TEMPERATURE DEPENDENCE OF DIELECTRIC LOSS OF SHELLAC IN MICROWAVE REGION

by S. S. Srivastava, D. D. Puri,* *and* P. C. Mehendru,*

Indian Naval Physical Laboratory, Cochin-4.

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1. Introduction

Shellac is produced in India after refinement from seedlac which is normally prepared from natural resin called stick lac, secreted by the lac insects. Seedlac contains more than 88% of lac, and 4·5% of wax, the remainder being made up of colouring matter, gluten and moisture. Various grades of shellac that are commercially made in India mostly contain insoluble impurities, varying percentages of wax, rosin and moisture. For microwave work a very high degree of purity is needed in dielectric samples. The three grades of shellac manufactured by Angelo Bros. Ltd. are free from rosin and orpiment and contain 0·1% only of insoluble impurities. They are at present the only samples of the highest degree of purity commercially available, and have, therefore, been used as samples for microwave measurements. Dielectric constant and tan δ measurements were carried out at room temperature at 3·2 cm. in these three grades of shellac and the variation of tan δ with temperature was studied by standing wave technique. This variation is found to be large in all the three grades of samples below their softening point.

2. Method of Measurement

The technique of measurements used for measuring the dielectric constant and loss factor of solid samples has been reported in previous papers (Khattar *et al.*, 1954; Rangan *et al.*, 1955; Mehendru *et al.*, 1956). The loss factor in case of shellac lies in the medium range so that standing wave technique was found to be most suitable. Samples of shellac were made to fit the wave guide cell and were placed in contact with a shorting plunger. The separation of the first minimum of the standing wave from the surface of the shellac sample is used to measure the dielectric constant, which is calculated from the value of the phase factor of the wave in the sample (Hippel and Roberts, 1947).

$$\frac{\tan \beta d}{\beta d} = -\frac{\lambda_g}{2\pi d} \cdot \tan \frac{2\pi x_0}{\lambda_g},$$

where x_0 = distance of the first minimum from the dielectric surface,
d = thickness of the dielectric sample in the guide,
λ_g = wavelength in the guide,

provided the attenuation in the sample and standing wave ratio $E_{\text{min.}}/E_{\text{max.}}$ are small. The dielectric constant is calculated by the expression

$$\epsilon' = \frac{\frac{1}{\lambda_c^2} + \left(\frac{\beta d}{2\pi d}\right)^2}{\left[\frac{1}{\lambda_c^2} + \frac{1}{\lambda_g^2}\right]}$$

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* Now at National Physical Laboratory, New Delhi.

and $$\tan\delta = \frac{\Delta x}{d}\left[\frac{\left(\frac{1}{\lambda_c^2}+\frac{1}{\lambda_g^2}\right)-\frac{1}{\lambda_c^2\epsilon'}}{\frac{1}{\lambda_c^2}+\frac{1}{\lambda_g^2}}\right]\left[\frac{\beta d\left(1+\tan^2\frac{2\pi x_0}{\lambda_g}\right)}{\beta d(1+\tan^2\beta d)-\tan\beta d}\right]$$

where Δx = width of the minimum of the standing wave between double power points.

In calculating the loss factor of the samples usually allowance has to be made for losses in the guide. These losses were found to be lower than the overall accuracy of measurements in this range of dielectric loss.

3. Measurements

The experimental set-up used in measuring the temperature variation of the tan δ of solid shellac samples by standing wave technique is shown in Fig. 1. Most of the equipment used was designed and assembled by us as reported earlier (Rangan and Srivastava, 1952; Barlow and Cullen, 1950), except for the standing wave detector which was Scanner's type. The dielectric cell consisted of a fixed wave guide cell, soldered to a metal container in which hot water was allowed to circulate at constant temperature. Temperature of the sample could be varied up to 70°C. by heating water electrically in a well insulated glass chamber and allowed to circulate constantly round the cell for sufficient length of time. The whole test bench was made vertical for easy flow of water round the cell. The standing wave pattern inside the cell and calibration of SWR indicator were carried out according to standard methods.

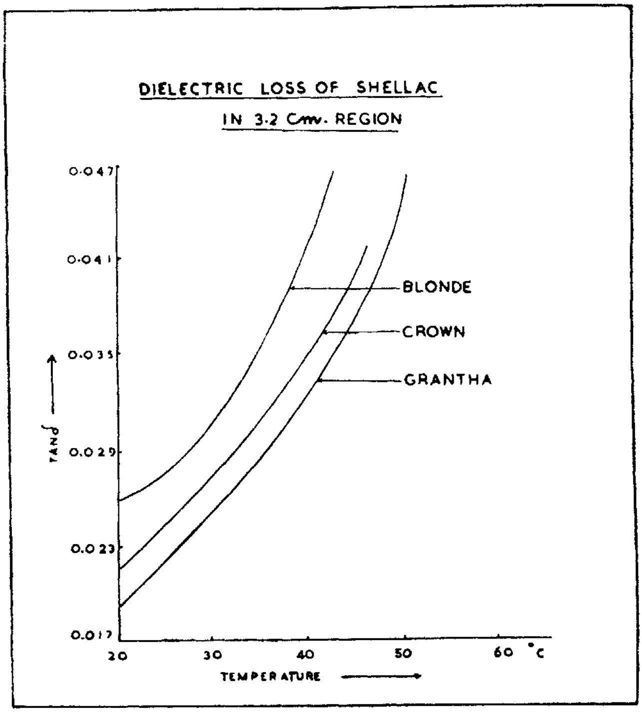

Fig. 2. Temperature variation of dielectric loss of shellac at 3·2 cm.

Wave guide samples of shellac were made by softening the material provided in form of flakes and then moulding it in a die under pressure. At least three samples of each grade of shellac of varying thickness between $\frac{\lambda s}{4}$ to $\frac{5\lambda s}{4}$ were used for loss measurement at every value of temperature. All samples were first dried in an electric oven at 40° and then left for desiccation for 48 hours. It is found that this method eliminates all the moisture that can be removed without detriment to the sample (Rangaswami and Sen, 1952).

The dielectric loss measured at 3·2 cm. at room temperature in the three grades of shellac manufactured in India by Angelo Bros. Ltd. is given in the table below:

Table 1

Grade of shellac	Insoluble impurities, %	Wax, %	ϵ' at 28°C.	tan δ at 25°C.
Blonde	0·1	Nil	2·771	0·0281
Crown	0·2	4·5	3·077	0·0245
Grantha	0·1	3·5	2·838	0·0222

The change measured in the dielectric loss due to variation in temperature is given in Fig. 2. Measurements have been carried out below the softening temperatures of the samples. Above these temperatures sample becomes distorted and sticks to the guide wall. The overall accuracy of these measurements was of the same order as reported in the previous paper (Mehendru *et al.*, 1956).

Perhaps the reason for varying degree of dielectric losses in microwave region in the three grades of shellac lies in their method of preparation. Dewaxed Blonde shellac is made by using cold alcohol in which wax is soluble, Grantha is processed from hot alcohol solutions and Crown grade is prepared by heat processes from seedlac. The carboxyl groups of shellac readily form esters with alcohols which are viscous liquids. For shellac prepared from the cold process, most of these esters will contribute their dielectric loss in microwave region, that is why the dielectric loss of Blonde is high.

4. Use of Shellac for Microwave Work

The dielectric loss of seedlac over a wide range of frequencies from 10^6 to 10^{10} c.p.s. has been reported in a previous paper (Srivastava, 1956). Spot frequency measurements in microwave region have been carried out on the dielectric loss of various grades of shellac commercially available. From the measured loss factor use of shellac as a general purpose dielectric for transmission line or for micro-strip work will give rise to considerable attenuation of microwave power.

Shellac consists (Angelo Bros. Ltd., 1956) of 3% of a petrol soluble wax like ester, with about 30% aleuritic acid, 20% water soluble aldehydic acids, 20% water soluble hydroxy dibasic acids which may include shellolic acid and 25% of hydroxy monobasic acids. Not all have been chemically separated and structurally analysed. The individual dipolar losses of these acids if measured in microwave range may perhaps help in understanding the complex behaviour of shellac in ultra high frequencies.

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Abstract

Microwave dielectric loss of commercial grades of shellac has been measured in 3 cm. region over a temperature range of 20°C. to 50°C. A wave guide cell was designed for keeping the temperature constant over the range for the duration of measurements. Standing wave technique was used for measuring the dielectric constant and loss factor at 3·2 cm. The tan δ of shellac is found to increase rapidly with temperature in all the three grades of shellac of high purity below their softening point.

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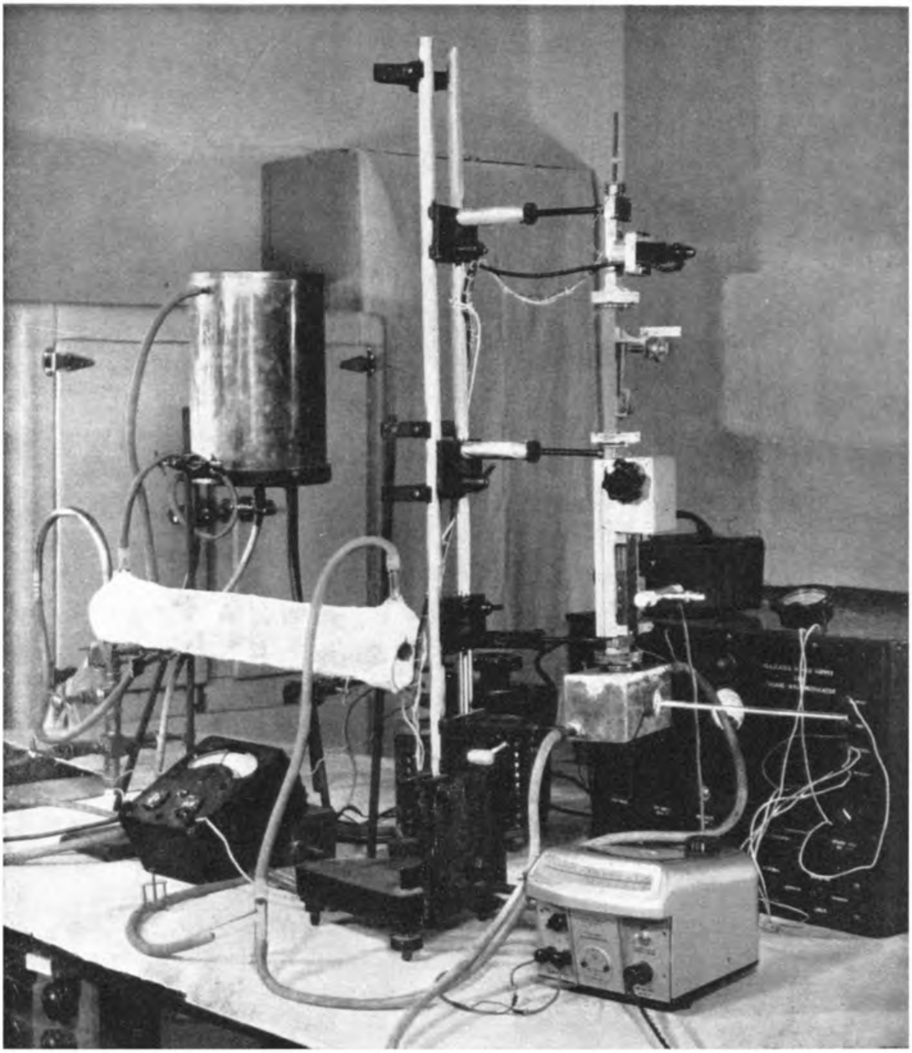

FIG. 1. Microwave test bench for temperature variation of tan δ in dielectric materials.