Dielectric Properties of Thallium Chloride –Polyvinyl Chloride composites (PVC–TlCl) Films

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Abstract

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polyvinyl chloride (PVC) was synthesized by mixed with different amounts of Thallium Chloride (TlCl) to get composite films. The samples were prepared by adding Thallium Chloride (TlCl) to the poly-vinyl alcohol with weight ratio from (TlCl), which is (0,1,5,10,20,25)wt.%. This work is an investigation of the effect of weight ratio of composite and frequency of the applied field on dielectric properties of polyvinylchloride. Results show that the dielectric constant, impedance, and capacitance decreases with increasing frequency. The dielectric constant, dielectric loss and then increases at increasing weight concentration. The A.C electrical conductivity increases with the increase of the frequency the relationship of capacitance, dielectric constant, loss factor, and dispersion factor with temperature and with concentration were studied.

1- Introduction

Polymer composite, particularly polyvinyl chloride (PVC) based on material, attracted worldwide attention due to its industrial applications and academic interests [1-3].In fact, there are many reports on different PVC based on composites [4-10]. Composites containing two materials with die rent physical properties exhibit often new properties. The composites can provide improved characteristics not obtain able by any of the original components alone and are used in a wide variety of industrial products. Polymer matrix composites are very popular due to their low cost, high strength to weight ratio, noncorrosive and simple fabrication methods. Polymer composites with high dielectric constants are being developed by the electronics industry in response to the need for power–ground decoupling to secure the integrity of high speed signals and to reduce electromagnetic interference (EMI). A Polymer composite with a high dielectric constant significantly reduces the field required to generate high strain with high elastic energy density. the dielectric properties (dielectric constant, dielectric loss, A.C electrical conductivity) very with the compositions of Thallium Chloride. From all the above we investigated the effect of the addition (TlCl) to PVC matrix into the dielectric properties of the composite films. This paper deals to study the effect addition the weight ratio of (TlCl) on dielectric properties of polyvinylchloride with different ranges of frequencies and temperatures.

2–Experimental Work

2–1 materials

The polymeric composite used in this work was a commercial polyvinylchloride PVC (N LICHIDE PVC cement 717-21 heavy duty-clear) from SWAN TRADING (L.L.C), it is solvent borne PVC resin based, single component cement most suitable for pvc pipe joining required for portable water irrigation , natural gas pipe, conduit, drain,…etc

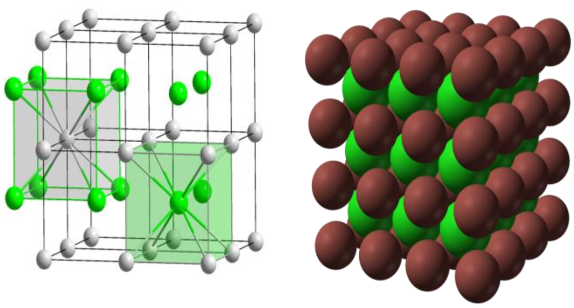
It was also used in the study Thallium (I) chloride (TlCl), as showing in figure (1), Figure a shows thallium chloride powder, while the other parts of figure (1) b and c show the Mono crystalline structure to thallium chloride. It is a white crystalline solid that is found in powder form and is toxic. Its chemical formula is TlCl and its molecular weight is 239.84 g / mol.

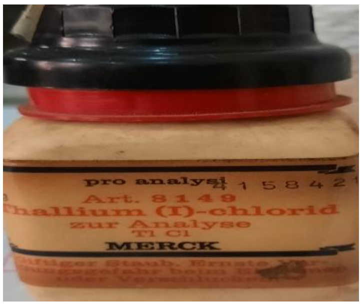
Its melting point is 430 degrees Celsius, its boiling point is 720 degrees Celsius, and its density is 7 grams / cm3.

It is soluble in cold water and increases solubility with heating and does not dissolve in alcohol. It is used as a catalyst in the chlorination process.

The crystalline structure is cubic caesium chloride type at room temperature, but it lowers to the orthorhombic thallium iodide type upon cooling, the transition temperature being likely affected by the impurities. [11] Nanometer-thin TlCl films grown on KBr substrates exhibit a rocksalt structure, while the films deposited on mica or NaCl are of the regular CsCl type. [12]

A very rare mineral lafossaite, Tl (Cl, Br), is a natural form of thallium (I) chloride.





a b c

Figure (1): Thallium(I) chloride, also known as thallous chloride, is a chemical compound with the formula TlCl. Figure a shows thallium chloride powder, while the other parts of figure (1) b and c show the Mono crystalline structure to thallium chloride.

2-2 preparation of the samples

The films' composite (PVC- TlCl) was prepared by mixing Polyvinyl Chloride (PVC) with a powder of Thallium chloride (TlCl). The mixing process was performed using an glass dish and a mixing spatula. while continuing manual mixing until homogeneous composite. Preparation of (PVC-TlCl) composite . Different concentrations (0,1, 5, 10, 20, and 25wt.%) of the synthesized TlCl particles were added to PVC according to the relation

$$(Wt\%)=\frac{W_f}{W_p+W_f}\times \text{١٠٠٪} \qquad ....(1)$$

Where W_f and W_p represent the weights of TlCl and PVC, Respectively.

2-3 measurements

The samples capacitance (c), the quality factor (Q), the loss tangent tanδ, and Impedance (Z) were measured by digital

RLC bridge type (MEGGER B131) at 1kHz. At continues frequencies in range (50− 1MHz). The real dielectric constant was calculated from the following relationship

$\epsilon' = \frac{c}{c_o}$ .... (2)

Where c is the capacitance in the presence of the insulating material, and c_o is Capacitance in air can be expressed as.

$$c_o = \epsilon_o \frac{A}{d}$$

Where ϵ_o is permittivity of the free space (ϵ_o= 8.85 $\times$ ١٠$^{-١٢}$), A the area of the electrodes, and d is the distance between the electrodes. The Imaginary dielectric constant (dielectric loss) is calculated from relationship

$\epsilon'' = \epsilon' \tan\delta$ .... (٣)

A.c. Conductivity ($\sigma_{a.c}$) is calculated according to the relation. $\sigma_{a.c}$=ϵ_owϵ'' .... (4

3−Results and Discussion

3−1 capacitance with frequencies and weight ratio

The variation of capacitance (C) as a function of frequency in the range at(10^2−10^6 HZ) at weight ratios (0,1,5,10,20,25%) of thallium chloride added to the polymer polyvinylchloride (PVC−TlCl) is depicted in figure (2).It is obvious that (c) decreases with increase of frequencies and its increases with increase Weight ratios of (TlCl) in PVC polymer. The increase in capacitance with the weight ratios of the composites (PVC − TlCl) is due to the increase in the density of the surface charge on one of the capacitor plates.

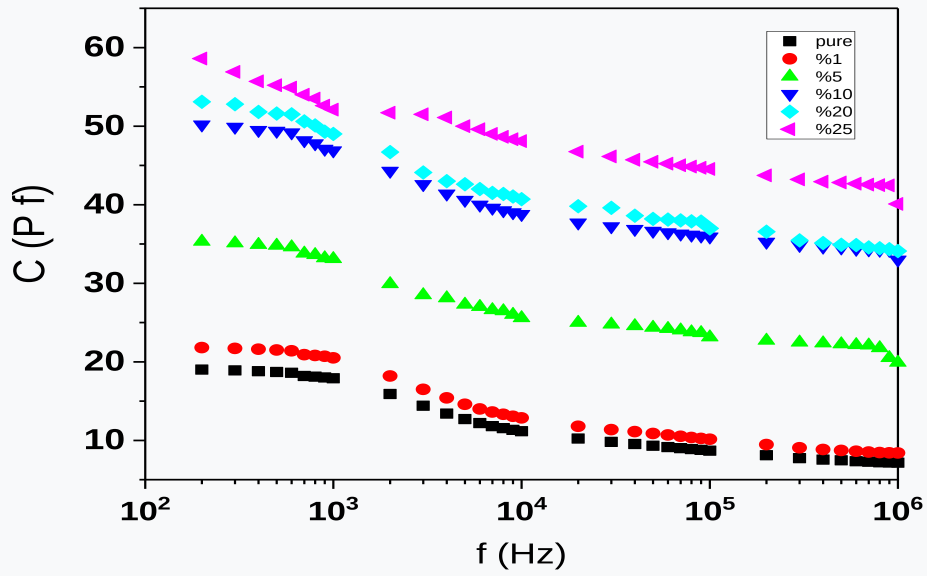


Figure (2): The variation of capacitance (C) as a function of frequency in the range at (10^2–10^6 HZ) at weight ratios (0, 1, 5, 10, 20, and 25%) of (PVC–TlCl).

3-2-1 The real dielectric constant ϵ' with frequencies and weight ratio

The variation of ϵ' and weight ratios of (PVC-TICL) as fiction of frequency in the rang (100Hz-1MHz) are shown in figure (3) and figure (4). The values of the real dielectric constant decrease slightly with increasing frequency, as shown in figure (3). We notice from figure (4) that the real dielectric constant increases at small weight ratios of (PVC-TlCl), this increase decreases at high concentrations greater than 10%.The higher value of ϵ'at lower frequency, is attributed to the process of interfacial polarization and polarization induced by segmental mobility in the polymer which appears more effective at low frequencies and high temperature respectively [13]. At higher frequencies the dipole is responsible for this polarization that cannot keep up orientation in the direction of the alternating field, which leads to a decrease in the ϵ'

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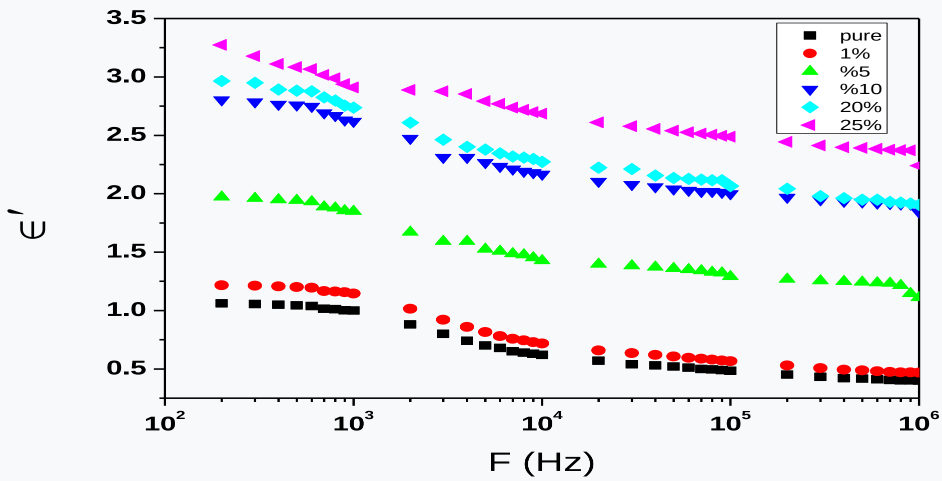


e rang (100Hz–

1MHz), at different weight ratios of (PVC–TICL).

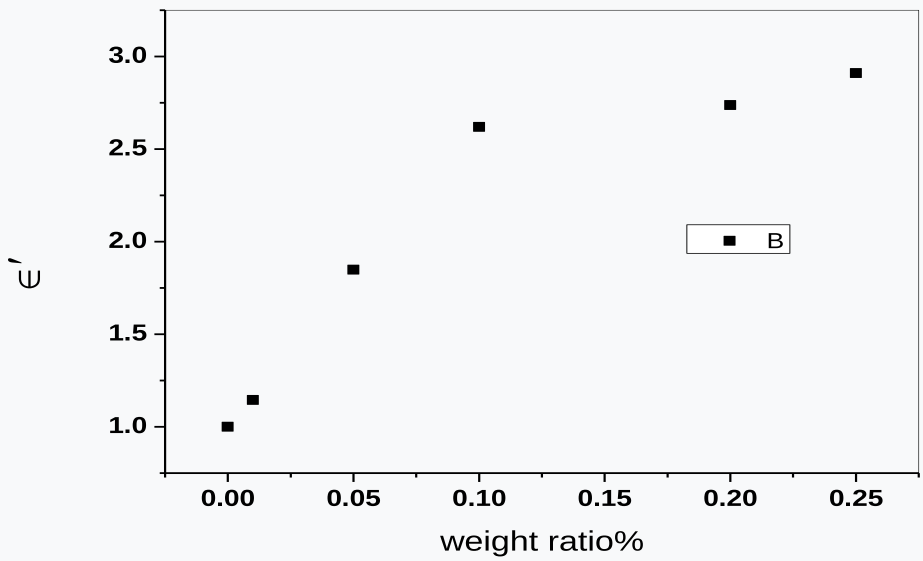
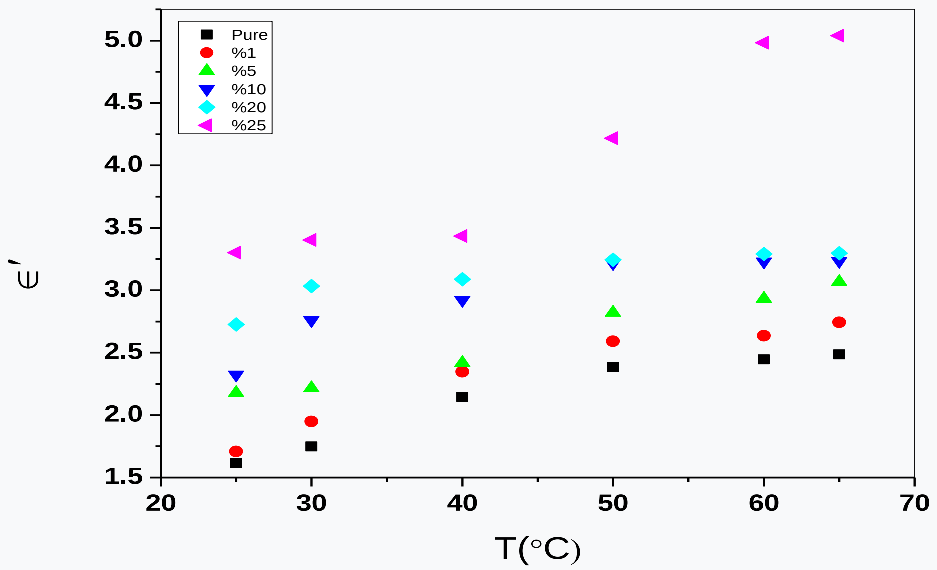


Figure (4): The variation of $\epsilon'$with weight ratios of (PVC–TICL), at a frequency (1kHz).

3-2-1 The real dielectric constant ϵ' with Temperatures and weight ratio

Effect temperature (T) on the real dielectric constant ϵ' and weight ratio of (PVC-TlCl) films shown in the two figures (5 and 6). Figure (5) shows that the change in the real dielectric constant with temperature is very small (quasi constant)., This means that the real dielectric constant has very little effect with increasing the temperature when adding weight ratios of TlCl to polymer (PVC). It appears that the real dielectric constant at high temperatures (65 ^{o}c) of the polymer is more effective at the weight ratio 25%, this temperature is less than the degree of glass transition, as shown in the figure(6). In telecommunications applications, it is preferred that the dielectric constant and the power factor be low, because the loss of power in this area is of great importance and must be controlled. When using the polymer in micro-ray applications, the dielectric constant is preferred to be of a high value.). That is, the real dielectric co



nstanhas very little effect with temperature when adding

Figure (5): The relationship between the real dielectric constant and temperature at different weight ratios of (PVC−TlCl)

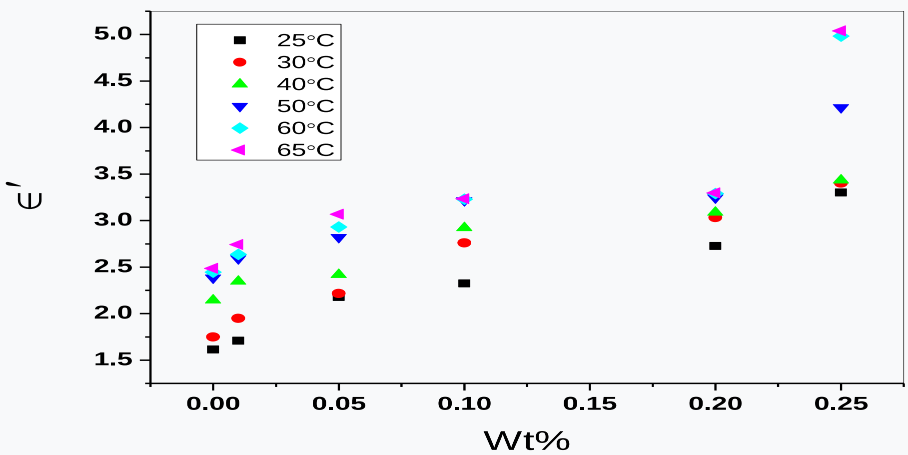


Figure (6): The relationship between the real dielectric constant and weight ratios of (PVC−TlCl) at different temperature

3-3 Dielectric loss Є"

The relationship between Dielectric loss Є" with frequency, temperature, and weight ratios of the polymer (PVC_TlCl) is shown in the figures (7, 8, and 9) We notice from figure (7) that the dielectric loss sharply increases with increasing the frequency to reach its maximum value at the frequency (1300 Hz), then it begins to fall when the frequency increases more than (14000 Hz) and for all weight ratios. The dielectric loss increases at high concentrations of (PVC-TlCl) and at different temperatures (25^{o}c - 65^{o}c) as shown in the figure (8). The behavior of dielectric loss with weight ratios of (PVC-TlCl) at different temperatures in figure (9) is quite similar to the behavior of dielectric loss with temperatures in figure (8). The loss factor is a measure of the heat dissipated energy, while the quality factor represents the quality of the insulator, and it is a measure of electrical charge storage. The change in dielectric loss with the temperature of the polymer is used in the study of relaxation processes in the polymer materials. We note from the figure (8) that the relaxation process is not clear in this polymer due to its complex behavior with temperature.

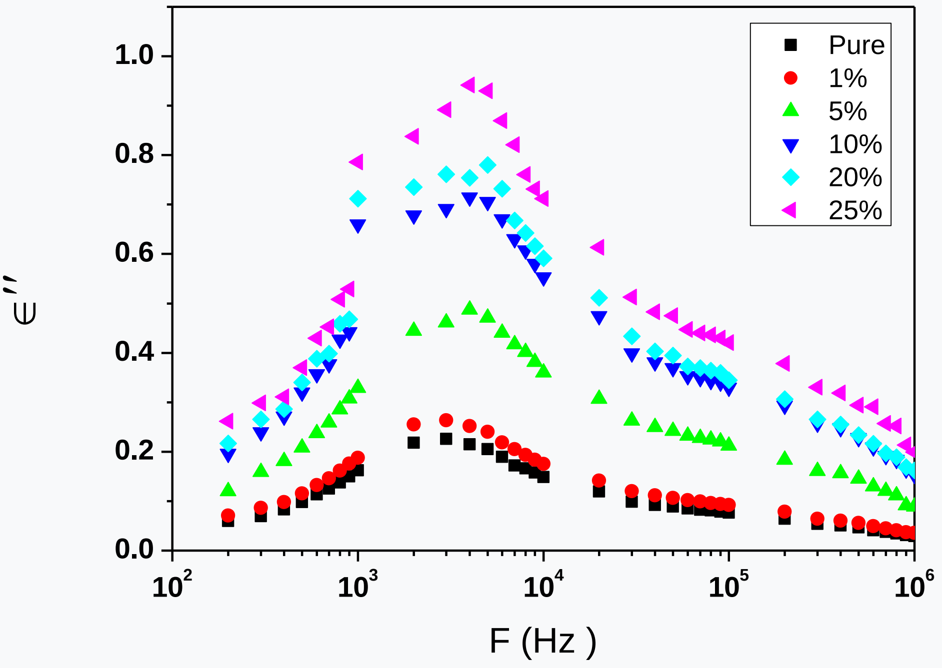


Figure (7): The relationship between Dielectric loss Є" and frequencies of (PVC–TlCl) at different weight ratio (0, 1, 5, 10, 20, 25%).

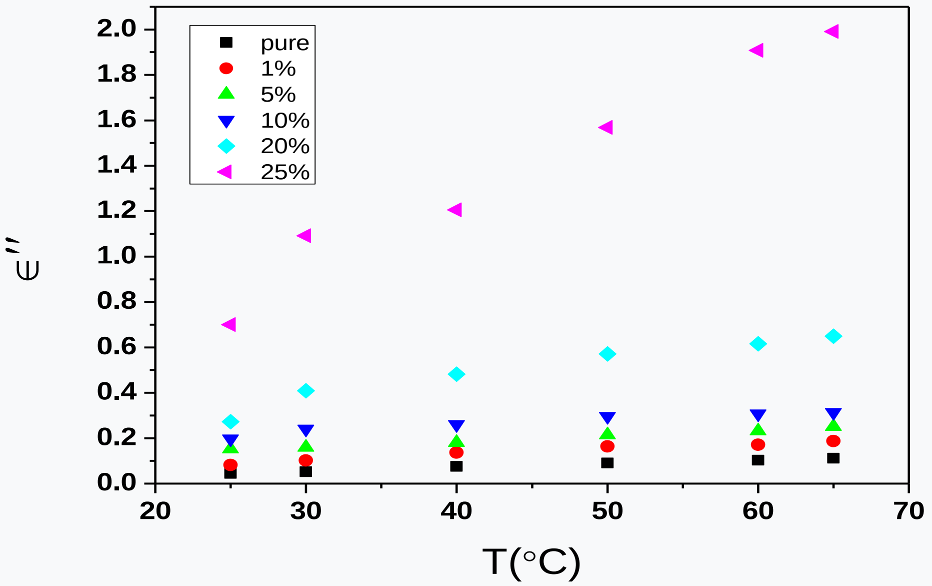


Figure (8): The relationship between Dielectric loss Є" and temperatures (T) of (PVC-TlCl) at different weight ratio (0, 1, 5, 10, 20, 25%).

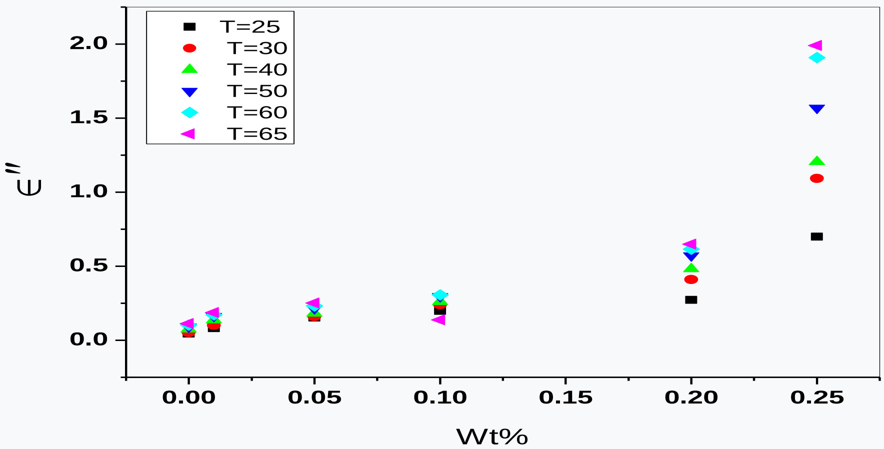


Figure (9): The relationship between Dielectric loss Є" and weight ratio at different temperatures (T)

3-4 A.C conductivity σ_{ac}

The frequency dependence of σ_{ac} conductivity for percent weight ratio of (PVC-TlCl) composite is shown in figure (10).There is almost a gradual exponential increase in a.c conductivity with increased frequency. This is a typical behavior for dielectric material, which may be attributed to the thin layer of the insulating phase (PVC). Which forms boundaries between the particle of composite (TlCl). The Conductivity shows strong frequency dependence at High frequencies,with frequency –variant slope.such dependence may be described by the relation is below[14]

$\sigma(w) = A\, w^s$ ....(5)

Where A is a complex proportionality constant, w is the Angular frequency and the index s is less than unity.This index is not constant, taking small values at low frequencies and high temperatures, and increasing with increasing frequency. At high temperatures the conductivity becomes almost frequency independent over the entire frequency range.

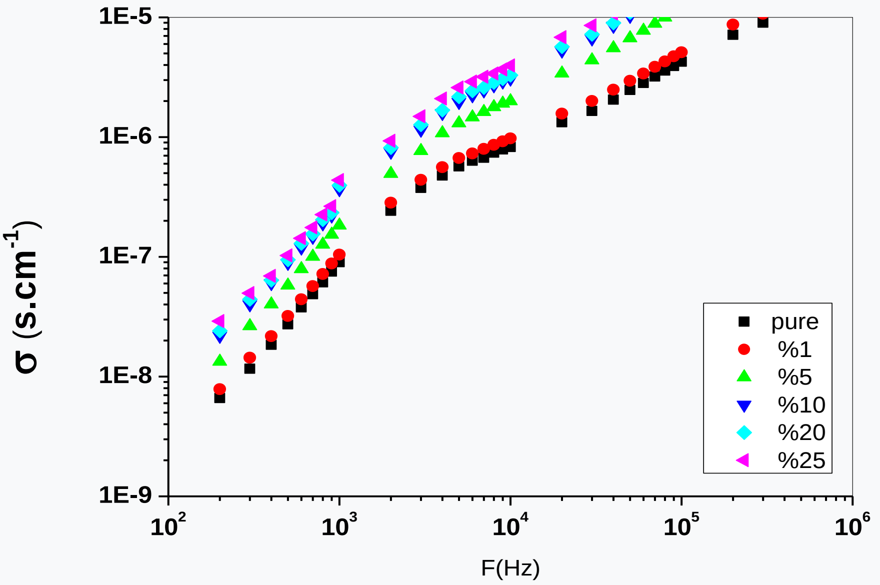


Figure (10): The relationship between σ_{ac} and f of (PVC−TlCl) composite at different weight ratio.

From the equation (5), a figure (11) is drawn, and then from the slope of the figure was calculated s values. Table 1 lists the mean values of the index s in various ranges of frequency and for different weight ratio. A similar frequency dependence of the a.c. conductivity in CuPc and magnesium phthalocyanine (MgPc) thin films has been observed by Vidadi *et al.*[15]. James *et al.* [16] have observed an index of approximately 0.9 in molybdenum phthalocyanine films at room temperature. On the contrary Blagodarov *et al.* [17] have noticed a weak frequency dependence of the a.c. conductivity of metal phthalocyanine thin films that disappeared when a constant voltage was applied across the films. They ascribe such an effect to the domination of a band conduction mechanism in this case. Results by Abdel-Malik *et al.* [18] on pellets of NiPc have shown that σ(w) remains constant at high temperatures throughout most of the frequency range except for a high-frequency region where σ(w) is proportional to w^s At lower temperatures frequency dependence was observed at lower frequencies and the value of s was just below unity.

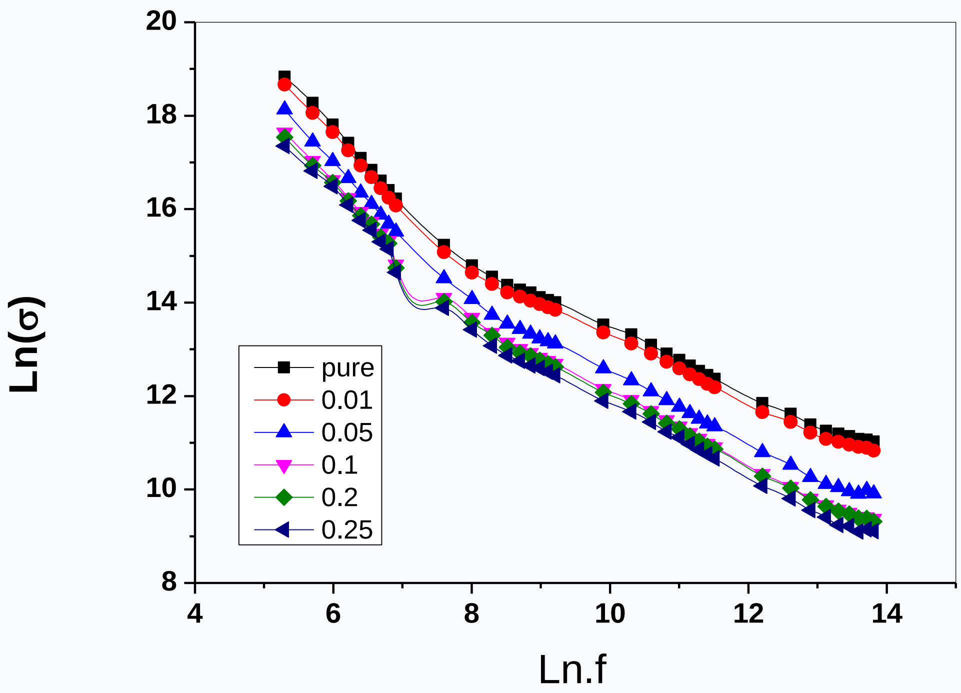


Figure (11): The relationship between Lnf and Ln(σ) of (PVC-TlCl) composite at different weight ratio.

Table (1): Derived values of the index s of (PVC-TlCl) as a function of weight ratio and frequency range.

Figure (12) shows the variation in a.c. conductivity of (PVC−TlCl) films with temperature at different weight ratio. The figure shows that the alternating conductivity at low weight

Weight ratio	**pure**	**1%**	**5%**	**10%**	**20%**	**25%**
Index (−s)	0.8497	0.8524	0.9061	0.9076	0.9134	0.92401
Ln. (A)	19	18.5	18.2	18	17.8	17.5

ratios less than 15% appears almost stable, after which the conductivity increases with temperature at the two weight ratios 20% and (25%). Figure (14) shows the relationship between the a.c conductivity and the weight ratios at different temperatures. From the figure we notice that the AC conductivity begins with a slight increase at low weight ratios, after that it increases sharply when the weight ratios increase This variation in the conductivity may be caused by charge transport through extended energy bands as was suggested by Vidadi et al.[15]. Figure () shows the relationship between the alternating conductivity

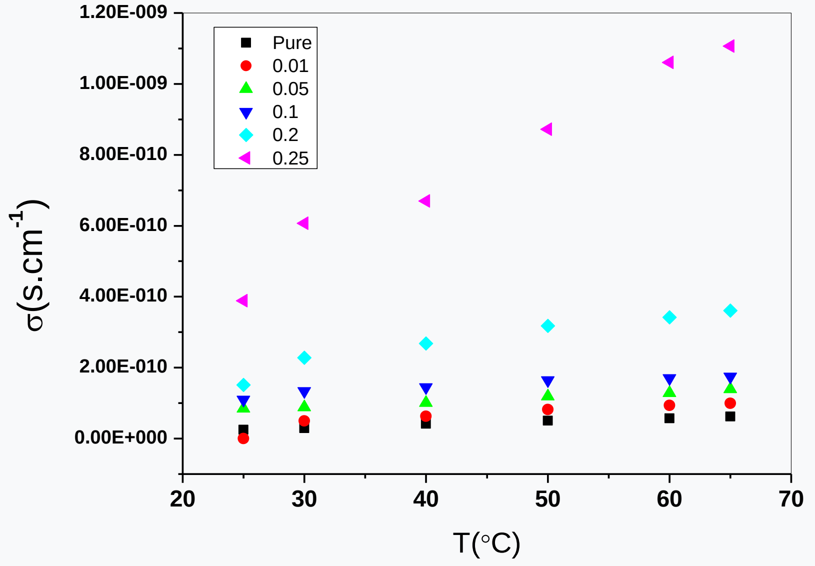


Figure (12): The relationship between σ_{ac} and T of (PVC−TlCl) composite at different weight ratio.

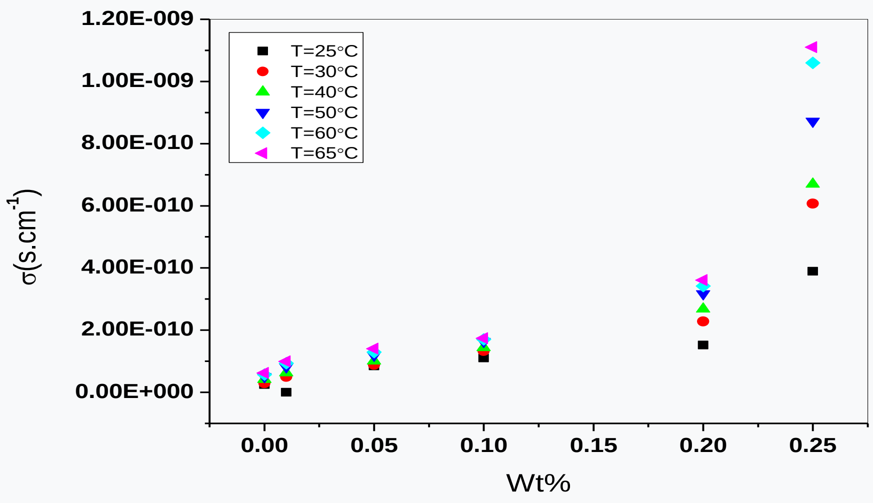
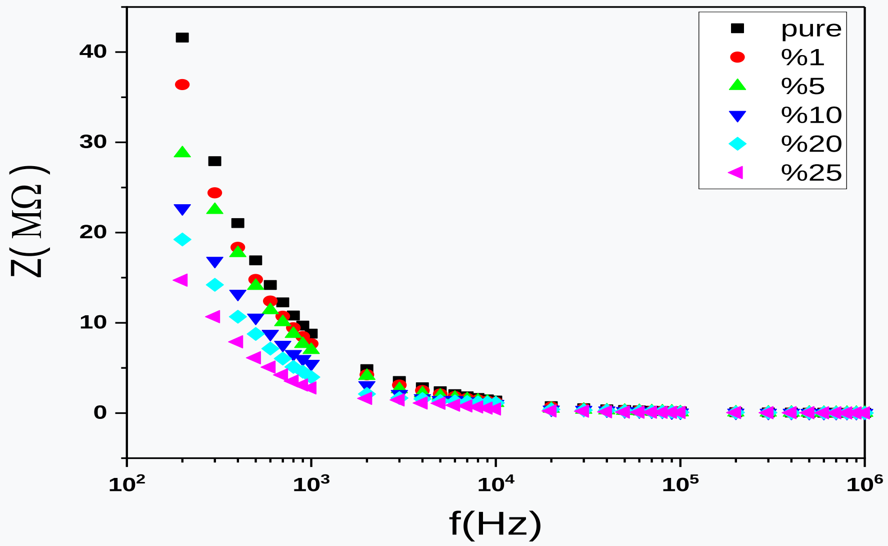


Figure (13): The relationship between σ_{ac} and weight ratio of (PVC−TlCl) composite at different temperature.

3−5−1 Impedance with frequency

Figure (14) shows the change of impedance with frequency at the added weight ratios of the polymer (PVC-TlCl) composite. It is noted from the figure that the impedance decreases almost exponentially with increasing frequency and for all weight ratios as well as the pure polymer. It is evident from the figure (15) that the



impedance in the case of low frequencies decreases rapidly when the weight ratios increase, but in the case of very high frequencies, the values of impedance are stable. The difference of impedance values with the weight ratios at the frequencies shown in figure (15) due to the polar properties possessed by the polymer (PVC) in addition to the polar properties to the weight ratios to thallium chloride(ThCl).

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Figuer (15): The relationship between Impedance Z(MΩ) and frequency (f) at weight ratio of (PVC-TlCl) composite In addition to the pure polymer.

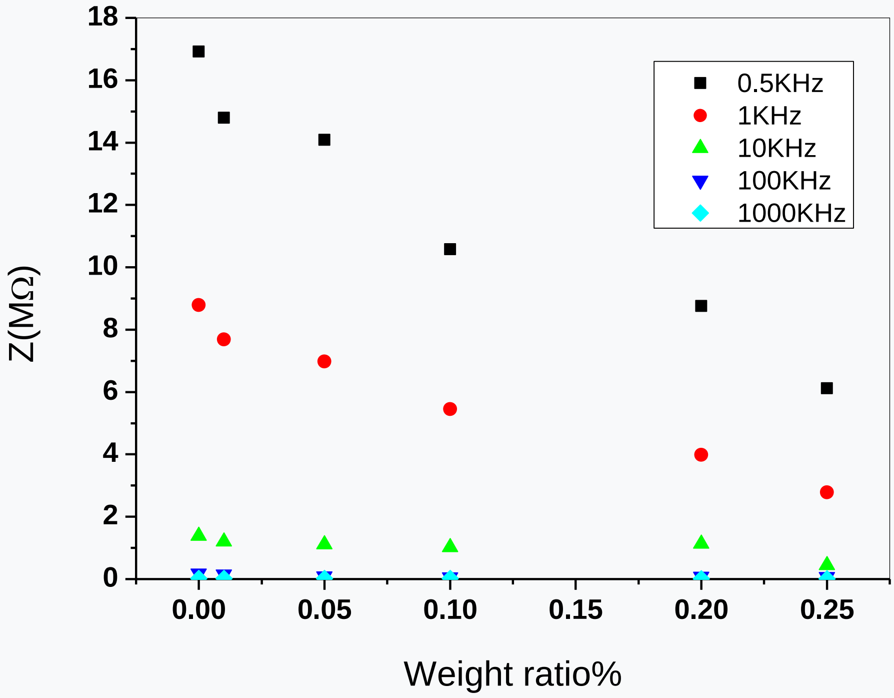

Figure (15): The relationship between Impedance Z(MΩ) and weight ratio of (PVC–TlCl) composite at different frequency (f) .

3-5-2Impedance with temperature

Figure (16) shows the relationship between impedance and temperatures within the range (25-65 °c) at different weight ratios In addition to the pure polymer. We notice from the figure that the values of impedance decrease with increasing temperature for all weight ratios, also, pure polymer including. This is a known characteristic of insulating and semiconducting materials. This behavior is due to the decrease in the values of parallel resistance, which is linked with the impedance of the following relationship.

$$\frac{1}{z} = \frac{1}{R_p} + jwcp \quad \text{.......}(6)$$

Where, (R_p) is the parallel resistance, (C_p) is the parallel amplitude, and (w) the angular frequency

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Figure (15) shows the relationship between impedance and different weight ratios in addition to the pure polymer at the range temperatures (25-65) ^{o}c. This behavior is similar to the previous figure (16), that is, by increasing the weight ratio to the thallium chloride (TlCl), the values of impedance decrease and for all the a degrees of temperature. It is also noted that the impedance has a negative temperature coefficient.

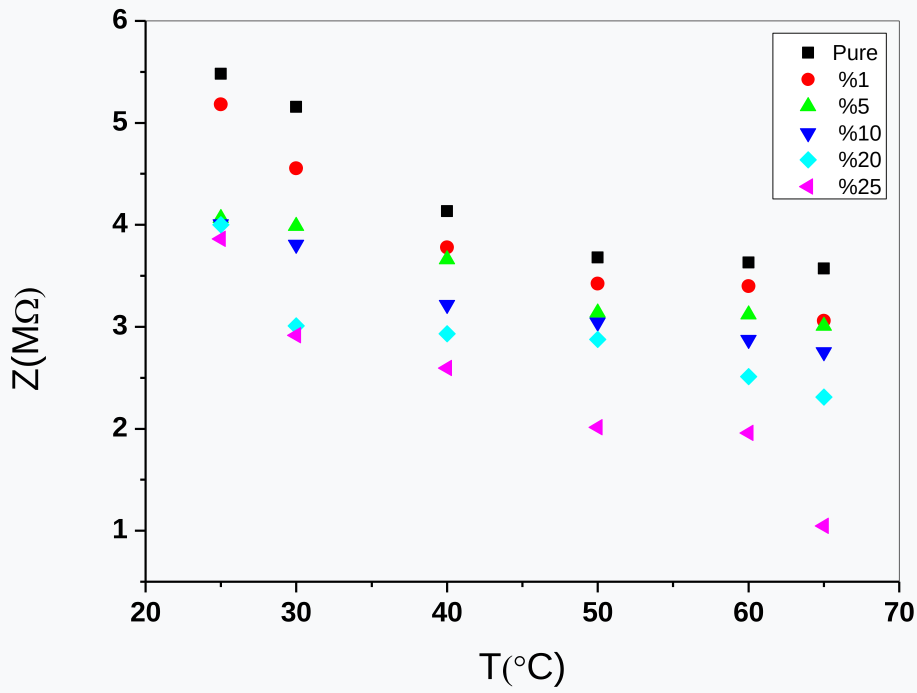

Figure (16): The relationship between Impedance Z(MΩ) and temperature at different weight ratio of (PVC-TlCl) composite.

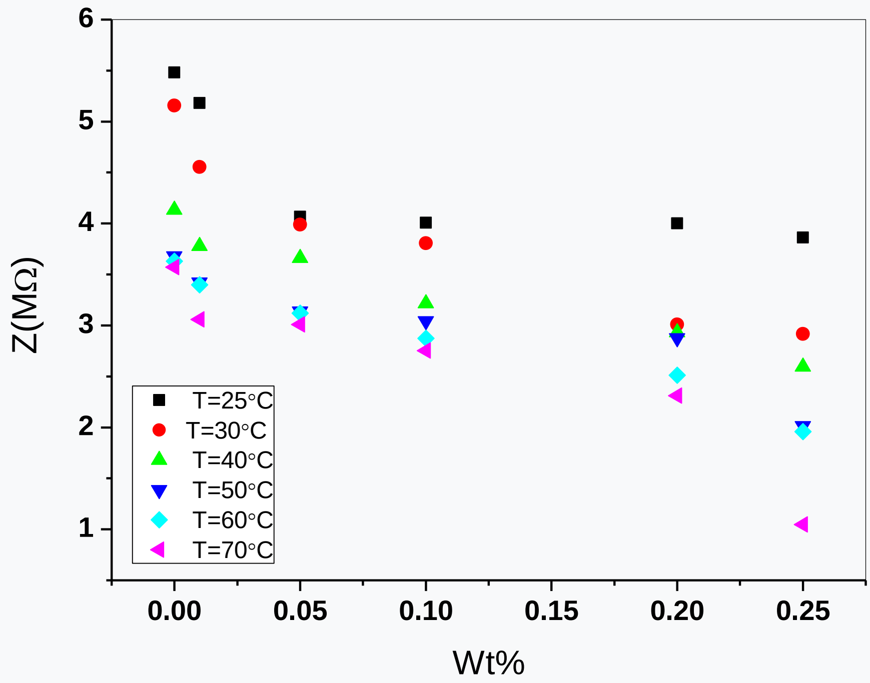

Figure (17): The relationship between Impedance Z(MΩ) and weight ratio of (PVC–TlCl) composite at different temperature.

4–Summary and conclusions

Through the practical results in this study, it was observed that both the capacitance and the dielectric constant decrease with increasing frequency, while the true dielectric constant increases with increasing the weight ratios of the polymer added. There is also a slight increase in the real dielectric constant with temperature and the weight ratios of the polymer. It is evident from the results that the imaginary dielectric constant increases with increasing both temperature and the weight ratios of ThCl of polymer. It has been observed that a.c. conductivity in (PVC–ThCl) films follows a $\sigma(w) \propto (w^s)$ dependence where (s ~< 1). Such behaviour appears to indicate that hopping is the predominant conduction process over the frequency range studied as observed by James *et al.* [16]. At low temperatures and high frequencies the observed values of s approach those predicted by the model of Elliott [19]. The values of impedance are decreased by increasing the frequency and weight ratios resulting from polymer polarization and the ratios of thallium chloride added to the polymer(PVC). The effect of temperature and increasing the weight ratios of (ThCl) make the conductivity values decrease with increasing of both factors.

5-References

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