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Deposition and Characterization of Conducting Polymer (polyaniline) Thin Film in Electrical and Optical Application Using Chemical Deposition Technique

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Abstract

Nano-structure polyaniline materials were deposited on glass substrate at room temperature,the material were doped using citric acid,formic acid,ammonia,hydrochloric acid and tetraoxosulphate(vi) acid.The optical and electrical properties of the polyaniline materials doped with dopants were investigated,the doped polyaniline material has high absorbance and transmittance in the wavelength range of 300-400nm.The energy band gap of the doped Nano-structure polyaniline varied from 2.41eV to 3.20eV,polyaniline material doped in HCl exhibiting the highest degree of conductivity making it most suitable doping agent in activating its electrical properties..Also from the result obtained we can deduce that dopants has a direct effects on the properties of polyaniline materials.

1. Introduction

In the earlier days, there were a plethora of innovative materials being developed for a variety of technologically oriented uses. The conducting polymer is one of the most versatile families of materials, and it is employed in a variety of applications [1]. Nano-structure polyaniline (PANI) is a highly conducting organic polymer with a range of interesting properties, including electrochemical redox performance and electro-chromic catalytic activities [2]. PANI is utilized to build a variety of sensors employing composite thin film by enzymes, such as biosensors, due to its conductive properties [3]. The desire for new polymeric materials that can be utilized as a matrix for biomaterial immobilization has gradually increased. Among the different polymeric materials, the porous polymer matrix is expected to have numerous uses in biosensors and is currently at the forefront of research and development.
Conducting polymers have sparked a lot of attention as a viable matrix for enzyme setup. Conducting polymers are applied in biosensors to improve their speed, sensitivity, and adaptability. Electrically conducting polymers have a chemical structure that is extremely flexible and may be adjusted to meet the needs of a specific application. As a result, conducting polymers are being used in biosensor applications such as pesticide detection in fruits and vegetables [4].
Previously, researchers concentrated on developing conductive polymers, which are employed in optics, electronics, energy, and other sectors [5-8]. High-precision molecular design and an appropriate preparation method are used to create basic types of conductive polymers [5]. Polyaniline (PANI) was formerly known as black aniline and comes in a variety of forms based on

its level of oxidation. PANI is also recognized for its ease of use [9], environmental stability, and ability to be doped by protonic acids [5]. Polyaniline is the material of choice for current and future electronics technology due to its ease of manufacture, controlled and reversible electrical and electronic properties by oxidation and protonation (non-redox doping) [10]. The lengthy polyaniline chain's alternating bonds make it extremely difficult to handle, infusible, and essentially insoluble in ordinary organic solvents [11].

Conducting organic polymers have piqued the interest of researchers due to their possible application in future optoelectronic devices. The nano-structure polyaniline family of polymers has been identified as one of the promising systems because of its superior electrical and optical properties, as well as its environmental resilience. In this paper we report about the preparation and the deposition of a conducting polymer (PANI), thin films made by the chemical deposition technique. These films, were further investigated for their optical and electrical properties.

2. Methodology

2.1. Preparation of Polyaniline (PANI)

Polyaniline was created through the chemical oxidative polymerization of aniline in the presence of hydrochloric acid as a catalyst and ammonium peroxidisulphate as an oxidant. For the synthesis, we used 50 ml of 1M HCl and 2 ml of aniline in a 250 ml container.a stirrer with an electromagnetic field After that, 5gm of $(NH_4)2S_2O_8$ (ammonium peroxydisulphate) in 50 ml of 1M HCl was abruptly added to the preceding solution. 0° C is the polymerization temperature was kept running for 5 hours to complete the polymerization reaction The obtained precipitate was then filtered.The product was washed with 1M HCl, then distilled water, until the wash solution turned colorless.It was then re-filtered and thoroughly washed with distilled water several times more to produce the emerald salt (ES) form of polyaniline. To obtain emeraldine base (EB) form of PANI, dedope (ES) form of PANI was mixed with 0.1M NH_4OH and dried in a vacuum oven at 60° C for 24 hours. As a result, an insulating polyaniline (EB) polymer powder was obtained [12].

2.2. Deposition Technique

Chemical deposition (CDT) technique is applied in this research, this technique involves the dipping of the substrate into the reaction mixture to enable the film form on it.The material used for the deposition is borosilicate glass,it was saline so that polyaniline can grow on it using a silating bath for 3 seconds.

2.3. Measurement of Absorbance of the Film

The absorbance of the deposited film was carried out using the Ultraviolet spectrophotometer for the liquid polyannile and different slides.To determine the wavelength with the maximum absorption,a blank (water) was used for the liquid polyaniline and blank slide was also used at a given wavelength.

3. Results and Discussion

This investigation was aimed to understand the synthesis and characterization of PANI based conducting polymers,modifications to conducting polymers can make them conductive.Electrical and optical qualities of metals or semiconductors can be found in conductive polymers, but they preserve their good mechanical properties. Polyaniline is a good example of a material that may be coverted into the conducting state by doping it [13].Ammonia,formic acid,citric Acid,HCl and H_2SO_4 were the dopants used for this evaluation.

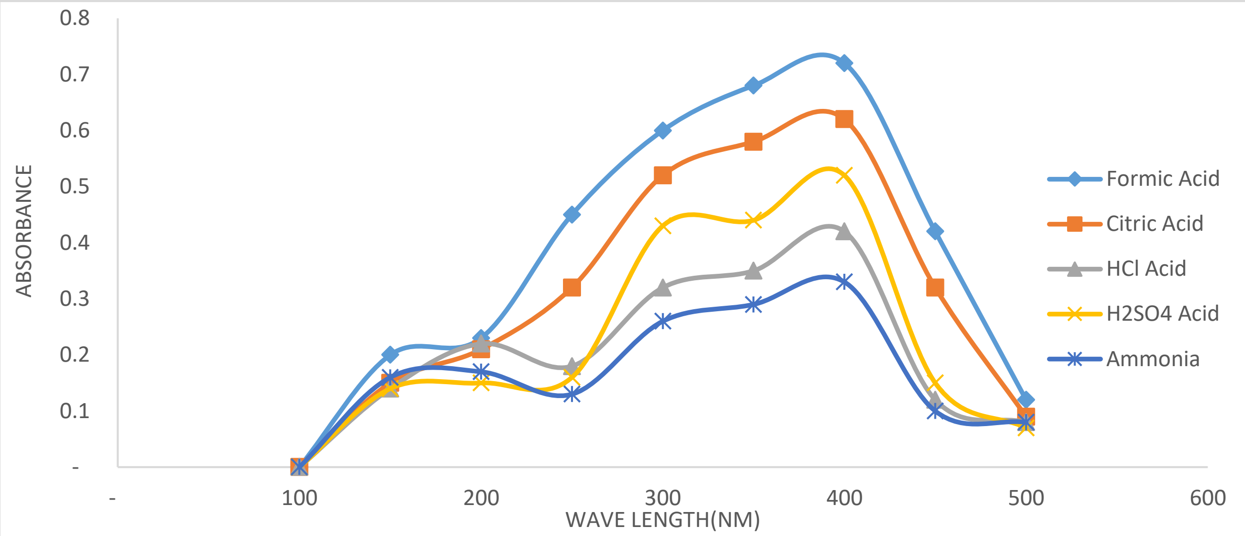

Figure 1: Variation of absorbance with wavelength for different doped poly-aniline material

From the plot in Figure 1 depicts the variation of absorbance with wavelength for different doped materials of polyaniline. In the wavelength range of 100-150nm, there is an increasing rise but maintained a steady rise at wave length 150-200nm.At wave length of 250nm, the absorbance increased drastically and the film exhibited maximum absorbance in the wavelength ranging from 300-400nm.Formic acid absorbance rate was highest followed by citric acid, H_2SO_4, HCl and Ammonia respectively. This result shows that polyaniline doped with formic acid tend to absorb more electromagnetic radiation in the ultra-violet region.

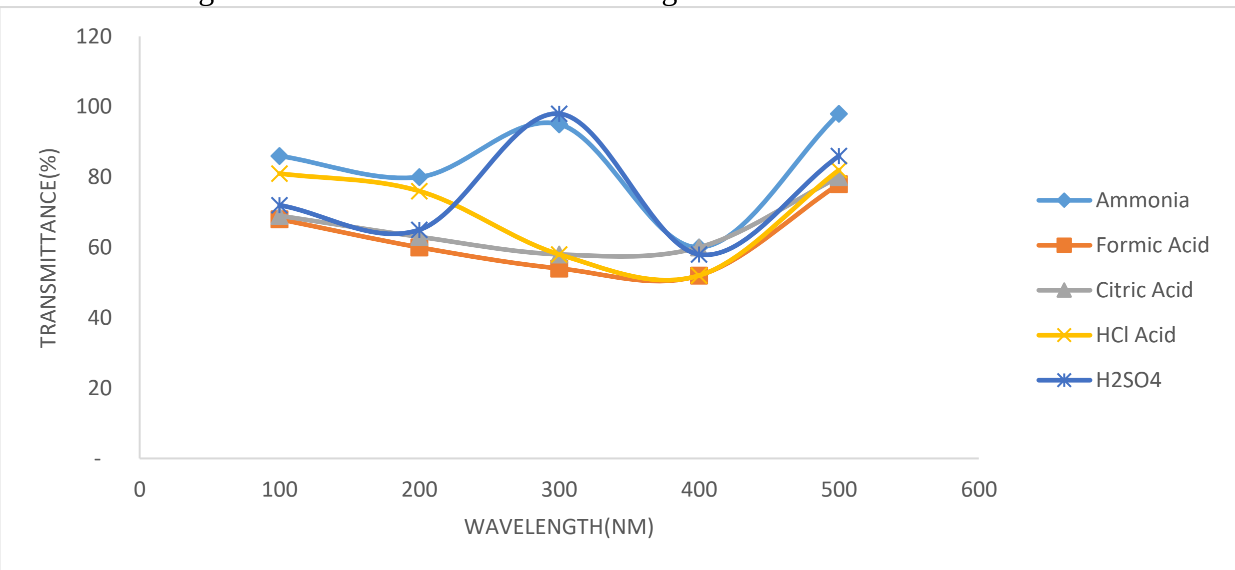

Figure 2: Variation of transmittance with wavelength for different doped polyaniline materials

The above Figure 2 show the variation of transmittance against wavelength of different materials of polyaniline doped in the wavelength range of 100-500nm.The transmittance increases as the wavelength increased from 200nm to 300nm but decreases drastically between wave length 300nm and 400nm.Also the doped polyaniline thin film increased rapidly from wavelength 400nm to 500nm,polyaniline doped formic acid has the least transmittance while polyaniline doped with ammonia has the highest transmittance. This shows that polyaniline doped ammonia will transmit more electromagnetic radiation.This result deduce that polyaniline can be used to cut-out the low wavelength of the ultra-violent region of the electromagnetic spectrum.

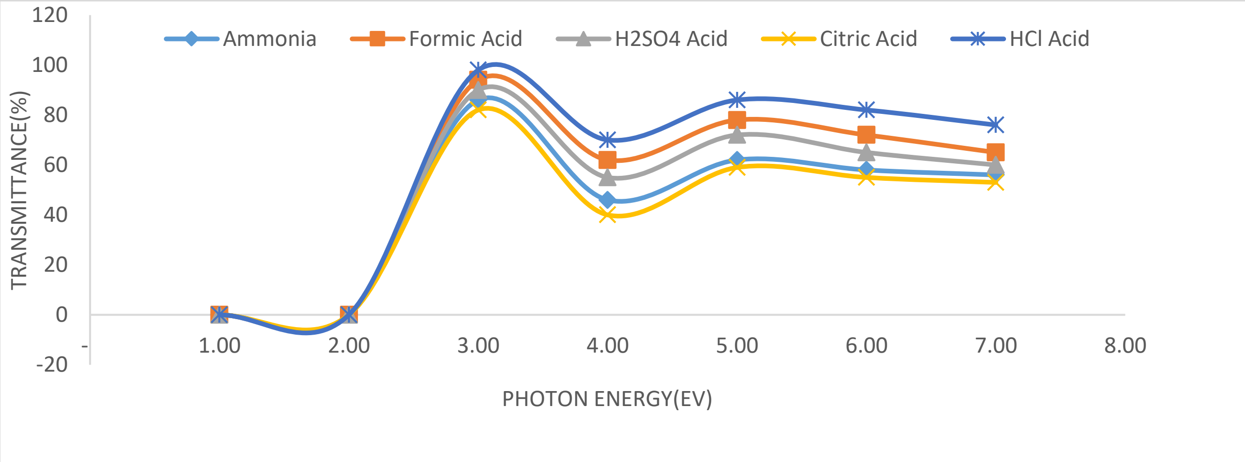

Figure 3: Variation of transmittance with photon energy for doped polyaniline materials.

Figure 3 shows the variation of transmittance with photon energy for doped polyaniline materials. Between 2.0 and 4.0eV, the transmittance increases rapidly and for photon energy greater than 4.0eV, the transmittance increased to a maximum value and remain fairly constant. The polyaniline material doped with citric acid has the least transmittance for photon energy from 1.3 to 7. 0eV.The maximum transmittance varied for different range of photon energy depending on the dopant. From the plot, photon energy polyaniline doped with HCl has the highest photon energy, followed by formic acid, H_2SO_4, Ammonia and citric acid.

Table 1: Electrical Characterization

S/N	Dopants	Resistivity	Conductivity	Energy Band Gap
1	H2SO4	16.944	0.059	3
2	Ammonia	1.457	0.69	2.41
3	Citric Acid	6.209	0.161	2.9
4	Formic Acid	0.852	1.174	2.5
5	HCl	1.382	2.153	3.2

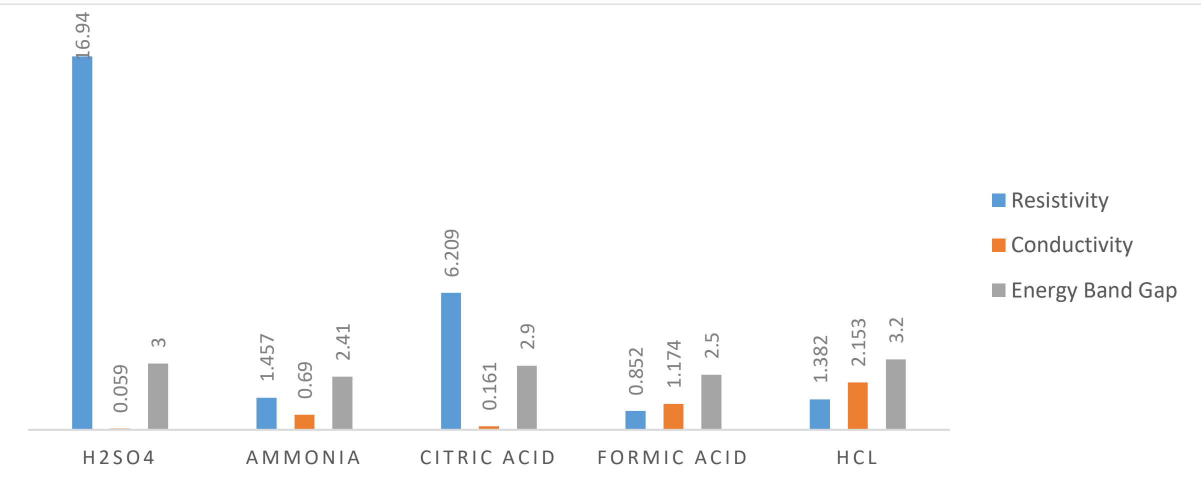

Figure:4: Plot of different dopants showing the level of resistivity, Conductivity and Energy band gap

From Table,1 and Figure 4, the polyaniline materials doped with HCl exhibited the highest energy band gap with a value of 3.2Ev followed by the ones doped with H_2SO_4, Citric acid, Formic acid and Ammonia with a corresponding value of 3,2.9,2.5,2.41Ev respectively. This shows that doping polyaniline with different dopant causes a change in the energy band gap. Also from the Table 1 and Figure 4,the result from the characterization data obtained it showed that polyaniline doped with H_2SO_4 Acid has the highest resistivity resulting to a lower conductivity of the doped material, this is an indication that polyaniline material doped H_2SO_4 Acid is resistant to the flow of electric current more readily than the other four dopants which is evident from the plot shown in figure 4. However, Polyaniline material doped with HCl acids have the highest conductivity as shown in figure 4 above. Therefore, it can be observed that the dopants disposed of HCl acid can aid in enhancing the material conductivity better than the other dopants utilized.

In light of the findings of the experiments, which compared the electrical conductivity of samples obtained by doping thin films of polyaniline with ammonia, formic acid, citric acid, H_2SO_4, and HCl acid, it is possible to claim that thin films obtained by doping polyaniline with hydrochloric acid have a higher electrical conductivity than those obtained by doping polyaniline with the other dopants.
It is clear from both Figure 4 and the experimental data presented in Table 1 that the thin films of polyaniline doped with hydrochloric acid have a better electrical conductivity than the samples obtained by doping with ammonia, formic acid, citric acid, and H_2SO_4 acid. This is the case because the thin films have a higher concentration of hydrogen chloride ions. This result has been earlier being reported in the study by [13].

4. Conclusion

This research evaluated the deposition and characterization of polyaniline thin film using different dopant. An optical and electrical characterization was investigated at different wavelength. The following results were obtained; In the variation of absorbance with wavelength, the film exhibited maximum absorbance in the wavelength range of 300-400nm.Formic acid absorb more radiation in the ultra-violet region than the other dopants. In the variation of transmittance with wavelength it as observed that polyaniline doped with ammonia transmitted more electromagnetic radiation more in the ultra-violet region, this is evidence why is use as a cut-out of wavelength part of the ultra-violet region of the electromagnetic spectrum**.** The variation of transmittance with photon energy reviews that the transmittance increases rapidly with the photon energy range of 2eV-3eV and decreases fairly from 3eV to 4eV, hence polyaniline materials doped with citric acid has the least transmittance while the maximum transmittance varies for different range of photon energy depending on the dopant applied. Also from the energy band gap result, HCl exhibited 3.2eV with a corresponding conductivity of 2.153 making it most suitable in doping polyaniline in activating its electrical properties.

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