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DIELECTRIC STUDIES OF OIL CAKES AT MICROWAVE FREQUENCIES

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The complex dielectric constant and loss tangent of the deoiled cakes of *Sesamum indicum, Eruca sativa, Brassica juncea* and cakes of coconut meat of *Coccos nucifera* have been determined at 9.44 GHz. The measurements were taken on the uniform films by mounting the specimen longitudinally along the symmetry axis of a rectangular waveguide, the electric field being in the plane of the film. The fields were excited in the TE_{10} mode. The results have been interpreted in terms of absorption and percentage of fatty acids in the different oil cakes.

Key Words : Cholesterol; Dielectric Constant; Fatty Acids; oil Cakes.

Introduction

Knowledge of the dielectric properties of the films at microwave frequencies is helpful in material characterization for device fabrication and various other applications. The conventional transmission and cavity resonance methods of dielectric measurement due to Roberts and Von Hippel[1], Von Hippel[2], Chelkowski[3] and Dube and Prasad[4] are difficult to use for thin samples because in that case the r-f signal has a weak interaction with the specimen. However, such measurements may be conveniently made at microwave frequencies by mounting a thin film of the specimen longitudinally at the centre of a rectangular waveguide, as proposed by Dube and Natarajan[5]. In the present work the dielectric constant and loss factor of the deoiled cakes of *Sesamum indicum, Eruca sativa, Brassica* juncea and cakes of coconut meat (endosperm) of Coccos nucifera have been determined by using this method. One of the advantages of this method is that it does not impose any restrictions on the length of the sample. The method as described by Dube and Natarajan[5], does not require the use of variable attenuator to bring the VSWR in the easily measurable range. Further this method is simple, straight and it also does not need any calibrated components as in the bridge methods. Although the accuracy is improved in the present method, yet it is limited due to the possibility of higher mode generation and power leakage through the slotted guide.

Deoiled cakes are waste products in the oil industry and used only as the cattle feed. Their dielectric properties have not been studied so far. Hence it was decided to carry out the studies of their dielectric properties. Such studies may prove of great importance in deciding their use for industrial application and in the fabrication of devices like capacitors. Further, such studies may also prove helpful in understanding the rise of cholesterol level in the blood and its effects on the functioning of heart in human beings and in animals. The reported studies of Ayachi[6,7] on the effect of Niger seeds and its deoiled cakes on rats indicate that these are rich in protein, fat and carbohydrate contents which are important ingrediants of food. A correlation may be established between the dielectric properties and the biological contents of the oil seeds and deoiled cakes by carrying out studies of their dielectric behaviour.

Theory and Experimental details

The observation for the shift in minima position and the maximum power output (with and without sample) were taken at 9.44 GHz by using X-Band set up. The apparatus used is shown in Fig. 1. The sample is mounted along the axis of the waveguide as shown in Fig. 2. With this configuration, the electric field acts in the plane of the film. Standing waves are produced in the rectangular waveguide by short circuiting the system. The positions of maxima and minima are detected in the slotted line by means of a travelling waveguide detector. Initially, the movable probe is placed at a minimum of the standing wave. The sample of length L is then placed in the sample holder, which is a waveguide of about 10 cm length, with a fine accurately cut longitudinally slot at the middle of the upper face, through which the sample can be introduced in the waveguide. This causes the minima positions to shift. Assuming this shift to be X the phase introduced by the specimen per unit length is $\beta_s = \beta_o x/L$......(1) where β_o is $2\pi/\lambda g$, λg being the guide wavelength in air. Thus the total phase constant β_r is given by $\beta_r = \beta_o x/L$........ (2)

For the measurement of attenuation constant β_i we follow the method proposed by Yadav and Gandhi[8]. The relevant formula for the calculation of β_i is

$$\beta_i = \frac{2.3026}{2L} \log \left[\frac{x_1^{1/2}}{2x_2^{1/2} - x_1^{1/2}}\right] \text{.....(3)}$$

where X_1 and X_2 are the deflections shown by the indicating meter without using the sample and with the sample, when the movable probe is located at the position of a maximum.

The complex permittivity $\varepsilon (= \varepsilon_r - i\varepsilon_i)$ is determined from the phase shift and attenuation measurements by using the following equations due to Dube and Natarajan[9]

$$\varepsilon_r = \frac{1}{K^2} \left[\beta_r^2 - \beta_i^2 + \left(\frac{a_1 a_3 + a_2 a_4}{a_3^2 + a_4^2}\right)\frac{2}{cd}\right] \text{.....(4)}$$

$$\varepsilon_r = \frac{1}{K^2} \left[2\beta_i \beta_r - \left(\frac{a_2 a_3 + a_1 a_4}{a_3^2 + a_4^2}\right)\frac{2}{cd}\right] \text{.....(5)}$$

Where

$$a_1 = d \operatorname{Re} (K^2 - \beta_r^2)^{1/2} \text{......(6)}$$

$$a_2 = d \operatorname{Im} (K^2 - \beta_r^2)^{1/2} \text{.....(7)}$$

$$a_3 = \frac{2 \sin 2 a_1}{\exp(2a_2) + \exp(-2a_2) + 2 \cos 2a_1} \text{.....(8)}$$

$$a_4 = \frac{\exp(2a_2) - \exp(-2a_2)}{\exp(2a_2) + \exp(-2a_2) + 2 \cos 2a_1} \text{...... (9)}$$

where $k = \omega/c_o$ is the free space propagation vector, ω is the angular frequency and C_o is the velocity of light, whereas we have taken c as the thickness of the film and $d = (a-c)/2$; a being the width of the waveguide (Fig.2).

Strips of deoiled cakes of *S.indicum, E.sativa, B.juncea* and cakes of coconut meat of *C. nucifera* are used to measure the dielectric constants at a frequency of 9.44 GHz. It was noticed that the deflection on the galvenometer slightly changed with the position of the sample in the sample holder. This was probably due to

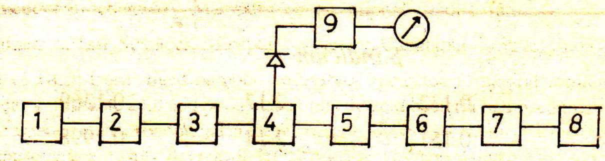

FIG-1

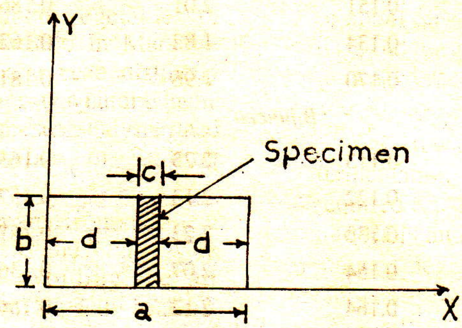

FIG-2

Figure 1 Schematic arrangement of exprimental set-up

1 Klystron power supply, 2. Frequency meter, 3. Ferrite isolator,4. Waveguide travelling detector, 5. Variable attenuator, 6. E-H tuner 7.Sample holder waveguide, 8. Movableshort, 9. Amplifier & galvenometer.

Figure 2 Cross section of a rectangular waveguide with specimen.

Table 1. Values of Phase shift/unit length (β_s)dielectric constant (ε_r & ε_i)and losstangent (tan δ) for deoiled cakes of *S. indicum, E.sativa, B.juncea* and cakes of coconut meat of *C.nucifera* at 9.44 GHz at different Lengths (L) and thicknesses (C).

Lin cm	C in cm	β_s in rad/cm	ε_r	ε_i	tan δ x 10^4
			S.indicum		
0.81	0.096	0.132	2.17	0.1369	633
1.89	0.112	0.151	2.14	0.1998	934
1.19	0.129	0.171	2.12	0.1622	766
1.10	0.139	0.176	2.08	0.1637	790
1.70	0.140	0.188	2.13	0.2069	972
1.10	0.166	0.221	2.13	0.1880	885
1.86	0.184	0.244	2.14	0.2065	969
1.09	0.197	0.253	2.10	0.2069	988
			E.sativa		
1.12	0.110	0.155	2.20	0.2076	948
1.12	0.124	0.157	2.07	0.1827	884
2.12.	0.126	0.151	2.01	0.1862	928
2.20	0.139	0.134	1.82	0.1622	892
1.91	0.152	0.170	1.96	0.1818	932
			B.juncea		
1.68	0.079	0.113	2.23	0.1633	734
2.29	0.092	0.122	2.13	0.1576	742
1.35	0.105	0.133	2.23	0.1874	844
1.84	0.122	0.154	2.07	0.1365	660
1.23	0.124	0.164	2.12	0.1568	740
0.93	0.136	0.214	2.33	0.1562	671
			C.nucifera		
0.58	0.100	0.108	1.92	0.1371	714
1.18	0.142	0.112	1.68	0.0972	580
2.23	0.151	0.137	1.78	0.1187	669
2.07	0.167	0.150	1.77	0.1161	656
1.35	0.177	0.158	1.77	0.1307	739
2.09	0.201	0.172	1.71	0.1276	734

reflections from the edges of the sample and leakage in the slotted guide. To minimise this effect, the sample was placed at different positions in the sample holder and average values of the maximum deflection of the output galvenometer were considered and similarly average values of the shift in minima positions were used in the calculations of attenuation β_i and total phase constant βr. These values of β_r and β_i are then used in equations (4) and (5) to calculate ε_r and.ε_i

Results and Discussion

Table 1 shows the values of β_s, ε_r, ε_i and loss tangent (tan δ), for the different cakes under consideration. It is seen that the phase shift per unit length (β_s) increases with the increase in the thickness of the specimen strip for all the cakes under consideration, which may be interpreted as the effect of increase in the absorption with the increase in the thickness of the samples. Further, it may be observed that the values of the dielectric constant ε_r, ε_i, and tan δ are of the same order for the deoiled cakes of *S. indicum, E. sativa* and *B. juncea,* showing similarity of their internal structures. For the cakes of *C. nucifera*, the values of the dielectric parameters are found to be lesser than the values of deoiled cakes of *S. indicum, E. sativa* and *B. juncea.* This may be due to the presence of about 75% of saturated fatty acids in *C.nucifera* and because of higher percentage of fatty acids and very small quantity of linoleic acid. This increases the cholesterol level in the blood,while in the other samples the quantity of fatty acids is small and the quantity of linoleic acid is greater than *C.nucifera*. In the case of *B.juncea* and *E.sativa* the dielectric properties are determined by the presence of Allyl isothiocyanate compound.The difference in the chemical structures of different fatty acids and amino acids of different sampes also plays a role in deciding their dielectric properties.

It may be concluded that the dielectric values of the deoiled and oiled cakes fall in the range so as to make them useful for industrial applications.

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