Study of the electrical characteristics of polyaniline prepared by electrochemical polymerization

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Abstract

Polyaniline (PAni) is one of imported polymer for synthesis solar cells. The quality of film depended on the method of polymerization. In this research PAni have been prepared by the electrochemical polymerization of aniline on stainless steel electrode. The electrical conductivity of these films was measured by two-probe method. The electrical conductivity is influenced by preparation conduction such as concentration of H₂SO₄ and current density. The conductivity between (0.1 - 10⁻¹⁰) S/cm depends on PH and current density. The best electrical conductivity about (0.1) S/cm was found PH at (4.2) and current density 0.3mA/cm².

Keywords: Solar cells, polyaniline, electrochemical polymerization, electrical characterisation.

1. Introduction

Organic semiconductors have attracted great attention in the field of active materials for solar cell applications such as in organic light emitting diodes (OLEDs)¹, field-effect transistors

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Polyaniline (PAni) is one of the most promising conducting polymers\(^{8-10}\). The most important feature that makes PAni so interesting as sensitive p-n junction layer for the solar cell is the variation of its electrical and optical properties at room temperature\(^{11,12}\). Polyaniline (PAni) is one of (ICP) and an attractive due to its considerable conductivity, easy synthesis route and good thermal stability. The conductivity could be increased by more than ten orders of magnitude by doping with protonic acids\(^{13}\). Depending on the oxidation level, PAni can be synthesized in various insulating forms such as the fully reduced leucoemeraldine base (LEB), the half oxidized emeraldine base (PAni EB) and the fully oxidized pernigraniline base (PNB)\(^{14-16}\). Of these three forms PAni EB is the most stable and widely investigated polymer in this family. PAni EB differs substantially from LEB and PNB in the sense that its conductivity can be tuned via doping from \(10^{-10}\) S/cm up to 100 S/cm and more where as the LEB and PNB forms can not be made conducting\(^9\). The insulating emeraldine base form of polyaniline (PAni EB) consists of equal numbers of reduced \([-\left(C_6H_4\right)-N(H)\left(C_6H_4\right)-N(H)-]\) and oxidized \([-\left(C_6H_4\right)-N=\left(C_6H_4\right)=N-]\) as show in figure (1).

In the present study polyaniline films have been prepared by electrochemical polymerization of aniline monomer and electrolyte containing different concentration ratios (PH) of \(H_2SO_4\). The polymer films have been characterized by Infra-red IR spectrophotometer. The conductivity measured by two probe method\(^{16}\).

![Figure 1](image)

(a) Insulating emeraldine base form of PANi,  
(b) conducting emeraldine salt form of PANi

2. Experimental

2.1 Films preparation

Polyaniline PAni prepared by electrochemical polymerization of aniline on stainless steel. The electrochemical cell consisting of working and counter electrodes of stainless steel and electrolyte solution. The aniline was distilled under reduced pressure and stored in darkness before use, \(H_2SO_4\) and purified double distilled water were used in preparing the electrolyte solution. The Polymerization was carried out at different current densities from (0.001 to 1) mA/cm\(^2\). The best condition for the preparing film was at current density 0.3mA/cm\(^2\), and Polymerization time about 25 min. The electrical conductivity influenced by (concentration) PH of \(H_2SO_4\). So the films were prepared at different PH (from 2.5 to 6.5) in order to have doped and undoped PAni. The electrochemical polymerization method and preparation techniques have been described by\(^{16}\).
2.2 The electrical measurement

The electrical conductivity measurement for the conducting polymers films were calculated by two-probe method. The two-probe method was explained by wejood\textsuperscript{15}. The thickness of the films was measured by using Faradays law\textsuperscript{16}.

3. Results and Discussion

The characterization of undoped (PAni) films have been curried out using IR analyzing technique as shown figure (2) and for doped PAni in figure(3). Table(1) tabulated the wave vector of functional groups of PAni. That have the same groups of other\textsuperscript{16-20}.
Figure (3) IR spectrum of doped PAM
The quality of the film was examined by the measurement of conductivity as a function of current density as shown in Figure(4). The best conductivity about (0.1) S/cm² at current density 0.3 mA/cm², this was carried out at PH (4 - 4.5). At values of current density higher than the characterized, the conductivity have lower values as indicated in figure (4). This could be attributed to the low value of current density which is not sufficient to give high doped (PAni- H₂SO₄), while high values of current density lead to low conductivity because the high values of current density make the polymerization too fast so that some polymer fragments fall in solution.
Figure (4) conductivity as a function of current density

Figure (5) show the conductivity as a function of PH degree (concentration of H₂SO₄). The electrical conductivity increase as PH increased, when reached to (4.2) the conductivity became (0.1)S/cm, then decreased to (1.5x10⁻¹⁰) S/cm at PH (6) the curve can be divided in to three regions one region when PH less than 4 the conductivity is low because small PH gives (reduced state) PANi can not doped with H₂SO₄ (low doping)⁸,¹⁰. The second region at (4 - 4.2) PH, the electrical conductivity is large, i.e. PANi doped with H₂SO₄ (high oxidation), while third region at PH higher than 4.5 the conductivity decrease because PANi can not doped with (H₂SO₄)¹⁶.
Figure (6) shows the electrical conductivity as a function of polymerization time for PANi prepared at 4 PH. The electrical conductivity increases as polymerization time increases until reach to 25 min the conductivity became constant at 0.1 S/cm, this can be explain, this time is enough to complete polymerization i.e to reach the maximum value for doping. 

Figure (5) conductivity as a function of PH
4. Conclusion

The electrical conductivity of PAin is influenced by the synthesis conditions such as current density, PH degree and polymerization time. The best electrical conductivity was found at PH degree (4-4.5) corresponding to current density 0.3 mA/cm² and polymerization time 25 min.

References