended polymers and then spin fila-

TABLE II
Compositions of the CD-N6/CD-PET Polyblended
Filaments

Polymer code	CD-N6/CD-PET blend ratio
Sample 1	100/0
Sample 2	75/25
Sample 3	50/50
Sample 4	25/75
Sample 5	0/100

ments. Before spinning, CD-N6 was dried for 24 h at 105°C, and CD-PET was dried for 4 h (120°C)/ 8 h(150°C). Melt spinning was carried out using a capillary rheometer. Undrawn yarns (UDY) were extruded at 285°C, and at a constant wind speed of 500 m/min were taken up for all samples. Then, UDY were drawn three times to produce fully drawn yarns (FDY) by a drawn-winder machine. The draw temperature and take-up speed were 110°C and 400 m/min, respectively. The specification of FDY yarn is 30 days/10 f (3 dpf). Table II shows the compositions of the CD-N6/CD-PET polyblended filaments.

Measurements

Gel permeation chromatograph (GPC) data were measured from a Waters Model 510 Type. Molecular weight distributions (MWDs) of CD-N6 and CD-PET polymers were measured in HFIP (1,1,1,3,3,3 hexa-fluoro-2-propanol) solvent system. Relative viscosity (R.V.) of CD-N6 was obtained by a solution of 1.0 g/ 100 mL in 96% H_2SO_4 at 25°C.[16] Intrinsic viscosity (I.V.) of CD-PET polymer was obtained by a mixed solution of 0.5 g/100 mL in phenol/tetrachloro-ethane (60/40) at 30°C.[17] Wide-angle X-ray diffraction (WAXD) studies of samples were conducted using a MAC Science X-ray unit operated at 35 kV and 20 mA. X-ray diffraction was then used with Cu Kα radiation and scan from 5 to 40° (2θ) with a scan speed of 4°/min.[18–20] Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) measurements of samples were made using a Perkin-Elmer Pyrix-1. The heating rate of TGA measurement was 10°C/min from 30°C to 600°C. Both the heating rate and cooling rate were 10°C/min from 30°C to 300°C, and the temperature was hold for 3 min at 300°C for DSC measurement. The crystallinity of the DSC method was calculated from the following equation: crystallinity (%) = $\Delta H_m / \Delta H_m^0 \times 100$ (%), where ΔH_m and ΔH_m^0 are the heat of fusion in J/g of repeating unit for the sample and 100% crystallinity, respectively. ΔH_m^0 of pure nylon 6 (/and pure PET) is equal to 230.1 (/and 140.1) J/g.[21] The densities of samples were determined using the density gradient method. A mixture of n-heptane and carbon tetra-chloride was used for the purpose. Densities of n-

heptane and carbon tetrachloride solvents were 0.684 g/cm³ and 1.595 g/cm³, respectively. The scale of density gradient method was prepared from 1.100 g/cm³ to 1.500 g/cm³. The melt viscosities of samples were measured by a capillary rheometer, and the length-to-diameter ratio of the capillary is 30. All stress–strain data of samples were obtained on a Zwick 1511 type Instron instrument at an extension rate of 200 mm/min. For the study of miscibility parameter μ value, the technique of dilute solution viscometry (DSV) was adopted. The intrinsic viscosity [η] of sample was measured using a Ubbelodhe capillary viscometer in HFIP solvent at 25°C.

RESULTS AND DISCUSSION

Analysis of flow behavior

Figure 1 presents capillary rheological data at temperatures and shear rates applicable to the spinning process. It indicates the melt viscosities of CD-N6, CD-PET, and CD-N6/CD-PET polyblended polymers at 260°C versus shear rate. From 1000 to 20,000 s⁻¹, five polymers exhibited pseudoplastic flow behavior. This trend was independent of the blend ratio. The rheological curves showed that the melt viscosity of the CD-PET polymer was higher than that of the CD-N6 polymer over the entire shear rate range. The melt viscosities of CD-N6, CD-PET and their blends followed the order CD-PET > CD-N6/CD-PET (25/75) > CD-N6 > CD-N6/CD-PET (75/25) > CD-N6/CD-PET (50/50).
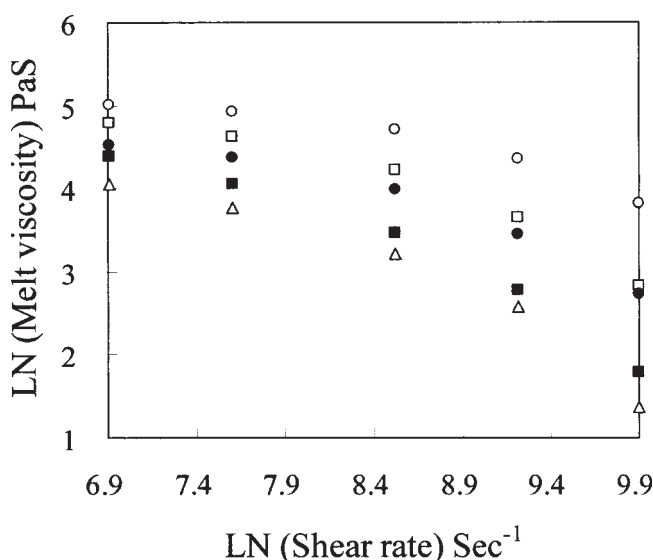

Figure 1 Relation between the melt viscosities and shear rate at for CD-N6, CD-PET, and CD-N6/CD-PET poly-blended polymers at 260°C. (●) CD-N6; (■) CD-N6/CD-PET (75/25); (△) CD-N6/CD-PET (50/50); (□) CD-N6/CD-PET (25/75); (○) CD-PET.
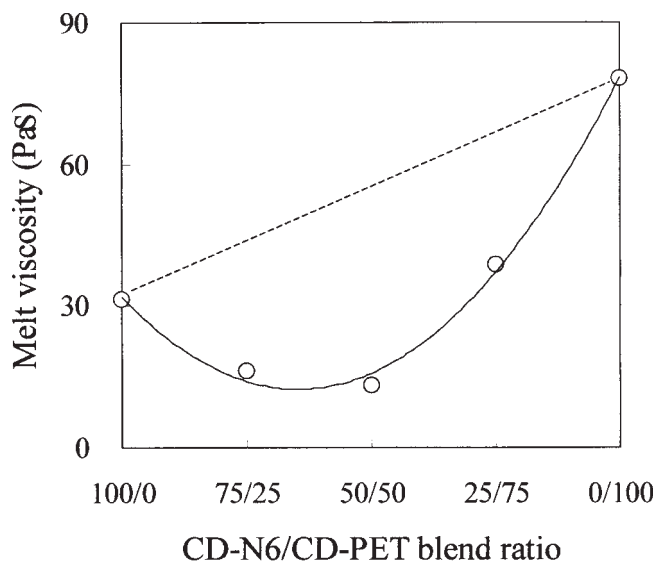
Figure 2 Relation between the melt viscosities and blend ratio for CD-N6/CD-PET polyblended polymers at 260°C/10,000 s^{-1}. --------: Calculated value; ○: experimental value.

Figure 2 shows the melt viscosities of CD-N6/CD-PET polyblended polymers exhibited negative-deviation blends (NDB).[22–26] Notably, the 50/50 blend of CD-N6/CD-PET showed a minimum value of the melt viscosity than that predicted by the additivity rule at 260°C and 10,000 s^{-1}. The rheological results indicated a poor interfacial adhesion between the CD-N6 and CD-PET polymers.

Analysis of thermal behavior

Table III and Figure 3 displays the thermal properties of CD-N6, CD-PET, and three CD-N6/CD-PET polyblended filaments. In the DSC heating process, the endothermic peaks of the CD-N6 and CD-PET filaments occurred at 210.2°C and 246.6°C, respectively. The endothermic peak (T_m) is due to the melting of the sample. The T_m of the CD-N6/or CD-PET filament is compared with that of the CD-N6/or CD-PET chip (for comparison, see Tables I and III). Because of the influences of the orientation and crystallization, the T_m of the CD-N6/or CD-PET filament

was obviously higher than that of the CD-N6/or CD-PET chip. The T_m of the CD-N6 filament was lower than that of the CD-PET approximated 36.4°C. The DSC data displayed a clearly melting endothermic peak, indicating that the CD-N6 and CD-PET filaments were originally crystalline. A double melting endothermic peak was observed from both CD-N6 and CD-PET filaments. Interestingly, large —SO$_3$Na side groups in CD-N6 and CD-PET polymers prevented the chain molecules from tightly coagulating and obstructed the formation of larger crystals. Owing to the effect of a —SO$_3$Na side group on polymer, thermal behavior of the CD-N6/CD-PET ployblended filaments resembled that of the CD-N6 and CD-PET filaments. The experimental phenomenon resembled the studies of Tsen et al. for the modified polyester hollow fiber and Pal et al. for cationic dyeable polyester yarns. Tsen et al. used 3 mol % of sodium-5-sulfoisophthalate (SIPM) to modify the component of the polyester hollow fiber.[27] In addition, the cationic dyeable polyester yarns of Pal et al. were produced through melt cationic dyeable chips having 2 mol % of sodium salt of dimethyl ester of 5-sulfoisophthalic acid (DMS).[28]

In the DSC cooling process, the exothermic peaks (the T_{cc} points) of the CD-N6 and CD-PET filaments occurred at 152.2°C and 197.3°C, respectively. The exothermic peak was due to the recrystallization behavior of the melting polymer. Clearly, the half-time of the recrystallization for CD-N6 filament was shorter than that of the CD-PET filament, implying that the recrystallization rate of the CD-N6 filament was faster than that of the CD-PET filament. For all CD-N6/CD-PET polyblended filaments, T_m of CD-N6 segments (T_{m1}) nearly did not shift and appeared around 211–213°C. Additionally, T_m of CD-PET molecules (T_{m2}) also did not clearly change and appeared at 242–245°C. In other words, the T_m change was independent of the blend ratio.

Figure 4 displays the linear variations of the heat fusion (ΔH_m) with the blend ratio of CD-N6/CD-PET polyblended filaments. ΔH_m of CD-N6 molecules (ΔH_{m1}) proportionally declined with an increasing CD-PET content. Meanwhile, ΔH_m of CD-

TABLE III
Thermal Properties of CD-N6, CD-PET, and CD-N6/CD-PET Polyblended Filaments

| | Heating process | | | | Cooling process | | | | | |
| | CD-N6 | | CD-PET | | CD-N6 | | | CD-PET | | |
Polymer code	T_{m1} (°C)	ΔH_{m1} (J/g)	T_{m2} (°C)	ΔH_{m2} (J/g)	T_{cc1} (°C)	ΔH_{cc1} (J/g)	Half-time (s)	T_{cc2} (°C)	ΔH_{cc2} (J/g)	Half-time (s)
Sample 1	210.2	57.8	–	–	152.2	53.1	82.6	–	–	–
Sample 2	211.3	43.4	242.8	13.2	153.6	39.8	–	192.6	10.1	–
Sample 3	212.4	28.9	243.5	26.4	155.3	26.6	–	194.3	20.1	–
Sample 4	213.1	14.5	245.1	39.5	156.7	13.3	–	195.5	30.2	–
Sample 5	–	–	246.6	52.7	–	–	–	197.3	40.2	92.5
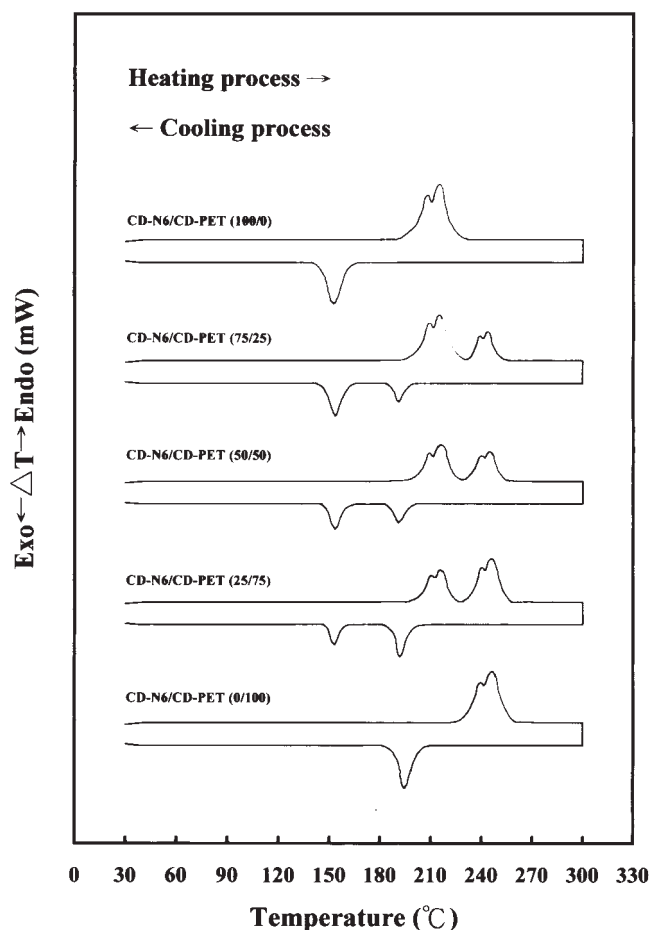
Figure 3 DSC curves of CD-N6, CD-PET, and CD-N6/CD-PET polyblended filaments.

Figure 4 Relation between ΔH_m and blend ratio of CD-N6/CD-PET polyblended filaments. (○) CD-N6; (●) CD-PET.

linity. Table IV reveals the crystallinities of CD-N6, CD-PET, and CD-N6/CD-PET polyblended filaments. The heat of fusion of melting was used to calculate crystallinity. Values of 230.1 and 140.1 J/g corresponding to 100% crystallinity were used for pure N6 and pure PET, respectively. The crystallinities of CD-N6 and CD-PET filaments were 25.1% and 37.6%, respectively. The crystallinity of CD-N6 filament was smaller than 12.5% that of CD-PET filament. After blending, the total crystallinity of CD-N6/CD-PET polyblended filament increased with the proportion of CD-PET increased. Crystallinities of WAXD method were slightly lower than those of

PET molecules (ΔH_{m2}) proportionally increased with an increasing CD-PET content. For all CD-N6/CD-PET polyblended filaments, the T_{cc} point of CD-N6 molecules (T_{cc1}) also nearly did not change and appeared around 153–157°C. The T_{cc} point of CD-PET molecules (T_{cc2}) was observed around 192–196°C. Figure 5 also shows the linear variations of the recrystallization heat of the exothermic peak (ΔH_{cc}) with the blend ratios of CD-N6/CD-PET polyblended filaments. ΔH_{cc} of CD-N6 molecules (ΔH_{cc1}) proportionally decreased with an increasing CD-PET content. Meanwhile, ΔH_{cc} of CD-PET molecules (ΔH_{cc2}) proportionally increased with an increasing CD-PET content. The DSC experimental results indicated that CD-N6 segments and CD-PET molecules were identified to be immiscible system.

Analysis of crystallinity

The heat of fusion was used to indicate the crystalline fraction of the material. A higher value of heat of fusion was expected to resort in a higher crystal-
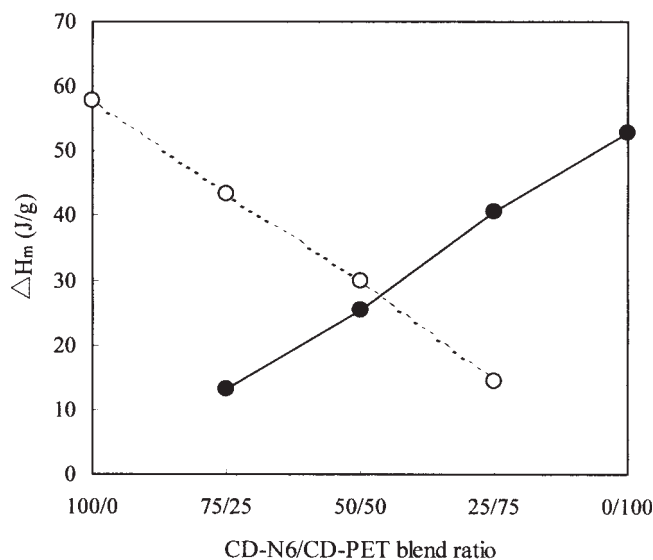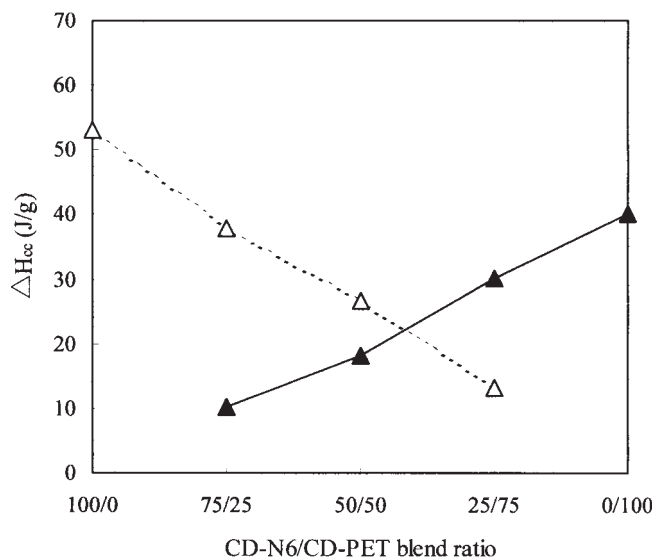

Figure 5 Relation between ΔH_{cc} and blend ratio of CD-N6/CD-PET polyblended filaments. (△) CD-N6; (▲) CD-PET.

TABLE IV
Crystallinities of CD-N6, CD-PET, and CD-N6/CD-PET Polyblended Filaments

| Polymer code | DSC method | | | | | WAXD method |
| | CD-N6 part | | CD-PET part | | | |
	ΔH_{m1} (J/g)	X_c (%) of CD-N6 part	ΔH_{m2} (J/g)	X_c (%) of CD-PET	Total X_c (%) of filament	Total X_c (%) of filament
Sample 1	57.8	25.1	–	–	25.1	23.2
Sample 2	43.4	18.8	13.2	9.4	28.2	27.8
Sample 3	28.9	12.6	26.4	18.8	31.4	29.7
Sample 4	14.5	6.3	39.5	28.2	34.5	31.2
Sample 5	–	–	52.7	37.6	37.6	35.3

DSC method. Figure 6 displays the relation between the crystallinities and the blend ratios of CD-N6/CD-PET polyblended filaments. For all CD-N6/CD-PET polyblended filaments, the experimental crystallinities agree fairly well with the calculated values. It indicated that CD-N6 and CD-PET formed an immiscible system.

Tenacity analysis

Figure 7 shows the relation between the tenacities and the blend ratios of CD-N6/CD-PET polyblended filaments. The tenacities of CD-N6/CD-PET polyblended filaments declined initially and then increased with the proportion of CD-PET. Obviously, the 50/50 CD-N6/CD-PET blend displayed a minimum value. The poor interfacial interactions between CD-N6 and CD-PET indicated poor mechanical properties. The tendency agreed with the flow behavior, and the 50/50 CD-N6/CD-PET blend displayed a minimum tenacity value.

Density analysis

Figure 8 displays the relation between the densities and the blend ratios of CD-N6/CD-PET polyblended filaments. For all CD-N6/CD-PET polyblended filaments, the experimental densities agree fairly well with the calculated values. This indicated that CD-N6 and CD-PET formed basically an immiscible system. The experimental results for the densities were consistent with the thermal behavior, crystallinity, and tenacity of the CD-N6/CD-PET polyblended filaments.

Miscibility parameter analysis

Based on Chee's research,[29] a modified approach has been suggested to determine miscibility parameter μ of stiff polymer/stiff polymer by viscometry in aqueous solution as follows[30]:

$$\mu = \{(b - b_{22})/([\eta] - [\eta]_2) - (b_{33} - b_{22})/([\eta]_3 - [\eta]_2)\}/2([\eta]_3 - [\eta]) \quad (1)$$
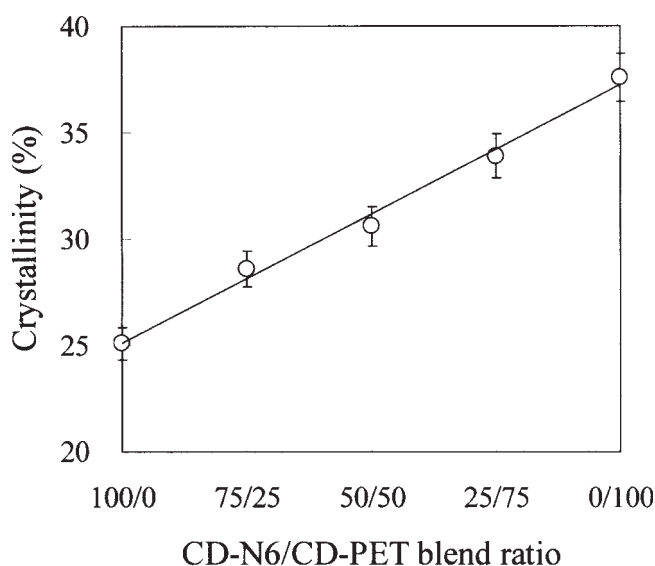

Figure 6 Relation between the crystallinities and blend ratio of CD-N6/CD-PET polyblended filaments.
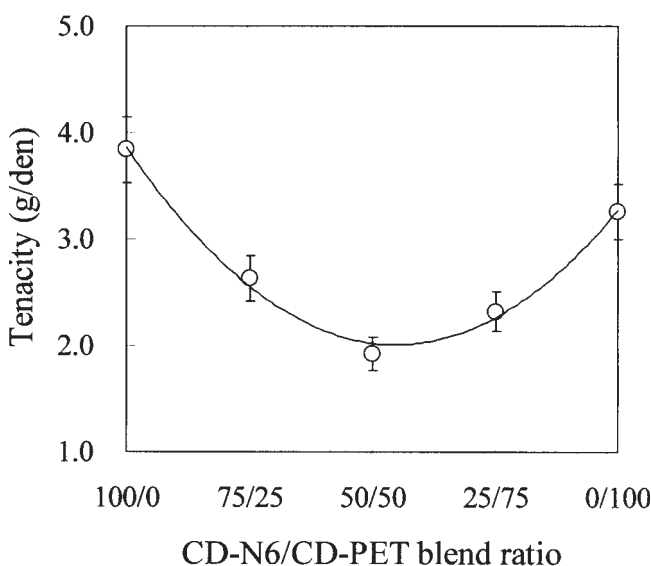

Figure 7 Relation between the tenacities and blend ratio of CD-N6/CD-PET polyblended filaments.
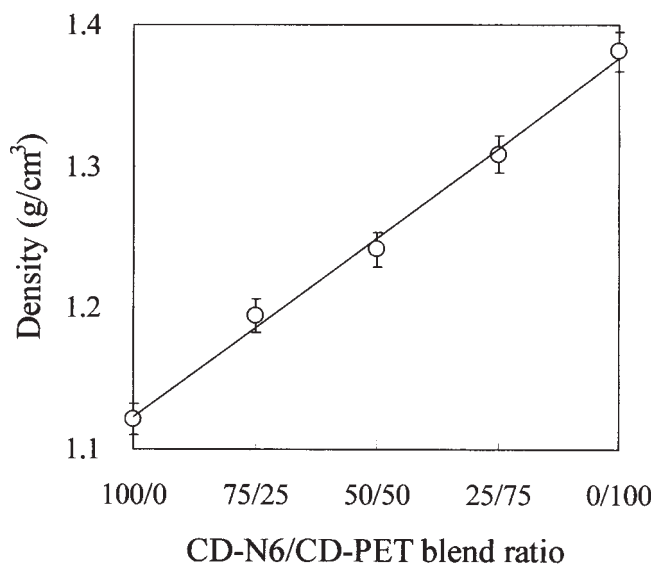
Figure 8 Relation between the densities and blend ratio of CD-N6/CD-PET polyblended filaments.

Figure 9 Relation between the miscibility parameter μ value and blend ratio of CD-N6/CD-PET polyblended filaments.

where $[\eta]_2$, $[\eta]_3$, and $[\eta]$ represent the intrinsic viscosity of polymer 2 (CD-N6) and 3 (CD-PET), and the mixture of the two polymers 2 and 3 (CD-N6/CD-PET blends), respectively, and are estimated from Huggins and Kraemer plots. The c is the concentration of solution. The coefficients b, b_{22}, and b_{33} are obtained from plots $\{(\eta_{sp}/c) - [\eta]\}/c$ vs. c for the mixture of two polymers, polymer 2 and polymer 3, respectively, which are based on the following equation:

$$\left(\eta_{sp}/c - [\eta]\right)/c = b + Ac \tag{2}$$

The miscibility parameter μ can predict miscible and immiscibility blends. When μ is more than zero, the blend of two polymers is miscible. The $[\eta]$ values obtained from extrapolation of the curves of η_{sp}/c vs. c and η_r/c vs. c plots are listed in Table V. The μ values of CD-N6/CD-PET all samples were less than zero. Figure 9 shows the relation between the miscibility parameter μ value and blend ratio of

CD-N6/CD-PET polyblended filaments indicated that the blends of CD-N6/CD-PET were phase separation and hence immiscible. The electrostatic repulsion was obvious between CD-N6 and CD-PET molecules. It indicated that CD-N6 and CD-PET polymers were identified to be immiscible.

CONCLUSIONS

CD-N6 polymer possesses both amide and 5-SSDMI functional groups. Furthermore, CD-PET molecules also possess 5-SSDMI functional groups. The interfacial adhesion plays a critical role for CD-N6 and CD-PET polyblended polymers. Rheological behavior of CD-N6/CD-PET polyblended polymers exhibited negative-deviation blends (NDB). The 50/50 blend of CD-N6/CD-PET showed a minimum value of the melt viscosity than that predicted by the additivity rule. Flow results indicated a poor interfacial adhesion between CD-N6 and CD-PET polymers. The experimental results of the DSC indicated CD-N6 and CD-PET molecules easily formed individual domains. Particularly, a double endothermic peak was observed from CD-N6, CD-PET, and their polyblended filaments. The tenacities of CD-N6/CD-PET polyblended filaments declined initially and then increased with the proportion of CD-PET. Obviously, the 50/50 CD-N6/CD-PET blend displayed a minimum value. The experimental crystallinities and densities agree fairly well with the calculated values. The miscibility parameter μ values of CD-N6/CD-PET all samples were less than zero. From the flow behavior, thermal property, crystallinity, tenacity, density, and the miscibility parameter μ value of poly-

TABLE V
The $[\eta]$, b, and Miscibility Parameter μ of Blend System for CD-N6, CD-PET, and CD-N6/CD-PET Polyblended Filaments

Polymer code	$[\eta]^a \times 10^{-1}$ (dL/g)	$b \times 10^{-4}$ (dL/g)^2	μ
Sample 1	3.55	8.78	–
Sample 2	3.26	6.65	−0.512
Sample 3	3.08	5.41	−0.632
Sample 4	3.87	11.7	−0.498
Sample 5	4.32	13.2	–

^{a} $[\eta]$ was measured using a Ubbelodhe capillary viscometer in HFIP solvent at 25°C.

blended filaments, The CD-N6 and CD-PET polymers were identified to be immiscible.

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