

# Battery Application Studies of Polypyrrole with Bio-waste Material as Composite

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**ABSTRACT** - As there is a need of research and development for the recycling and usage of a bio waste material to minimize the extensive usage of conventional conducting materials, the study of electric properties such as conductivity, electric modulus, cyclic voltammetry, dielectric constant, and AC impedance analysis are carried out by using Polypyrrole with sugarcane bagasse ash as its composite. Pyrrole likely to be an organic compound with insulation properties has been studied to exhibit many electrical and dielectric characteristics on its polymerization through the standard procedure of chemical oxidation and addition of sugarcane bagasse ash. The composites of Polypyrrole with different weight percents of sugarcane bagasse ash have been examined and compared by drawing the results. The surface topography and sample composition are analyzed using Scanning Electron Microscope, whereas the impedance analyzer is used to measure the electrical impedance with the changing frequency. The crystal structure of both the solutions is obtained using X-ray diffraction and the result values acquired by X-ray, SEM, impedance analyzer is represented graphically using the software Origin by inputting the discrete values. Hence this experimental approach provides that sugarcane bagasse ash improves the electrical properties of the Polypyrrole to be good organic dielectric material for storage devices which hence finds application in batteries, electrodes, sensors, switching devices and so on.

**Key Words:** PolyPyrrole (PPy), Scanning Electron Microscope (SEM), Sugarcane Bagasse Ash (SBA), Origin, X-Ray Diffraction (XRD), Lattice Boltzmann Method (LBM), Lanthanum Calcium Manganite (LCM)

## 1. INTRODUCTION

The characteristics of metal and semiconductor possessed by the polymers can become conducting materials and their electric, optical, and mechanical properties pay a way for the in-detail study of them. Easy synthesis and fabrication and the environmentally friendly nature are the add-ons to the natural conducting polymers.

These polymeric materials also have the advantages of being flexible, lightweight, and easily produced. Conjugated double bonds are present throughout the polymer chain, which is one of conducting polymers' key properties. While conducting polymers are limited in many ways when they are intrinsic, these constraints can be circumvented by hybridizing with other materials. Conducting polymer

composites have numerous applications in the sectors of electrical, electronics, and optoelectronics due to their combinatorial properties. Of all conducting polymers, Polypyrrole (PPy) is one of the most originally synthesized and biocompatible, with affordable synthesis costs and processing flexibility. Due to its greater stability, improved conductivity, and ease of homopolymer and composite formation, Polypyrrole is unique and has attracted considerable economic interest.

PPy has been synthesized and prepared by employing diverse techniques, such as electrochemical or chemical oxidation of pyrrole monomer in various organic solvents and aqueous media. It has been actively used in many potential applications, such as electronic devices, sensors, batteries, micro actuators, and biomedical devices.

Conducting polymers are synthesized during the chemical polymerization process by oxidizing agents or catalysts on its actual monomers. Chemical synthesis has the benefit of mass production at an affordable price. However, the direct production of conducting polymers using the electrochemical approach allows for greater control over the thickness and structure of the polymer film, making it appropriate for its applications. In many electronic and magnetic devices, such as supercapacitors, magnetic tape recorders, and spintronic devices, there is a huge demand for high-quality dielectric materials as well as for the tuning of materials from magnetic to semiconducting and vice versa.

## 2. LITERATURE SURVEY

Polypyrrole is synthesized by in situ method of polymerization. Impedance analysis is carried out both in the room and at high temperatures. The study enables us to determine the contribution of dopants to the impedance and transport properties of materials [1]. Using different synthesis techniques of Polypyrrole increase in the yield is achieved with improved properties [2]. Samples of Polypyrrole are produced with various oxidants, and their electrical and thermal prosperities are assessed and contrasted. [3].

Improved electrical and transport qualities are found when LBM nanoparticles are studied in relation to PPy's electrical transport properties. [4]. According to the study, PPy/LCM composites can function as an electrically tunable material that switches from a capacitive to a resistive mode

depending on the weight percentage of PPy/LCM. This makes them a unique material for use in organic dielectric material for electric storage devices. [5].

### 3. EXPERIMENTAL DETAILS

The experiment and analysis involve the steps from preparation of Polypyrrole and Polypyrrole SBA composite and then the results by the properties of those solutions are captured using Scanning Electron Microscope, X Ray Diffraction and Impedance Analyzer as shown in Figure 3.1

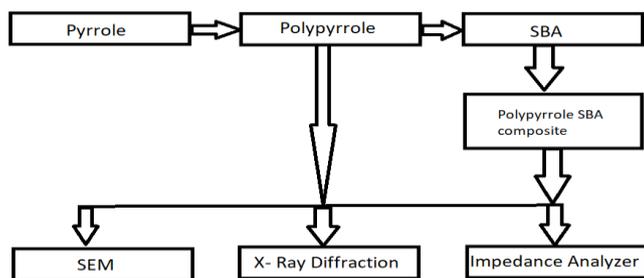


Fig 3.1 Flow Chart

#### 3.1 Preparation of Sugarcane Bagasse Ash:

After the sugarcane juice is extracted, the roughage discarded as waste is used to make sugarcane bagasse ash. The bagasse is first heated to a temperature to reduce the moisture to below 10%, and then it is heated once more to a temperature of approximately 500–700°C to cause it to turn to ash and eventually spherical structure is formed. To remove moisture content, it is sieved to a size of 75 microns and then roasted for two hours in a hot air oven.

#### 3.2 Polymerization of Pyrrole:

Ammonium Per sulphate (APS) is used as an oxidizing agent in the in situ chemical oxidation process to carry out the polymerization of pyrrole. After measuring out 2.1 ml of pyrrole, it is added to a beaker holding a magnetic bead. An ice tray loaded with ice pellets is used to hold the beaker. After then, the entire apparatus is set up on a magnetic stirrer. The bead is calibrated to rotate at 400 revolutions per minute. On the other hand, a transparent solution is prepared by dissolving 13 g of Ammonium Per Sulphate in 100 ml of water and thoroughly stirred.

Next, the ammonium per sulphate solution is transferred into a burette. Drop by drop, APS is added to the beaker holding the pyrrole. The solution becomes black as the reaction begins and constant stirring causes the solution's viscosity to rise. A vacuum pump is used to filter the precipitate Polypyrrole, which is then stored at 100 °C in a hot air oven. The partly dried sample is stored for two hours at 100 °C in a muffle furnace.

#### 3.3 Synthesis of Polypyrrole SBA composite:

The prepared SBA is added at 10% weight percent (SBA10) to the 2.1 ml of pyrrole and further steps are carried out as described in the section 3.2 and in the same way 20%, 30% weight percent SBA is added to prepare SBA20 & SBA30 respectively.

### 4. RESULTS & DISCUSSIONS

#### 4.1 MORPHOLOGY

**4.1.1 Structure under SEM:** At first, the pure Polypyrrole powder is observed under Scanning Electron Microscope to study the size distribution of the sample as shown in Fig 4.1.1a it shows that SBA powder forms a cluster of particles with size 0.5µm approximately.

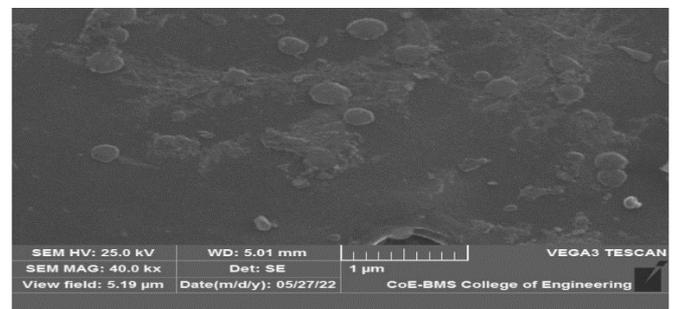


Fig 4.1.1a Pure PPy under SEM

Similarly, Polypyrrole SBA 30% composite is subjected to SEM as shown in the Figure 4.1.1b and the illustration demonstrates that how the particles cluster is enmeshed in the Polypyrrole chain

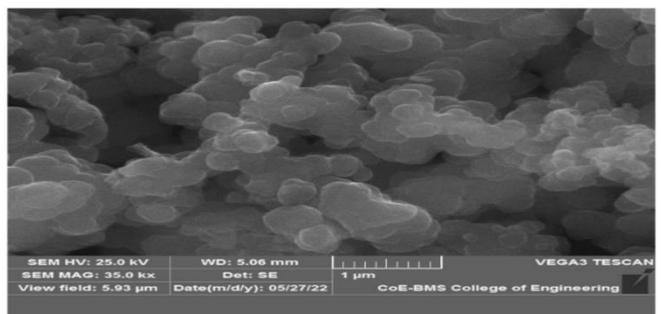


Fig 4.1.1b PPy/SBA30 under SEM

**4.1.2 X-ray Diffraction Analysis:** Using the X-ray diffraction the crystallographic structures of pure Polypyrrole and Polypyrrole SBA 30% composite are captured.

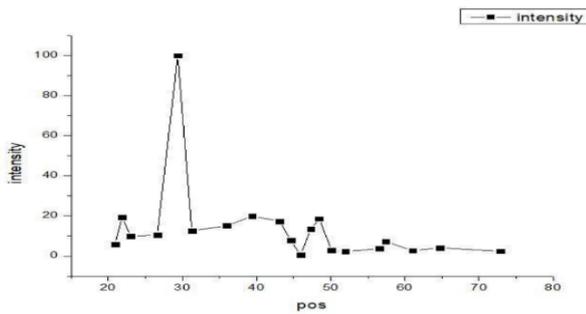


Fig 4.1.2a X-ray of PPY

In Figure 4.1.2a, the intensity of the PPY particles is plotted against the different positions on the textile

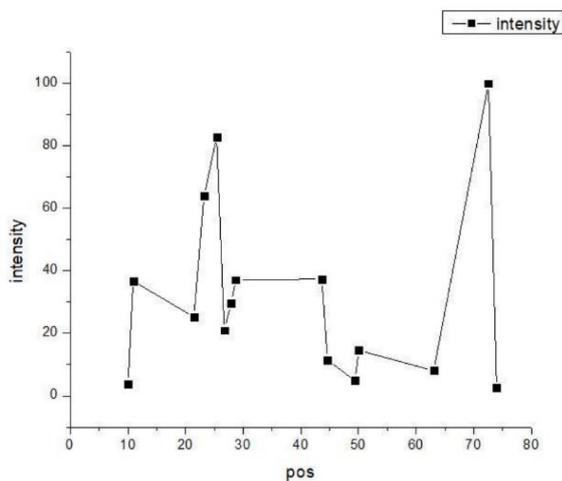


Fig 4.1.2b X-ray of PPY/SBA30

Figure 4.1.2b shows the intensity vs position distribution for Polypyrrole SBA 30 composite.

## 4.2 ELECTRICAL ANALYSIS

**4.2.1 AC Impedance Analysis :** The ionic transport behaviour of PPY/SBA composites is investigated by using AC impedance analysis, the impedance studies of pure PPY and PPY/SBA composites are carried out in the frequency range between 20Hz to 5MHz at room temperature.

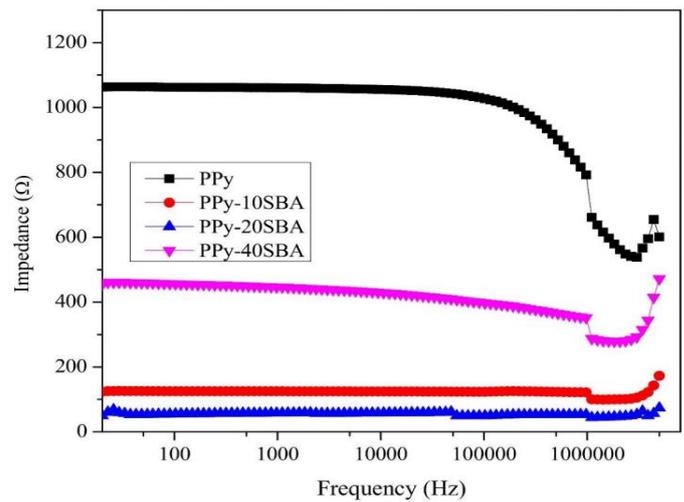


Fig 4.2.1 Impedance vs Frequency plot

From Figure 4.2.1, the impedance is observed to decrease with frequency and it is evident from the behavior that the composite behaves as a capacitive type. Therefore, the composite can be used to exhibit the property of a capacitor. SBA powder which is an insulator also contributes to the impedance in the circuit and since SBA is emmeshed in the PPY chain, this obstructs the electron hopping and thus, the impedance increases.

**4.2.2 AC Electrical Conductivity Measurement :** At room temperature, the electrical conductivity is measured in 20Hz–5 MHz frequency range. A hydraulic press is used to create pellets for the purpose of study, with 8–10 tons of pressure applied. The samples ranged in thickness from 1 to 3 mm. In order to make electrical connections, the top and bottom of the pellet are coated with silver paste. Next, the impedance analyzer furnace probe is put underneath the pellets of the composite to measure electrical resistance.

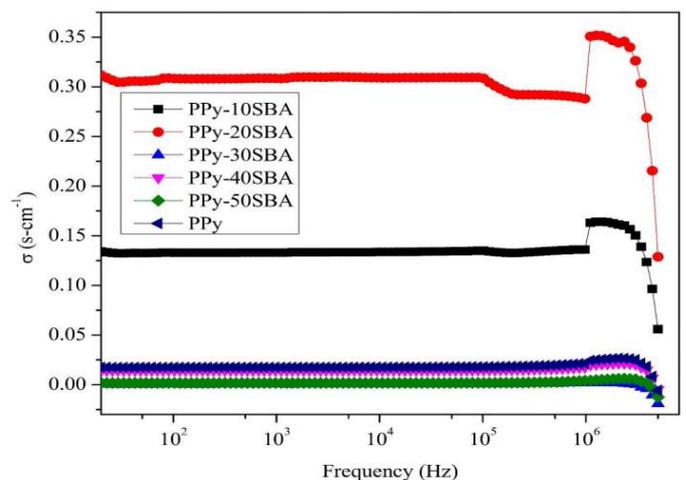


Fig 4.2.2 Conductivity vs Frequency plot

Figure 4.2.2 shows the electrical conductivity behavior of the PPy and PPy/SBA composites with respect to frequency at room temperature. For PPy and PPy/SBA composites, a regularly seen plateau area exists on the low-frequency side. On the other hand, conductivity rises to maximum at frequency of 5 MHz and then falls below that. Both the pure PPy and the PPy/SBA composites exhibit a reduction in conductivity value above 5 MHz, which indicates that the samples are relaxing in the AC field. The PPy/SBA20 composite shows a high conductivity value, measuring 0.3257 S/cm (at 2.35MHz). A higher number of polarons and bipolarons that hop over the grain and grain border is the cause of the high conductivity value. The reason for the lower conductivity in the other composites is thought to be the presence of Jahn-Teller distortion. Grain and grain boundary resistance affects the free motions of the ionic charge carriers.

**4.2.3 Dielectric Constant Studies :** As Figure 4.2.3 shows, dielectric constant changes with frequency in PPy and PPy/SBA composites. Plots show that for both pure PPy and PPy/SBA composites, the dielectric constant steadily falls with frequency and becomes constant at high frequencies. The system's many polarization processes is the cause of this behavior. Electronic, ionic, orientation, and space charge polarization are the main polarization processes. Because the dipoles follow the field and may respond quickly, causing polarization, the dielectric constant is large in the low frequency.

However, when frequency rises, the field is unable to create a dipole moment for the abrupt frequency shift. As a result, polarizability diminishes and dielectric constant values fall. Space charge polarization is the primary cause of the polarization that is taking place in the system. The dielectric constant value is significantly altered by the addition of SBA.

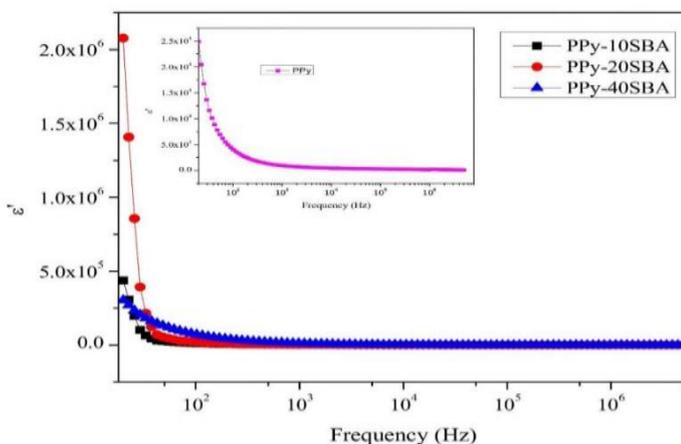


Fig 4.2.3 Dielectric constant vs Frequency plot

**4.2.4 Electric Modulus Analysis:** The electric conductivity of the samples is analyzed using frequency-dependent electric modulus study results, which provides

insight into the conducting property supplied by either the electrode or the flaws. When the displacement of electric charges is constant, the electric modulus often reflects how relaxing the electric field is.

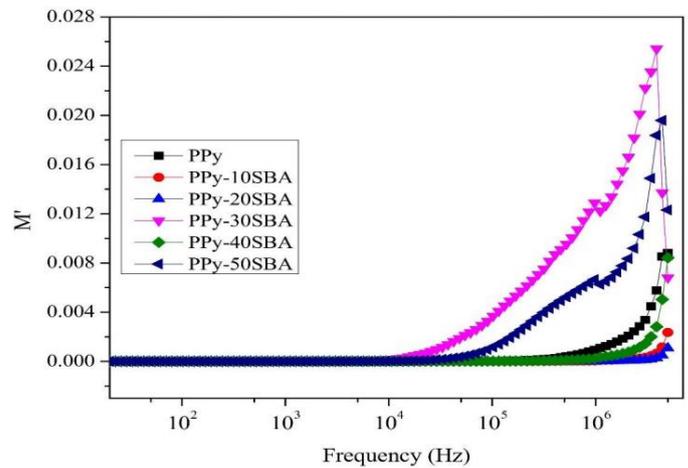


Fig 4.2.4a M' versus frequency of PPy/SBA composite

Figure 4.2.4a shows  $M'$  - the real part of the electrical modulus varying with frequency at room temperature.  $M'$  starts out extremely low in the low-frequency zone, grows with frequency, reaches a maximum value at 5MHz, and then saturates in the high-frequency region (beyond 5 MHz). The electrode effect is revealed at low frequencies when the value appears to be very low and almost equal to zero at high frequencies, the influence appears to diminish. Because of the mobility of charge carriers, the conduction process causes a rise in modulus value at high frequencies, which results in composites. Because the composites may transport the charge carrier, it is determined that PPy SBA30 has more value.

Figure 4.2.4b illustrates the frequency-dependent fluctuation of the imaginary component of the electrical modulus  $M''$  at ambient temperature. The composites exhibit a lengthy low-frequency trailing curve which is followed up to a certain frequency by a rise in the  $M''$  value. For PPy and PPy/SBA composites, the value of  $M''$  reaches its maximum (about 5 MHz) and then decreases at the higher frequency end. The peak's migration towards the higher frequency side suggests that the ion charges are mobile and have a strong correlation between their motions. Additionally, a widening of the peak is noticed and pure PPy is observed to have a greater peak widening.

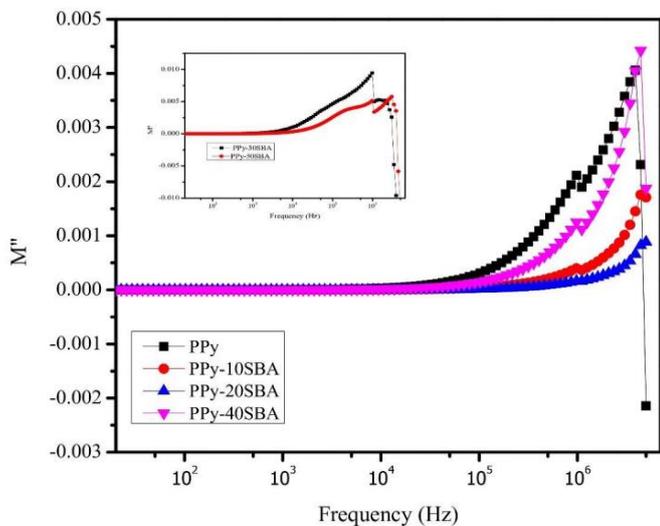


Fig 4.2.4b  $M''$  versus frequency of PPy/SBA composites.

The dispersion of relaxation times with varying time constants leads to the peak widening. This behavior also indicates a non-Debye form of relaxation. High-frequency peaks imply that ions are restricted to the movement within their potential well, whereas low-frequency peaks are caused by long-distance ion movement. The measured spectrum's characteristics corroborate the charge carriers hopping process that occurs during the compound's electrical conduction.

### 4.3 ELECTROCHEMICAL ANALYSIS

**4.3.1 Cyclic Voltammetry :** The current flowing through an electrochemical cell while the voltage is swept throughout a voltage range is plotted using cyclic voltage monitoring. In the sweep, a linear voltage ramp is employed and a CV test frequently involves sweeping the voltage between two limit potentials repeatedly.

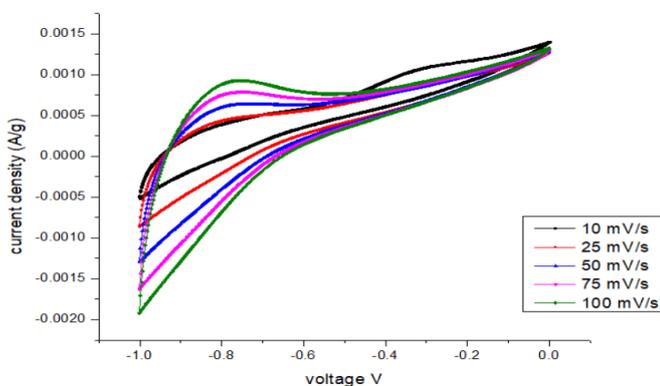


Fig 4.3.1a CV plot of pure PPy

Figure 4.3.1a and 4.3.1b shows the voltage limits of 0 and -1 V are entered in the setup. A user has adequate time to adjust to the higher current because of the scan rate's

slowness. This curve's segment integration demonstrates how capacitance is calculated using CV data. Evidence of well-developed capacitance behavior is shown by the half quasi rectangular profile of the rectangular CV profile at lower scan speeds.

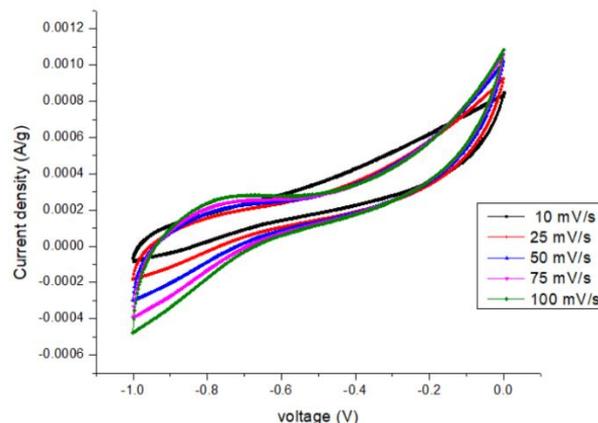


Fig 4.3.1b CV plot of 30% PPy/SBA Composite

## 5. CONCLUSION

PPy/SBA composite is prepared using in situ chemical oxidation technique. At room temperature, impedance study is performed in the frequency range of 20Hz to 5MHz. At room temperature, it is discovered that the produced composites electrical conductivity depend on the frequency and the relaxation processes in the samples rely on frequency and the frequency causes the dielectric constant to drop. The space charge polarization mechanism or electric polarization is the cause of this phenomenon. The single phase, non-Debye type conductivity relaxation, and the hopping mechanism involved in electrical transport processes are all confirmed by modulus analysis.

The current study demonstrates that the PPy/SBA20 composite has superior AC conductivity, with 0.3257 S/cm at 2.35 MHz and a dielectric constant value of 553.34 at 5 MHz. Based on the study, we can conclude that the PPy/SBA composites can function as an electrically tunable material that switches from capacitive type to resistive type based on the SBA percentage in the PPy chain. They can also be a novel material to work as good organic dielectric materials for electric storage devices at room temperature. Additionally, the composite is simple to functionalize and useful in situations where customized organic-inorganic nanocomposite materials are needed.

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