Study Of Dielectric Constant

Study of Dielectric Constant and Curie Temperature of Ferroelectric Ceramics:-

Dielectric or electrical insulating material are understood as the material in which electrostic field can persist for long times. Layers of such substance are commonly inserted into capacitors to improve their perfomance, and the term dielectric refers specifically to this application. An electric field polarizes the molecules of dielectric producing concentrations of charge on its surface that create an electric field opposed (antiparallel) to that of capacitor. This reduces the electric potential.Considered in reverse, this means that, with a dielectric, a given electric potential causes the capacitor to accumulate a larger charge.

Applications:-

Beside the common and well known application of capacitors in electrical and electronic circuits, the capacitors with an exposed and porous dielectric can be used to measure humidity in air. A huge leap in the research on dielectric (ferroelectric materials) came in 1950's, leading to the wide spread use of Barium Titanate ($BaTiO_3$-Perovskite Structure) based ceramics in capacitor applications and piezoelectric transducer devices. Since then, many other ferroelectric ceramics have been developed and utilized for variety of applications: various type of capacitors, non volatile memories in computers, etc.

Perovskite Structure:-

Perovskite is family name of a group of materials and the mineral name of calcium titanate ($CaTiO_3$) having a structure of the type ABO_3 (Fig 1)

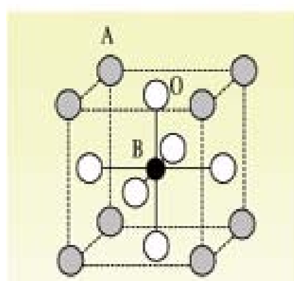

Fig 1 Perovskite ABO_3 structure with the A and B cations on the corner and body centre positions, respectively. Three oxygen anions per unit cell occupy the faces and form octahedra surrounding the B-site.

A practical advantage of perovskite structure is that many different cations can be substituted on both A and B sites without changing the over all structure. Even though two cations are compatible in solution, their behaviour can be radically different when apart from each other. Thus it is possible to manipulate material's properties such as Curie temperature or dielectric constant with only a small substitution of given cation

All ferroelectric material have a transition called the Curie point (T_c). At $T>T_c$, the crystal does not exhibit ferroelectricity, while for $T<T_c$ it is ferroelectric. If there is more than one ferroelectric phase, the temperature at which the crystal transforms one phase to another is called transition temperature. Near the Curie

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temperature point or transition temperatures, the thermodynamic properties including dielectric, elastic, optical and thermal constants show an anomalous behaviour.
Fig 2 shows the variation of dielectric constant (ε) with temperature for Lanthanum doped Lead Zirconate Titanate (PLZT) ceramic, which is cooled from its paraelectric cubic phase to ferroelectric rhombohedral phase.

Description of the Experimental Set -up:-

1 . Probes Arrangement
It has two individually spring loaded probes. The probes arrangement is mounted in a suitable stand, which also holds the sample plate. To ensure the correct measurement of sample temperature, the RTD is embedded inthe sample plate just below the sample. This stand also serves as the lid oftemperature controlled oven. Proper leads are provided for connection to Capacitance Meter and Temperature Controller.

2 . S ample
Barium Titanate ($BaTiO_3$)

3 . Oven
This is a high quality temperature controlled oven. The oven has been designed for fast heating and cooling rates, which enhances the effectiveness of the controller.

4 . Main Units
The Set-up consists of two units housed in the same cabinet.

(i) Oven Controller
Platinum RTD (A class) has been used for sensing the temperature. A Wheatstone bridge and an instrumentation amplifier are used for signal conditioning. Feedback circuit ensures offset and linearity trimming and a fast accurate control of the oven temperature.

SPECIFICATIONS:-

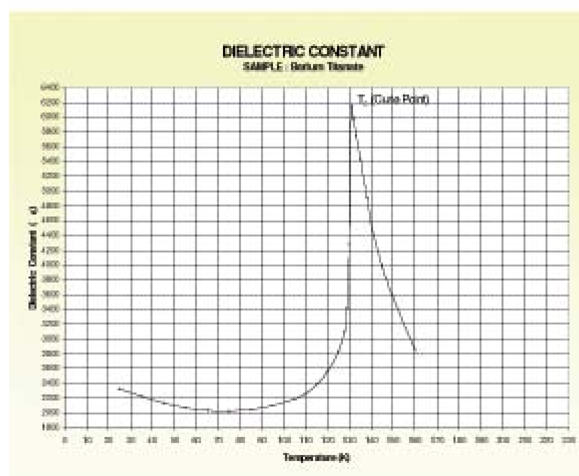
- Temperature Range : Ambient to 200°C
- Display : 3½ digit, 7 segment LED with autopolarity & decimal indication
- Resolution : 0.1°C
- Accuracy : ±0.5°C (typical)
- Stability : ±0.1°C
- Power : 150W

(ii) Digital Capacitance Meter

This a compact direct reading Instrument for the measurement of capacitance of the sample.

SPECIFICATIONS:-

- Range : 50-6000 pf
- Resolution : 1pf
- Display : 3½ digit, 7segment LED



Typical results obtained with the above set-up are as shown in the graph

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Study of P-N Junctions

Experimental Determination of :

> Reverse saturation current I_0 and material constant η

> Temperature coefficient of junction voltage dV/dt

> Energy band-gap V_{G0}

> Junction capacitance

STUDY OF THE ENERGY BAND-GAP AND DIFFUSION POTENTIAL OF P-N JUNCTIONS:-

Introduction:

This is an advanced level experiment to be performed on commercially available diodes viz. germanium orsilicon diodes, various types of LED's and also on the base-emitter/collector-base junctions of a transistor. The results of the experiments not only give the device characteristics but also provide an insight into the properties of the materials used in the fabrication of the junction. In the set-up, all the necessary instrumentation is integrated as a result of which a minimum of external connections need to be made by the user. A CRO is the only accessory that is required.

Experiments:

Given below is a brief description of the experiments that may be performed.

(a) Reverse saturation current I_0 and material constant η

The magnitude of I_0 is too small to be measured conveniently and further, it is a function of the applied voltage. The direct measurement of this current is therefore both difficult and erroneous. In the present set-up, readings for the forward V-I characteristics are obtained by 3½ digit DPM for a wide range of currents. If, V and lnI are plotted on a graph paper a straight line is obtained. This line intersects the current (lnI) axisat $\ln I_0$ and its slope $\Delta V/\Delta \ln I$ may be solved to compute η. (fig.1)

(b) Energy band-gap and temperature coefficient of the junction voltage

The P-N junction under test is kept in a small, fast temperature controlled oven. The temperature is adjustable in the range from room temperature to about 80°C. From the readings of the temperature and junction voltage on digital instruments provided on the panel, the temperature coefficient and energy band-gap are computed. (fig.2)

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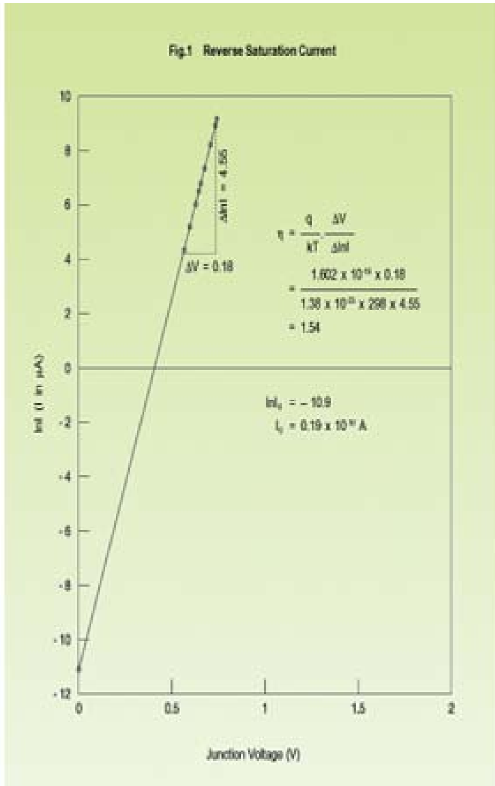


Fig.1 Reverse Saturation Current

(c) The Junction Capacitance

The junction capacitance of a typical diode varies in the range 10pf-100pf approximately, as a non-linear function of the reverse voltage. This parameter though important in high frequency circuits, is difficult to measure because of its small value. In the present set-up, the output V_1 and V_2 at two frequencies f_1 &f_2, where f_2>f_1, are obtained at different values of bias voltage to compute the junction capacitance.A typical graph between bias voltage and junction capacitance is shown in fig.3.

The experimental set-up consists of the following:-

(1) Study of P-N Junction, Model PN-1

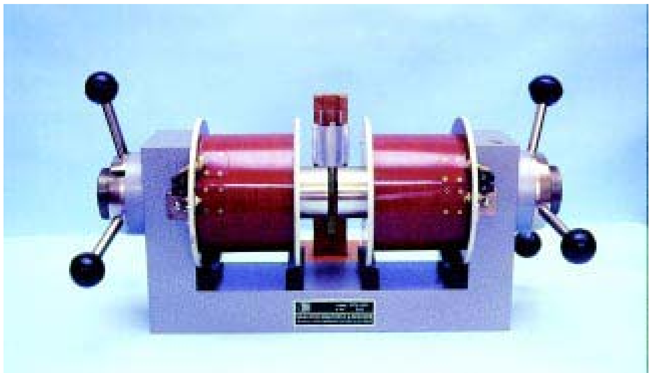
(a) 3½ digit DPM for current/temperature measurements.
(b) 3½ digit DPM for bias voltage/junction voltage measurements.
(c) Two parts to connect the diode - one for experiment 1 & 2 and other for experiment 3.
(d) Two fixed frequency oscillators (5KHz & 20KHz) with the same output (200 mV).

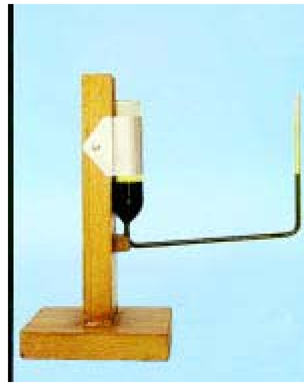
(2) Fast temperature controlled oven with sensor

(3) Set of samples

(a) Transistor BC109 (base-emitter)-Si
(b) Transistor AC126 (base-emitter)-Ge
(c) Diode 1N 5408/1N 4002-Si

Quinck's Tube Method





APPARATUS FOR THE MEASUREMENT OF SUSCEPTIBILITY OF PARAMAGNETIC SOLUTION BY QUINCK'S TUBE METHOD:

Introduction:

It was established by Faraday in 1845 that magnetism is universal property of every substance. He classified all magnetic substances into two classes, viz., paramagnetic and diamagnetic. Weber, later on, tried to explain para and diamagnetic properties on the basis of molecular currents. The molecular current gives rise to theintrinsic magnetic moment to the molecule, and such substances are attracted in a magnetic field, and called paramagnetics. The repulsion of diamagnetics is assigned to the induced molecular current and its respective reverse magnetic moment. The force acting on a substance, either of repulsion or attraction, can be measured with the help of an accurate balance in case of solids or with the measurement of rise in level in narrow capillary in case of liquids. The force depends on the susceptibility K, of the material, i.e., on ratio of intensity of magnetisation to magnetising field (I/H). Evidently it refers to that quantity of substance by virtue of which bodies get magnetised. Quantitatively it refers to the extent of induced magnetisation in unit field. If the force on the substance and field are measured, the value of susceptibility can be calculated.

The value of the susceptibility K of liquid aqueous solution of a paramagnetic substance in air is given by a well know expression:

$$K = \frac{2(\rho - \sigma)gh}{H_2}$$

where ρ is the density of the liquid or solution
σ is the density of air
g is the acceleration due to gravity
h is the height through which column rises on switching on the field
H is the magnetic field at the centre of pole pieces

Procedure:

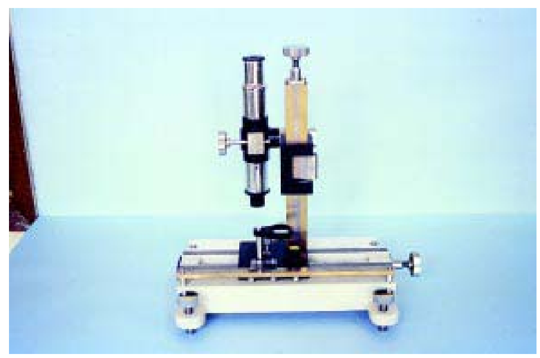
The apparatus consists of U-shaped tube known as Quinck's tube. One of the limb of the tube is wide and the other one narrow. The experimental liquid or solution is filled in the tube and is placed in such a way that the meniscus of the liquid in narrow limb is at the centre of the magnetic field.

The level of the liquid in the narrow tube is read by a travelling microscope when magnetic field is off. The magnetic field is switched on and the new raised level of the column is again read with the travelling microscope.

The apparatus consists of the following:

> Quinck's tube with stand
> Sample: $FeCl_3$
> Electromagnet, Model: EMU-50T
> Constant Current Power Supply, Model: DPS-50
> Digital Gaussmeter, Model: DGM-102
> Travelling Microscope

TRAVELLING MICROSCOPE (Horizontal and Vertical):



The bed is of heavy casting, thoroughly aged, machined and is fitted with levelling screws. On the dovetail guide ways slides the horizontal carriage which can be clamped at any position by means of a thumb screw. A second sliding carriage slides along a gun metal vertical pillar fitted on the horizontal carriage. The slow motion guide bars are made of sturdy material and the motion is very smooth.

Optics:

(i) True achromatic objective with 7.5cm focussing distance
(ii) 10X Ramsden eyepiece with fine cross wire

Scale and Vernier:

(i) Horizontal scale: 20cm divided at 0.5mm interval
(ii) Vertical scale: 15cm divided at 0.5mm interval
(iii) Venier scales: 50 divisions with a least count of 0.01mm

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