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Temperature Dependent Dielectric Properties Using Reflectrometric Technique of *Moringa oleifera Lam*.

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Abstract: The use of dielectric properties of agricultural products for sensing moisture in seeds and their powder form and their applications in microwave dielectric heating are discussed briefly. Values of dielectric properties of products in powder form are presented in tables and graphically to show the dependence of these properties on frequency, moisture content, and temperrature. Use of dielectric properties of Moringa oleifera Lam. For moisture measurement has been most prominent agricultural applications for such data. The results show that, there was a systematic increase in dielectric constant (ε') and loss factor (ε") with increasing values of relative packing fraction (δ_r) and decrease in dielectric constant and loss factor with increasing temperature. The moisture percentage measured by Thermo -gravimetric method. Experimental results of different relative packing fractions were further used to obtain transformation to 100% solid bulk using correlation equations of Landau-Lifshitz- Looyenga and Bottcher. The result shows that, there is a fair agreement between experimental values and theoretical values of different dielectric parameters.
Keywords: Dielectric constant, Loss, Relaxation time, Conductivity, Packing fractions, Moisture content, Loss Tangent, Moringa oleifera Lam.

I. INTRODUCTION

Drumstick is scientifically known as *Moringa oleifera Lam*. It belongs to the family *Moringaceae*. It is a small, fast-growing, evergreen tree that grows in tropical regions. It is found in the Himalayan areas of India, Bangladesh, Afghanistan and Pakistan. Every part of the drumstick might contain essential properties for human health; hence, it may be one of the crucial nutritional herbs. For many years, the drumstick has been used as traditional medicine. According to the Ayurvedic system of medicine, drumsticks may have potential use and be helpful for various diseases due to their high nutritional value, water retention and capacity for purification.[1]

A. Nutritional Value of Drumstick

Drumstick provides large and rare varieties of vital minerals and nutrients. Pods, leaves, flowers, barks, roots and seeds of drumsticks also contain bioactive compounds. Nutritional value of raw drumstick pods per 100 grams, Energy 37 Kcal, Protin 2.1gm, Fat 0.2gm, Carbohydrate 8.53gm, Fibre 3.2gm, Calcium 30mg, Iron 0.36mg, Magnesium 45mg, Phosphrous 50mg, Pottasium 461mg, Sodium 42mg, Zinc 0.45mg, Copper 0.084mg, Manganse 0.259mg, Selenium 0.7μg, Vitamin C 141mg, Thiamine 0.053mg, Riboflavin 0.074mg, Vitamin B6-0.12mg, Folate 44μg, Vitamin A-4μg[2].

B. Properties of Drumstick

The major constituents of the drumstick possess biological activities that might play a role in its potential use in several medicinal systems such as Ayurveda, homoeopathy, naturopathy and siddha.[1] The potential properties of drumstick are as follows:
Drumstick used for an anti-oxidant, anti-diabetic (reduces blood glucose levels) and anti-cancer properties. It is also used for anti-asthmatic, help in alleviation of inflammaton, anti-parasitic agent, anti-bacterial, anti-fungal and anti-pyretic (reduces fever) agent properties. It may act as an anti-ulcer (reduces the formation of ulcers) agent anti-spasmodic (relieves muscle spasms) property, an anti-allergic potential. It also help in blood pressure-lowering, kidney stone-reducing, hepato-protective (prevents damage to the liver), cholesterol-lowering, a laxative (manages constipation) and act as a diuretic (promotes urine formation).[1,3]
The dielectric properties or permittivity of sample determine the interaction with electric fields. Dielectric properties have been previously defined and discussed in detail from an electric viewpoint [9] and in terms of electromagnetic field concepts [11]. For practical use, the dielectric properties of usual interest are dielectric constant and the dielectric loss factor, the real and imaginary parts, respectively of the relative complex permittivity, ($\varepsilon = \varepsilon' - j\varepsilon''$).

Where, δ – is the loss angle of the dielectric. In this paper, "Permittivity" is understood to represent the relative complex permittivity, i.e. the permittivity relative to free space or the absolute permittivity divided by permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m. Often the loss tangent $\tan\delta = \frac{\varepsilon''}{\varepsilon'}$ or dissipation factor is also used as a descriptive dielectric parameter and sometimes the power factor ($\tan\delta$) is used. The a c conductivity of dielectric in S/m is $\sigma = \omega\varepsilon_0\varepsilon''$. Where, $\omega = 2\pi f$ is the angular frequency, with frequency in Hertz. The dielectric constant of Diphenyl Sulphone is associated with energy storage capability in the electric field in the material and loss factor is associated with energy dissipation, conversion of electric energy to heat energy in the material. Here, ε'' - is interpreted to include the energy losses in the dielectric due to all operating dielectric relaxation mechanism and ionic conduction.

II. BASIC MICROWAVE INTERACTION

When microwave directed towards the powder in sample form, part of the energy is reflected, part is transmitted through the surface and of this latter quantity part of it is absorbed. The properties of energy, which fall into these three categories, have been defined in terms of dielectric properties. The fundamental electrical property through which the interaction is described the complex relative permittivity of the compound, it is mathematically expressed as,

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \;\text{..........}\; (1)$$

Where, ε' – is dielectric constant,

ε'' – is dielectric loss factor.

The absolute permittivity of a vacuum ε_0 - is determined by,

$$C_0\mu_0\varepsilon_0 = 1 \ldots\ldots \quad (2)$$

Where,

The value of $\varepsilon_o = 8.85 \times 10^{-12}$ F/m. In other media (solid, liquid and gaseous), the permittivity has higher values and is usually expressed relative to the value in vacuum.

To obtain useful information of *Molinga Oriera Lan.* Samples, the physical properties of various kinds of medicinal products, the study of dielectric behaviour from microwave absorption is of great value. The dielectric properties of medicinal products describe interaction [3,7,8,10] with microwave energy and depends on frequency of electromagnetic field as well as on bulk particle properties of the materials such as moisture content, density, temperature, packing fraction and composition. The dielectric heating effect on germination early growth of medicinal, agricultural products, improvement in nutritional quality, stored-grain insect control, drying of grains, sterilization of grains, making medicine etc., is of great importance to know the actual process at molecular level. To get some information, dielectric properties of the sample were determined at various temperature.

III. EXPERIMENTAL METHOD

Dielectric constant (ε') and dielectric loss (ε'') were measured by using reflectometric technique [6,7,13]. Measuring the reflection co-efficient from air dielectric boundary of sample in the microwave X – band at 9.85 GHz frequency at 25, 35°, and 50°C temperature. The following equations were used to determine the dielectric parameters.

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \quad \text{..........} (3)$$

$$\epsilon'' = \frac{1}{\pi}\left(\frac{\lambda_0}{\lambda_d}\right)^2 \alpha_d \beta_d \quad \text{..........} (4)$$

Where,

λ_0 = the wavelength in free space.

λ_c = 2a is cut-off wavelength of the wave guide.

a – is broader dimension of the rectangular wave guide.

αd = is the attenuation introduced by the unit length of the dielectric materials.

$\beta d = 2\pi\lambda_d$ is phase shift introduced by the unit length of the dielectric materials.

λ_d = wavelength in the dielectric powder.

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Figure: Reflectometric Technique Measurement setup.

In order to determine (λ_d) accurately, [15] designed and developed a dielectric cell to hold sample powder so as to introduce it in the cell conveniently and exert equal amount of pressure by the plunger on the powder column in the cell. During present investigation, small quantity of powder sample was introduced in the cell and the plunger was brought over the column. A pressure was allowed to exert by plunger on compound in the dielectric cell. The height of the compound column and the corresponding reflection co-efficient was measured by means of a crystal pick-up in the directional coupler. This process was repeated at every addition of powder sample in the cell. The relationship between reflected power and height of the compound column was approximately given by a damped sinusoidal wave. The distance between two adjacent minima of the curve gave half the dielectric wavelength (λ_d =2L). For the determination of dielectric parameters of sample the conductivity (σ_p) and relaxation time (τ_p) were obtained by using following relations.

$$\sigma_p = \omega \in_0 \in'' \quad .... (5)$$

$$\tau_p = \frac{\in''}{\omega \in'} \quad .... (6)$$

Where,

ω - is angular frequency of measurement (9.85 GHz).

ε_o - is permittivity of free space.

For low loss materials, dielectric constant (Є′) and loss factor (Є″) for bulk materials can be correlated with their compound form by the relations derived independently by Landau-Lifshitz and Looyenga.

$$\in'_S = \frac{\left[\left(3\delta + 2\in'_p - 2\right)\in'_p\right]}{\left(3\delta - 1\right)\in'_p + 1} \quad .... \quad (7)$$

$$\in''_S = \left(\frac{\in''_P}{\delta_r}\right)\left(\frac{\in'_S}{\in'_P}\right)^{2/3} \; for \frac{\in''}{\in'} << 1 \quad ...... \quad (8)$$

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Where,
Є′s – is the dielectric constant for the material in bulk,
Є′p – is the dielectric constant of powder sample at relative packing fraction (δr).
Є″s and Є″p – are the dielectric losses for solid and powder respectively.
These experiment results have been verified with values obtained from Bottcher's equation[20].

$$\in'_S = \frac{(2\in'_P + 3\delta - 2)\{(3\delta - 1)(\in'^2_P + \in''^2_P) + \in'_P - 2\in''^2_P\}}{(3\delta - 1)^2(\in'^2_P + \in''^2_P) + 2\in'_P(3\delta - 1) + 1}$$

…………… [10]

$$\in''_S = \frac{2(3\delta - 1)(\in''^3_P + \in'^2_P \in''_P) + \in''_P(3\delta - 2) + 4\in'_P\in''_P}{(3\delta - 1)^2(\in'^2_P + \in''^2_P) + 2\in'_P(3\delta - 1) + 1}$$

…………. (11)

IV. RESULTS AND DISCUSSION

Dielectric constant (ε') , and dielectric loss (ε") of sample are given in table. The values of (ε'_p) and (ε''_p) obtained experimentally for different temperature showed that, there is simultaneous increase in dielectric constant (ε') and loss factor (ε") with increasing temperature.

This was expected, because with higher values of relative packing fraction (δr) the inter particle hindrance offered to the dipolar motion for a compact medium will be much higher than for less bounded particles. Such observations have been already made by other workers [3,4,11,14] for higher values of packing fraction.

On examination of values of relaxation time (τ_p) loss tangent (tanδ) conductivity (σ_p) and different temperature revealed that there was increase in σ_p, τ_p and tanδ with the increasing values of packing fraction (δr). There was systematic decrease in σ_p, τ_p and tanδ, with increasing values of temperature.

Such behaviour is expected because when polar molecules are very large, the rotator motion of the molecules is not sufficiently rapid for the attainment of equilibrium with the field.

The increase in conductivity therefore suggests that at higher compactions, no micro cracks are developed in the sample due to high mechanical pressure. The decrease in relaxation time (τ_p) with increasing temperature may be due to increase in the effective length of dipole. In addition, due to increasing temperature, number of collisions increases causes increase in energy loss and thereby decreasing relaxation time.

Table shows measured and computed values of dielectric parameters for bulk from sample in powder measurements. The results reported at δr = 1 are those measured on the finest crushed powder sample packed very closely in a wave-guide cell pressing it under a fixed pressure, so as to obtain minimum voids between the particles. The samples having minimum particle size is defined as finest which is about 0.70μm.

In this case, we assumed it as solid bulk for getting correlation between compound and solid bulk. The correlation formulae were used to find other value for (δr >1). The bulk values obtained for (ε') and (ε") are same to the measured values and those calculated from [10], are closer to the values calculated from [5] formulae. The values of packing density increase linearly with the values of dielectric constant, dielectric loss and conductivity increases. There was a simultaneous decrease of dielectric constant, dielectric loss and conductivity with increase in the temperature.

V. CONCLUSIONS

It was thus, found that experimentally measured values of (ε') and (ε") at (δr = 1) are similar to those calculated from Landau-Lifshitz-Looyenga formulae. There was agreement between the values obtained experimentally and calculated theoretically by using Bottcher's formulae. The correlation formulae of Landau-Lifshitz-Looyenga and Bottcher can be used to provide accurate estimate of (ε') and (ε") of compound materials at known bulk densities. It may be thus, predicted that the used sample is having cohesion in its particles and serve as a continuous medium.

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Table Shows Measured and calculated values of dielectric constant (Є'$_s$), and dielectric loss (Є"$_s$) for bulk from powder at different temperatures and packing fraction (δ_r)

Temp °C	Relative Packing fraction (δr)	Є's For solid bulk			Є"s For solid bulk		
		Measured	Calculated From Bottcher's formula	Calculated From Landu, et al formula	Measured	Calculated From Bottcher's formula	Calculated From Landu, et al formula
20°C	0.8746		2.907	2.881		0.326	0.320
	0.9558		2.838	2.795		0.373	0.371
	1.00	3.285	3.189	3.11	0.862	0.762	0.662
35°C	0.8736		2.861	2.839		0.302	0.297
	0.9568		2.803	2.773		0.355	0.363
	1.00	3.126	3.023	2.971	0.749	0.449	0.459
50°C	0.8746		2.805	2.790		0.203	0.279
	0.9547		2.753	2.726		0.324	0.332
	1.00	3.022	2.906	2.995	0.659	0.317	0.346

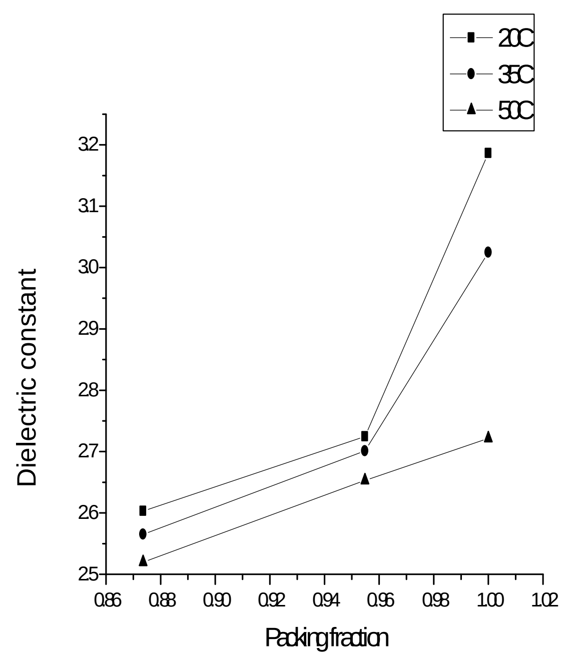

Fig.1: Packing fraction Vs Dielectric constant

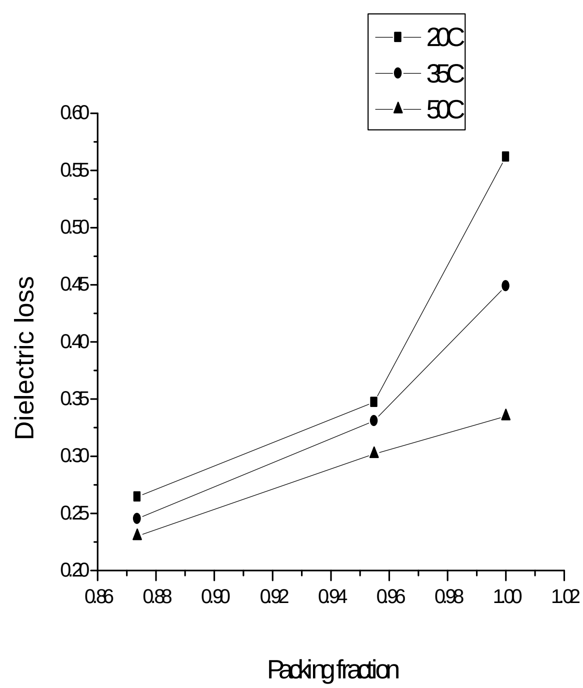

Fig.2 : Packing fraction Vs Dielectric loss

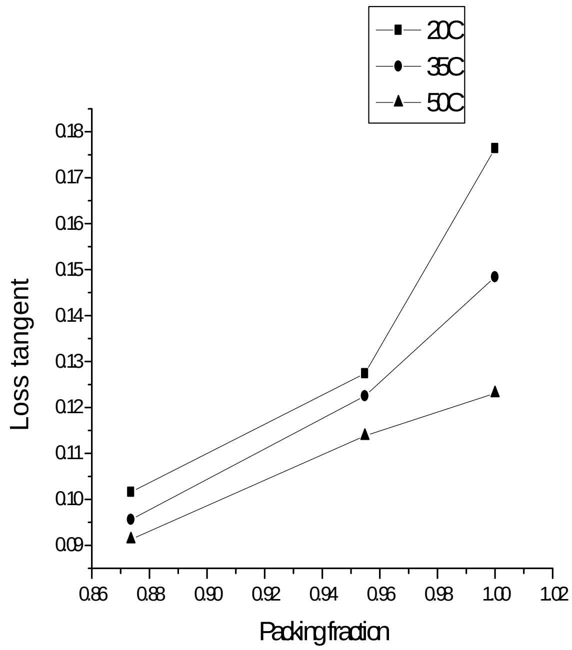

Fig.3 : Packing fraction Vs Loss tangent

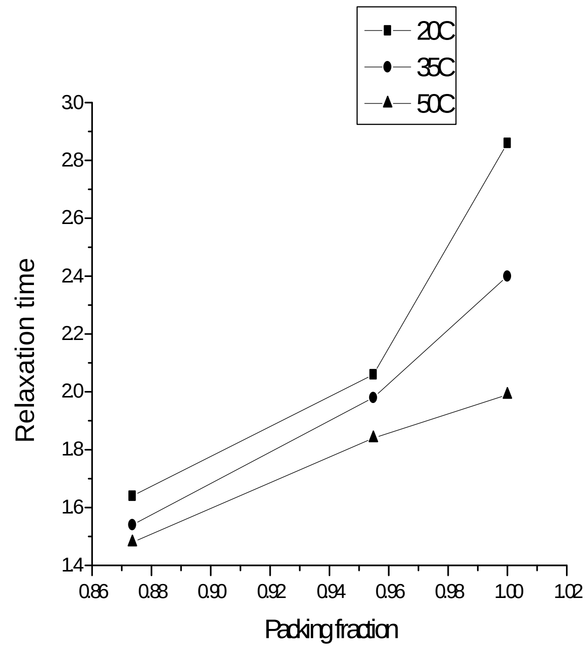

Fig.4 : Packing fraction Vs Relaxation time

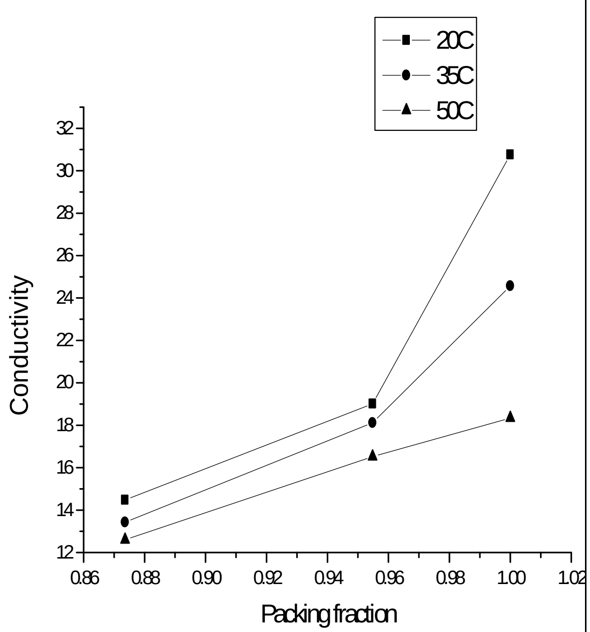

Fig.5 : Packing fraction Vs Conductivity

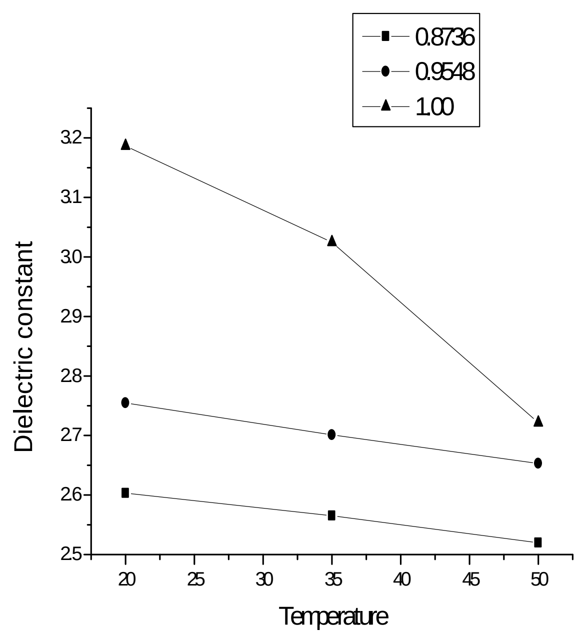

Fig.6 : Temperature Vs Dielectric constant

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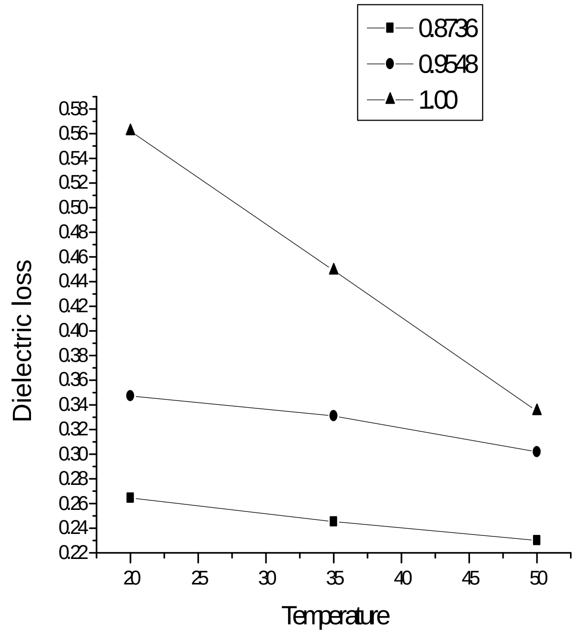

Fig.7 : Temperature Vs Dielectric loss

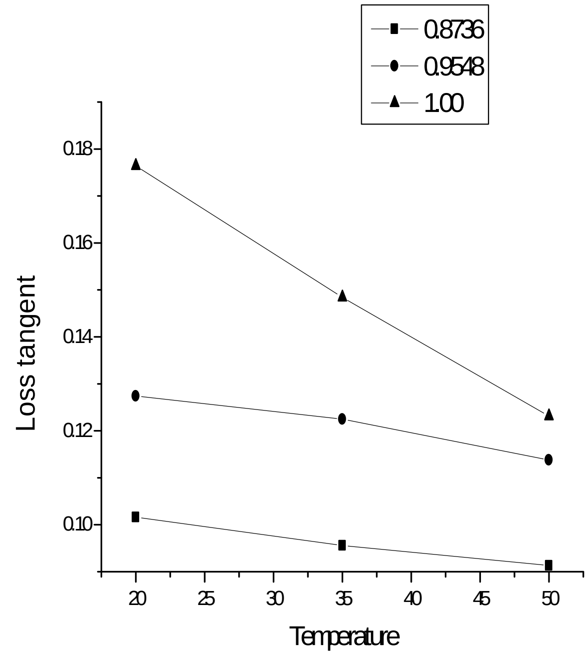

Fig.8: Temperature Vs Loss tangent

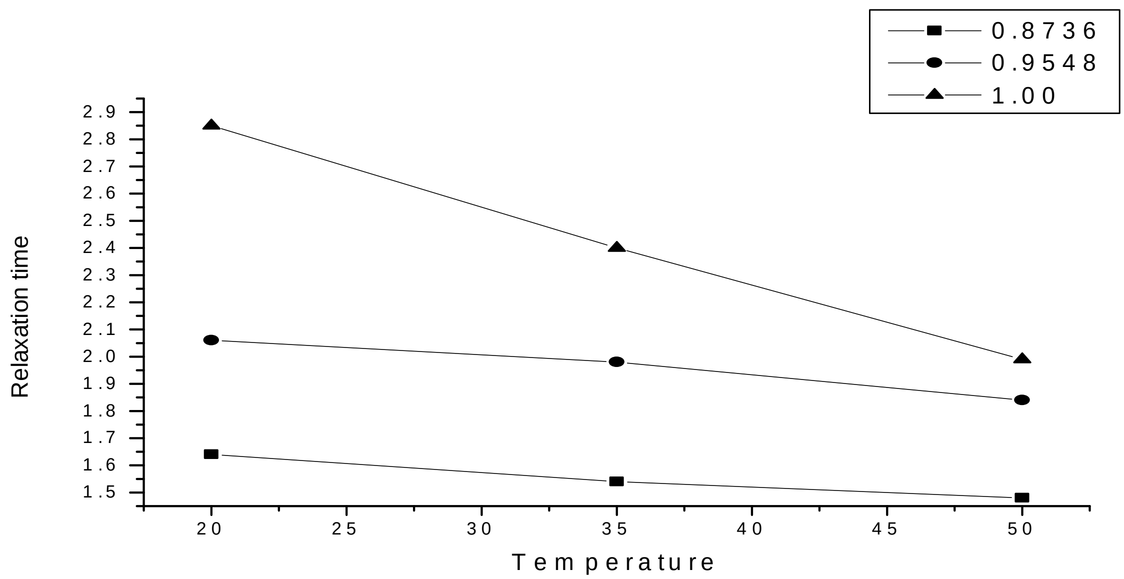

Fig.9 : Temperature Vs Relaxation time

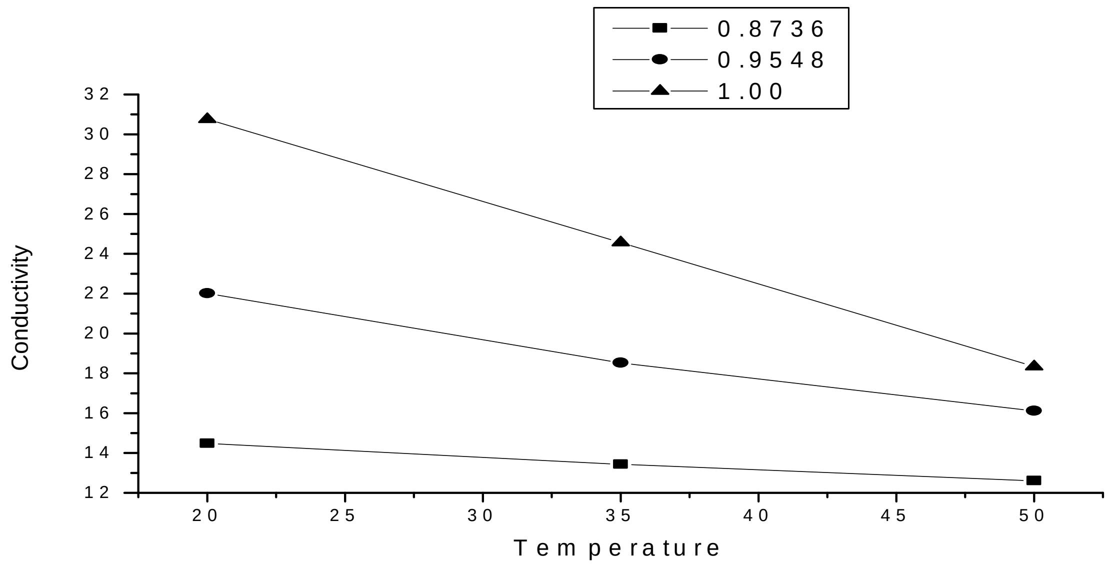

Fig.10 : Temperature Vs Conductivity

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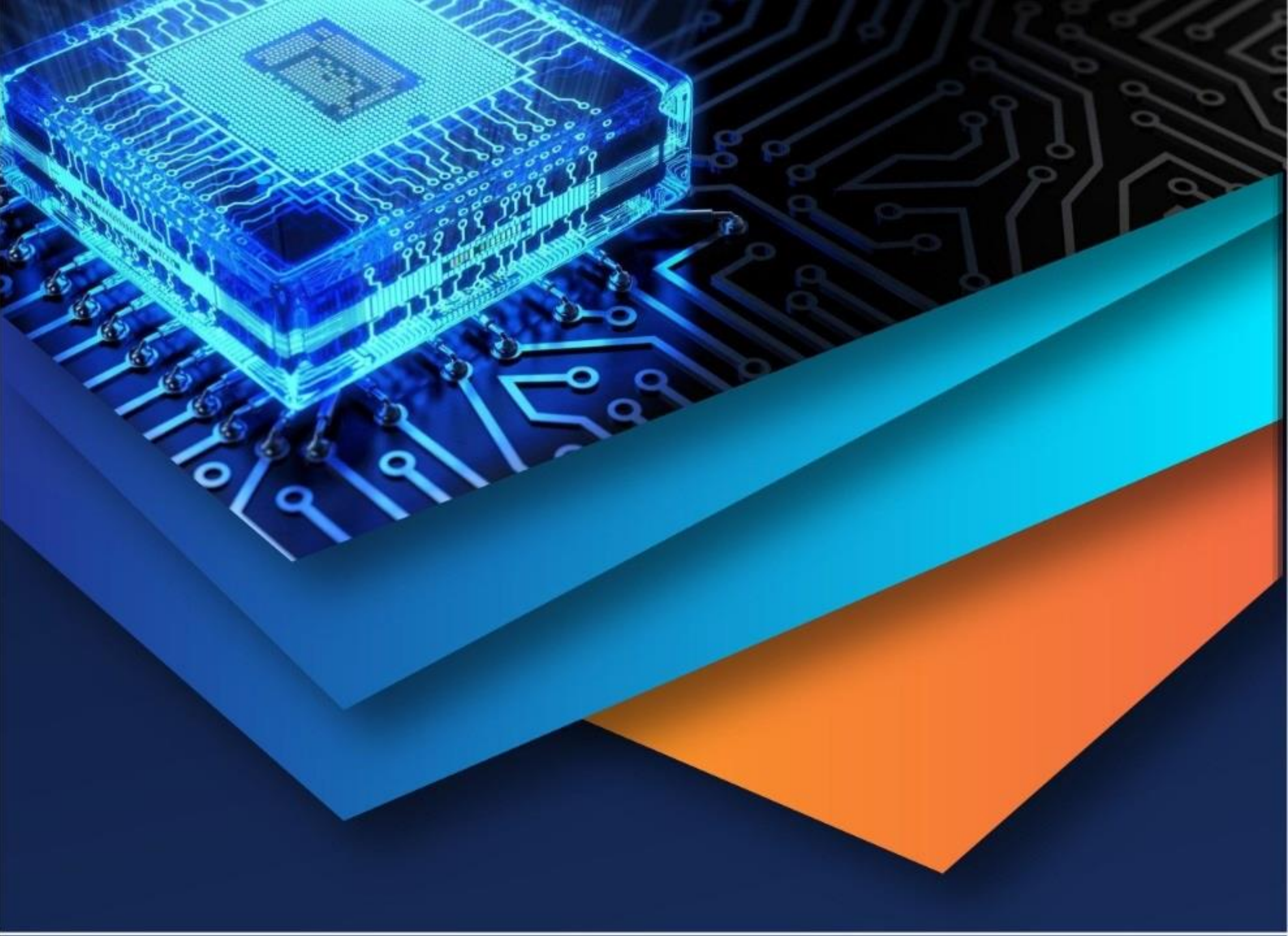

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