

Electrically Conductive, Melt-Processed Polyaniline/EVA Blends

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Received 21 May 2000; accepted 12 November 2000

ABSTRACT: Mechanical blends of ethylene–vinyl acetate copolymer and polyaniline doped with dodecyl benzene sulfonic acid (PAni–DBSA) were prepared in a two-roll mill at 50°C and in a Haake internal mixer at 150°C. The effects of the blend composition and processing conditions on the electrical conductivity and mechanical properties were investigated. These blends exhibited high levels of electrical conductivity at a small amount of PAni complex. Blends prepared in a two-roll mill displayed conductivity values as high as 1 S/cm and a higher protonation degree than the pure PAni–DBSA, as indicated by X-ray photoelectron spectroscopy. Two different insulator–conductor transition points were observed in these blends. The mechanical performance decreased as the amount of PAni–DBSA increased, indicating blend incompatibility and a plasticizing effect of the DBSA. The morphology of the blends were studied by scanning electron microscopy. © 2001 John Wiley & Sons, Inc. *J Appl Polym Sci* 82: 114–123, 2001

Key words: polyaniline; dodecyl benzene sulfonic acid; ethylene–vinyl acetate (EVA) blends; mechanical blend

INTRODUCTION

In recent years, considerable efforts have been made to improve the processability and mechanical properties of intrinsically conducting polymers (ICPs). Various strategies have been employed in this area. The technique based on dis-

persion of conducting polymer particles in a matrix constituted by a common, insulating polymers has received increasing attention and is very attractive because of the possibility of combining the good processability and mechanical performance of the conventional polymer with the electrical and optical properties of ICPs.^{1–4}

There is increasing interest in the development of ICP-based conducting blends with as low a concentration of the conducting filler as possible to minimize processing problems and depletion of the mechanical properties of the host-insulating polymer. The amount of the conducting filler corresponding to the insulator–conductor transition is known as the *percolation threshold point* and depends greatly on the size of the conducting par-

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Contract grant sponsor: Conselho Nacional de Desenvolvimento Científico e Tecnológico—CNPq, Coordenação de Aperfeiçoamento Pessoal de Nível Superior—CAPES, FAPERJ, Conselho de Ensino para Graduados e Pesquisa—UFRJ; contract grant number: PADCT/CNPq 620132/98; contract grant number: PADCT/FINEP 8898.0558.00.

Journal of Applied Polymer Science, Vol. 82, 114–123 (2001)
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ticles and processing conditions.^{5,6} This transition is usually very sharp when extraconductive carbon black is used as a conducting filler and may occur lightly when polyaniline (PAni) is the conducting phase.^{7,8} In the case of PAni, particles of spherical, rice grain or needlelike morphologies of varying polydispersities in size have been described.^{2,9} This complex morphology is believed to be responsible for the less sharp insulator-conductor transition in PAni-based blends.⁸

PAni is one of the most promising ICPs because of its straightforward polymerization, good environmental stability and high electrical conductivity, which can be reversibly controlled by a change in the oxidation state and protonation of the imine nitrogen groups. The main disadvantage of conductive PAni, like others ICPs, is its intractable nature, especially in the doped form. Significant progress in this area has been achieved with functionalized sulfonic acids as protonating agents.⁹⁻¹² For example, PAni doped with dodecyl benzene sulfonic acid (PAni-DBSA) can be melt- or solution-blended with conventional polymers to enable the fabrication of polymeric conducting blends with desired properties. PAni-DBSA also presents higher thermal stability than PAni doped with hydrochloric acid (HCl) and also shows good compatibility with insulating polymers because of the nature of the counteranion. The solubility and compatibility are significant when the PAni-DBSA conducting complex contains an excess of DBSA.^{8,9-16}

The use of ethylene-vinyl acetate (EVA) copolymer as the matrix for the PAni-DBSA complex is very attractive because of its excellent processability, transparency, mechanical properties, and good adhesion to other materials.¹⁷ In addition, melt blending with EVA copolymers can be performed at temperature not so high as to cause degradation of PAni.

In this article, we report on recent studies of the melt blending of EVA copolymer with PAni-DBSA in different processing conditions. The electrical conductivity of the blends was determined as a function of the PAni content for blends prepared in a two-roll mill or in a Haake internal mixer. Scanning electron microscopy (SEM) was also employed to investigate the blend morphology and X-ray photoelectron spectroscopy (XPS) was used for the determination of the protonation degree of PAni in the blend.

EXPERIMENTAL

Materials

Aniline (Ani; analytical grade, Merck, Darmstadt, Germany) was distilled twice under vacuum and stored under nitrogen in a refrigerator. Ammonium peroxydisulfate (analytical grade, Merck), HCl (analytical grade, Merck), and dodecylbenzenesulfonic acid (DBSA; technical grade, Pro-Quimica do Brasil, São Paulo, Brazil) were used without purification. EVA copolymer (18 wt % vinyl acetate; MFI = 2.3 g/10 min at 120°C) was kindly supplied by Petroquimica Triunfo S.A., Rio Grande do Sul (Brazil).

Synthesis of Conductive PAni

PAni was prepared by the oxidative polymerization of Ani in aqueous acid media (1M HCl) with ammonium peroxydisulfate as an oxidant according to the literature.¹⁸ A molar ratio of monomer to oxidant of 1:4 was used. The reaction was carried out at 0°C for 2 h. Deprotonation of PAni-HCl samples was performed by stirring the PAni-HCl powder in a 0.1M aqueous solution of ammonium hydroxide for 24 h at room temperature, thus producing the polymer in the emeraldine-base (EB) form. The resulting polymer was then dried under vacuum for 48 h at room temperature. The redoping of the PAni EB with DBSA was performed by mixing the EB with DBSA in a proportion by weight of 1:3 in an agate mortar, as described in literature.⁹ The PAni-DBSA obtained by this method had an electrical conductivity of 0.92 ± 0.2 S/cm.

Preparation of Conductive Blends with EVA

EVA was blended with PAni-DBSA in various proportions on a two-roll mill at 50°C for 10 min and at a rotor speed of 15 rpm. EVA/PAni-DBSA blends were also prepared in a Haake internal mixer (Rheomix 600) at 150°C and 50 rpm for 12 min.

Characterization

Small strips of the conductive blends (3.0, 1.5, and 0.3 cm) were prepared by compression molding at different times and temperatures. The electrical conductivity of the samples were measured with a four-probe method. A Keithley 614 electrometer (Ohio, USA) and a Keithley 224-A high-voltage supply were employed for the analysis of low-

Table I Electrical Conductivity of EVA/PAni-DBSA Blends as a Function of the PAni-DBSA Content and Molding Conditions

PAni-DBSA in the Blend (wt %)		Conductivity (S/cm)			
		Blend Compression-Molded at 100°C		Blend Compression-Molded at 150°C	
A	B	1 min	10 min	1 min	10 min
0	0	7.3×10^{-12}	7.3×10^{-12}	7.3×10^{-12}	7.3×10^{-12}
5	2.6	9.2×10^{-9}	7.9×10^{-9}	9.6×10^{-9}	1.6×10^{-9}
15	10.0	1.0×10^{-8}	8.1×10^{-8}	4.2×10^{-8}	2.9×10^{-9}
20	14.0	4.5×10^{-6}	2.4×10^{-6}	9.0×10^{-6}	8.1×10^{-8}
25	17.0	5.2×10^{-3}	3.8×10^{-4}	9.2×10^{-4}	4.9×10^{-7}
30	20.0	2.0×10^{-2}	4.8×10^{-3}	7.3×10^{-3}	2.7×10^{-6}
40	25.0	4.5×10^{-1}	3.3×10^{-1}	5.2×10^{-1}	3.9×10^{-4}
50	33.0	1.0	0.9	4.2×10^{-1}	2.1×10^{-1}

A = total amount of PAni-DBSA sample; B = PAni-DBSA conducting complex in the PAni-DBSA sample.

resistivity samples. For high-resistivity samples, a Keithley 617 electrometer was employed.

For mechanical testing, the blends were compression-molded at 100°C and 6.5 MPa for 10 min, thus producing test specimens of 40 × 40 × 2 mm. These specimens were cut by the standard ASTM D-638-34 method. Stress-strain tests were performed on a Instron model 4204 (Massachusetts, USA) at 25°C with a crosshead speed of 100 mm/min.

For SEM analysis, samples were fractured under liquid nitrogen, and the surfaces were coated with a gold vapor. Micrographs were taken with a JEOL JSM-5300 scanning electron microscope (Tokyo, Japan).

The thermal stability of PAni and the corresponding blends were investigated by thermogravimetric analysis (TGA) measurements with a NETZSCH STA 409C machine (Selb-Bavaria, Germany), operating under nitrogen atmosphere at 10°C/min, from 40 to 600°C.

XPS analyses were performed on a Kratos analytical instrument (XSAM-800) (Moscow, Russia) dual-chamber spectrometer equipped with a hemispherical electron energy analyzer and a quasianode X-ray source. The analyzer was operated in a fixed-retardation-ratio mode. The energy scale calibration and the conditions of operation were described earlier.¹⁹ To compensate for the surface-charging effects, all binding energies (BEs) were referenced to the C1s neutral carbon peak at 284.6 eV. In peak synthesis, the line width of the Gaussian peaks was maintained as constant for all components in a particular spectrum.

RESULTS AND DISCUSSION

Electrical Conductivity of EVA/PAni-DBSA Blends

Table I presents the results concerning the electrical conductivity of compression-molded EVA/PAni-DBSA blends as a function of molding time and temperature. These blends were prepared in a two-roll mill at 50°C. The PAni-DBSA sample used in this study was prepared by mechanically mixing the EB and DBSA in a proportion by weight of EB/DBSA = 1:3. It was constituted by a mixture of PAni-DBSA conducting complex and an excess of DBSA that did not participate in the doping process. With regard to the doping degree value of the conducting complex equal to 48 mol % related to all nitrogen species in the PAni chain, as determined by XPS analysis, the actual proportion of the PAni-DBSA complex responsible for the conductivity could be calculated. These values in the EVA/PAni-DBSA blends are also presented in Table I.

The dependence of the conductivity on the PAni-DBSA concentration is also illustrated in Figures 1–3. An estimated percolation threshold point at around 2.5 wt % of the conducting complex was observed, whatever the molding condition employed. Also, two different conductivity jumps were present. By the addition of a small amount of the conducting component (2.5 wt % of PAni-DBSA complex), an increasing in the conductivity of around three orders of magnitude was observed. Then, a plateau was reached, and the conductivity was constant until a PAni-DBSA concentration of around 10 wt %. After this point,

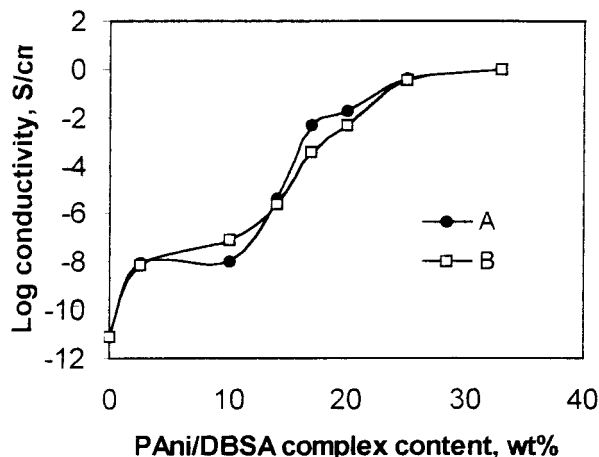


Figure 1 Effect of PANi-DBSA content on the electrical conductivity of EVA/PANI-DBSA blends compression-molded at 100°C for (A) 1 min and (B) 10 min.

there was a second transition point, and the conductivity values started to increase again with the PANi-DBSA concentration. The second transition of the conductivity level was not so sharp as the first transition stage. For blends compression-molded at 100°C, the electrical conductivity values of all blends were not influenced by the molding time (see Fig. 1). The electrical conductivity profiles were also similar for blends compression-molded at 100 and 150°C for 1 min (Fig. 2). When the blends were molded at 150°C for 10 min, the second insulator-conductor transition occurred in a lighter fashion. (Fig. 3). The lower conductivity values of EVA/PANI-DBSA blends compression-molded at 150°C were not attributed to a

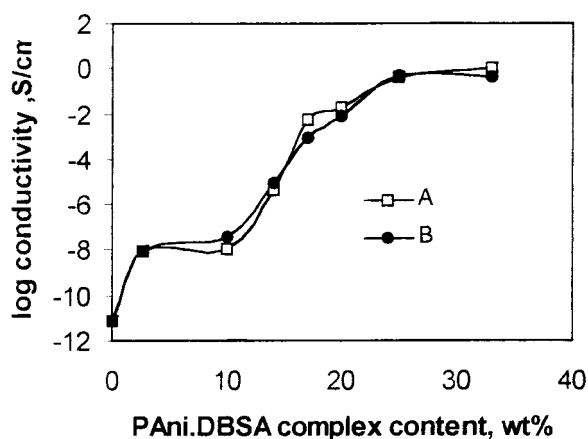


Figure 2 Effect of PANi-DBSA content on the electrical conductivity of EVA/PANI-DBSA blends compression-molded at (A) 100°C and (B) 150°C for 1 min.

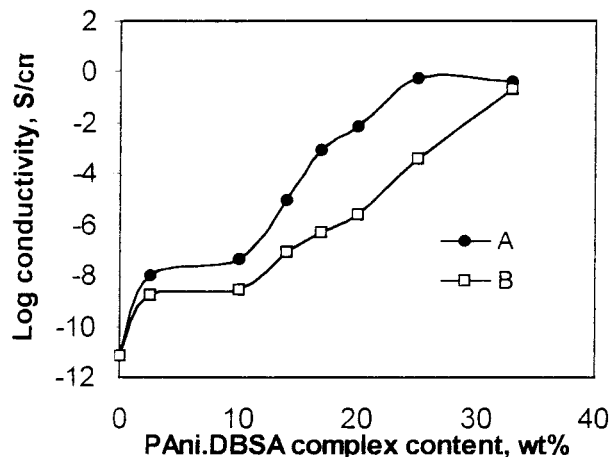


Figure 3 Effect of PANi-DBSA content on the electrical conductivity of EVA/PANI-DBSA blends compression-molded at 150°C for (A) 1 min and (B) 10 min.

thermal dedoping or degradation of the PANi-DBSA component because the blend with 33 wt % of the conducting complex displayed similar conductivity values whatever the molding conditions. These values were close to the intrinsic conductivity of the pure PANi-DBSA sample used in these blends (~ 0.9 S/cm).

A percolation threshold profile that showed two distinctly different phase transition points was also reported by Wessling for polyurethane/polyethylene glycol blends loaded with carbon black.²⁰ According to the theory proposed by Wessling, the conductivity increase phenomenon is considered a phase transition when the conductive phase is suddenly converted from the fully dispersed stage to a flocculated one. This transition point depends on the interaction between the conductive phase and the matrix. Below the critical volume concentration, the conductive phase is completely dispersed and acquires an adsorbed monolayer of matrix polymer molecules. At the critical point, the dispersed phase flocculates, forming branched elongated chains.²⁰

The peculiar percolation threshold profile found in our system may have been related to the nature of the PANi-DBSA sample. As indicated in Table I, an amount of free DBSA was always present in the PANi-DBSA sample and increased as the concentration of PANi-DBSA in the blend increased. The free DBSA acted as plasticizing agent for the EVA matrix. This phenomenon contributed to a better dispersion of the conducting particles.

When a small amount of PANi-DBSA was employed, the EVA matrix was less plasticized be-

cause of the small amount of free DBSA. As a consequence, the dispersed conducting phase flocculated, giving rise to branched elongated chains that were responsible for an increase in the conductivity of three orders of magnitude. When the PANi-DBSA concentration was increased, the EVA matrix became more plasticized, that is, less viscous, and could be adsorbed on the conductive phase, forming a shell. At the concentrations corresponding to the plateau region, the increased amount of PANi-DBSA conducting complex increased the ability of the dispersed particles to flocculate, whereas the increased amount of free DBSA favored the encapsulation of the conducting particles. These opposite effects (the dispersion-flocculation process) resulted in an equilibrium, and no significant variation of the conductivity was observed.

After the second transition point, both phenomena were still operating, but the flocculation process seemed to predominate, resulting in an increasing of the conductivity. Nevertheless, free DBSA was present in a higher proportion, and the dispersion process was considered. The oscillation of the PANi-DBSA conducting particles between the dispersed and the flocculated structure phase associated with the complex morphology of PANi, constituted by aggregates and fine particles, may have been responsible for the less sharp, second insulator-conductor transition in these blends.

This phenomenon may also explain the conductivity curve profile found in the blends compression-molded at 150°C for 10 min (Fig. 3). For this molding condition, the flow ability of the EVA matrix was enhanced. The EVA chains could penetrate through the PANi-DBSA phase in a higher extent and encapsulated a higher amount of PANi-DBSA phase, mainly the small particles. This process contributed to the peculiar conductivity profile of EVA/PANi-DBSA system as observed in Figure 3.

EVA/PANi-DBSA blends were also prepared in a Haake internal mixer at 150°C to impart a better dispersion of the conducting component within the EVA matrix. According to the data reported in literature,²¹ PANi-DBSA shows conductivity stability at this temperature. Figure 4 compares the electrical conductivity of the blends as a function of melt processing. For this study, all blends were compression-molded at 100°C for 1 min. The percolation threshold profiles of the blends showed two insulator-conductor transition points as discussed previously. The first transition occurred at around 2.5 wt % and was not

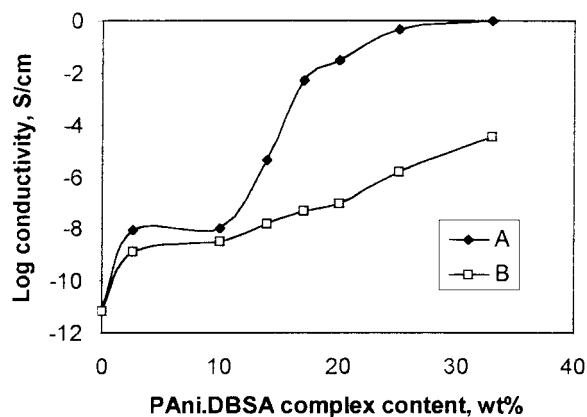


Figure 4 Effect of PANi-DBSA content on the electrical conductivity of EVA/PANi-DBSA blends prepared in (A) a two-roll mill at 50°C and (B) a Haake internal mixer at 150°C (all samples were compression-molded for 1 min).

influenced by the processing conditions. With regard to the second stage, blends prepared in a Haake internal mixer at 150°C displayed considerably lower conductivity values in all the composition ranges studied. These results indicate that a degradation of the system or a dedoping process of PANi-DBSA may have also been taking place because of the high temperature associated to the high shear stress imposed during intensive mixing. In addition, this mixing condition contributed to a higher dispersion level of the PANi particles and also to a decreasing of the viscosity of the EVA matrix. These effects favored a higher level of encapsulation of the PANi particles and, consequently, a decreasing in the conductivity.

Figure 5 illustrates the torque versus time curves for EVA copolymer and its blends with 10 and 33 wt % of the PANi-DBSA complex. During EVA processing, the torque decreased with 2 min of mixing and remained stable at 5.2 Nm until the end of the experiment [see Fig. 5(a)] The curve corresponding to the EVA/PANi-DBSA blend with 10 wt % of the conducting component displayed a small increase in the torque, reaching a value corresponding to 7.5 Nm at the end of the experiment [Fig. 5(b)]. With regard to the blend with 33 wt % of the conducting component, the curve displayed a sharp increase in the torque at around 2.4 min that corresponded to the feeding torque of PANi-DBSA. Then, it decreased quickly because of the plasticizing effect of the free DBSA in the sample. After around 3.6 min, the torque value started to increase, reaching a maximum value of about 17 Nm, and then started to de-

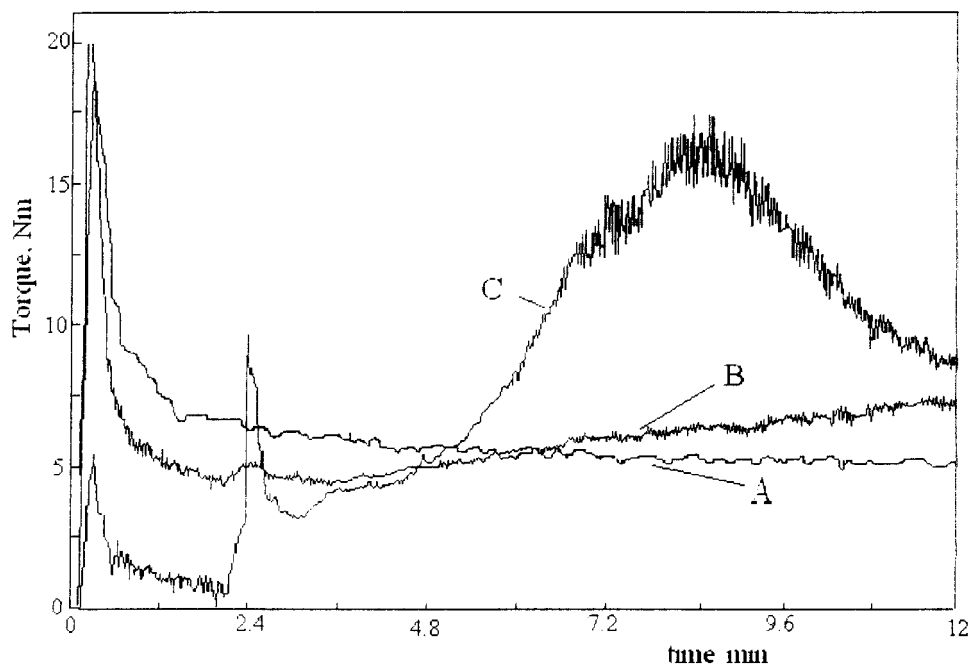


Figure 5 Torque versus time curves of (A) EVA and its blends with (B) 10 wt % and (C) 33 wt % of PANi-DBSA complex.

crease. This behavior is typical of a reaction process. Indeed, blends with a PANi-DBSA content higher than 17 wt % resulted in a material too brittle to be submitted to any mechanical testing. The typical smell of acetic acid was also perceived during the blending process, indicating a decomposition of the EVA chain, with the elimination of the acetate groups. This degradation was favored by the presence of free DBSA and by the high temperature and high shear stress.

XPS Analysis

XPS analysis constitutes a powerful tool for characterizing the doping degree of conducting PANi. From the characteristic BEs of the photoelectron, the elements involved could be identified, and the peak intensity could be directly related to the atomic concentration in the sample surface. In addition, the various intrinsic redox states of PANi and the different neutral and positive nitrogen species could be quantified from the properly curve-fitted N1s core-level spectrum.²²

Figure 6 presents the N1s core-level spectra that corresponded to the PANi-DBSA and EVA/PANi-DBSA blend (with 33 wt % of the conducting complex) prepared in a two-roll mill at 50°C and compression-molded at 100°C for 1 min. The N1s spectrum of PANi-DBSA was composed of a

peak at 399.4 eV related to amine groups and three other peaks with BEs at 400.8, 402.0, and 403.5 eV that were attributed to the positively charged nitrogens [see Fig. 6(a)]. The peak with BE at about 398.2 eV, related to imine groups, was very small, indicating the protonation of almost all the imine groups of the PANi chain, as expected. The proportion of the peaks related to the positively charged nitrogens was found to be 0.48 mol %, which corresponded to the protonation degree.

The N1s spectrum of the EVA/PANi-DBSA blend with 33 wt % of the conducting complex that were prepared in a two-roll mill showed a higher proportion of the positive nitrogens [see Fig. 6(b)]. Table II summarizes the amount of the different neutral and positive nitrogen species on the surface of the EVA/PANi-DBSA blend. The proportion of positively charged nitrogen in the blend was considerably higher than that corresponding to the PANi-DBSA sample, indicating an additional protonation during the melt blending. This phenomenon is known as *thermal doping*. The amine nitrogens had decreased substantially, suggesting that the amine units were also protonated.

The blend of similar proportion (with 33 wt % of PANi-DBSA) that was prepared in a Haake

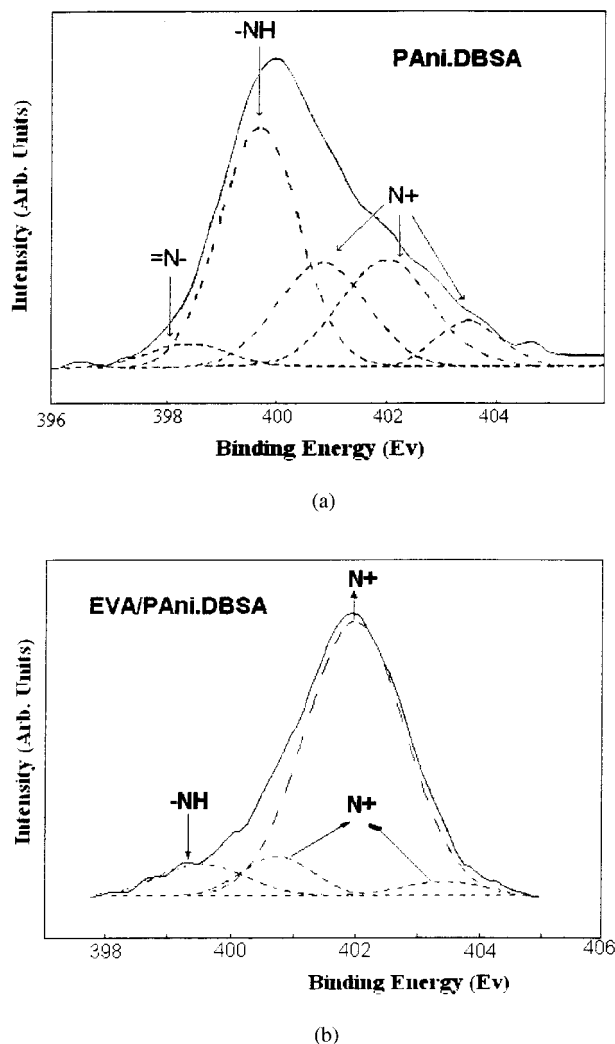


Figure 6 N1s core-level spectra corresponding to (a) PANi-DBSA and (b) EVA/PANi-DBSA that contained 33 wt % of the conducting complex and were prepared in a two-roll mill at 50°C.

internal mixer was also analyzed by XPS. Surprisingly, any signal related to the nitrogen atoms was not observed. The XPS technique is able to detect the elements situated at a surface layer at not more than a depth of about 50 Å. Therefore, the absence of the nitrogen atoms at the sample surface could be explained by the encapsulation of the PANi-DBSA particles by a thin layer of the EVA matrix. These results were in agreement with the conductivity behavior and support the idea that EVA matrix was more plasticized by the presence of free DBSA and could promote a better dispersion of the PANi-DBSA particles. In addition, the intensive mixing in the internal mixer caused a fracturing of the PANi particles. Smaller

particles could be surrounded by the EVA matrix in a higher extent. The conducting pathway was difficult to form, and the conductivity values fell.

Morphological Analysis

The effect of the PANi-DBSA addition on the morphology of the EVA/PANi blends was investigated by SEM. Figure 7 illustrates the SEM micrographs of the cryogenically fractured surfaces of the EVA/PANi-DBSA blends with 33 % of the conducting component prepared in a two-roll mill (Fig. 7A) and in a Haake Internal mixer (Fig. 7B). The conducting phase is shown as the white points in the micrograph. As shown in Figure 7(A), the PANi-DBSA domains were uniformly dispersed in the EVA matrix for blends prepared in a two-roll mill. In addition, the formation of the conducting path is evident and agrees with the results concerning electrical conductivity. This blend displayed a conductivity value similar to that of pure PANi-DBSA. The morphology of the blend prepared in the internal mixer [Fig. 7(B)] was characterized by a better dispersibility of PANi particles within the EVA matrix, apparently down to a molecular level. The continuous conductive networks were unobservable by SEM. This result agreed with the lower conductivity values found in blends prepared in a Haake internal mixer and also to the surface composition observed by the XPS technique and suggests that the intensive mixing promoted by the high shear forces in the mixer increased the fracturing level of the original PANi-DBSA particles.

TGA

TGA thermograms of PANi-DBSA and the blends of EVA/PANi-DBSA are shown in Figure 8. The PANi-DBSA thermogram (see curve B) showed a small weight loss below 100°C, presumably caused by the loss of water and low-molecular-weight oligomers. The weight loss between 230

Table II Distribution of Nitrogen Species on the Surface of EVA/PANi-DBSA Blends Obtained by XPS Analysis

	-NH-	=N-	N ⁺
PANi-DBSA	0.47	0.07	0.48
EVA/PANi-DBSA (50 : 50 wt %) blend in a two-roll mill	0.10	—	0.90

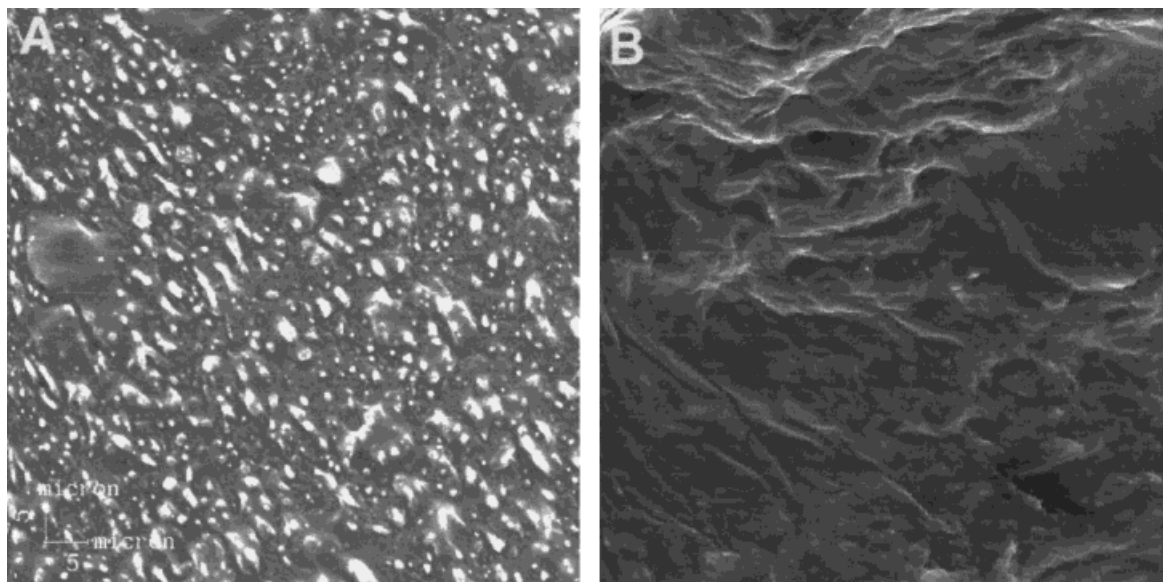


Figure 7 SEM micrographs of EVA/PANI-DBSA blends that contained 33 wt % of PANI-DBSA and were prepared in (A) a two-roll mill at 50°C and (B) a Haake internal mixer at 150°C.

and 400°C corresponded to the degradation of the PANI-DBSA main chain and also free DBSA. The TGA thermogram of EVA (curve A) showed two distinct steps of decomposition. The first step corresponded to the elimination of the acetate groups along the EVA backbone, and the second weight

loss (starting at around 400°C) was caused by the thermal decomposition of the main chain. The thermograms of the EVA/PANI-DBSA blends prepared in a two-roll mill (curve C) and in a Haake internal mixers (curve D) were similar and also showed two main steps of decomposition: the first

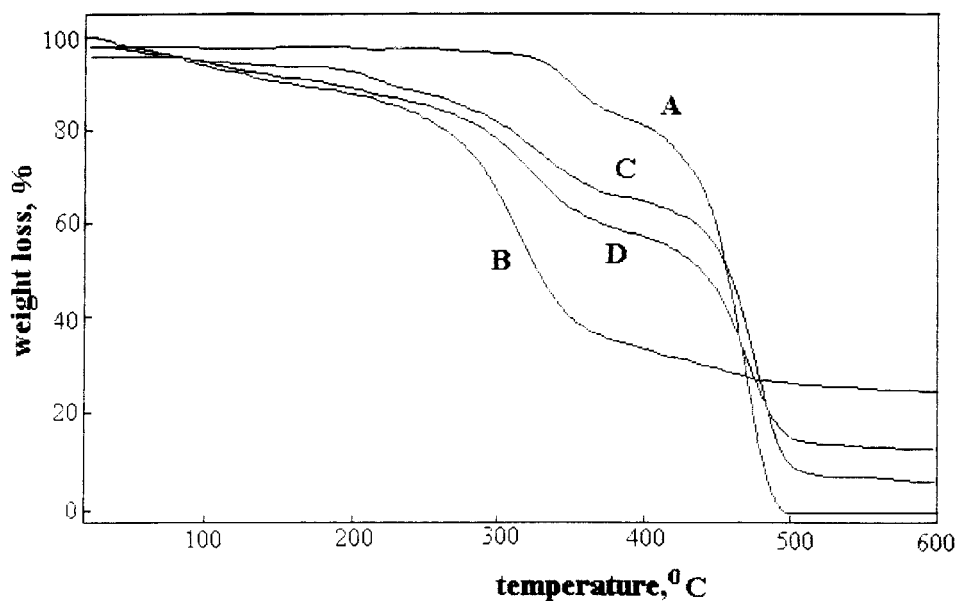


Figure 8 TGA thermograms of (A) EVA, (B) PANI-DBSA, and EVA/PANI-DBSA that contained 33 wt % of the conducting complex and were prepared in (C) a two-roll mill at 50°C and (D) a Haake internal mixer at 150°C.

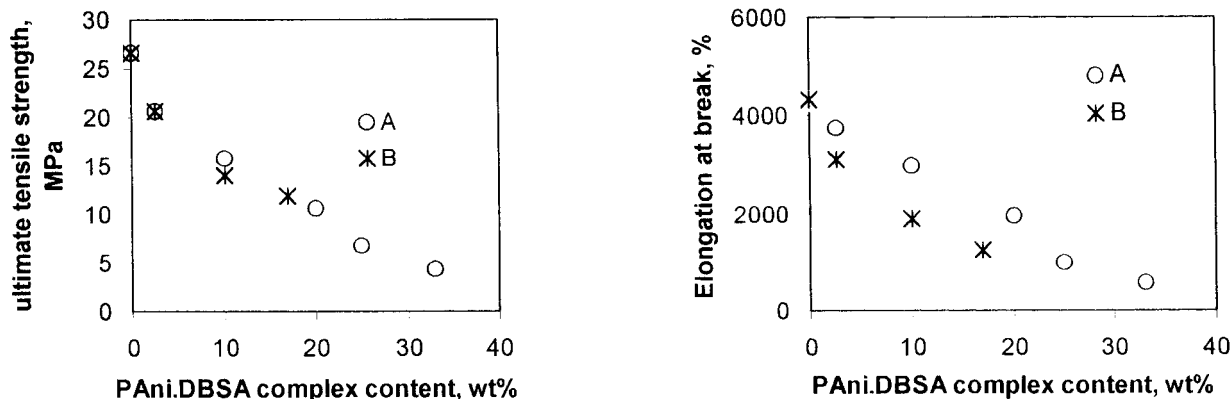


Figure 9 Effect of PANi-DBSA content on the mechanical properties of EVA/PANi-DBSA blends prepared in (A) a two-roll mill at 50°C and (B) a Haake internal mixer at 150°C (all samples were compression-molded for 1 min).

step occurred in the range between 250 and 420°C because of the thermal decomposition of the PANi-DBSA component and also the acetate groups of EVA. The second decomposition step may have been related to the EVA backbone. Because both PANi-DBSA and the acetate groups in the EVA backbone degraded at a similar temperature, it was difficult to confirm the elimination of the acetate groups during the melt-mixing of the blend in the Haake internal mixer, as suggested from the smell of acetic acid perceived during mixing.

Mechanical Properties

Figure 9 illustrates the mechanical performance of EVA/PANi-DBSA blends as a function of the conductive component composition. The ultimate tensile strength decreased considerably with the addition of a small amount of PANi-DBSA. The elongation at break also decreased, indicating that the conducting component was incompatible with the EVA matrix despite the nature of the counteranion used for PANi protonation. This behavior was more pronounced in blends prepared in a Haake internal mixer. With this processing condition, blends with a higher amount of PANi-DBSA complex (<15 wt %) were too brittle and could not be submitted to tensile testing.

CONCLUSIONS

Melt blends of PANi-DBSA in an EVA matrix presented a high conductivity level when performed in a two-roll mill at 50°C, reaching values

as high as 1 S/cm with the addition of around 33 wt % of the conducting complex. These high conductivity values were attributed to an additional doping process during mixing (the thermal doping process). Indeed, from XPS analysis, it was possible to observe the increase of the proportion of positively charged nitrogen species in the blend prepared in a two-roll mill.

The dependence of the conductivity on the PANi-DBSA content showed two percolation threshold points. The first insulator-conductor transition occurred with a small amount of PANi in the blend and was not influenced by the processing conditions. The second transition took place at around 10 wt % of PANi-DBSA and was not as sharp as the first transition. The curve profile corresponding to the second transition depended on the molding conditions. This phenomenon may have been associated with the presence of free DBSA in the blend, which acted as a plasticizing agent for the EVA matrix and contributed to a better dispersion of the conducting particles. This effect was more pronounced at higher PANi-DBSA proportions because these blends also contained higher amounts of free DBSA.

Blends performed under intensive mixing and at higher temperatures in a Haake internal mixer displayed lower conductivity values. These results could be attributed to a degradation and/or dedoping process associated with a higher level of dispersion of the PANi particles. The fracturing of the PANi aggregates in a higher extent contributed to the formation of very small PANi particles that could be easily encapsulated by the EVA matrix. This phenomenon was confirmed by XPS

analysis and SEM micrographs. With regard to XPS analysis, no peaks related to nitrogen atoms could be detected, indicating that the PANi particles were surrounded by the EVA matrix. The high dispersion level in the blends prepared in a Haake internal mixer was also observed by SEM.

From the results presented in this article, one can conclude that it is possible to develop conducting composites with acceptable mechanical performance by blending PANi–DBSA in an EVA matrix. Attempts were made to employ the PANi–DBSA conducting complex without the presence of free DBSA, but the blends resulted in a too-heterogeneous system with low conductivity values. This behavior indicates that for a good dispersion level and good conductivity, the presence of free DBSA as plasticizing agent is important. However, the dispersion of the PANi particles cannot reach too high a level to ensure the formation of the conducting path with as low a concentration of PANi as possible.

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