Rheology, Thermal Characteristics, Crystallinity, Tenacity and Density of Cationic Dyeable Polycaproamide/ Cationic Dyeable Poly(trimethylene terephthalate) Polyblended Fibers

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ABSTRACT: Cationic dyeable polycaproamide (CD-PCA) and cationic dyeable poly(trimethylene terephthalate) (CD-PTT) polymers were extruded (in ratios 75/25, 50/50, and 25/75) from one melt twin-screw extruders to prepare three CD-PCA/CD-PTT polyblended polymers and then spin fibers. This work examines the rheology, thermal characteristics, crystallinity, tenacity, density, and miscibility parameter μ value of CD-PCA/CD-PTT polyblended polymers and fibers using gel permeation chromatography, differential scanning calorimetry, thermogravimetric analysis, potentiometer, rheometer, the density gradient analysis, wide-angle X-ray diffraction, and extension stress–strain measurement. The melting behavior of CD-PCA/CD-PTT polyblended polymers revealed negative-deviation blends (NDB). The 50/50 blend of CD-PCA/CD-PTT had the lowest melt viscosity. The experimental DSC results demonstrated that CD-PCA and CD-PTT molecules constituted an immiscible system. In particular, CD-PCA, CD-PTT, and their polyblended fibers yielded a double endothermic peak. The tenacity of CD-PCA/CD-PTT polyblended fibers initially declined and then increased as the CD-PTT content increased. The crystallinities and densities of CD-PCA/CD-PTT polyblended fibers were linearly related to the blend ratio. The values of the miscibility parameter μ for all CD-PCA/CD-PTT samples were under zero, revealing electrostatic repulsion between CD-PCA and CD-PTT molecules. All experimental data supported the immiscibility of CD-PCA/CD-PTT polyblended fibers. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 106: 644–651, 2007

Key words: rheology; thermal characteristics; CD-PCA; CD-PTT; polyblended fiber

INTRODUCTION

Polycaproamide (PCA) is the most important polyamide polymer for fiber manufacturing, because it is relatively inexpensive since the reagent ε-caprolactam, which is required for its polymerization, can be obtained from relatively cheap substrates such as cyclohexane, benzene, and phenol. However, PCA fibers are still more expensive than the other polymer fibers. This high cost can be reduced by the preparation of blends with lower-cost polymers. Blend preparation is broadly considered to be an economically feasible and practical technique for improving the properties or cost-benefit relationships of common polymers to avoid the need to synthesize new polymers.[1] Cationic dyeable polycaproamide (CD-PCA) polymers have been produced at the Material and Chemical Research Laboratories/Industrial Technology Research Institute (MCL/ITRI) in Taiwan. CD-PCA fiber not only has the advantages of

PCA fiber but also can be colored using cationic dyeable dyes. CD-PCA fibers can be utilized in two-tone fabrics.

Poly(ethylene terephthalate) (PET) are still popular materials globally. Although the mechanical properties of PET are sufficiently favorable to warrant its use as fibers, films, and engineering plastics, some difficulties exist in processing PET because of its high melting temperature. Numerous researchers have concentrated on enhancing the processibility of PET with good mechanical properties.[2–8] The diacid group affects the mechanical properties of polyester and its processibility depends on the nature of the diol group. In particular, poly(trimethylene terephthalate) (PTT), synthesized using 1,3-propanediol as a diol, is a highly crystalline polymer. Its melting temperature is lower than that of PET by 25°C. Accordingly, the processibility of PTT exceeds that of PET. Moreover, highly flexible PTT fibers were obtained herein because of its low initial modulus. The elasticity and dyeability of PTT were better than those of PET or poly(butylenes terephthalate) (PBT), enabling the use of PTT in engineering plastics, films, carpets, and clothing materials. Consequently, PTT has been

TABLE I
Characteristics of CD-PCA and CD-PTT Polymers

Chip	RV[a]	IV (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-PCA	2.41	–	1.98	29,000	1.96	41.2	208.6	315
CD-PTT	–	0.76	2.03	23,000	1.91	20.1	225.3	376

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

considered regarded as the most promising replacement of PET in the world. These fibers will undoubtedly become an important new family of fibers. PTT has attracted considerable interest in both the fiber and the textile industries. No pH adjustment, carrier, or high-temperature dyeing machine is required in the disperse dyeing of PTT.[9] Cationic dyeable poly (trimethylene terephthalate) (CD-PTT) polymers have also been successfully produced at the MCL/ITRI in Taiwan. CD-PTT fiber not only offers the advantages of PTT fiber but also can be colored by cationic dyeable dyes. CD-PTT fibers can be also employed in two-tone fabrics.

In a previous investigation, we reported some miscible and immiscible polymer blends. Miscible polymers included PET/CD-PET,[10] PCA/CD-PCA,[11] and PTT/CD-PTT.[12] Immiscible polymers included PCPL/CD-PET,[13] PA 6/m-iPP,[14] PTT/MIPP,[15] CD-PET/m-iPP,[16] and CD-PTT/m-iPP.[17] The polyblended fiber of CD-PCA with CD-PTT is absent from the literature. CD-PCA/CD-PTT polyblended fibers can be adopted in flame fabrics. Several groups have studied the miscibility of polymer blends by measuring the viscosity of the corresponding ternary (polymer–polymer–solvent) systems.[18–22] The miscibility behavior of polystyrene (PS)/poly(vinyl chloride) (PVC), PS/poly(vinyl acetate) (PVA_C), PS/vinyl chloride–vinyl acetate copolymer (VCVA_C), and PVC/poly(n-butyl methacrylate) (PBMA) blends has been successfully examined using dilute solution viscometry (DSV).[23] The miscibility behavior of CD-PCA/CD-PTT polyblended fibers will be checked using DSV.

In this work, CD-PCA polymer has both amide (—NHCO— groups) and 5-sodium sulfonate dimethyl isophthalate (5-SSDMI; —SO₃Na groups) functional groups. CD-PTT molecules also have 5-SSDMI functional groups. Interfacial adhesion is critical in CD-PCA/CD-PTT polyblended fibers. Good interfacial interaction is expected between the CD-PCA polymer and CD-PTT molecular chains. This study thoroughly elucidates the rheology, thermal characteristics, crystallinity, tenacity, density, and miscibility parameter µ value of CD-PCA/CD-PTT polyblended fibers.

EXPERIMENTAL

Materials

CD-PCA chips were obtained from the MCL/ITRI in Taiwan (Hsinchu). The CD-PCA chips were of a bright grade, crystallized, with a normal relative viscosity (RV) of 2.41 (at 96% H_2SO_4, 1.0 g/100 mL, and 25°C conditions). CD-PTT chips were also produced at the MCL/ITRI in Taiwan (Hsinchu). The CD-PTT polymer, in the form of white pellets with a mean diameter of 3–5 mm and of bright grade, was designed especially for the fiber-spinning process. Its intrinsic viscosity (IV) is 0.76 dL/g. Table I presents the synthetic characteristics of CD-PCA and CD-PTT polymers.

Melting spinning

CD-PCA and cationic dyeable poly(ethylene terephthalate) (CD-PTT) polymers were extruded (in ratios of 75/25, 50/50, and 25/75) from a KOBELCO HYPERKTX 30 twin-screw extruder (Kobe, Japan) to prepare three CD-PCA/CD-PTT polyblended polymers and then spin fibers. Prior to spinning, CD-PCA was dried for 24 h at 105°C and CD-PTT was dried for 4 h (120°C)/8 h (150°C). Melt spinning was performed using a capillary rheometer (Tulsa, OK). Undrawn yarns (UDY yarns) were extruded at 260°C, and, at a constant wind speed of 500 m/min, were taken up for all samples. Then, the UDY yarns were drawn three times to form fully drawn yarns (FDY yarns) by a drawn-winder machine. The drawing temperature and take-up speed were 120°C and 500 m/min, respectively. The FDY yarn was 30 denier/10 filament (3dpf). Table II presents the compositions of the CD-PCA/CD-PTT polyblended fibers.

Measurements

Gel permeation chromatograph (GPC) data were obtained using a Waters Model 510 Type (Milford, MA). Molecular weight distributions (MWDs) of CD-PCA and CD-PTT polymers were measured in HFIP (1,1,1,3,3,3 hexafluoro-2-propanol) solvent sys-

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

tem. The RV of CD-PCA was obtained using a solution of 1.0 g/100 mL in 96% H_2SO_4 at 25°C.[24] The IV of CD-PTT polymer was determined using a mixed solution of 0.5 g/100 mL in phenol/tetrachloroethane (60/40) at 30°C.[25] Wide-angle X-ray diffraction (WAXD) studies of samples were performed using a MAC Science X-ray unit (Tokyo, Japan) that was operated at 35 kV and 20 mA. X-ray diffraction was then conducted with Cu Kα radiation and scanning from 5°–60° (2θ) at a scan speed of 2°/min.[10,26,27] Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) measurements of samples were made using a Perkin-Elmer Pyrix-1 (Boston, MA). The heating and cooling rates for TGA measurement were 10°C/min between 30 and 600°C. The temperature was held for 3 min at 300°C for DSC measurement. The crystallinity was calculated using the DSC method according to the following equation; crystallinity (%) = $\Delta H_m / \Delta H_m^\circ \times 100\%$, where ΔH_m and ΔH_m° are the heats of fusion in Joules per gram of repeating units for the sample and at 100% crystallinity, respectively. The ΔH_m° of pure PCA and pure PTT are 230.1 and 145.6 J/g, respectively.[28,29] The densities of the samples were determined using the density gradient method. A mixture of n-heptane and carbontetrachloride was used. The densities of n-heptane and carbontetrachloride solvents were 0.684 and 1.595 g/cm^3, respectively. The density gradient method was implemented from 1.100 to 1.500 g/cm^3. The melt viscosities of the samples were measured using a capillary rheometer (Tulsa, OK), and the length (30 mm)-to-diameter (1 mm) ratio of the capillary was 30. All stress–strain data of samples were measured using a Zwick 1511 Instron instrument (Zwick, Bamberg, Germany) with an extension rate of 200 mm/min.

RESULTS AND DISCUSSION

Rheology

Figures 1 and 2 plot capillary flow data at temperatures and shear rates that are appropriate for the spinning process. Figure 1 plots the melt viscosities of CD-PCA and CD-PTT polymers at 260°C as func-
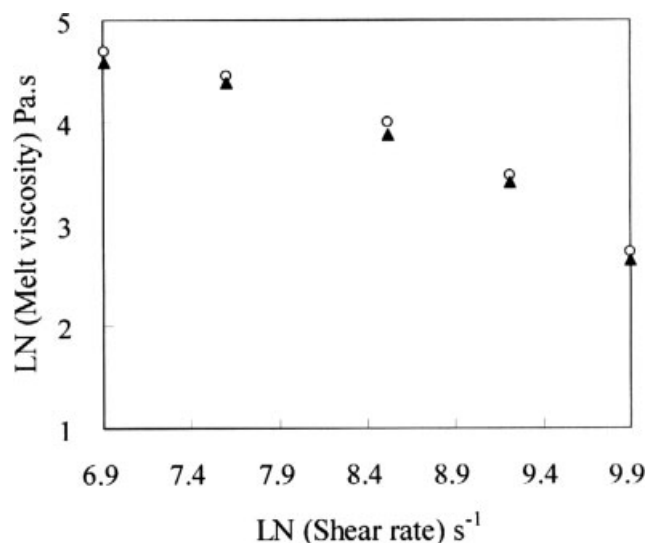
Figure 1 Melt viscosity as a function of shear rate at for CD-PCA and CD-PTT polymers at 260°C. (○) CD-PCA and (▲) CD-PTT.

tions of shear rate. From 1000 to 20000 s^{-1}, the two polymers exhibited pseudoplastic flow behavior. The flow curves demonstrated that the melt viscosity of the CD-PCA polymer exceeded that of the CD-PTT polymer over the entire range of shear rates. Figure 2 plots the melt viscosities of CD-PCA/CD-PTT polyblended polymers at 260°C as functions of shear rate. The melt viscosities of CD-PCA/CD-PTT polyblended polymers also revealed pseudoplastic flow behavior. This trend was independent of the blend ratio.
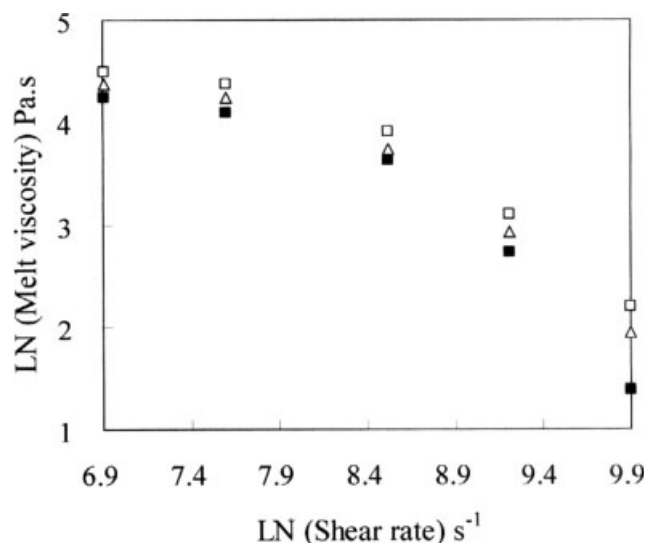
Figure 2 Melt viscosity as a function of shear rate for CD-PCA/CD-PTT polyblended polymers at 260°C. (□) CD-PCA/CD-PTT (75/25), (■) CD-PCA/CD-PTT (50/50), (□) CD-PCA/CD-PTT (25/75).
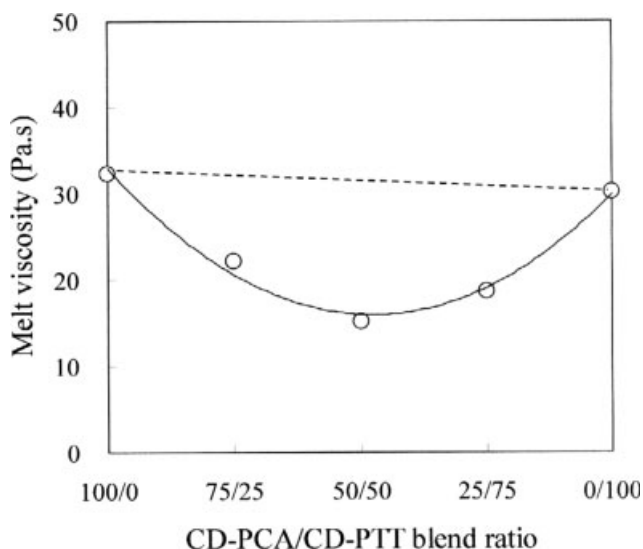
Figure 3 Melt viscosity as a function of blend ratio for CD-PCA/CD-PTT polyblended polymers at 260°C and 10000 s^{-1}. ------, calculated value; ○, experimental value.

Figure 3 plots the melt viscosities of CD-PCA/CD-PTT polyblended polymers exhibited negative-deviation blends (NDB).[30–34] Notably, the 50/50 blend of CD-PCA/CD-PTT had a lower melt viscosity than was predicted by the additivity rule at 260°C and 10000 s^{-1}. The melting results indicated poor interfacial adhesion between the CD-PCA and CD-PTT polymers. The melt viscosities of CD-PCA, CD-PTT and their blends followed the order CD-PCA > CD-PTT > CD-PCA/CD-PTT (75/25) > CD-PCA/CD-PTT (25/75) > CD-PCA/CD-PTT (50/50).

Thermal characteristics

Table III and Figure 4 show the thermal characteristics of CD-PCA, CD-PTT, and three CD-PCA/CD-PTT polyblendted fibers. In the DSC heating process, the endothermic peaks of the CD-PCA and CD-PTT fibers were obtained at 211.2 and 227.7°C, respectively. The endothermic peak (T_m) is associated with the melting of the sample. Tables I and III compare

the T_m of the CD-PCA/or CD-PTT fiber with that of the CD-PCA/or CD-PTT chip. The orientation and crystallization caused the T_m of the CD-PCA/or CD-PTT fiber to exceed clearly that of the CD-PCA/or CD-PTT chip. The T_m of the CD-PCA fiber was lower than that of the CD-PTT by ~16.5°C. The thermal data revealed a clear melting endothermic peak, suggesting that the CD-PCA and CD-PTT fibers were originally crystalline. The CD-PCA and CD-PTT fibers yielded a double-melting endothermic peak. Interestingly, large —SO$_3$Na side groups in CD-PCA and CD-PTT polymers prevented the chain molecules from tightly coagulating and inhibited the formation of larger crystals.[35] A —SO$_3$Na side group on polymer caused the thermal behavior of the CD-PCA/CD-PTT ployblended fibers to resemble that of the CD-PCA and CD-PTT fibers. This experimental phenomenon was similar to the observation of Pal et al. for a cationic dyeable polymer.[36]

During the DSC cooling process, the exothermic peaks (the T_{cc} points) of the CD-PCA and CD-PTT fibers were obtained at 152.3 and 166.6°C, respectively. The exothermic peak was associated with the recrystallization of the melting polymer. Clearly, the half-time of recrystallization of the CD-PCA fiber was shorter than that for the CD-PTT fiber, implying that the recrystallization rate of the CD-PCA fiber exceeded that of the CD-PTT fiber. For all CD-PCA/CD-PTT polyblended fibers, the T_m of CD-PCA segments (T_{m1}) almost did not shift, appearing at 212–215°C. Additionally, the T_m of CD-PTT molecules (T_{m2}) did not clearly change, and was at 222–226°C. Restated, the change in T_m was independent of the blend ratio. The DSC behavior of the T_{cc} points resembled that of the T_m points for all CD-PCA/CD-PTT polyblended fibers. The T_{cc} points of CD-PCA (T_{cc1}) and CD-PTT molecules (T_{cc2}) barely changed and were around 153–157°C and 161–165°C, respectively. Restated, the change in T_{cc} was also independent of the blend ratio.

Figure 5 plots the linear variations of the heat fusion (ΔH_m) with the blend ratio of CD-PCA/CD-PTT polyblended fibers. ΔH_m of CD-PCA molecules

TABLE III
Thermal Properties of CD-PCA, CD-PTT and CD-PCA/CD-PTT Polyblended Fibers

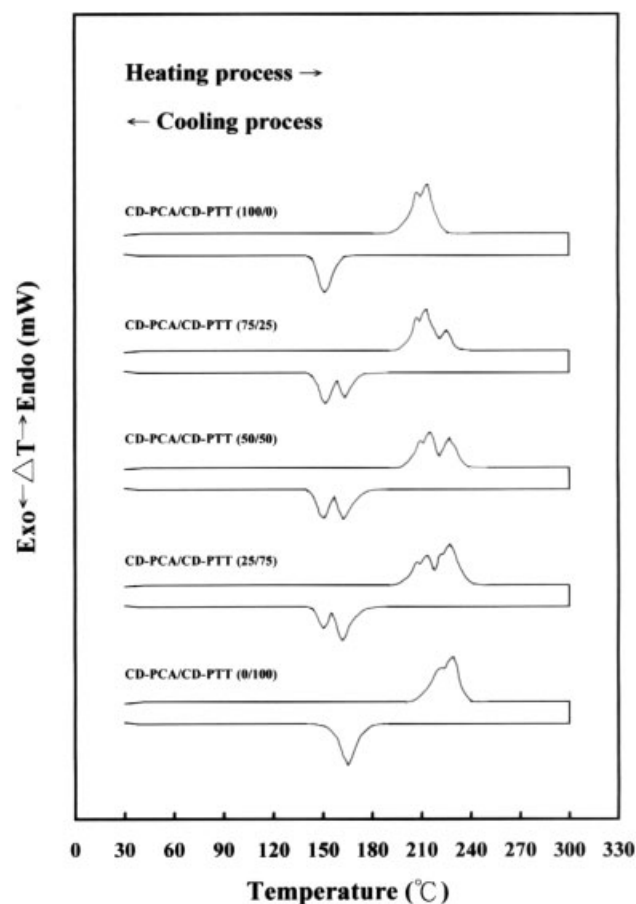| Polymer code | Heating process | | | | Cooling process | | | | | |
| | CD-PCA | | CD-PTT | | CD-PCA | | | CD-PTT | | |
	T_{m1} (°C)	ΔH_{m1} (J/g)	T_{m2} (°C)	ΔH_{m2} (J/g)	T_{cc1} (°C)	ΔH_{cc1} (J/g)	Half-time (s)	T_{cc2} (°C)	ΔH_{cc2} (J/g)	Half-time (s)
Sample 1	211.2	58.2	–	–	152.3	53.2	82.7	–	–	–
Sample 2	212.3	43.7	222.7	11.9	153.7	39.9	–	161.7	11.4	–
Sample 3	213.4	29.1	223.2	23.9	155.5	26.6	–	163.9	22.8	–
Sample 4	214.1	14.6	225.3	35.8	156.8	13.3	–	164.7	34.1	–
Sample 5	–	–	227.7	47.7	–	–	–	166.6	45.5	89.2

Figure 4 DSC curves of CD-PCA, CD-PTT, and CD-PCA/CD-PTT polyblended fibers.

(ΔH_{m1}) fell in proportion to the increase in the CD-PTT content. Meanwhile, ΔH_m of CD-PTT molecules (ΔH_{m2}) increased in proportion to CD-PTT content. Figure 6 also plots the linear variations of the recrystallization heat of the exothermic peak (ΔH_{cc}) with the blend ratios of CD-PCA/CD-PTT polyblended fibers. ΔH_{cc} of CD-PCA molecules (ΔH_{cc1}) decreased in proportion to the increase in CD-PTT content, while ΔH_{cc} of CD-PTT molecules (ΔH_{cc2}) increased in proportion to CD-PTT content. The experimental results of the DSC demonstrated that CD-PCA and CD-PTT molecules easily formed individual domains, indicating that CD-PCA segments and CD-PTT molecules were immiscible.

Crystallinity

The heat of fusion was used to evaluate the crystalline fraction of the material. A higher heat of fusion was expected to result in a higher crystallinity. Table IV presents the crystallinities of CD-PCA, CD-PTT, and CD-PCA/CD-PTT polyblended fibers. The heat of fusion of melting was used to determine
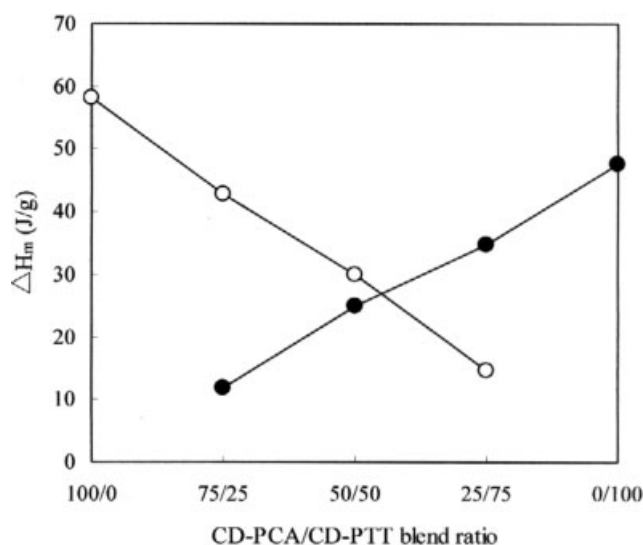
Figure 5 ΔH_m as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers. (○) CD-PCA and (●) CD-PTT.

crystallinity. Values of 230.1 and 145.6 J/g, corresponding to 100% crystallinity, were used for pure PCA and pure PTT, respectively. The crystallinities of CD-PCA and CD-PTT fibers were 25.3 and 32.8%, respectively. The crystallinity of CD-PCA fiber was less than 7.5% of that of CD-PTT fiber. After blending, the total crystallinity of the CD-PCA/CD-PTT polyblended fiber increased in proportion to the amount of CD-PTT. The crystallinities obtained using the WAXD method were slightly lower than those obtained using the DSC method. Figure 7 plots the relation between the crystallinities and the blend
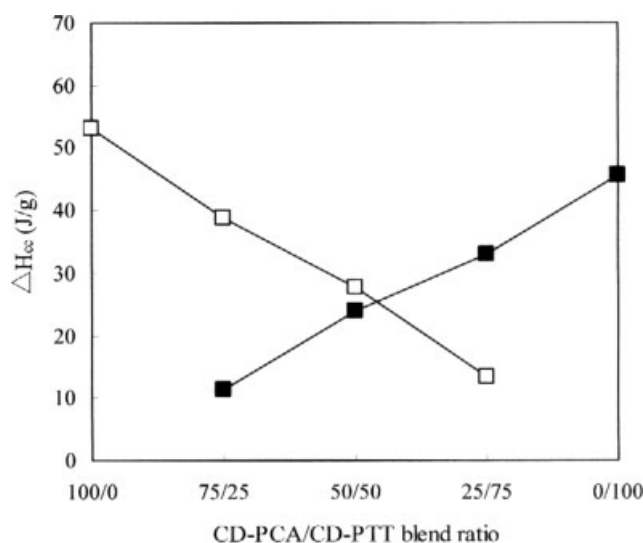

Figure 6 ΔH_{cc} as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers. (□) CD-PCA and (■) CD-PTT.

TABLE IV
Crystallinities of CD-PCA, CD-PTT, and CD-PCA/CD-PTT Polyblended Fibers

	DSC method					WAXD method
	CD-PCA part		CD-PTT part			
Polymer code	ΔH_{m1} (J/g)	X_c (%) of CD-PCA part	ΔH_{m2} (J/g)	X_c (%) of CD-PTT	Total X_c (%) of fiber	Total X_c (%) of fiber
Sample 1	58.2	25.3	–	–	25.3	23.5
Sample 2	43.7	19.0	11.9	8.2	27.2	26.8
Sample 3	29.1	12.6	23.9	16.4	29.0	27.7
Sample 4	14.6	6.3	35.8	24.6	30.9	30.2
Sample 5	–	–	47.7	32.8	32.8	31.2

ratios of CD-PCA/CD-PTT polyblended fibers. For all CD-PCA/CD-PTT polyblended fibers, the experimental crystallinities are fairly close to the calculated values. The experimental crystallinities demonstrated that CD-PCA and CD-PTT molecules easily formed individual domains, indicating that CD-PCA and CD-PTT together constituted an immiscible system.

Tenacity

The flow behavior of the CD-PCA and CD-PTT polymers and the melting results indicated weak interfacial adhesion between them. Figure 8 plots the relationship between the tenacities and the blend ratios of the CD-PCA/CD-PTT polyblended fibers. The tenacities of the CD-PCA/CD-PTT polyblended fibers initially declined and then increased with the proportion of CD-PTT. Clearly, the 50/50 CD-PCA/CD-PTT blend had the lowest tenacity. This tendency was consistent with the flow behavior, and the 50/50 CD-PCA/CD-PTT blend exhibited the least te-

nacity. The weak interfacial interactions between CD-PCA and CD-PTT demonstrated poor mechanical properties.

Density

Figure 9 plots the relationship between the densities and the blend ratios of CD-PCA/CD-PTT polyblended fibers. For all CD-PCA/CD-PTT polyblended fibers, the experimental densities are fairly consistent with the calculated values. The densities revealed that CD-PCA and CD-PTT molecules easily formed individual domains, and that they therefore were immiscible. The experimental densities were consistent with the thermal characteristics and crystallinities of the CD-PCA/CD-PTT polyblended fibers.

Miscibility parameter μ value

Following Chee,[23] a modified technique has been suggested to evaluate the miscibility parameter μ
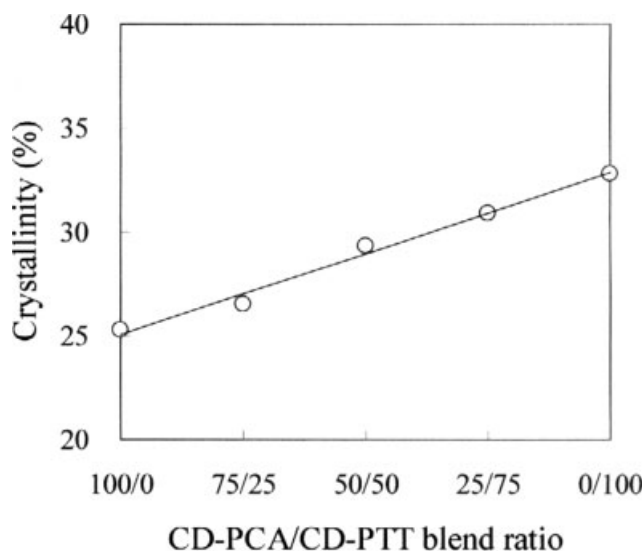
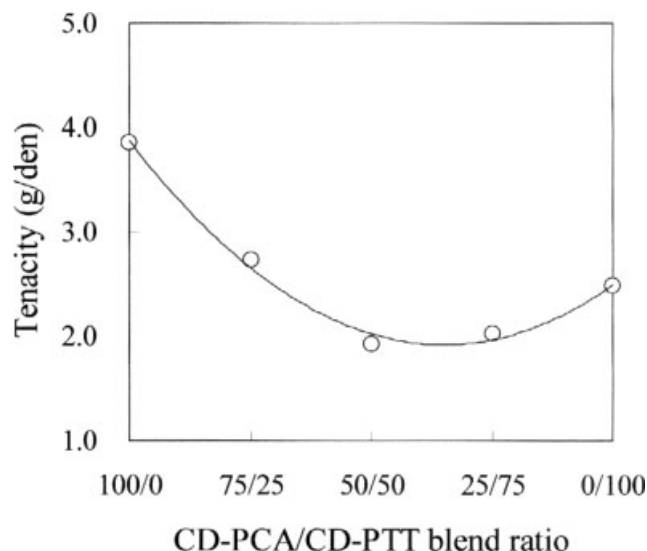**Figure 7** Crystallinity as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers.

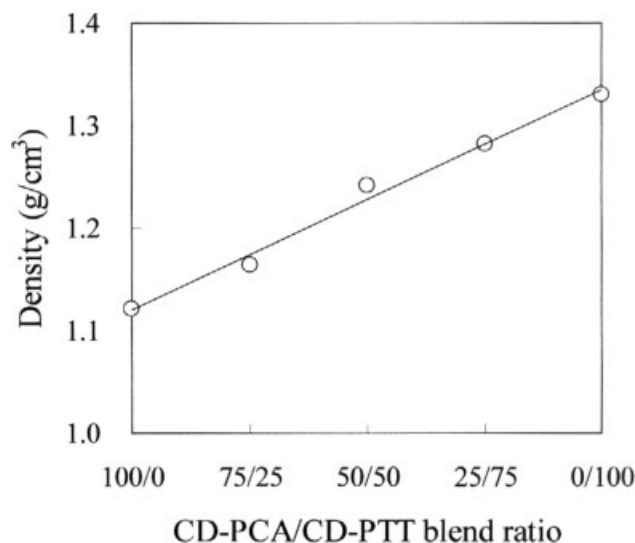**Figure 8** Tenacity as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers.

Figure 9 Density as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers.
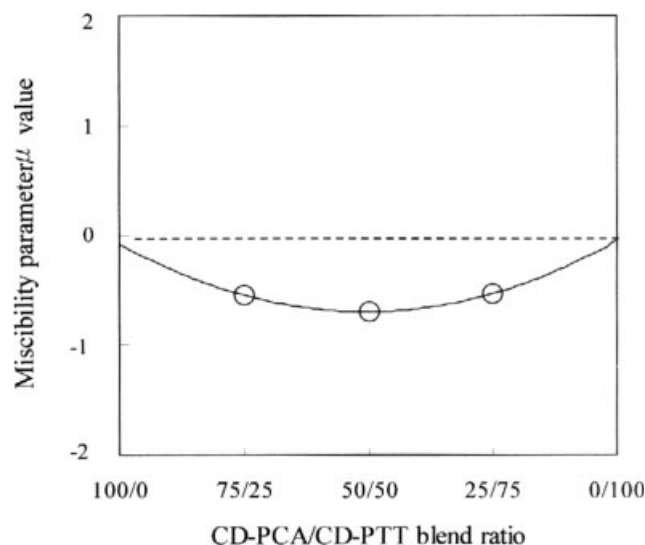

Figure 10 Miscibility parameter μ value as a function of blend ratio for CD-PCA/CD-PTT polyblended fibers.

value of stiff polymer/stiff polymer by viscometry in aqueous solution, as follows.[37,38]

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

where, $[\eta]_2$, $[\eta]_3$, and $[\eta]$ represent the IV of polymer 2 (CD-PCA) and polymer 3 (CD-PTT), and the mixture of the two polymers 2 and 3 (CD-PCA/CD-PTT blends), respectively. They are estimated using Huggins and Kraemer plots. c denotes the concentration of solution. The coefficients b, b_{22}, and b_{33} are obtained from plots of $\{(\eta_{sp}/c) - [\eta]\}/c$ vs c for the mixture of two polymers, polymer 2 and polymer 3, respectively, according to the following equation.

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

The miscibility parameter μ value predicts the miscibility or immiscibility of blends. When μ exceeds

TABLE V
[η], b, and Miscibility Parameter μ of Blend System for CD-PCA, CD-PTT, and CD-PCA/CD-PTT Polyblended Fibers

Polymer code	$[\eta] \times 10^{-1}$ (dL/g)	$b \times 10^{-4}$ (dL/g)^2	μ
Sample 1	3.58	8.84	–
Sample 2	3.28	6.67	−0.546
Sample 3	3.18	5.51	−0.698
Sample 4	5.16	12.8	−0.532
Sample 5	6.81	14.6	–

[η] was measured using a Ubbelodhe capillary viscometer in HFIP solvent at 25°C.

zero, the blend of two polymers is miscible. Table V presents the [η] values obtained by extrapolating the curves of η_{sp}/c vs c and η_r/c vs c plots. The μ values of all CD-PCA/CD-PTT samples were less than zero. Figure 10 plots the relationship between the miscibility parameter μ value and the blend ratio of CD-PCA/CD-PTT polyblended fibers, indicating that the blends were phase-separated and therefore immiscible. Electrostatic repulsion was evident between CD-PCA and CD-PTT molecules, indicating that CD-PCA/CD-PTT polyblended fibers were immiscible.

CONCLUSIONS

The melting behavior of CD-PCA/CD-PTT polyblended polymers revealed NDBs. The 50/50 blend of CD-PCA/CD-PTT had a lower melt viscosity than was predicted by the additivity rule. Flow results demonstrated weak interfacial adhesion between CD-PCA and CD-PTT polymers. The experimental results for the DSC indicated that CD-PCA and CD-PTT molecules easily formed individual domains. In particular, a double endothermic peak was observed from CD-PCA, CD-PTT, and their polyblended fibers. The tenacities of CD-PCA/CD-PTT polyblended fibers initially declined and then increased with the proportion of CD-PTT. Clearly, the 50/50 CD-PCA/CD-PTT blend had the least tenacity. The experimental crystallinities and densities agree fairly well with the calculated values. The crystallinities and densities also indicated that CD-PCA and CD-PTT molecules easily formed individual domains, and that CD-PCA segments and CD-PTT molecules were therefore immiscible. The miscibility parameter μ values of all CD-PCA/CD-PTT samples were less

than zero, indicating electrostatic repulsion between CD-PCA and CD-PTT molecules. Results of this study demonstrated that CD-PCA/CD-PTT poly-blended fibers were immiscible.

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