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Study of Variation of Capacitance in (ZnO-$PbCrO_4$) Thick Binder Layer

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Abstract: ***In this paper the variation of capacitance with different parameters like compositions, intensity of illumination, a.c frequency and temperature has been studied. The solid mixture of (ZnO- $PbCrO_4$) was prepared by heat treatment technique. For measurement purpose the thick binder layer (cell) were fabricated in the form of parallel plate capacitors, by embedding the sensitive material in polystyrene binder and sandwiching it between aluminium plates and conducting glass plate. The best result was obtained with (75%ZnO- 25% $PbCrO_4$) composition heated at 600˚C for 35 minute. The measurements ware carried out in frequency range 1kc/s – 45kc/s with intensity of illumination upto 1200lux and at temperature between 31˚C to 79 ˚C. Increase in capacitance at high frequencies suggest of dipolar relaxation effect. The capacitance in the presence of light is higher than in dark due to the presence of greater total space charge.***

Keywords: Dielectrics, Capacitance, Mixed material, Thick binder layer, Radiation.

1. Introduction

Capacitance is ability of body to store an electrical charge. Any material that can electrically charged exhibits capacitance. Certain photo conducting materials in the form of sandwich type cell are found to exhibit an increase in the capacitance when exposed to radiation in presence of alternating field. This is known as photo dielectric effect (PDE).The change in capacitance with different parameters like light, ac field frequency gives us valuable information about the electronics process taking place inside the material. Though such information is also obtainable by using dc method, there are a large number of situations where dc method fails to yield useful information [1], [2]. Study of capacitance variation on powers of ZnS, ZnO or CdS [3], [4] and compounds of GaAs, GaP [5], ZnS activated with copper have been made. The frequency and composition dependence on the dielectric properties is made on ferriet materials too [6]. In the case of powdered material, the photocurrent characteristics cannot be attributed to change in bulk conductivity, with the consideration of nature of intergranular and sample-electrode contacts [7]. In these situations ac measurements are more successful than dc techniques [2].

According to Garlik and Gibson [8] the effect could be attributed to the real change in the dielectric constant arising from the additional polarizability of the photo excited carriers loosely bound to certain trapping centers. Some authors consider that change in capacitance is due the presence of photoconductivity in certain portions of the cell which effectively decreases the distance between the plates of the capacitors and hence increase the capacitance and the apparent dielectric constant. Existence of space charge at grain boundaries has also been held responsible [9] for it.

Study of capacitance variation has been made on a number of materials [10], [11] but mixed materials have been relatively less reported. Increasing demands for special materials led to the conception of composites, since valuable properties of different types of materials can be combined. Capacitance studies on ZnO material have been made by many workers [12]. In this paper study is made on (ZnO-$PbCrO_4$) mixed material. The capacitance is controlled by intensity of illumination, field frequency and temperature [10], [13]. For (ZnO- $PbCrO_4$) mixed material the capacitance increases with increasing intensity of illumination.

2. Experimental Detail

For the preparation of solid mixture of ZnO and PbCrO4 high purity $PbCrO_4$ and ZnO 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 Aluminium plate and conducting glass plate. The cell area was 2.25 cm^2 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 was 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.

3. Results and Discussions

Various synthesizing parameters such as firing temperature, time and composition (% of $PbCrO_4$)of the sample were changed to get optimum conditions of capacitance variation. Best change in capacitance was observed in (75% ZnO-25% $PbCrO_4$) sample fired at 600˚C for 35 min. So the general measurements have been made with cells using the above sample. The variation of capacitance with intensity of illumination, a.c. field frequency has been measured. The results are as following:

A. Variation with Intensity of Illumination

The variation of capacitance (C) with intensity of illumination is shown in Table.1. The measurements have been made for two different samples i.e. (75% ZnO -25% $PbCrO_4$) and (25% ZnO - 75% $PbCrO_4$) samples. For both the samples capacitance initially increases with intensity of illumination then saturation is observed in higher light intensity side. This is due to increase in space charge. Space charge is an electrical inhomoginity appearing in the material [13] which causes dielectric losses. The probable mechanisms for space charge formation are:

(a) Polarization of equilibrium charge carriers under the action of electric field.
(b) Polarization of photo generated carriers.
(c) Injection of charge carriers from the electrode.

Space charge is formed (1) near the electrode (2) around the boundaries and (3) both with in the volume and at the surface of the bulk.

More and more charge carriers are generated with increasing intensity of illumination. This increases the total space charge due to photo generated carriers. Thus capacitance increases with light intensity. The changes of the capacity are accompanied by relatively fast changes of the electrical conductivity which reaches quite rapidly its saturation value with the increasing illumination intensity. The capacitance is larger for (75% ZnO- 25% $PbCrO_4$) sample in comparison to (25% ZnO-75% $PbCrO_4$) sample. So the general measurements have been made for this sample.

Table 1(a): Variation of capacitance with Intensity of illumination for (75% ZnO- 25% $PbCrO_4$) composition (frequency = 1 kHz, a.c field = 566.6 volts/cm and temperature =28 ˚C).

Sr. No	*Intensity of Illumination (lux)*	*Total Capacitance (pF)*
1	0	440
2	20	480
3	100	500
4	180	520
5	380	530
6	500	540
7	1000	540
8	1200	540

Table 1(b): Variation of capacitance with Intensity of illumination for ((25% ZnO- 75% $PbCrO_4$) composition (frequency = 1 kHz, a.c field = 566.6 volts/cm and temperature =28 ˚C)

Sr.No.	*Intensity of Illumination (Lux)*	*Total Capacitance (in pF)*
1	0	60
2	40	90
3	120	100
4	180	120
5	340	120
6	500	120
7	700	130
8	1000	140
9	1200	140

B. Variation with Field Frequency

The capacitance is large for composition (75% ZnO- 25% $PbCrO_4$), so the measurements have been made for this sample. Under fixed illumination of 1200 lux and 30 volts a.c field of variable frequency, the variations of capacitance have been shown in Table 2. Measurements have been also made in dark. it is observed that the capacitance of the layer decreases with increasing frequency up to 6Kc/s both in light (C_I) and dark (C_D), but increases as the frequency is increased further. The larger value of C_D at lower frequency can be explained on the basis of space charge polarization. Space charge or interfacial [14] polarization arises generally due to the inhomogenity in the electrical properties of a dielectric. The charges either electrons or ions may tend to pile up at the edges of intercrystalline boundaries of a sample. This takes place at the lowest frequency. At low frequencies, it is possible for the space charge formation to be in step with the variation of the applied field [15]. But this is not possible at higher frequencies. So space charge is noticeable only in the lowest frequency region. This explains why capacitance decreases with increasing frequency. Illumination causes generation of charge carriers which ultimately increases total space charge. This explains the occurrence of higher values of C_I than the corresponding value of C_D. Increase in capacitance at higher frequencies suggest of dipolar relaxation effect. It is expected that some diploes exist in material though their exact nature can not be understood from the present study.

Table 2: Variation of capacitance with frequency of a.c. field (Intensity of Illumination= 1200 lux, a.c field = 566.6 volts/cm and Temperature =28 ˚C).

Sr. No.	*Frequency (in kHz)*	*Capacitance in Dark C_D (pF)*	*Capacitance in Light C_I (pF)*
1	1	430	450
2	2	200	230
3	3.5	80	160
4	4.0	60	150
5	5.0	35	130
6	6.0	50	80
7	8.0	60	120
8	14	70	150
9	20	160	180
10	24	240	260
11	30	300	580
12	40	340	630
13	45	460	650

C. Variation with Temperature

Table 3 shows the variation of capacitance temperature. The observations have been taken in dark (C_D) as well as under illumination (C_I). The C_D and C_I decreases with increasing temperature up to 60°C, but beyond this C_D increases and C_I decreases with 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 hypothesis.

Table 3: Variation of capacitance with temperature (frequency = 1 kHz, a.c field = 566.6 volts/cm and Intensity of illumination = 1200 lux)

Sr. No.	Temperature (°C)	Capacitance in dark C_D (pF)	Capacitance in light C_I (pF)
1	30	500	530
2	35	460	480

3	40	425	430
4	45	410	420
5	55	400	410
6	61	390	395
7	67	400	395
8	72	410	390
9	79	410	390

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 [16]. More and more detrapping takes place with increasing temperature, thus a fall in capacitance is obtained. An increase of C_D with temperature may be attributed to the creation and destruction of diploes leading to appreciable space charge polarization.

4. Conclusion

This paper shows that the capacitance of a material varies with composition, a.c. frequency, intensity of illumination and temperature. The capacitance has larger value both in dark and light at lower frequency region and increases in higher frequency this is due to Dopler relaxation effect. An increase in capacitance (C_D and C_I) with temperature may be attributed to the creation and destruction of dipoles, leading to appreciable space charge polarization. Electret condenser microphone, as name suggested is parallel plate capacitor and works on the principle of variable capacitance. Use of electrets has been suggested for biomedical applications.Such developments have thrown new challenges in material science research.

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