

Studies on Novel Semi-2-IPNs from Polyetherimide and Citraconimide

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ABSTRACT: A series of novel semi-2-interpenetrating polymeric networks (semi-2-IPNs) were prepared through blending in solution using two different polyimides, biscitraconamic acid as a precursor of biscitraconimide (MBMI) with various proportions of polyetherimide (PEI) to achieve optimum properties. Biscitraconamic acid was prepared by reacting citraconic anhydride (CA), 3,3',4,4'-benzophenone tetracarboxylic dianhydride (BTDA) and bis(3-aminopropyl)phenyl phosphine (BAPPP) and it was characterized by differential scanning calorimetry (DSC), FTIR, and ¹H-NMR spectroscopy. Both biscitraconamic acid and PEI were blended in *N,N*-dimethylacetamide (DMAc) solution, casted and thermally cured up to 300°C to give semi-2-IPNs. The MBMI/PEI semi-IPN systems were characterized by UV-Vis spectroscopy, FTIR spectroscopy and ther-

mal techniques. The phase morphology, isothermal aging, and water uptake of semi-IPN systems have also been studied. The morphological studies on phase distribution were investigated by scanning electron microscopy (SEM). Thermal performance of MBMI/PEI semi-IPN systems were evaluated by DSC and thermo gravimetric analysis (TGA). All the compositions of semi-IPN polyimide system were stable up to 400°C and their thermal stability increased with increase in the content of PEI. Isothermal aging studies done at 300°C for various time periods showed good thermo-oxidative stability. © 2011 Wiley Periodicals, Inc. *J Appl Polym Sci* 120: 2790–2799, 2011

Key words: semi-2-IPNs; PEI; biscitraconimide; bis(3-aminopropyl)phenyl phosphine

INTRODUCTION

There is a continual search for polymers with improved processability and high thermal stability for use as moldings, adhesives and composite matrices in aerospace and electronic technologies. Materials used in these environments must have a variety of desired properties including easy processing, good damage tolerance, high glass transition temperature, good mechanical performance, capable of withstanding high temperature, low moisture absorption and resistance to a variety of solvents.

Addition polyimides, such as 5-norbornene-2,3-dicarboximide (nadimide), maleimide and ethynyl terminated imide resins are a leading class of thermosetting polyimides and have received attention because of their excellent thermal stability, good chemical resistance, good mechanical and electrical properties.^{1–9} Since early 1970's these resins have been extensively investigated as matrix resins for advance fiber reinforced composites, adhesives and in multilayer circuit boards in electronic industry. The drawback of these resins is their brittleness due to high crosslink density.^{10–12}

To overcome the above disadvantages the concept of semi-interpenetrating polymeric networks (semi-IPNs) has been developed to obtain macromolecular systems which combine the processability of thermosetting polymers and high temperature properties of thermoplastic polymers.^{13–19} Semi-IPNs are composed of two chemically different polymers, one is crosslinked and other is linear. If the crosslinkable material is polymerized in presence of linear polymer the resulting system is called semi-2-IPN.²⁰

A number of semi-IPN polyimide systems have been investigated in the past prepared from thermosetting resins such as bismaleimide and bisnadimide with linear polyimides.^{21–25} But the potential of biscitraconimide resins which cure at lower temperature than bismaleimide and bisnadimide resins is still less explored. Thus in the present article a phosphorous containing biscitraconimide resin was prepared by reacting citraconic anhydride (CA), 3,3',4,4'-benzophenone tetracarboxylic dianhydride (BTDA) and bis(3-aminopropyl)phenyl phosphine (BAPPP). One important advantage of phosphorous containing polyimide is that these resins show good flame resistant properties. The synergistic fire retarding properties of phosphorous and nitrogen containing functionalities are well documented in literature.²⁶ Moreover incorporation of flexible chain segment helps to overcome brittleness and enhance

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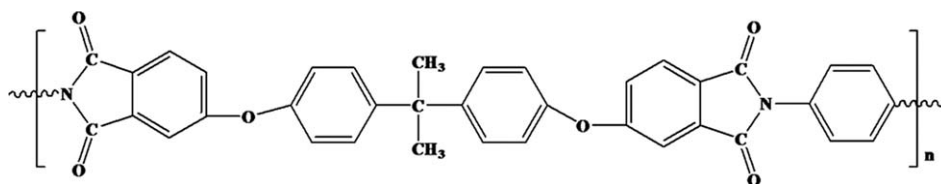


Figure 1 Chemical structure of PEI.

ductility as well as toughness.²⁷ Resins of this type may be used in variety of application including e.g., impregnation, laminated boards, molded articles or components, electronic circuit board manufacture and adhesives. Only few researchers have studied the synthesis and properties of different types of biscitraconimides.^{28–31} So far, to the best of our knowledge, preparation of semi-IPNs from such type of biscitraconimide has not been reported.

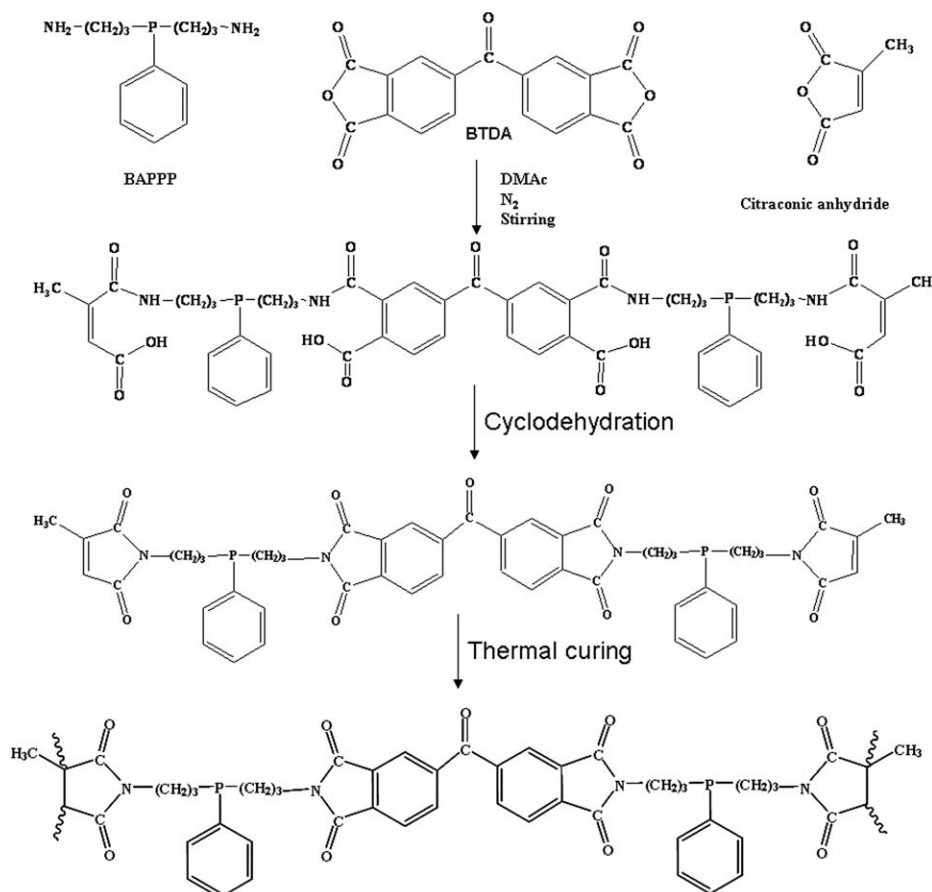
In view of the above, a series of novel semi-2-IPNs were prepared through solution-blending using biscitraconamic acid as a precursor of polyetherimide (PEI). Since PEI (Fig. 1) is an excellent engineering thermoplastic having good mechanical properties as well as high glass transition temperature (T_g) and thermo-oxidative stability. As expected, greater percentage of aliphatic moieties in the MBMI resin improves its

solubility and offers the advantage of easy processability whereas PEI improves the thermal stability and moisture resistance of the synthesized semi-IPN polyimide films. The main focus of the present studies was to synthesize a novel biscitraconamic acid which was used to prepare semi-IPN polyimide systems with PEI. The synthesized biscitraconamic acid was characterized by DSC, FTIR, and NMR spectroscopy and prepared semi-IPNs were examined for their spectral, thermal and morphological properties.

EXPERIMENTAL

Materials

PEI (Ultem[®] 1000) was supplied by General Electric Plastics, in pellet form and was dried for 8 h in an oven at 150°C before use to remove moisture, if any.



Scheme 1 Schematic of crosslinked biscitraconimide synthesis route.

TABLE I
Designation for Compositions of semi-IPN Polyimide Systems

Composition of semi-IPN MBMI:PEI	Designation
90 : 10	MP 90/10
80 : 20	MP 80/20
70 : 30	MP 70/30
60 : 40	MP 60/40
50 : 50	MP 50/50
40 : 60	MP 40/60
30 : 70	MP 30/70
20 : 80	MP 20/80
10 : 90	MP 10/90

BAPPP (Alfa Aesar) and CA (Aldrich) was used as received. BTDA supplied by Aldrich was recrystallized from acetic anhydride before use. *N,N*-dimethylacetamide (DMAc) from Merck was purified by distillation over phosphorous pentoxide under reduced pressure and stored over 4 Å molecular sieves.

Measurements

The infrared spectra were recorded on Perkin–Elmer FTIR spectrophotometer (Model RX1) using KBr pellets in the range 4000–400 cm^{-1} . $^1\text{H-NMR}$ spectrum was recorded using Bruker AVANCE 400 MHz FT-

NMR spectrometer using Me_4Si as reference. Glass transition temperature (T_g) was determined by differential scanning calorimetry (DSC), Model DSC Q 200, TA instruments; at a heating rate of $10^\circ\text{C}/\text{min}$ under nitrogen atmosphere at a flow rate of 50 mL/min. The degradation temperature was recorded using Hi-Res TGA-2950, TA instruments; at a heating rate of $10^\circ\text{C}/\text{min}$ under nitrogen atmosphere at a flow rate of 50 mL/min. The optical transmittance was recorded on Varian Carry 5000 UV-Vis analyzer. Morphology of the semi-IPN systems was examined by Carl Zeiss EVO 50 low vacuum scanning electron microscope (SEM). The acceleration voltage used was 20 kV. The water uptake was determined by the change of the mass in vacuum dried film specimens before and after immersion in water at room temperature for 48 h.

Synthesis of biscitraconamic acid

Biscitraconamic acid (CA/BAPPP/BTDA), the chemical structure of which is shown in Scheme 1, was prepared in two steps. Step one concern reaction of diamine and dianhydride (BAPPP/BTDA). Step two deals with the addition of CA with BAPPP/BTDA according to the following procedure.

A 500 mL three neck round bottom flask equipped with a nitrogen inlet, a stirrer bar and a guard tube

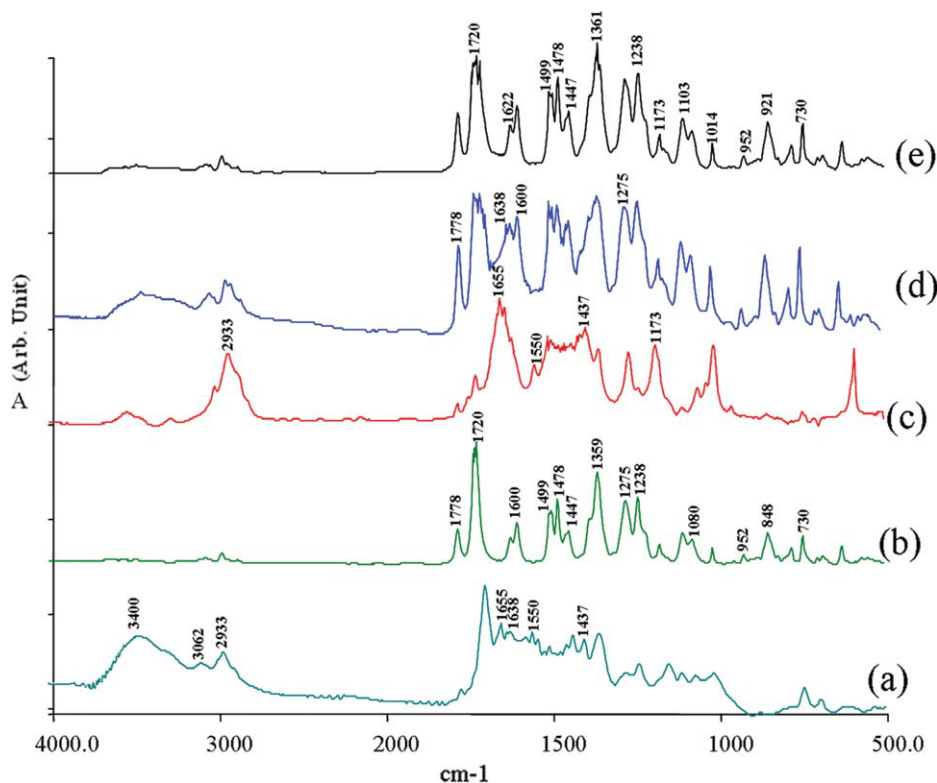


Figure 2 FTIR spectra of (a) biscitraconamic acid (b) PEI (c) biscitraconamic acid/PEI (d) precured MBMI/PEI (e) cured MBMI/PEI (20/80) semi-IPN system. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://www.interscience.wiley.com).]

TABLE II
The FTIR Assignment of Functional Groups of Polyimides and Crosslinkable Oligomer

Wavenumbers (cm ⁻¹)	Assignment
3200–3500	Multiple stretching vibration due to –OH (carboxylic) and –NH (amide) group
3062	Aromatic-CH stretching
2933	Aliphatic –CH stretching
1778	Asymmetric stretch of >C=O (imide)
1720	Symmetric stretch of >C=O(imide)
1655	Amide>C=O stretching
1600	Aromatic ring
1550	C–NH stretching
1437	P–Ph stretching
1380	C–N stretching
1238	Diarylether asymmetric stretch
1080	Imide ring
952	Aromatic ring
848	Aromatic ring
730	Imide ring

was charged with 41.67 mmol of diamine (BAPPP) and 150 mL of freshly distilled DMAc. The solution was stirred until the diamine dissolved completely. 20.84 mmol of dianhydride (BTDA) was added in fractions to this solution under effective stirring. The reaction mixture was stirred for 8 h at room temperature. A solution of 41.67 mmol of CA in 50 mL DMAc was added to the same solution over a period of 15 minutes. After 10 minutes the color of the reaction changes from white to yellow, room temperature stirring for 8 h was further continued to ensure complete reaction. Thereafter DMAc was distilled off

under reduced pressure (10 mmHg) at 90°C. Last portion of solvent was removed under vacuum (0.01 mmHg) at 90°C for 2 h. The solid material obtained was biscitraconamic acid (FMW 922). Then dry benzene was added to biscitraconamic acid and distilled. This process was repeated twice to remove moisture completely. Sample was again treated under vacuum (0.01 mmHg) at 90°C for 1 h to completely remove solvent traces. Biscitraconamic acid was obtained in quantitative yield and it was characterized by DSC, FTIR and ¹H-NMR spectroscopy.

Synthesis of semi-interpenetrating polymeric networks

1.085 mL (217 mg), 20 wt % solution of biscitraconamic acid (equivalent to 200 mg of biscitraconimide, FMW 850) in DMAc was mixed with 4 mL (800 mg) 20 wt % solution of PEI in same solvent. The mixture was stirred for 1 h at room temperature to give a clear brown solution, which contained 20% by weight of solid. The weight ratio of biscitraconimide and PEI was 20 to 80 and this composition was designated as MP 20/80. The solution was casted onto clean and dry glass plate by a doctor blade. The glass plate was washed with soap solution then rinsed with acetone and dried in an oven before use. The speed of doctor blade was 4–6 cm / second and thickness of wet film was 250 μm. Thermal imidization and curing of the film was carried out in an oven by sequential heating at 100, 150, 250, and 300°C for 1 h each. The film was removed from the glass plate by soaking it in the cold water and

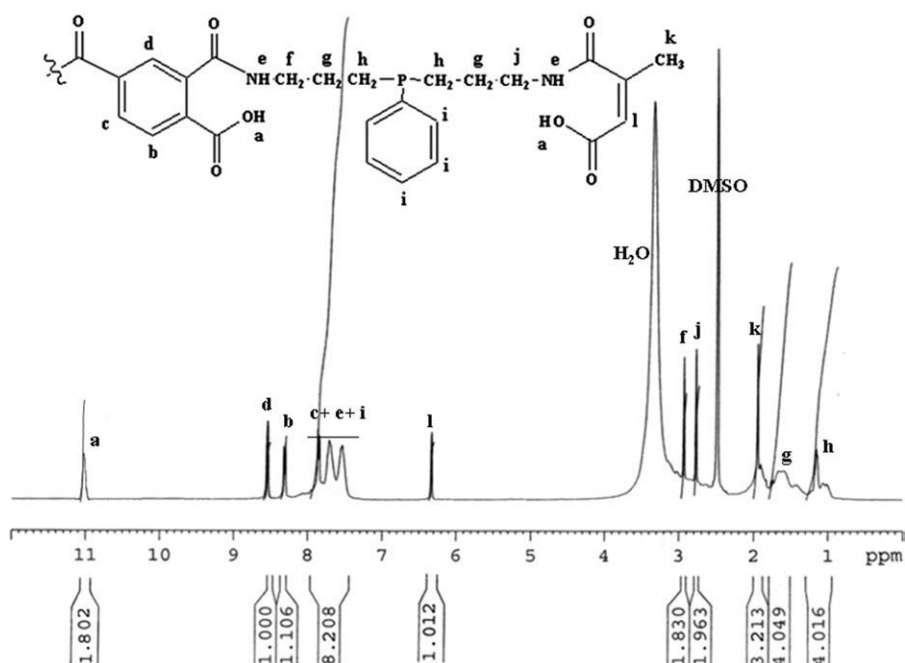


Figure 3 ¹H-NMR of biscitraconamic acid.

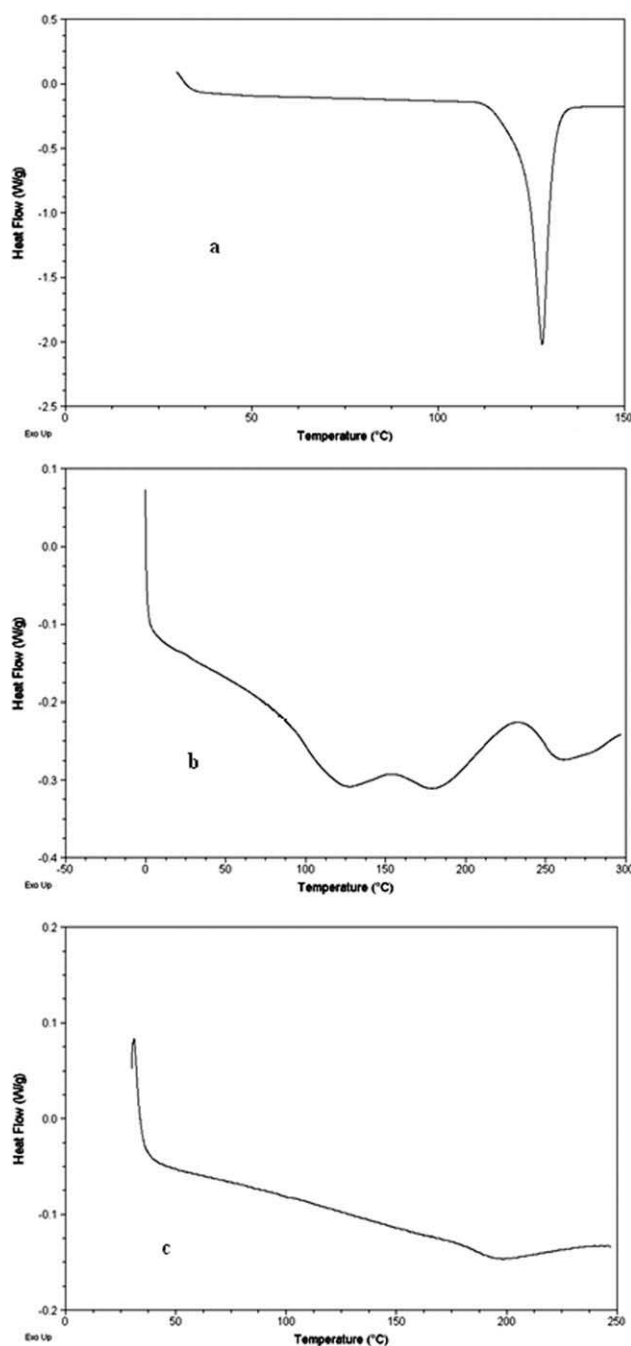
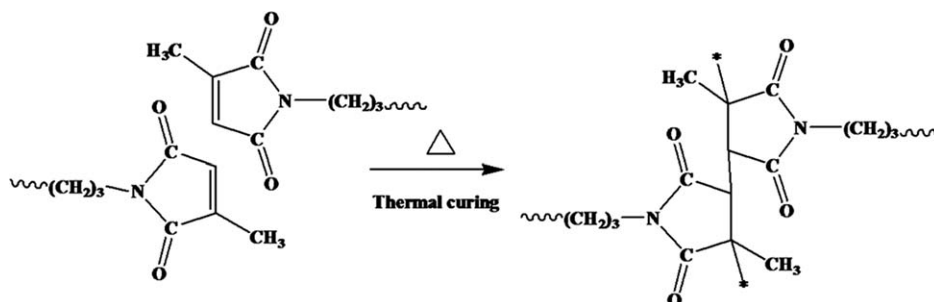


Figure 4 DSC curve of biscitraconamic acid (a) first heating cycle (b) Second heating cycle (c) third heating cycle.



Scheme 2 Crosslinking mechanism of biscitraconimide.

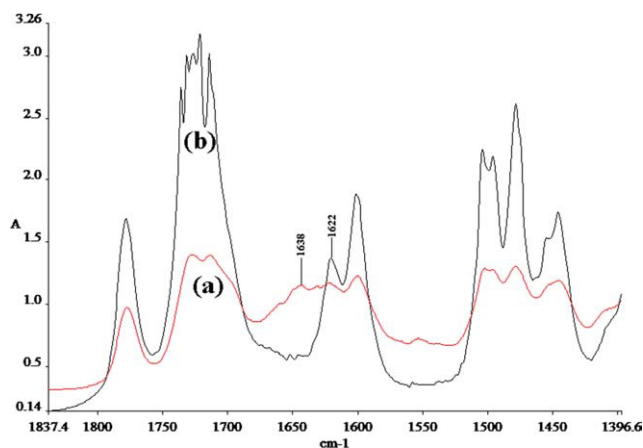


Figure 5 The FTIR spectra of MP 20/80 semi-IPN system between 1400 and 1800 cm^{-1} : (a) before cure (b) after cure. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

thickness of dry film was 50 μm . Other compositions of semi-IPNs were prepared in a similar manner by adding the above component in the required ratios and their designations are given in Table I.

RESULTS AND DISCUSSION

Characterization of biscitraconamic acid

FT-infrared and NMR spectroscopy

The FTIR spectrum of biscitraconamic acid is shown in Figure 2. Figure 2 shows multiple stretching vibrations due to $-\text{OH}$ (carboxylic group) and $-\text{NH}$ (amide group) in the region 3200–3500 cm^{-1} . The peak at 1638 cm^{-1} may be attributed to the terminal $\text{C}=\text{C}$ of biscitraconamic acid while the peaks at 1655 and 1550 cm^{-1} may be due to carbonyl and $\text{C}-\text{NH}$ stretching, respectively. The detailed assignments of peaks have been made in Table II. Figure 3 shows the $^1\text{H-NMR}$ spectra of biscitraconamic acid (half of the symmetrical structure is shown in Fig. 3) in DMSO-d_6 . BTDA aromatic protons were observed at $\delta = 7.8\text{--}8.7$ ppm, P-Ph protons at $\delta = 7.3\text{--}7.8$ ppm, vinylic protons at $\delta = 6.3$ ppm and $\text{N}-\text{CH}_2$ protons were observed at $\delta = 2.7\text{--}3.0$ ppm. A broad multiplet

TABLE III
Thermal Data of Crosslinked MBMI, Neat PEI and semi-IPN Polyimide Systems

Sample designation	T_g (°C) ^a	T_i (°C) ^b	T_{max} (°C) ^c	T_f (°C) ^d	γ_c at 800°C ^e	% of weight loss at 300°C after ^f	
						200 h	400 h
MBMI	193	400	418	441	58	14.6	25.7
MP 90/10	195	408	439	466	58	13.7	24.6
MP 80/20	197	410	441	468	58	12.7	22.4
MP 70/30	198	413	447	475	60	12.1	21.5
MP 60/40	200	418	452	487	61	11.6	21.1
MP 50/50	203	420	466	542	62	10.4	20.5
MP 40/60	206	425	480	555	63	10.0	19.9
MP 30/70	207	429	500	575	63	9.9	18.2
MP 20/80	209	435	513	646	64	9.1	17.9
MP 10/90	212	477	518	655	65	8.9	16.6
PEI	218	490	550	670	68	8.5	15.4

^a Glass transition temperature measured by DSC at a heating rate of 10°C/min in nitrogen.

^b Temperature of onset of decomposition measured by TGA at a heating rate of 10°C/min in nitrogen.

^c Temperature of maximum rate of weight loss measured by TGA at a heating rate of 10°C/min in nitrogen.

^d Temperature of endset of decomposition measured by TGA at a heating rate of 10°C/min in nitrogen.

^e Char yield at 800°C under nitrogen.

^f % of weight loss at 300°C in air after 200 h and 400 h.

due to aliphatic protons attached to phosphorous were observed at $\delta = 1.0$ – 1.8 ppm and allylic protons of terminal CA part were observed at $\delta = 1.9$ ppm. —CONH and —COOH protons were observed at $\delta = 7.8$ and 11.0 ppm respectively. Broad peak at $\delta = 3.0$ – 3.7 was observed due to dissolved water present in DMSO- d_6 .

Curing study

Curing behavior of biscitraconamic acid was observed by DSC at a heating rate of 10°C/min under N₂. Figure 4 shows the DSC curves of biscitraconamic acid. Since the residual solvent and moisture may influence the curing temperature of biscitraconamic acid, therefore sample was first heated to 150°C and the curing temperature was determined by second heating cycle. Figure 4(a) shows the first heating cycle in which melting and cyclodehydration of biscitraconamic acid takes place at around 128°C and biscitraconamic acid converts into biscitraconimide. Then the sample was hold isothermally at 150°C for 15 minutes to remove moisture completely generated from cyclodehydration. Figure 4(b) shows the second heating cycle in which an endothermic peak centered at 117°C shows melting of biscitraconimide and an exothermic transition associated with the curing of citraconic >C=C< was observed in the temperature range of 184–261°C. Third heating cycle was also performed to ensure whether curing was complete in second run or not. Figure 4(c) shows the third heating cycle in which no exothermic peak appears which indicates complete curing of biscitraconimide; however an endothermic peak

at 193°C is obtained which corresponds to the softening temperature of cured biscitraconimide.

Structural characterization of semi-IPNs

The FTIR spectra of MBMI/PEI semi-IPN systems are shown in Figure 2. The FTIR assignment of functional groups is listed in Table II.^{32–36} FTIR spectroscopy allows monitoring of the imide ring formation and crosslinking reaction of the crosslinkable groups. The imidization reaction was monitored by following appearance of imide bands around 1780 cm⁻¹ (asymmetric stretch of carbonyl groups), 1720 cm⁻¹ (symmetric stretch of carbonyl groups), 1380

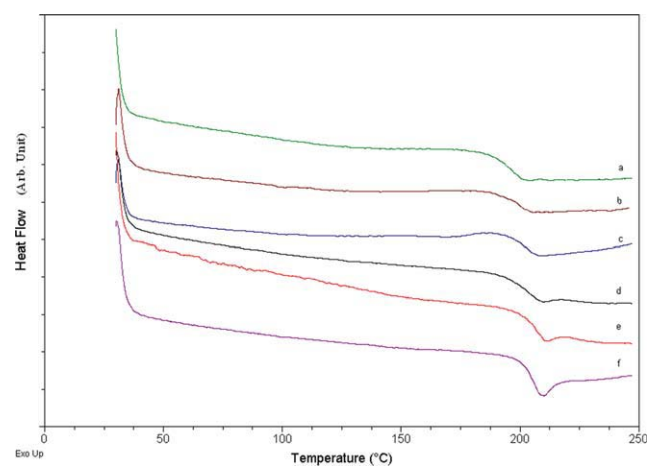


Figure 6 DSC curves of cured semi-IPN system (a) MP 90/10 (b) MP 70/30 (c) MP 60/40 (d) MP 50/50 (e) MP 40/60 (f) MP20/80. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

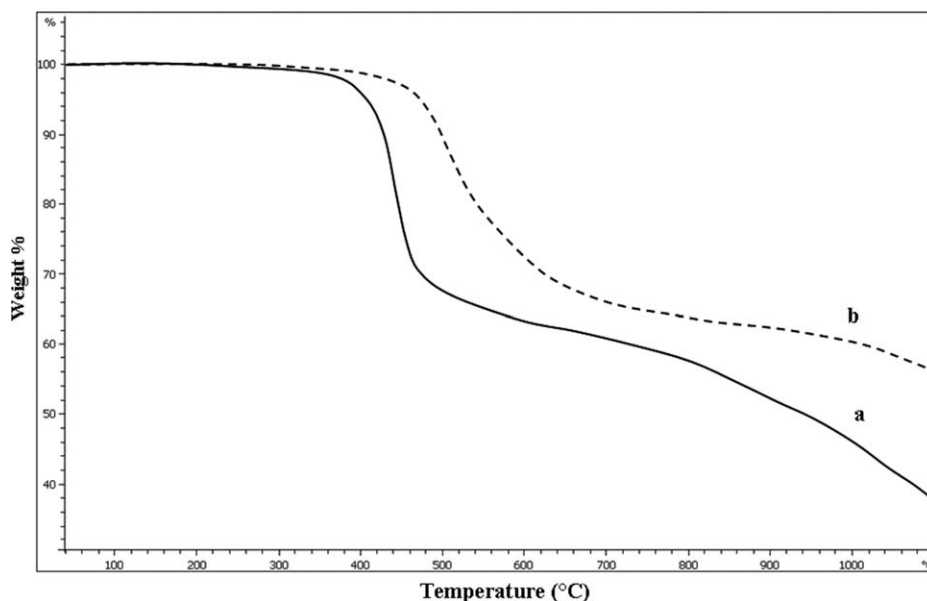


Figure 7 TGA thermographs of cured semi-IPN system (a) MP 90/10 (b) MP 20/80.

cm^{-1} (C—N stretch), and 730 cm^{-1} (deformation of imide ring).^{32,33,37,38} The multiple stretching vibrations of amide and carboxyl groups in the region of $3000\text{--}3500$ and $1500\text{--}1700\text{ cm}^{-1}$ disappeared from the MBMI/PEI semi-IPN system [Fig. 2(e)] indicating a virtually complete conversion of biscitraconamic acid precursor into biscitraconimide.

The crosslinking reaction of biscitraconimide was monitored by disappearance of citraconimide $>\text{C}=\text{C}<$ absorption at 1638 cm^{-1} .³⁹ The citraconimide $>\text{C}=\text{C}<$ at 1638 cm^{-1} in precured MBMI/PEI semi-IPN system disappeared when cured at 300°C for 1 h as shown in Figure 5. The disappearance of double bond ($>\text{C}=\text{C}<$) was also quantified from the FTIR spectra by peak area calculation taking $\text{C}=\text{O}$ imide (1778 cm^{-1}) as reference. Using peak area calculation software of FTIR spectrometer, the peak area ratio of ν_{1638} to ν_{1778} was found to be 0.0921 for precured sample; whereas it is about zero (only 0.0002) for the cured MBMI/PEI semi-IPN system. This evidence indicates that citraconimide is fully reacted during the curing process. Complete curing of biscitraconimide was also confirmed by DSC measurement [Fig. 4(c)]. The crosslinking mechanism for biscitraconimide is given in Scheme 2. This mechanism involves thermal initiation to form free radicals, which react with citraconimide double bonds to form crosslinking networks.

Thermal studies

Thermal behavior of semi-IPN polyimide systems was evaluated by DSC and thermo gravimetric analysis (TGA). DSC measurements were conducted at a heating rate of $10^\circ\text{C}/\text{min}$ under nitrogen. Samples

were dried at 150°C for 5 h in an oven before DSC measurement to remove residual solvent and moisture which may influence the T_g of polymers. Table III summarizes the glass transition temperature (T_g) of crosslinked MBMI, neat PEI and different compositions of semi-IPNs. The glass transition temperatures of crosslinked MBMI and neat PEI are 193 and 218°C , respectively. Semi-IPNs have T_g s in the range of $195\text{--}212^\circ\text{C}$. From Table III, it is clear that glass transition temperature of semi-IPNs increases with increasing weight proportion of PEI. This increase in T_g may be attributed to rigid aromatic polymeric chains of PEI which increases the potential energy barrier to rotation and causes a substantial increase in T_g .⁴⁰ DSC data shows that all the compositions of MBMI/PEI semi-IPNs have only one T_g (Fig. 6). But appearance of some broadness in T_g peak may be taken as indication of some phase separation, which can also be seen in SEM pictures [Fig. 8(b–e)].

The decomposition temperatures (T_d) of MBMI, PEI and MBMI/PEI semi-IPN compositions were recorded using TGA measurements conducted at a heating rate of $10^\circ\text{C}/\text{min}$ under N_2 atmosphere. Table III summarizes the thermal data of crosslinked MBMI, neat PEI and different compositions of semi-IPNs. The initial weight loss temperatures (T_i) and maximum weight loss temperatures (T_{max}) of semi-IPNs were observed in the range of $408\text{--}477^\circ\text{C}$ and $430\text{--}518^\circ\text{C}$, respectively. The onset degradation temperature of MBMI was 400°C which increases to 408 and 435°C with incorporation of 10 and 80 wt % of PEI, respectively (Fig. 7). This gradual increase in thermal stability of semi-IPNs may be attributed to the aromatic backbone structure of PEI which requires more thermal energy for degradation.⁴¹

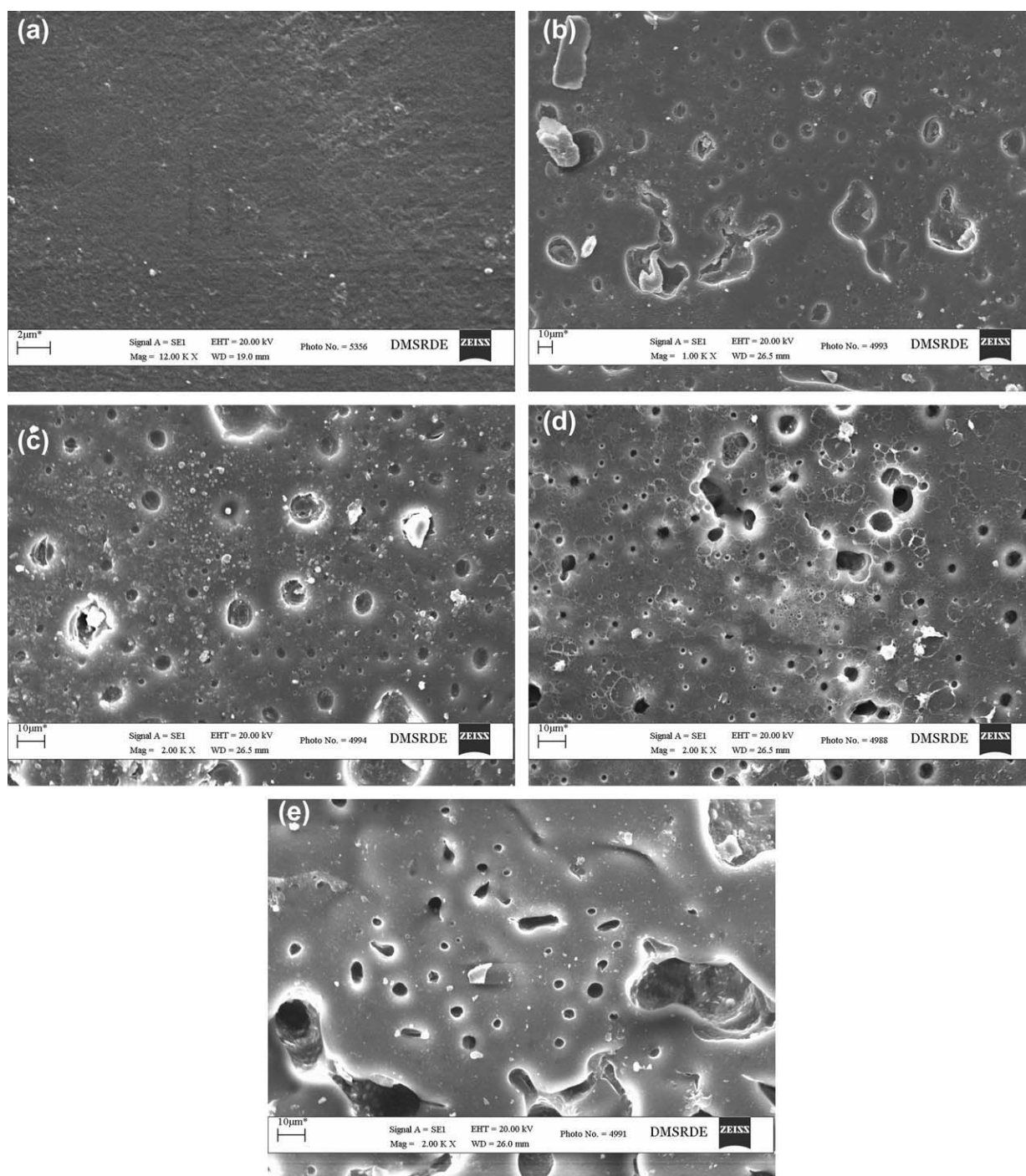


Figure 8 (a) Scanning electron micrograph of cured MBMI. (b) Scanning electron micrograph of etched MP 90/10 semi-IPN system. (c) Scanning electron micrograph of etched MP 70/30 semi-IPN system. (d) Scanning electron micrograph of etched MP 60/40 semi-IPN system. (e) Scanning electron micrograph of etched MP 50/50 semi-IPN system.

MBMI and PEI showed char yields of 58% and 68%, respectively at 800°C under nitrogen (Table III). The presence of high carbon content in PEI is the reason of its greater char yield in comparison to MBMI. Semi-IPNs showed char-yield in the range of 58–65% at 800°C. The char yield of semi-IPNs is observed to increase as the content of PEI increases.

Morphological studies

To obtain the information of morphology in the bulk of semi-IPNs solvent etching technique was used. In this technique one component is selectively dissolved in a solvent in which other component is not soluble. In present work trichloromethane was used as etching solvent which selectively dissolves PEI

TABLE IV
Optical Transmittance of Some Compositions
of Semi-IPN Polyimide System

Sample designation	Optical transmittance at 800 nm (%)
PEI	86
MP 10/90	78
MP 20/80	63
MP 30/70	57
MP 40/60	48

leaving MBMI intact. Samples were etched for 10 h at room temperature. The surface morphology was studied using scanning electron microscopy. Figure 8(a–e), shows the etched micrographs of cured MBMI as well as MP 90/10, MP 70/30, MP 60/40, and MP 50/50 semi-IPN compositions. Homogeneous distribution of PEI in MBMI matrix can be seen from the micrographs. On etching most of the PEI gets dissolved in chloroform, leaving pores in the matrix. The pores in the micrographs indicate occurrence of phase-separation in semi-IPN polyimide systems.

Optical properties

The optical transmittance of some compositions of semi-IPN polyimide systems is presented in Table IV. The optical transmittance of semi-IPNs was measured on films of thickness 50 μm . It can be seen from Figure 9, that as the content of PEI increases in Semi-IPNs, optical transparency increases, e.g. Optical transmittance of MP 40/60, MP 30/70, and MP 20/80 semi-IPN systems are 48%, 57% and 63%, respectively at 800 nm. This increase in optical transmittance may be explained as: MBMI film obtained after thermal curing was dark amber colored (nearly opaque) whereas PEI shows 80% optical transparency between 380 and 800 nm. Dark color in MBMI could be due to formation of intermolecular charge-

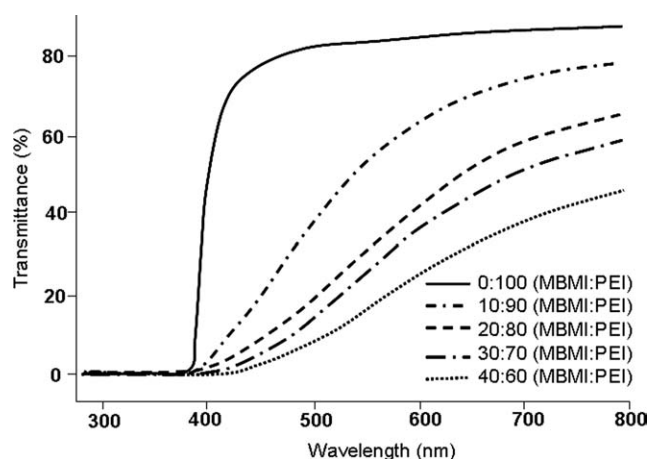


Figure 9 Optical Properties of semi-IPN polyimide systems.

transfer complexes (CTCs).^{42,43} Preparation of amber colored polybiscitraconimides has also been reported by Galanti and Scola.²⁹ Therefore, increasing weight percentage of PEI increases the optical transmittance of semi-IPNs.

Water uptake

Water uptake of the polyimide films was measured by immersing vacuum dried films into deionized water for 48 h at room temperature. Then the films were taken out, wiped with tissue paper and quickly weighed on a microbalance. The water uptake of the film was calculated using the following equation

$$\text{Water Uptake (\%)} = \frac{W - W_0}{W_0} \times 100$$

Where, W_0 is the initial weight of the polymer sample, W is the weight of the polymer sample after immersion in water for 48 h. The amount of moisture uptake for these semi-IPN systems is shown in Figure 10. The data are average of three measurements with error limit of 2%. Researchers have suspected that the water absorption is related to free volume in polymers.^{44–47} From Figure 10, it is clear that cure MBMI has more free volume than PEI, therefore as the weight proportion of PEI increases in semi-IPN systems, water uptake decreases. Thus, the synthesized semi-IPN polyimide films show good moisture resistance in comparison to MBMI network.

Isothermal aging

Semi-IPN polyimide samples were placed in an air circulating oven at 300°C for 200 h and further extended for 400 h. The samples were weighed at the scheduled aging time intervals. Table III depicts the thermo-oxidative stability of crosslinked MBMI, PEI and semi-IPNs in the air at 300°C for 200 and 400 h. Semi-IPNs lost 9–14 and 17–25% of its original weight after isothermal aging at 300°C for 200 and

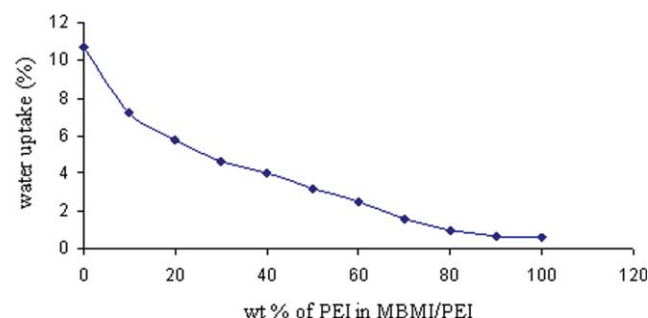


Figure 10 Water uptake in semi-IPN polyimide systems. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

400 h, respectively. It can be observed from Table III that neat MBMI resin showed 25.7% of weight loss at 300°C for 400 h which reduces to 24.6 and 20.5 with incorporation of 10 and 50 wt % of PEI. This increase in thermo-oxidative stability is attributed to the presence of phenyl rings in the backbone of PEI. As discussed earlier that semi-IPNs are thermally stable up to 400°C under nitrogen but they showed some weight loss at 300°C in air. This weight loss at 300°C in air should be due to additional oxidative degradation from oxygen present in air.⁴⁸

CONCLUSIONS

In the present communication, a series of MBMI/PEI semi-IPNs were prepared by using synthesized bis-citraconamic acid as a precursor of MBMI with various proportions of PEI. The synthesized polymers were characterized by FTIR, TGA, and DSC studies. The thermo-oxidative, morphological and optical properties of semi-IPNs were also studied. Appearance of broadness in T_g peak in DSC as well as SEM studies showed that there is partial phase separation between both the polyimides. Relative to MBMI the resulting semi-IPNs showed improved moisture resistance, better thermal as well as thermo-oxidative stability. Semi-IPNs showed both easy processability and good thermal stability which are difficult to be obtained simultaneously in a single polymer. Thus, from the series of semi-IPNs reported here, with variable properties, an appropriate composition may be chosen depending on the end application, e.g., preparation of fiber reinforced composites, nanocomposites, coatings, membranes for gas separation, etc.

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