Preparation and Characterization of Conducting Polystyrene Graft Polyaniline

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Abstract: The electroactive graft of polystyrene (PS) and polyaniline (PANi) copolymer can be synthesized by chemical and electrochemical polymerization method using a polymer as precursor which contains an aniline moiety in its side chain. Poly(styrene-*co*-p-chloromethylstyrene), poly(S-*co*-PCMS), was chemically synthesized with chloromethylated styrene then copolymerized styrene by free radical mechanism. Poly(styrene-*co*-p-aminoanilinemethylstyrene), poly(S-*co*-PAAMS), was prepared chemically with poly(S-*co*-PCMS) and 1,4-phenylenediamine, too. Therefore, PANi grafted to PS, (PS-*g*-PANi) synthesized by ammonium peroxydisulfate as the oxidant and p-toluenesulfonic acid in dimethylsulfoxide (DMSO) solution with adding aniline on oxidated poly(S-*co*-PCMS). The formation of graft copolymer was confirmed by FT-IR, UV-visible, ^{1}H and ^{13}C-FT-NMR spectroscopy. Therefore, molecular weight and amount of PANi grafted on PS have been measured by gel permeation chromatography and elemental analysis, respectively. The thermal analysis of graft copolymer was carried out using thermogravimetic analysis (TGA) and differential scanning calorimetric (DSC). The solution of poly(S-*co*-PAAMS) in DMSO was spin-coated on GC electrode and electrochemically polymerized in electrolytic mixture solution consisting of 0.05 M aniline, 0.1 M H_2SO_4 and 1 M HCl. Electrolysis constant potential showed that aniline groups in the precursor were oxidized to form PANi, that is, they acted as grafting centers at which the PANi grew. Results of scanning electron microscopy (SEM) results and conductivity measurements supported the formation of the graft copolymer. The morphological feature of PS-*g*-PANi copolymer film has been shown homogeneous structure, the PS/PANi composite film shows irregular structure. Electrical conductivity of copolymer has been studied by four probe method and produced 3.3×10^{-2} S/cm.

INTRODUCTION

Conjugated polymers maybe made by a variety of techniques, including cationic, anionic, radical chain growth, co-ordination polymerization, step growth polymerization or electrochemical polymerization.

Electrochemical polymerization occurs by suitable monomers which are electrochemically oxidized to create an active monomeric and dimeric species which react to form a conjugated polymer backbone [1]. The main problem with electrically conductive plastics

stems from the very property that gives it its conductivity, namely the conjugated backbone. This causes many these polymers to be intractable, insoluble films or powders that cannot melt [2]. There are two main strategies to overcoming these problems. There are to either modify the polymer so that it maybe more easily processed, or to manufacture the polymer in its desired shape and form. There are, at this time, four main methods used to achieve these aims [3].

The first method is to manufacture a malleable polymer that can be easily converted into a conjugated polymer. This has been done when the initial polymer is in the desired form and then, after conversion, is treated so that it becomes a conductor. The treatment used is most often thermal treatment. The precursor polymer used is often made to produce highly aligned polymer chain which are retained upon conversion. These are used for highly orientated thin films and fibers. Such as these films and fibers are highly anisotropic, with maximum conductivity along the stretch direction [4].

The second method is the synthesis of copolymers or derivatives of a parent conjugated polymer with more desirable properties. This method is the more traditional one for making improvements to a polymer. What has been done is to try to modify the structure of the polymer to increase its processability without compromising, its conductivity or its optical properties. All attempts to do this on polyacetylene have failed as they always significantly reduced, its conductivity. However, such this attempt on polythiophenes and polypyrroles proved more fruitful. The hydrogen on carbon 3 on the thiophene or the pyrrole ring was replaced with an alkyl group with at least four carbon atoms in it. The resulting polymer, when doped, has a comparable conductivity to its parent polymer whilst be able to melt and it is soluble. A water soluble version of these polymers has been produced by placing carboxylic acid group or sulphonic acid group on the alkyl chains. Then such system can maintain charge neutrality in its oxidized state and so they effectively dope themselves. Such polymers are referred to as "self-doped" polymers. One of the most highly conductive derivative of polythiophene is made

by replacing the hydrogen on carbon three with a -CH_2-O-CH $_2CH_2$-O-CH $_2CH_2$-O-CH_3. This is soluble and reaches a conductivity of about 1000 S cm^{-1} upon doping [5].

The third method is to grow the polymer into its desired shape and form. An insulating polymer impregnated with a catalyst system is fabricated into its desired form. This is then exposed to the monomer, usually a gas or a vapour. The monomer then polymerizes on the surface of the insulating plastic producing a thin film or a fibre. This is then doped in the usual manner. A variation of this technique is electrochemical polymerization with the conducting polymer being deposited on an electrode either the polymerization stage or before the electrochemical polymerization. This maybe used for further processing of the conducting polymer. For instance, by stretching aligned bends of polyacetylene/polybutadiene the conductivity increase 10 fold, due to the higher state of order produced by this deformation [6].

The final method is the use of Langmuir-Blodgett trough to manipulate the surface active molecules into a highly ordered thin films whose structure and thickness which are controllable at the molecular layer. Amphiphilic molecules with hydrophilic and hydrophobic groups produces monolayers at the air-water surface interface of a Langmuir-Blodgett trough. This is then transferred to a substrate creating a multilayer structure comprised of molecular stacks which are normal about 2.5 nm thick. This is a development from the creation of insulating films by the same technique. The main advantage of this technique is its unique ability to allow control over the molecular architecture of the conducting films produced. It can be used to create complex multilayer structures of functionally different molecular layers as determined by the chemist. By producing alternating layers of conductor and insulator it is possible to produce highly anisotropic film which is conducting within the plane of the film, but insulating across it [7]. In this investigation, we pointed out the production of graft copolymer films of polystyrene (PS) and polyaniline (PANi) (Scheme I). Emeraldine salt (half oxidized PANi, y=0.5) is the most

conductive form of PANi, which can be obtained by protonation of emeraldine base and oxidation of leucoemeraldine base as shown in Figure 1.
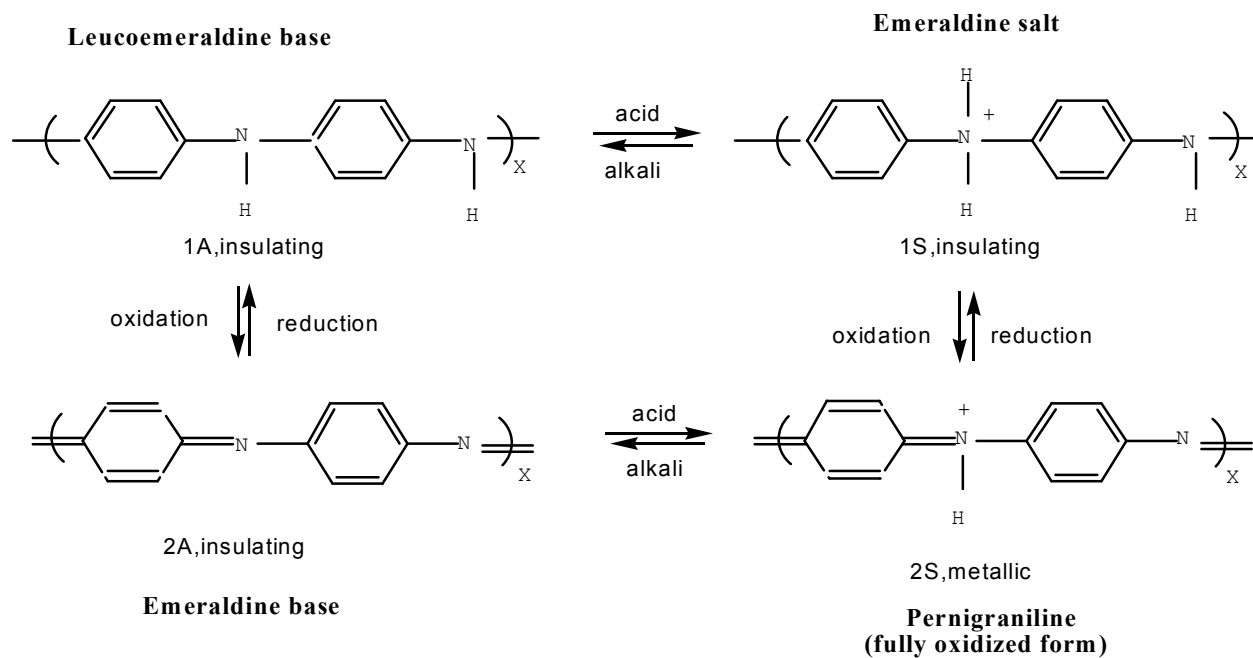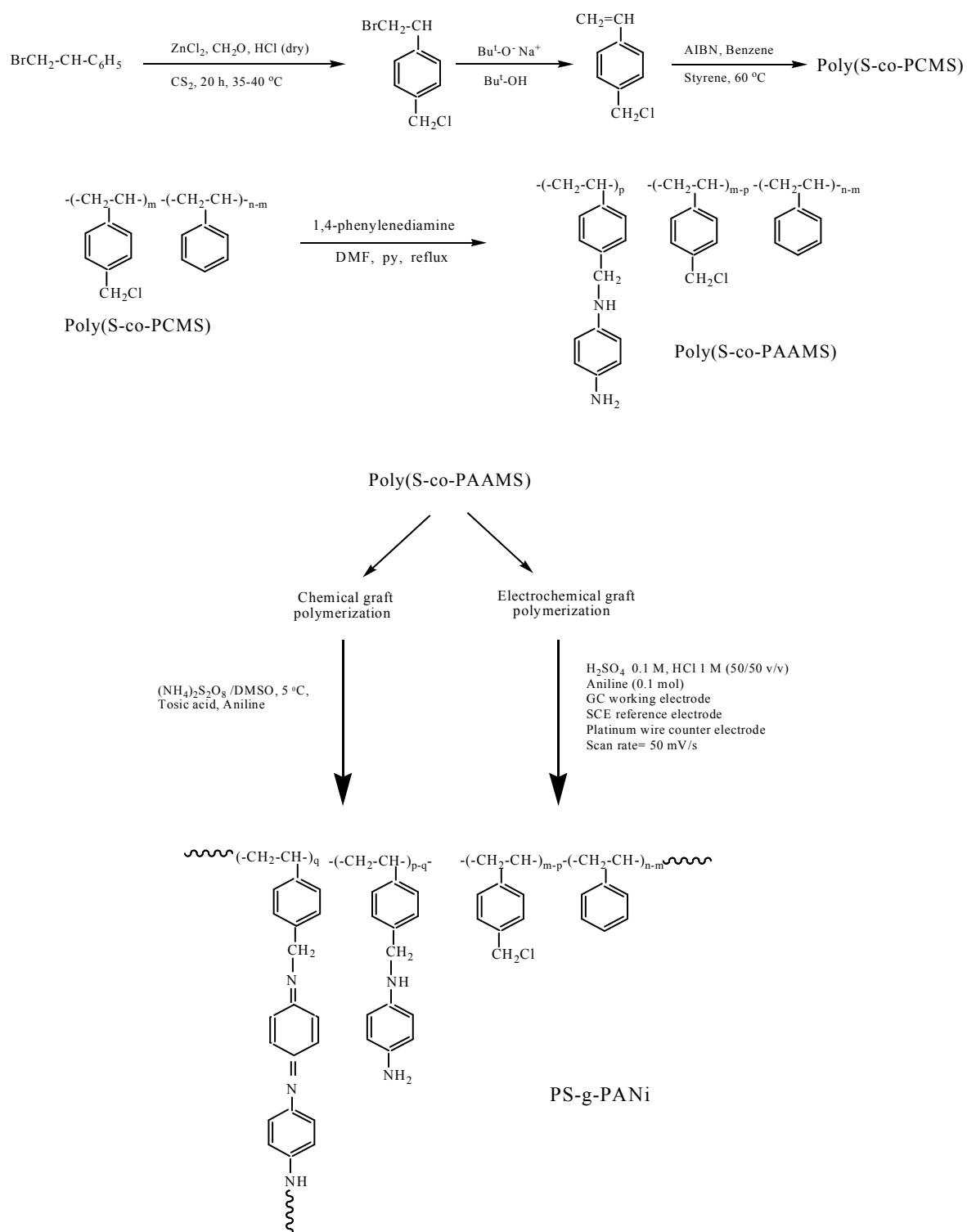

Figure 1. The different of polyaniline forms

Scheme I

The preceding works, we have prepared graft copolymer polypyrrole on poly(vinyl acetate), PS [8,9] and polyaniline on polyacrylonitrile [10]. These These copolymer showed high conductivity but decreased solubility by increasing polypyrrole ratio on copolymers.

Here we determined the composition as well as the conductivity and solubility properties of those graft copolymers PS-*g*-PANi depending on the reaction conditions.

The graft copolymer materials prepared from hydrophilic polymers, PS-*g*-PANi could be appropriate for various applications in science and technology due to the good mechanical properties and their electrical conductivity. The changes and maximum balance's of doping are limited. But they have stability of electrical conduction and high physical resistance.

EXPERIMENTAL

Materials

Aniline (GPR) was dried with NaOH, fractionally distillated under reduced pressure from sodium or CaH_2. Polystyrene with 5% polybutadiene (Aldrich, Medium molecular weight) was used as matrix polymer. Acetonitrile (Merck) was dried on silicagel, distilled on P_2O_5 in the presence of nitrogen gas. 1,4-Phenylenediamine (Aldrich) purified by recrystalled in ethanol. Azobisisobutyronitrile (AIBN) and all the other materials and gases used in this work were purchased from Merck chemicals and purified, or were prepared by literature methods.

Instrumentals

Elemental analysis was determined with Perkin-Elmer 2400 CHN. A fourier-transform infrared spectrometer (8101 M-Shimadzu) was used in spectral measurements of the polymer and reported by sharp (sh), weak (w), broad (b), middle (m). Cyclic voltammetry and electrochemical polymerization were carried out using digital potentiostate DP8 and the electrical conductivity of polymer was measured at room temperature by the four-probe technique (ASTM Standards, F 43-93). Proton nuclear magnetic resonance (FT-H[1], ^{13}C-NMR) spectra were recorded at 250 MHz on a Bruker WP 200 SY spectrometer . NMR data are reported in the following order: chemical shift (ppm), spin multiplicity (s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet, b= broad) and integration. Visible spectra were obtained by Perkin Elmer Lambda 15 spectrophotometer. Molecular weights were measured at 30 ^{0}C with a gel permeation chromatography (GPC) (Waters Associates, model 150-C). Three styragel packed columns with different pore sizes (10^4-10^6 A^0) were used. The mobile phase was tetrahydrofuran (THF) with flow rate of 1.5 ml/min. The solution concentration was 0.2 wt%. Calibration of the instrument was performed with nine standard samples of monodisperse polystyrene having molecular weights between 3.0×10^3 and 1.4×10^6. The thermal properties of polymer were studied by thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) of PL Thermal Science. Scanning electron microscopy (SEM) was employed to study the type of surface morphology of polymer. A Cambridge S-360 SEM was used for this purpose.

Synthesis of p-(2-bromoethyl)benzyl chloride

2-Phenylethyl bromide (70 g, 0.38 mole) was dissolved in 50 ml of carbon disulfide in a 1 liter three-necked round-bottomed flask equipped with a stirrer, gas inlet tube, and a reflux condenser. Anhydrous zinc chloride (11 g) and paraformaldehyde (13 g) were added to the flask in three separate portion during the course of reaction. Hydrogen chloride was bubbled into the reaction mixture the rapid stirring for 20 hr at 35-40 ºC. The lower phase of the reaction mixture was soluble in water. The organic layer was washed with water, diluted sodium carbonate and again with water. After being dried with anhydrous sodium sulfate, the carbon disulfide was distilled from the product and unreacted 2-phenylethyl bromide was recovered by distillation at a pressure of about 10 Torr. The product a mixture of o- and p-(2-bromoethyl)benzyl chloride was obtained by distillation bp 91-94 ºC/2 Torr. The mixture was dissolved in 200 ml of petroleum ether and the solution was chilled overnight in a refrigerator. The remaining liquid was decanted and obtained solid was

recrystallized twice from 200 ml of petroleum ether. The yield was 39 g (54%); mp 48-50 ^{o}C. [10] Gas chromatography of obtained compound showed one peak (Carbowax 20M, 10%, Celite 545, 1 m, 160 C, Hz). The ^{1}H-NMR spectrum showed 2.97-3.64 (-CH_2CH_2Br), 4.47 (-CH_2Cl) and 7.19 ppm (aromatic protons).

Synthesis of p-chloromethylstyrene

A portion of sodium metal 0.32 g (0.014 mol) was carefully added to 25 ml of tert-butyl alcohol at 50 ^{o}C. After all the metal reacted, the solution was cooled to the room temperature and 3 g (0.013 mole) of p-(2-bromoethyl)benzyl chloride was added to the solution. The mixture was stirred at 35 ^{o}C for 2 hr. Then the reaction mixture was poured into 500 ml of water and extracted with ether then extraction dried with anhydrous sodium sulfate. The ether was removed under reduced pressure and the residue was distilled in the presence of p-tert-butyl catecohol to give 1.7 g of p-chloromethylstyrene, bp 88-90 ^{o}C/ 2 Torr. [11]

Preparation of poly(styrene-co-p-chloromethylstyrene), poly(S-co-PCMS)

The copolymerization of p-chloromethylstyrene and styrene was carried out in a sealed tube at 60 ^{o}C. The required amounts of p-chloromethylstyrene, styrene, AIBN, and then benzene as solvent were charged into a pyrex glass tube, which was then degassed under vacuum by conventional freezing and thawing technique and sealed off under vacuum. All copolymerizations were poured into a large amount of methanol to precipitate the copolymer. The resulting copolymers were then purified by the reprecipitation of the benzene solution of with excess methanol. The composition of the copolymer was calculated from their elementary analysis of cholorine, 19.8% (2.77 mmol of Cl/g).

UV (DMSO): $\square_{max}$ = 221 nm (3.1 intensity), 270 nm (0.7 intensity).

FT-IR: 3009(m), 2980(m), 1610(m), 1550 (b), 1490(sh), 1450(sh),1360(sh), 1090(b), 1020(b), 760(w), 690(sh) and 550(w) cm^{-1}.

^{1}H-NMR (CDCl$_3$) δ 6.5-7.5 (b and d, 6H), 3.36 (s, 2H), 1.80 (b and m, 1H), 1.43 (b, 2H) ppm.

^{13}C-NMR (CDCl$_3$) δ 143, 127, 126, 125, 68.1, 40.5, 30.1 ppm.

Preparation of poly(styrene-co-p-aminoanilinemethylstyrene), poly(S-co-PAAMS)

A 250 ml three-necked flask containing 30 ml dimethylformamide(DMF) and 1.5 g poly(S-*co*-PCMS) is equipped with a mechanical stirrer and maintained at temperature of 75 ^{o}C by an external water bath. Then 1 g (0.01 mol) 1,4-phenylenediamine, 2 g anhydrous pulverized sodium carbonate and 5 ml pyridine are added to the flask and the resulting mixture is stirred and heated for 3 hours. At the end of this time, the polymer solution is filtered and precipitate into ice methanol; the product washed with methanol and dried under vacuum.

UV (DMSO): $\square_{max}$ = 230 nm (3.2 intensity), 282 nm (1.7 intensity), 325 nm (0.4 intensity).

FT-IR: 3400(b), 3010(w), 2980(w), 1610(m), 1570(b), 1550(m), 1475(m), 1445(mh), 1363(w),1080(m), 1015(w), 760(w) and 680(m) cm^{-1}.

^{1}H-NMR (d$_6$-DMSO) δ 6.5-7.5 (b and d, 8H), 3.35 (b, 3H), 1.78 (b, 1H), 1.40 (b, 2H) ppm.

^{13}C-NMR (d$_6$-DMSO) δ 145, 128, 127, 125, 96.4, 94.5, 67.4, 40.4, 29.3, 26.5 ppm.

Preparation of polystyrene-graft-polyaniline, PS-g-PANi

0.5 g poly(S-*co*-PAAMS) is completely dissolved in 30 mL of dimethylsulfoxide (DMSO). 1 g aniline and 0.5 g p-toluensulphonic acid are added to the solution, then mixture is vigorously stirred and reduced temperature to 5 ^{o}C. In a separate container 2 g (0.0088 mmol) $(NH_4)_2S_2O_8$ (ammonium peroxydisulphate) is dissolved in 10 mL tosic acid solution. The oxidant solution is slowly added at a rate of approximately 5 mL per minute to the mixture.

After the mixture is allowed to stir for 10 minutes, a solution containing 1 g sodium sulfite in 5 mL water/DMSO is added to the mixture. The mixture is stirred for about 2 hours and polymer solution is filtered using G2 sintered glass filter, then precipitated into ice methanol. The product was washed successively by distilled water and methanol and dried at 60 ^{o}C for 24 h.

UV (DMSO): $\square_{max}$ = 230 (1.7 intensity), 292 nm (2.9 intensity), 330 nm (2.7 intensity), 640 nm (1.1 intensity).

FT-IR: 3335(b), 3175(m), 2985(m), 1733(w), 1593(m), 1516(m), 1329(m), 1275(m), 1181(sh), 1064(m), 1005(m), 880(s), 845(m), 693(w), 573(w) cm^{-1}.

^{1}H-NMR (d$_6$-DMSO) δ 6.0-7.5 (b, H-aromatics), 4.6-4.8 (-NH, -NH$_2$), 3.3-3.5 (-CH$_2$Cl and –CH$_2$), 1-2 (b, H-aliphatics) ppm.

^{13}C-NMR (d$_6$-DMSO) δ 146, 144, 142, 140, 122, 121, 117.1, 116.1, 97.5, 95.6, 68.5, 41.4, 30.7, 29.5, 27.1 ppm.

Electrochemical preparation of PS-g-PANi

Electrochemical synthesis of PS-*g*-PANi was carried out using a conventional three electrode system with a SCE reference, platinum wire counter electrode and GC disk working electrode. The solutions cyclic voltammetry are 0.1 M H$_2$SO$_4$ and 1 M HCl (50/50 v/v). Firstly coated a suitable amount poly(S-*co*-PAAMS) on the GC disk electrode using casting method and then add 0.05 M aniline. Polymer was grown on GC disk electrode under scan potential in the range of 0.3 to 1.4 mV and scan rate 50 mV/s. The thickness of the film was ca. 23-30 μm as determined by scanning electron microscopy.

RESULTS AND DISCUSSION

In order to assess the percentage of polymers in mixture we use elemental analysis. Assessing the percentage of the mixture is so important because in this way we are able to justify condition of electron conductivity in mixture. In all the mixtures, we study the variation of parameters such as: density of the oxidant, solvent effect, density of monomers and based on polymers. We are intended to get the acceptable condition in order to use the sensitivity usage. For this reason we studied elemental analysis on reliable films in view of electrical conductivity, stability and mechanical properties [8-10]. If each styrene ring had received one chloromethyl group the resulting product would have had a chloride content of 22.9%. Elemental analysis for poly(S-*co*-PCMS) showed 19.8% (2.77 mmol of Cl/g), which means that 85**%** of the rings were chloromethylated. Since provided polymer bases on aniline and on the other hands, PS is without nitrogen atom, so by measuring the percentage of nitrogen in elemental analysis, we can achieve the percentage of PANi in copolymer. To assess the aniline and PANi percentages in copolymer we use the following equations. In beginning we will measure percentage of theoretical mass of nitrogen in each monomer unit or base polymer poly (S-*co*-PAAMS) and then on PS-*g*-PANi.

$$\text{Percentage of theoretical mass of nitrogen in polymer} = \frac{\text{Molecular mass of nitrogen}}{\text{Mass unit of monomer (p-aminoanilinemethylstyrene)}} * 100$$

$$\text{Percentage of theoretical mass of nitrogen in poly(S-co-PAAMS)} = \frac{14}{224} * 100 = 6.25$$

$$\text{Percentage of aniline in copolymer poly(S-co-PAAMS) (\% aniline)} = \frac{\%N \ \text{Found}}{\text{Theoretical mass of nitrogen in polymer}} * 100$$

$$(\% \text{ aniline}) = \frac{8.5}{6.25} * 100 = 136 \implies \frac{136}{2} = 68$$

which means that 68% of the chloromethylated rings were converted phenylamine. On the other hands, for calculation of percentage of PANi on graft copolymer, we measured according following equations, we know percentage of nitrogen after grafting is 19.2, so:

$$\text{Percentage of aniline or PANi in PS-}g\text{-PANi} \ (\% \text{ PANi}) = \frac{19.2}{6.25} * 100 = 307$$

which means that aniline would growth on poly(S-*co*-PAAMS) as well.

Figure 2 (a,b) shows FT^{1}H-NMR and FT^{13}C-NMR spectra of poly(S-*co*-PMMAS). Figure 3 shows FT^{1}H-NMR spectrum of PS-*g*-PANi. The occurrence of the peaks at 6-7.5 ppm indicates H-aromatics containing phenylenediamine and aniline groups. The peaks of 4.5-4.8 ppm and 3.3-3.7 ppm shows –NH, -NH$_2$ and –CH$_2$Cl, -CH$_2$- groups, respectively. Finaly, peaks at between 1-2.5 ppm indicate H-aliphatics for polymer backbone, too. The FT^{13}C-NMR spectrum of poly(S-*co*-PMMAS), Figure 2(b), shows peaks below 45 ppm and between 90-145 ppm for different types of aliphatic and aromatic carbons, respectively. The peak of 67.5 ppm can be related to the unreacted –CH$_2$Cl on main chain.
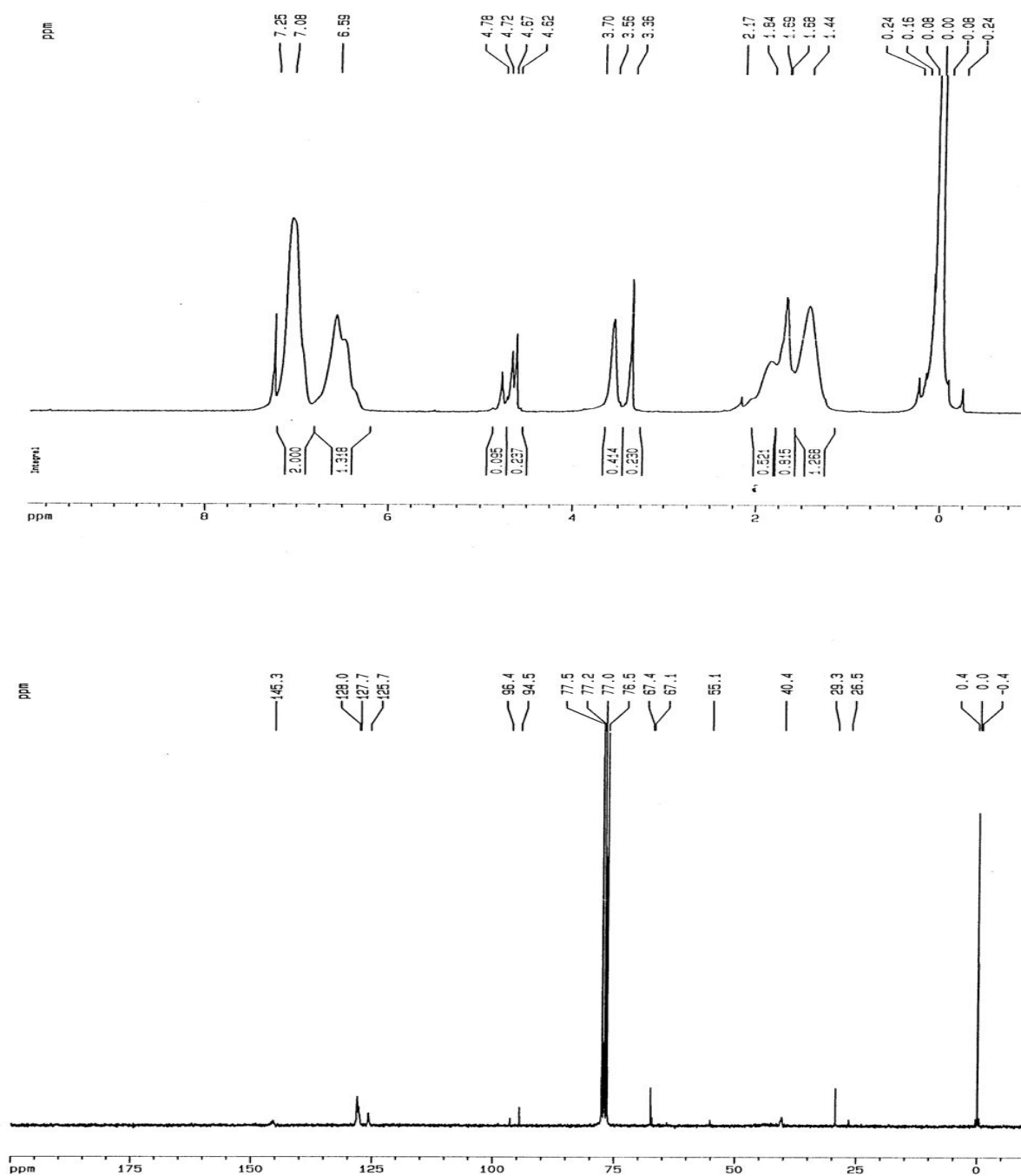
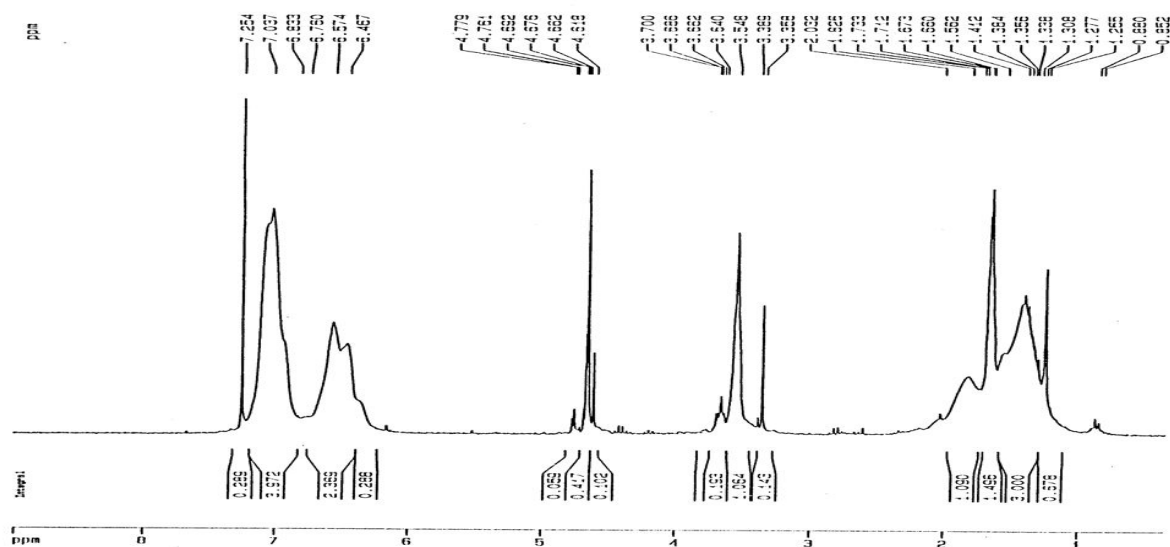**Figure 2.** NMR Spectra of poly(S-*co*-PAAMS) a) FT[1]H-NMR b) FT[13]C-NMR

Figure 3. FT^{1}H-NMR Spectra of PS-*g*-PANi

Electropolymerization of aniline on poly(S-*co*-PAAMS) carried out in the above condition. Figure 4 shows the cyclic voltammogram of PS-*g*-PANi formation on a Pt electrode that spin coated by poly(S-*co*-PAAMS) in aqueous, 1 M H_2SO_4, 0.1 M HCl and 0.1 M aniline solution (v = 50 mV/s); potential range between 0.3 to 1.4 V *vs*. SCE. The redox anodic and cathodic peaks appears in the initial curves and increase in intensity in each next cycles. At the same time, during the cycling, the electrode is covered with a thick deposit and extensive dissolution occurs. The solution near the electrode surface became an intensive green color. Figure 5 shows cyclic voltammograms of PS-*g*-PANi in different scan rate. The oxidation-reduction potentials of this copolymer is different with it's homopolymer. Therefore, cyclic voltammogram confirm that formation of copolymer. Spectroscopy data certify the formation of copolymer at the chemical polymerization, too. As it shows in voltmmogram, PS-*g*-PANi has reversibility and well stability on electrode's surface. The polymer obtained by electropolymerization was precipitated completely on an electrode surface. As it's shown in Figure 4 and 5, the oxidation of the polymer is done easily, but the reduction is done slowly. The growth of the polymer on the surface of the electrode has been done slowly, then in continue it becomes stable gradually.
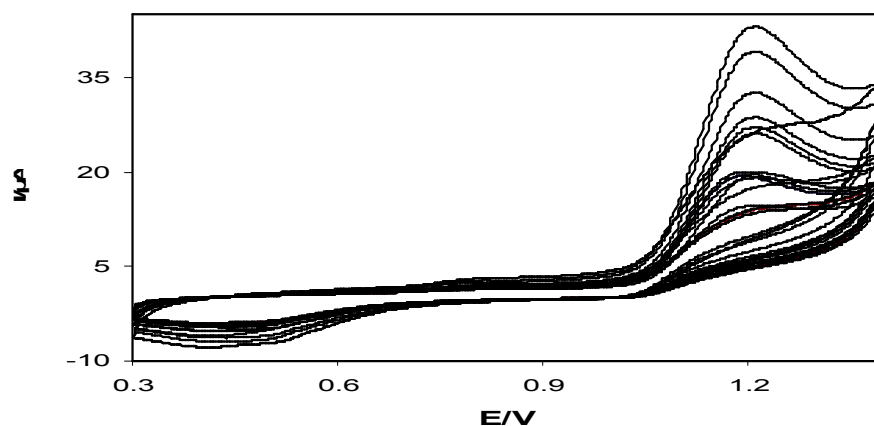
Figure 4. Cyclic voltammogram of PS-*g*-PANi formation on a Pt electrode that spin coated by poly(S-*co*-PAAMS) in aqueous 1 M H_2SO_4, 0.1 M HCl and 0.1 M aniline solution (v = 50 mV/s); potential range between 0.3 to 1.5 V *vs*. SCE (14 cycles).
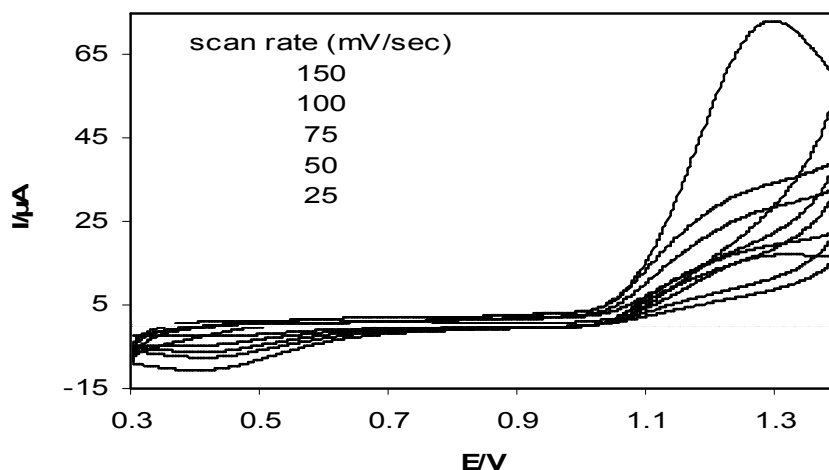

Figure 5. Cyclic voltammograms of PS-*g*-PANi on a Pt electrode in aqueous 1 M H_2SO_4, 0.1 M HCl and 0.1 M aniline solution (v = 50 mV/s); potential range between 0.3 to 1.4 V *vs*. SCE in different scan rates.

Figure 6 show the anodic (ipa) and cathodic (ipc) peak current via different scan rate (SCE reference electrode) of PS-*g*-PANi. The curves are linear, therefore, the polymers are stable on the electrode surface. Redox of reaction polymer film on electrode surface is a surface absorption type.
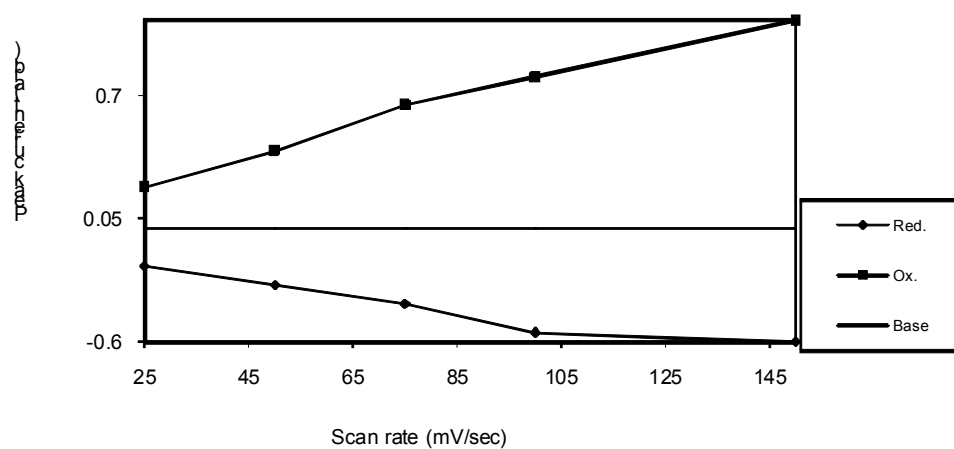
Figure 6. The anodic and cathodic peak current vs. different scan rates of PS-*g*-PANi.

The thermal properties of polymer were studied by thermogravimetric analysis (TGA), differential scanning calorimetry (DSC). Thermograms of STA (DSC and TGA) PS-*g*-PANi illustrated in Figure 7. According to these thermograms with STA thermograms of PS shows that softness, melting points and thermal resistance of the produced copolymer is higher than non-grafted copolymer.
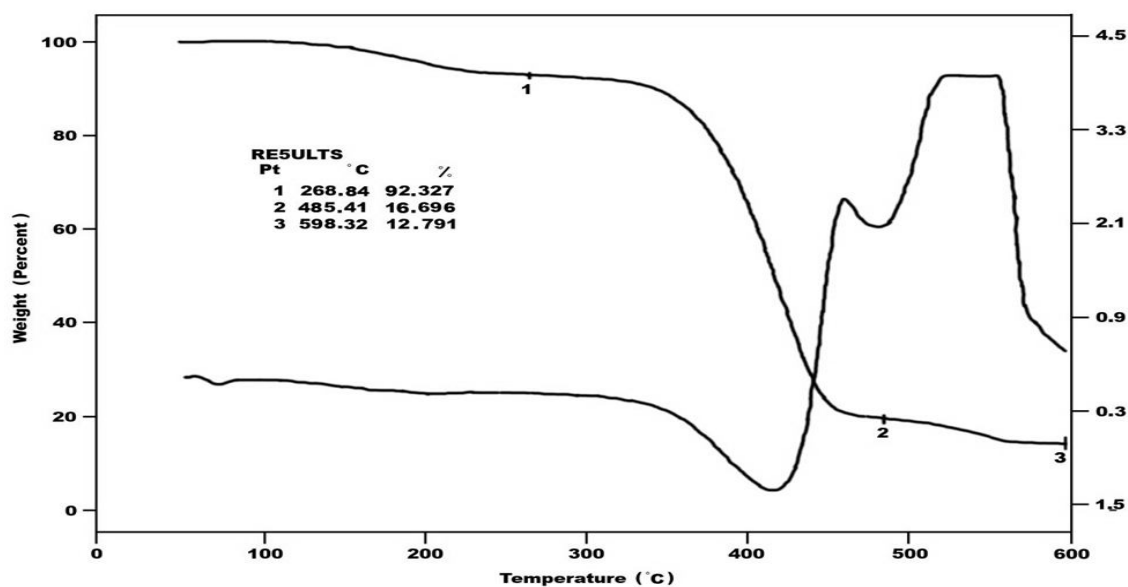

Figure 7. STA (TGA and DSC) Thermmograms of PS-*g*-PANi

As it shows in PS-g-PANi thermogram, this polymer in 50 ^{o}C started to become soften and up to 268.84 ^{o}C it approximately losses 7.628% of it's weight which is due to humidity and existing solvent or part of HCl in chains polymer, and in about 485.41 ^{o}C it will lose approximately degraded. PS-*g*-PANi is good stable to below 350 ^{o}C and in over 360 ^{o}C polymer starts it's complete distraction and continue to 450 ^{o}C. The methods of interpreting TGA results are numerous and also lack standardization. Some of these note the temperature of the 5-10% loss, or by the temperature inflection of the down ward slope, or by the first detectable break in the curve. The STA of PS-*g*-PANi illustrated that initial decomposition temperature (IDT), polymer decomposition temperature (PDT) and the maximum polymer decomposition temperature (PDT$_{max}$) are 350 ^{o}C, 400 ^{o}C and 480 ^{o}C, respectively. The residual weights (γ_c) of the polymers were reported at 600 ^{o}C that it is 12.791%. These polymers were stable in natural atmosphere up to presented temperatures.

Polymer structure and morphology are greatly affected by electrosynthetic conditions [12], such as electrode materials, solvent and electrolyte salts, oxygen and water content of the system and the current density used for electropolymerisation. Although a quantitative measurement of these effects has not been established, some general observations have been made. Thin films generally appear smooth, whilst thicker samples have a much more uneven textured surface [13]. Potentials used during electropolymerisation give rise to smoother films [14]. Scanning electron microscopy (SEM) of figures shows monotony, kind of phases and surface of polymers completely. SEM also shows that the doping/dedoping process is often accompanied by major changes in morphology [15], perhaps due to swelling caused by the insertion and removal of ions within the polymer matrix.

Figure 8 shows the SEM image of PS-*g*-PANi. As it shows in this figure monotony and single phase of polymers are completely clear. PANi shows a sponge-like morphology in contrast to PS-*g*-PANi, which have smooth surfaces indicating that no morphological characteristics could be observed. Earlier studies on the surface morphology of PS and poly(S-*co*-PCMS) have demonstrated theirs smooth surface. Despite the fact that PS-*g*-PANi contained about 307 wt% PANi and according to elemental analysis determination, no free PANi is seen in SEM picture of the graft copolymer. This observation enforces the assumption that covalent bonds between poly(S-*co*-PCMS) and PANi chain have been produced.
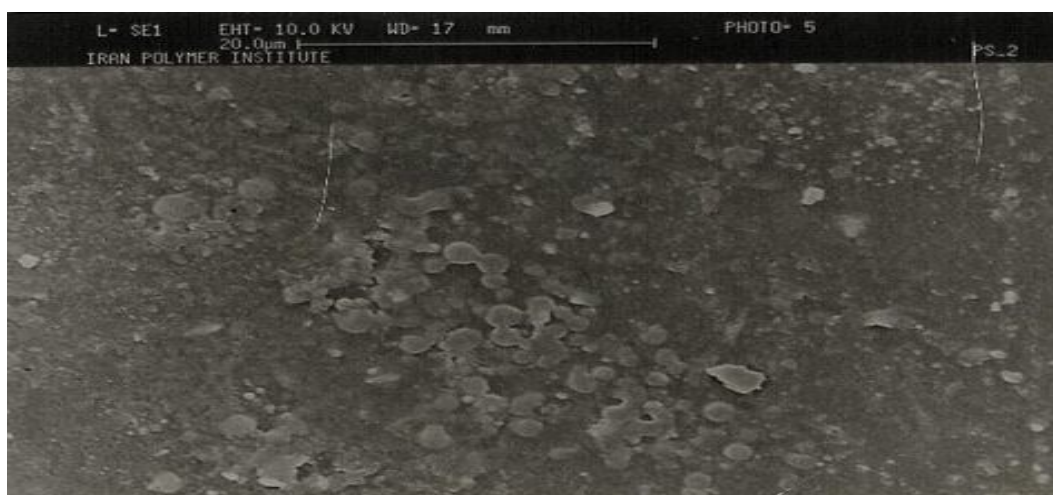

Figure 8. SEM Image of PS-*g*-PANi

The GPC of PS-*g*-PANi was analyzed using a polystyrene standard. The GPC curves obtained show a unimodal distribution. The molecular weight distribution averages for the polymer are presented in Table 1. High molecular weight of the polymer shows the growth of PANi on PS-*g*-PANi.

CONCLUSION

In our recent works, the grafted copolymers were synthesized from polypyrrole on polyvinyl acetate and polystyrene [8,9]. But polymers of solubility decreased by increasing the percentage of polypyrrole. We increased both conductivity and solubility by changing polypyrrole with polyaniline. As we described at the beginning of our discussion, grafting of aniline in polymers such as polystyrene and it is growth on chain, creates a conducting copolymer solution with a new physical properties. The produced PS-*g*-PANi have new physical properties, such as high flexibility, the ability to produce film, high conductivity, conductance of stability to air, sufficient thermal resistance and solubility in DMSO, DMF and m-cresol. The observed new properties of PS-*g*-PANi implies that this grafted copolymer is a better candidate for gas sensing.

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