Tunable optical and dielectric properties of polymeric composite materials based on magnesio-silicate

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Abstract. Magnesio-silicate (MgSi) as an inorganic ion exchange material was synthesized by a precipitation technique. Then, the MgSi was impregnated into polyacrylamide acrylic acid and its composites (Poly) by condensation polymerization. To study the effect of γ -radiation, the polyacrylamide acrylic acid and its MgSi samples were synthesized using γ -irradiating systems at 25, 65 and 90 kGy. The variations in the radiation dose and amorphous structure were altered and confirmed by X-ray diffraction (XRD). Moreover, the absorbance and band-gap energy were enhanced by inserting MgSi into the polymeric composites (Poly). Furthermore, variations in temperature with dielectric constant, dielectric loss and conductivity of the samples at various frequencies from 100, 500, 1000, 2000 to 4000 Hz have been explained.

Keywords. Magnesio-silicate; polymeric composites; dielectric properties; radiation.

1. Introduction

In recent years, polymers have been developed in different fields such as transport, electronic and pharmaceutical industries because of their notable material properties [1,2]. Nowadays, polymers are attracting great interest because of their low cost, low weight, easy processability, high-quality surface, easy fabrication of thick and thin samples, etc. One of the most valuable advantages of polymers is their capacity to inhibit electrical conductivity as insulators, but now they are attracting considerable attention as conducting polymers [3,4]. In addition, useful polymers with controlled refractivity, photochromic, electrochromic and optoelectronic capacities have been produced recently [5–9]. Furthermore, the use of polymers with tunable refractive properties as optical modulators, optical filters or electro-optic waveguide devices have also been reported [10–12].

On the other hand irradiation of polymers has also emerged as a novel way of modifying the polymer properties. Irradiation of polymers alters the structure by cross connecting, free-radical development, irreversible bond cleavages and so forth which results in the discontinuity of atoms and arrangement of immersed and unsaturated groups [13,14]. All these procedures induce defects inside the material that affect its optical, electrical, and mechanical and conduction properties. Changes in optical properties are significant as they can

be used to create optical sensors and light emitting diodes (LEDs) [15–17].

Recently, much work has been done on polymer composites. Starting from the continuous improvement towards the scaling down of electronics to high dielectric steady polymer composites, they have turned out to be promising materials for installed capacitor applications [18–20]. On the other hand, the polymers having low dielectric constants in the scope of 2–5 generally utilized as a part of low leakage capacitors are adaptable, easy to fabricate and result in high dielectric constant [21–23].

In this work, magnesio-silicate (MgSi) as an inorganic ion exchange material was synthesized using a precipitation technique. Then, the polyacrylamide acrylic acid and its MgSi composites were synthesized using γ -radiation for initiating polymerization at radiation doses of 25, 65 and 90 kGy. The prepared composite materials were investigated using different analytical techniques and presented a new ion-exchange characteristic compared to the original ones.

2. Experimental

2.1 Materials

Acrylamide (AM) (C_3H_5NO ; BDH, UK), acrylic acid (AA) ($C_3H_4O_2$; Merck, Germany), acetone ($(CH_3)_2CO$; Aldrich

Figure 1. The possible copolymerization reaction of AM with AA by irradiation to give a molecular structure of cross-linking acrylamide AA copolymers (Poly).

products, Germany), magnesium(II) chloride hexahydrate ($\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$; ADWIC, Egypt) and sodium metasilicate (Na_2SiO_3 ; Avondale, England) were used. All reagents and chemicals used were of analytical grade and used without further purification.

2.2 Synthesis of co-monomer solutions (Poly)

The investigated monomer solutions of AM and AA are prepared by dissolving 10% of each monomer in deoxygenated water. Then, the AM monomer solution is mixed dropwise with aqueous solutions of AA under constant stirring at room temperature. Polyacrylamide AA copolymers (Poly) are prepared as shown in figure 1. The co-monomer solutions were irradiated under different doses of 25, 65 and 90 kGy with a dose rate of 1.05 kGy h^{-1} to obtain Poly 25, Poly 65 and Poly 90, respectively.

2.3 Synthesis of MgSi

MgSi was prepared by dropwise addition of equimolar solutions (0.5 M) of Na_2SiO_3 to $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ with a volumetric ratio of $\text{Mg/Si} = 1:5$ under constant stirring at room temperature. After the addition was complete, diluted ammonia solution was added until a precipitate was obtained and then the reaction mixture was kept undisturbed overnight. The precipitate was washed with 0.1 M HNO_3 to remove Cl^- ions and impurities. Then, the precipitate was washed with dilute water to remove NO_3^- ions. It was filtered and washed several times with deionized water. The precipitate was dried at 50°C and sieved for different mesh sizes and stored at room temperature.

2.4 Synthesis of polymeric composite materials

Polyacrylamide AA MgSi (MgSi Poly) was synthesized by dropwise addition of Poly to equimolar solutions (0.5 M) of MgSi under constant stirring at room temperature. Then, MgSi Poly 25, MgSi Poly 65 and MgSi Poly 90 composites were prepared by subjecting MgSi Poly to γ -radiation at doses 25, 65 and 90 kGy with a dose rate of 1.05 kGy h^{-1} , respectively. After irradiation, the obtained hydrogel was cut into small pieces with stainless-steel scissors, soaked in acetone for removal of unreacted monomers, washed with water, dried at 50°C , grained and sieved for different mesh sizes.

2.5 Physical characterization and measurements

X-ray diffraction (XRD) patterns of the resulting products were recorded by using a Bruker D8-advanced X-ray powder diffractometer with $\text{Cu K}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$). The micrographs of the produced samples were inspected by direct observation via a scanning electron microscope (SEM) (model JSM-5400, JEOL Instrument, Japan). The elemental composition was determined by energy-dispersive X-ray (EDX) analysis. IR spectra were obtained by mixing the solid with KOH in a ratio of 1:5 and ground to a very fine powder. A transparent disc was formed under a moisture-free atmosphere. IR spectra were recorded using a BOMEM FTIR spectrometer in the range of $400\text{--}4000 \text{ cm}^{-1}$. UV-Vis absorption and diffuse reflectance spectra were recorded at room temperature using a UV-VIS-NIR spectrophotometer (Jasco-V-570 spectrophotometer, Japan) fitted with an integrating sphere reflectance unit (ISN) in the wavelength range of $200\text{--}2000 \text{ nm}$. The dielectric and conductivity properties

were measured using a network impedance analyser (HIOKI 3532-50 LCR Hi TESTER) in the frequency range of 1 Hz–5 kHz. The artificial sources of current to produce an electrical potential field were grounded. An electrometer and two probe heads were used for the characterization of the samples.

3. Results and discussion

In this paper, the γ -radiation was utilized for the crosslinking of the AM and AA hydrogels. The scheme of polymerization reaction of AM with AA by γ -beam radiation is shown in figure 1. It can be seen that a mixture of AM with AA was irradiated; a π bond in the twofold obligation of AM with AA was broken and monomer radicals were shaped. These monomer radicals were consolidated together and the AM/AA copolymer was achieved.

3.1 Crystal structure results

The XRD patterns of Poly copolymers at radiation doses of 25, 65 and 90 kGy are shown in figure 2a. From this figure, it can be seen that Poly composites have an amorphous structure and a broad peak in the range of 15° to 30° [24,25]. There is no doubt that the crystallinity of the synthetic samples was affected by the radiation dose. It increased with increasing radiation doses as revealed in figure 2a. However, the sample which was irradiated with 90 kGy has a crystalline structure compared to other samples. These results were similar to the data obtained from the XRD of polyacrylamide-co-acrylic acid prepared by Hassan *et al* [24,26]. The peaks at 2θ 13.8° and 16.8° correspond to the (100) and (020) crystalline peaks of Poly 90. This confirms the partial crystallization of Poly 90 units in the copolymer and the semi-crystalline structure [27].

Also, the addition of MgSi to the radiated copolymer added some features to the new materials. Accordingly, figure 2b reveals the XRD patterns of MgSi Poly 25, MgSi Poly 65 and MgSi Poly 90 composites which have been prepared at radiation doses of 25, 65 and 90 kGy, respectively. It can be found that the different indexed peaks at 30.5, 31.1, 45.3, 55.5 and 75.70° correspond to (031), (131), (231), (321) and (360) in all the MgSi Poly composite patterns (XRD JCPDS data file no. 43-1022) [28,29], indicating that it is enriched with crystalline moieties. The reason for this is attributed to the presence of MgSi composites in the prepared sample. Other peaks appearing at 13.8 and 16.8° are attributed to the presence of acrylamide AA copolymers [30]. Noticeably, the crystalline characteristics of MgSi Poly samples increased with radiation dose from 25 to 90 kGy. This could explain the nature and similar behaviour of the prepared samples at radiation doses of 90 and 65 kGy which are crystalline in nature. The increase of crystallinity of Poly 90 and MgSi Poly 90 in the final stage of irradiation might be due to molecular disintegration and rearrangement within the acrylamide AA copolymers by which copolymer gets exposed and

Figure 2. Powder XRD patterns for (a) Poly 25, 65 and 90 and (b) MgSi Poly 25, 65 and 90 samples.

converted to the amorphous state with prolonged irradiation. The decrease in the crystallinity index is mainly due to the conversion of the crystalline form of acrylamide AA copolymers to the amorphous form.

3.2 Morphology structures

Figure 3 shows the SEM images of all Poly and MgSi Poly composite films. All samples were examined in solid shape as shown in figure 3a–f. It can be seen that the SEM micrographs, in figure 3a and b, appeared wrinkled for the Poly 25 and Poly 65 samples. Figure 3c shows that the surface form of the specimen seems to have a compact morphology with a coarse surface distribution. On the other hand in figure 3d and e, the surface morphology of MgSi Poly 25 and MgSi Poly 65 films appeared uneven and harsh, and some cubic states of various sizes were evident in a specific area. Whereas, figure 3f shows the SEM image of the highest radiation of MgSi Poly 90.

Figure 3. SEM micrographs of (a) Poly 25, (b) Poly 65, (c) Poly 90, (d) MgSi Poly 25, (e) MgSi Poly 65, (f) MgSi Poly 90 samples and (g) EDX analysis of MgSi Poly 25.

The morphology appears blended with small and vast wrinkles connected together with a couple of cubic shapes. Finally, in figure 3g the selected EDX micrograph of MgSi Poly 25 shows clearly distinguishable phases of Mg, Si, O and C, and the resulting relative atomic percentages of different metals at the points are: Si = 45.2%, Mg = 20.3%, O = 15.1%, C = 11.6% and N = 7.7%.

Figure 4. FT-IR spectra of (a) Poly 25, Poly 65 and Poly 90 and (b) MgSi Poly 25, MgSi Poly 65 and MgSi Poly 90 samples.

3.3 Fourier transform infrared spectra

The IR spectra of Poly copolymers prepared at radiation doses of 25, 65 and 90 kGy are presented in figure 4a and table 1. The spectrum of Poly copolymers displays a broadened band at 3255–3500 cm^{-1} due to the stretching vibration both of the hydroxyl groups and water molecules [31–33]. While, the bands appearing at 3090, 2950 and 2870 cm^{-1} may be due to the stretching mode of C–H of AM and AA [34]. The strong band appearing at 1717–1731 cm^{-1} is attributed to the stretching mode of C=O of AA [34]. A strong band appearing at 1549–1563 cm^{-1} is attributed to the bending mode of the N–H bond of AM [35]. Moreover, two bands appearing at 1450 and 1370 cm^{-1} may be attributed to the bending mode of C–H of AM and AA. Two broad bands appeared at 1213 and 1022 cm^{-1} and are attributed to the bending vibration of C–N of AM [36]. On the other hand, the IR spectra of MgSi Poly composites prepared at radiation doses of 25, 65 and 90 kGy are presented in figure 4b. This figure shows that a broad band observed at 3460–3200 cm^{-1} can be attributed to the stretching mode of water and OH groups absorbed on the composites [37]. The bands appearing at 2960–2875 cm^{-1} may be due to the stretching mode of C–H of AM and AA. A weak band appeared at 2245 cm^{-1} due to the stretching mode of the C≡C bond and may be present by rearrangement in the structure [38]. The bands appearing at 1675–1663 cm^{-1} are due to the stretching mode of the C=O group of AA [34]. The band appearing at 1571–1561 cm^{-1} is due to the bending mode of the N–H bond of AM. Two bands appeared at 1315–1413 cm^{-1} and may be attributed to the bending mode of C–H of AM and AA. A band appeared at 1104 cm^{-1} , this band reflects the metal oxygen bond Mg–O [39]. Three bands appeared at 793, 611 and 465 cm^{-1} . The first band may be attributed to Mg–OH deformation vibration or overlapping of the Si–O and Si–OH and Mg–O bonds in the structure [39,40]. The second band may be attributed to the Si–O–Mg bending vibrations [39,40]. The third band may be due to the Si–O–Si bending vibrations, the bands at 1104, 793, 611 and 465 cm^{-1} indicating the impregnation of Mg and Si into the polymeric resin.

3.4 Optical properties

Photoactive materials were extensively characterized as the materials react to light or electromagnetic radiation [41].

Table 1. FT-IR spectral data of Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples.

Sample	$\nu_{\text{H}_2\text{O}}$	$\nu_{\text{O-H}}$	$\nu_{\text{C-H}}$ stretching	$\nu_{\text{C=O}}$	$\nu_{\text{N-H}}$ bending	$\nu_{\text{C-H}}$ bending	$\nu_{\text{M-O}}$	$\nu_{\text{Si-O-Mg}}$	$\nu_{\text{Si-O-Si}}$
Poly 25	3482	3222	3090–2863	1717	1549	1374–1451	—	—	—
Poly 65	3454	3243	3088–2870	1725	1563	1366–1444	—	—	—
Poly 90	3464	3234	3087–2871	1731	1562	1367–1451	—	—	—
MgSi Poly 25	3433	3208	2960–2875	1675	1570	1310–1413	1106	614	467
MgSi Poly 65	3447	3209	2961–2872	1663	1563	1315–1415	1099	613	474
MgSi Poly 90	3440	3209	2963–2874	1665	1561	1316–1420	1105	611	460

Figure 5. (a) and (b) Absorbance, (c) and (d) diffuse reflectance, (e) and (f) optical band gap of Poly 25, Poly 65 and Poly 90, MgSi Poly 25, MgSi Poly 65 and MgSi Poly 90 samples.

In this specific situation, the differences in the structures for Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples were affected by the optical properties of the materials. Figure 5a and b shows the absorbance range for Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples. The absorption onset of Poly 25, 65 and 90; MgSi Poly

25, 65 and 90 samples was recorded at 385, 430, 400, 470, 465 and 430 nm, respectively (table 2). Accordingly, the radiation measurements at 25 give a viable approach to continuously tune the retention ability of MgSi Poly 25 films covering a large area from 380 to 470 nm. For all samples, they demonstrate the band peaks at 300 and

Table 2. Optical properties of Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples.

Sample	Radiation dose (kGy)	Abs. edge	Optical band gap (eV)	Refractive index
Poly 25	25	385	3.2	2.345
Poly 65	65	430	2.9	2.424
Poly 90	90	400	3.1	2.370
MgSi Poly 25	25	470	2.65	2.498
MgSi Poly 65	65	465	2.68	2.489
MgSi Poly 90	90	430	2.87	2.432

520 nm, because of the metal-to-ligand charge-exchange (MLCT) and ligand-to-metal charge exchange (LMCT) progress which were clearly observed, individually [42].

In turn, the presence of an NIR band between 1100 and 2000 nm is attributed to the metal-to-metal charge exchange (MMCT) [43]. The structural properties of composite materials have obviously demonstrated that the NIR was high intensity and relies upon the electronic condition of the radiation dosage. Diffuse reflectance UV–Vis spectra for the samples were additionally recorded to determine the optical band gap (E_g) (figure 5c and d). The optical band gap energy can be estimated from the UV–Vis spectra in the diffuse reflectance mode. Then, the optical absorption coefficient (α/S) was calculated using the reflectance data according to the Kubelka–Munk equation [36,43,44]. A plot of $(\alpha h\nu)^2$ against $h\nu$ (figure 5e and f) was linear confirming the direct band gap energy in composite films. Consequently, the calculated band gap energies for Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples were found to be 3.2, 2.9, 3.1, 2.65, 2.68 and 2.87 eV, respectively. A comparison of these data is presented in table 2. Basically, the optical band gap energy varied with different radiation doses. Obviously, the MgSi Poly 25 was found to have a low band gap energy of 2.65 eV [45]. To analyse the physical properties of the polymers, the calculated values of the refractive index were calculated using the conventional formula. The refractive index shown in table 2 can be calculated by using the following equation [46]:

$$R = \frac{(n-1)^2}{(n+1)^2} \quad (1)$$

The comparison between optical and refractive index properties of Poly 25, 65 and 90, MgSi, MgSi Poly 25, 65 and 90 samples is shown in figure 6.

3.5 Dielectric properties

Frequency and temperature dependence of dielectric constant and dielectric loss of Poly 65 and MgSi 25 samples has been studied in the temperature range 300–600 K at different frequencies of 100, 500, 1000, 2000 and 4000 Hz. The powder was compressed in a stainless dye under five tones to form the disc. The disc dimensions were about 1 cm diameter and

Figure 6. The comparison of optical and refractive index for Poly 25, 65 and 90, MgSi Poly 25, 65 and 90 samples.

1.5 mm thickness. Additionally, the two faces of the disc were polished and coated with a thin layer of conducting silver paste to ensure electrical contact. Figure 7 depicts the variation in fixed frequency for the Poly 65 and MgSi 25 samples as a function of temperature from 300 to ~600°C. The dielectric displacement (D) found in a dielectric material when subjected to an alternating field (E) was given by [47],

$$D = \epsilon^* \times E \quad (2)$$

where ϵ^* is the dielectric constant of the polymer compounds given as follows:

$$\epsilon = \epsilon' + j\epsilon'' \quad (3)$$

For an alternating field, the displacement (D) and electric field (E) were not in phase. Hence, the dielectric constant was a complex quantity involving real (ϵ') and imaginary (ϵ'') parts,

Figure 7. The frequency and temperature dependence of (a) and (b) dielectric constant and (c) and (d) dielectric loss in Poly 65 and MgSi Poly 25 samples.

which were related by a loss factor ($\tan \delta$) as,

$$\tan \delta = \frac{\epsilon'}{\epsilon''} \quad (4)$$

Therefore, the power loss per unit volume of the material is given by

$$P = \omega E^2 \epsilon_0 \epsilon' \tan \delta \quad (5)$$

where symbols have their usual meaning. The frequency and time dependence of the complex dielectric constant (assuming Koop's two-layer model) can be given as,

$$\epsilon^* \left(\frac{\epsilon_0 + \epsilon_\infty - \epsilon_0}{1 + \omega^2 \tau^2} \right) + i \left(\frac{\epsilon_0 - \epsilon_\infty}{1 + \omega^2 \tau^2} \right) \omega \tau \quad (6)$$

Table 3. Dielectric properties of Poly 25, 65 and 90, MgSi, MgSi Poly 25, 65 and 90 samples.

Sample (Hz)	Temp. (K)	Poly 65		Temp. (K)	MgSi Poly 25	
		Dielectric const.	Dielectric loss		Dielectric const.	Dielectric loss
100	613	3.8×10^{-6}	7.0×10^{-7}	530, 453	7.1×10^{-7}	9.0×10^{-7}
500	591	2.1×10^{-7}	1.5×10^{-6}	513, 503	2.1×10^{-7}	9.8×10^{-8}
1000	612	7.5×10^{-8}	7.7×10^{-7}	563, 512	3.4×10^{-9}	2.1×10^{-8}
2000	594	3.0×10^{-8}	3.0×10^{-7}	553, 532	1.3×10^{-9}	2.4×10^{-9}
4000	613	8.1×10^{-8}	3.0×10^{-7}	463, 443	5.7×10^{-9}	5.6×10^{-9}

From equations (3 and 4), we have $\tan \delta = \text{loss current}/\text{charging current}$, and then the Debye equation is given as follows [48]:

$$\tan \delta = \frac{(\epsilon_0 - \epsilon_\infty) \omega \tau}{\epsilon_0 - \epsilon_\infty \omega^2 \tau^2} \quad (7)$$

The ϵ has the highest value and the curve has an inflective point. In this paper, the dielectric properties were demonstrated for the best characteristic samples. From figure 7a, an important observation can be made that the dielectric constant decreases considerably with the increasing of frequency in Poly 65 and MgSi Poly 25 samples. The dielectric constants (ϵ) value of Poly 65 and MgSi Poly 25 at 100 Hz were 3.8×10^{-6} and 7.1×10^{-7} , which can be explained by the polymer having a higher temperature and thus resulting in higher ϵ dielectric constant values. While, the ϵ values of Poly 65 and MgSi Poly 25 at 2000 Hz were 3.0×10^{-8} and 1.3×10^{-9} , respectively. These values were the lowest with increasing the applied frequency as shown in table 3. It is evident from figure 7a and b that dielectric constant values decrease with increasing frequency at various temperatures. It is also evident from these figures that decrease was very prominent at both low frequencies and at high temperatures [49]. The decline of ϵ with increasing frequency was the normal conduct in most dielectric materials. This was because of dielectric relaxation which was the main reason for a typical dispersion. From a basic perspective, the dielectric relaxation includes the orientation polarization which thus relies on the sub-atomic of dielectric to be material. In this way, at higher frequencies, the rotational movement of the polar particles of the dielectric was not adequately fast for the accomplishment of harmony with the field. Subsequently, the dielectric constant in all samples diminishes with increasing frequency [50,51].

On the other hand, figure 7c and d shows the variation of a dielectric loss factor (δ) with frequency at different temperatures for the Poly 65 and MgSi Poly 25 samples. Generally, the $\tan \delta$ decreases with increasing frequency at different temperatures for the Poly 65 and MgSi Poly 25 samples. However, the composite materials revealed an absorbed dampness at the interface. These special characteristics have increased the mobility of the polymer chain and therefore convey the loss peak because T_g has the epoxy-like shape at high-frequency

which has to be identified in our measurement [52]. It can be observed that the dielectric loss factor increased with the temperature, especially at bring down frequency. This resulted in the chain movement of the polymer becoming faster. Also, the glass state has changed the temperature of the polymer. At high frequencies, the dielectric loss was lower and remained consistent with increasing temperature on the grounds. The introduction of polarization because of chain movement of the polymer cannot keep up with the quickly wavering electric field [53,54]. This work alluded to the similitude of dielectric phenomena which have seen in different materials. Moreover, these phenomena can be elucidated as being characteristics of materials that have microstructures containing conducting and dielectric phases. The expansion in relative permittivity ϵ' with the decreasing in estimation frequency was a piece of the 'All-inclusive Dielectric Response' identified by Jonscher [55] as summarized in table 3.

3.6 Conductivity properties

The plots of $\ln \sigma_{ac}$ vs. $1000/T$ at different frequencies are shown in figure 8. The conductivity behaviour for Poly 65 is shown in figure 8a. It was observed that the electrical conductivity has lower values in the range of 34–298°C. As the temperature increases from 298 to 393°C, the electrical conductivity sharply increases to a higher value [56]. On the other hand, figure 8b reveals the characteristic of the MgSi 25 sample. It can be seen that the initial conductivity increases up to 87°C, followed by a moderate increase up to 300°C, and then a final rapid decrease from 300 to 441°C. This behaviour was assigned to the conversion of polymer to metallic MgSi, elimination of organic components from the polymer phase to form the composites of magnesium silicate. Narasimha Rao and Subba [57] reported thermally stimulated discharge currents in the composite polymer as a function of the polarizing field strength and concluded that the Poole–Frenkel model describes the dominant mechanism. Blythe [58] stated that polyamides show pronounced ionic conduction effects at elevated temperatures, evidently as a result of the dissociation of amide groups to give protons [59]. In particular, incorporation of metals into the polymer resulted in great improvement in the electrical conductivity of the composites.

Figure 8. The variation of σ_{ac} vs. $1000/T$ of (a) Poly 65 and (b) MgSi Poly 25 samples.

4. Conclusions

MgSi based on polymeric materials have been successfully prepared *via* γ -irradiating systems with 25, 65 and 90 kGy. The XRD patterns uncovered that they had a specific comparability with some distinction identified with radiation measurement. The optical band gap for these materials revealed the photoactive characteristic as a response to light or electromagnetic radiation. The reduction in temperature with the raise in frequency was because of the introduction of polarization and the expansion in the dielectric loss factor. The raise in temperature was because of a tendency for the development of the dipole chain of the polymer at high temperature. Dielectric loss peaks in the composite materials at high temperature were because of the glass progress temperature of the composite polymer. This research could provide a practical guidance in the manufacturing of electrical conductive polymer composites for desirable applications.

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