

Polyaniline, Ethylene Vinyl Acetate Semi-Conductive Composites as Pressure Sensitive Sensor

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ABSTRACT: This study focuses on the pressure sensitivity of ethylene vinyl acetate (EVA)/polyaniline (Pani) composites prepared through *in situ* polymerization of aniline in solutions of insulating EVA matrix. It is found that both DC and AC resistivity of the composites decreases with the increase in Pani concentration. The investigation shows that the composites senses to applied pressure through the decrease in resistivity with the increase in applied pressure. Moreover, the pressure sensitivity is also effective when the composites are kept under constant load for a period of time. Both DC and AC resistivity are found to decrease exponentially with respect to time. Relaxation time for the composites has been calculated and found that more time is required to be relaxed for the composite with lower Pani content. However, the composite with lower Pani content exhibits relatively higher change in electrical properties when subjected to both the applied pressure and time. The results show that these composites can be used as pressure sensitive sensor. © 2012 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 000: 000–000, 2012

KEYWORDS: composites; conducting polymers; sensors and actuators

Received 21 March 2012; accepted 2 June 2012; published online

DOI: 10.1002/app.38137

INTRODUCTION

Conducting polymer composites have gained a significant interest due to their practical applications in different electrical and electronic equipments as pressure, strain, temperature, dielectric, gas, organic vapor, magneto and bio sensor materials.^{1–11} Compared to metals, these composites are light in weight and flexible in nature.¹² Pani has been found to be very promising due to their monomer low cost, ease to synthesis by various polymerization techniques, and multifunctional application.^{13–16} However, the main drawback associated with Pani is that it is brittle in nature and insoluble in most of the solvents which make difficulty in its processing and various applications where some mechanical strength and flexibility are desired. This can be overcome by blending synthetic Pani with different thermoplastics.¹⁷ The electrical properties of these conducting polymer composites depend on fillers shape, size, concentration, orientation, and interfacial attraction between filler and polymer matrix.¹⁸ Polyaniline and its blends have been widely used as gas, liquid, pH, humidity, and chemical sensing materials.^{19–23} In these sensing applications polyaniline has been modified with different types of dopant. However, the reports based on the use of ethylene vinyl acetate (EVA)/Pani composites as pressure sensors materials are scanty.

Previously, the *in situ* emulsion polymerization of Pani in polymer matrices has been reported by various authors.^{24–29} Jiong-

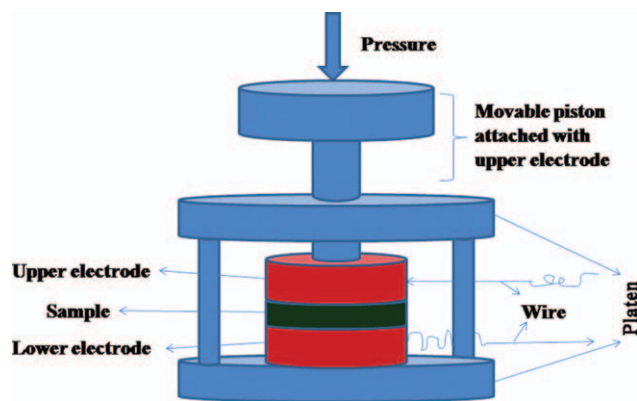
xin et al.³⁰ have investigated the electrical properties of *in situ* synthesized Pani in insulating epoxy matrix.

In our present work, *in situ* synthesis of Pani in EVA matrix has been carried at room temperature. DC and AC resistivity, and pressure sensitivity of EVA/Pani composite have been investigated with respect to Pani concentration. Scanning electron microscopy (SEM) and Fourier transform infra red (FTIR) spectroscopy for the composites have also been carried out. The effect of time under constant pressure on DC and AC resistivity has also been investigated. The results have been discussed in the light of formation and breakdown of conductive networks in the polymer matrix. The response that has obtained from EVA/Pani composite through the change of conductivity with respect to applied pressure and time reveals that these composites can serve the purpose to be used as pressure sensitive sensor.

EXPERIMENTAL

Materials

EVA Copolymer (EVA-2806, mooney viscosity, ML_{1+4} at 100°C is 20) with vinyl acetate content 28% (MFI = 6) was purchased from NOCIL, Mumbai, India. Aniline (Aldrich, Germany) was vacuum distilled before use. Ammonium peroxydisulphate (APS) (analytical grade, Merck) was used as oxidant without purification. Methanol (AR) was obtained from SISCO Research Laboratories, Mumbai; toluene (Synthetic Grade) from Merck



Scheme 1. Set up of home made electrode for pressure sensitivity measurement. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Specialities Private Limited, Mumbai, and HCl (LR) from S. D. fine – chem., Mumbai.

In situ Synthesis of Pani in EVA Matrix

The *in situ* synthesis of Pani in EVA matrix has been carried out by a standard chemical oxidative method.³¹ In a typical procedure, aniline was taken in a solution of EVA (5 gm), which was previously dissolved in 200-mL toluene. This was followed by dropwise addition of HCl in it and treated with an equimolar amount of oxidant, aqueous APS at room temperature. The addition of APS was done for 30 min. The reaction was carried out for 6 h with constant stirring and finally quenched with methanol. As the two solvents (toluene and water) are immiscible, the synthesis is a type of interfacial *in situ* polymerization. The resultant mixture was then washed several times with methanol and water followed by cast in Petridis where evaporation of the mixture takes place. The composite film was obtained by drying in desiccator and finally under vacuum at 50°C for 48 h. Different weight ratio of EVA/Pani composites were synthesized by taking same amount of EVA in toluene, and keeping same molar ratio of aniline/HCl and aniline/APS. The conversion and proportion of Pani in the composite were calculated gravimetrically.

Different composites were designated by using alpha numerical number; for example, E₁₀₀P₃₂ means composite of EVA/Pani containing 32 parts of Pani by weight per hundred parts of EVA (php) and so on, where *E* stands for EVA and *P* for polyaniline.

Testing and Characterization

DC volume resistivity was measured for high resistive samples by using the instrument Agilent 4339B (High Resistance Meter attached with Agilent 16008B Resistivity Cell), and for low resistive samples by the instrument GOM-802 (GW Instek DC milli Ohm Meter). AC resistance at frequency 10³ Hz was estimated by using the instrument QuadTech 7600 (LCR meter).

The effect of applied static pressure up to 73 kPa on DC resistivity of EVA/Pani composites was measured by the instrument Agilent 34401A (Digital multimeter) coupled with a home made electrode. The design of home made electrode has been shown in Scheme 1. This is having two electrodes namely upper

electrode and lower electrode. These electrodes are placed within a platen. The lower electrode is fixed with lower platen but the upper electrode is movable and coupled with a piston. The electrodes are made up with brass whereas the other materials like Teflon sheet and movable piston are made of insulating material like Teflon sheet. Both electrodes are connected with the electrical instrument through the wires. For measuring pressure sensitivity, the composite samples are placed in between the electrodes and the pressure is applied on the sample through the movable piston. The pressure is applied stepwise on the sample and the resistance value is noted after some stabilization of the data. Here, the stabilization time has been taken as five minutes after application of the load. The pressure effect on AC resistivity was measured up to 60 kPa by GW Instek LCR meter 819 coupled with the same electrode and following the same procedure.

The effect of time on DC resistivity under a constant pressure (12.2 kPa) was estimated by using the instrument Agilent 34401A (Digital multimeter). The variation of AC resistivity was measured by GW Instek LCR meter 819. The same home made electrode was used during the measurement.

The relative electrical properties with respect to either applied pressure or time have been calculated by using the following formula 1;

$$R_{ep} = E_p/E_0 \quad (1)$$

where, R_{ep} = relative electrical property, E_p = electrical property at any pressure or time, and E_0 = electrical property at zero pressure or time.

SEM study of EVA/Pani composites was performed by using JEOL JSM 5800 scanning electron microscope (Tokyo, Japan). Vacuum gold-sputter machine was used for gold coating of the samples before SEM study. The SEM study was carried out on cryo-fractured surface of the samples.

The infrared spectrums of EVA, Pani, and their blend were carried out using FTIR spectrophotometer (model spectrum RX-I, PerkinElmer Life and Analytical Sciences, MA). FTIR spectrometer (model Nexus-870, Thermo Nicolet Corporation, WI) equipped with an attenuated total reflectance probe attachment with a germanium (Ge) crystal internal reflectance element with an end-face angle of 45° was used to evaluate the composites. FTIR spectra were recorded in dispersive mode within a range of 400–4000 cm⁻¹ with a deuterated triglycine sulfate detector at a 4 cm⁻¹ resolution, and 16 scans were collected for per trace.

RESULTS AND DISCUSSION

Variation of DC and AC Resistivity against Pani Concentration

The variation of DC resistivity, AC resistivity for EVA/Pani composites with respect to Pani content have been depicted in Figure 1. It is observed that the progressive increase of Pani content in EVA matrix decrease both the DC and AC resistivity of the composite system. Initially, up to 30 phr of Pani loading, there is a remarkable decrease in DC resistivity, but the

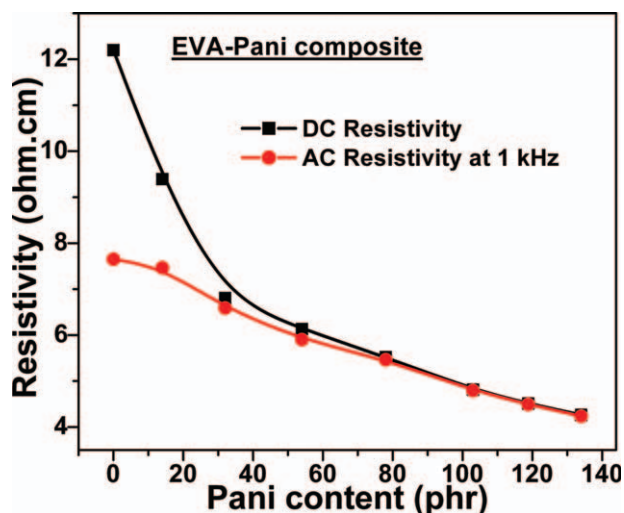


Figure 1. DC and AC resistivity of EVA/Pani composite. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

decrement is marginal at higher Pani content. The concentration (Pani) after which the change in resistivity becomes marginal is known as percolation threshold.^{32–34} For the present system, the conductive composite is reaching to percolation limit at around 30–35 phr of Pani content. Actually, the electrical conduction through the EVA/Pani composite system is mainly due to the mobility of free π electrons present in the backbone of Pani.³⁵ At percolation threshold, continuous conductive networks of Pani are formed throughout the polymer matrix where the π electrons move freely within the polymer composite. As a result, after percolation, the increase in amount of Pani in the polymer matrix contributes more to the increase in its volume but less to the increase in conductivity.³² AC resistivity was measured at the frequency 10^3 Hz. It reveals that the AC resistivity decreases smoothly with the increase in Pani content in the polymer matrix.

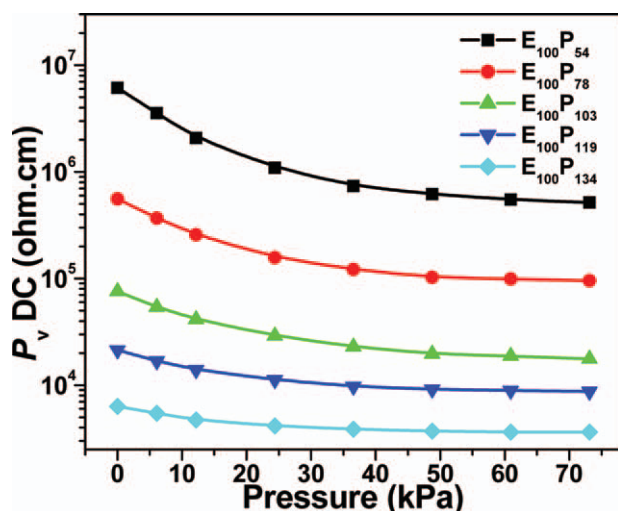


Figure 2. Effect of applied pressure on DC resistivity. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Effect of Pressure on Resistivity

The effect of applied pressure (0–73 kPa) on resistivity and relative resistivity of EVA/Pani composite has been shown in Figures 2 and 3. It is found that initially there is a sharp decrease in resistivity for all composite systems under investigation. However, further increase in pressure gives a marginal decrease in resistivity for all the cases. The sharp decrease in resistivity at the initial point can be attributed to the fact that the applied pressure reduces the thickness/volume of sheet thus resulting more compact structure.³⁶ As a result, the inter particle distance is reduced and the conductive meshes come closer which facilitates the formation of some new closed packed conductive network.³⁷ On the contrary, the application of pressure on the composite system makes breakdown of some conductive networks which had already formed.³⁸ At lower pressure, the numbers of formation of some new conductive networks are sufficiently large compared to the breakdown of some existing conductive network. As a result, the sharp decrease in resistivity is observed. However, at higher pressure, the formation and breakdown of conductive meshes are almost same and hence marginal reduction in resistivity is observed.^{39,40}

It is also clear from Figure 3 that as we proceed from lower to higher Pani content, the change in relative resistivity decreases. At lower Pani content, the number of formed networks are less and most of the networks are supposed to form. As a result, application of pressure helps to form more number of new conductive networks, and consequently change in resistivity is high. However, the progressive increase in Pani content increase the number of such conductive networks in the polymer matrix. Consequently, the number of formation of new conductive mesh with the application of pressure is going to be less. This is why the change in relative resistivity is less.

The experimental data for both the DC resistivity and DC relative resistivity can be fitted in an eq. (2) of best fit;

$$\rho_{(dc \text{ or } ac)} = A_{(dc \text{ or } ac)} \times \exp(-P/d) + \rho_{(dc \text{ or } ac)}^0 \quad (2)$$

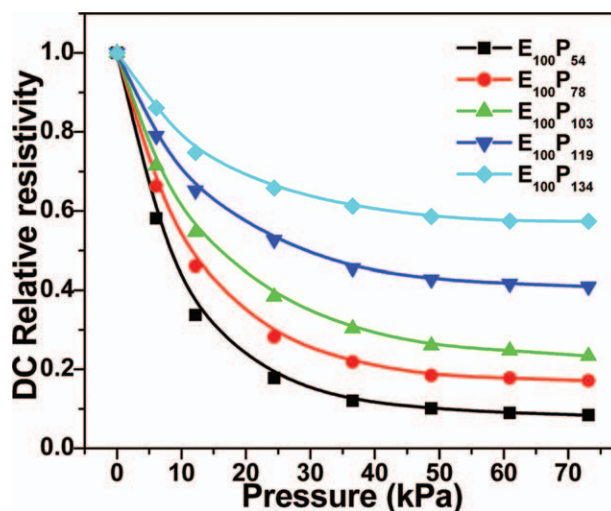


Figure 3. Effect of applied pressure on DC relative resistivity. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Table I. Parameters Value of DC and AC Resistivity and Relative Resistivity with Respect to Pressure

Parameters value of DC resistivity and relative resistivity with respect to pressure						
Composition	Initial value (ρ^0_{dc})		Amplitude (A_{dc})		Decay (d_{dc})	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
E ₁₀₀ P ₅₄	565467 ± 31484	0.09 ± 0.005	5564356 ± 63546	0.91 ± 0.010	9.7 ± 0.27	9.7 ± 0.27
E ₁₀₀ P ₇₈	96955 ± 1719	0.17 ± 0.003	458542 ± 3135	0.82 ± 0.006	11.7 ± 0.20	11.71 ± 0.20
E ₁₀₀ P ₁₀₃	18128 ± 528	0.24 ± 0.007	56990 ± 855	0.75 ± 0.011	13.9 ± 0.55	13.9 ± 0.55
E ₁₀₀ P ₁₁₉	8754 ± 89	0.41 ± 0.004	12552 ± 141	0.59 ± 0.007	14.2 ± 0.42	14.2 ± 0.42
E ₁₀₀ P ₁₃₄	3613 ± 28	0.57 ± 0.004	2715 ± 44	0.43 ± 0.007	14.7 ± 0.63	14.7 ± 0.63

Parameters value of AC resistivity and relative resistivity with respect to pressure						
Composition	Initial value (ρ^0_{ac})		Amplitude (A_{ac})		Decay (d_{ac})	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
E ₁₀₀ P ₅₄	96306 ± 4041	0.173 ± 0.007	466889 ± 4899	0.84 ± 0.009	18.2 ± 0.52	18.2 ± 0.52
E ₁₀₀ P ₇₈	12302 ± 567	0.198 ± 0.009	85624 ± 2156	0.81 ± 0.008	23.6 ± 0.94	23.6 ± 0.94
E ₁₀₀ P ₁₀₃	4526 ± 154	0.213 ± 0.012	9324 ± 846	0.76 ± 0.005	27.7 ± 1.04	27.7 ± 1.04
E ₁₀₀ P ₁₁₉	936 ± 95	0.246 ± 0.021	2346 ± 375	0.73 ± 0.004	31.8 ± 1.85	31.8 ± 1.85
E ₁₀₀ P ₁₃₄	286 ± 37	0.273 ± 0.032	1125 ± 167	0.69 ± 0.004	35.6 ± 2.59	35.6 ± 2.59

where, ρ is the resistivity at the corresponding pressure P , ρ^0 is the initial value of resistivity, A is the amplitude of resistivity, and d is the decay constant. The parameter value of the eq. (2) has been given in Table I. It is seen from the table that the amplitude A is gradually decreasing but the decay constant d is gradually increasing with the increase in Pani content. Actually, the amplitude A can be correlated with the molecular flexibility in the polymer matrix. At lower Pani content, due to the less amount of Pani, polymer chains get more free space for their movement. This attributes to the higher value of amplitude for the composite having lower Pani content, and consequently exhibits higher change in resistivity. However, the Pani present

in polymer matrix restricts the movement of polymer chain, and hence the decay constant can be correlated with the restriction exerted by the Pani content on the polymer chains. The increase in Pani content increase such type of restriction. This results the increase in decay constant.

The effect of pressure on AC resistivity and relative resistivity at the frequency of 1 KHz for the EVA/Pani composites has been shown in Figures 4 and 5. The parameter values according to the above eq. (2) have also been given in Table I. The trend in the change of AC resistivity is in the same line as like DC resistivity; but the only difference is in their magnitude and the

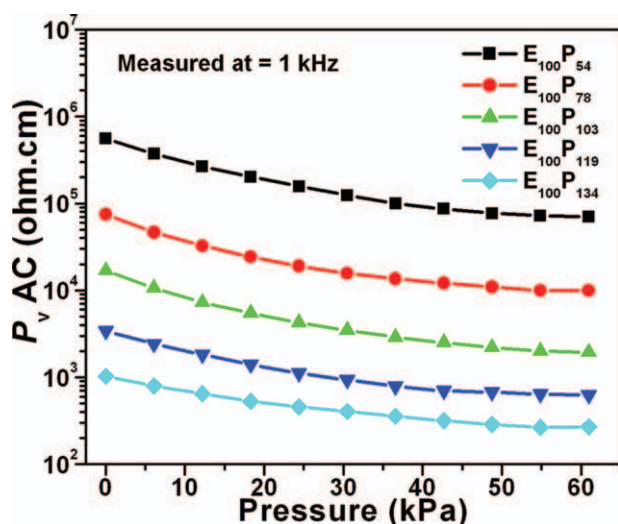


Figure 4. Effect of applied pressure on AC resistivity. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://www.wileyonlinelibrary.com).]

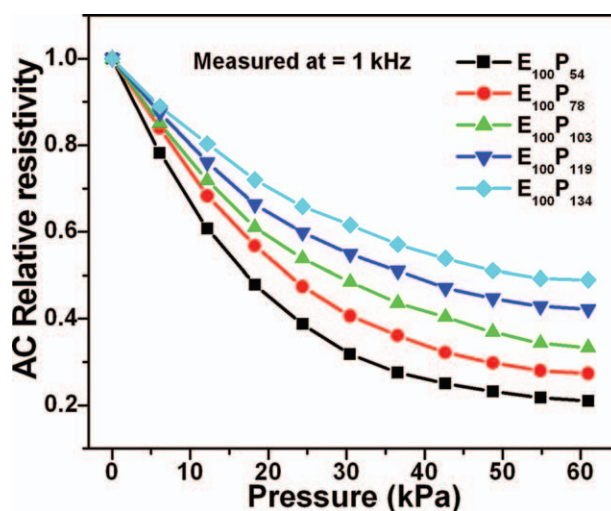


Figure 5. Effect of applied pressure on AC relative resistivity. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://www.wileyonlinelibrary.com).]

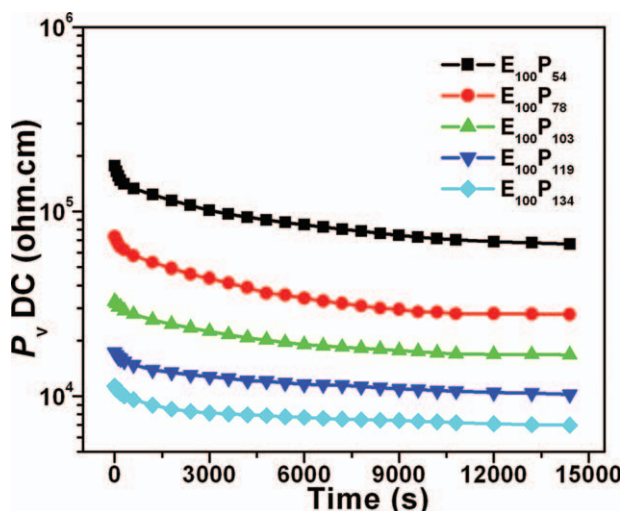


Figure 6. Effect of time on DC resistivity under constant pressure. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

phenomena can be explained in the same manner as has explained in the case of DC resistivity.

Effect of Time on Resistivity Under Constant Pressure

Figures 6 and 7 show the variations of DC resistivity and relative resistivity against time under constant pressure for the EVA/Pani composites, respectively. It is observed that for both the composites, DC resistivity decreases with respect to time. Initially, the decrement is very sharp, but after some time it shows very marginal change and finally exhibits asymptotic behavior. This can be attributed to the fact that under constant pressure there is the formation of some new conductive networks in the polymer composite by slow mobility of the polymer chains and Pani particles which results in decrease of resistivity.³⁷ However, the composite is having lower Pani content exhibits higher change in resistivity compared to higher ones. This is because the chain mobility and average distance between the Pani particles for lower filled composite is higher compared to higher filled one which results in the formation of more conductive network. On the contrary, the composite with higher Pani content is having large number of conductive networks and the average distance between the Pani particles is also small. As a result, the effect of time under constant pressure on resistivity is comparatively less.

At initial time period, the chain mobility and the rearrangement of Pani particles are faster due to sudden application of pressure, but as the time proceeds, both the effect decrease gradually and at sufficiently long time the chain mobility and the rearrangement of Pani particles are almost stopped. Hence, there is the relaxation of polymer chain and Pani particles at this stage. This relaxation characteristic can better be studied by fitting the data of volume resistivity against time in the form of the following exponential eq. (3).

$$\rho_{(dc \text{ or } ac)} = \rho_{(dc \text{ or } ac)}^0 + A_{(dc \text{ or } ac)} e^{-x/t} \quad (3)$$

where, $\rho_{(dc \text{ or } ac)}$ = log volume resistivity (dc or ac) in ohm.cm, x = time in seconds, $\rho_{(dc \text{ or } ac)}^0$ = offset or initial value of vol-

ume resistivity (dc or ac), $A_{(dc \text{ or } ac)}$ = amplitude for dc or ac, and t = decay constant or relaxation time. The parameters values obtained from the equation of best fit have been shown in Table II.

It is observed from this table that the amplitude A is decreasing with the increase in Pani content. This is a measure of relative/total change in resistivity and can be correlated with the polymer chain mobility that occurs in the polymer composite when subjected to constant pressure. It is believed that the polymers chains are interlinked with the filler aggregates by some types of physical crosslink which restrict the movement of polymer chains. So, it is expected that the increase in Pani content increase such type of restriction in polymer composite. This leads to the decrease in amplitude A , and hence the relative resistivity.

The parameter t is also decreasing with the increase in Pani content and is a measure of relaxation time. The relaxation time is the time at which the resistivity or any other parameters become asymptotic in nature to the time axis. Actually, the polymer chain mobility under any constant pressure for the lower filled system is more compared to higher filled system. This is due to availability of more number of free polymer chains which are unrestricted and unlinked with the filler aggregates, and hence takes more time to be relaxed. In the case of higher filled system, the availability of polymer chains is less, and hence their movements are restricted. So these composites are required less time to be relaxed.

The effect of time on AC resistivity and relative resistivity for the same composites at a frequency of 1 kHz has shown in Figures 8 and 9. The trend in change of AC resistivity is almost same as like DC resistivity. The relaxation time and other parameters that have obtained by the equation of best fit have also been given in Table II. The parameters can be explained in the same manner as it has explained in case of DC resistivity.

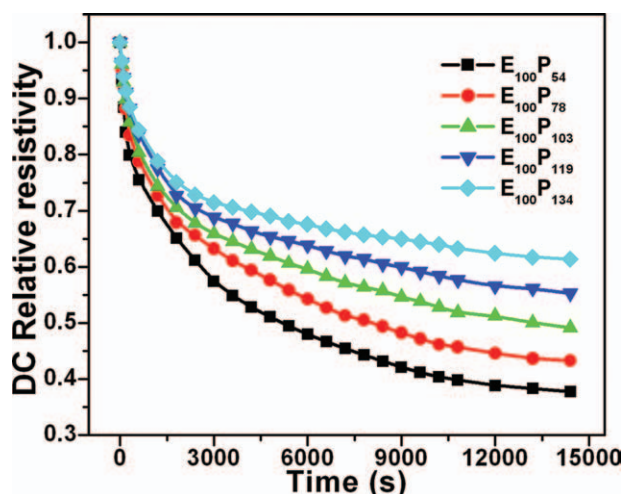


Figure 7. Effect of time on DC relative resistivity under constant pressure. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Table II. Parameters Value of DC and AC Resistivity and Relative Resistivity with Respect to Time

Parameters value of DC resistivity and relative resistivity with respect to time						
Composition	Initial value (ρ_{dc}^0)		Amplitude (A_{dc})		Relaxation time(t_{dc})	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
E ₁₀₀ P ₅₄	70231 ± 2395	0.39 ± 0.014	89415 ± 3079	0.506 ± 0.02	2847 ± 296	2847 ± 296
E ₁₀₀ P ₇₈	38261 ± 1965	0.46 ± 0.017	46213 ± 2684	0.432 ± 0.03	2563 ± 276	2563 ± 276
E ₁₀₀ P ₁₀₃	24563 ± 1254	0.53 ± 0.015	21654 ± 2315	0.375 ± 0.04	2248 ± 263	2248 ± 263
E ₁₀₀ P ₁₁₉	12365 ± 562	0.59 ± 0.021	9642 ± 958	0.338 ± 0.02	2034 ± 234	2034 ± 234
E ₁₀₀ P ₁₃₄	7323 ± 72	0.64 ± 0.006	3552 ± 123	0.313 ± 0.01	1874 ± 197	1874 ± 197

Parameters value of AC resistivity and relative resistivity with respect to time						
Composition	Initial value (ρ_{ac}^0)		Amplitude (A_{ac})		Relaxation time(t_{ac})	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
E ₁₀₀ P ₅₄	45117 ± 2495	0.3428 ± 0.0189	79283 ± 2599	0.602 ± 0.02	2110 ± 213	2110 ± 213
E ₁₀₀ P ₇₈	32564 ± 2165	0.3852 ± 0.0234	53254 ± 2164	0.573 ± 0.03	1965 ± 197	1965 ± 197
E ₁₀₀ P ₁₀₃	21654 ± 1654	0.4223 ± 0.2653	33598 ± 1967	0.546 ± 0.01	1726 ± 185	1726 ± 185
E ₁₀₀ P ₁₁₉	13256 ± 1364	0.4562 ± 0.2956	17653 ± 1526	0.513 ± 0.02	1627 ± 168	1627 ± 168
E ₁₀₀ P ₁₃₄	3654 ± 365	0.4954 ± 0.1653	5364 ± 1134	0.465 ± 0.03	1564 ± 216	1564 ± 216

Morphology of EVA/Pani Composites

The scanning electron microscopic (SEM) images of pure EVA, pure Pani, and EVA/Pani composites have been presented in Figure 10. It is observed from the figure that neat EVA exhibits smooth surface morphology which is ductile in nature. The morphology of Pani depends on its synthesis process and nature of dopant used. Depending on the synthesis techniques, different types of morphology like granular, spherical, fibrillar, honeycomb crews like, ribbon like etc shape and size of Pani have been reported in literatures.^{41–45} Our synthesized Pani has granular crew type morphology whose grain diameter is about 0.5–3.0 μm . This grain-shaped morphology of polyaniline is helpful for pressure sensitivity application compared

to fibrous/rod like/ribbon shaped ones because the applied pressure on grain shaped particles results in systematic and regular decrease in resistivity whereas for fibrous/rod like/ribbon shaped fillers the breakdown of fillers along with conductive networks also takes place which finally leads to the irregular change in resistivity with the increase in applied pressure.⁴⁶ It is observed from the figure that the morphology of EVA/Pani blends changes from its ductility to brittle fracture as we proceed from neat EVA to higher Pani loaded composites. The Pani particles are not well dispersed in the polymer matrix rather aggregation of particles is observed. This aggregation of Pani particles is favorable for the formation of continuous conductive networks easily in the polymer matrix.

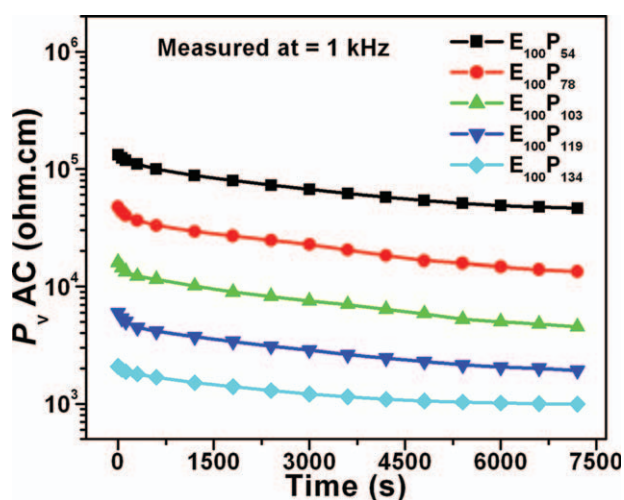


Figure 8. Effect of time on AC resistivity under constant pressure. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

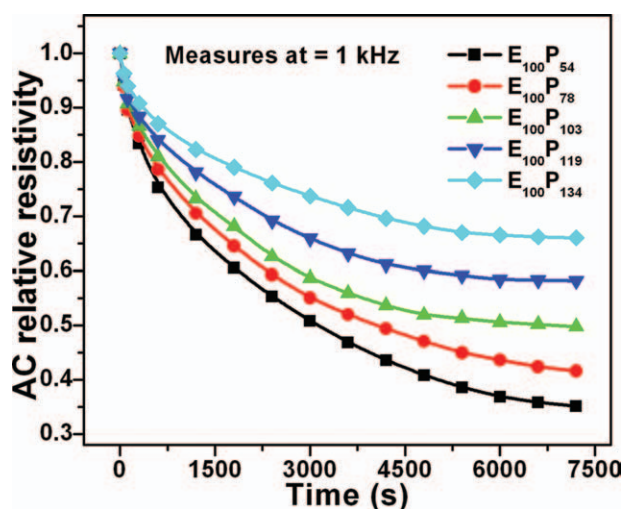


Figure 9. Effect of time on AC relative resistivity under constant pressure. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

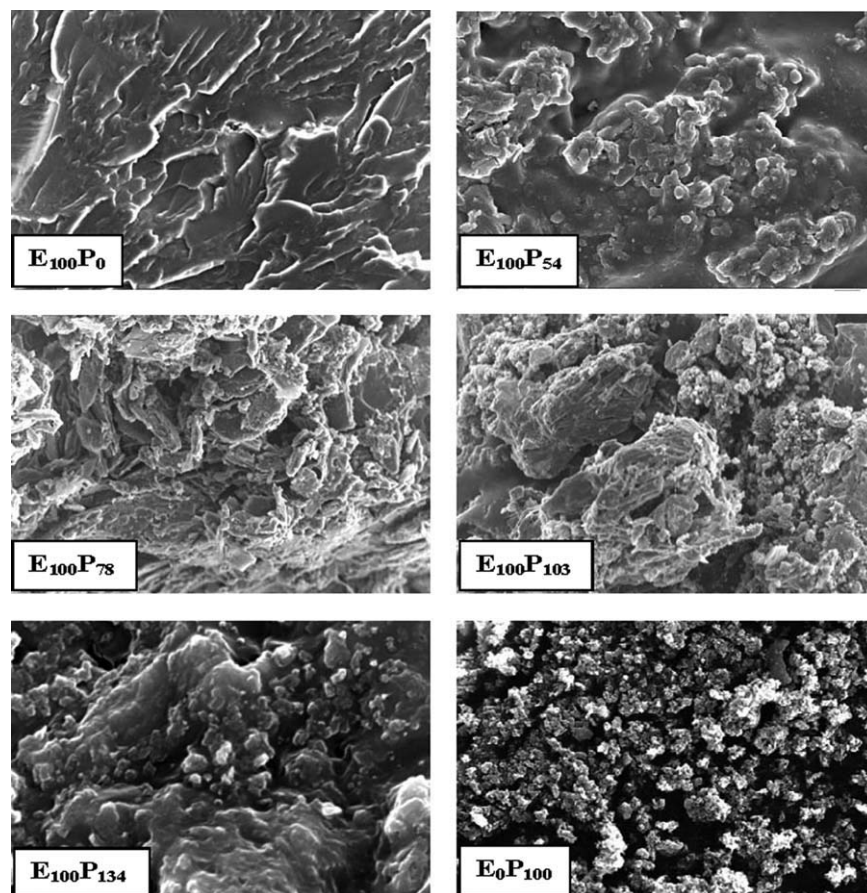


Figure 10. SEM images of neat EVA, neat Pani, and their composites.

FTIR Analysis

The FTIR spectra of Neat EVA, Neat Pani and blend ($E_{100}P_{54}$) have been presented in Figure 11. The Pani exhibits bands at 1570 and 1480 cm^{-1} those corresponds to C=C stretching frequencies of quinoidic and benzoic ring, respectively. Moreover, the peak at 1300 cm^{-1} is due to stretching of C–N bond.^{43,44} A broad peak near 3430 cm^{-1} is observed due to NH_2 asymmetric stretching and a very small peak near 3200 cm^{-1} corresponds to H-bonded NH stretching.⁴⁷ Corresponding absorption peak of the saturated C–H stretching at 2900 cm^{-1} may be due to impurities or to overtones or a combination of some modes of the benzoid or quinoid units.⁴⁷ The band near 1110 cm^{-1} is due to in-plane bending of C–H bond present on the 1,4-position of the ring. Similarly, the peak at 798 cm^{-1} corresponds to out-of-plane bending of C–H bond present on 1,4-position of the ring.⁴⁷ Another peak around 500–645 cm^{-1} that is at 615 cm^{-1} may be due to deformation of aromatic ring.⁴⁷

The neat EVA shows absorbance peaks at 1740, 1240, and 1020 cm^{-1} which can be attributed to the CO, OCOR and COC groups, respectively.⁴⁸ The characteristics absorbance bands at 2920, 2850, 1460, and 721 cm^{-1} are related to ethylene groups. The vibration at 3400 cm^{-1} corresponds to a characteristics overtone band that is double frequency of carbonyl group of vinyl acetate units.⁴⁹ The characteristics absorbance bands for EVA/Pani composites are found to be same with the characteristics peaks of neat EVA. The only difference is in their absorbance

value which is found to be less for EVA/Pani composite compared to neat EVA. This may be due to the interference created by the high absorbance value of EVA which masks the peaks of polyaniline.

CONCLUSIONS

DC and AC resistivity of the composite have been found to decrease with the progressive increase in Pani content. The DC

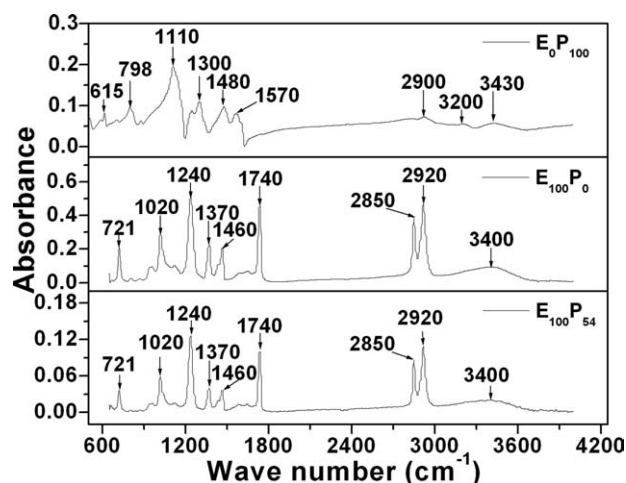


Figure 11. FTIR spectra of neat EVA, neat Pani, and $E_{100}P_{54}$ composite.

and AC resistivity are decreasing with the increase in pressure in an exponential manner. The relative change in resistivity is found to be higher for the composite with lower Pani content. However, the effect of time under constant pressure on DC resistivity, AC resistivity has also been exhibiting similar behavior as like the effect of pressure, but the difference is only in their change in magnitude. These results show that the composites can be used as pressure sensitive sensor. The relaxation time for the composite having lower Pani content has been found to be higher compared to the higher filled ones. SEM study shows granular morphology of Pani. The addition of Pani in EVA matrix changes the composite from its ductile behavior to brittle fracture. The characteristics FTIR spectra peaks obtained for Pani supports its novel synthesis through *in situ* polymerization technique.

ACKNOWLEDGMENTS

The authors thank Aeronautic Research and Development Board (ARDB), Government of India, for their financial support to carry out the research work.

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