EXPERIMENT

DIELECTRIC BEHAVIOUR OF BARIUM TITANATE

AIM: To determine dielectric constant (ξ) and the Curie-Weiss Temperature (Tc) of Barium Titanate.

THEORY: Barium titanate, $BaTiO_3$, exhibits the following polymorphic transformations:

$$\text{Rhombohedral} \underset{\leftarrow}{\overset{-80^0C}{\rightarrow}} \text{Orthorhombic} \underset{\leftarrow}{\overset{0^0C}{\rightarrow}} \text{Tetragonal} \underset{\leftarrow}{\overset{120^0C}{\rightarrow}} \text{Cubic}$$

The tetragonal-cubic phase change at 120^0C is studied in the present experiment. The cubic $BaTiO_3$, stable at temperatures over 120^0C, has the perovskite structure as shown in Fig 5.1

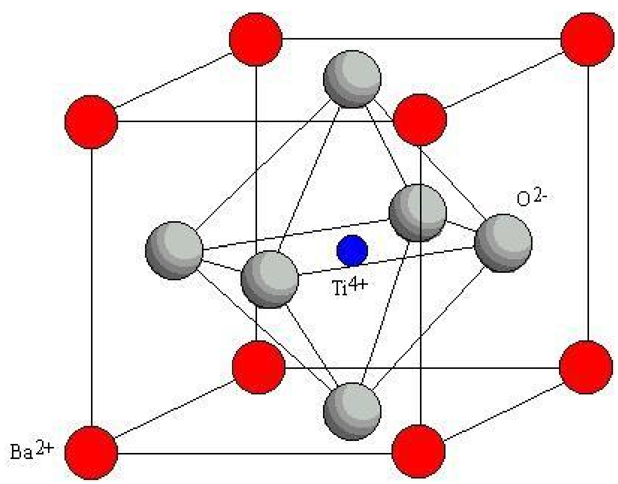

Fig. 5.1 Barium Titanate

On cooling below 120^0C, one of the cubic edges becomes elongated so that the material assumes tetragonal symmetry **($a=b\neq c$; $\alpha=\beta=\gamma=90^0$)**. At room temperature, **$c/a = 1.01$**; the c axis is elongated by **1** percent. The titanium ion is centrally located with respect to the six surrounding oxygen ions in the cubic phase.

The equidistant tetragonal distortion produces a perturbation in the crystalline potential within the unit cell so that the titanium ion, instead of remaining equidistant from the two oxygen ions in the c- direction, moves closer to one oxygen ion or another. This non - centro symmetric location of the titanium ion sets up a permanent dipole and causes spontaneous ionic polarization. When the direction of the spontaneous polarization of a material can be reversed by an applied electric field, the material is called a ferroelectric and the phenomenon, ferroelectricity. A ferroelectric material (e.g. **BaTiO3**) exhibits the following characteristics:

(i) High dielectric constant, l0-l0,000, compared to 1-10 for most materials.
(ii) A hysteresis loop between the dielectric displacement, D, and the electric field, E, analogous to the B-H hysteresis loop of a ferromagnetic material.
(iii) A critical temperature, called the Curie temperature, beyond which the spontaneous polarization is lost and the material becomes paraelectric.
(iv) A sharp peak in the dielectric constant-temperature plot, occurring at the Curie temperature.
(v) Domains, or volume elements in which the direction of polarization is uniform.
(vi) Domain growth: under the influence of an applied electric field, favorably oriented domain grow at the expense of those less favorably oriented, through domain wall motions.
(vii) Curie-Weiss temperature dependence: above the Curie temperature, the dielectric constant (Ç) varies with temperature (T) as stated in the Curie-Weiss Law:

$$\xi \ (T-T_C) = C$$

where C is called the Curie constant and T_C is the Curie-Weiss temperature.
(viii) Piezoelectricity: electric charge is generated by the application of mechanical pressure and conversely, crystal dimension can be changed by applying an electric field.

The chief application of ferroelectric material such asBaTi3 arise from these properties. For example, ferroelectric materials are used for miniature capacitors because of their high dielectric constant: for memory devices because of their D-E hysteresis loops: or for electro-mechanical transducers because of their piezoelectric behavior.

EQUIPMENT:

Barium titanate sample, Sample holder, A tube furnace, Chromel-Alumel thermocouple and Milli-voltmeter, Capacitance meter.

PROCEDURE:

1. Measure the diameter and the thickness of the specimen with a micrometer. Note down the values from the label pasted on the furnace. Place the sample disk in the specimen holder and the specimen holder in the tube furnace.
2. Connect the specimen holder to the capacitance bridge.
3. Heat the furnace from room temperature to 150^0C.

4. Measure capacitance (in pF) for every 10^0C rise of temperature up to 150^0C. Take closer temperature intervals in the vicinity of phase change.
5. Plot the capacitance (pF) vs temperature (^{0}C).

From the dimensions of the sample the dielectric constants (ξ) can be calculated as follows

$\xi = C\,(d/A\,Ç0)$

C= is measured capacitance (farads)
A= Area of cross section (meters^2)
d = Thickness (meter)
$\xi_0 = 8.85 \times 10^{-12}$ (farad/m.)

6. Estimate the Curie-Weiss Temperature (TC) from the curve.

QUESTIONS:

1.What factors contribute the difference between the observed value and literature value (120^0C) of the Curie temperature?

2.Estimate the temperature coefficient of capacitance in the temperature range normally used for electronic components,say room temperature to 80^0 C.