

Spectral, Thermal, and Electrical Properties of Poly(*o*- and *m*-toluidine)-Polystyrene Blends Prepared by Emulsion Pathway

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ABSTRACT: Conducting poly(*o*-toluidine) (POT) and poly(*m*-toluidine) (PMT) blends containing 10, 30, 50, 70, and 90 % wt/wt of polystyrene (PSt) were prepared by employing a two-step emulsion pathway. The bands characteristic of both polystyrene and POT/PMT are present in the IR spectra of POT–PSt and PMT–PSt blends. The UV-visible spectra of POT–PSt and PMT–PSt blends exhibit two bands around 313 and 610 nm, confirming that some amount of POT/PMT base is present in the blends. The EPR parameters such as line width and spin concentration reveal the presence of POT/PMT salt in the respective blends. The TGA, DTA, and DSC results suggest a higher thermal stability for the POT and PMT blends than that for the respective salts. The conductivity values of POT(70)–PSt(30) and POT(90)–PSt(10) blends are almost the same (1.1×10^{-2} and 1.3×10^{-2} S cm⁻¹, respectively) and these values are very close to that of pure POT salt, suggesting that POT can be blended with up to 30% wt/wt of PSt to improve its mechanical properties without a significant drop in its conductivity. The conductivity values of PMT–PSt blends are lower than those of the corresponding POT–PSt blends by two to three orders of magnitude, indicating that POT is a better system than PMT to prepare blends by this method. The dielectric constant and tan δ values of the blends increase with the amount POT/PMT and are greater than that of polystyrene.

Keywords: poly(*o*-toluidine) (POT); poly(*m*-toluidine) (PMT); polystyrene (PSt); blends; emulsion pathway; spectroscopy; thermal stability; conductivity

INTRODUCTION

Conducting polyaniline has attracted tremendous attention because of its unique electrical and optical properties coupled with numerous potential applications. Until recently, however, a major drawback of the conducting polyaniline has been its modest environmental stability and/or intractability, which has made its conventional process-

ing into useful products difficult. Several methods have been employed to improve its processibility. Substituted polyanilines soluble in organic solvents have been prepared such as alkyl,¹ alkoxy,² as well as alkyl-*N*-substituted polyanilines.³ Using the copolymerization approach, Chen and Hwang⁴ have very recently synthesized the first water soluble self-acid-doped polyaniline, poly(aniline-*co-N*-propanesulphonic acid aniline). Heeger et al.⁵ have doped polyaniline with functionalized surfactants such as camphorsulphonic acid and dodecylbenzenesulphonic acid to make it soluble in organic solvents and render it compat-

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ible with a wide variety of commercially available polymers.

Recently, conducting polyaniline blends and composites have generated greater interest, as they are easy to prepare and they exhibit excellent electrical, optical, and mechanical properties. The methods commonly employed for preparing polyaniline blends and composites are chemical in situ polymerization,⁶ solution blending,⁷ colloidal dispersion,⁸ and melt processing.⁹ They have also been synthesized electrochemically.¹⁰ It is surprising to note that emulsion polymerization that is industrially important is rarely employed to synthesize polyaniline. Recently, Ruckenstein et al.^{11,12} have obtained polyaniline–polystyrene and polyaniline–polymethylmethacrylate blends employing the emulsion pathway. They have also used the inverted emulsion pathway to prepare polyaniline–rubber composites.¹³ Compared to polyaniline blends and composites, poly(*o*- and *m*-toluidine) blends and composites have received much less attention. Recently, Yang et al.¹⁴ have reported the synthesis of poly(*o*-toluidine)–polypropylene composite films by chemical in situ polymerization.

In the present study, conducting poly(*o*-toluidine) (POT) and poly(*m*-toluidine) (PMT) blends containing 10, 30, 50, 70, and 90% wt/wt of polystyrene (PSt) have been prepared by employing a two-step emulsion pathway. First, a gel-like emulsion was prepared starting from a solution of polystyrene and *o/m*-toluidine in chloroform as the dispersed phase and a solution of sodium dodecylbenzenesulphonate in water as the continuous phase. Secondly, an oxidizing agent dissolved in aqueous HNO₃ was added dropwise to the emulsion with vigorous stirring to polymerize *o/m*-toluidine and to dope poly(*o/m*-toluidine) formed. The choice of the dopant was dictated by the fact that the HNO₃-doped POT and PMT salts exhibit the highest conductivity when compared to other salts.^{15,16} The blends have been characterized by (a) spectral methods such as UV-visible, FTIR, and EPR; (b) electrical measurements such as conductivity, dielectric constant, and tan δ ; and (c) thermal methods such as TGA, DTA, and DSC.

EXPERIMENTAL

Materials

o-Toluidine (Loba Chemie, India) and *m*-toluidine (Fluka) were distilled twice prior to use under

reduced pressure. Ammonium persulphate, chloroform, and nitric acid (Merck) were analytical grade reagents. Sodium dodecylbenzenesulphonate was procured from Aldrich. Polystyrene was of commercial grade.

Synthesis of POT–PSt and PMT–PSt Blends

The blends were prepared starting from an emulsion in which an aqueous solution of sodium dodecylbenzenesulphonate (NaDBS) constitutes the continuous phase and a chloroform solution of toluidine and polystyrene (PSt) as the dispersed phase. Toluidine was polymerized by adding ammonium persulphate dissolved in an aqueous solution of HNO₃ in the emulsion containing polystyrene under vigorous stirring. The initial ratio of toluidine to polystyrene required for preparing polystyrene blends containing 10, 30, 50, 70, and 90% wt/wt doped polytoluidine was determined by carrying out emulsion polymerization of toluidine under identical conditions in the absence of polystyrene. From the yields of POT–HNO₃ and PMT–HNO₃ salts, the amount of toluidine monomer required for the preparation of a given blend was calculated.

In a typical experiment, a solution of 1.9 g of NaDBS in 16 mL water was taken in a 250-mL flask. To this solution, 40 mL of chloroform solution containing 2.0 g of polystyrene and 2.7 mL of *o*-toluidine was added dropwise with stirring, when a gel-like emulsion was obtained. To this emulsion, 80 mL of 1.5 N HNO₃ containing 10.7 g of ammonium persulphate was added dropwise, with stirring to polymerize toluidine, and dope poly(*o*-toluidine) formed. The polymerization was allowed to proceed for 24 h with stirring. The blend formed was precipitated using 500 mL methanol and filtered. It was washed with 170 mL of 1.5 N HNO₃, followed by 1 L of double distilled water and dried in vacuum for 48 h. The yield of the POT (50)–PSt(50) blend obtained was 80% (see Table IV). The PMT(50)–PSt(50) blend was obtained in a similar way when *m*-toluidine was added instead of *o*-toluidine.

The POT–HNO₃ and PMT–HNO₃ salts prepared by the emulsion polymerization were converted in to corresponding bases by treatment with 0.5 M NH₄OH under vigorous stirring for 8 h. The base that separates was filtered, washed with 0.5 M NH₄OH, and dried under vacuum.

Measurements

The FTIR spectra of the samples were recorded using Bruker FTIR Multiscan 15 Sf II instrument

Table I. IR Peaks and Electronic Absorption Maxima of POT–PSt and PMT–PSt Blends

System	IR Peaks (cm^{-1})				λ_{max} (nm)	
PSt	1600 m	—	756 s	698 vs	—	—
POT–HNO ₃ salt	—	1384 vs	—	—	313	610
POT–HNO ₃ base	—	—	—	—	312	610
POT(10)–PSt(90)	1600 m	1385 w	757 s	697 vs	316	610
POT(30)–PSt(70)	—	—	—	—	315	610
POT(50)–PSt(50)	1600 w	1385 vs	756 m	697 vs	316	615
POT(70)–PSt(30)	—	—	—	—	313	610
POT(90)–PSt(10)	1590 w	1384 vs	—	696 w	313	620
PMT–HNO ₃ salt	—	1384 vs	—	—	312	610
PMT–HNO ₃ base	—	—	—	—	312	610
PMT(10)–PSt(90)	1600 m	1385 w	757 s	697 vs	309	610
PMT(30)–PSt(70)	—	—	—	—	309	610
PMT(50)–PSt(50)	1590 w	1384 w	750 m	696 vs	308	610
PMT(70)–PSt(30)	—	—	—	—	309	610
PMT(90)–PSt(10)	1590 w	1384 vs	—	696 w	308	610

employing the KBr pellet technique. The UV-visible absorption spectra of the samples were measured using an Hitachi U3400 spectrophotometer. The samples were dissolved in dimethylsulphoxide (DMSO) and then filtered. The filtrate was used for recording the spectra. For each sample, the spectra were recorded for two different portions for consistency. The EPR spectra were obtained for the solid samples using a Varian E109 spectrometer operating in the X-band. The samples were evacuated before recording the spectra to remove moisture. The g value, line width, and spin concentration of the samples were determined using charred dextrose as the standard.^{15,16} The TGA and DTA thermograms were recorded using an STA-1500 thermal analysis system (Polymer Laboratories, USA) in air atmosphere up to 900°C and at a heating rate of 10°C min⁻¹. The DSC measurements were carried out in oxygen atmosphere at a heating rate of 10°C min⁻¹ from ambient temperature to 300°C using a DuPont 9900 TA system. The electrical conductivity of the samples was measured at ambient temperature using the four-probe method (pressure contact) on pressed pellets obtained by subjecting the powder to a pressure of 50 kN. The error in the resistance measurements under galvanostatic condition using Keithley Model 220 programmable current source and Keithley Model 195A digital voltammeter is estimated to be less than 2%. The reproducibility of the results was checked by measuring (a) the resistance twice for each pellet, and (b) the resistance for a batch of two pellets for each sample. The dielectric data

for the samples were obtained using a Keithley Model 3330 LCZ meter at ambient temperature at four frequencies, 120 Hz, 1 kHz, 10 kHz, and 100 kHz. The densities of the blends were estimated for the pressed pellets obtained by subjecting the powder to a pressure of 50 kN. The mechanical strength of the pellets was determined using Shore-D hardness tester (C.V. Instruments, UK). The pellets were of equal weight (0.7 g) and pressed at a pressure of 50 kN.

RESULTS AND DISCUSSION

Spectroscopy

FTIR

The IR spectra of polystyrene (PSt), POT–HNO₃ salt, PMT–HNO₃ salt and their blends are given in Table I. The IR spectrum of POT–HNO₃ salt prepared by the emulsion polymerization exhibits six principal absorptions at 1550, 1486, 1384, 1209, 1149, and 800 cm⁻¹, as observed also for polyaniline–HCl salt.¹⁷ The high-frequency bands at 1550 and 1486 cm⁻¹ correspond to the C–C ring stretching vibrations of the benzenoid form. The sharp intense peak at 1384 cm⁻¹ is assigned to the C–H bending mode. The bands at 1209 and 1149 cm⁻¹ correspond to the C–C (or C–N) stretching and in plane C–H bending modes, respectively. The 807 cm⁻¹ band is assigned to the out-of-plane C–H bending mode. The IR spectrum of PSt shows four characteristic bands at 1600, 1493, 757, and 698 cm⁻¹.

The IR spectra of POT–PSt blends have been analyzed by monitoring the relative intensities of the peaks at 1600, 757, and 698 cm^{-1} , characteristic of the PSt and at 1384 cm^{-1} characteristic of POT– HNO_3 salt discussed above. The high-frequency band around 1490 cm^{-1} was not considered because it appears in the spectrum of both PSt and POT salt. The IR spectrum of POT (10)–PSt (90) blend almost resembles that of PSt, and the 1384 cm^{-1} band characteristic of POT is observed as a weak band. With an increase in the amount of POT in the blend, the intensity of the bands due to PSt decreases and becomes slightly broad. For example, in the IR spectrum of POT(50)–PSt(50) blend, the 1385 cm^{-1} band becomes intense, while the 757 cm^{-1} band appears as a band of medium intensity. For POT(90)–PSt(10) blend, the bands are similar to those of POT– HNO_3 salt. The spectral characteristics of PMT–PSt blends are similar to those of the corresponding POT–PSt blends.

UV-Visible

The POT– HNO_3 , PMT– HNO_3 salts and bases and the blend samples were dissolved in DMSO and the absorption spectra recorded. The absorption maxima are listed in Table I. As representative systems, the absorption spectra of POT– HNO_3 salt, its base and POT(50)–PSt(50) blend are shown in Figure 1. The absorption spectrum of POT– HNO_3 base shows two bands at 313 and 610 nm. Because only two bands were observed in the absorption spectrum of POT salt, and because the absorption spectra of POT salt and its base are similar, it indicates that the POT salt is insoluble in DMSO, and some amount of the base is also present along with the salt in solution. The POT–PSt blends also exhibit two bands around 313 and 610 nm, confirming the presence of POT in the blends. Thus, it can be concluded that some amount of POT base is always present in the blend. The spectra of both PMT– HNO_3 salt and its base exhibit two bands at 312 and 610 nm. The absorption characteristics of PMT–PSt blends are similar to those of the POT–PSt blends.

EPR

The g value, line width, spin concentration, and A/B peak ratio, that is, the ratio of the area of the positive peak to that of the negative peak of POT–PSt and PMT–PSt blends, are presented in Table II. The ambient temperature EPR spectra of POT–PSt blends show a single signal without

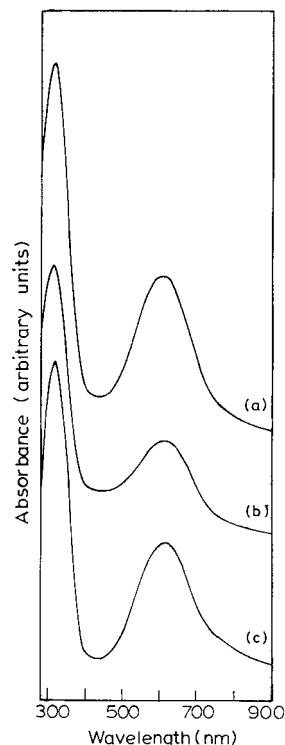


Figure 1. UV-visible absorption spectra of (a) POT– HNO_3 salt, (b) POT– HNO_3 base, and (c) POT(50)–PSt(50) blend.

hyperfine structure, as observed for POT– HNO_3 salt and its base. As representative systems, the EPR spectra of POT– HNO_3 salt, its base, and POT(50)–PSt(50) blend are shown in Figure 2. As noted from Table II, the g values of the POT salt and its base are close and, therefore, cannot be used to determine whether POT is present in the salt form or base form in the blend. However, the line width and spin concentration are well suited to determine whether POT is present in the salt form or the base form in the blend. For the POT–PSt blends, the g values are in the range 2.0015–2.0028 and the A/B peak ratios are close to unity, indicating that the spins are of the free electrons type. The line widths (1.5–2.0 G) are nearer to that of POT salt, which indicate the presence of POT in the POT–PSt blend. However, the spin concentration of POT(10)–PSt(90) blend (1.02×10^{17} spins g^{-1}) is close to that of the POT base. The spin concentration increases with the amount of POT in the blend and becomes nearly constant (10^{20} spins g^{-1}). The EPR characteristics of PMT–PSt blends are similar to those of the corresponding POT–PSt blends.

Table II. EPR Parameters of POT–PSt and PMT–PSt Blends

System	g Value	Line Width (G)	Spin Conc. Spins g^{-1}	A/B Ratio
POT–HNO ₃ salt	2.0018	1.7	1.14×10^{21}	1.1
POT–HNO ₃ base	2.0033	8.0	2.78×10^{17}	1.0
POT(10)–PSt(90)	2.0028	1.5	1.02×10^{17}	1.0
POT(30)–PSt(70)	2.0025	1.8	2.08×10^{19}	1.0
POT(50)–PSt(50)	2.0016	1.5	3.27×10^{20}	1.0
POT(70)–PSt(30)	2.0028	2.0	5.02×10^{20}	1.0
POT(90)–PSt(10)	2.0015	1.7	7.60×10^{20}	1.1
PMT–HNO ₃ salt	2.0019	1.0	4.29×10^{20}	1.1
PMT–HNO ₃ base	2.0039	8.0	3.61×10^{17}	1.0
PMT(10)–PSt(90)	2.0017	1.3	2.63×10^{17}	1.0
PMT(30)–PSt(70)	2.0017	1.8	5.95×10^{18}	1.0
PMT(50)–PSt(50)	2.0019	2.0	1.92×10^{20}	1.0
PMT(70)–PSt(30)	2.0024	2.0	2.47×10^{20}	0.9
PMT(90)–PSt(10)	2.0015	1.7	2.58×10^{20}	1.0

Thermal Stability

TGA and DTA Thermograms

The TGA and DTA thermograms for POT–HNO₃ and PMT–HNO₃ salts, their bases, polystyrene, POT–PSt, and PMT–PSt blends, were recorded in air atmosphere, and the percent weight loss and the corresponding temperature range are given in Table III. As representative systems, the TGA and DTA thermograms of POT–HNO₃ salt and POT(50)–PSt(50) blend are shown in Figure 3. The TGA thermogram of POT–HNO₃ salt exhibits a two-step weight loss in the range of 30–205°C.¹⁸ The first step (30–170°C) is assignable to the loss of moisture. In the second step (170–205°C), elimination of dopant is expected. The degradation starts near 205°C and a 7.5% residue is left around 675°C. The DTA shows a weak exotherm around 185°C and a strong one at 610°C. The TGA data for polystyrene reveal that it is stable up to 275°C. The polymer degradation commences near 345°C and goes to completion around 450°C.

The POT–PSt blends also exhibit a two-step weight loss. For POT(10)–PSt(90) blend, the first step (40–240°C) is due to loss of moisture, while the second step (240–315°C) could be attributed to the loss of dopant. The degradation starts near 315°C and goes to completion around 410°C. The DTA exhibits a sharp exotherm at 415°C corresponding to the decomposition of the blend. For the POT(50)–PSt(50) blend, the degradation commences from 290°C onwards, and around 700°C, a 10% residue is left. The DTA exhibits a weak

exotherm around 185°C, and two sharp exotherms at 345 and 490°C. For the POT(90)–PSt(10) blend, the DTA shows a weak exotherm

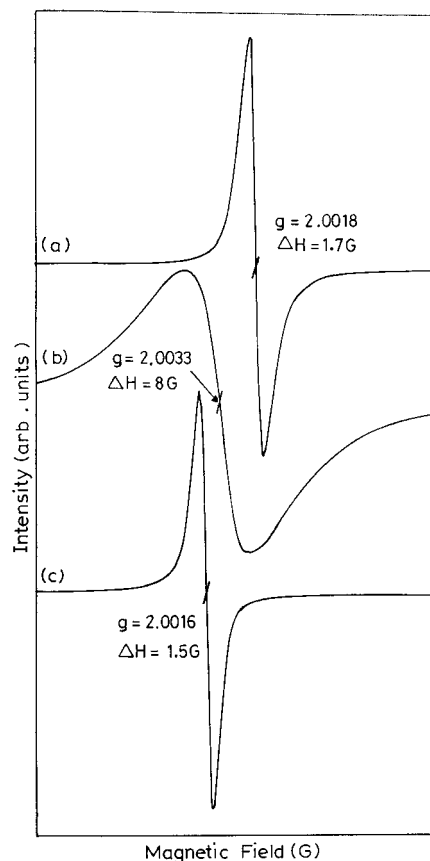


Figure 2. EPR spectra of (a) POT–HNO₃ salt, (b) POT–HNO₃ base, and (c) POT(50)–PSt(50) blend.

Table III. TGA and DSC Data of POT–PSt and PMT–PSt Blends

System	Temp Range, °C First Step	and % wt Loss Second Step	Peak Temp (°C) exo	Enthalpy Change, J g ⁻¹ exo
POT–HNO ₃ Salt	30–170 8.0	170–205 6.5	193	4409
POT(10)–PSt(90)	40–240 7.0	240–315 6.5	180	90
POT(50)–PSt(50)	30–200 5.0	200–290 2.5	185	120
POT(90)–PSt(10)	30–170 6.5	170–215 5.5	180	2805
PMT–HNO ₃ Salt	35–145 5.0	145–190 5.0	185	5040
PMT(10)–PSt(90)	40–235 6.5	235–310 7.0	180	90
PMT(50)–PSt(50)	35–210 4.5	210–300 3.0	180	120
PMT(90)–PSt(10)	35–170 6.5	170–220 5.0	190	2430

around 185°C, corresponding to the second step. The degradation commences near 215°C and a 13% residue is left around 700°C. The DTA exhibits an endotherm around 595°C. The results suggest that the thermal stability of POT–PSt blends is higher than that of POT–HNO₃ salt, and the stability decreases with an increase in the amount of POT in the blend. The thermal behavior of PMT–PSt blends is very similar to that of the POT–PSt blends.

DSC Thermograms

The DSC thermograms of the POT–HNO₃ salt and POT(50)–PSt(50) blend are shown in Fig-

ure 4 as representative systems. The DSC thermogram of POT–HNO₃ salt exhibits an endotherm around 80°C due to loss of moisture, and an exotherm around 193°C corresponding to the degradation, with an enthalpy change of 4409 Jg⁻¹. The DSC thermograms of POT–PSt blends also exhibit a weak endotherm below 100 °C and an exotherm around 180°C. The exothermic peak maxima and the corresponding enthalpy values for POT–PSt blends are presented in Table III. The energy released by the POT–PSt blends increases with an increase in the amount of POT in the blend. The DSC thermograms of PMT–PSt blends are similar to those of POT blends.

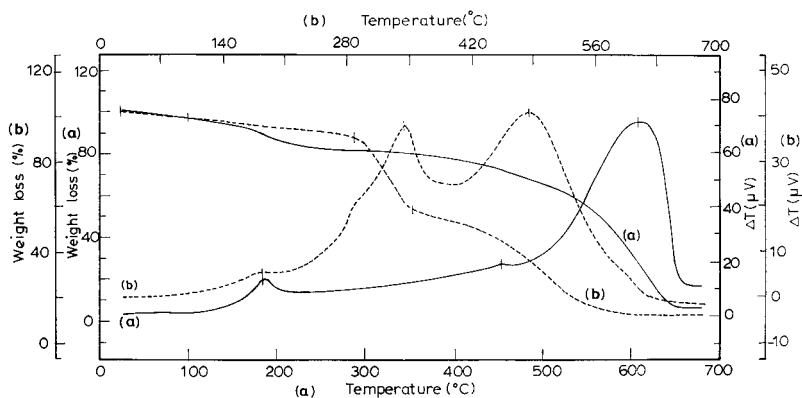


Figure 3. TGA and DTA thermograms of (a) POT–HNO₃ salt, and (b) POT(50)–PSt(50) blend.

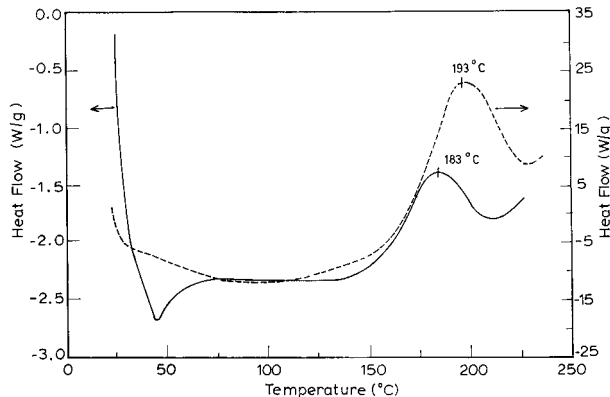


Figure 4. DSC thermograms of POT-HNO₃ salt (---) and POT(50)-PSt(50) blend (—).

Electrical Properties

Conductivity

The conductivity values of the POT-HNO₃, PMT-HNO₃ salts, and their blends with polystyrene are given in Table IV. The POT(10)-PSt(90) blend is an insulator (10^{-8} S cm⁻¹), and it is not useful. The onset of conductivity is observed with POT(30)-PSt(70) blend (8.0×10^{-4} S cm⁻¹). With an increase in the amount of POT in the blend, the conductivity of the POT-PSt blend increases and reaches a maximum value of 1.3×10^{-2} S cm⁻¹. The conductivity values of POT(70)-PSt(30) and POT(90)-PSt(10) blends are nearly the same (1.1×10^{-2} and 1.3×10^{-2} S cm⁻¹, respectively) and these values are very close to that of the pure POT-HNO₃ salt.

The conductivity characteristics of the PMT-PSt blends are similar to those of the POT-PSt blends. However, the conductivity of the PMT-PSt blend is lower than that of the corresponding POT-PSt blend by two to three orders of magnitude, showing that POT is a better system with regard to conductivity than PMT to prepare blends by this method. The conductivities of the PMT(70)-PSt(30) and PMT(90)-PSt(10) blends are lower than that of pure PMT-HNO₃ salt. From the above discussion it can be concluded that the POT/PMT salt can be blended with up to 30% wt/wt of PSt using the emulsion method to enhance its mechanical properties without significantly compromising on conductivity.

Dielectric Measurements

The dielectric constant (ϵ'_r) and dissipation factor ($\tan \delta$) of the POT-PSt and PMT-PSt blends are

given in Table V. The values given are for the POT-PSt blends containing 10, 50, and 90% of POT, as only these values show significant variation. The dielectric constant and $\tan \delta$ of POT-HNO₃ salt could be measured only at 100 kHz. The ϵ'_r is 2.9×10^4 , and $\tan \delta$ is 2.5 for the POT-HNO₃ salt. As noted from Table V, the ϵ'_r and $\tan \delta$ values of POT-PSt blends decrease with increase in frequency. The ϵ'_r and $\tan \delta$ values of polystyrene measured at 10 kHz is 2.56 and 5×10^{-5} , respectively.¹⁹ The dielectric constant and $\tan \delta$ values of POT(10)-PSt(90) blend are greater than that of polystyrene, and they increase with the amount of POT. For example, at 10 kHz, for POT(10)-PSt(90), POT(50)-PSt(50), and POT(90)-PSt(10) blends, the ϵ'_r values are 4.7×10^1 , 1.4×10^2 , and 6.2×10^2 , respectively, and the $\tan \delta$ values are 2.9, 9.4, and 9.6, respectively. It can be noted from the above results that the dielectric constant and $\tan \delta$ of polystyrene are drastically affected by blending with the POT salt. The dielectric characteristics of the PMT-PSt blends are similar to those of POT-PSt blends.

Hardness Measurements

The mechanical strength of the samples was estimated by hardness measurements. The hardness of PSt is 87, while that of pure POT salt is 70. The value of hardness of the POT(10)-PSt(90), POT(50)-PSt(50), and POT(90)-PSt(10) blends is 83, 80, and 75, respectively. The mechanical strength of the blends is higher than that of pure conducting POT salt, and it increases with an in-

Table IV. Conductivity, Yield, and Density of POT-PSt and PMT-PSt Blends

System	Conductivity (S cm ⁻¹)	Yield (%)	Density (g cm ⁻³)
POT-HNO ₃ salt	1.4×10^{-2}	75.7	1.28
POT(10)-PSt(90)	$<10^{-8}$	79.3	0.92
POT(30)-PSt(70)	8.0×10^{-4}	79.7	0.96
POT(50)-PSt(50)	1.7×10^{-3}	80.1	0.98
POT(70)-PSt(30)	1.1×10^{-2}	82.5	1.25
POT(90)-PSt(10)	1.3×10^{-2}	77.1	1.27
PMT-HNO ₃ salt	6.5×10^{-3}	74.7	1.25
PMT(10)-PSt(90)	$<10^{-8}$	78.0	0.92
PMT(30)-PSt(70)	1.4×10^{-6}	79.1	1.01
PMT(50)-PSt(50)	2.4×10^{-5}	88.3	1.10
PMT(70)-PSt(30)	3.7×10^{-5}	82.9	1.18
PMT(90)-PSt(10)	1.2×10^{-4}	84.1	1.21

Table V. Dielectric Constant (ϵ_r') and Dissipation Factor ($\tan \delta$) Values of POT–PSt and PMT–PSt Blends

System	120 Hz	1 kHz	10 kHz	100 kHz
	ϵ_r' and $\tan \delta$			
POT–HNO ₃ salt	—	—	—	2.9×10^4
	—	—	—	2.5
POT(10)–PSt(90)	4.3×10^2	8.9×10^1	4.7×10^1	2.2×10^1
	2.4×10^1	1.4×10^1	2.9	1.2
POT(50)–PSt(50)	8.0×10^2	2.3×10^2	1.4×10^2	9.7×10^1
	1.0×10^2	8.8×10^1	9.4	1.4
POT(90)–PSt(10)	1.1×10^4	2.5×10^3	6.2×10^2	1.9×10^2
	1.7×10^2	9.4×10^1	9.6	1.5
PMT–HNO ₃ salt	—	—	—	3.2×10^4
	—	—	—	2.3
PMT(10)–PSt(90)	7.0×10^1	4.4×10^1	2.7×10^1	2.1×10^1
	5.6	0.4	0.4	0.2
PMT(50)–PSt(50)	2.9×10^2	2.2×10^2	1.3×10^2	5.2×10^1
	9.5×10^1	8.4×10^1	1.4×10^1	1.9
PMT(90)–PSt(10)	7.2×10^3	4.1×10^3	2.9×10^3	1.9×10^3
	1.6×10^2	9.4×10^1	5.1×10^1	2.0

crease in the amount of PSt. A similar behavior was noted for PMT–PSt blends. The hardness of PMT salt is 68. The value of hardness of the PMT(10)–PSt(90), PMT(50)–PSt(50), and PMT(90)–PSt(10) blends is 81, 79, and 76, respectively.

Yield and Density

The yield of POT–PSt and PMT–PSt blends lie in the range of 77.1–82.5% and 78.0–88.3%, respectively (Table IV). These values demonstrate that the emulsion pathway is suitable for preparing conducting polymer blends in good yield in the powder form. The density of the POT(10)–PSt(90) and POT(30)–PSt(70) (0.92 and 0.96 g cm^{-3} , respectively) is close to that of polystyrene (1.04 g cm^{-3}) (Table IV). The density of the POT–PSt blend increases with the amount of POT, and reaches a maximum of 1.27 g cm^{-3} , which is close to that of pure POT salt. A similar behavior was noted for PMT–PSt blends (Table IV).

CONCLUSIONS

The spectral studies confirm the presence of POT/PMT in the blends at all the compositions presently studied. The thermal stability of POT–PSt and PMT–PSt blends is higher than that of the pure POT and PMT salts, respectively. The dielectric constant and $\tan \delta$ values of PSt are

greatly increased by blending with POT/PMT salt. Using the present method, the POT/PMT can be blended with PSt up to 30% (by weight) to improve its mechanical strength without significant loss in its conductivity.

The authors gratefully acknowledge the financial support from the CSIR, New Delhi, under Grant No. 01 (1366)/95/EMR-II.

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