

Synthesis and Characterization of Polyaniline (PANI)

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Abstract: Polyaniline (PANI) is one of the most extensively studied conducting polymers due to its ease of synthesis, environmental stability, low cost, and tunable electrical properties. In this research, polyaniline was successfully synthesized through the chemical oxidative polymerization of aniline using ammonium persulfate as the oxidizing agent in an acidic medium. The synthesis was carried out under controlled conditions to obtain high-yield emeraldine salt polyaniline. The structural, morphological, and electrical properties of the synthesized polyaniline were systematically characterized using various analytical techniques. Fourier Transform Infrared Spectroscopy (FTIR) was employed to confirm the formation of characteristic benzenoid and quinoid structures of polyaniline. X-ray Diffraction (XRD) analysis revealed the semi-crystalline nature of the polymer. Scanning Electron Microscopy (SEM) showed an irregular granular morphology with interconnected networks, which is favorable for charge transport. UV-Visible spectroscopy indicated the presence of polaron and bipolaron transitions, confirming the conductive form of polyaniline. Electrical conductivity measurements demonstrated that the synthesized PANI exhibits significant conductivity enhancement upon protonation. The results indicate that the synthesized polyaniline possesses desirable structural and electrical properties, making it a promising material for applications in sensors, anticorrosion coatings, energy storage devices, and electronic components.

Keywords: PANI, SEM, XRD, FTIR

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Conflict of interest: None

Introduction

Polyaniline (PANI) is the most important of polymers mentioned, which has been used in research as an advanced polymeric material during the last decade, because it is a polymer rich in electrons and has good electrical conductivity, as well as it has a good ability to modify and processing [1] PANI has been used in many applications including solar cells [2], lithium batteries [3], supercapacitors [4], fuel cells [5], flexible electrodes [6], corrosion-resistant coatings [7], water pollutant removal [8], screen printing [9], and sensors [10]: [11]. suggested different kinds of basic PANI. He proposed three idealized oxidation state structures including completely reduced leucoemeraldine base (LEB), semi-oxidized emeraldine base (EB), and fully oxidized pernigraniline base. The is the greatest broadly studied PANI type [11].

Different forms of PANI display various colors some of the PANI is colorless or white in color, emeraldine type is blue in base structure and green in salt form, and pernigraniline structure is blue to violet color. Using protonic acids and oxidative doping procedures, EB can be converted into a conducting state, but this process cannot be performed for LEB and Pernigraniline Base [12].

The chemical method (oxidative polymerization) for the preparation of polymers is characterized as a simple and cheap method capable of preparing large quantities of polymers within a short time. Until now, it is the common method used by many companies to prepare PANI [13].

Later, different techniques were used for the irradiation process to form PANI using an external source, including gamma rays [14] microwaves [15] ultraviolet rays and X-rays.

Methodology

Synthesis of Polyaniline

PANI was prepared using chemical oxidative polymerization method by aniline, dopant (HCl), and Ammonium persulphate, (APS) as an oxidizing agent. Hence, APS was added dropwise until polymerization completed for 15 min, after which a thin film of PANI-HCl formed. This procedure is repeated at 4 °C, 13 °C, and 31 °C using 1 and 2 M HCl. The synthesized thin layers were washed distilled water and dried at ambient temperature.

Results and Discussion

FTIR Analysis of Polyaniline (PANI)

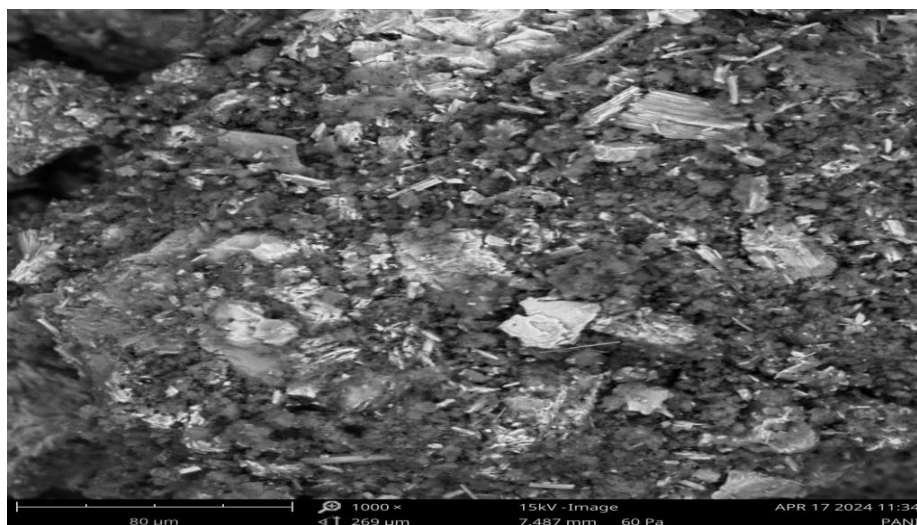
Table 1: FTIR Absorption Bands and Corresponding Functional Groups for ZnO, PANI

PANI		
3384		N-H stretching vibration
3056		C-H bond stretching (Sp ³ formation)
2325		v(N-H) + Unsaturated amine
1547		C-N stretching of quinoid rings
1478		C-N stretching of benzenoid ring
1297		Vibration band
1114		C-H in-plane bending vibration
797		C-H out-of-plane in benzenoid ring

The FTIR spectrum of PANI shows several distinct absorption bands at 3384 cm⁻¹, corresponding to N-H stretching vibrations, indicating the presence of amine groups, at 3056 cm⁻¹, corresponding to C-H in-plane bending vibrations, suggesting the presence of aromatic rings and at 1547 cm⁻¹ and 1478 cm⁻¹, corresponding to C-N stretching of quinoid and benzenoid rings, respectively, which are characteristic of

PANI's conductive structure. Additional peaks at 1297 cm^{-1} , 1114 cm^{-1} , and 797 cm^{-1} are attributed to various vibration bands and C-H stretching vibrations in the polymer backbone [4].

SEM Analysis of Polyaniline



Surface Morphology and Texture

The SEM micrographs of PANI at X1000 magnification reveal a rough, granular surface texture characteristic of polyaniline. This rough texture can be attributed to the irregular and agglomerated [4].

XRD Analysis for Polyaniline (PANI)ature of PANI particles.

PANI	27.7700	109.79	0.0984	3.21259	100.00	46.04
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The XRD analysis revealed distinct peaks corresponding to the crystalline phases of the materials. The key parameters such as position ($^{\circ}2\theta$), height (cts), Full Width at Half Maximum (FWHM), d-spacing ($\text{\AA}$), relative intensity (%), and crystallite size (nm) are essential for understanding the structural characteristics. The XRD pattern for PANI shows a peak at $27.7700^{\circ}2\theta$, with a height of 109.79 counts, a FWHM of $0.0984^{\circ}2\theta$, and a d-spacing of $3.21259\text{ \AA}$. The crystallite size is approximately 46.04 nm. This peak indicates the semi-crystalline nature of PANI, with distinct polymer chain alignment contributing to the observed diffraction pattern [4].

Conclusion

The FTIR study demonstrated that (PANI) exhibit several distinct absorption bands at 3384 cm^{-1} , corresponding to N-H stretching vibrations, indicating the presence of amine groups, at 3056 cm^{-1} , corresponding to C-H in-plane bending vibrations, suggesting the presence of aromatic rings and at 1547 cm^{-1} and 1478 cm^{-1} , corresponding to C-N stretching of quinoid and benzenoid rings, respectively, which are characteristic of PANI's conductive structure. Additional peaks at 1297 cm^{-1} , 1114 cm^{-1} , and 797 cm^{-1} are attributed to various vibration bands and C-H stretching vibrations in the polymer backbone.

Fourier Transform Infrared Spectroscopy (FTIR) revealed the presence of characteristic functional groups in PANI.

Scanning Electron Microscopy (SEM) provided detailed images of the surface morphology and topography. The SEM micrographs showed a rough, granular texture for PANI.

The XRD pattern for PANI shows a peak at $27.7700^{\circ}2\theta$, with a height of 109.79 counts, a FWHM of $0.0984^{\circ}2\theta$, and a d-spacing of $3.21259 \text{ \AA}$. The crystallite size is approximately 46.04 nm. This peak indicates the semi-crystalline nature of PANI, with distinct polymer chain alignment contributing to the observed diffraction pattern.

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