Variation of Dielectric Properties with Temperature In (HgO – $PbCrO_4$) Solid Mixture

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Abstract - In this work variation of dielectric properties like capacitance, conductance and Loss factor (tan δ) of (HgO – $PbCrO_4$) solid mixture with temperature have been studied. The solid mixture of HgO and $PbCrO_4$ were prepared by heat treatment technique taking temperature 400 ˚C for 30 min. The best result obtained with composition (75%HgO – 25% $PbCrO_4$). Measurements were made by thick binder layer (cell). For this cell were fabricated in the form of parallel plate capacitors. The capacitance(C) and conductance (G) were measured through an a.c bridge LCR- Q meter. The measurements have been carried out in temperature range of 309 K to 335 K. The capacitance (C), conductance (G) and loss factor (tan δ) decreases with increasing temperature. The decrease in capacitance with temperature is due to decrease in number of equilibrium carriers available for the space charge formation with increasing temperature. The decrease in conductance (G) and loss factor (tan δ) with increasing temperature may be attributed mainly to the contribution of the frequency independent dc conductivity towards the measured loss factor.

Key word: Dielectric, Loss factor, Mixed material, Thick binder layer.

I. INTRODUCTION

The dielectric properties of insulators are also important to a wide range of electrical product, where rapid manufacturing parts may be used as components or housing. There are several different dielectric properties like Dielectric loss (tan δ), Dielectric constant, Volume Resistivity, surface Resistivity, Conductance etc. that can be used to quantity the Dielectric performance of material and depending upon the applications. The loss factor (tan δ) represents the energy loss from the absorption process, and is a ratio of the energy which is dissipated to the energy which is stored in the materials.
The effect of frequency and temperature on dielectric behavior offers much valuable information about the localized charge carrier which in turn helps to elucidate the mechanisms responsible for charge transport phenomena and dielectric behavior[1].
When certain photoconducting material are placed as a dielectric in sandwiched type cell in presence of alternating field , the radiation absorbed by the photoconductor increases the capacitance(C) , conductance(G) and dielectric loss (tan δ). This phenomenon is known as Photodielectric effect (PDE)[2].These studies have been made in several material like ZnS in ZnO [3], CdS powder and in single crystal[4][5]. The dielectric properties were studied on polymers [6] and solution and poly film [7]. The a.c conductance and dielectric properties were also carried on the sheet of polycarbonate [8]. Change in dielectric properties in presence of light is essentially another manifestation of photoconductivity was investigated by Kallmann [9], [10]. According to Garlic and Gibson [11] the change in capacitance (C), conductance (G) and loss factor (tan δ) is due to real change in the dielectric constant arising bound to certain trapping centre .The dielectric properties like capacitance, conductance and loss factor are controlled by the intensity of illumination, a.c. field frequency and temperature [12],[13]. The capacitance increase with increasing intensity of illumination .The space change is observed only in the lower frequency region. The variation of the a.c. conductance with frequency may be due to the variation in the formation of space change. Study of dielectric properties have been made on number of materials [14][15][16]. But mixed material have been relatively less reported demands for special material led to the conception of composites , since valuable properties of different types of material can be combined . So, In this paper study is made on (HgO-PbCrO4) mixed material in thick binder layer.

II. EXPERIMENTAL DETAIL

The mixed material of HgO and PbCrO4 was synthesized by heat treatment technique. For this high purity HgO and PbCrO4 were taken in different proportions by weight and ground properly in order to get homogeneous mixing. This mixture was then fired in a ceramic tube in a cylindrical furnace in air atmosphere. Then heated material was suddenly quenched to room temperature and again ground. For measurement purpose the cells were fabricated in the form of parallel plate capacitors, by embedding the sensitive material in polystyrene binder and sandwiching it between Aluminum plate and conducting glass plate. The cell area was 2.25 cm2 and the thickness was varied from 0.053 cm to 0.059 cm. For the change of field frequency and voltage arbitrarily, two conducting glass plates were connected at the ends of the capacitor. This makes the cell a four electrodes system. The capacitance and conductance were measured through an a.c. bridge LCR-Q meter. The external field was obtained through an oscillator cum amplifier assembly. The cell was mounted in a chamber under complete darkness and radiations from Hg-lamp (300 W) were allowed through a window over the transparent surface of the cell.

III. RESULTS AND DISCUSSION

Various synthesizing parameters such as firing temperature, time and composition (% of PbCrO4)of the sample were changed to get optimum conditions of capacitance variation. Best change in dielectric properties were observed in (75% HgO- 25% PbCrO4) sample fired at 400°C for 30 min. So the general measurements have been made with cells using the above sample. The variation of capacitance (C), conductance (G) and loss factor(tan δ)with intensity of illumination and Temperature have been measured. The results are as following:

3.1 VARIATION OF CAPACITANCE WITH TEMPERATURE

Table 3.1 shows the variation of capacitance with temperature. The observations have been taken in dark(CD)and as well as under illumination(CI).

Table 3.1: Variation of Capacitance (C) with Temperature for (75% HgO- 25% $PbCrO_4$), (Frequency = 1.5 kHz, Intensity of Illumination =5400 lux, a.c voltage =30 volts)

Sr. No.	Temperature(K)	Capacitance In Dark(C_D) (in pF)	Capacitance In light (C_P) (in pF)
1	308	216	230
2	312	200	206
3	318	188	198
4	324	184	194
5	334	182	188

The CD and CI both decreases with increasing temperature. The decrease in the dark capacitance with increasing temperature at the lower temperature side can be explained on the basis of the space charge [12] hypothesis. The number of equilibrium carriers available for space charge formation decrease with increasing temperature, thereby decreasing the capacitance. The decrease in capacitance with increasing temperature, at first sight is also indicative of a dependence of the capacitance on some filled traps [17]. More and more detrapping takes place with increasing temperature, thus a fall in capacitance is obtained. An increase of CD with temperature may be attributed to the creation and destruction of diploes leading to appreciable space charge polarization. Illumination causes generation of charge carriers which ultimately increases total space charge. This explains the occurrence of higher values of CI than the corresponding value of CD.

3.2 VARIATION OF CONDUCTANCE WITH TEMPERATURE

Table 3.2 shows the variation of conductance with temperature .The observations have been take in dark (GD)as well as under illumination(GI).Table 3.2 shows that GD and GI decrease with temperature .This behavior of GD is due to the contribution of the frequency independent d.c. conductivity[18] .

Table 3.2: Variation of Conductance (G) with Temperature for (75% HgO- 25% $PbCrO_4$), (Frequency = 1.5 kHz, Illumination Intensity of =5400 lux, a.c voltage =30 volts)

Sr. No.	Temperature(K)	Conductance In Dark(G_D) (in $k\Omega^{-1}$)	Conductance In light (G_P) (in $k\Omega^{-1}$)
1	308	13.8	14.8
2	312	11.4	11.8
3	318	9.6	10.0
4	324	8.6	9.0
5	330	8.0	8.4
6	334	7.0	7.6

3.3 VARIATION OF LOSS FACTOR WITH TEMPERATURE

The variation of loss factor (tan δ) with temperature is shown in Table 3.3. The tan δ is calculated using the formula $\tan \delta = G/\omega C$ where G is conductance (G = 1/R), ω is angular frequency (2πf) and C is capacitance. The observations have been taken both in dark and under illumination. The tan δD and tan δI both initially decreases with increasing temperature up to 309°K, then increasing in higher temperature region. This may be attributed to the contribution of the frequency independent d.c conductivity [19] towards the measured loss factor. For (75% HgO-25% PbCrO4) composition the conductivity initially decreases with temperature and then increases in higher temperature side. Slightly larger value of tanδI is due to the photogenerated carriers which increases the space charge.

Table 3.3: Variation of loss factor (tan δ) with Temperature for (75% HgO- 25% $PbCrO_4$), (Frequency = 1.5 kHz, Intensity of Illumination =5400 lux, a.c voltage =30 volts)

Sr. No.	Temperature(K)	Loss factor in Dark($\tan \delta_D$) x 10^{-2}	Loss factor in Light ($\tan \delta_I$) x 10^{-2}
1	308	64	65
2	312	61	62
3	318	58	56
4	324	50	47
5	334	44	49

IV.CONCLUSION

The decrease in capacitance and conductance with increasing temperature is indicative of dependence of capacitance on same filled traps. More and more de-trapping takes place with increasing temperature. Variation of loss factor with temperature may be attributed to the contribution of dc conductivity towards the measured loss factors.

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