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<u>**WORK INSTRUCTION**</u>

**1.0 Experiment No: BS/PHP101/06**
**2.0 Name of Experiment:** Study Dielectric Constant & Curie Temperature
**3.0 Aim:** Determination Dielectric Constant & Curie Temperature of
Ferroelectric Ceramics

**4.0 Principle:** Dielectric or electrical insulating materials are understood as the materials in which electrostatic fields can persist for a long time. These materials offer very high resistance to passage of electric current under the action of applied direct current voltage and therefore sharply differ in their basic electrical properties from conductive materials. Layers of such substances are commonly inserted into capacitance to improve their performance, and the term dielectric refers specifically to this application

**PEROVSKITE STRUCTURE**

Perovskite is a family name of a group of materials and the mineral name of calcium titanate ($CaTiO_3$) having a structure of the type $ABO_3$. Many piezoelectric (including ferroelectric) ceramics such as Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Lead Zirconate Titanate (PZT), Lead Lanthanum Ziconate Titanate (PLZT), Lead Magnesium Niobate (PMN), Potassium Niobate ($KNbO_3$), etc. have a cube perovskite type structure (in the paraelectric state) with chemical formula $ABO_3$ .

**BARIUM TITANATE ($BaTiO_3$,)**

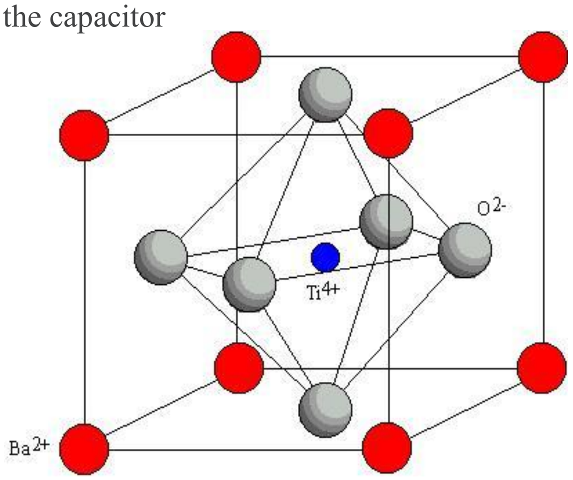
Barium Titanate ($BaTiO_3$) has a ferroelectric tetragonal phase below its curie point of about 120°C and paraelectric cubic phase above Curie point. The temperature of the curie point appreciably depends on the impurities present in the sample and the synthesis process.

**DIELECTRIC CONSTANT**

The dielectric constant (ε) of a dielectric material can be defined as the ratio of the capacitance using that material as the dielectric in capacitor to the capacitance using a vacuum as dielectric.

Dielectric constant (ε) is given by $\varepsilon = \dfrac{C}{C_0}$ where $C_0 = \dfrac{\varepsilon_0 A}{t}$

$C$ = Capacitance using the material as the dielectric in the capacitor
$C_0$ = Capacitance using vacuum as the dielectric
$\varepsilon_0$ = Permittivity of free space ($8.85\times10^{-12}$ F/m).
$A$ = Area of the plate /sample cross section area.
$t$ = Separation between two plates of the capacitor having vacuum as dielectric




**5.0 Apparatus required:**

- Two probe arrangement
- Barium Titanate ($BaTiO_3$,) plate
- Oven
- Oven Controller
- Digital Capacitance Meter

**6.0 PROCEDURE:** (Don't write the procedure in your Lab. Copy)

- Calculate $C_0$ with the supplied values of $A$, $\varepsilon_0$ and $t$.

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- Switch on the heater. Rotate the temperature controlling knob by one division. The LED will be illuminated which indicates the oven is on and the temperature increases.

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- Note down the increasing temperatures and corresponding capacitance ($C$) in the Table – 1 until a certain final temperature is attained and the LED gets off. If this temperature is not appreciably high, rotate temperature controlling knob by one more division. The LED will be illuminated again and the temperature of the oven increases further.

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- Again start to note down the increasing temperatures and corresponding capacitance in the Table – 1. Each time from the formula calculate the value of dielectric constant

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- Continue the above steps until you have an appreciable high temperature (say 180°C)

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- Draw a graph to show the variation of dielectric constant with temperature (Temperature is along $x$-axis and Dielectric along $y$-axis.) From the graph determine the Curie temperature where the dielectric constant is maximum

**7.0 Tabulation:**

Sample: Barium Titanate ($BaTiO_3$) Area ($A$): 57.15 $mm^2$ Thickness ($t$): 1.67 mm
Permittivity of Space ($\varepsilon_0$): $8.85\times10^{-12}$ F/m or $8.85\times10^{-3}$ pf/mm

Dielectric Constant $\varepsilon = \dfrac{C}{C_0}$ where $C_0 = \dfrac{\varepsilon_0 A}{t} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots pf$

**TABLE-1**

**Temperature (°C) - Capacitance, C (pf) data**

| Sl.No. | Temperature (°C) | Capacitance $C$ (pf) | Dielectric Constant ($\varepsilon$) = $C/C_0$ |
|---|---|---|---|
| 1 | 25 | | |
| 2 | 35 | | |
| .. | | | |
| .. | 95 | | |
| .. | 100 | | |
| .. | 105 | | |
| .. | | | |
| .. | 125 | | |
| .. | 128 | | |
| .. | 129 | | |
| .. | 130 | | |
| .. | .. | | |
| .. | 136 | | |
| .. | 138 | | |
| .. | 140 | | |
| .. | 145 | | |
| .. | .. | | |
| | 180 | | |

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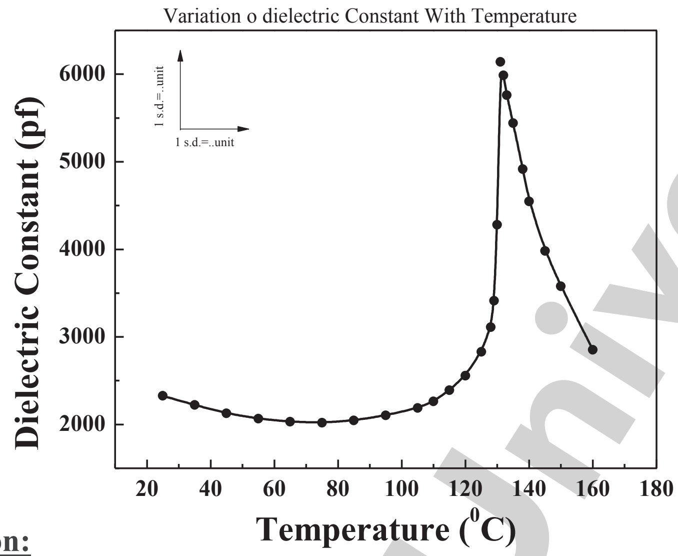
Curie temperature (From Graph) = $\quad\quad\quad\quad$ $^{o}$C




**8.0 Error calculation:**

We have the formula for the Dielectric constant as $\varepsilon = \dfrac{C}{C_0}$ where $C_0 = \dfrac{\varepsilon_0 A}{t} = ........pf$

So, $\varepsilon = \dfrac{Ct}{\varepsilon_0 A}$

Taking ln in both sides we get, $\ln \varepsilon = \ln C + \ln t - \ln \varepsilon_0 - \ln A$

Differentiating we get for maximum proportional error,

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

( Rest of the term will be zero as t, $\varepsilon_0$, and A are constants and differentiation of these terms will vanish)

δC= error in measuring C
= smallest division of the capacitance meter.
(Because probability of making error is in one side)

Hence, the percentage error is $\left(\dfrac{\partial\varepsilon}{\varepsilon} \text{ x } 100\right)$ %

**9.0 Discussion** :

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

**References**

1) Solid State Physics – S. O. Pillai
2) Solid State Physics – Kittle
3) Solid State Physics – Dekker
4) Feynman Lecture Vol. 2.