INSTRUCTION MANUAL

DIELECTRIC CONSTANT KIT
(For Solids)

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DIELECTRIC CONSTANT KIT

INTRODUCTION

A dielectric is a material having electrical conductivity low in comparison to that of a metal. It is characterized by its dielectric constant. Dielectric constant is measured as the ratio of the capacitance C of an electrical condenser filled with the dielectric to the capacitance C_0 of the evacuated condenser i.e.

$$\varepsilon = \frac{C}{C_0}$$

FRONT PANEL DESCRIPTION:

Front panel comprises of

i) Digital Volt meter (DVM), that measures the voltage across the dielectric cell (DC) or standard capacitor (SC).

ii) Switch S_1 to select di-electric cell or standard capacitor.

iii) Switch S_2 to select one of the standard capacitors SC_1, SC_2, SC_3

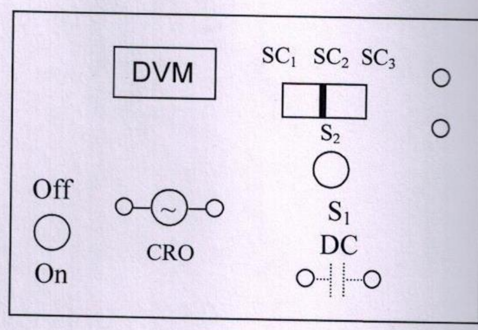

Fig. 1

DIELECTRIC CELL-I

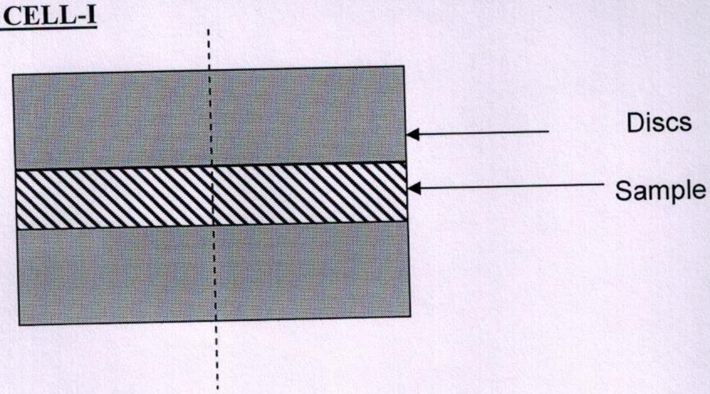

Fig.2

(i) Dielectric cell –1 having two Gold plated brass discs (75 mm. each)

IMPORTANT: Dielectric cell (metal discs) and sample should be coaxial.

DIELECTRIC CELL- II

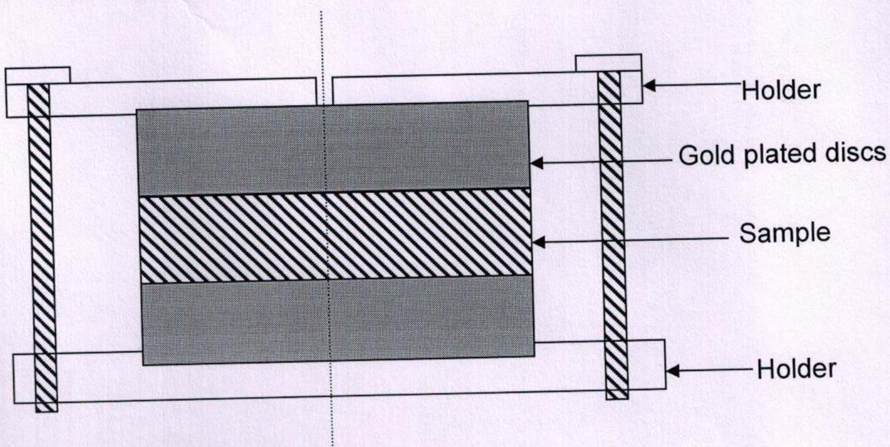

Figure 3

Dielectric cell consists of two 1" dia. Gold plated brass discs fitted in between the cell holder (Teflon plates). Keep the ferroelectric sample in between the metal plates and tighten the three screws such that sample fits in between the metal plates without any air gap.

IMPORTANT: Dielectric cell (metal discs) and sample should be coaxial. Do not apply extra pressure on screws as that may damage the sample.

THEORY

In this experiment an LC circuit is used to determine the capacitance of the dielectric cell and hence the dielectric constant. The circuit details are shown below:

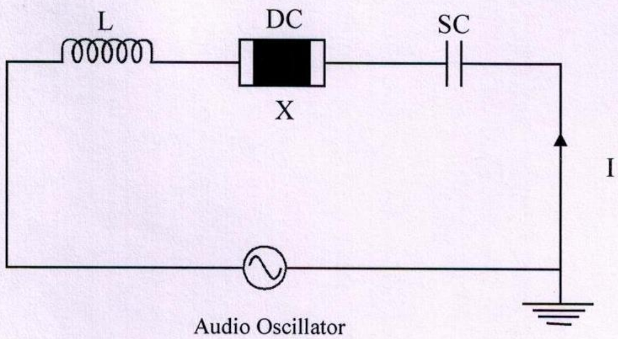

Figure 3

DC : Dielectric cell
SC : Standard capacitor
L : Inductor
X : Sample

The audio oscillator is incorporated inside the instrument. If C_{SC} and C_{DC} represents the capacitances of the standard capacitor and dielectric cell respectively and if V_{SC} and V_{DC} are the voltages across SC and DC then.

$$\frac{V_{SC}}{I} = \frac{1}{\omega C_{SC}} \qquad \ldots(1)$$

$$\Rightarrow \qquad I = \omega V_{SC} C_{SC} \qquad \ldots(2)$$

The same current I passes through the dielectric cell.

$$\frac{V_{DC}}{I} = \frac{1}{\omega C_{DC}} \qquad \ldots(3)$$

$$\Rightarrow \qquad C_{DC} = \frac{I}{\omega V_C} = \frac{\omega C_{SC} V_{SC}}{\omega V_{DC}} = \frac{C_{SC} V_{SC}}{V_{DC}} \qquad \ldots(4)$$

By measuring V_{SC} & V_{DC} and using the value of C_{SC} we can determine the capacitance of the dielectric cell containing the sample.

If C_0 represents the capacitance of the dielectric cell without the sample and the plates separated by air gap whose thickness is the same as the thickness of the sample then C_0 is given by

$$C_0 = \frac{\varepsilon_0 A}{d} = \frac{r^2}{36d} \text{ nf.} \qquad \ldots(5)$$

where r represents the radius of the gold plated discs and d represents thickness of the sample in meters.

The dielectric constant of the sample is given by

$$\varepsilon_r = \frac{C}{C_0} \qquad \ldots(6)$$

Experimental setup

<u>PROCEDURE for Dielectric Cell-I</u>

1) Connect C.R.O. to the terminals provided on the front panel of main unit. If no sinusoidal waveform appears on C.R.O. then adjust "CAL" such that waveform appear.

2) Connect the dielectric cell-I assembly to the main unit and insert the sample in between the metal discs.

IMPORTANT: Do not put extra pressure, as PZT sample and Glass samples are brittle and may be damaged.

3) Switch ON the unit.

4) Choose the standard capacitor (with the help of switch S_2) SC_1 for materials having low dielectric constants (like Bakelite, Glass, Plywood samples) or SC_2 for material having high dielectric constant (PZT sample).

5) Throw S_1 towards DC to measure the voltage across dielectric cell,say V_{DC} and towards SC to measure voltage across standard capacitor, say V_{SC}. Calculate the capacitance C using relation

$$C = \frac{V_{SC}}{V_{DC}} \times C_{SC}$$

IMPORTANT : **For samples, other than provided with the kit, measure the capacitance of the sample placed in between the Dielectric Cell-I with the help of any capacitance meter available. If measured capacitance value is not comparable to either of SC_1 or SC_2 put capacitor having value near to that measured value in between the plugs provided at SC_3 and throw switch S_2 to SC_3 and repeat step 5.**

NOTE : DIAMETER OF THE SAMPLES SHOULD NOT BE LESSER THAN THE GOLD PLATED DISCS.

6) Measure thickness of the sample using the cell holder and calculate the value of C_0(air) using relation (5).

7) Determine the dielectric constant of the sample using the relation

$$\varepsilon = \frac{C}{C_0(air)}$$

PROCEDURE for Dielectric Cell-II

1) Select SC2 among standard capacitors.

2) Measure the voltage (using digital voltmeter provided on front panel) across the dielectric cell DC, say V_{DC}, by throwing switch S_1 towards DC and measure voltage across standard capacitor SC, say V_{SC}, throwing switch S_1 towards SC, while heater is switched off (i.e. at room temperature).

$$V_T = V_{SC} + V_{DC}$$

3) Determine the dielectric constant of the crystal using the relation

$$\epsilon_r = \frac{C}{C_0} = \frac{C_{SC} V_{SC}}{V_{DC} C_o} \quad \ldots\ldots\ (7)$$

where C_0 is calculated using relation (5)

4) Switch ON the oven and set the desired temperature (Follow instructions to set the temperature of the oven). Measure voltages V_{DC} at different temperatures at 10°C interval in the range RT-90°C. V_{SC} may be calculated as

$$V_{SC} = V_T - V_{DC}$$

NOTE: Readings should be taken in ascending order only.

5) Measure V_{DC} at 5°C interval upto 110°C and at intervals of 1 °C - 2 °C until you reach the maximum value of the dielectric constant (or C). Thereafter take few points.

IMPORTANT : DO NOT INCREASE THE TEMPERATURE OF OVEN BEYOND 180°C.

6) Make the observation table as shown below:

TEMPERATURE (°C)	SC1		SC2		SC3		CALCULATED CAPACITANCE	ϵ_r
	V_{DC}	V_{SC}	V_{DC}	V_{SC}	V_{DC}	V_{SC}		

7) Calculate the dielectric constant (as explained above).

8) Draw a graph of ϵ_r vs. T. At the transition the dielectric constant sharply rises and falls suddenly after the transition temperature and then decreases slowly beyond the transition temperature.

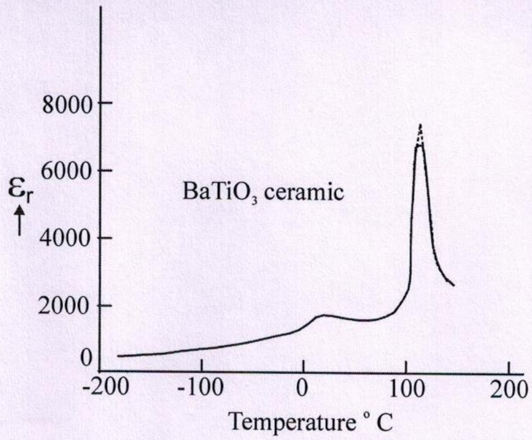

Figure 5

Fig. 5 shows the variations of dielectric constant of $BaTiO_3$ ceramic as a function of temperature (After W. B. Westphal, Laboratory for Insulation Research, M.I.T.). An examination of Figure 5 shows that it is difficult to make measurements at the Curie temperature due to sharp variation. Extension of the curves below and above the transition temperatures allows one to estimate the Curie temperature.

9) Determine the transition temperature (Curie Temperature) from the graph.

NOTE: As the measurements are repeated the nature of the curve remains same but it might not be possible to get the same values.

COMPONENT VALUES (S.NO. 1718258)

L = 25 *mH*

SC_1 = 48 *pf*

SC_2= 20*nf*

PRECAUTIONS

1. Sample surface must be flat so that there is no air gap between the sample and the disc.
2. Dielectric cell should be placed on insulating surface in humid weather conditions.
3. Least pressure should be exerted on the brittle samples.

PARTS LIST

1. MAIN UNIT ☐
2. DIELECTRIC CELL (2 Nos) ☐
3. SAMPLES (3 Nos) ☐
4. BNC-BNC cable (1 no) ☐
5. INSTRUCTION MANUAL ☐

SAMPLE READINGS/CALCULATIONS:

1. PLYWOOD:

SC = 55.5 pf
V_{DC} = 0.75 V
V_{SC} = 1.51 V
d = 2.8 mm
r = 3.8×10^{-2} m.

$$\therefore \quad C = \frac{V_{SC}}{V_{DC}} \times SC = 107.91 pf$$

$$C_0 = \frac{r^2}{36d} = \frac{\left(3.8 \times 10^{-2}\right)^2}{36 \times 2.8 \times 10^{-3}} = 14.3 pf$$

$$\varepsilon = \frac{C}{C_0} = \frac{107.91}{14.3} = 7.546$$

2. GLASS:

V_{DC} = 1.75 V
V_{SC} = 1.62 V
SC = 55.5 pf
d = 4.66 mm

$$\therefore \quad C = \frac{V_{SC}}{V_{DC}} \times SC = 51.37 pf$$

$$C_0 = \frac{r^2}{36d} = \frac{\left(3.8 \times 10^{-2}\right)^2}{36 \times 4.6 \times 10^{-3}} = 8.6 pf$$

$$\varepsilon = \frac{C}{C_0} = \frac{51.37}{8.6} = 5.97$$

3. PZT-SAMPLE:

V_{SC} = 1.83 V
V_{DC} = 1.74 V
SC = 11 nf
d = 1.08 mm
r = 12 mm

$$\therefore \quad C = \frac{V_{SC}}{V_{DC}} \times SC = 11.57 nf$$

$$C_0 = \frac{r^2}{36d} = \frac{\left(12 \times 10^{-3}\right)^2}{36 \times 1.08 \times 10^{-3}} = 3.7 \times 10^{-3} nf$$

$$\varepsilon = \frac{C}{C_0} = \frac{11.57}{3.7 \times 10^{-3}} = 3127$$

NOTE: These readings are of particular samples and may vary for sample to sample.

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