Study of Dielectric Constant and Curie Temperature of Ferroelectric Ceramics

Introduction

Dielectric or electrical insulating material are understood as the material in which electrostatic field can persist for long times. Layers of such substance are commonly inserted into capacitors to improve their performance, 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 (BaTiO3-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 (CaTiO3) having a structure of the type ABO3 (Fig 1).

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 (Tc). At T>Tc, the crystal does not exhibit ferroelectricity, while for Tc 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 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 (e) with temperature for Lanthanum doped Lead Zirconate Titanate (PLZT) ceramic, which is cooled from its paraelectric cubic phase to ferroelectric rhombohedral phase.

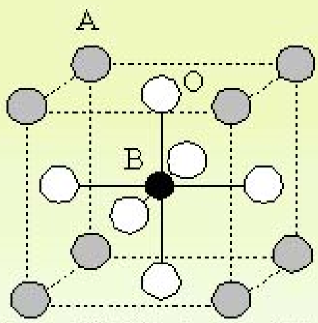

Fig 1 Perovskite ABO_3 structure with the A and B cations on the corner and body centre positions, respectively. Three oxygen anions per unit cell occupy the faces and form octahedra surrounding the B-site.

Fig 1

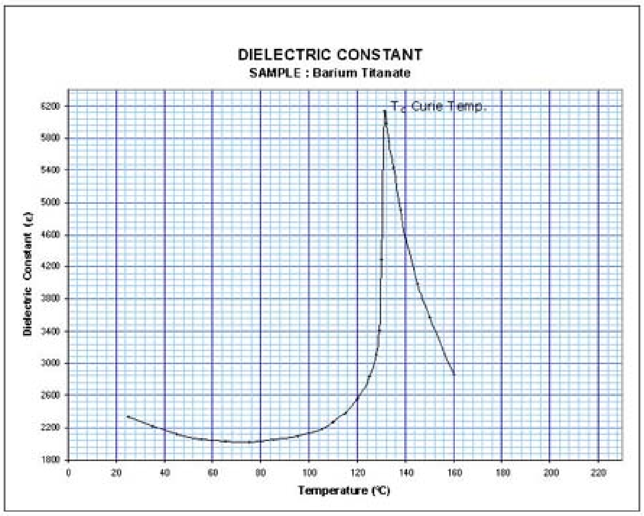

Fig 2

Description of the experimental set-up

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 in the sample plate just below the sample. This stand also serves as the lid of temperature controlled oven. Proper leads are provided for connection to Capacitance Meter and Temperature Controller.

Sample

Barium Titanate (BaTiO3)

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.

Main Units

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

a) 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 of the Oven	
Temperature Range	Ambient to 473K
Resolution	1K
Stability	0.5K
Measurement Accuracy	1K (typical)
Oven	Specially designed for Dielectric measurement
Sensor	RTD (A class)
Display	3½ digit, 7 segment LED with autopolarity and decimal indication
Power	150W

b) Digital Capacitance Meter

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

Specifications of the Oven	
Range	50-6000pf
Resolution	1pf
Display	3½ digit, 7 segment LED with autopolarity and decimal indication

Typical results obtained with the above set-up are as shown in Fig 2.

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