Studies on electropolymerization of aniline in the presence of sodium dodecyl sulfate and its application in sensing urea

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Abstract

In this paper, we report a detailed investigation of the effect of varying concentrations of sodium dodecyl sulfate (SDS) on the rate of polymerization of aniline. Quantitative analysis of the data is done in order to propose a probable mechanism for the growth of polyaniline (PANI) in presence of SDS (SDS/C1/PANI). The SDS–PANI films were characterized by cyclic voltammetry, electrochemical quartz crystal microbalance (EQCM), in situ conductance, in situ UV–vis spectroscopy and scanning electron microscopy (SEM) and were contrasted with polyaniline prepared under identical conditions in the absence of SDS. The polymerization rate was found to decrease initially with increase in concentration of SDS; it passes through a minimum at 1.5 mM and then increases rapidly on further increasing the SDS concentration. EQCM studies showed that the polymerizing species is a charge transfer complex formed between SDS and aniline. Leaching out of SDS was observed during redox cycling of the SDS–PANI films, which results in the formation of a porous polymer film allowing more inclusion of ions. This was further confirmed by observing a higher transport rate of urea across SDS–PANI coated membrane. These porous polyaniline films were then used as transducer for sensing urea.

Keywords: PANI; SDS–PANI; Microstructure; Urea sensor

1. Introduction

Conducting polymers are novel organic semiconducting materials with great promise because of their wide range of potential technological applications. This include their applications in storage batteries [1,2], electrochromic devices [3,4], light emitting diodes [5], non-linear optics [6], as a corrosion inhibitor [7] and in a variety of sensors including chemical [8,9] and biosensors [10–12]. The understanding of the nature of these polymers is of utmost importance for developing electrochemical devices. Among the conducting polymers, polyaniline has been studied extensively due to the commercial availability of the monomer, its easy synthesis, well-behaved electrochemistry, good environmental stability, high conductivity and multiple redox and protonation states [13].

Normally intractable polyaniline can be made processable either by making it soluble by doping it with organic sulfonic acids [14,15] or by the preparation of polyaniline in colloidal form [16]. Polymeric as well as non-polymeric surfactants have been used to make colloidal polyaniline. The presence of a surfactant or polyelectrolyte significantly modifies both the microscopic and macroscopic properties of the final polymer [16–27]. Polyaniline films prepared in the presence of poly (vinyl sulfonate) remain conducting even in neutral solution [18], whereas polyaniline itself becomes insulating at pH higher than 4. Sodium dodecyl sulfate (SDS) has been used extensively as a surfactant for micellar/emulsion polymerization of aniline using both chemical and electrochemical polymerization routes [17,21–27]. An enhancement in the rate of polymerization was observed in the presence of SDS and this has been attributed to the high local concentration of aniline monomer in the micellar reaction medium. However, the SDS concentrations used for these studies were much higher than the cmc of SDS under the experimental conditions. Interestingly, Albuquerque Maranhao and
Torresi [24] have observed a decrease in the rate of polymerization in the presence of SDS when the concentration of SDS was either below or around the cmc. These two observations suggest that the rate of polymerization of aniline in the presence of SDS should pass through a minimum. Surprisingly, there are no detailed mechanistic studies on the effect of varying concentrations of SDS on the rate of polymerization of aniline. Furthermore, there are no detailed reports available in the literature where the polyaniline obtained in the presence of SDS was compared with polyaniline films prepared under similar conditions but in the absence of SDS. In this paper, we report the detailed mechanistic investigations of the effect of varying amount of SDS on the rate of polymerization of aniline. Quantitative analysis of the data is also done in order to propose a probable mechanism for the growth of polyaniline in the presence of SDS. We also report the effect of the presence of SDS on various properties of the polymer obtained and have compared them with those of polyaniline prepared under identical conditions but in the absence of SDS. Finally the use of this modified polyaniline as a sensor material has also been discussed.

2. Experimental

2.1. Chemicals and materials

Aniline was distilled under reduced pressure before use. Sulfuric acid used was MOS grade with 99.99% purity. Urease EC 3.5.1.5 (Jackbean meal) was obtained from Sigma. The activity of urease was determined by the conventional assay method [28]. Deionized water from a Millipore purification system was used for the preparation of the solutions. 0.5 mm diameter AT cut quartz crystals were obtained from PARC, USA. Polycarbonate membranes with 1.2 μm pore diameter were obtained from Millipore. The membrane electrodes were fabricated using the procedure given earlier [29].

2.2. Cmc of SDS in aniline monomer solution

The cmc of SDS in water, 0.5 M H₂SO₄ and aniline monomer solution was determined by the surface tension method [30]. The cmc of SDS in water was found to be 8 mM, which is in agreement with the literature value [31]. The cmcs of SDS in aniline monomer solution (0.1 M aniline +0.5 M H₂SO₄) and 0.5 M H₂SO₄ were found to be 0.06 and 0.07 mM, respectively. There is a significant change in the cmc value of SDS when going from water to 0.5 M H₂SO₄. These values are in agreement with the values reported by Albuquerque Maranhao and Torresi. [24].

2.3. Polymerization

SDS–PANI films were synthesized using aniline monomer solution (0.1 M aniline in 0.5 M H₂SO₄) in the presence of various concentrations of SDS (0.02 mM –50 mM). A Pt foil, membrane electrode or a gold coated quartz crystal was used as the working electrode. PANI films were synthesized from aniline monomer solution. The polymerization was carried out by the potentiostatic method at a constant potential of 0.7 V versus SCE or by scanning the potential between −0.2 and 0.8 V versus SCE (50 mV s⁻¹).

2.4. Characterization of polyaniline synthesized in the presence of SDS

Characterization of SDS–aniline monomer solution was done by optical microscopy with the help of an OLYMPUS BX 60 analyzer. The electrochemical characterization of SDS–PANI film was carried out with the help of a 273 EG & G PARC potentiostat/galvanostat coupled to a LINSEIS 16100 XYt recorder. EQCM studies were carried out with a QCA 917 quartz crystal analyzer to monitor the redox charges and mass changes. In situ resistance measurement of the polymer was done with the help of a PINE AFRDE4 bipotentio- stat coupled to a XYt recorder. For in situ resistance measurements, the polymer was synthesized electrochemically within the pores of an isoporous polycarbonate membrane electrode. This concept of template synthesis of conducting polymers described by Martin has been adapted in our laboratory to fabricate microelectrochemical devices [32]. The morphology of the polymer film was studied with a JEOL JSM 6400 scanning electron microscope at an accelerating voltage of 10 kV. The samples were prepared electrochemically on Pt electrodes or on gold coated polycarbonate membranes with a pore diameter of 1.2 μm. To observe the polymer formation within the pores the template membrane was dissolved in dichloromethane. Transport of urea across PANI and SDS–PANI coated membranes were carried out in an H-type cell. PANI and SDS–PANI films of the same polymerization charge were grown electrochemically within 1.2 μm pore diameter polycarbonate membranes. SDS was allowed to leach out from the polymer by repeated cycling. The compartment A was filled with 7 ml of 100 mM urea in pH 5.2 acetate buffer and compartment B was filled with pH 5.2 acetate buffer. The membrane was maintained at a particular potential for 20 min. The potential was varied between −0.5 to 0.5 V versus SCE. After equilibrating at each potential all the solutions were withdrawn from compartment B and assayed by a conventional assay procedure. In situ UV–vis spectra of the polymer were recorded with a Shimazdu 2100 UV–vis Spectrophotometer. An Ag | AgCl wire was used as the reference
electrode. The potential was controlled with the help of an EG & G PARC 362 potentiostat/galvanostat.

2.5. Application of SDS–PANI as a sensor for urea

SDS–PANI synthesized on the membrane device was used as the transducer and immobilization matrix for the fabrication of a urea sensor. The sensor response was measured in terms of a dimensionless factor, $\Delta R/R$, where $R_0$ is the resistance of the sensor without any urea and $\Delta R = R - R_0$, where $R$ is the resistance of the sensor in the presence of various concentrations of urea. Representation in $\Delta R/R_0$ normalizes the sensor response and minimizes the variation of response from sensor to sensor.

3. Results and discussion

3.1. Effect of SDS on electrochemical polymerization

In order to study the effect of varying concentrations of SDS on polyaniline growth, aniline was electropolymerized at a constant potential of 0.7 V versus SCE from monomer solution (0.1 M aniline in 0.5 M H$_2$SO$_4$) on a Pt foil in the presence of varying amounts of SDS (0.02–50 mM). The amount of charge passed was monitored and the total charge passed at a given time has been taken as the index for the rate of polymerization. A plot of charge passed in 300 s versus SDS concentration is shown in Fig. 1. It is clear from the figure that the rate of polymerization decreases as the concentration of SDS increases and reaches a minimum around 1.5 mM SDS. The rate of polymerization then increases rapidly on further increase of the SDS concentration and saturates at around 15 mM. The rate of polymerization does not change significantly when the concentration of SDS is further increased from 15 up to 50 mM. Similar results were obtained when the amount of charge passed in 600 s was plotted against SDS concentration. The horizontal line represents the polymerization charge at 300 s in the absence of SDS. Fig. 1 can be divided into three regions. The first one is up to 0.5 mM SDS where the rate of polymerization is higher than that in the absence of SDS. The second region is from 0.5 mM up to approximately 1.8 mM where the rate of polymerization is lower than that in the absence of SDS. The third region is above 1.8 mM where the rate of polymerization increases rapidly with further increase in SDS concentration and saturates at around 15 mM. In the first region the increase in the rate of polymerization is attributed to the formation of a complex between the anionic surfactant and the anilinium cation and is in agreement with the results of Albuquerque Maranhao and Torresi [24]. The surfactant tends to accumulate at the electrode | electrolyte interface and draws in the monomer, thereby enhancing the local concentration. Above the cmc, the anilinium cations are present mostly bound to the surface of the micelles. The supply of monomer to the electrode is now limited by the diffusion of the micelles. In view of their large size, the rate of arrival of monomer towards the electrode will be low, which results in lowering the polymerization rate. On further increasing SDS concen-

![Fig. 1](image-url)  
*Fig. 1. Amount of charge passed in 300 s as a function of SDS concentration for the electropolymerization of aniline. The horizontal line represents the polymerization charge in the absence of SDS.*
The number of micellar structures increase and on further increasing the concentration, an emulsion is formed. Fig. 2 shows the optical microscopy of 20 mM SDS–aniline solution. Droplets of various sizes from 0.1 to 40 μm were observed. It was not possible to see droplets of less than 0.1 μm because of the limitation of the microscope. The presence of aniline in these droplets was confirmed spectrophotometrically as follows. A 20 mM SDS–aniline solution was allowed to remain undisturbed for a few hours. The bottom phase appeared to be a clear solution and all the droplets were accumulated on the top of the solution. The oil phase was carefully removed, using a microsyringe. The UV–vis spectrum showed the presence of protonated aniline in the oil phase. The UV–vis spectrum of the aqueous phase also showed the presence of aniline but its concentration was eight times less than that in the oil phase. This was in close agreement with the studies by Lelièvre et al. [33] who have shown that SDS micelles have a partition coefficient of aniline in water of 9.5. Because of the increase in the local concentration of aniline in the droplets, which tend to accumulate at the electrode | solution interface, the polymerization rate increases and finally saturates around 15 mM. For all further studies, 20 mM SDS was used because the rate of polymerization does not change on further increasing the SDS concentration and the resulting films are referred to as SDS–PANI. To study the nucleation and growth of PANI and SDS–PANI films, current–time profiles were recorded by potentiostatic polymerization of aniline on a Pt foil in the presence and absence of SDS. For SDS–PANI, the current increases much faster than in the absence of SDS indicating a more efficient polymerization. The current–time transients were linear for a period of 100 s after which the polymer growth occurred rapidly obeying an I versus t^2 relationship. The linear time dependence found in the early stages refers to 2D instantaneous nucleation and growth followed by 3D instantaneous nucleation and growth [34]. Scanning electron micrographs of the polymer film confirm the above observation. Fig. 3 shows the scanning electron micrographs of SDS–PANI formed on a Pt surface. The micrograph shows islands of SDS–PANI forming randomly on a surface covered with a thin compact film. The sizes of these islands vary from less than 0.1 to 40 μm. These three-dimensional islands were found to form on the top of a two dimensional planar surface thus supporting the information obtained for the current versus time profile for SDS–PANI. The diameter of the three dimensional islands in SDS–PANI can also be compared with the droplets observed in the optical micrographs of SDS–aniline monomer solution. This further confirms that the polymerization occurs from the droplets, which are rich in aniline. On the other hand, for PANI, the current transients are linear with time for 600 s followed by an exponential growth (1D needle type growth). The nucleation and growth of polyaniline is in agreement with other reported work [35]. EQCM studies on polymer films of different polymerization charges (8, 21, 32 mC cm\(^{-2}\)) were
carried out and the total mass of the polymer deposited was calculated by using the Sauerbrey equation for the resonance frequency of the quartz crystal [36]. The theoretical mass is calculated from the polymerization charge, assuming 100% current efficiency and these values are also given in Table 1. Since the molar mass of the polymerizing species is higher in the presence of SDS (PhNH$_3^+$SO$_4^-$/C$_{27}$H$_{52}$) compared with that in the absence of SDS (PhNH$_3^+$HSO$_4^-$) the calculated theoretical mass is also higher for the same polymerization charge. It is evident from Table 1 that the efficiency of polymerization is much higher in the presence of SDS as the mass deposited is considerably higher for the same polymerization charge. In the case of PANI films, the experimental mass was found to be much less than the theoretical mass. This may be due to the formation of soluble oligomers that diffuse away from the electrode. However, with increasing polymerization time the concentration of oligomer in the solution increases and further dissolution of oligomer is prevented. In the case of polymerization in the presence of SDS, the calculated theoretical mass was found to be in good agreement with the experimental values, which further supports our hypothesis, that polymerization occurs mainly from the complex formed between aniline and SDS.

### 3.2. Study on the redox charge and mass change of SDS–PANI

Studies on the redox charge and mass change were carried out in pH 1 chloride solution. Polyaniline films were prepared in the presence and absence of SDS. In the cyclic voltammogram of SDS–PANI a shoulder was observed around 150–200 mV and a peak around 350–400 mV in the positive scan (Fig. 4). The shoulder was not observed with PANI films. The shoulder is attributed to the presence of SDS in the film. This was further confirmed by the fact that a shoulder appeared at the same potential when PANI films are cycled at pH 1 in SDS-free chloride buffer solution after they had been cycled repeatedly at pH 1 in the presence of 20 mM SDS (Fig. 4). Another interesting point to note in the figure is that the redox peak becomes sharper (Fig. 4) when the PANI films are cycled in buffer solution of pH 1 in the presence of 20 mM SDS. This implies a higher value of the overall charge transfer rate constant in the presence of SDS and more facile charge transfer [37]. Fig. 5a shows the cyclic voltammograms of PANI and SDS–PANI having the same polymerization charge. SDS–

![Fig. 3.](image)

Fig. 3. (A) Scanning electron micrograph of SDS–PANI (polymerization charge = 8 mC cm$^{-2}$). (B) Microstructure of one of the islands of SDS–PANI (size = 20 µm).

<table>
<thead>
<tr>
<th>Polymerization charge/ mC cm$^{-2}$</th>
<th>PANI</th>
<th>SDS–PANI</th>
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<tr>
<td></td>
<td>Experimental mass/ µg cm$^{-2}$</td>
<td>Theoretical mass a/ µg cm$^{-2}$</td>
</tr>
<tr>
<td>8.1</td>
<td>0.9</td>
<td>8.1</td>
</tr>
<tr>
<td>21.9</td>
<td>6.1</td>
<td>21.41</td>
</tr>
<tr>
<td>32.6</td>
<td>10.3</td>
<td>32.12</td>
</tr>
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</table>

* The theoretical mass was calculated by considering that the polymerizing species are PhNH$_3^+$HSO$_4^-$ (Molar mass 191 D) in the case of PANI and PhNH$_3^+$SO$_4^-$/C$_{16}$H$_{33}$ (Molar mass 359 D) in the case of SDS–PANI.
PANI films were found to have a higher redox charge compared with PANI. This was because of the trapped counterions inside the polymer film. The $\Delta n$ versus $E$ profile (Fig. 5b) shows that inclusion of ions takes place at a more positive potential in SDS–PANI films (0.3 V) compared with PANI (0.15 V) and the amount of inclusion of anions is less in SDS–PANI compared with PANI. This may be because the presence of anionic SDS in the polymer matrix obviates the need for inclusion of chloride ions for charge neutrality. Here protons will participate strongly in the charge compensation process. Due to the small mass of protons, no noticeable mass change occurs up to 0.3 V as is shown in Fig. 5b.

3.3. In situ conductance and in situ UV–vis spectroscopy of SDS–PANI

In situ conductance studies were carried out as a function of pH for SDS–PANI grown through the pores (1.2 µm) of gold coated PC membranes. As described by Martin [32] the polymer nucleates and grows preferentially along the pore walls due to the hydrophobic nature of the pore wall forming polymeric tubes. Fig. 6A and B shows the micrographs of tubes of SDS–PANI formed inside the pores (1.2 µm) of polycarbonate membranes. Fig. 6A shows tubules of SDS–PANI with a solid base. Fig. 6B shows a bunch of tubules fallen on the surface of the stub. These tubules are of 9–10 µm length and the length of these tubules is approximately the same as the thickness of the polycarbonate membrane. The polymerization was carried out for 20 min. It should be noted here that the time taken to plug the pores of SDS–PANI tubules was 20 min in contrast to PANI, where the time taken to plug the pores was 45 min. As can be seen, the time taken to plug the pores is in good agreement with the time taken to form full length tubules growing from one end of the PC membrane to the other end. Fig. 7a shows the three dimensional surface state diagram of SDS–PANI show-
ing changes in conductance with potential at various pHs. Contrary to the case for PANI, where the conductance falls sharply at pH higher than 3, SDS-PANI remains conducting up to neutral pH (pH 7). The extended conductance of SDS-PANI to the neutral pH is attributed to the modified ‘Donnan potential’ at the interface of the polymer and electrolyte due to the immobilization of SDS into the polymer matrix [18,20]. The above conclusions were further supported by the data from in situ UV–vis studies of the polymer. Spectra of SDS–PANI and PANI films were recorded both at pH 1 and 6.4. Fig. 7b shows the plot of absorbance at 800 nm versus potential for SDS–PANI and PANI at pH 1 and 6.4. For SDS–PANI the 800 nm band increases with increase in potential both at pH 1 and 6.4 indicating a conducting SDS–PANI at pH 6.4 also. On the other hand, the absorption spectra of PANI represent a poorly conducting form of the polymer at pH 6.4. The in situ conductance of SDS–PANI at pH 1 and 6.4 are also shown in the same figure for comparison. The in situ UV–vis spectra of the electrochemically polymerized SDS–PANI films are in agreement with the absorption spectra of PANI dispersion synthesized chemically in the presence of SDS [22]. The absorption spectra of PANI dispersion synthesized in the presence of SDS showed that the transition between conducting and insulating states occurs between pH 7-8.

3.4. Leaching out of SDS from the polymer film

It is clear from the above results that the SDS–PANI films have modified microscopic and macroscopic properties. However, SDS is loosely bound to the polymer chain and leaches out by repeated cycling of the film between the reduced and the oxidized state in buffer solution for a few hours. SDS can also leach out by dedoping the film in aqueous ammonia solution for a
few hours followed by keeping it in water. The cyclic voltammogram of this modified polymer shows a disappearance of the shoulder and a 100 mV negative shift of the anodic oxidation peak of the polymer (Fig. 8a). The polyaniline film of same polymerization charge is also shown in the figure for comparison. It should be noted that leaching out of SDS from the polymer film does not bring back the anodic oxidation peak of the polymer to the same peak potential as that of polyaniline. There is no significant difference in the redox charge of the SDS–PANI film before and after leaching out of SDS. This modified polymer shows a more porous and open structure compared with polyaniline as shown by EQCM studies of the polymer film after leaching out of SDS. Fig. 8b shows the $\Delta m$ versus $E$ profile for SDS–PANI at pH 1 buffer after repeated cycling. The ion inclusion into the polymer film was greater than that before leaching out of SDS from the polymer film. In addition, the ion inclusion is greater than in PANI film formed with the same polymerization charge. This indicates a porous structure of SDS–PANI. This was further confirmed by comparing the inclusion of phthalate and chloride into PANI and SDS–PANI films having the same polymerization charge. Table 2 shows the moles of chloride and phthalate ion inclusion into PANI and SDS–PANI films at pH 3 having polymerization charges of 8, 21 and 32 mC cm$^{-2}$. The $\Delta m$ versus $E$ profile of the polymer film was recorded by scanning the potentials between $-0.2$ and $+0.5$ V versus SCE. Three important observations can be noted from this: (a) chloride ion inclusion is found to be greater compared with phthalate both in PANI and SDS–PANI films; (b) the chloride and phthalate ion inclusion is greater in SDS–PANI than PANI; (c) the ratio of chloride to phthalate is less in SDS–PANI compared with PANI prepared under identical conditions (Table 3). All the above observations imply that chloride, being a smaller ion, incorporates into the polymer film more easily than phthalate. The greater inclusion of ions into the SDS–PANI film implies a more porous nature of the film than that of PANI. The EQCM studies were further supported by the data from the transport studies. Urea was transported across PANI and SDS–PANI films of the same polymerization charge (25 mC cm$^{-2}$) grown electrochemically in the pores (1.2 $\mu$m) of polycarbonate membranes. The transport rates in both cases were found to be potential dependent. Fig. 9 shows the transport rates of urea through PANI and SDS–PANI films as a function of potential. The transport rate increases with increase in potential up to 0.3 V, after which it decreases slightly. In both PANI and SDS–PANI, the transport rate was found to be a minimum at $-0.5$ V when the polymer is in the reduced state. This is because of the fact that in the reduced state the polymer is in a compact coiled and tightly packed form, which allows a lesser amount of urea to be transported to the other side of the membrane. As the potential is made more positive the polymer chains open up and this results in a faster transport of urea. In addition, it was observed that in the reduced state of the polymer the transport rate of urea is comparable in both PANI and SDS–PANI. However, when the polymer was subjected to a more positive potential, the transport of urea in SDS–PANI was found to be twice that in PANI. This indicates a larger change in conformation from the reduced to the oxidized state in SDS–PANI. The bigger pores in SDS–

![Fig. 8](image-url)
3.5. Application of SDS/C1/PANI microtubules as a sensor for urea

A thin film of the SDS–PANI was formed through the pores (1.2 μm) of polycarbonate membranes so that it bridged the two sides of the membrane. SDS was allowed to leach out from the polymer film by cycling it repeatedly in the buffer solution and the film was washed thoroughly with water. Urease was immobilized in the polymer matrix by physical adsorption from pH 5.2 acetate buffer containing 250 U ml⁻¹ urease. The polymer was then exposed to different concentrations of urea solution. The urease catalyzed reaction results in hydrolysis of urea to NH₃ and CO₂. This causes a net increase in pH of the microenvironment of the polymer and a simultaneous increase in the resistance of the film. Fig. 10a shows the sensor response of a urea microtubule sensor based on SDS–PANI and PANI at +0.2 V. The sensor shows a linear response from 0 to 60 mM concentration of urea. The sensitivity of the sensor (defined as the change in the response of the sensor per unit change in the concentration of the substrate in the linear range of the response) was found to be 0.17 mM⁻¹. This is in contrast to polyaniline grown under identical conditions, where the sensor response was linear between 0 and 20 mM concentrations of urea and had a sensitivity of 0.03 mM⁻¹. This implies that the sensitivity and the linear range of the response, which are two important parameters for the performance of a sensor have increased significantly in this modified polyaniline film. The increase in the linear range of response and sensitivity of the sensor can be explained by the pH dependence of the conductance behavior for SDS–PANI and PANI. Fig. 10b shows the change in conductance versus pH for SDS–PANI and PANI microtubules at 0.2 V. For SDS–PANI, SDS was leached out from the polymer matrix by repeated cycling. As is seen from the figure, the slope of the conductance versus pH profile is greater in SDS–PANI compared with PANI with increasing pH after pH 5. In addition, the increase in the sensor response of the SDS–PANI film can be attributed to the increased enzyme loading on the polymer matrix due to the porous nature of the polymer and also faster diffusion.

<table>
<thead>
<tr>
<th>Polymerization charge/mC cm⁻²</th>
<th>Moles of Cl⁻: moles of phth in PANI films</th>
<th>Moles of Cl⁻: moles of phth in SDS–PANI films</th>
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<tr>
<td>pH 3</td>
<td>pH 4</td>
<td>pH 3</td>
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<tr>
<td>8.1</td>
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<td>32.6</td>
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Table 3
Ratio of chloride (Cl⁻) to phthalate (phth) uptake in PANI and SDS–PANI films at pH 3 and 4
of substrates to the polymer film which was supported by the transport of urea across the SDS–PANI matrix.

4. Conclusions

In this paper, we have shown that polymerization of aniline in the presence of SDS proceeds mainly from the complex between aniline and SDS. The rate of polymerization initially decreases with increase in SDS concentration and passes through a minimum before it increases rapidly and saturates at 15 mM. The current time profile and SEM studies indicate that the mechanism of growth and morphology of the film is different from PANI. The presence of SDS in the polymer film modifies the conductance versus pH profile and extends its conductance to neutral pH. However, SDS is loosely bound to the polymer matrix and leaches out during cycling. This leaves behind a porous film. This porous polymer was used as an immobilization matrix and a transducer for sensing urea. It shows an increase in the sensitivity and linear response compared with polyaniline, which is attributed to the modified pH dependent conductance of the polymer, more loading of the enzyme and faster diffusion of substrates in the former due to the porous nature of the polymer.

Acknowledgements

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