Activities of Laboratories

Dielectrics Laboratory at Indian Institute of Technology Ropar

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1. Introduction

The Indian Institute of Technology Ropar (IIT Ropar) is a new generation IIT, set up by the Ministry of Human Resource Development (MHRD), Government of India, in 2008, to expand the reach and enhance the quality of technical education in India. Currently the institute operates from a transit campus, situated in Rupnagar town of Punjab state in northern India. It has been allotted a land of 500 hectors on the bank of river Sutlej in Rupnagar, where the permanent campus will be set up within a few years.

The institute has already initiated dielectric research laboratory as well as several central facilities (already established), that are useful for carrying research on dielectric materials in the transit campus. Also, plans to build a new generation high voltage laboratory are already floated for future new campus.

The objectives of current dielectrics laboratory are as follows:

1. Education: The laboratory is useful for under-graduate study in electric fields and space charges in dielectrics supplementing lecture courses.

2. Research: The laboratory contributes to various research fields including space charges and electric fields in dielectrics, measurement techniques, nano-composite materials for electrical insulation, development and applications of novel dielectric materials for high-speed circuits.

State-of-art space charge measurement equipment, electrometer (pico ammeter), a 100 kV hv source for breakdown test and a hv amplifier (±20 kV) are on track for the laboratory. Apart from these equipments, institute's central research facilities augment the dielectrics lab for nano-composite dielectric research.

As a part of this facility Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS) facilities have been created by the institute, Fig. 1. The SEM uses a focused beam of high energy electrons to generate a variety of signals that reveal the information about the sample including external morphology, chemical composition, crystalline structure and orientation of materials making up the sample. The EDS is an analytical technique used for elemental analysis or chemical characterization of sample.

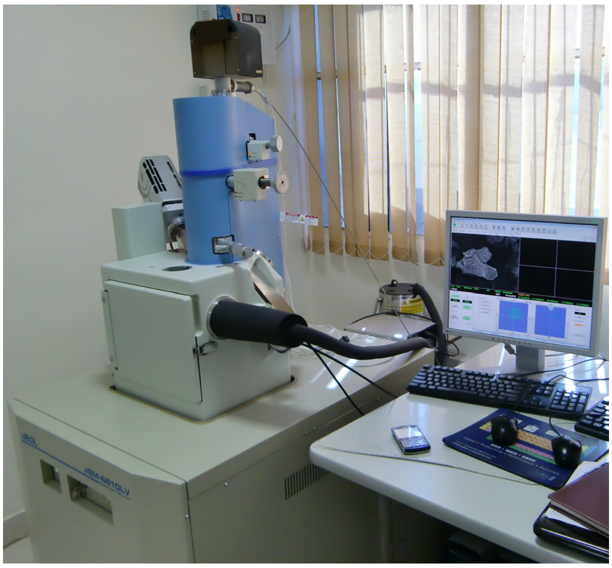

Fig. 1: Scanning Electron Microscope at IIT Ropar

2. Research

In the area of space charges, the dielectrics laboratory deals with both the techniques of measurement of space charges as well as the space charge phenomena in dielectrics.

(i) Measurement Techniques

Among the measurement techniques the laboratory is currently engaged on the research on pulsed electro-acoustic (PEA) method. It is planned to develop a novel measurement system that has added capabilities than the existing systems in the world. Simulations that are discussed in sub-section below are already carried out for this purpose.

(ii) Space charge phenomena

The Space charge phenomena are not understood completely until now. The research in this lab is directed towards understanding the relation between various physical properties of materials and space charges in dielectric. Effect of space charge on dielectric breakdown is also being investigated. Measurements of space charge, conduction current and breakdown strength form prime measurements in this research.

In the area of nano-composites, novel dielectric materials for several applications are being researched.

2.1 Simulation of Pulsed Electro-Acoustic Measurement Technique

With the aim to understand the design and develop an improved measuring system simulation tool is used. Pulsed electro-acoustic measurement technique, whose block diagram is given in Fig. 2, was simulated using PSpice software, Fig. 3, and this helped in understanding some design related issues of PEA system e.g. effect of coupling capacitor during voltage polarity reversal, as shown in fig.3.

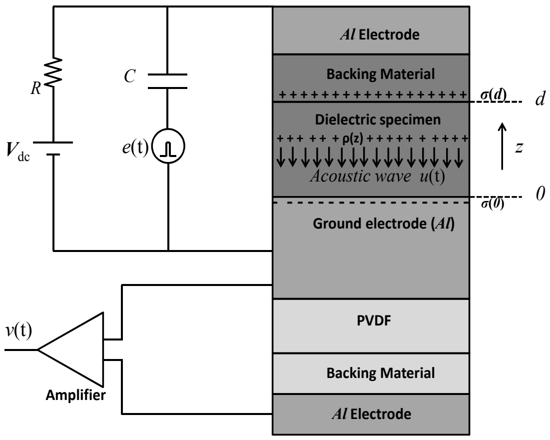

Fig. 2 Depicting the principle of PEA method

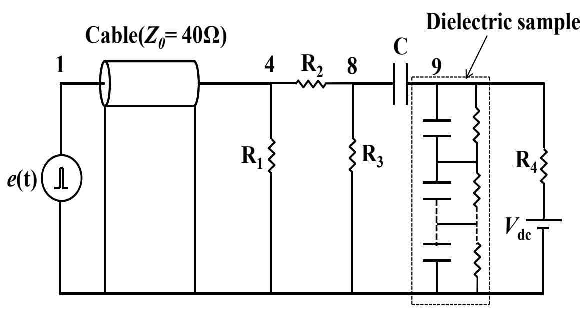

Fig. 3. Model circuit of PEA method

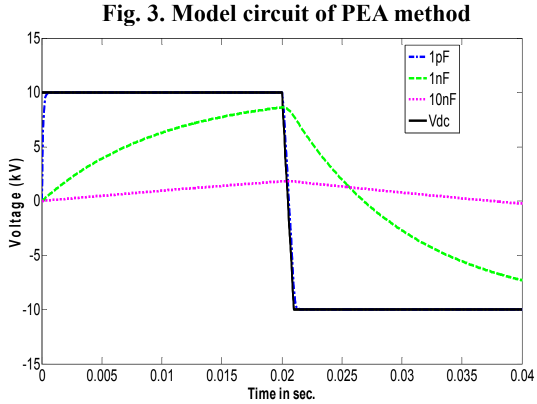

Fig. 4. Voltage at sample during polarity reversal with different coupling capacitance values

2.2 Space Charge Phenomena

Despite copious experimental results, space charge formation in dielectrics is yet to be understood. Dynamics of current conduction across dielectric specimen is attributed for the formation of different types of space charges.

The research in this area is focused on relationship between conduction and different types of space charge formation in dielectrics, namely, charge-packet evolution in certain dielectrics, homo space charge and hetero space charge.

The lab was partly successful in relating steady state space charge distribution to conductivity, diffusion constant and permittivity as,

$$\rho = \varepsilon \frac{dE}{dx} = \varepsilon \sqrt{\frac{\sigma}{\varepsilon D_c}} \left(E_0 - \frac{J_0}{\sigma} \right) \frac{Sinh\left(\left[x - \frac{d}{2} \right] \sqrt{\frac{\sigma}{\varepsilon D_c}} \right)}{\cosh\left(\frac{d}{2} \sqrt{\frac{\sigma}{\varepsilon D_c}} \right)}$$

and the electric field distribution as,

$$E = \left(E_0 - \frac{J_0}{\sigma} \right) \frac{\cosh\left(\left[x - \frac{d}{2} \right] \sqrt{\frac{\sigma}{\varepsilon D_c}} \right)}{\cosh\left(\frac{d}{2} \sqrt{\frac{\sigma}{\varepsilon D_c}} \right)} + \frac{J_0}{\sigma}$$

where, standard symbols are used to mean various quantities. The experimentally observed phenomena of homo and hetero charge profiles have been explained by these equations

Referring to Fig. 5, imbalance in charge profile has been shown to be due to imbalance in diffusion coefficient of positive and negative charge carriers.

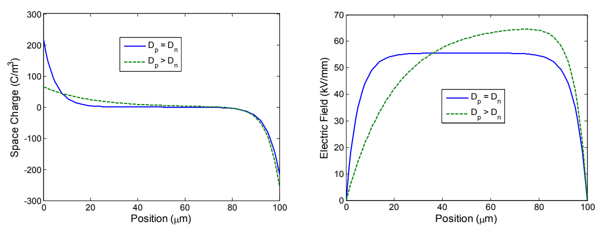

Fig. 5 Space charge profile and electric field due to unbalanced diffusion

The research is still continuing with a hectic activity of young institute shaping its future with modern technology.

Acknowledgment

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