Synthesis and Characterizations of Polyaniline Thin Films Prepared by Chemical Bath Deposition method

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Abstract
The electrical and optical properties of Polyaniline thin films can vary depending on various factors such as the synthesis method, doping level, film thickness, and processing conditions. Polyaniline is a conductive polymer that can exhibit both metallic and semiconducting properties depending on its oxidation state, doping level, and molecular structure. Chemical Bath Deposition (CBD) is versatile technique and it is used to deposit various materials, such as metal oxides, semiconductors, and thin films for various applications like solar cells, sensors, coatings, and others. The present work is focused on the synthesis and characterization of Polyaniline (PANI) - thin films. The PANI thin films were prepared by the chemical bath deposition method. Thin films were prepared on glass substrate. The electrical and photo luminous properties were studied successfully using standard characterization tools. The resistivity of PANI films was found to be 28.82 × 10 ^{4} Ω.m. It was confirmed that prepared thin films of PANI also shows good electrical, and optical results.

Keywords: Polyaniline, chemical bath deposition, thin films, resistivity, photo luminous.

1. Introduction:

Polyaniline (PANI) is a conducting polymer and organic semiconductor that has been of interest since the 1980s due to its electrical conductivity and mechanical properties [1]. It is a conducting polymer that has gained significant attention in the field of materials science due to its unique properties. It is derived from the inexpensive monomer aniline and can exist in three idealized oxidation states: leucoemeraldine (white/clear and colorless), emeraldine (green for the emeraldine salt, blue for the emeraldine base), and pernigraniline (blue/violet). The emeraldine base form is considered the most useful due to its high stability at room temperature and its ability to become highly electrically conducting upon doping with acid [2, 3]. PANI has been used in various applications, including printed circuit board manufacturing, antistatic and ESD coatings, corrosion protection, sensors, and electrochromic devices. The conductivity of undoped PANI is approximately 6.28×10^{-9} S/m. It has band gapes of 4.3 and 2.7 eV in its reduced and oxidized forms respectively [4, 5]. It has high chemical stability. Polyaniline exhibits a relatively small bandgap, making it a semiconductor material. It has a relatively high dielectric constant (~20-30), indicating its ability to store electrical energy in an electric field. PANI has also been used in the production of microwave shielding, photothermal therapy, rechargeable batteries, photovoltaic cells, and other advanced applications. Its versatility, allowing for easy processing into films, fibers, and nanoparticles, makes it useful for applications in composite materials, coatings, and flexible electronics [6, 7]. PANI is a flexible and lightweight material that can be used in applications that need to be flexible, like sensors and wearable electronics [8]. The energy needed to excite electrons from the valence band to the conduction band is determined by the bandgap, which also affects the materials optical and electrical conductivity characteristics [9, 10]. Since polyaniline's characteristics are adjustable, there are numerous uses for it. Because of its flexibility and low weight, it can be used in wearable electronics, electronic displays, flexible batteries, and other flexible electronics technologies [10-13]. Polyaniline thin films can be prepared using the chemical bath deposition (CBD) method, which is a cost-effective and versatile technique for synthesizing thin films. The CBD process involves the oxidative polymerization of aniline in a chemical bath, typically containing an inorganic acid and an oxidant. The method allows for the controlled deposition of PANI thin films on various substrates at low temperatures. The present research work is presented the novel method for synthesis and preparation of PANI thin films and the characterizations of prepared PANI thin films.

2. Experimental work

The thin films of PANI were prepared on glass substrate using chemical bath deposition method. In this method, the bath consists of aniline, an oxidant (ammonium persulfate), and an acid (hydrochloric acid). The substrate (electrically nonconductive) were washed using acetone. The substrates immersed in the chemical bath. After start reaction using magnetic stirrer at normal room temperature and pressure. The PANI thin film were formed on the substrate through the oxidative polymerization of aniline. Fig. 1 shows the experimental set-up of preparation and synthesis of thin films of PANI by using chemical bath deposition method.

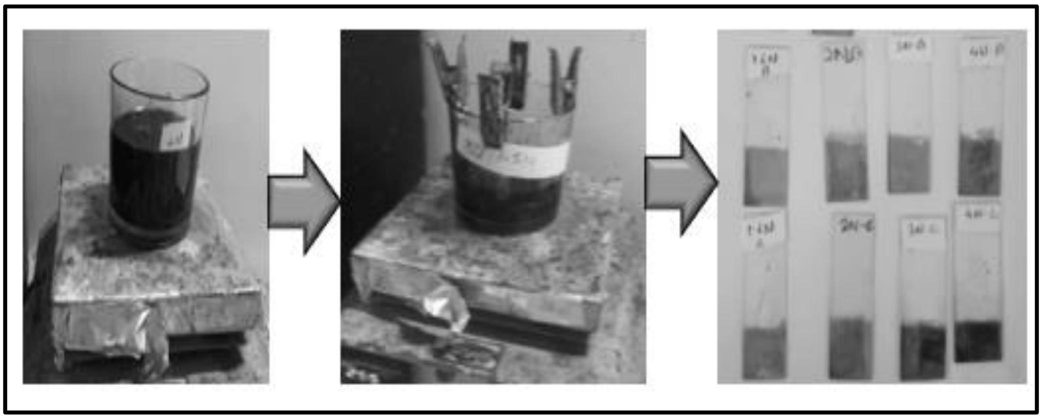

Figure 1: Preparation of thin films of PANI using CBD

3. Result and Discussion

The electrical characterizations of prepared PANI thin films were carried out using static electrical characterization system. In this system the films were used as resistive film resistor and half bride circuit method was employed. In the electrical characterizations the resistivity, temperature coefficient of resistance (TCR) and activation energy at lower and higher regions were investigated using equations 1, 2 and 3 respectively [15, 16].

$$\rho = \left(\frac{R \times b \times t}{l} \right) \Omega - m \qquad (1)$$

Where,
ρ = Resistivity of prepared film, R = resistance at normal temperature, b = breadth of film,
t = thickness of the film, L = length of the film.

$$TCR = \frac{1}{R_o}\left(\frac{\Delta R}{\Delta T}\right) \; /^{O}C \qquad (2)$$

Where, ΔR = change in resistance, ΔT = temperature difference, and R_o = Initial resistance of the film.

$$\Delta E = \frac{\log R}{\log Ro} \times KT \qquad (3)$$

Where, ΔE = Activation energy, R = Resistance at raised temperature, R_0 = Resistance at room temperature. The optical or photo luminous characterizations were investigated using homemade photo luminous system [17]. This system consist of light source, lux meter, sample holder and distance variation arrangement as shown in Fig. 2.

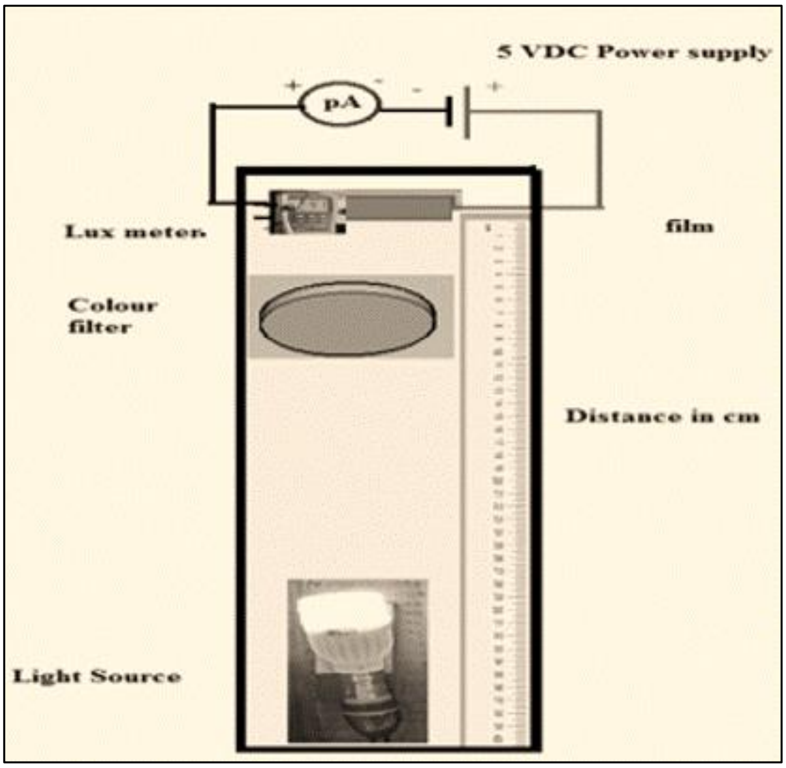

Figure 2: Schamatic of photo luminous characterizations system

The electrical properties of polyaniline thin films are a key aspect of their characterization. PANI thin films exhibit electrical conductivity, which can be modulated by various factors such as doping level, film thickness, and the method of preparation. The conductivity of PANI thin films can be enhanced by doping with acids and other dopants, leading to a significant increase in electrical conductivity. The electrical properties of polyaniline thin films are important for optoelectronics applications due to their ability to conduct electricity and their optical properties. The electrical conductivity of PANI thin films can be enhanced by doping with various acids and dopants, which can increase the conductivity by up to ten orders of magnitude. Fig. 3 shows the ttemperature versus resistance plot of PANI thin films. From Fig. 3, it was observed that as surrounding temperature increased the resistance of the film was decline, attributed semiconducting nature of the films.

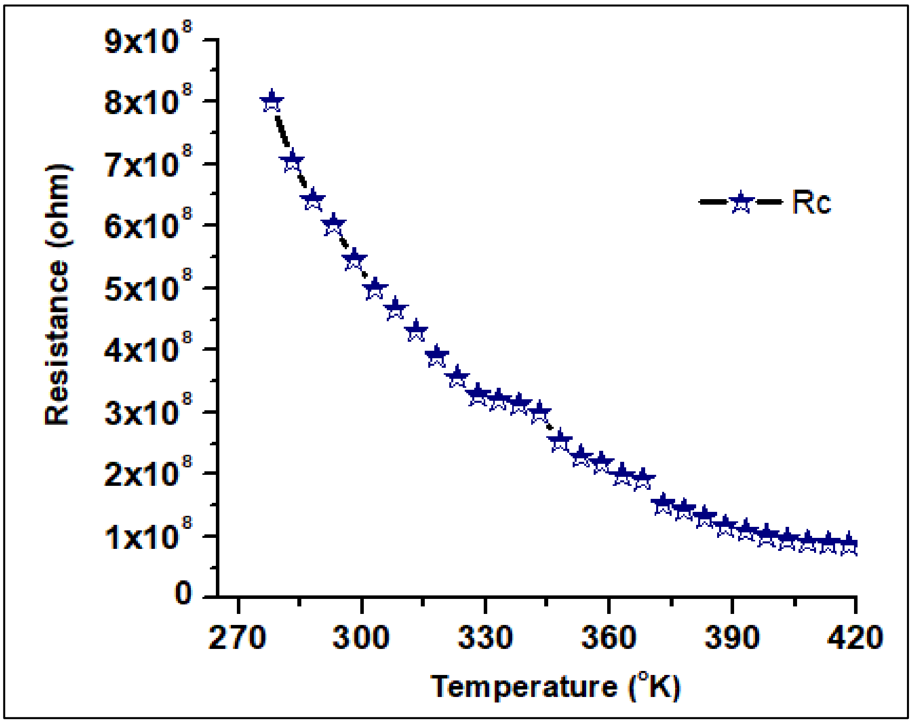

Figure 3: Temperature v/s resistance plot of PANI thin films

The Arrhenius plot is a graphical representation of the relationship between the temperature and the rate of a chemical reaction, which is often used to study the activation energy of a process [18]. In the context of PANI thin films, the Arrhenius plot can be used to analyze the relaxation times of the film's dielectric properties, which are influenced by the film's morphology, doping level, and temperature. The Arrhenius plot of PANI thin films is shown in Fig. 4. The resistivity of the prepared PANI thin films was found to be 28.82×10^{4} Ω.m. The TCR of PANI films was found to be -0.00576/°C. The activation energy at lower temperature region and at higher temperature region was found to be 0.1207 eV and 0.3123 eV respectively.

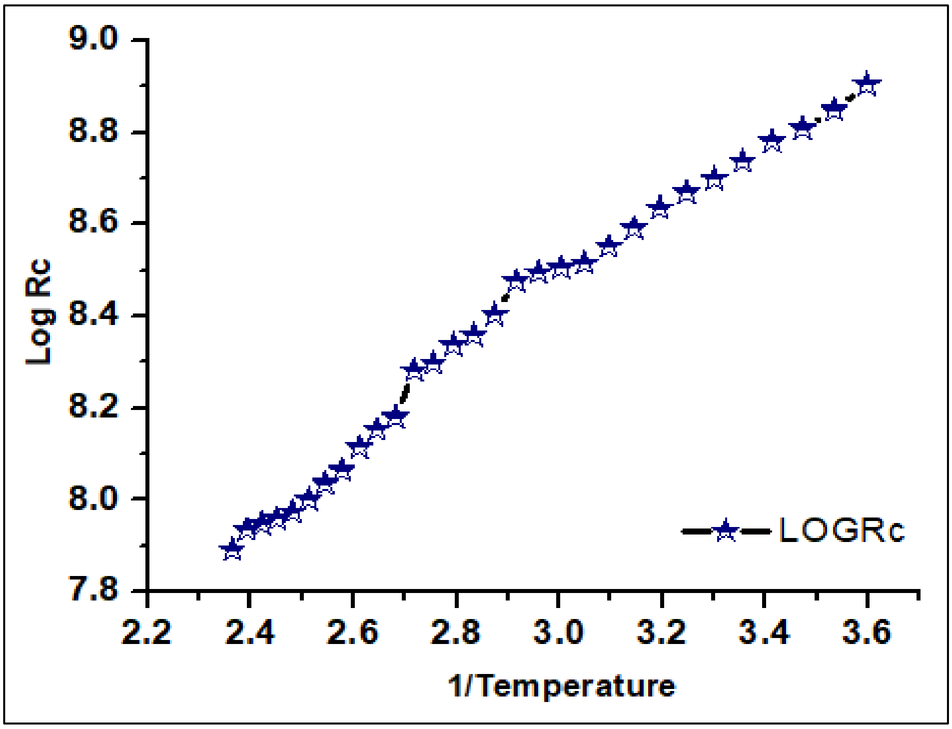

Figure 4: Arrhenius plot of PANI thin films

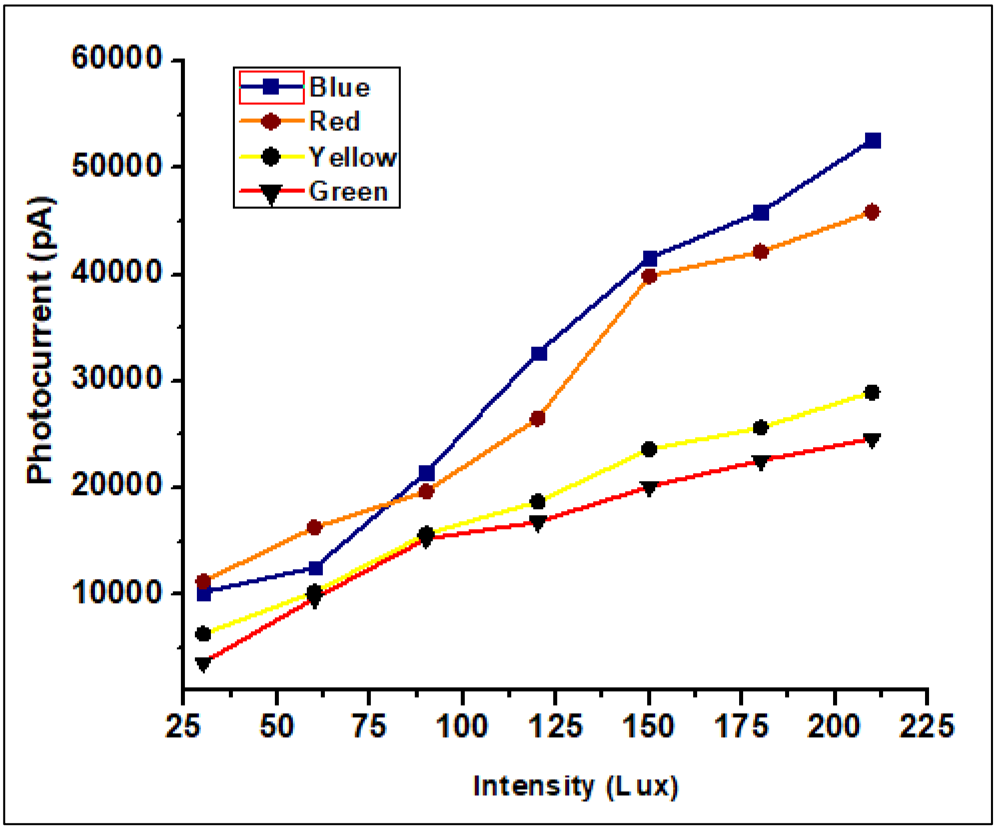

Figure 5: Intensity versus photocurrent plot of PANI thin films

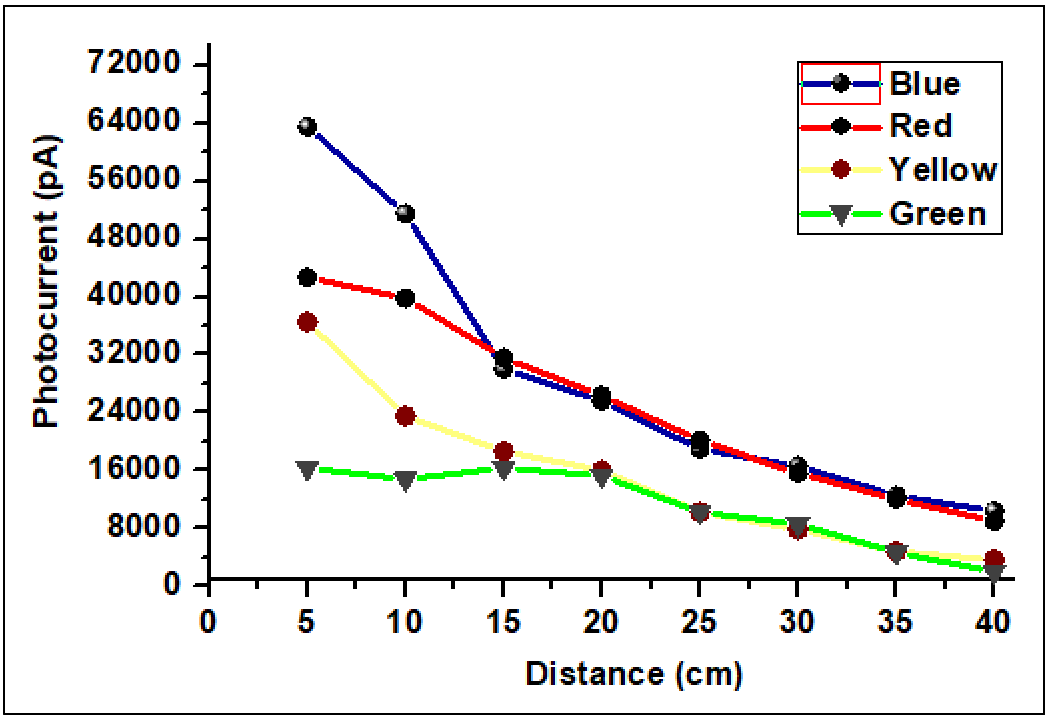

Figure 6: Distance versus photocurrent plot of PANI thin films

At different wavelengths of 640, 550, 510, and 450 nm, the light sensing characteristics of films were examined using color filters of red, yellow, green, and blue as well as a photoresponse characterization system. The photoresponses characterisation static system consists of a fixed power supply of +5VDC, a color filter holder, a sample holder, a 5 Watt light source, and a distance adjustment function. In this arrangement, the light intensity-dependent change in current was investigated by shifting the films and light source. A shift in film current with an intensity variation across a range of 2 to 40 cm was found using a Lux meter. By positioning the filter close to the PANI films, shifting it to a different point or altering the distance from the light source, and then measuring the photocurrent response, the photocurrent through the film was measured. Intensity versus photocurrent plot of PANI thin films shown in Fig. 5. Fig. 5 reveals that as intensity increases the optical response of the film in the form of photocurrent is raised. The current response of PANI films to different color filters is depicted in Fig 6. Fig. 6 shows that as the distance was increased, the photocurrent of the films decreased. This plot shows that the PANI films can be used to build optical devices because of their optical or light response.

Conclusion

Thin films of PANI were synthesized and prepared on glass substrate using chemical bath deposition method. The prepared films were shown semiconducting in nature from electrical characterization. It was confirmed that prepared thin films of PANI shows good electrical, and optical results.

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