

# Pseudothermoset Blends of Poly (methyl methacrylate) and Polypyrrole Morphological, Thermal, and Conductivity Studies

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**ABSTRACT:** Blends of poly (methyl methacrylate) (PMMA)/Polypyrrole (PPy) were synthesized by emulsion polymerization of methyl methacrylate (MMA) and *in situ* oxidative polymerization of pyrrole (Py) with varying concentrations of Py and ferric chloride. The influence of the varying concentrations of ferric chloride, Py, and MMA on the morphological, spectral, thermal, and conductance characteristics of the blends were investigated. Hydrogen bonding between PPy and PMMA was inferred from FTIR studies that indicate blend formation. DSC and TGA analysis of the blends were done. A curious thermal behavior was observed that the blends lost their elasticity and flexibility on heating and turned into rigid and brittle material. DSC thermogram did not show glass transition temperature, in-

dicating molecular and chain reorganization on heating. We have therefore called these blends pseudothermoset. The physicomechanical characteristics of the films of the blends were found to deteriorate with the increased ratio of ferric chloride in the blend, causing a decrease in the conductivity. Maximum conductivity (percolation threshold) was found at 14 wt % loading of Py in the blend ( $1.6 \times 10^{-3} \text{ S cm}^{-1}$ ), which was further correlated with the morphology of the films. © 2004 Wiley Periodicals, Inc. *J Appl Polym Sci* 93: 82–91, 2004

**Key words:** pseudothermoset; conducting polymers; blends; polypyrrole; emulsion polymerization

## INTRODUCTION

Polypyrrole (PPy), polyaniline, and other conducting polymers were intensively investigated over the past two decades because of their wide scope of applications in various technologies.<sup>1–10</sup> Poor processibility of these conducting polymers, however, have restricted their applications. Efforts have been ongoing to improve the processing and mechanical properties of these polymers by formulating blends and composites with nonconducting thermoplastic polymers.<sup>11–21</sup> Considerable scope of application of the electrical properties of polymeric blends and composites has prompted several researchers to develop a relationship that can explain the electrical properties of these composites and blends with the processing characteristics, morphology, and composition.<sup>15</sup> Much attention has been focused on the method of preparation of these conducting blends, which predominantly influences their conducting behavior. Methods of blending such as mechanical mixing, solution casting, or the synthesis of interpenetrating network are generally adopted.<sup>17,22–24</sup> The conductivity of the blends was

found to be in the range of  $10^{-5}$ – $10^{-1} \Omega^{-1} \text{ cm}^{-1}$ , depending on the morphology, type of dopant, and other variables.<sup>6</sup> Blends of PPy/polyaniline with nonconducting thermoplastic polymers exhibit a dramatic increase in conductivity by several orders of magnitude at a certain concentration range referred to as the percolation limit. Various statistical, geometrical, and thermodynamic models of conductivity and percolation were proposed but no general theory exists that can explain the experimentally observed results.<sup>25–26</sup>

Much work has been reported on the poly(methyl methacrylate) PMMA/PPy composites.<sup>27–30</sup> The conductivity of these composites lies in the range  $10^{-5}$ – $0.18 \Omega^{-1} \text{ cm}^{-1}$ .<sup>31</sup> Recently, nanocomposites of PMMA/PPy were reported by using mesoporous silica template.<sup>32</sup> Literature survey reveals that the effect of the varying concentrations of dopant (ferric chloride) on the physicomechanical, thermal, electrical, as well as the morphological characteristics of the composites has not been investigated, whereas it has been extensively investigated in the case of pure PPy. It was noticed that in the preparation of the composites PMMA was used as matrix and PPy was incorporated into it by different methods at a fixed concentration of ferric chloride.<sup>33–34</sup> The simultaneous polymerization of pyrrole (Py) and methyl methacrylate (MMA) was not carried out<sup>31,35</sup> and the effect of the variation of concentration of Py with respect to PMMA as well as variation of the concentration of ferric chloride with

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respect to Py was not investigated. It was also noticed that most of the PMMA/PPy composites show thermoplastic behavior.<sup>31</sup> Interestingly, the thermoset behavior of PMMA/PPy composites was not reported so far.

The present work reports the synthesis of PMMA/PPy composite by controlled emulsion polymerization of PMMA and oxidative polymerization of Py with varying concentrations of Py and ferric chloride as well as their characterization. The blends obtained were cast into films. Conductivity, XRD, spectral, thermal, as well as morphological studies of the films were undertaken. It is expected that the study would shed more light of the role of ferric chloride and PPy on the properties of the composite.

## EXPERIMENTAL

Py (Merck, Darmstadt, Germany) was distilled twice under reduced pressure and stored in a refrigerator prior to use. MMA (Merck) was made inhibitor-free by washing with 5% NaOH followed by distilled water to remove the alkali. Water from the monomer was removed by dehydrating over anhydrous sodium sulfate. Sodium laurylsulfate (Aldrich, St. Louis, MO) was of analytical grade. Anhydrous ferric chloride and potassium persulfate were of analytical grade (S.D. FineChem Ltd., Boisar, India) and were used as received.

### Preparation of the blends

Blends of PMMA/PPy were synthesized by emulsion polymerization. Twenty milliliters of distilled water was added into a four-necked round-bottom flask fitted with nitrogen inlet tube, thermometer, and electrical stirrer maintained at  $65 \pm 1^\circ\text{C}$ . MMA (4.4 ml), potassium persulfate (0.01 g), and sodium laurylsulfate (0.03 g) were added to the flask in the above order. The reaction was carried out for 1 h, and the mixture was cooled to  $30 \pm 1^\circ\text{C}$ . Py (2.8 g) was then added dropwise along with ferric chloride (6.8 g) with continuous stirring at  $30 \pm 1^\circ\text{C}$  for about 1 h. PMMA present in the composite was then precipitated by adding aluminum sulfate (2.5%). Following the same procedure, polymerization was carried out for different molar ratios of ferric chloride : Py. The samples were purified by repeated washings with distilled water and methanol until excess of ferric chloride was completely removed (tested with potassium ferrocyanide). The pure composites so obtained were then dried for 8 h in a vacuum oven maintained at  $60^\circ\text{C}$ .

### Preparation of films

Films of PMMA/PPy were prepared in solutions of *N*-methylpyrrolidone of analytical grade (Merck, In-

dia). Films were then cast by pouring the solution in a petri dish (covered properly to avoid contamination) and drying for 2–3 days. They were further heated in a vacuum oven at  $60^\circ\text{C}$  for 8 h. The films were all black in color.

### Polymer characterization

FTIR spectra of the samples were taken in KBR on a spectrometer model Impact 410 (Nicolet USA). DSC thermograms were taken on a differential scanning calorimeter model DSC-10 (TA Instruments, USA). TGA was recorded on a model TGA51 thermogravimetric analyzer (TA Instruments). Scanning electron micrographs of the films of various compositions were taken on a JEOL (JSM840) scanning electron microscope under gold film. X-ray diffractograms were recorded on X-ray diffractometer model Philips PW3710 using copper  $K\alpha$  radiations. Conductivity was measured by standard four-probe method at  $30 \pm 0.5^\circ\text{C}$ .

## RESULTS AND DISCUSSION

### FTIR spectra of the blends

FTIR spectra of some compositions of the blends were recorded. The spectra shows characteristic peak of C=O of methacrylate, C=C peak of pyrrole, heterocyclic ring peak of Py, as well as the N—H vibration peak of Py. We notice that in the blend of composition MMA : Py :  $\text{FeCl}_3 = 1 : 0.5 : 0.10$  and MMA : Py :  $\text{FeCl}_3 = 1 : 0.25 : 0.50$ , the positions of the characteristics peaks for N—H stretching vibrations appear at 3433 and  $3425 \text{ cm}^{-1}$ . C=O vibrations are observed at 1725 and  $1716 \text{ cm}^{-1}$  and N—H bending mode are found at 1661 and  $1654 \text{ cm}^{-1}$ . Other peaks are also observed to shift as the amount of PPy increases in the composite. This shows that the proton of the amino group of Py is linked to the oxygen of the carbonyl of PMMA through hydrogen bonding. Binding of PPy with PMMA through hydrogen bonding is expected to impart rigidity in the polymeric chains of PMMA, causing perceptible change in its mechanical properties, and, thereby, the mechanical properties of the blend. A similar type of bonding was reported in the case of PPy/polycarbonate (PC) and PPy/poly(vinylmethylketone) composites studied by Wang and Fernandez.<sup>12</sup>

### Film characteristics

Luster, elasticity, and toughness of the films of various blend compositions were examined visually and manually. The qualitative estimates, as will be given hereafter, provide reliable judgment about the relative difference in the above properties of the films. The film blend of composition MMA : Py :  $\text{FeCl}_3 = 1 : 0.05 : 0.10$

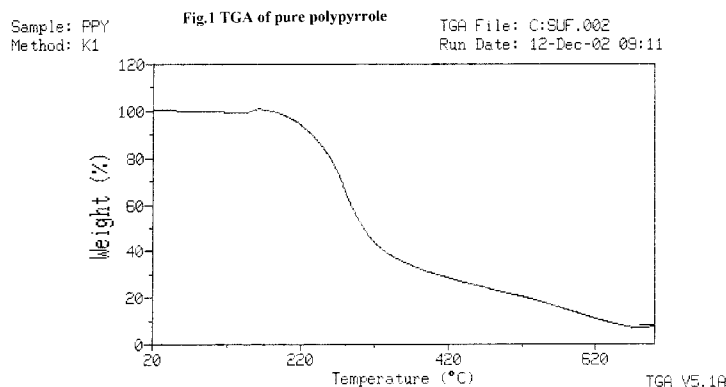


Figure 1 TGA thermogram of pure polypyrrole.

was found lustrous and flexible and highly elastic and showed fair toughness, whereas the film of composition MMA : Py :  $\text{FeCl}_3 = 1 : 0.05 : 0.2$  did not show any luster and was lesser in strength than the film of the previous composition. The film of the blend of composition, MMA : Py :  $\text{FeCl}_3 = 1 : 0.14 : 0.14$ , with an increased amount of PPy in the blend was found to be lustrous, flexible, and of higher toughness. However, the film with twice the above amount of ferric chloride and the same amount of Py, 1 : 0.14 : 0.28, was flexible, lustrous, and of lesser toughness than the former; also, the film containing four times the above amount of ferric chloride to Py, of composition MMA : Py :  $\text{FeCl}_3 = 1 : 0.14 : 0.56$ , was found to be of lower toughness than the film containing twice the amount of ferric chloride, MMA : Py :  $\text{FeCl}_3 = 1 : 0.14 : 0.28$ . Films containing 25% Py, MMA : Py :  $\text{FeCl}_3 = 1 : 0.25 : 0.25$ , showed relatively less luster and was also of lower toughness, whereas the films with ferric chloride being twice and four times the above amount of Py showed higher brittleness than the previous composition.

From the above observations, it can be concluded that the quality as well as the stiffness of the film depended upon the molar ratios of Py :  $\text{FeCl}_3$  and Py

: MMA. It was found that films of the blend with a higher proportion of ferric chloride (with two and four times the amount of PPy) were brittle and those obtained with MMA : Py > 2 showed higher toughness and possessed a smooth structure without visible defects. The ratio of ferric chloride to Py significantly influences the toughness and quality of the film. Films with a molar ratio of  $\text{FeCl}_3 : \text{Py} < 2$  are lustrous in appearance and tougher. An increase in the relative amount of ferric chloride above this ratio results in the deterioration of the physicomechanical properties of the films; they lose their luster and smooth appearance. The poor physical characteristics of these films would expectedly impede the migration of the charge carriers and would reduce the conductance of the films. We have actually observed the above effect.

#### Thermogravimetric analysis

The TGA thermogram of pure PPy (Fig. 1) shows a sluggish decomposition curve spreading from 170–420°C, although final decomposition is observed at 670°C, leaving a residue of about 6 wt %. Fifty percent weight loss is found to occur at 300°C, whereas 80% weight loss is observed at 520°C. We have found that

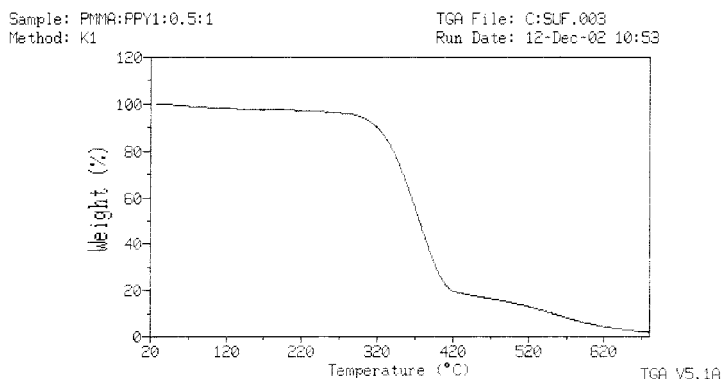


Figure 2 TGA thermogram of blend of composition MMA : Py :  $\text{FeCl}_3 = 1 : 0.5 : 1$ .

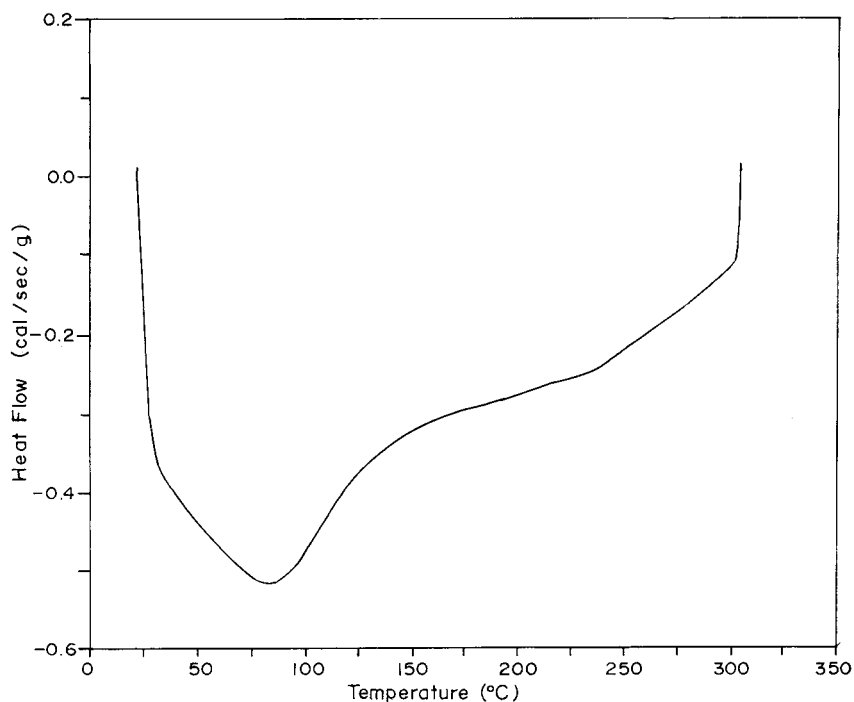


Figure 3 DSC thermogram of pure polypyrrole.

pure PMMA shows a steep decomposition curve spreading between 280 and 400°C. The TGA thermogram of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.5 : 1.0 (Fig. 2) shows a slanting decomposition curve spreading between 280 and 420°C, whereas complete decomposition occurs at 670°C. The residue left is hardly 3%. The 50% weight loss is observed at 380°C and 80% weight loss occurs at 420°C. We thus observe that the decomposition rate of the blend is faster than that of pure PPy; the spread of the decomposition curve of the blend is reduced by almost 100°C. Moreover, in the case of pure PPy, the decomposition curve is of the shape of a skewed inverse S, showing that both in the beginning as well as near completion, the decomposition is fairly slow as compared to the decomposition in the middle. Compared to the decomposition of pure PPy (Fig. 1), the decomposition of the blend (Fig. 2) is fairly uniform throughout the whole decomposition range. The disposition of the TGA curve of the blend clearly indicates that PMMA and PPy are intimately mixed and are also bonded to each other. Omastova and coworkers<sup>33</sup> also prepared the PMMA/PPy composites adopting a different method. Similar to their case, the composite prepared by us also shows maximum decomposition at about 420°C, leaving a residue of 3%. However, the PPy prepared by them showed a different thermal behavior from the one prepared by us. They measured a 76% residue at 695°C, showing that only small decomposition of PPy took place up to the above temperatures. The above authors have, however, not reported any change in the morphology

and physical characteristics when the films are heated, which is an important aspect of this study.

### DSC

DSC thermograms of some selected blends were recorded. The thermogram of pure PPy (Fig. 3) shows an endothermic peak at 84.5°C, which can be correlated to the conformational changes in the PPy chains at this temperature. We have observed that no softening of PPy occurs at or above this temperature. The DSC thermograms of different compositions of the blends show a very wide endothermic peak that spans in the temperature range of 30–200°C. The DSC thermogram of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.14 : 0.28 and 1 : 0.05 : 0.05 (Figs. 4 and 5, respectively) shows an endothermic peak centered at 116.5°C.

We have observed that the films of the composite with 5 and 14 wt % loading of Py are fairly flexible and elastic. However, when heated above 200°C, the flexibility and elasticity of the films are lost and the films became hard and brittle. The very wide endothermic peak clearly shows considerable molecular organization when the films are heated. It appears that on heating, the polymers crosslink each other more actively through increased hydrogen bonding, which causes considerable increase in the hardness of the film and changes its nature from an elastic and flexible film into a hard and brittle material. The heated samples of the blends appear to be pseudothermosets, as in this case, hardening occurs on heating. This is a

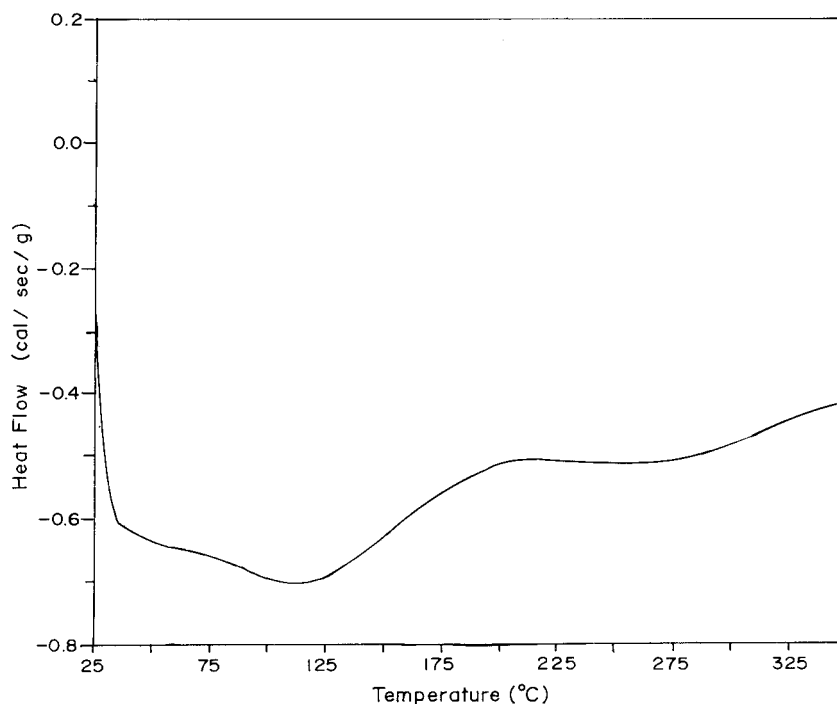


Figure 4 DSC thermogram of the blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.14 : 0.28.

very interesting phenomenon observed in these blends. These blends also do not show any glass transition temperature, although PMMA, a thermoplastic polymer, is a major constituent of the films of these blends. Moreover, the microstructure (given in a later

section) shows that the PMMA is dispersed or sandwiched between the PPy aggregates, which offers the opportunity for higher crosslinking between the two polymers at elevated temperatures to bring change in its physical state. We have carried out the XRD pow-

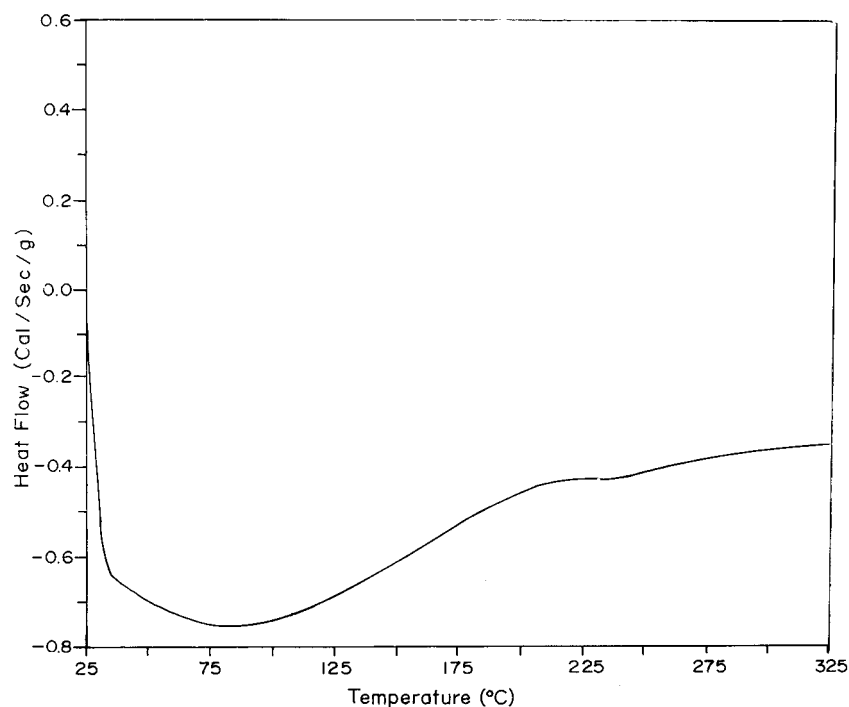


Figure 5 DSC thermogram of the blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.25 : 0.50.

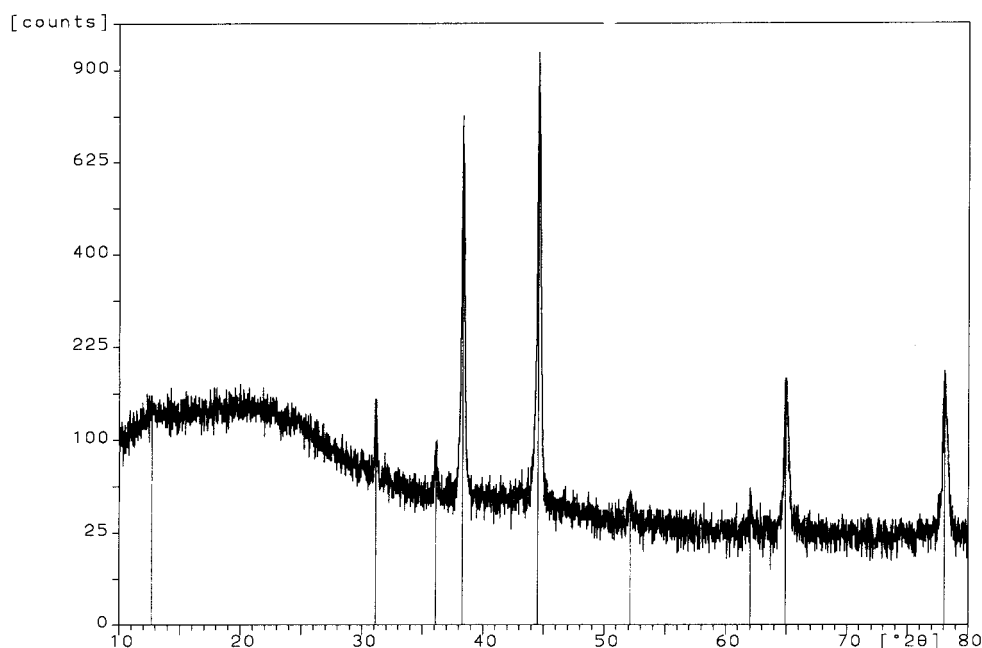


Figure 6 XRD of blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.25 : 0.50 as prepared.

der diffraction of the blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.25 : 0.50, which also confirms the above conclusion.

#### XRD

The XRD (Fig. 6) of the blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.25 : 0.50 shows a broadly amorphous structure but crystalline peaks are also

observed at  $2\theta$  values equal to 12.700°, 31.120°, 36.105°, 38.285°, 44.525°, 52.130°, 62.030°, 64.915°, and 78.050°. However, between these peaks, there are wide amorphous disordered regions in the blend. It can be inferred that PMMA chains are packed in an ordered manner with different planar spacings along with amorphous regions. Because PPy does not show any crystallinity (Fig. 7), whatever crystalline regions are observed are due to the

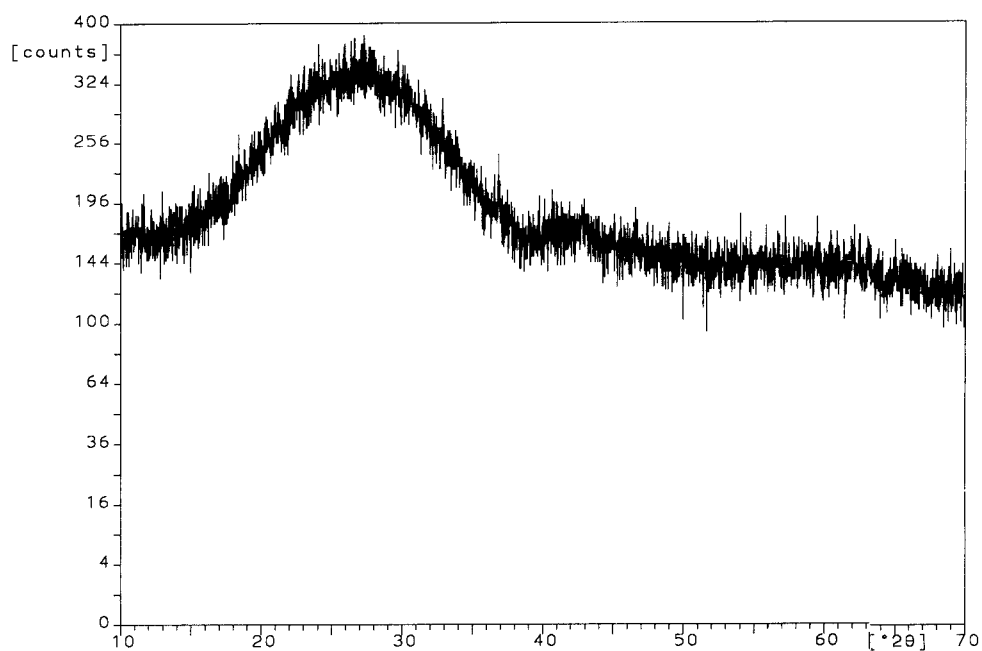
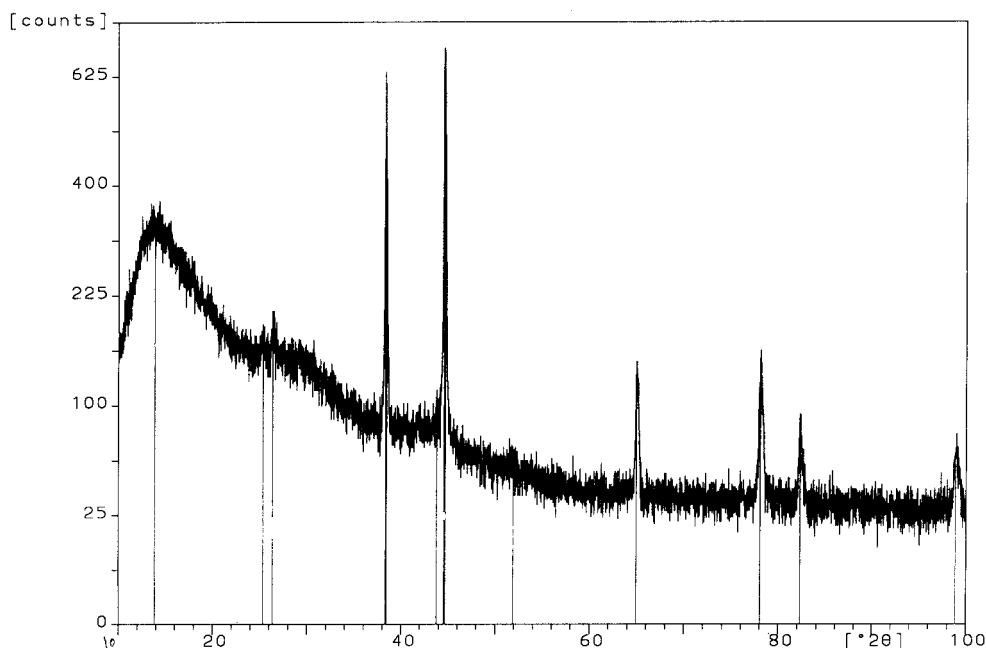


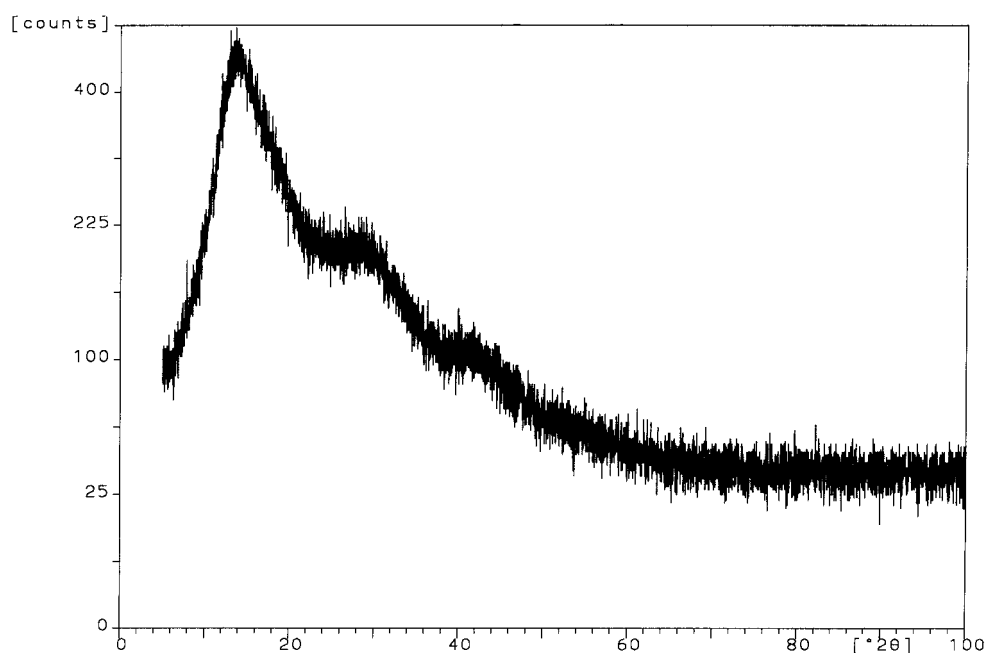
Figure 7 XRD of pure polypyrrole.



**Figure 8** XRD of blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.25 : 0.50 heated at 125°C.

PMMA phase. It is also observed that when the blend was heated up to 125°C (Fig. 8), a change occurred in the XRD spectra of the blend and three new peaks were formed at  $2\theta$  values equal to 25.310°, 26.370°, and 43.750°. Moreover, the peaks observed at 31.120° and 36.105° disappear. Shifting of peaks also occurs; the low-angle peak of  $2\theta$  at 12.700° shifts to 13.835° and the peak at 52.130° shifts to 51.880°. This indicates that the heating of

the blend up to this temperature brings about only a phase change, whereas on further heating at 175°C (Fig. 9), the XRD shows the collapse of the ordered domains and amorphization of the blend. We have noticed that the DSC thermogram of the blend (Fig. 5) showed a broad endothermic peak centered at 94.7°C but extending up to 200°C. The broadness of the peak confirms a solid–solid type phase transformation up to this temperature as also indicated by



**Figure 9** XRD of blend of the same composition after heating at 175°C.

**TABLE I**  
**Conductivity of PMMA/PPy Composites**  
**of Different Compositions**

Composition of blends (MMA : Py : FeCl <sub>3</sub> )	Conductivity $\sigma$ (S cm <sup>-1</sup> )
1 : 0.05 : 0.05	$5.4 \times 10^{-4}$
1 : 0.05 : 0.10	$3.3 \times 10^{-4}$
1 : 0.05 : 0.20	$1.1 \times 10^{-5}$
1 : 0.14 : 0.14	$1.8 \times 10^{-3}$
1 : 0.14 : 0.28	$1.6 \times 10^{-3}$
1 : 0.14 : 0.56	$6.5 \times 10^{-4}$
1 : 0.25 : 0.25	$4.5 \times 10^{-4}$
1 : 0.25 : 0.50	$2.6 \times 10^{-4}$
1 : 0.25 : 1.00	$8.6 \times 10^{-5}$
1 : 0.50 : 0.50	—
1 : 0.50 : 1.00	$2.2 \times 10^{-4}$
1 : 0.50 : 2.00	$5.2 \times 10^{-5}$

XRD (Fig. 9). It can thus be concluded that the presence of PPy in the PMMA hampers the glass transition of PMMA.

### Conductivity studies

Table I shows the conductivity of PMMA/PPy blends obtained with different composition ratios of MMA : Py : FeCl<sub>3</sub>, determined by standard four-probe method. The blends with 5, 14, 25, and 50 wt % loading of PPy in PMMA with FeCl<sub>3</sub> : Py molar ratio varying as 1 : 1, 2 : 1 and 4 : 1 were prepared. We found the conductivity of blends with 5 wt % loading of PPy and FeCl<sub>3</sub>:Py molar ratios as 1:1, 2:1, and 4:1 is equal to  $5.4 \times 10^{-4}$ ,  $3.3 \times 10^{-4}$ , and  $1.1 \times 10^{-5}$  S cm<sup>-1</sup>. With the increase in the molar ratio of FeCl<sub>3</sub> : Py, the conductivity decreases slightly, but when the molar ratio of FeCl<sub>3</sub> : Py is equal to 4 : 1, it decreases by an order of magnitude. In fact, the same trend of change in the conductance with regard to FeCl<sub>3</sub> : Py ratio was found in the case of blends with higher loading of PPy. Thus, with 14 wt % loading of PPy, the conductivity of samples with FeCl<sub>3</sub> : Py equal to 1 : 1, 2 : 1, and 4 : 1 was found to be  $1.8 \times 10^{-3}$ ,  $1.6 \times 10^{-3}$ , and  $6.5 \times 10^{-4}$  S cm<sup>-1</sup>, respectively. It was also found that as the loading of PPy in the blend was increased from 5 to 14 wt %, the conductivity increased by an order of magnitude. However, with 25 wt % loading of PPy in the blend, the conductivity was found to decrease by an order of magnitude (Table I). The above results clearly show that the best conductance was found when the ratio of FeCl<sub>3</sub> : Py was 1 : 1 and, when this molar ratio was increased, the conductance was found to decrease. Some authors reported that as the molar ratio of FeCl<sub>3</sub> : Py is increased from 1 : 1 to 4 : 1, the conductance increases continuously.<sup>36</sup> In fact, these results were obtained with neat PPy. Omastova et al.<sup>33</sup> reported the conductance of the composite of PPy/PMMA in the range of  $10^{-10}$ – $10^{-2}$  S cm<sup>-1</sup> and

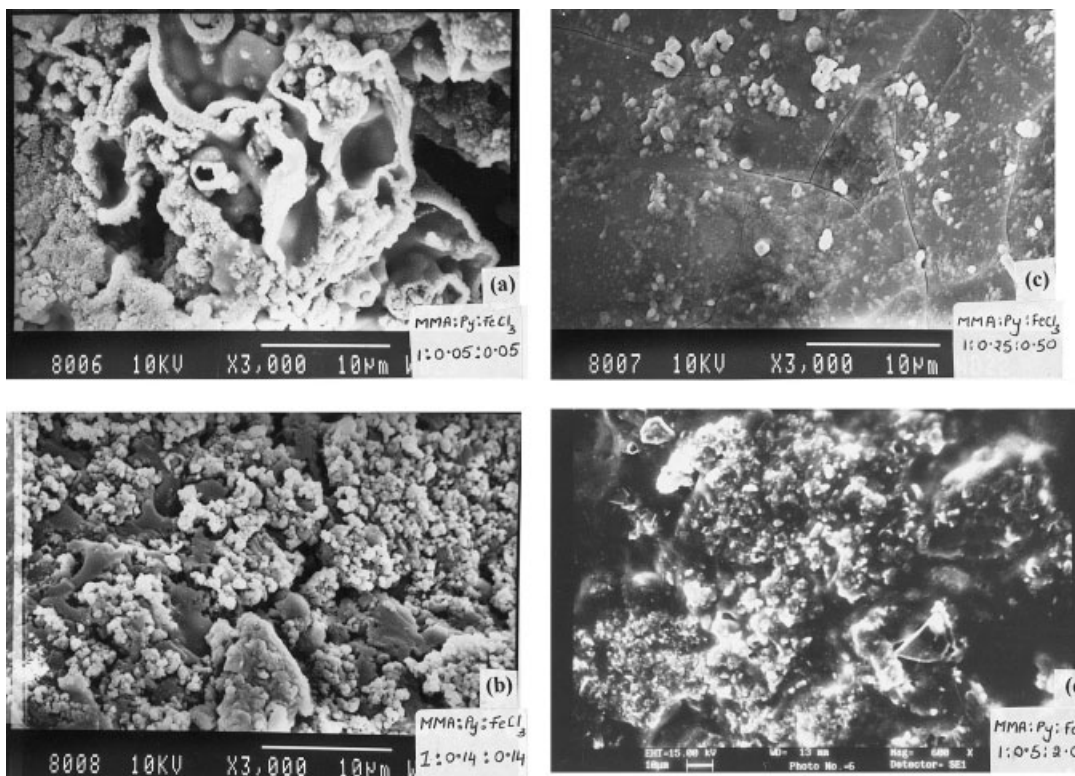
achieved maximum conductance when FeCl<sub>3</sub> : Py ratio was equal to 2:1, the values being in the same range as we have found. They have, however, not studied the effect of varying ratios of FeCl<sub>3</sub> to Py on the conductance.

It was also observed that, even with 5 wt % PPy in the composite, conductance was relatively high. We attribute this to the blend formation. Composites of PPy/PC and PPy/PVMK prepared by Wang and Fernandez<sup>12</sup> showed the percolation limit at 8–10 wt % PPy. They have attributed this low value to a greater degree of miscibility originating from hydrogen-bonding interactions of N—H group in PPy with C=O group in PVMK. We found maximum conductance in the blend containing 14 wt % PPy. Above this limit, the conductance was found to decrease. It is interesting to note that percolation limit in our case is close to the threshold value predicted by percolation theory (16 vol %) and is much lower than that reported for statistical blends (20 wt %).<sup>37,38</sup> Our results are not in agreement with those obtained by Mandal and Mandal,<sup>35</sup> as the PMA/PPy IPN composites prepared by them show no evidence of interaction despite having a low percolation limit of 4.2 wt % at 30°C. We attempted to correlate the conductance of the above blends with the morphology of their films in the following section.

### SEM studies

SEM micrographs of blend of composition MMA : Py : FeCl<sub>3</sub> = 1 : 0.05 : 0.05 with 5 wt % loading of PPy and with molar ratio of FeCl<sub>3</sub> : Py equal to 1 : 1 [Fig. 10(a)] shows distinctively two phases : one appearing bright with large floral aggregates and interconnected with each other, while the other phase, looking dark and structureless, surrounded by the bright phase. The conductivity of this composition was found to be  $5.4 \times 10^{-4}$  S cm<sup>-1</sup>. On the basis of the results of XRD, the bright phase, which shows structures, can be correlated with PMMA and the structureless dark phase, with PPy. This morphology also indicates that the films would be flexible and stiff as was actually found. The blend with 14 wt % loading of PPy [Fig. 10(b)] shows considerable decrease in the agglomerate size of the bright phase. The bright phase appears to be surrounded by the dark phase. There seems to be fair interconnectivity between the regions of the dark phase. The conductance of this composition of the composite was found to be  $1.8 \times 10^{-3}$  S cm<sup>-1</sup>. This morphology distinctively indicates a flexible and tough structure of the films, which was actually observed. In the case of the composite with 25 wt % loading of PPy and FeCl<sub>3</sub> : Py molar ratio as 1 : 1 [Fig. 10 (c)], the micrograph shows different-sized particles ranging from minute to fair-sized aggregates distributed intimately in the dark phase. Conductance in this





**Figure 10** SEM micrographs of fractured surfaces of the films of composites. (a) MMA : Py : FeCl<sub>3</sub> = 1 : 0.05 : 0.05; (b) 1 : 0.14 : 0.14; (c) 1 : 0.25 : 0.25; (d) 1 : 0.5 : 2.0.

case was found to be  $4.5 \times 10^{-4} \text{ S cm}^{-1}$  lower from the previous composition, although the dark conductive phase in this case appears to be predominant. We infer that because of the intimate distribution of the non-conductive phase of varying sizes in the former phase, the resistance to the flow of current is significant, which may have caused the decrease in the conductivity of this composition. This morphology also accounts for the rigidity and brittleness of the films of the blend of this composition. With 50 wt % loading of PPy in the blend and FeCl<sub>3</sub> : Py molar ratio equal to 2 : 1 [Fig. 10(d)], SEM micrograph shows dense distribution of particles of extremely fine to a little larger size of the bright phase in the apparently continuous dark conductive phase. The conductivity of this composition was found to be still lower at  $5.1 \times 10^{-4} \text{ S cm}^{-1}$ . It appears that at higher loading of PPy, the size of PMMA particles largely become extremely fine and their intimate distribution in the matrix offers good resistance to the flow of current, causing a decrease in the conductance of the blend. In this case also, morphology indicates higher rigidity of the films as has actually been found. It can further be concluded that the microstructure of the blend explains very well its mechanical and electrical properties.

### CONCLUSION

The effect of the relative concentration of ferric chloride, Py, and MMA on the conductivity morphology

and mechanical characteristics of PMMA/PPy blends was observed. Maximum conductivity of the blend prepared by the method used in this study was found to be  $1.6 \times 10^{-3} \text{ S cm}^{-1}$  at 14 wt % loading of PPy, with the molar ratio of FeCl<sub>3</sub> : Py being unity, which can be taken as the percolation threshold. Increasing the molar ratio of FeCl<sub>3</sub> : Py from unity to higher values causes a decrease in the conductance of the blend instead of an increase, which was found by some authors. The conductivity decreases by an order of magnitude when the molar ratio of FeCl<sub>3</sub> : Py increases from 1 : 1 to 4 : 1 at any loading of PPy in the blend. The mechanical and physical properties of the films also deteriorate when the molar ratio of FeCl<sub>3</sub> : Py is increased from unity to 4 : 1. The XRD and SEM show the broadly amorphous nature of the blends with part crystallinity. The blends on heating show pseudothermoset behavior confirmed by XRD and DSC. The blends do not show any glass transition on heating; instead they are transformed into a hard, brittle, and crosslinked structure through hydrogen bonding. The blends are therefore called pseudothermoset. It appears that the method and the conditions of polymerization govern the mechanical and electrical properties of the composite, including the percolation limit.

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