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RESEARCH ARTICLE

STUDY OF DIELECTRIC PROPERTIES OF PPy WITH NBR BASED CEC USING TWO POINT METHOD AT X-BAND USING MICROWAVE BENCH

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ABSTRACT

The dielectric properties like dielectric constant, loss tangent, loss factor, conductivity, Absorption Coefficient, Skin depth, Dielectric heating coefficient of various conducting polymers like PPy based on Acrylonitrile butadiene rubber (NBR) with conducting elastomer composites (CECs) methods and using two point technique, at microwave frequencies in the X- band (7-13 GHz).were studied. The absolute value of the dielectric constant, absorption coefficient and AC conductivity of the conducting polymers prepared are greater than the polymers prepared by gum vulcanizates. Heating coefficient and skin depth PPy and fibre coated PPy (F-PPy) dielelctrics decreases. For NPFp5, LNPFp3 and BP3 the Dielectric constants obtained are 37, 57.5 and 44 respectively. At 10.8 GHz maximum AC conductivity of 6.9 S/m was obtained by the CEC for NPFp5.

INTRODUCTION

Microwave properties of conductive polymers plays a vital role in the applications like coating in electronic equipment, coating in reflector antennas, frequency selective surfaces, microchip antennas, EMI materials etc. Understanding the transport mechanism in conducting polymers and absorbing materials have encouraged the study of dielectric properties at micro wave frequencies. Conducting polymers gives some specific characteristics in microwave frequencies. Conducting polymers are good absorbers at microwave frequecies and exhibts technological lead when compared to inorganic electromagnetic absorbing materials and can be used for making microwave absorbers in space applications. The intrinsic conductivity of conjugated polymers leads to high levels of dielectric constant. Many absorbing materials based on conducting polymers have been developed to work at microwave frequencies. In recent years electromagnetic wave absorbing materials used in gigahertz (GHz) range developed with the development of radar detection, GHz microwave communication etc. Conducting polymers and their composites are good shielding materials. Polypyrrole powders have included in thermoplastics, plastics with silicon and fluroplastics. Fibers and textiles coated with PPy are reported to yield high shielding effectiveness. All dielectric materials are characterized by their dielectric parameters such as dielectric constant, conductivity and dielectric loss factor.

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These parameters differ with frequency, temperature, pressure etc.

Microwave characteristics

A. Experimental method to find the Dielectric constant using Two Point Method

The dielectric constant (∈') and dielectric loss (∈") of the Coducting polymers were measured in the range of 7.2 GHz to 12 GHz microwave frequencies using microwave benches and employing the two-point method. The reflex Klystron and Gunn diode were used to generate microwave frequencies, respectively. The experimental set up is shown in fig 1. The sample holders for frequency measurements were fabricated from the standard wave guides. The one end of the sample holder is connected with metallic flange and other end was carefully shorted. First, with no dielectric in the short-circuited line, the position of the first minimum DR in the slotted line was measured (Figure 4.6). Now the Conducting polymer sample of certain length (l∈) was placed in the sample holder, such that the sample touches the short-circuited end. Then the position of the first minimum D on the slotted line and the corresponding VSWR, r were *measured*. The VSWR was measured using a VSWR meter which in turn is connected a PC. For the measurement of VSWR, the VSWR meter was connected and the amplitude modulation using pin diode was applied to the microwave signal set up. This procedure was repeated for another conducting polymer sample of same sample length (l'∈).

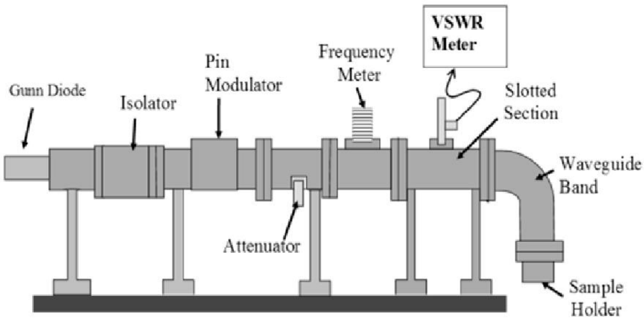

Fig. 1. Experimental setup of Microwave Bench

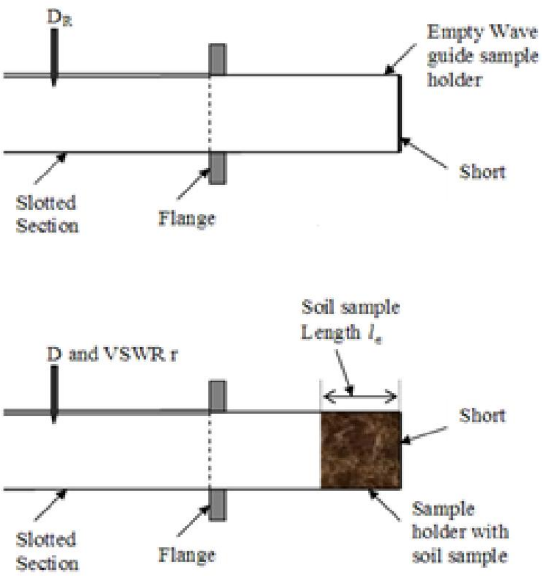

Fig. 2. Block diagram of flange connection

The block diagram of flange connection is as shown in the fig. 2. The propagation constant (in the empty wave-guide) is calculated as

$$k = \frac{2\pi}{\lambda_g}$$

Where, λg =2x (distance between successive minima with empty short circuited wave- guide sample holder)

The value of λg is calculated using the formula

$$\left(\frac{1}{\lambda_o}\right)^2 = \left(\frac{1}{\lambda g}\right)^2 + \left(\frac{1}{\lambda c}\right)^2$$

Using the above formula the various parameters are calculated

i. Dielectric constant: $\epsilon'r = \frac{\left(\frac{a}{\pi}\right)^2\left(\frac{\beta\epsilon l\epsilon}{l\epsilon}\right)^2+1}{\left(\frac{2a}{\lambda g}\right)^2+1}$

Where 'a' is the wave guide dimension, λc is twice the waveguide dimension (= 4.582) and λo is the ratio of velocity and frequency of microwave(=3.03).

ii. Loss Tangent (Tan δ): Tan $\delta = \left(\frac{(\Delta Xs - \Delta X)}{\varepsilon' d}\right)\left(\frac{\lambda_o}{\lambda g}\right)^2$

Where

ΔXs = Width at twice minimum or maximum with sample
ΔX = Width at twice minimum or maximum without sample

iii. Loss Factor (ε''): ε''= ε' Tan δ

iv. Absorption Coefficient (α) = $\frac{\varepsilon_r'' f}{nc}$

v. A.C conductivity σ = $2\pi f \varepsilon_0 \varepsilon_r''$

vi. Dielectric Heating Coefficient, J = $\frac{1}{\varepsilon_r \tan\delta}$

vii. Skin depth, d = $\frac{1}{\alpha}$

RESULTS AND DISCUSSION

NBR based CECs

Dielectric Constant

Fig. 3.1 shows the changes in dielectric constant (ε') of NBR with PPY loading and Fibre loaded PPy in X-Band frequencies. Especially for BP_0 and BP_2 it has been observed that the dielectric constant (ε') is almost invariable in spite of applied micro frequency for BP series. Therefore electronic and ionic polarization mechanisms may be contributed to ε'. For BP3 and BP_4, when there is change in frequency there is a slight increase in ε' which may be due to the increased dipolar polarization obtained from increased PPY content. While for BFp series at high frequency of applied field, PPY coated fibers contribute more conducting regions which leads to increase in space charge polarization. The observed decrease in the value of ε' with increase in frequency in the case of BFp series is mainly due to the decrease in space charge polarization. This behavior is in food coincidence with Maxwell-Wagner interfacial polarization. Due to increase in DC conductivity of Elastane based composites, the value of ε' increases substantially with PPY loading. At 12 GHz frequency A dielectric constant of 44 is obtained for 75 phr PPY loaded composite (BP3). Addition of Fibre loaded PPY results an increase in ε', reaches a maximum value at 50phr loading and then gradually decreases. This is in accordance with DC conductivity values. At 50phr Fibre loaded PPy attains maximum conductivity. Further loading does not bring about any increase in conducting regions and therefore space charge polarisability too remains unchanged.

Dielectric loss

Fig. 3.2 shows the changes of dielectric loss (ε") of PPY filled and Fibre loaded PPy filled Elastane composites at X-band micro frequencies. Due to increase in mobility of charge carriers the values of Dielectric loss is found to increase with PPY while frequency has little consequence on ε" except at higher loading. In the case of BFp series, the value of dielectric loss increases with loading and reaches a maximum value at 50phr loading and then it gradually decreases.

AC conductivity

Fig. 3.3 shows the changes in AC conductivity (S/m) of composites with PPY and Fibre loaded PPy at various micro frequencies. It is observed that it posses the same nature as that of the dielectric loss factor. The reason for this lower threshold and high value of AC conductivity of fiber filled composites compared to PPY filled composites is as given in section 5.2.2.1.3. Maximum conductivity 3.2 S/m is obtained at 50phr Fibre loaded PPY sample at a frequency 7.2 GHz.

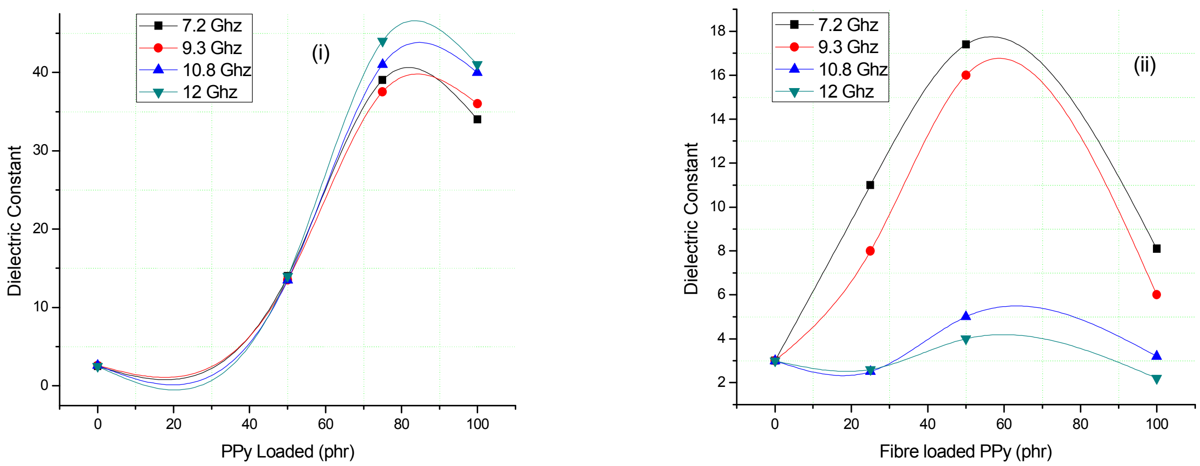

Fig. 3.1. The changes in dielectric constant with loading of (i) BP, (ii) BFp series

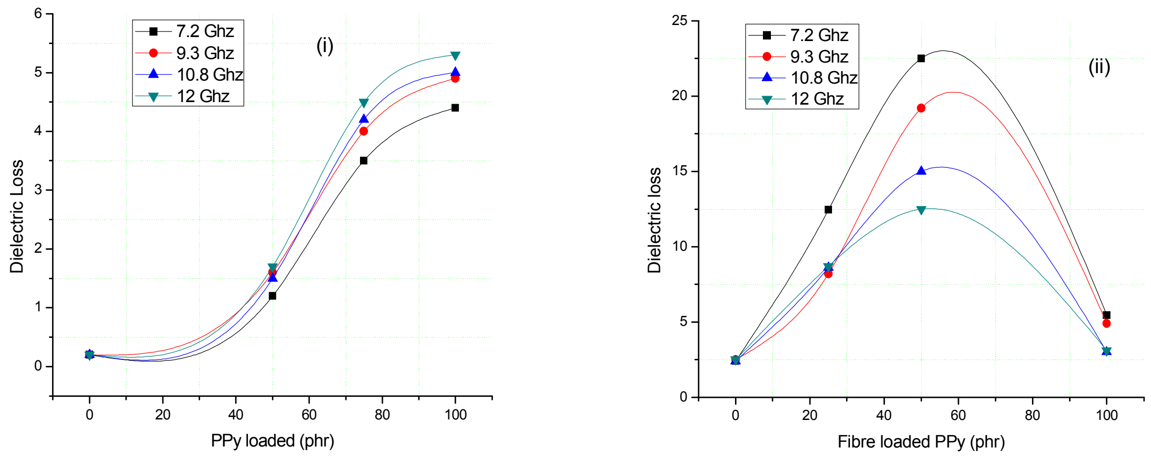

Fig. 3.2. The changes in dielectric loss with loading of (i) BP, (ii) BFp series

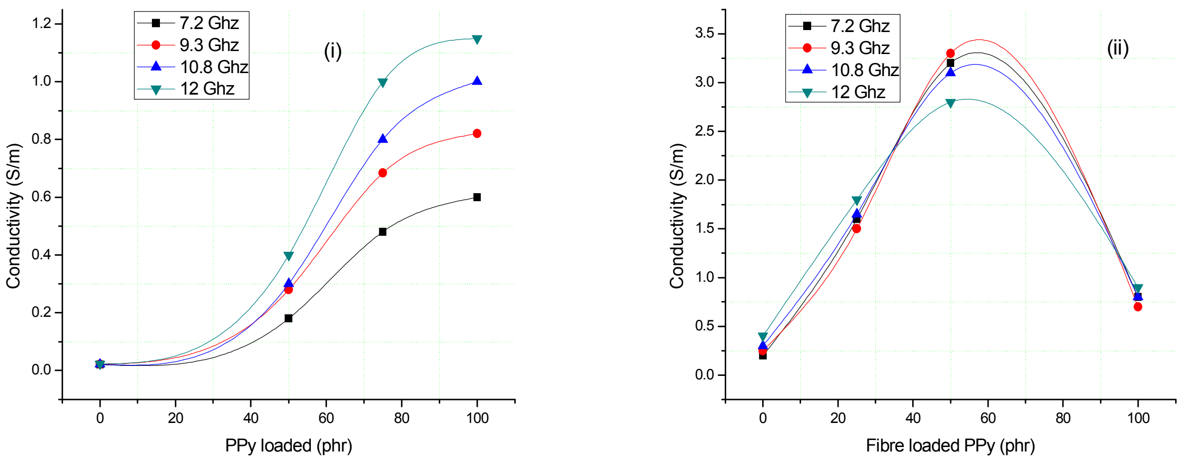

Fig. 3.3. The changes in conductivity with loading of (i) BP, (ii) BFp series

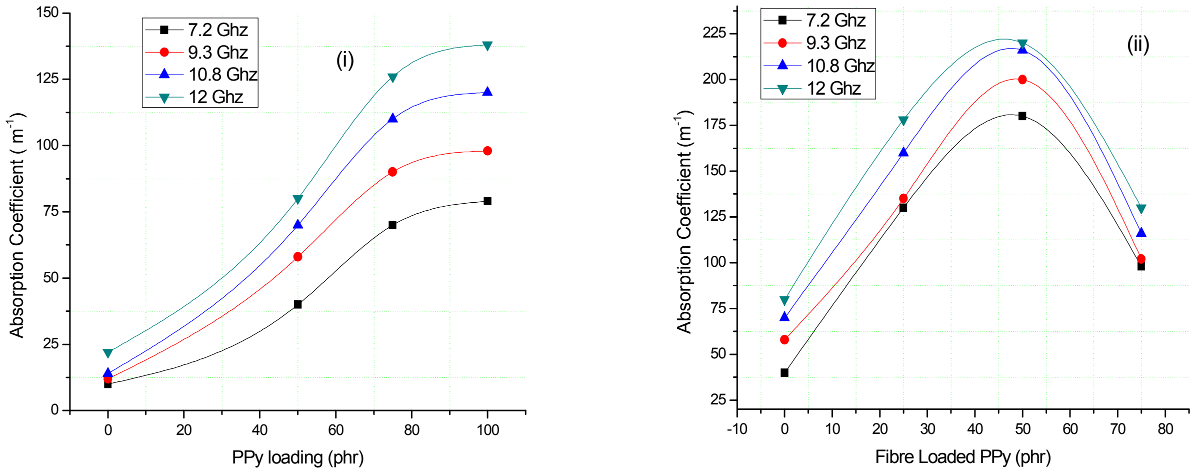

Fig. 3.4. The changes in absorption coefficient with loading of (I) BP, (II) BFp series

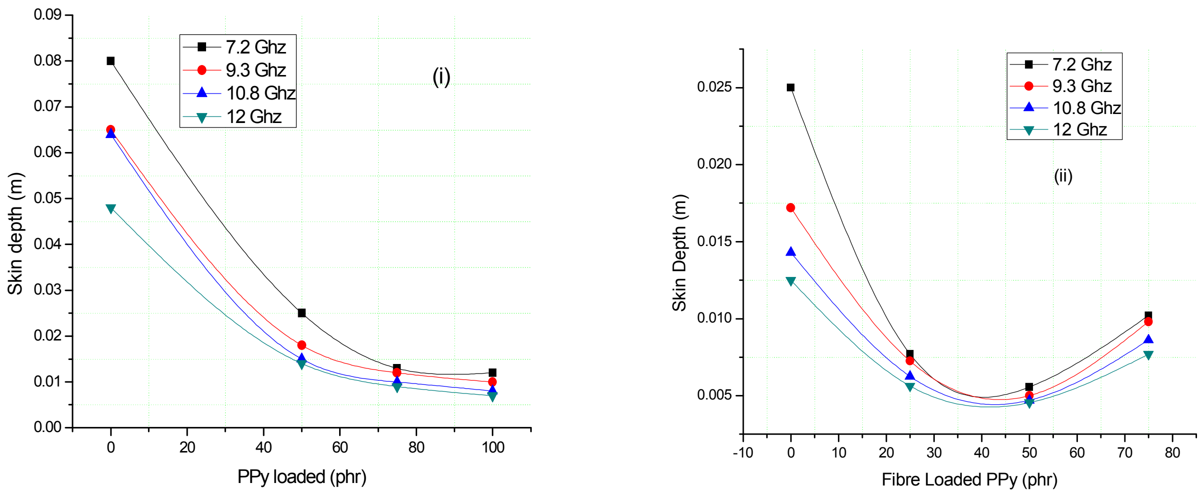

Fig. 3.5. The changes in Skin depth with loading of (i) BP, (ii) BFp series

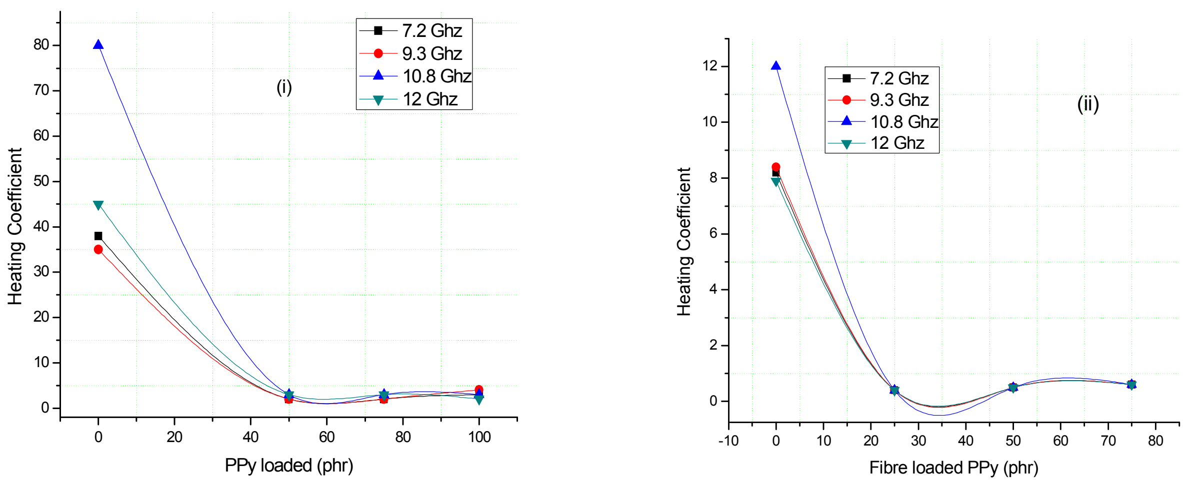

Fig.3.6. The changes in heating coefficient with loading of (I) BP, (II) BFp series.

Absorption Coefficient

Fig. 3.4 shows the changes in Absorption coefficient with frequency and filler loading. This is due to the fact that microwave conductivity and absorption coefficient are direct functions of dielectric loss. It is also evident that there is an increase in absorption coefficient with increase in frequency and also with filler loading. The maximum absorption coefficient value is attained for 50 phr Fibre Loaded PPy composite.

Skin depth

Fig. 3.5 shows the changes in skin depth of BP and BFp series with micro frequency and with loading. It is unambiguous that the skin depth decreases with frequency and also with loading. The lowest value of skin depth is for the 50 phr Fibre Loaded PPy.

Dielectric heating coefficient

From fig. 3.6 it is observed that the heating coefficient decreases with change in frequency and also with filler loading. The heat generated is directly proportional to both frequency and the product of ε and tan δ. Higher the value of J poorer will be the polymer for dielectric heating reason. In the current study J value is found to be the lowest for 50phr Fibre Loaded PPy sample.

Conclusions

Using Two point technique, Microwave dielectric properties at X-band frequencies were studied for elastomer conducting polymer based on NBR Elastane and that prepared by in situ polymerization in NR latex. The prepared conducting polymer gives large values of dielectric constant, AC conductivity and absorption coefficient than the gum vulcanizes. It is also observed that there is a reduction in the values of the dielectric heating coefficient and skin depth for PPY and Fibre loaded PPY significantly. Dielectric Constants 37, 57.5 and 44 are obtained for the composites NRFp5, LNPFp3 and BP3 respectively. The CECs will have appreciable shielding effect depending on loading of PPY and FIBRE LOADED PPY and in turn the conductivity.

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