Temperature Dependence Dielectric Properties of $DPSO_2$ At X – Band Frequency.

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Abstract:

The effect of various temperature on dielectric parameters such as dielectric constant (ε'), dielectric loss (ε"), loss tangent (tanδ), relaxation time (τ_p), conductivity (σ_p) for Diphenyl sulphone was assessed. 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. 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. There is a fair agreement between experimental values and theoretical values of different dielectric parameters.

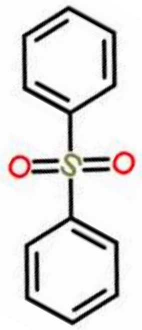
Key Words: Dielectric constant, Dielectric Loss, Relaxation time, Conductivity, DPSO2.

Introduction:

The dielectric properties or permittivity of compound $DPSO_2$ determine the interaction with electric fields. Dielectric properties have been previously defined and discussed in detail from an electric viewpoint [7] and in terms of electromagnetic field concepts [9]. 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 tanδ $= \frac{\varepsilon''}{\varepsilon'}$ or dissipation factor is also used as a descriptive dielectric parameter and sometimes the power factor (tanδ) 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.

Diphenyl sulfone is an organosulfur compound with the formula $(C_6H_5)_2SO_2$. It is a white solid that is soluble in organic solvents. It is used as a high temperature solvent. Such high temperature solvents are useful for processing highly rigid polymers, which only dissolve in very hot solvents. Melting point of Diphenyl sulphone is 123°C and boiling point is 379 °C.

Chemical structure of DPSO2:



Basic Microwave Interaction: -

When microwave directed towards a $DPSO_2$ compound in powder 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,

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

Where, The value of $\varepsilon_o = 8.85*10^{-12}$ 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 on chemical compound 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 [1,5,6,8] 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 Diphenyl sulphone were determined at various temperature.

Experimental Details:

Dielectric constant (ε') and dielectric loss (ε") were measured by using reflectometric technique [4,5,11]. Measuring the reflection co-efficient from air dielectric boundary of sample in the microwave X – band at 9.85 GHz frequency at 15º, 25, 35º, 45, 50, and 60ºC temperature. The following equations were used to determine the dielectric parameters.

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

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

Where, $\lambda_0 =$ the wavelength in free space.

$\lambda_c = 2a$ 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.

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

λ_d = wavelength in the dielectric powder.

X – band set up for measurement.

In order to determine (λ_d) accurately, [13] 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 DPSO4 compound 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 $DPSO_2$ 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 $DPSO_2$, the conductivity (σ_p) and relaxation time (τ_p) were obtained by using following relations.

$$\sigma_p = \omega \in_0 \in'' \text{........ (5)}$$

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

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.

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

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

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].

$$\in'_S = \frac{\left(2\in'_P + 3\delta - 2\right)\left\{\left(3\delta - 1\right)\left(\in'^2_P + \in''^2_P\right) + \in'_P - 2\in''^2_P\right\}}{\left(3\delta - 1\right)^2\left(\in'^2_P + \in''^2_P\right) + 2\in'_P\left(3\delta - 1\right) + 1} \quad \ldots\ldots\ldots\ldots\ldots \quad [10]$$

$$\in''_S = \frac{2\left(3\delta - 1\right)\left(\in''^3_P + \in'^2_P\in''_P\right) + \in''_P\left(3\delta - 2\right) + 4\in'_P\in''_P}{\left(3\delta - 1\right)^2\left(\in'^2_P + \in''^2_P\right) + 2\in'_P\left(3\delta - 1\right) + 1} \quad \ldots\ldots\ldots\ldots \quad (11)$$

Results and Discussion: -

Dielectric constant (ε') , and dielectric loss (ε") of $DPSO_2$ are given in table -1. 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 [1,2,9,12] for higher values of packing fraction.

On examination of values of relaxation time (τ_p) loss tangent ($\tan\delta$) conductivity (σ_p) and different temperature revealed that there was increase in σ_p, τ_p and $\tan\delta$ with the increasing values of packing fraction (δr). There was systematic decrease in σ_p, τ_p and $\tan\delta$, 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 -2 shows measured and computed values of dielectric parameters for bulk from compound powder measurements. The results reported at $\delta r = 1$ are those measured on the finest crushed $DPSO_2$ 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 ($\delta r > 1$). The bulk values obtained for (ε') and (ε'') are same to the measured values and those calculated from [8], are closer to the values calculated from [3] 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.

Conclusion: -

It was thus, found that experimentally measured values of (ε') and (ε'') at ($\delta r = 1$) 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 $DPSO_2$ compound is having cohesion in its particles and serve as a continuous medium.

Table -1

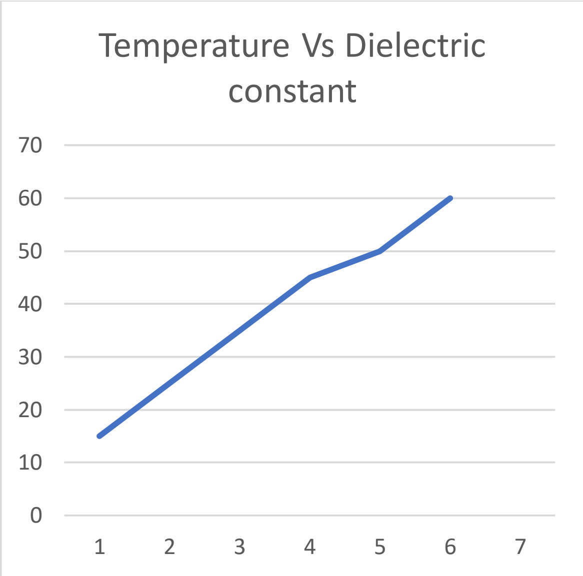
Values of dielectric constant ($Є'_p$), dielectric loss ($Є''_p$), loss tangent (tanδ), relaxation time (τ_p), conductivity (σ_p) of $DPSO_2$ at different temperatures.

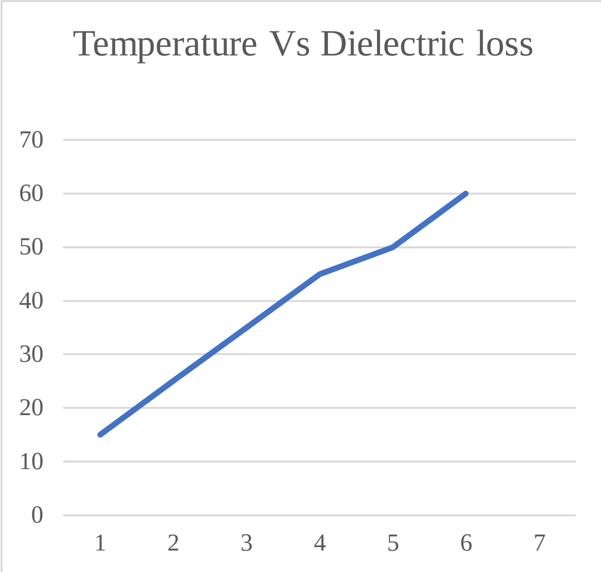
Temp ˚C	**Dielectric constant** (ε')	**Dielectric loss** (ε")	**Loss tangent**	**Relaxation Time** **(10^{-12})**	**Conductivity** **(10^{-2})**
15	2.461	0.037	0.015	0.244	2.06
25	2.555	0.006	0.002	0.039	0.33
35	2.774	0.116	0.042	0.677	6.35
45	2.298	0.062	0.027	0.436	3.39
50	2.386	0.042	0.017	0.286	2.30
60	2.418	0.006	0.002	0.042	0.34

Table -2

Measured and calculated values of dielectric constant (Є'$_s$), and dielectric loss (Є"$_p$) for bulk from DPSO$_2$ at different temperature.

Temp ˚C	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
45	2.299	2.299	2.298	0.062	0.062	3.39
50	2.386	2.384	2.390	0.042	0.042	2.30
60	2.418	2.418	2.421	0.006	0.006	0.34


Temperature Vs Dielectric constant
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7


Temperature Vs Dielectric loss
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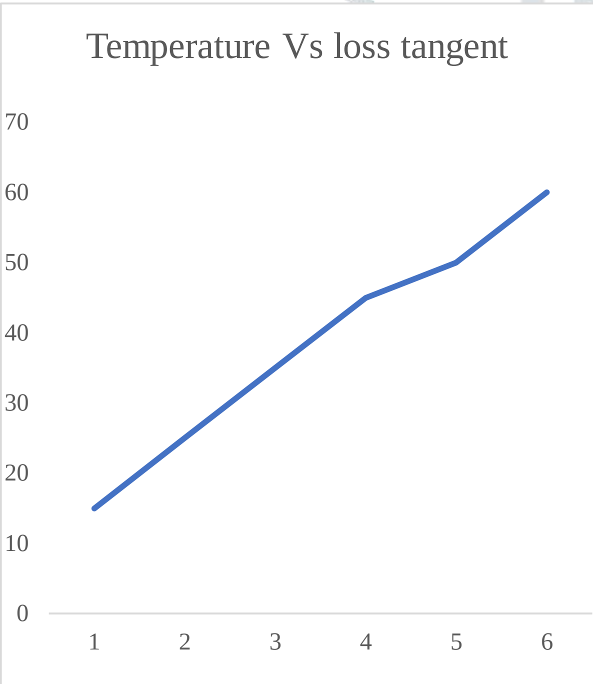
60
50
40
30
20
10
0
1 2 3 4 5 6 7


Temperature Vs loss tangent
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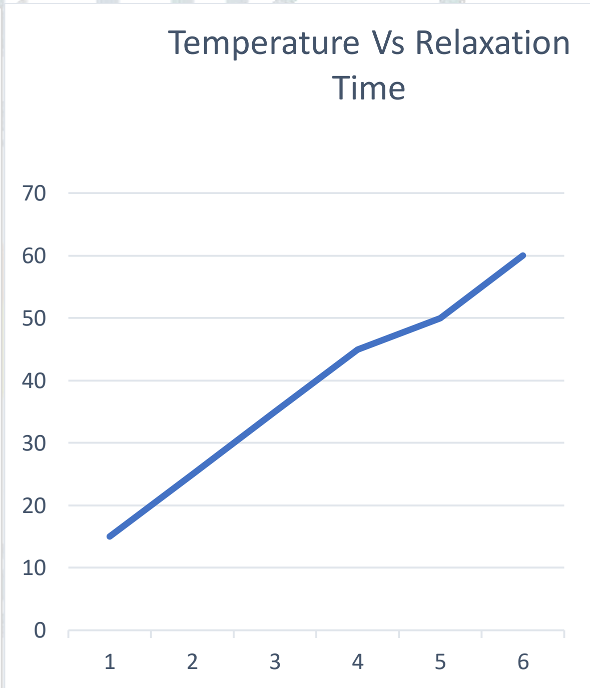
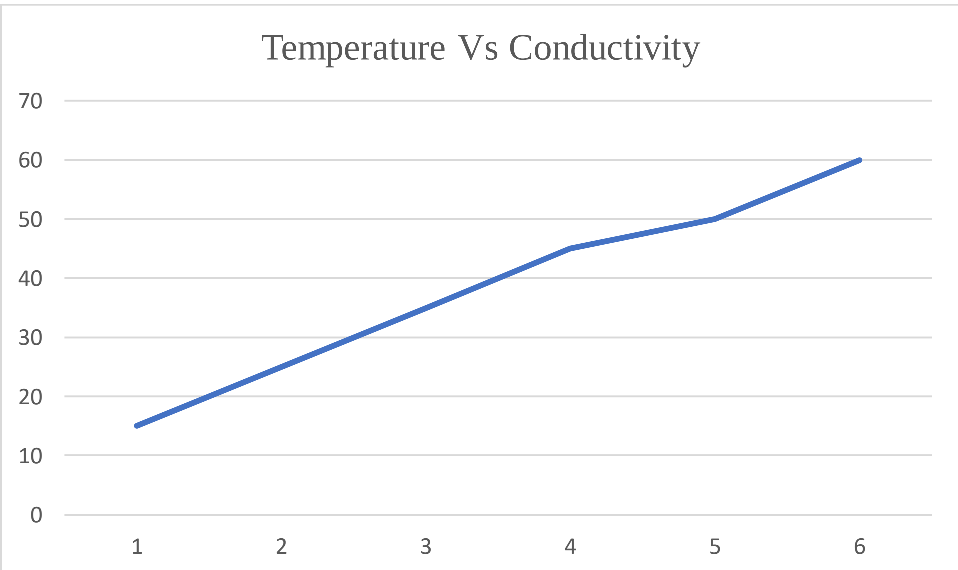
60
50
40
30
20
10
0
1 2 3 4 5 6


Temperature Vs Relaxation Time
70
60
50
40
30
20
10
0
1 2 3 4 5 6


Temperature Vs Conductivity
70
60
50
40
30
20
10
0
1 2 3 4 5 6

REFERENCES:

1 Bansal, A. K., Singh, P.J. and Sharma, K. S. (2001) *Indian Journal of Pure and Applied Physics* **39**: 799.

2 Bhatnagar, D., Gandhi, J. M. and Yadav, J. S. (1996) *Indian Journal of Physics* ***70A (4);*** 539.

3 Bottcher, C. J. F. (1952) "*Theory of dielectric polarization*." Elsevier publication, Amsterdam.

4 Chelkowski, A. (1980) "*Dielectric Physics*". Elsevier publication, Amsterdam.

5 Gandhi, J. M. Jangid, R. A., Neeru, Bhatnagar, D. and Jangid, R. A (1996) *Indian Journal of Pure and Applied Physics* **34**; 316.

6 Kraszewski, A. and Nelson, S. O. (1993) *Journal of Microwave Power and Electromagnetic Energy* **28(3)**; 165.

7 Kraszewski, A. and Nelson, S. O. (1994) *Journal of Agricultural Engineering Research* **58**; 37.

8 Landau, L.D. and Lifshitz, E. M. (1960) "*Electrodynamics of continuous media*". Pergamon press, London. pp-46**.**

9 Nelson, S.O. (1992) *IEEE Transaction on Instrumentation and Measurement.* **41(1***):* 116.

10 Peter, H. (1997) "*Dielectric spectroscopy of polymers".* Adam Hilger Ltd, Bristol.

11 Sisodia, M. L. and Raghuvanshi, G. S. (1990).

"*Basic microwave techniques and Laboratory Manual"* Willey Eastern Ltd, New Delhi.

12 Gandhi, J. M. and Yadav, J. S. (1992) *Indian Journal of Pure and Applied Physics* **30**; 427.

13 Kalamse, V. G. and Kalamse, G. M. (2007) *Lab Experiments.* **(30-38)**, pp-35.