

Poly(butadiene-co-acrylonitrile)-Polyaniline Dodecylbenzenesulfonate [NBR-PAni.DBSA] Blends for Corrosion Inhibition of Carbon Steel

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NBR-PAni.DBSA blends with useful electrical conductivity (up to 10^{-1} S.cm⁻¹) were prepared and their corrosion inhibiting behaviours for carbon steel were successfully assessed for the first time. The level of compatibility between NBR and PAni.DBSA was enhanced through the introduction of 1.0 wt% hydroquinone. As found from both total immersion and electrochemical corrosion tests, NBR-PAni.DBSA blends with 10.0-30.0 wt% of PAni.DBSA content exhibited the best corrosion inhibiting behaviour for carbon steel, either in acid or artificial brine environment. On the other hand, blends consisting of very low and very high PAni.DBSA contents (i.e. ≤ 5.0 wt% and ≥ 40.0 wt%) showed significantly poorer corrosion inhibiting behaviour for carbon steel.

Keywords: Conductive rubber; nitrile rubber; polyaniline; carbon steel; corrosion inhibition

Corrosion inhibition using conductive polymers was first suggested in the year 1985¹. Among all of these known conductive polymers, polyaniline (PAni) has received the most attention in the field of corrosion science. This is due to its ease of preparation, excellent environmental stability and feature of redox properties associated with the nitrogen chain²⁻⁷.

PAni containing organic coatings are known to offer corrosion protection of steel in acid and saline media^{2-4,8}. In most of these studies, PAni was doped with either hydrochloric acid or

sulphonic acid or phosphonic acid or dioctyl phosphate or camphor sulfonic acid and the doped PAni was used in the protection coating. The mechanism of corrosion protection of steel by PAni coating had been studied by Kinlen *et al.*^{2,8} and Jain *et al.*⁹ They reported that doped PAni coatings passivated the pin hole defects in the coatings. Further, it was also reported in scientific literature that steel coated with PAni had gained 100–200 mV in corrosion potential in a 3% NaCl aqueous solution due to a decrease in the iron dissolution reaction by passive film formation and shifted the potential to the passive region¹⁰⁻¹¹.

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The corrosion inhibiting ability of PANi on carbon steel is widely acknowledged, but the mechanism for this process is still under investigation. Several hypotheses have been suggested for the mechanism of corrosion protection using PANi, *i.e.* (a) PANi contributes to the formation of an electric field at the metal surface, restricting the flow of electrons from metal to oxidant (b) PANi forms a dense, strong adherent, low-porosity film similar to a barrier coating and (c) PANi causes the formation of protective layers of metal oxides on a metal surface¹².

There are also a few reasons that limit the PANi's application in terms of corrosion inhibition, *i.e.* the brittleness and poor adhesion of PANi to its substrate, particularly in the corrosive environment¹³⁻¹⁴. Troch-Nagels *et al.*¹⁵ found that a PANi film electro-polymerised in the nitric acid solution, unlike polypyrrole, could not offer corrosion protection and also pointed out that the adhesion of both PANi and polypyrrole film to a substrate was poor and both films were brittle. Lu *et al.*³ reported that coatings of PANi deposited from aqueous solution exhibited rather poor adhesion to a steel substrate. Wessling¹⁶ drew the conclusion that proper coatings on metals with PANi from dispersion could lead to a significant shift of the corrosion potential in the direction of noble metals and to the formation of a passive metal oxide layer on the surface of the metals. Besides this, he emphasised that the PANi coating prepared by whatever method must adhere well on the metal surface, especially under the corrosion conditions.

This work aims to study electrically conductive rubber blends prepared by mixing of poly(butadiene-*co*-acrylonitrile) (NBR) with different proportions of dodecylbenzenesulfonate acid doped PANi (PANi.DBSA) in the presence of hydroquinone as compatibiliser for the corrosion inhibition of carbon steel. These blends were solution

mixed in a shared solvent, *i.e.* toluene. Special interest has been focused on NBR due to its excellent resistances in terms of chemical, oil, heat ageing, abrasion, water and gas permeability. PANi.DBSA was selected here due to its low toxicity, good thermal stability, high electrical conductivity, good compatibility with NBR and well established synthesis method¹⁷⁻²³.

In this work, electrical conductivities of these NBR-PANi.DBSA blends were determined. Fourier transform infrared (FTIR) spectroscopy and morphological study using transmission electron microscopy (TEM) were performed in order to assess the compatibility level of these two major constituent polymers. Two common techniques were used to study the corrosion inhibiting behaviour of these NBR-PANi.DBSA blends, *i.e.* (a) A total immersion corrosion test in 5 wt% sodium chloride aqueous solution and (b) An electrochemical test with a potentiostat system.

EXPERIMENTAL

Chemicals and Raw Materials

Aniline monomer (99 wt%, Sigma-Aldrich), ammonium persulphate (APS) (98 wt%, Sigma-Aldrich), 36.5-38 wt% hydrochloric acid (HCl) solution (GPR), ferric chloride (FeCl₃) solution (purum, 45% FeCl₃ basis, Sigma-Aldrich), 33 wt% ammonia solution (GPR, Sigma-Aldrich), 70 wt% dodecylbenzene sulfonic acid (DBSA) solution in 2-propanol (GPR, Sigma-Aldrich), toluene (GPR, Sigma-Aldrich), methanol (GPR). Commercial grade NBR [Krynac® 50.75, manufactured by Bayer Germany] was selected as the elastomeric host. The NBR was washed with methanol for 24 h using Soxhlet extraction in order to remove chemical additives. By ¹H-NMR analysis of solutions in THF-d₈, the actual ACN content for NBR was determined as 48.2 ± 1.0 wt%.

Pure PAni.DBSA, NBR Krynac® 50.75 and toluene have solubility parameter values of 20.8, 20.7 and 18.3 (MJ m^{-3})^{0.5}, respectively². Both NBR and PAni.DBSA were highly soluble in toluene. Hydroquinone (benzene 1, 4-diol) was used as received (ReagentPlus®, ≥99 wt%, Sigma-Aldrich).

Synthesis of PAni.DBSA

Conductive emeraldine salt PAni.HCl was synthesised by the oxidative chemical polymerisation technique based on an oxidant (APS)/monomer (aniline) initial molar ratio of 1.0. 50 mL of aniline and 125.2 g of APS were dissolved in 375 mL and 276 mL of 2 M HCl respectively, which had been pre-cooled to 1°C. The aniline solution was placed in an ice bath with an overhead stirrer. After the addition of FeCl₃ solution (about 1 mL) as a catalyst, the APS solution was added gradually over a period of 20 min, with constant stirring to ensure thorough mixing. The temperature of the polymerisation mixture was maintained to ≤2°C while the pH was adjusted to be ≤1.0 by the addition of concentrated HCl. The mixture was left for 6 h to complete the polymerisation and the precipitate was allowed to settle before decanting and final washing with distilled water until the filtrate was colourless. PAni emeraldine base (EB) was prepared by deprotonating the wet PAni.HCl in 33% aqueous ammonia solution (about 5000 mL) with 24 h stirring, followed by washing and reprotonation in 1M aqueous DBSA at a molar ratio EB:DBSA of 1:1. Filtration was performed with a sintered glass funnel of grade 3 porosity (16-40 microns). All products were washed with large quantities of distilled water until the filtrates were colourless and no odour of ammonia could be detected. Final drying of the powdered filter cake was done in a vacuum oven at 50°C for 24 hours. A sample of PAni.DBSA synthesised here was submitted for elemental analysis at the Malaysian Rubber

Board Characterisation Laboratory and was estimated thereby to have a 42% protonation level on the basis of the S:N atomic ratio.

Blend Preparation

Masterbatch solutions of pure NBR (50 mg NBR/mL solvent) and PAni.DBSA (16.5 mg PAni.DBSA/mL solvent) in toluene were prepared and filtered. The pure NBR solution was added to the PAni.DBSA solution in appropriate amounts in order to obtain the following compositions (wt% NBR : wt% PAni.DBSA), 50:50, 60:40, 70:30, 80:20, 90:10, 95:5, 97.5:2.5 and 99:1 respectively. Hydroquinone of 1.0 wt% (dosage as recommended by literature²³⁻²⁴) was added to each blend solution as compatibiliser. Each of the above blend solutions was magnetically stirred for 24 h at room temperature prior to casting/coating.

Fourier Transform Infrared (FTIR) Spectroscopy (FTIR)

FTIR spectra of PAni.DBSA, pure NBR and all NBR-PAni.DBSA blends were recorded on a Nicolet Magna-IR 560 infrared spectrometer. A small amount of each sample solution was cast onto a potassium bromide (KBr) window and dried for 24 h in an air conditioned room (23°C). As a result, a reasonably thin and transparent film was obtained. The thickness of each film is estimated at about 3.0 μm, based on the amount and concentration of each solution that was used for casting.

Determination of Electrical Conductivity

The DC electrical conductivities for PAni.DBSA, pure NBR and NBR-PAni.DBSA blends were calculated from electrical resistances measured by guarded 2-probe

techniques. The equipment employed was a Keithley 6517A Electrometer (with built-in voltage source up to 1kV). A pressed pellet of pure PANi.DBSA (diameter 13 mm, thickness 1.5 mm) was placed in a holder with two spring loaded metallic contacts in order to measure its electrical resistance. Samples of pure NBR and NBR-PANi.DBSA blend were cast respectively from their solution onto square microscope slides (625 mm²) and the solvent was allowed to evaporate for 24 h in an oven at about 100°C.

Electrical conductivities were calculated from the mean resistance values (based on a set of five samples) obtained by the 2-probe method using Equation 1¹⁷.

$$\sigma = \frac{1}{R} \frac{L}{A} \quad \dots 1$$

where σ is the electrical conductivity, R is the mean value of apparent resistance (voltage/current) for the cast blend, L is the measured electrode spacing distance and A is the cross-sectional area of the electrode, which is in close contact to the cast film.

Morphological Study (Transmission Electron Microscope)

All NBR-PANi.DBSA blends were studied by using a transmission electron microscope (Philips CM12 microscope, at accelerating voltage 80 kV). Ultra-thin (ca. 150 nm) samples of each blend (frozen with liquid nitrogen) were obtained for this study by sectioning with a microtome.

Total Immersion Corrosion Test

The immersion test technique is one of the most common corrosion tests used for carbon steel samples, coated with acrylic

paint pigmented by synthesised pigments. The prepared NBR-PANi.DBSA solutions were kept in an air tight jar to avoid any solvent evaporation. Carbon steel samples of circular shape were cut from sheet (not bar stock) in order to minimise the exposed end grain according to the *ASTM G31*²⁵. The samples were polished by fine size emery paper (600 grit), cleaned, degreased with acetone (GPR, Sigma-Aldrich), dried and weighed with an electronic balance (Mettler Toledo AL204, accuracy of ± 0.1 mg). Sample shape and size were made convenient to laboratory corrosion tests according to the *ASTM G31*²⁵. Three sets of test samples with respective diameter of about 38 mm and thickness of approximately 3 mm, with a hole about 8 mm in diameter were prepared for each blend. First, each test sample was dip coated for 1 min in the NBR-PANi.DBSA blend and left for 1 h to dry and then the second dip was for another 1 min then dried in an oven for 48 h at 40°C.

After the end of immersion test period (60 days) in 5.0 wt% sodium chloride aqueous solution, the test samples were taken out and the coating removed and cleaned according to *ASTM G1*²⁵. The performance of the coating was examined through calculation of the sample's mass loss (in mean value).

Electrochemical Corrosion Test

Each NBR-PANi.DBSA blend coated carbon steel sample was mounted to the working electrode (it was the bottom of the rod that was directly exposed to the electrolyte). At the same time, all the edges were sealed with epoxy resin (DowTM, D.E.R. 671-T75). The electrochemical corrosion test was conducted by using a system based on the Wenking M Lab potentiostat (Bank Elektronik-Intelligent Control GmbH, Germany) in a standard corrosion test cell equipped with a platinum counter electrode and a saturated calomel

reference electrode (SCE). The scanning rate was fixed at 2.0 mVs^{-1} . All potential values here are reported in reference to the SCE. All the measurements were performed at room temperature ($\sim 23^\circ\text{C}$) and the selected electrolyte was either HCl (0.1 M) or 5.0 wt% sodium chloride aqueous solution.

RESULTS AND DISCUSSION

FTIR Spectroscopy

FTIR spectra examples for PAni.DBSA, pure NBR and their blends are shown in *Figure 1*.

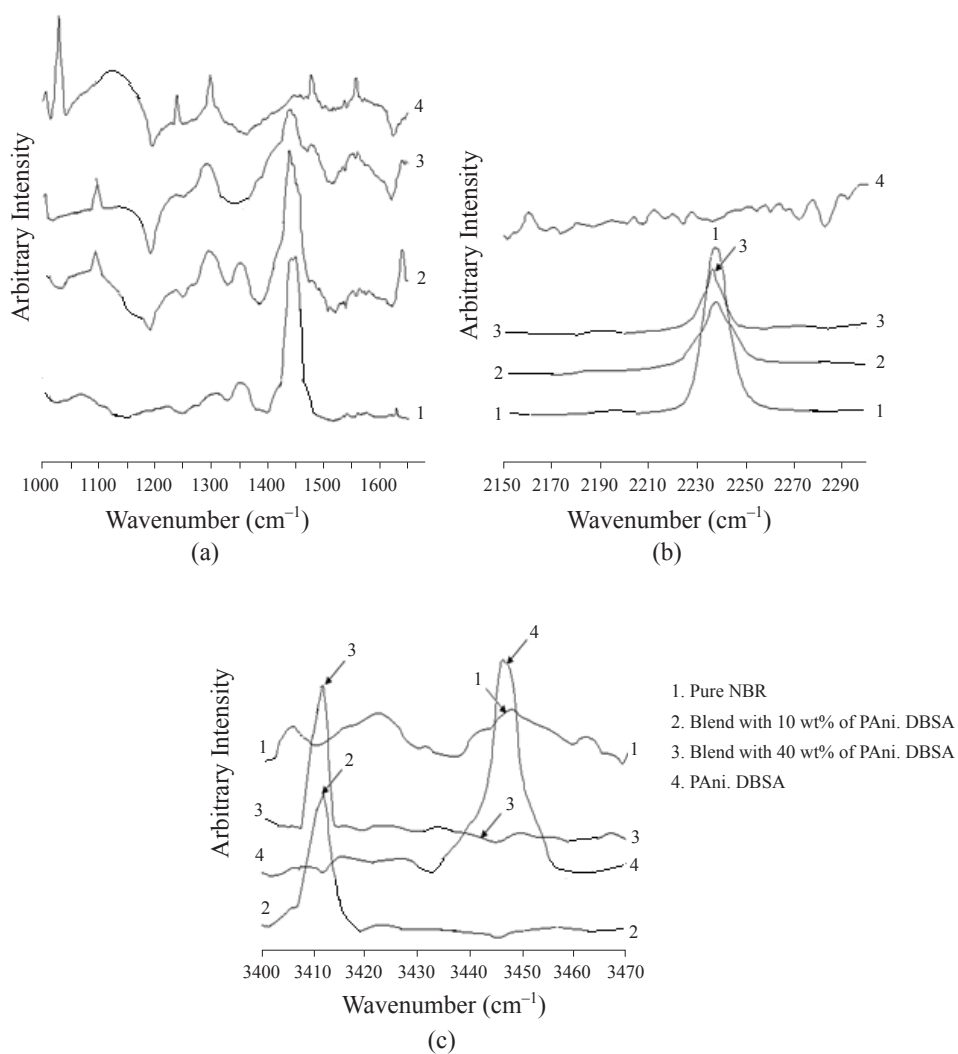


Figure 1. FTIR spectra of PAni.DBSA, pure NBR and NBR-PAni.DBSA blends. (a) Region 1000 cm^{-1} to 1650 cm^{-1} , (b) Region 2150 cm^{-1} to 2300 cm^{-1} and (c) Region 3400 cm^{-1} to 3470 cm^{-1} .

The FTIR spectrum for the cast film of pure NBR shows the characteristic absorptions at 2236 cm^{-1} ($\text{C}\equiv\text{N}$ stretching), 1631 cm^{-1} ($\text{C}=\text{C}$ stretch) and $1440\text{--}1445\text{ cm}^{-1}$ (out of plane C-H wagging). The spectrum of the PANi.DBSA cast film also exhibits characteristic absorptions at 3448 cm^{-1} (N-H stretching), 1558 cm^{-1} ($\text{N}=\text{quinoid}=\text{N}$), 1477 cm^{-1} (N-benzoid-N), 1294 cm^{-1} ($\text{quinoid}=\text{N-benzoid}$), 1240 cm^{-1} (C aromatic-N stretching) and 1031 cm^{-1} (S=O stretching).

Detailed examination of the FTIR spectra of the blend films reveals significant shifts of certain key bands. The compatibility level of the two constituent polymers may be assessed by studying some of these shifts (*Table 1*). It is proposed that the larger the peak shift, the higher the intermolecular interaction (or compatibility) of the two constituent polymers. The bands at 3448 cm^{-1} (N-H stretching) and 1031 cm^{-1} (S=O stretching) solely correspond to PANi.DBSA, while that at 2236 cm^{-1} derives from NBR.

In the spectra of all blends, these bands have intensities comparable to those for the pure polymers. However, two large opposing peak

shifts can be seen, *i.e.* a decrease to 3406 cm^{-1} for the N-H stretch and an increase to 1081 cm^{-1} for the S=O stretch. This phenomenon could be attributed to changes in the intermolecular interactions as a result of the addition of compatibiliser⁸. The peak positions only revert to those of the pure PANi.DBSA at a high level of PANi.DBSA loading, *i.e.* 50 wt%. It is possible to say that reasonably large amounts of PANi.DBSA could be added into this blend before encountering a serious phase separation problem.

According to literature^{17,19–20,22–23}, the positively charged N-H hydrogens of PANi.DBSA would have a strong propensity for hydrogen bonding with the negative sulphonate oxygens, and hence the FTIR frequency changes suggest that this bonding was disrupted by polar interactions with the NBR matrix in the dilute, well dispersed blends. The larger, more aggregated PANi.DBSA particles in concentrated blends feature smaller specific surface areas. Hence, strong H-bonding characteristic of bulk PANi.DBSA (peak positioned at 1031 cm^{-1}) could be detected by the FTIR spectrometer for these blends.

TABLE 1. REPRESENTATIVE FTIR SPECTROSCOPY PEAKS FOR PANI.DBSA, PURE NBR AND NBR-PANI.DBSA BLENDS

Pure material/ Blend (wt% NBR: wt% PANi.DBSA)*	Peak assignment, cm^{-1}		
	Indication of peak intensity: W = weak; M = medium		
	=N-H stretching	S=O stretching	-C≡N stretching
PAni.DBSA	3448W	1031M	-
Pure NBR	-	-	2236M
Blends			
90:10*	3414W	1080W	2236W
80:20*	3413W	1081W	2236W
70:30*	3406W	1081W	2235W
60:40*	3413W	1080W	2235W
50:50*	3437W	1031W	2235W

Determination of Electrical Conductivity

The calculated mean electrical conductivity values for PAni.DBSA, pure NBR and their blends are shown in *Figure 2*. Pure NBR is a good electrical insulator, with conductivity in the region of 10^{-14} S.cm⁻¹. The in-house synthesised PAni.DBSA showed a high electrical conductivity of 1.5 ± 0.5 S.cm⁻¹.

The electrical conductivities of all blends generally increased with the loading of PAni.DBSA^{17–23,26–27}. The blends prepared with added compatibiliser showed high electrical conductivities, up to about 10^{-1} S.cm⁻¹. It is also suggested that the more compatible constituent polymers favour the formation of a higher level of microscopic conductive pathways (*Figure 3*).

The conductivity percolation threshold for NBR-PAni.DBSA blends was estimated

by fitting the data from *Figure 2* to a simple percolation model as defined by *Equation 2*²⁸.

$$\sigma_f = c f - f_p^t \quad \dots 2$$

where c is a constant, t is the critical exponent, f is the volume fraction of the conductive medium and f_p is the volume fraction at the percolation threshold. All the weight fractions referred to above were converted into volume fractions for this analysis. By fitting the data to a plot of log electrical conductivity (σ) versus $\log(f - f_p)$, it was possible to estimate the values of t and correlation coefficient (R) for each set of data. The estimated electrical conductivity percolation threshold for the NBR-PAni.DBSA blends is 6.0 wt%/5.3 volume % of PAni.DBSA (with $t = 3.8$ and $R = 0.99$). A low electrical conductivity percolation threshold can evidently be achieved for the NBR-PAni.DBSA blends, which can be attributed to the high compatibility level between the two constituent polymers.

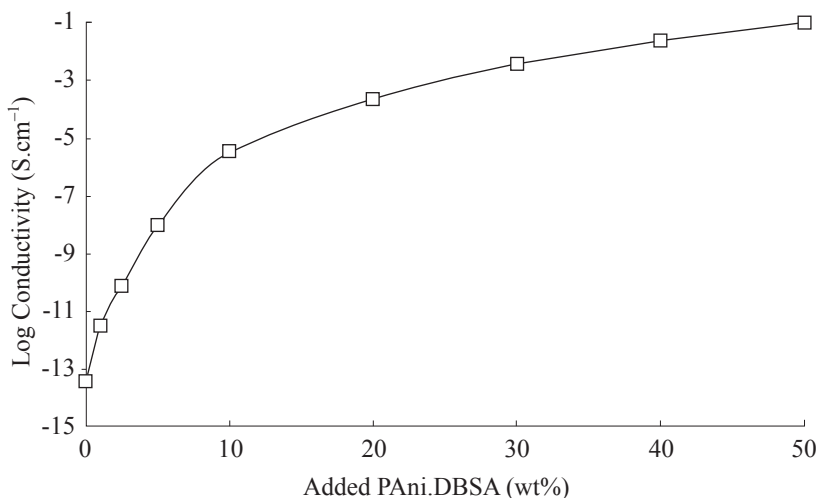


Figure 2. Electrical conductivities for NBR-PAni.DBSA blends as a function of PAni.DBSA loading (wt%).

Morphological Study

All NBR-PAni.DBSA blends were studied by using TEM, but only examples of micrographs of blends with 10 and 40 wt% PAni.DBSA are shown in *Figure 3*. The darker coloured regions (rich in PAni.DBSA) are large conductive particles and their agglomerates result from some degree of phase separation. The lighter coloured regions (rich in NBR) are related to well blended PAni.DBSA and NBR. In *Figure 3*, the PAni.DBSA particles are starting to cluster or form conductive pathways, which is consistent with the enhanced conductivities of both blends.

Total Immersion Corrosion Tests

Table 2 shows the mean values of total mass loss from carbon steel samples at the end of immersion test period, *i.e.* 60 days. *Figure 4* shows the influence of the aggressive media on the samples at the end of the test period. The efficiency of NBR-PAni.DBSA coatings

(in different ratios) against corrosion can be directly estimated from this test. As can be observed, the control sample without coating developed an extensive number of blisters and recorded the highest mass loss (*i.e.* 1.17% of the original sample's weight before the test). Samples coated with very low and very high PAni.DBSA contents (*i.e.* ≤ 5.0 wt% and ≥ 40.0 wt% respectively) are also severely degraded with a lot of rust spots on the exposed surface. Conversely, a diminished rust development was found for samples coated with 10.0 – 30.0 wt% of PAni.DBSA contents. The greatest inhibition in the rust development was observed for the sample coated with 10.0 wt% of PAni.DBSA. This particular sample also revealed the lowest mass loss, *i.e.* 0.38% of the original sample's weight.

Electrochemical Corrosion Tests

Figure 5 shows some examples of corrosion potential against time for samples coated with NBR-PAni.DBSA blends (*i.e.* with PAni.

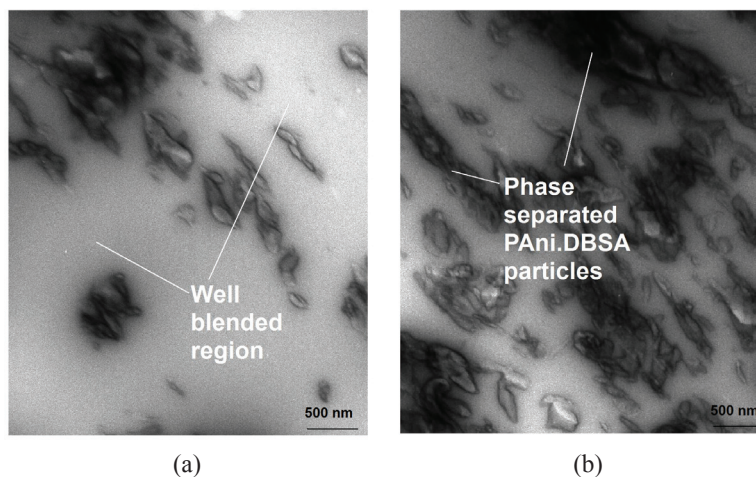


Figure 3. Transmission electron micrographs of NBR-PAni.DBSA blends (a) Blend with 10 wt% of PAni.DBSA and (b) Blend with 40 wt% of PAni.DBSA.

TABLE 2. MEAN VALUES OF TOTAL MASS LOSS FOR CARBON STEEL SAMPLES COATED WITH NBR-PANI.DBSA BLENDS

Sample	Total mass loss (gram)
Control sample	0.2367
Sample coated with 1.0 wt % PAni.DBSA	0.2204
Sample coated with 2.5 wt % PAni.DBSA	0.1921
Sample coated with 5.0 wt % PAni.DBSA	0.1592
Sample coated with 10.0 wt % PAni.DBSA	0.0783
Sample coated with 20.0 wt % PAni.DBSA	0.1088
Sample coated with 30.0 wt % PAni.DBSA	0.1379
Sample coated with 40.0 wt % PAni.DBSA	0.1687
Sample coated with 50.0 wt % PAni.DBSA	0.1779



(a)



(b)



(c)



(d)

Figure 4. Carbon steel samples after 60 days fully immersion corrosion test in 5.0 wt% sodium chloride aqueous solution. (a) Control sample (b) Sample coated with 5.0 wt% PAni.DBSA (c) Sample coated with 10.0 wt% PAni.DBSA (d) Sample coated with 50.0 wt% PAni.DBSA.

DBSA contents, 5.0, 10.0 and 40.0 wt%) in 0.1 M HCl solution. In this figure, -0.165 V represents the corrosion potential of pure carbon steel. The sample coated with 10.0 wt% PAni.DBSA content exhibited the most positive potential values among all tested samples. In other words, the NBR-PAni.DBSA blend with 10.0 wt% PAni.DBSA content showed the best corrosion inhibiting behaviour in the acid environment. It was also found that the corrosion potentials of all analysed samples stayed almost unchanged for over 50 minutes. It is likely that the doping and undoping of H^+ could easily occur for coatings with high loadings of PAni.DBSA, *i.e.* ≥ 40.0 wt%. Coatings with high PAni.DBSA contents suffered more serious phase separation problems (as discussed in the morphological studies). H^+ and other ions could penetrate these coatings easily through the pores of the

phase separated PAni.DBSA. For coatings with ≤ 30.0 wt% of PAni.DBSA content, the pores of the coatings were almost covered due to the less phase separation between NBR and PAni.DBSA. The high content of NBR is believed to be able to unite the PAni.DBSA particles into a network during the electrodeposition and subsequently enhance the corrosion inhibiting behaviour.

Figure 6 shows some examples of corrosion potential against time for samples coated with NBR-PAni.DBSA blends (*i.e.* with PAni.DBSA contents, 5.0, 10.0 and 40.0 wt%) in 5.0 wt% sodium chloride aqueous solution. As expected, the NBR-PAni.DBSA blend with 10.0 wt% PAni.DBSA content showed the best corrosion inhibiting behaviour in the sodium chloride solution as well. However, a decreasing trend of corrosion potentials for all

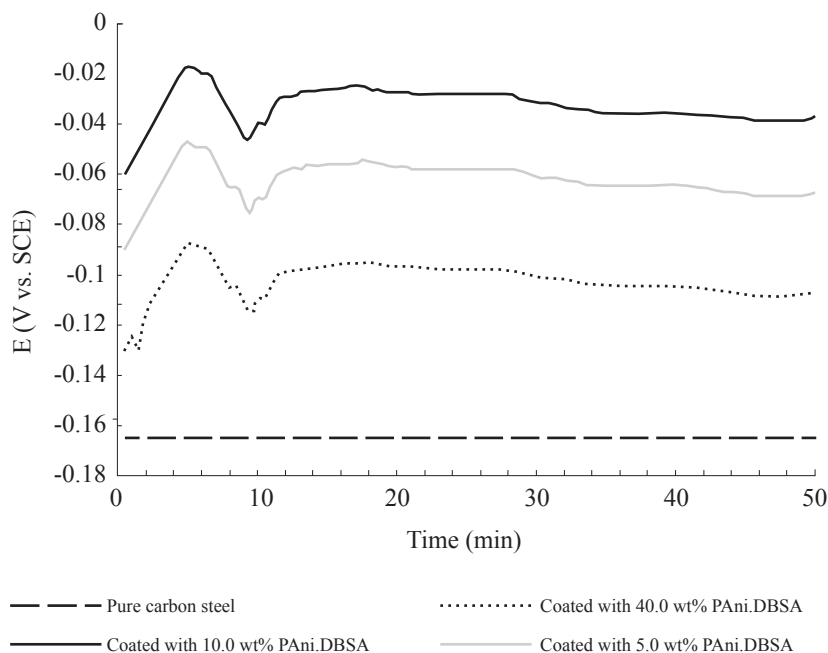


Figure 5. Plot of open circuit potential in 0.1 M HCl solution versus time.

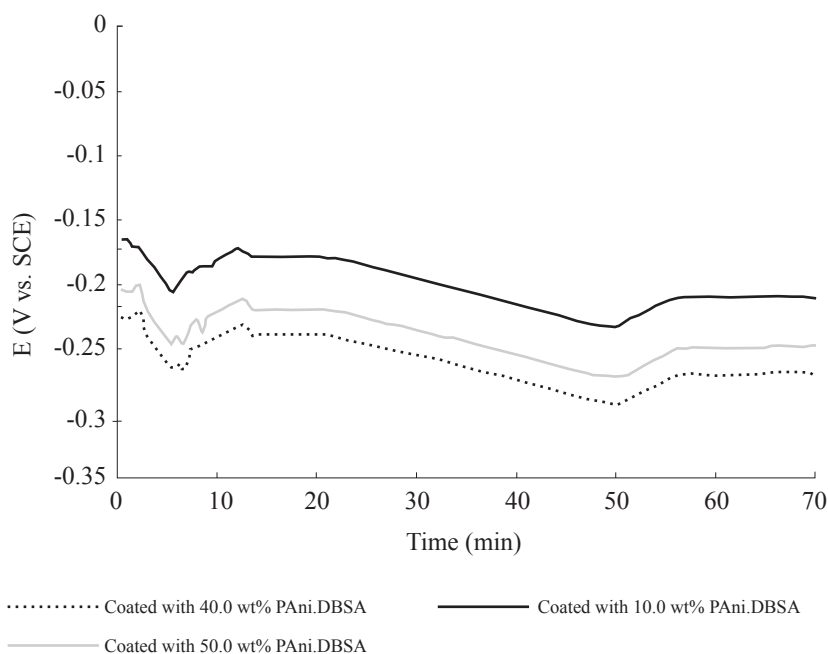


Figure 6. Plot of open circuit potential in 5.0 wt% sodium chloride aqueous solution versus time.

coated samples is also visible, indicating the corrosion process was taking place slowly over a relative period. Both *Figures 5 and 6* suggest that H^+ is the main corrosion source for the NBR-PAni.DBSA coating and by introduction of NBR, the corrosion inhibiting behaviour of this type of coating could be improved to a certain degree.

Tafel plots were generated by scanning the potential from E_{corr} to -250 mV versus E_{corr} (cathodic plot) or to $+250$ mV versus E_{corr} (anodic plot). *Figure 7* shows an example plot for sample coated with 10.0 wt% PAni.DBSA in the 5.0 wt% sodium chloride aqueous solution. The corrosion current (i_{corr}) was determined by superimposing a straight line along the linear portion of the cathodic or anodic curve and extrapolating it to E_{corr} , as illustrated in *Figure 7*. Correspondingly, the slope of the straight line is the cathodic

or anodic Tafel's constant (β_c or β_a , respectively). The corrosion current should be directly proportional to the corrosion rate. The determined i_{corr} values of all coated samples are summarised in *Table 3*. As observed from *Table 3*, all coated samples could prohibit the absorption of water and ions quite efficiently, particularly for those with 10.0–30.0 wt% of PAni.DBSA content. Coated samples with 10.0–30.0 wt% of PAni.DBSA content also appeared to be less corroded even after two weeks in the laboratory environment upon completing the electrochemical measurements. Hence, it is strongly believed that the NBR (as the rubber host matrix) could unite the PAni.DBSA particles together, which could subsequently lead to a stronger corrosion inhibiting behaviour for carbon steel. All results obtained from the electrochemical tests are consistent with the immersion tests.

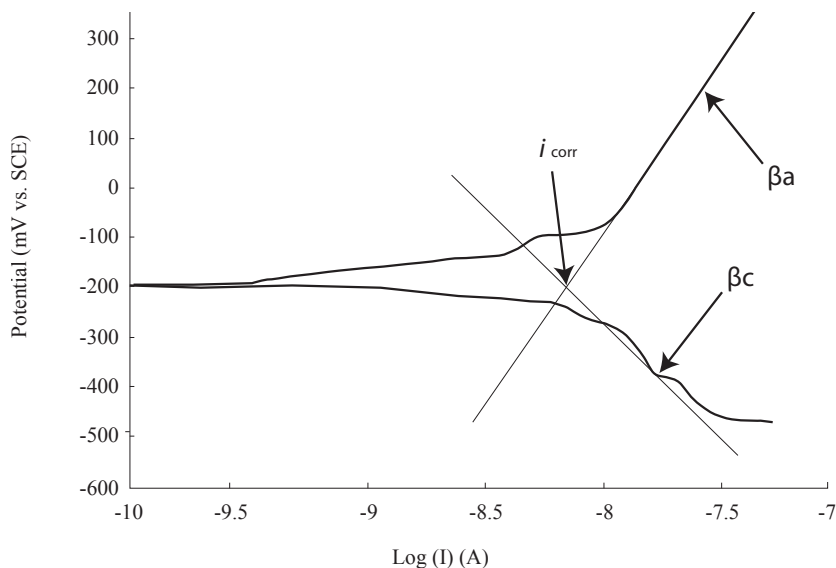


Figure 7. Tafel plot for sample coated with 10.0 wt% PANi.DBSA in 5.0 wt% sodium chloride aqueous.

TABLE 3. i_{corr} VALUES OF CARBON STEEL SAMPLES COATED WITH NBR-PANI.DBSA BLENDS

Sample	i_{corr} value (μA)
Sample coated with 1.0 wt% PANi.DBSA	0.1279
Sample coated with 2.5 wt% PANi.DBSA	0.0828
Sample coated with 5.0 wt% PANi.DBSA	0.0225
Sample coated with 10.0 wt% PANi.DBSA	0.0067
Sample coated with 20.0 wt% PANi.DBSA	0.0085
Sample coated with 30.0 wt% PANi.DBSA	0.0101
Sample coated with 40.0 wt% PANi.DBSA	0.0342
Sample coated with 50.0 wt% PANi.DBSA	0.0533

CONCLUSION

NBR-PANi.DBSA blends with good electrical conductivity (up to $10^{-1} \text{ S.cm}^{-1}$) were successfully prepared for the purpose of corrosion inhibiting of carbon steel. As found from both FTIR spectroscopy and TEM morphological studies, a reasonably high level of compatibility between the NBR and PANi.DBSA was achieved *via* the introduction of

1.0 wt% of hydroquinone. From the results of total immersion and electrochemical corrosion tests, NBR-PANi.DBSA blends with 10.0–30.0 wt% of PANi.DBSA content are deemed to be the best corrosion inhibitors for carbon steel, either in acid or artificial brine environment. This phenomenon is attributed to their best compatibility level and lowest phase separation problem of the two constituent polymers.

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