

PAPER • OPEN ACCESS

Synthesis and characterizations of new conducting polyamide (Nylon 6,6) composites, conductivity and thermal Studies.

To cite this article: Oras Jasim Obies *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **871** 012083

View the [article online](#) for updates and enhancements.

You may also like

- [Thermal metrology for climate: a review of projects, activities and open issues](#)
Andrea Merlone
- [Extreme event impacts on CO₂ fluxes across a range of high latitude, shrub-dominated ecosystems](#)
Rachael Treharne, Jarle W Bjerke, Hans Tømmervik et al.
- [Sustainable energy harvesting and breath sensing with electrospun triboelectric nylon-6](#)
E J Jelmy, Mathew Sunil, Chitra Kandappanthodi et al.





The
Electrochemical
Society

Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Synthesis and characterizations of new conducting polyamide (Nylon 6,6) composites, conductivity and thermal Studies.

Oras Jasim Obies¹, Prof. Dr. Raheem Gaaed Kadhim², Prof. Dr. Mohammed Ali Mutar³

¹Department of physics College of science, Babylon university, Iraq

²Department of physics College of science, Babylon university, Iraq

³Department of Chemical engineering College of engineering.AL-Qadisiyah university, Iraq

Abstract

The composites are having the capability of combining constitutive component's individual properties, creating distinctive materials with certain characteristics proper for specific applications. The major goal of the presented research is developing polymeric reinforced composite materials, that is considered to be anti-static as well as light. The potential regarding conducting the synthesis of PA(nylon 6,6) as well as involving it in the polymeric matrices, including polyamide-6,6 which is enabling creating anti-static reinforced materials. (PANI:Ny-6,6) as well as the composite films have been subjected to preparation through a process of diffusion as well as the aniline's oxidative polymerization in Ny-6,6 matrixes. Composite films have been subjected to characterization through SEM, FTIR, in addition to their electrical properties. Surface electrical conductivity that is related to HCl of (1M) doped composite films increase and increment in film's PAn contents. Studying electrical properties within certain isothermal conditions at temperature in range (130-200⁰C) indicated that composite films have been stable in ambient conditions not more than a temperature of 200 ⁰C with regard to DC electrical conductivity retention.

Key Words: Composites, Conductivity, Thermal stability.



Introduction

The hybrid materials, including the conducting polymer/polymer composites might be defined as excellent way for combining improved component's properties, such as conducting polymer's electrical conductivity, as well as mechanical strength that is related to reinforced polymeric matrix. Polyamide-6,6 (PA-6,6) can be considered as one of the insulating matrices which are generating static electricity's accumulation on surface. Surface coating that is related to the insulating polymer matrix, as PA-6,6, with conducting polymer such as PANi, might be decreasing surface electrical resistance and that will promote rapid dissipation regarding static charge that is accumulated at surface [1].

Many conducting polymers, such as polyaniline (PANI), poly (paraphenylen), polythiophene, poly (paraphenylenvinyle), polypyrrole, poly (3,4-ethylene-dioxythiophene), have been used in gas sensing from more than 30 years [2-6]. The conducting polymer based sensors prove to have many improved characteristics in comparison with the sensors usually based on metal oxides, and their capability to operate at room temperature is one of the most important [7-10]. Polyaniline, with a unique structure that allows it to exist in five oxidation states, raise a special interest due to the ease of its synthesis and its versatility as sensor [11].

The high processibility of Polyamide has stimulated the attention of several investigations in order to develop the role and applications of this polymer. PA conducting polymers were excellent for the commercial applications like sensors, batteries, separation in addition to the electro-chromic devices [1][12-13]. Other advantages are their ease of synthesis in both aqueous and non-aqueous solutions, low cost of monomer, relatively high conductivity (1-20 S/cm) and environmental stability. Regarding conducting polymers, one can find out that many researchers have been devoted to polyaniline during the last quarter of century [14-16]. PAN might be subjected to synthesizing through aniline's oxidation in the solution phase in Bronsted acids electro-chemically or through chemical oxidants [18-21]. PAN will change to base form which is referred to as emeraldine base (EB) through treatment process with the use of dilute aqueous alkali solutions. EB is considered to be insoluble in the water, yet it is soluble in certain non-aqueous and aqueous mixed solvents like 1-methyl 2-pyrrolidinone (NMP), dimethylsulfoxide (DMSO), aqueous acetic acid (80%), concentrated sulphuric acid, formic acid (88%), as well as dimethylformamide (DMF). This is going to allow it to be considered as solution which is processed for producing free standing, flexible, as well as large films related to EB polymer that might be protonated (doped) with non-oxidizing protonic acids like HCl to films which have conductivity of ~10 S/cm [22-23]. PAN's electrical conductivity is on the basis of pH of polymer or solution. It changes into an insulator material by simple base treatment or at pH above 4. It has been reported [24] that organic acid dopants produce more thermal (in air) and environmental (water) stability than small sized anions. This stability can be due to immobility of the larger size counter ions. Therefore, the large size dopants anions contrast to Cl⁻ do not migrate or removed when the polymer immersed in water. In generally doped polyanilines are less thermally stable than undoped form. EB (undoped, oxidized base form) of PAN is the most thermally stable form of polyaniline (up to 500°C) with regard to structural integrity [25]. There is no difficulty in controlling aniline's chemical polymerization in insulating polymer matrix for preparing conducting composites with regard to the needed electrical properties in the same time as retaining mechanical strength that is related to the insulating polymer matrix [26-28]. The presented study indicated straightforward chemical route for preparing PANi:Ny-6,6 as well as nylon6 composite films. One of the major materials used as thermoplastics or fibers is the Nylon.

Experimental Materials

The major applied chemicals to prepare composite films have been potassium persulphate (98%) (CDH, India), nylon6 (powder) and nylon6,6 (textile) (from Design, Research, and Standard Organization), aniline (99%) (CDH, India), (Purified water), ammonia solution 32 w/w (Spain), as well as hydrochloric acid (35%) ("E. Merck, India").



Fig. (1) nylon6,6 (textile) .

Prepare polyamide:nylon-6,6 composite films

Pieces of nylon 6,6 with the shape (1cmx2.5cm) and the mass (0.2g, 0.3g) have been cut from the sheet of Ny-6,6, after that subjected to pressing in thin films through using pressure (10 tons) in certain Electrically operated Automatic Pressure Machine which has been managed at 220 °C. Film's thickness was different and in range (0.40mm-0.50mm). Pieces of (0.2g) has been soaked in (20ml) of aniline, also pieces of (0.3g) has been soaked in (25ml) of the doubly distilled aniline for various time periods in air oven at a temperature of 80 °C for allowing the diffusion of aniline into Ny-6,6 matrix. The aniline soaked films have been subjected to treatment with (3 g) of the potassium persulphate in HCL solution of (1M), after that left for twenty-four hours at ice temperature for the purpose of polymerizing aniline in Ny-6,6 matrix. Therefore, the prepared PA:Ny-6,6 composite films have been subjected to washing with the use of doubly distilled water up to the acid neutralizations as well as undoped through treating with excess of the aqueous ammonia (1M) succeeded via wash with the use of distilled water till filtrate become neutral. Composite films have been left to dry for twenty-four hours at a temperature of 40 °C in dry box, after that kept in desiccators for experiment purposes. PA:Ny-6,6 composite films have been doped through treatment with hydrochloric solution of (1M) at room temperature for a period of twenty-four hours. Details of preparation are provided in figure (3) and Table 1.



Fig.(2): Image of polyamide:NY6,6 product.

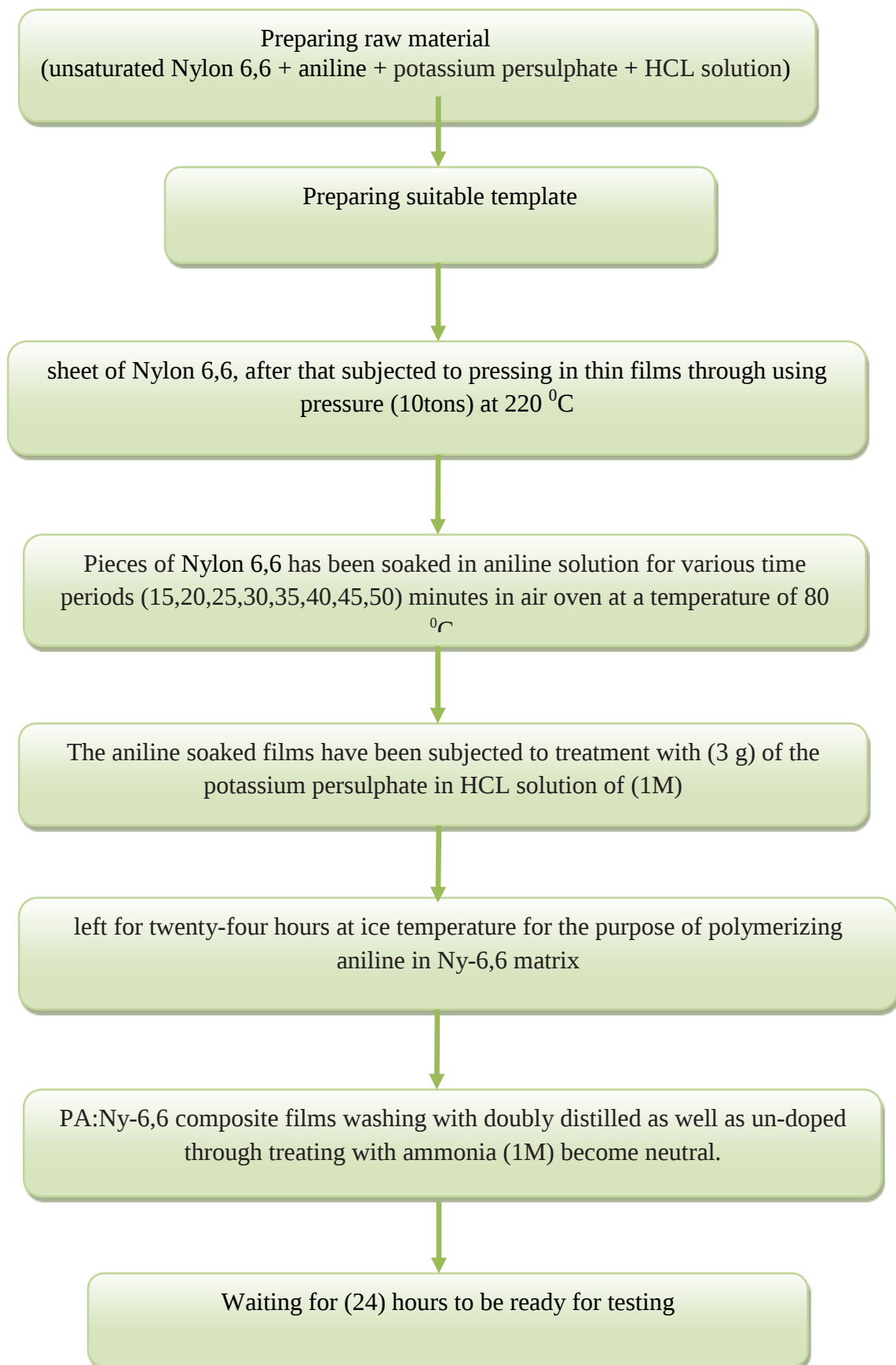


Figure.3: Prepare polyamide:nylon-6,6 composite films.

Table (1) preparation details of polyamide:nylon-6,6.

Simple ID	Temp [°C]	Time [min]	Mass of nylon 6,6 [g]	Amount of aniline soaked [ml]	potassium persulphate (g)	HCl solution (ml)
PA6,6 (1)	80	15	0.2	20	3	15
PA6,6 (2)	80	20	0.2	20	3	15
PA6,6 (3)	80	25	0.2	20	3	15
PA6,6 (4)	80	30	0.2	20	3	15
PA6,6 (5)	80	35	0.3	25	3	20
PA6,6 (6)	80	40	0.3	25	3	20
PA6,6 (7)	80	45	0.3	25	3	20
PA6,6 (8)	80	50	0.3	25	3	20

Instrumental

SEM micrographs were taken by Mira3 Tescan instrument. The FT-IR spectra regarding PAN: nylon 6 as well as nylon-6,6 composites have been recorded through BRUKER-TENSOR 27. The DC electrical conductivity that is related to doped composites films has been determined with the increase in temperature with the use of Keithly model 2400 technique. The DC electrical conductivity (σ) has been determined with the use of Equations (1) and (2):

$$\rho_{D.C} = R_e \frac{\omega t}{L} \quad (1)$$

Where: R_e : represent sample's (thin film) resistance, ω : represent the electrodes' width, L : is distance between two electrodes and $\rho_{D.C}$: is electrical resistivity of the films.

$$\sigma_{D.C} = \frac{1}{\rho_{D.C}} \quad (2)$$

Where: $\sigma_{D.C}$: is the conductivity of the thin film.

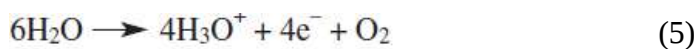
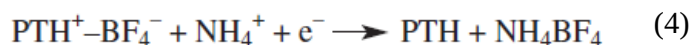
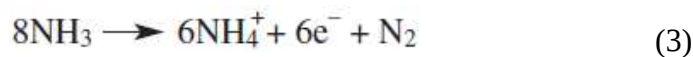
Arrangement has been put in over controlled electrically. Current pass via outer probes, also floating potential across probes' inner pair has been evaluated [23]. Oven's power supply has been switched on; the temperature subjected to gradual increase. Voltage and current have been simultaneously recorded with increase in temperature. Composite sample's thermal stability with regard to DC electrical conductivity retention has been examined in certain isothermal conditions with the use of

DC electrical conductivity measuring instrument. The presented research has been conducted on at temperatures of (130, 140, 150, 160, 170, 180, 190, and 200) °C with regard to polyamide. Electrical conductivity measurement has been achieved in intervals of five minutes. The Digital micrometer related to the film's measuring thickness as well as accurate digital voltmeter (Keithly) to measure potential throughout conductivity measurements have been used.

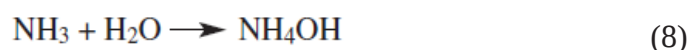
Results and discussions

Prepare conducting polymer composite films

Prepare the PA:Ny-6,6 composite films have been achieved through the diffusion regarding aniline to Ny-6,6 matrix. Throughout such process, not many of Ny-6,6 has been subjected to dissolving in aniline which will produce precipitate similar to jelly at a temperature more than 80 °C in addition to being kept in the aniline for over thirty minutes at a temperature of 80 °C. Thus, duration and temperature regarding aniline's soaking in Ny-6,6 matrix have been chosen at thirty minutes and a temperature of 80 °C. Composite film's composition to determine the change in composite film's electrical conductivity, because of the changes in Ny-6,6 amount, there are 4 distinctive samples have been subjected to preparation as same time and temperature. Therefore, some of the HCl doped PA:Ny-6,6 composite film samples have been subjected to preparation as specified in the Table 1. In the case when aniline has been oxidized with the use ($K_2S_2O_8$) of (0.1) in acidic media (HCl), protonated conducting form regarding the PANi (emeraldine salt) has been created with black color [29]. A study conducted by [30] indicated that the redox reactions with regard to the ammonia or amine intercalations in layered metal chalcogenides, that has been additionally verified through the study of [31]. Based on disproportionation reactions related to the ammonia as indicated through [33] for un-doping of polythiophene (PTH) by water. Overall chemical reactions might be provided in the next Equations:



Charge neutralization reaction is dependent on chemical reaction's rate between un-doping agent and the doped polymer, that is on the basis of polymer chain's reactivity as well as un-doping agent's basic strength [34]. There is extremely low basic strength related to the water, therefore, it is not acting as efficient effective un-doping agent with regard to PAn, yet, analogous neutralization reaction related to the un-doping of PAn component of composites through ammonia solution might be indicated as can be seen in the equations below:



Today, it was indicated that the PANi:Ny6 composite films included layers, outer layers have been conducting composite layers, the inner layer has been pristine Ny-6 [34]. In comparable approach, it might appear that PANi is majorly polymerized in outer layer regarding composite films (PANi:Ny6,6), also such layers retard diffusion regarding oxidant solution to interior side as well as prohibiting the PANi from being polymerized in film or aniline doesn't diffusing deep within polymer matrix as can be seen in cross-sectional view regarding films.

FT-IR studies

FT-IR spectra related to PAN:nylon-6,6 composites have been specified in the Figure. Band which correspond to the out plane bending vibration that is related to the C–H bond of p-disubstituted benzene rings appear at 824cm^{-1} . Bands which correspond to the stretching vibration regarding N–B–N in addition to the N=Q=N structures appears at 1497cm^{-1} as well as 1587cm^{-1} respectively in which –B– in addition to =Q= represent benzenoid and the quinoid moieties in polymer. Bands which correspond to the vibration mode that is related to N=Q=N ring as well as the stretching mode related to C–N bond will appear at $1,143$ as well as 1302cm^{-1} . Band which is close to 1130cm^{-1} has been specified as characteristic related to conducting polymer because of delocalization regarding the electrical charges resulted from deprotonation. FT-IR spectrum support the existence of benzenoid in addition to quinoid moieties in PAN. Characteristic bands at approximately (688) , $(1,642)$, $(3,303)\text{cm}^{-1}$ due to nylon-6,6 exist in all composites. As-prepared PAN: nylon-6,6 composites indicated strong band of about 1650cm^{-1} that correspond to the carbonyl group regarding nylon-6,6.

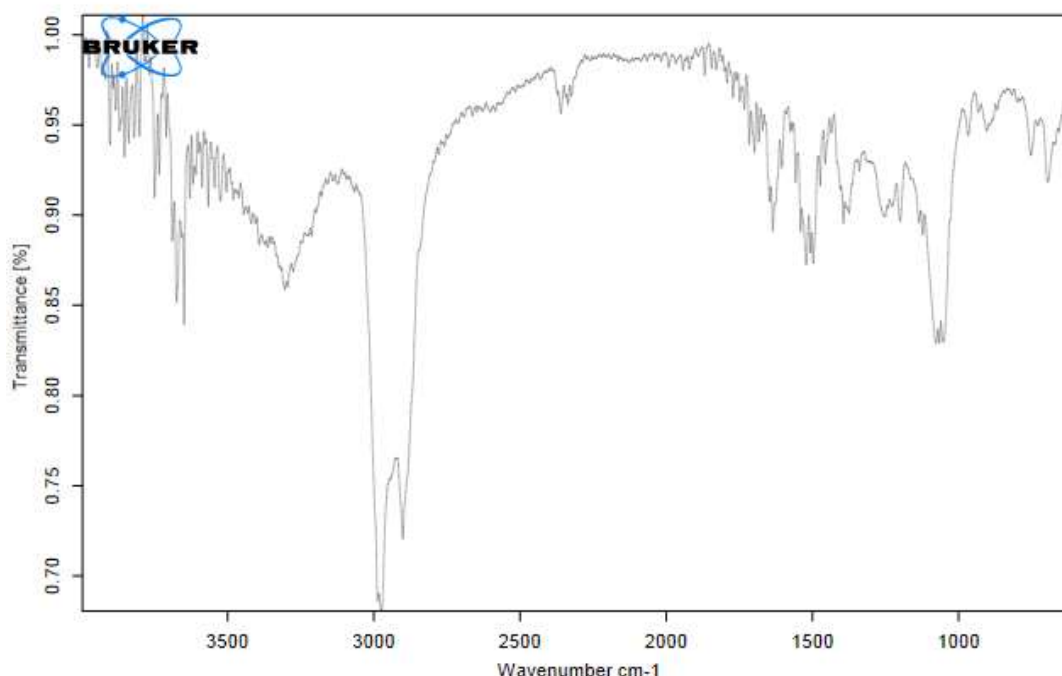


Fig. (4): FT-IR spectra for PANi: Ny-6,6.

Table (2): Absorption packages for the polyamide.

vibration group	absorption package (cm^{-1})
C-H	824
N-B-N	1497
N=Q=N	1587,1302
C-N	1143
C=O	1650

SEM studies

The figure will show SEM photographs that are related to PA: Ny-6,6 composites at various. Obviously, homogeneous formation regarding the PA composites in Nylon-6,6 matrix has been indicated. Surface morphology regarding the PA which is prepared chemically indicated cloudy structure, where as that of Ny-6 is granular, also the composite film's morphology has been completely distinctive from the parent compounds, for example, Ny 6, Ny-6,6, as well as PA. Differences regarding the composite's surface morphology indicate binding of parent component thus, creating composites.

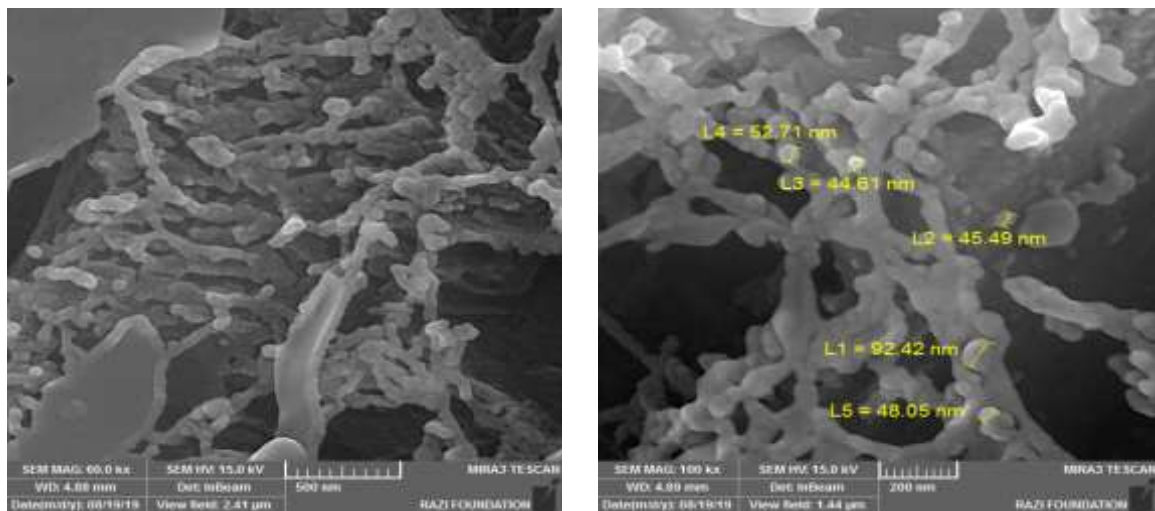
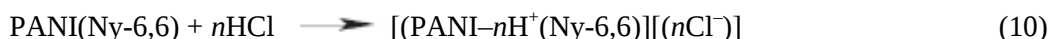


Fig. (5): SEM for PA (Nylon 6,6).

Stability with regard to DC electrical conductivity retention

Four samples, PANI:Nylon-6,6 have been chosen for studying the thermal stability with regard to the DC electrical conductivity retention. It has been indicated that electrical conductivity related to the PANI:Ny6,6 composites elevated when exposed to the hydrochloric acid, because of doping related to the PAn component of composite films, as can be seen in the Equation:



Isothermal stability test that is related to HCl doped films with regard to DC electrical conductivity retention has been conducted at a temperature of (130, 140, 150, 160, 170, 180, 190 as well as 200) °C in air oven. Electrical conductivity measurements have been achieved at intervals of five minutes in accelerated ageing experiments. Electrical conductivity has been measured with regard to time regarding the accelerated ageing as can be seen in the Figures (4,5). Furthermore, thermal stability has been examined through continuously measuring the DC electrical conductivity with increase in temperature from 130 °C to 200 °C for 5 times at intervals of forty minutes. All composite films were in accordance with Arrhenius equation for temperature dependence related to electrical conductivity at a temperature from 130 °C to 200 °C. Combination regarding some or all following factors might be accountable for the increase in electric conductivity beyond a temperature of 130 °C like dopant in addition to degradation, dopant's chemical reaction with PAn or the nylon6,6. Researches on electrical conductivity's stability within isothermal conditions for the nylon-6,6 indicated that electrical conductivity has high stability at a temperatures of (130 and 140) °C. From figures (4,5) we note that the electrical conductivity increases with the increase of the temperature of PA: nylon 6,6 at different concentrations. This means that these materials have resistance of negative thermal coefficient, that is having the resistance decrease with the increase of temperature. This is because polymer chains could act as traps for the moving charge carriers by hopping process, with the increase of temperature, the motion of polymer chains increase, as a result for the increase of the charge carriers and mobility of these charges. These results in agreement with [36,37].

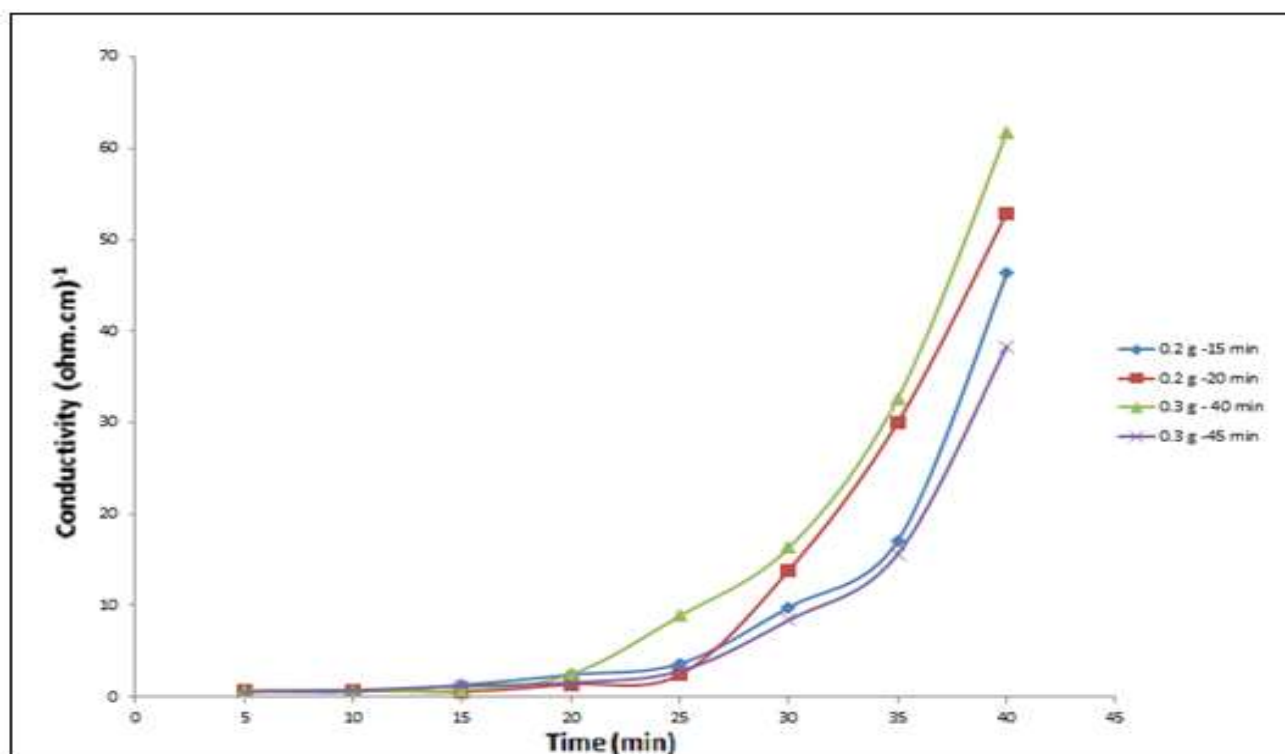


Fig. (6):Variations of D.C electrical conductivity with time for PA 6,6.

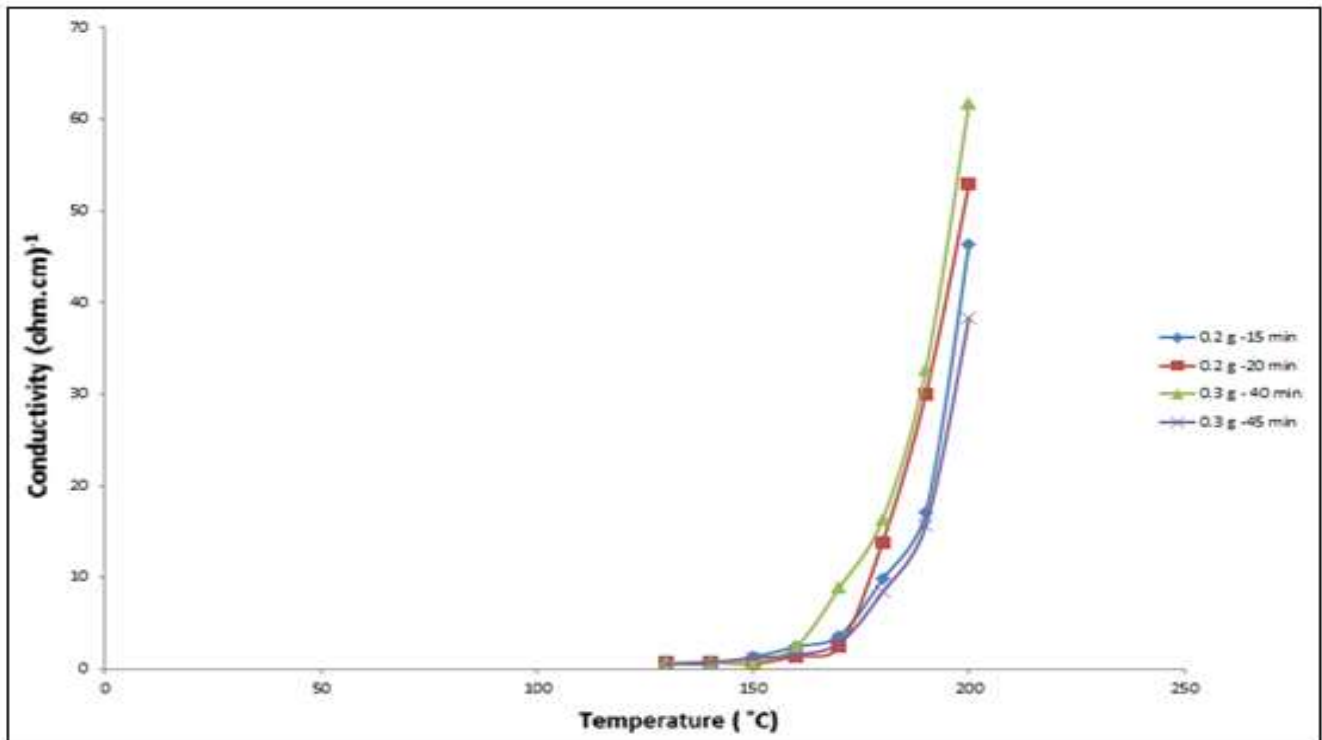


Fig. (7):Variations of D.C electrical conductivity with temperature for PA 6,6.

The Activation Energy

For figure (6) the relationship between $\ln\sigma$ and the inverse absolute temperature is for PA(nylon 6,6). The activation energy was calculated using equation (5), Table (2) showing the activation energy increased with increasing temperature and concentrations.

a result of the impact of space charge. The addition of concentrations creates local energy levels in the forbidden energy gap which acts as traps for charge carriers, which move by hopping among these levels. By increasing the concentrations, the activation energy increases as a result of the increase in the local levels in the distance between conduction band and valence band, as shown in Tables 2). Thus the mechanism of conduction in the samples having low concentrations is the hopping [37,38].

The PA(nylon 6,6) activation energy values range from (1.1744 - 1.7491) eV. This is due to the formation of a continuous network of PA(nylon 6,6) that contains paths within a compound and allows charge carriers to pass through.

$$\sigma = \sigma_0 \exp\left(\frac{-E_a}{k_B T}\right) \quad (11)$$

Where:

E_a : is the electric activation energy

T : is the absolute temperature

k_B : is the Boltzmann constant

σ_0 : is the minimum electrical conductivity at 0K.

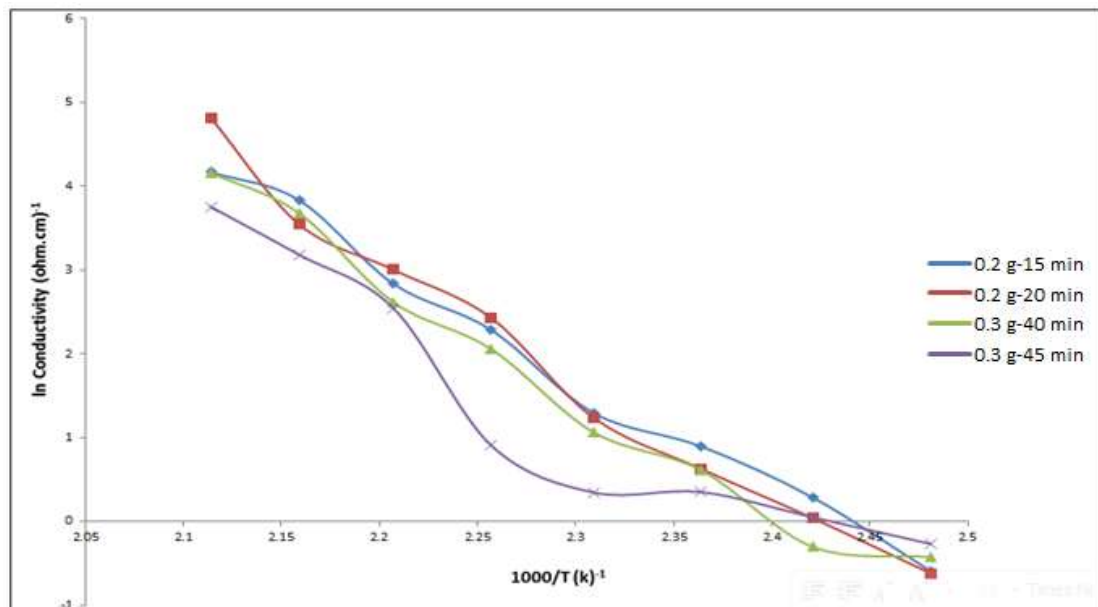


Fig. (8): Variation of D.C electrical conductivity with inverse absolute temperature for PA:Nylon6,6.

Table (3): Values of activation energy with temperature and concentration of PA(nylon 6,6).

PA:Nylon6,6	Ea(ev)
0.2g-15min	1.1744
0.2g-20min	1.2977
0.3g-40min	1.4488
0.3g-45min	1.7491

Hall Effect Measurements

Charge carrier's type, resistivity (ρ), Hall mobility (μ_H), concentration (n_H), in addition to the conductivity (σ) were determined from the Hall measurements. Tables (3 and 4) indicated the major parameters which have been assessed from the Hall effect measurements for PANI(nylon 6) thin films with various temperatures and concentrations. Hall coefficient (R_H) is important to know the electrical properties, (R_H) depends on the value of incident magnetic field on the film is located vertically in front that field. We can notice from this Tables (3 and 4) which films have p Hall coefficient. This is indicating that conducting type (P-type charge carriers), such result is in accordance with the results of [43].

From this Tables, the Hall coefficient and mobility increases, while conductivity and carrier concentration decrease with increasing of PANI this attributed to the greater charge carrier's concentration leads to shrinking region between Fermi level and the edge of the conductivity this agreement with increase the activation energy with increasing of the adding ratios. Value related to σ subjected to increase with the increase in temperature and PANI. The thin film's structure has been changed to reduce grain size as well as increasing internal grain's barrier potential, and that will make capture change carriers in grain bounding and after that increasing the scattering.

Table (3 and 4) shows the results of the measurements of the Hall effect that all films PA-6 prepared is the n-type through negative sign of the Hall coefficient. In films vestiges there was a clear increasing in the concentration of carriers and a decreasing in the values of mobility at increasing temperatures with increasing doping ratio, this was due largely to an increasing in the concentration of carriers formed near the conductive band, which in turn lead to an increasing the number of donor atoms of electrons capable of ionization within the thermal energy does not exceed the value of topical levels ($k_B T$), as for the decreasing in mobility shall be due to the increased concentration of carriers. These results are in agreement with [44].

Table (4): Hall parameters for PA (nylon 6,6 – 0.2g) thin films.

Sample	R_H (cm^3 / C)	n_H ($1 / \text{cm}^3$)	$\sigma_{R.T}$ ($\Omega.\text{cm}$) ⁻¹	$\rho_{R.T}$ ($\Omega.\text{cm}$)	μ_H ($\text{cm}^2 / \text{V.s}$)
0.2g-15sec	-6.786×10^7	-9.199×10^{10}	1.537×10^{-6}	6.508×10^5	1.043×10^2
0.2g-20sec	-5.079×10^7	-1.229×10^{11}	1.360×10^{-6}	7.353×10^5	6.907×10^1
0.2g-25sec	-6.258×10^7	-9.975×10^{10}	3.384×10^{-6}	2.955×10^5	2.118×10^2
0.2g-30sec	-1.078×10^8	-5.788×10^{10}	2.006×10^{-6}	4.986×10^5	2.163×10^2

Table (5): Hall parameters for PA (nylon 6,6 – 0.3g) thin films.

Sample	R_H (cm^3 / C)	n_H ($1 / \text{cm}^3$)	$\sigma_{R.T}$ ($\Omega.\text{cm}$) ⁻¹	$\rho_{R.T}$ ($\Omega.\text{cm}$)	μ_H ($\text{cm}^2 / \text{V.s}$)
0.3g-35sec	-1.082×10^7	-5.770×10^{11}	7×10^{-5}	4.747×10^4	2.279×10^2
0.3g-40sec	-3.866×10^5	-1.614×10^{13}	5.225×10^{-7}	1.914×10^6	2.020×10^{-1}
0.3g-45sec	-1.341×10^6	-4.654×10^{12}	3.216×10^{-4}	3.109×10^3	4.313×10^2
0.3g-50sec	-6.786×10^7	-9.199×10^{10}	1.537×10^{-6}	6.508×10^5	1.043×10^2

Thermal gravimetric analysis (TGA) study

Thermogravimetric Analysis determine the change in mass as temperature's functions. It can be mainly applied to specify degradation temperature, material's absorbed content, the level of inorganic as well as the organic parts in the materials as well as residues of analysis solvent. It does use sensitive electronic balance through which a sample will be suspended in furnace, which is managed through temperature programmer. The thermal characteristics related to samples regarding such polymers have been examined by TGA in Argon atmosphere at heating rate (10 °C per minute) [39-42]. With regard to this test, many values have been recognized including T_i , T_{op} , T_f , $T_{50\%}$, Residue at 600 °C, and char yields at 500 °C as can be seen in (Table 6) .

Temperatures of fifty percent weight loss of (PA6,6) of polymers have been between (420-200) °C, char results of Pan6,6 26% at 500 °C in Argon atmosphere, indicating that they could satisfy the requirements of temperature resistance that may be utilized in a variety of applications. Weight residue of PAN6,6 is 27%, at 600 °C .

Table 6: Some Thermal Stability Characteristics Curves Thermal Gravimetric Analysis (TGA) of polymers represents the temperature of decomposition.

Sample	T_i	T_{op1}	T_f	$T_{50\%}$	Residue at °C600	Char % At 500°C
PA-nylon (6,6)	530	410	688	390	27	26

T_{op} represents optimal temperature of decomposition.

T_i represents the temperature of the initial decomposition.

$T_{50\%}$ represents the temperature of 50% weight loss, which has been obtained from the TGA.

T_f represents the final temperature of decomposition. The final degree of dissociation temperature.

Char% at 500 ° C represents the residual weight percentage at 500°C in Argon by TGA.

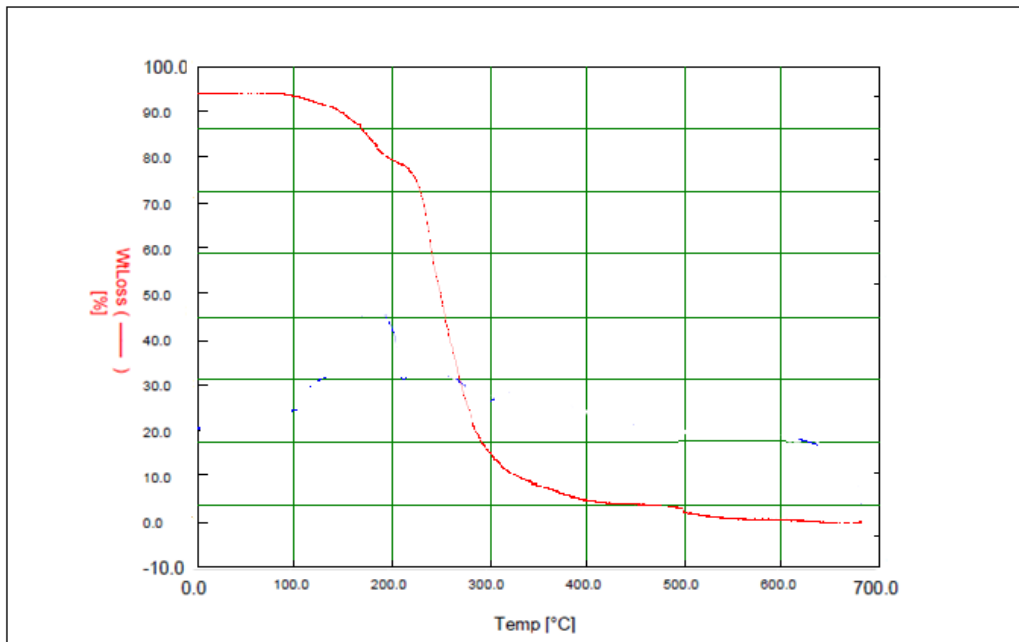


Fig. (9) The TGA of PA: NY(6,6)

Differential Scanning Calorimeter Analysis (DSC) Study

DSC is an approach regarding thermal analysis which study the way that heat capacity (C_p) of materials undergo transformation via temperature. Recognized mass sample has been cooled or heated, also variations in C_p have been indicated as heat flow's alterations. This will allow revealing transitions like crystallization degree (TC), melting point (TM) and glass transitions (Tg). Results related to (PA6,6) polymer indicated in the figure (8) that the value of Tg of mixture at a temperature of (18.5 °C), which indicate election in temperature's flow and after that elevation in the sample's absorption rate to temperature till (Tm) at a temperature of (450 °C) in the case when totally melted and after that sample's absorption rate to heat and through curve has been set (Tc) of mixture at a temperature of (180 °C) [43].

Table 7: Indicates Tg, Tm, Tc in Differential Thermal Analysis.

Simple	Tg (c°)	TM (c°)	TC (c°)
PA:N(6,6)	18.5	450	180

Tg: represents the Degree glass transition.

Tm: represents the Melting Point.

Tc: represents the crystallization degree.

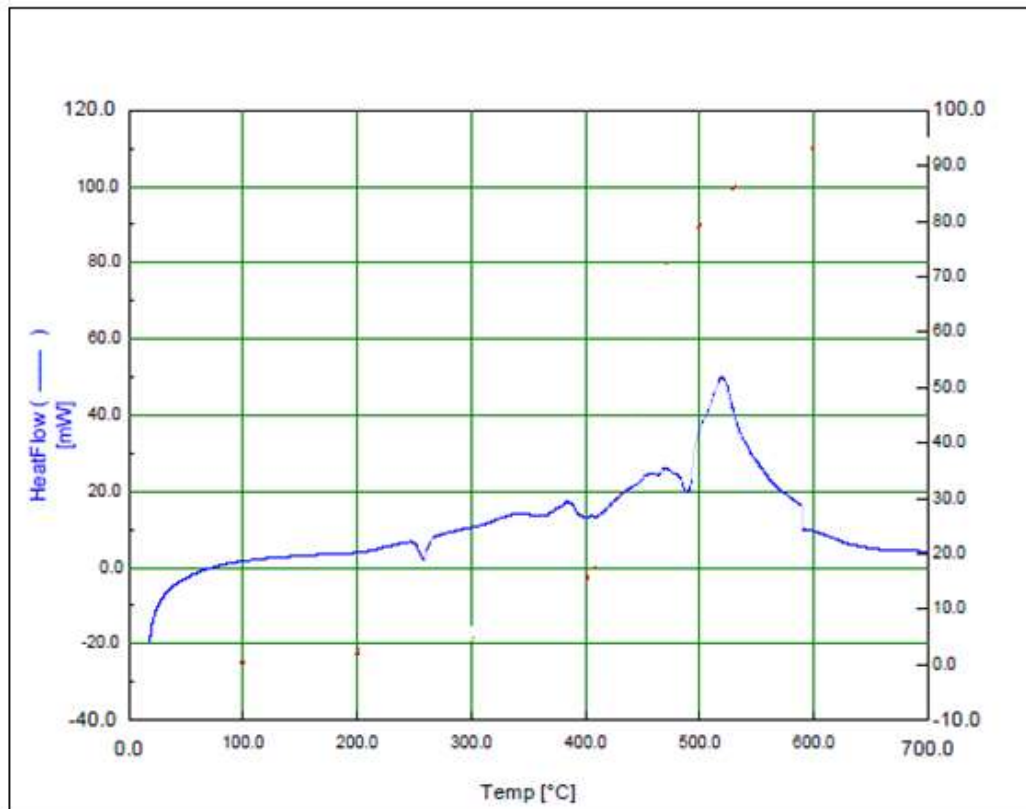


Fig. (10) The DSC of PA: NY(6,6)

Conclusions

This study indicated that there is possibility for synthesizing PAn composites with certain traditional thermoplastic polymers like nylons with enhanced mechanical properties, with excellent thermal stability as free standing films or membranes.

The molar ratio regarding PAn to nylon is of maximum impact on the composite material's mechanical properties. A lot of applications related to the PAn conducting polymers might require that is must be prepared as membranes. Preparation related to the conductive PAn:nylon6,6 composite films is excellently specified via aniline monomer's diffusion into nylon6,6 matrix succeeded via aniline's oxidative polymerization in nylon-6 matrix method. Therefore, prepared PAn:nNy-6,6 composite films have high electrical conductivity at high doping level. Also, it is indicated that electric conductivity related to PAn:nylon-6,6films increase with the increase in PAn content of composite. Composite material has been effectively characterized with regard to the electrical properties, SEM and FTIR. The thermal stability with regard to DC electrical conductivity retention is sufficient as examined through a few of the experimental approaches. The conductivity related to the PAn/Nylon composites following doping with HCl is extremely low in comparison to pure PAn, yet it is extremely high in comparison to Nylon (insulator). PAn/Ny composites change into 7hlator when in the case of treatment with dilute ammonia solution. Conductivity recover totally in the case of re-doping with HCl solution. The majority of formulations related to composites prepared are utilized in electrical as well as electronic applications not more than 90 Celsius within ambient conditions.

References

- [1] Kakhkashan Hamadani and K. L.Cheng (1999), *Microchemical Journal*, 61, 198-217.
- [2] Lange U, Roznyatovskaya N V and Mirsky V M (2008), *Analytica chimica acta*, 614 1.
- [3] Panday S *Journal of Science* (2016), *Advanced Materials and Devices*, 1 431.
- [4] Adhikari B and Majumdar S (2004), *Prog. Polym. Sci.* 29 699 .
- [5] Manea L R, Berteau A, Nechita E, Popescu C V and Sandu I (2016), *Rev. Chim. (Bucharest)* 67.
- [6] Manea L R, Chirita M, Hristian L and Sandu I (2016), *Mat. Plast.* 53 (3) 361.
- [7] Macagnano A, Perri V, Zampetti E, Bearzotti A and De Cesare F (2016), *Sensors and Actuators B Chem.* 232 16 .
- [8] Manea L R, Danu M C and Sandu I Rev (2015), *Chim. (Bucharest)* 66 (6) 868.
- [9] Manea L R, Cramariuc B, Caunii V, Sandu I Ma (2015), *Plast.* 52 (1) 82.
- [10] Manea L R, Cramariuc B, Scarlet R, Cramariuc R, Sandu I and Popescu V (2015), *Mat. Plast.* 52 (2) 180.
- [11] Kunzo P, Lobotka P, Micusik M and Kovacova E *Sens* (2012), *Actuators B Chem.* 171-172 838 .
- [12] W. W. Focke, and Y. Wei, J. (1987), of *Physical Chemistry*, Vol.91, No.22, PP 5813- 5818.
- [13] Y. Wei and K. F. Hsueh, J (1989), of *Polymer Science: Part A: Polymer chemistry*, Vol. 27, 4351-4363.
- [14] A. G. MacDiannid Chang, A. F. Somasiri, N. L. D. and A. J (1987), Epstien, in "Conducting polymers", Reidel Publishing Co.Dordrecht, PP. 105.
- [15] A. G. MacDiannid, S. K. Manouar, E. M. Scherr and Xun Tang, M. A. Druy and A. J.Epstein, J (1991), *Polymer Material Science and Eng.*,V. 64, pp. 254-255.
- [16] W. S. Huang, B.D. Humphrey and A.G. MacDiannid (1986), *Chem. Soc. Faraday Trans.*, 82,2385-2400.
- [17] J. Prokes, S.Nespurek,J. Stejskal (2001), *Vesmir*,80,35-38.
- [18] F. Lux, G. Hinrichsen, M. M. Pohl, J (1994), of *Polymer Sci. Part B, Polymer Physics*, No. 32,Part 12.
- [19] M. A. Rodrigues and M. A. D. Paoli (1991), *Synthetic Metals*, 41-43, 2957-2962.
- [20] M. Angelopoulos, G. E. Austurias, S. P. Ermer ,(1988),*Mol. Cryst.*, Vol. 160, PP. 151-163.
- [21] K.G. Neoh, E. T. Kang, S. H. Khor & K. I. Tan (1990), *Polymer Degradation and stability*, 27,107-117, .
- [22] M. Angelopoulos, G. E. Austurias, S. P. Ermer, A. Ray, E. M. Mol (1988), *Cryst*, Vol. 160,PP. 151-163.
- [23] A.G.MacDiarmid, A. J. Epstein, J (1991), *PolymerMaterial Science and Eng.*, 64, 254-255.
- [24] K.G. Neoh, B.K.Tay, E.T. Kang J. (2000), *Polymer*,V. 41,9-15.
- [25] R. Ansari, W.E. Price and G.G. Wallace (1996), *Polymer* Vol.37, No.6, pp.917-923.
- [26] Yam W. Y., Ismail J., Kammer H. W., Lechner M. D., Kummerlowe C (2000), *Thermal properties of poly (styreneblock-caprolactone) in blends with poly (vinyle methyle ether)*. *Polymer*, 41, 9073–9080.
- [27] Hsu C-H., Vaca-Segonds P., Epstein A. J (1991), *Polyaniline/PPD-T fibres*. *Synthetic Metals*, 41, 1005–1008.
- [28] Kang E. T., Neoh K. G., Tan K. L (1998),*Polyaniline: apolymer with many interesting intrinsic redox states*.*Progress in Polymer Science*, 23, 277–324.
- [29] MacDiarmid A. G., Epstein A (1995), *Secondary doping in polyaniline*. *Synthetic Metals*, 69, 85–92.
- [30] Schöllhorn R., Zagefka H-D (1997), *Demonstration of the ionic structure of the intercalation compound TaS₂NH₃*. *Angewandte Chemie International Edition in English*, 16, 199–200.
- [31] Foot P. J. S., Shaker N. G (1983), *Amine intercalates of lamellar compounds NiPS₃ and CdPS₃*. *Materials Research Bulletin*, 18, 173–180.

- [32] Mohammad F (1998), Compensation behavior of electrically conductive polythiophene and polypyrrole. *Journal of Physics D: Applied Physics*, 31, 951–959.
- [33] Tchmutin I. A., Ponomarenko A. T., Krinichnaya E. P., Kozub G. I., Efimov O. N (2003), Electrical properties of composite based on conjugated polymer and conductive fillers. *Carbon*, 41, 1391–1395.
- [34] Sung W. B., Soon S. I (1998), Physical properties and doping characteristic of polyaniline-nylon 6 composite films. *Polymer*, 39, 485–489.
- [35] Rao C. N. R (1963), *Chemical application of infrared spectroscopy*. Academic Press, New York.
- [36] Huitao Yu, Bangwen Zhang, Chaoke Bulin, Ruihong Li and Ruiguang Xing (2016), "High-efficient Synthesis of Graphene Oxide Based on Improved Hummers Method", *Scientific Reports*, 6:36143.
- [37] Z. A. Al.maamori (2017), "Characterizations of Nanostructure (SnO₂)_{1-x}(ZnO)_x Thin Films and their Applications", Ph. D. thesis, College of Science, University of Babylon.
- [38] J. Hildenbrand (2003), "Simulation and Characterization of Micromachined Gas Sensors and Preparation for Model Order Reduction", Ph. D. Thesis, Albert Ludwig University.
- [39] Tarasove, A (2012), "thermal analysis: methods, principles, application." Lecture on thermal analysis.
- [40] Cantre, K. B.; Martin J. H.; Ro, K. S (2009), "Application of thermogravimetric Analysis for the proximate Analysis of livestock wastes". *Journal of ASTM international*.
- [41] Adivarekar, R.V.; Dasarwar, S.D.; Khurana, N.S (2012), "synthesis of halogen free flame retardant and application polypropylene." *India journal of fiber & textile research* vol.
- [42] Wunderlich, B. (1980), *Thermal analysis, text for an audio course*. ATHAS, Advanced Thermal analysis. A laboratory for research and instruction.
- [43] Santanu Chattopadhyay, Nikhil K. Singha (2007), Improvement of conductivity of electrochemically synthesized polyaniline.
- [44] Natsumi Taniguchi and Koji Fuka (2018), Dielectric relaxation of thin films of polyamide random copolymers.