Interpretation of AC and DC Breakdown Characteristics and Charge Transport of Various Conducting Polymers

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Abstract: This study has been commenced to interpret the comparison of AC & DC characterization of conducting polymers (CP) such as Polyethylene terephthalate (PET) with doped Polypyrrole (PPY), PET with doped Polyaniline (PANI), and PET with doped Poly (3, 4-ethylene-dioxythiophene)-poly (styrene sulfonate) (PEDOT-PSS) in view of thermo-electric properties. Lean identical thickness films of each material were prepared by a simple strategy via glass coating technique and its experimental setup is shown in fig a. The glass pieces of sampled materials prepared conducting polymers were studied under different parameters, different temperatures and frequencies. The results were examined using characterization technique called scanning electron microscopy (SEM). Due to alleviate of dispensation, elasticity, tremendous charge transport, and thermo-electric properties, these nano- composite films can be potential thermo-electric materials for organic electronic devices operated at room temperature.

***IndexTerms* – Electric Properties, Conducting Polymers, Frequencies, Electrical conductivity· Dielectric properties · Nanocomposites· Percolation threshold· Transport properties.**

I. INTRODUCTION

Nanodielectrics have massive potential to develop the performance of applications in the field of electrical and electronics starting from generation of power to HV transmission components, as a solid-state heating and cooling devices to sensors, small-scale electronics components and many more [1]. The emerging phenomena of past century are Nanodielectrics as a larger field of composites containing a matrix & fillers. That is, a polymer in which inorganic oxide nanoparticles are integrated to form an electrically insulating material with improved properties. The use of nanoparticles in polymer reveals large improvements on electrical properties [2]. In case of thermoplastics, the dielectric properties are finely tuned and the importance of polymer-particle interactions is augmented in polymer nanocomposites, along with the interface and the co-operatively between nanoparticle and polymeric matrix dominate the macroscopic properties. The most significant accomplishments of nanodielectrics are still ahead of us. Electrical strength of polymer-based nanocomposites used as insulating materials have been studied along the last years.

Composites of PET geared up in the form of fiber, coated with thin film of polyaniline have involved vast industrial interest and have been researched by many [3] due to technical potential in appliances. While it is a known fact that the synthetic conditions used were greatly affect the structure, morphology and final properties of CP [3].

Conducting polymers (CPs) are rising as promising materials in sensor technology as conducting and resistive sensors. The CPs is constructive for various sensing applications due to their excellent sensing performance at room temperature [7–11]. Among CPs, poly (3, 4- ethylenedioxythiophene) (PEDOT) is a well-known commercially available conducting polymer emerged to be most promising flexible electrode materials over rigid metallic oxides.

II. SAMPLE PREPARARION:

Preparation of samples composed of high-density polyethylene blend with 20 wt. % and 80 wt.% of low-density polyethylene was made using twin-rotor R600 mixer. The sample of thickness 60 mm 6021 Milky white polyester film which is a biaxially oriented polyethelene terephthalate (PET) substrate is taken as a host material, and is roughened on its surface and made it ready to absorb thin film layers further. Before coating the conducting polymers like PANI, PPY and PEDOT-PSS. The base PET substrate was cleaned in Acetone and then washed in IPA (Iso Propyl Alcohol) about 30 minutes. After this process the cleaned PET substrate was dried in dynamic oven to remove the impurities and moisture contents. After this process the PET substrate was kept on dip coating polymers. The dip time was set to be order of 30 minutes for uniform coating of conducting polymers. Later the conducting polymer coated PET substrate was dried in dynamic oven about 1 hour to remove the absorbed moisture contents in the prepared conducting polymers. Thin films were repeated for all conducting polymers.

III. EXPERIMENTAL SETUP:

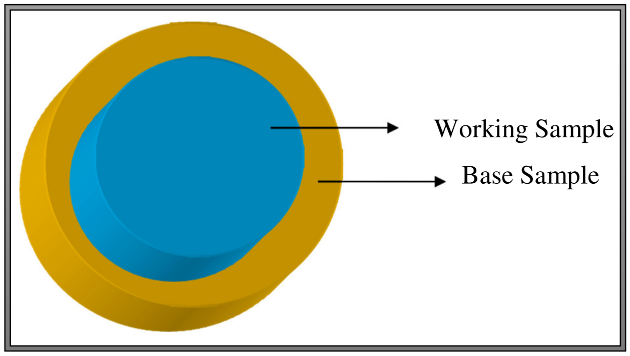


Figure a: Showing experimental setup of base sample and working sample

IV. RESULTS AND DISCUSSION

In the following paragraphs, a glance history is provided, and then the barriers to achievement are accessible followed by the toolbox available for nano-dielectric materials design and optimization. The perception then turns to the most pertinent properties from a commercial perspective and the trail forward for these materials to meet their potential for improving the effectiveness of electrical generation and transmission, and the functionality of capacitors. This is followed by some of the most motivating new ideas in nanodielectrics research.

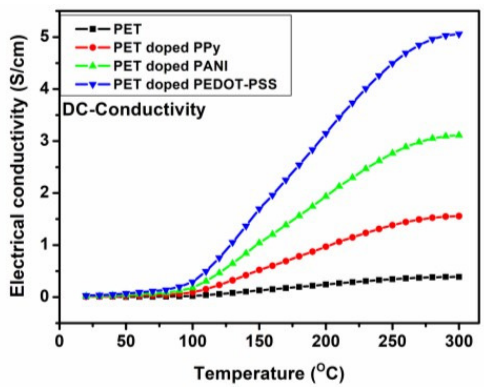


Figure 1: Variation of DC Conductivity versus Temperature

Here in the graph of fig 1, DC conductivity of CP's was examined. Electrical conductivity of PET was analysis over a range of temperature from 50 to 300o C. Electrical conductivity in S/cm of PET increase in temperature in degrees are almost constant which means that Electrical conductivity is independent of temperature for PET. Similarly, in PET doped with PPy, it can be seen that Electrical conductivity over a range of temperature is increasing with increase in temperature and at 300o C the Electrical conductivity is at a peak point, so conductivity for PET doped with PPy is dependent on temperature and is slight linear curve. Again, for PET doped with PANI Electrical conductivity is increasing with increase in temperature and at 300o C the Electrical conductivity is at its maximum point i.e., 3 (S\cm). Also, for PET doped with PEDOT-PSS, Electrical conductivity over temperature increase with increase in temperature and at 300o C the Electrical conductivity is at its peak point i.e., 5 (S/cm). Among these samples it is observed that, PET with doped PEDOT-PSS gives improved Electrical conductivity.

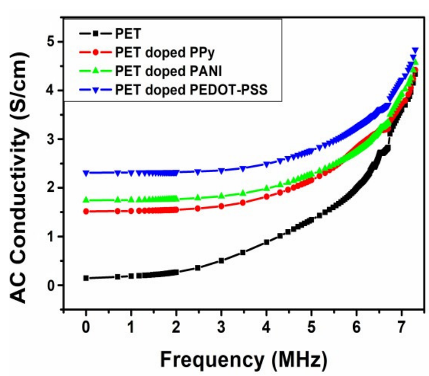


Figure 2: Variation of AC Conductivity versus frequency

To obtain Charge Transport AC conductivity is studied and in this graph of fig 2, Frequency dependence of AC conductivity of PET and PET with different conduction polymers is shown, it can be seen that AC conductivity remains constant for almost all the values of frequencies below or up to 2 MHz and it increases with increase in frequency after the range 3 MHz which shows that AC conductivity is entirely frequency dependent and at 7 MHz frequency, the AC conductivity is at its maximum point. Similarly, for PET doped PPy, PET doped PANI and PET doped PEDOT- PSS, all of the AC conductivity increase with the increase in frequency range which shows that AC conductivity is entirely frequency dependent. Hence it is also observed that there is no much change in the range of frequencies for AC Conductivity weather it is with PET alone or with combo of other conducting polymers.

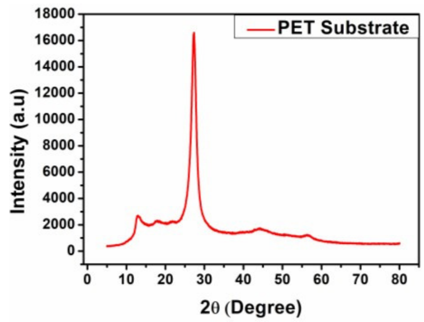
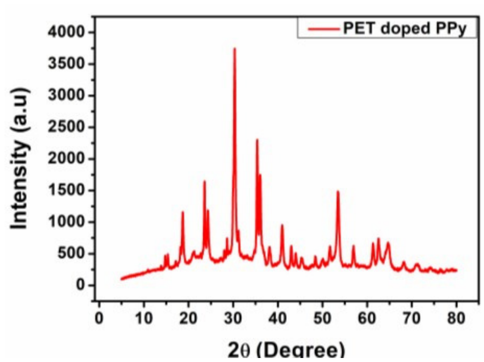


Figure3: Intensity of PET substrate

In the graph of fig 3, for intensity v/s degree for PET substrate shows that the corresponding peaks of the PET substrate at 2θ have very high intensity which means that there is a deposition on the PET substrate. The intensity of the corresponding peak of the films deposited on the PET substrate is the highest as compared to the other intensity of the film.

Figure 4: Intensity of PET with doped PPy



In the graph of fig 4, for intensity v/s degree for PET doped PPy shows that the corresponding peaks of the PET doped PPy at 2θ have very high intensity (i.e., at 30-degree, intensity = 4000 a.u). Theintensity of the corresponding peak of the PET doped PPy is the highest as compared to the other intensity of the film and can see be seen that for different range of degree has different intensity.

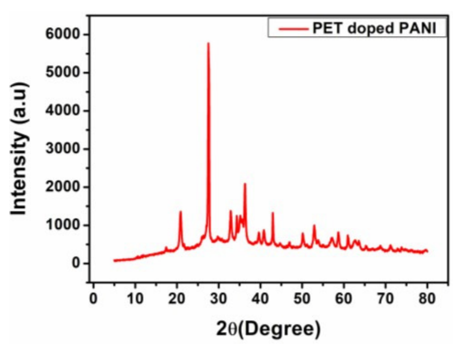


Figure 5: Intensity of PET with doped PANI

It can be seen clearly in the graph of fig 5 that the intensity of the observed peaks of the film are higher while going across the corresponding films for PET doped PANI. The highest peak of the intensity is at 29 degree i.e.,6000 a.u.

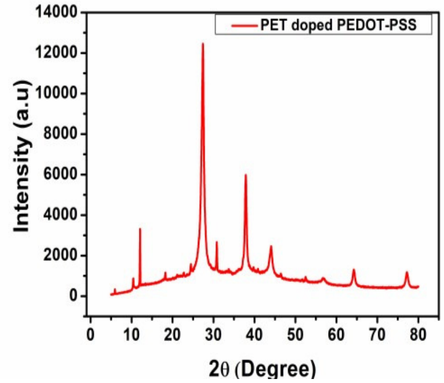


Figure 6: Intensity of PET with doped PEDOT-PSS

In the graph of fig 6, for intensity v/s degree for PET doped PEDOT-PSS shows that the corresponding peaks of the PET substrate at 2θ have very high intensity which means that there is a deposition on the PET films. The intensity of the corresponding peak of the films deposited on the PET doped PEDOT-PSS is the highest as compared to the other intensity of the film.

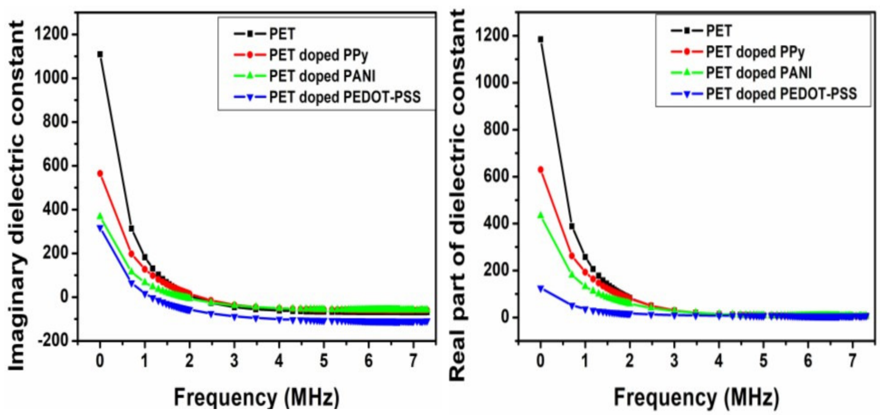


Figure 7: Study of Real & Imaginary Dielectric Constant versus Frequencies

The real and imaginary dielectric constant of PET versus frequency was obtained to study the PET films. It can be seen in the above fig 7 both a and b graphs that the dielectric properties of the PET decrease with the increase in frequency and become constant after frequencies more than 3.5 MHz, which means that the dielectric properties are lost and the gap between the film get narrow with the increase in frequency. Similarly, for PET doped PPy, PET doped PANI and PET doped PEDOT-PSS, it can be seen that the dielectric properties of the PET after addition of reagent at first is at peak point and decrease with the increase in frequency and become constant after some frequency.

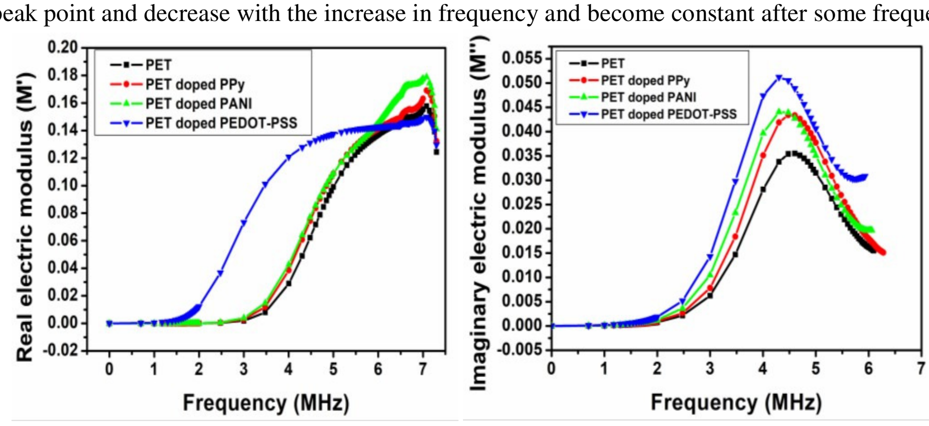


Figure 8: Study of real and imaginary electric modulus versus frequency

The consecutive plots of the real and imaginary part of the Electric modulus versus Frequency for all the composites of fig 8, shows that there is more peak occuring in the middle frequency region for PET, PET doped PPy, PET doped PANI and PET doped PEDOT-PSS which tells that with the incresase in frequency the Electric Modulus increases at a certain peak point and then decrease to its original level even after the addition of reagent.

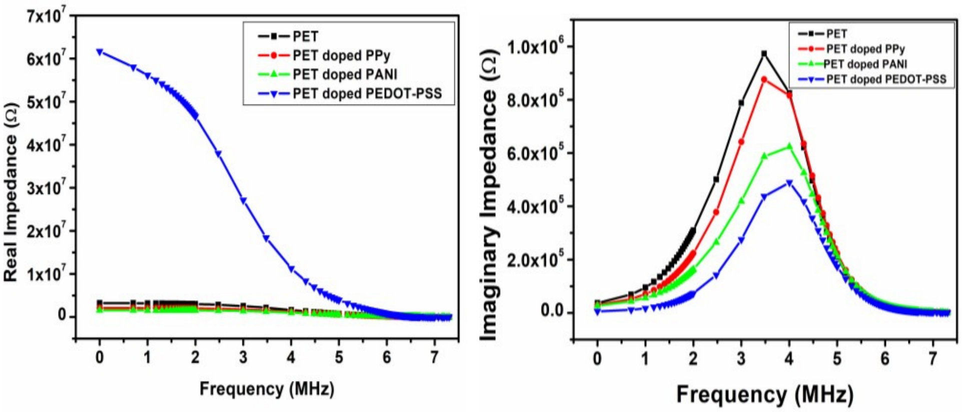


Figure 9: Study of Real and Imaginary Impedances versus Frequencies

The absorbance as a function of wavelength for samples is plotted in the graph of fig 9, in representation as a function of angular frequency i.e., in omega. In impedance spectroscopy, the electrochemical system which includes a coupled quantity of magnitude and phase of different samples are observed and found to be almost constant characteristics for real impedance with increased frequencies (MHz) in all samples except PET with doped PEDOT-PSS. Whereas in imaginary impedance with change in frequencies reflects increased impedances for 3 – 4 Mega Hertz frequency. And it is approximately constant for lesser & larger values of frequencies.

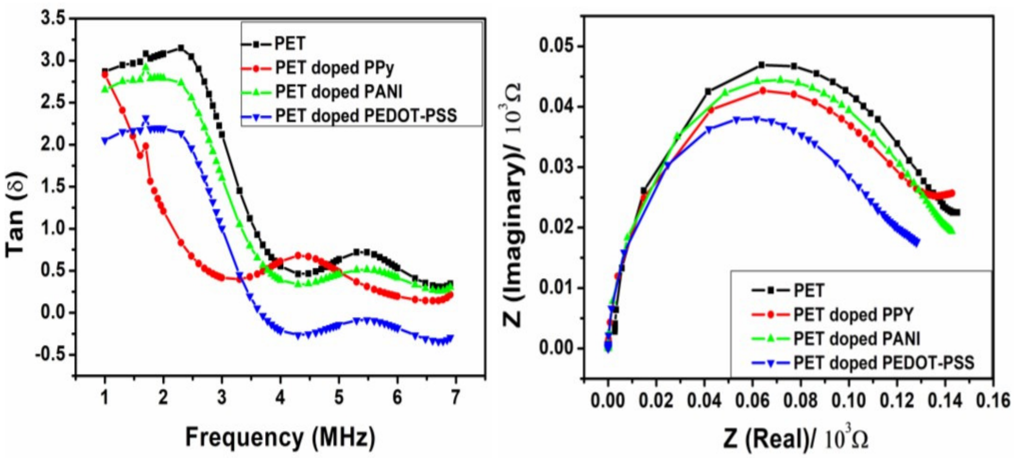


Figure 10: Relative permittivity measurement of dielectric loss versus frequency

On the basis of experimental results, relative permittivity was measured and dependence of dielectric loss tangent tanδ and frequency of the samples were plotted shown in the figure 10.

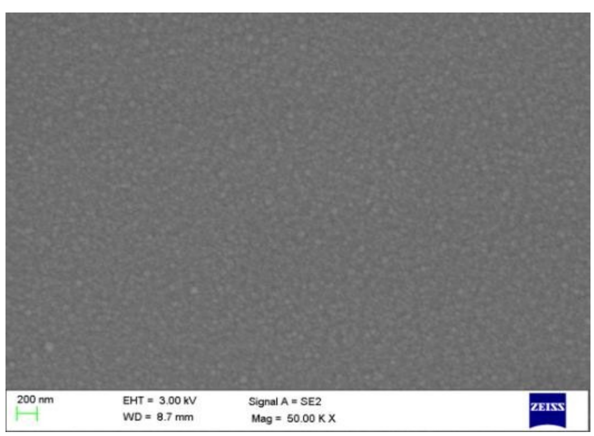


Figure 11: SEM Micrograph of PET

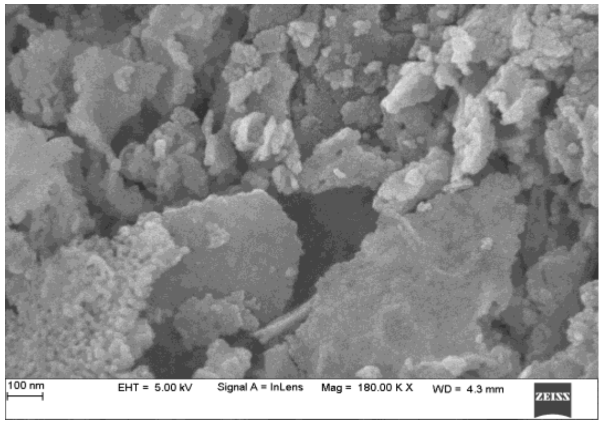


Figure 12: SEM Micrograph of PET doped Poly Pyrrole (PET doped PPy).

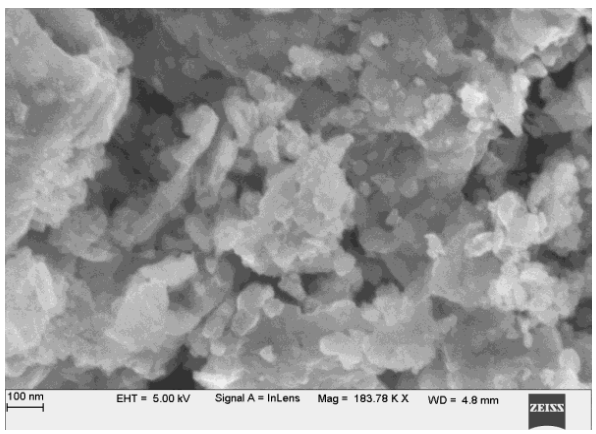


Figure 13: SEM Micrograph of PET doped Poly Aniline (PET doped PANI).

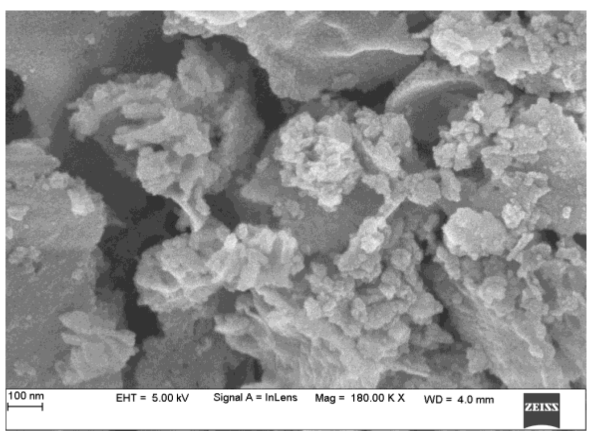


Figure 14: SEM Micrograph of PET doped PEDOT-PSS (PETdoped PEDPT-PSS).

Figures 11, 12, 13 & 14 above shows the extension of Scanning Electron Microscope (SEM) Micrograph for pure PET, PET with doped PPy, PET with doped PANI and PET with doped PEDOT-PSS. Investigations of these micrographs were obtained to interpret the effect of Gr nanomaterials inclusions. The SEM micrograph of a pure PET was observed to be uniform distribution of granular molecular structure with change in temperature and at voltages upto 3kVolts as shown in figure 11. Whereas the composites prepared for PET with doped PPy it was observed that the molecular structure includes gap for voltage under 5 kVolts. Similarly PET with other two conducting polymers, PET with doped PANI and PET with doped PEDOT-PSS it was observed dilute in the molecular structure.

V. ACKNOWLEDGMENT

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Conflict of Interest: The authors declare that they have no conflict of interest.

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