

Photoelectret Properties of (HgO-Fe₂O₃) Mixed Material

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Abstract: In this paper the photoelectret properties of (HgO-Fe₂O₃) mixed material have been studied. The Fe₂O₃ is poor photoelectret but when HgO is mixed with Fe₂O₃ then it shows photoelectret characteristics. The HgO which forms mixed material with Fe₂O₃ in different compositions, shows maximum photoelectret charge (Q_{ph}) for (75% HgO- 25% Fe₂O₃), sample. For all the three composition i.e. (75% HgO-25% Fe₂O₃), (50% HgO - Fe₂O₃) and (25% HgO - 75% Fe₂O₃) the photoelectret charge has been found to be greater than the base material 100% HgO and 100% Fe₂O₃. The dependence of photoelectret charge on various parameters such as applied field, intensity of illumination, charging time and dark depolarisation time has been studied to get the optimum condition of maximum charge storage.

Keywords: Photoelectret, Mixed Material, HgO, Photopolarization

1. Introduction

The Electret (formed of elektr – from "electricity" and – et from "magnet") is a dielectric material that has a quasi-permanent electric charge or dipole polarization. An electret generates internal and external electric fields, and is the electrostatics equivalent of permanent magnet. Oliver Heaviside coined this term [1]. The first representative of the electrets was the thermoelectret discovered by Eguchi[2]. The electret family contains nowadays a members – thermoelectrets, photoelectrets, thermophotoelectret, radioelectrets, magnetolectrets etc. The photoelectret was discovered by the Bulgarian physicist G. Nadzakov in 1937 [3]. Nadzakov observed the photoelectret effect by exposing a photoconducting dielectric to light radiation and electric field simultaneously. Space charge accumulated during photoconduction is retained for long time even after removal of electric field and illumination. The photoelectret charge (Photoelectret state) is widely used nowadays such as electrophotography, Xerography, Electrofax, Radiation Dosimeters, prosthetic devices, microphones etc. The first publication on photopolarization and photoelectret state in vitreous semiconductors was reported in 1962 by B. Kolomiets et. al [4]. Later photoelectret state was found in many other wide- band gap materials, crystalline or amorphous [5],[6]. The photoelectret properties of both organic, inorganic materials [7],[8] and single base material [9],[10] have been studied by several researchers. Some workers also studied electret effect on monocrystalline [11], rare earth doped material [12], glasses and thin film [13].

Here an attempted has been made to study photoelectret properties on mixed materials. The mixed materials of two or three base materials possess interesting problems. Mixed materials are supposed to have an intermediate energy gap. By varying the relative proportion of two compounds [14] in mixed materials, the resultant energy gap is adjusted accordingly.

3. Results and Discussions

By heat treatment technique, five samples (100% HgO), (75% HgO - 25% Fe₂O₃), (50% HgO - 50% Fe₂O₃) and

HgO having low energy gap (0.3 eV) show photoelectret effect [10], But Fe₂O₃ does not give this property. When the mixed material of the two base materials are formed, a resultant compound material is obtained, the energy gap of which depends on relative composition of the two base material. Thus the composition becomes another effective parameter to control the photoelectret property. The effect of various parameters such as composition, strength of field (E), time of polarization (t_{pp}) and dark depolarization (t_{dd}), light intensity and temperature (T) have been studied.

2. Experimental Details

Samples were prepared by heat treatment technique as described in research paper [15]. The various synthesizing parameters such as firing time, firing temperature and composition were changed to get the optimum photoelectret charge. The optimum firing time and firing temperature were found to be 400 °C and 35 minutes respectively. The electret cells were prepared in the form of parallel plate capacitor for measurement of photoelectret charge as described earlier [15,16]. The cells were spread over area of about 3.1 cm² and the thickness was varied from 0.02 cm to 0.040 cm. To measure the photoelectret charge the cell was kept in a dark wooden chamber with slit, where from the light is allowed to fall over the with the help of 300 W mercury lamp. For the measurements of photoelectret charge (Q_{ph}), the cell was first illuminated in presence of stabilized dc field (from 5 kV/cm to 50 kV /cm) this gave photopolarization of the sample. After this the illumination was cut off, and the field was removed, now short circuiting the electrodes through an electrometer. The free charge carriers now diffuse and recombine giving rise to dark depolarization of polarized cell. After stabilization, again the radiations were allowed to fall on glass electrode in the absence of field causing photodepolarization of the sample. The photodepolarization current was recorded on Y- t graphic recorder. The time integral of the curve gave photoelectret charge, Q_{ph} .

(25% HgO -75% Fe₂O₃) and 100% Fe₂O₃ were prepared. The photoelectret charge has been found to be maximum for (75% HgO - 25% Fe₂O₃) sample fired at 400 °C for 35 minutes. The measurements have been made for three

compositions i.e. (75% HgO - 25% Fe₂O₃), (50% HgO - 50% Fe₂O₃) and (25% HgO - 75% Fe₂O₃). The results are as following:

3.1 Effect of % of Fe₂O₃

The variation of photoelectret charge as a function of percentage of Fe₂O₃ is shown in Figure.1. The (75% HgO -

25% Fe₂O₃) stores optimum charge (Q_{ph}). The Photoelectret charge (Q_{ph}) then decreases as percentage of Fe₂O₃ increases. The 100% HgO sample stores less charges. It is clear from the Fig .1 that the resultant Q_{ph} is increased by mixing the two different base materials. The observation has been made in similar experimental conditions for all compositions.

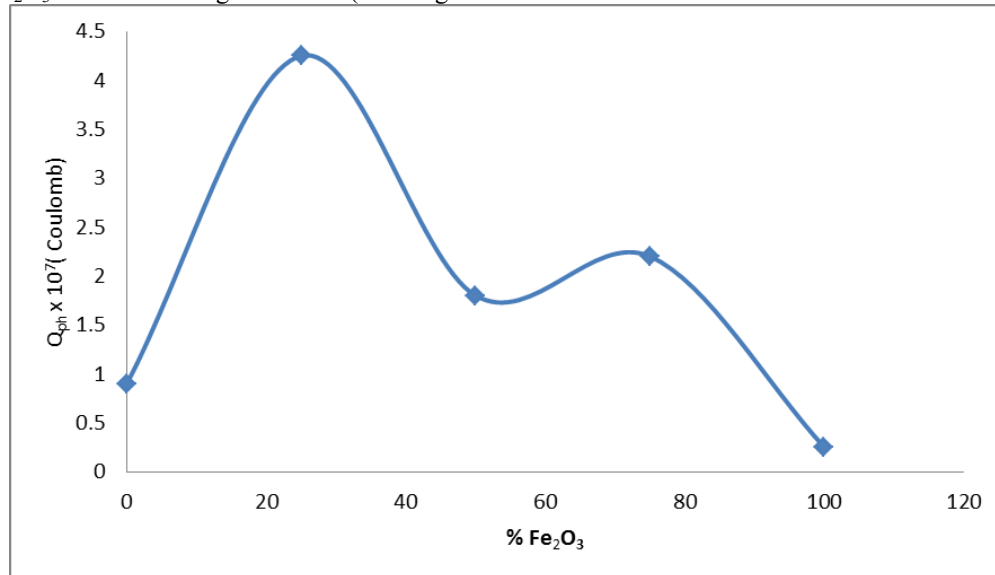


Figure 1: Variation of Photoelectret charge with % of Fe₂O₃ in hgo. (Field = 15 kv/cm, Polarization Time (t_{pp}) = 30 sec, Dark depolarization Time (t_{dd}) = 15 sec, Temp = 20 °C).

3.2 Effect of Polarizing Field

For all the samples the variation of photoelectret charge with field has been shown in Figure.2. It has been confirmed that maximum Q_{ph} is retained by (75% HgO-25% Fe₂O₃) sample. For (75% HgO - 25% Fe₂O₃) sample the photoelectret charge increases rapidly with increase in polarizing field. The Q_{ph} for (25% HgO - 75% Fe₂O₃) sample increases linearly with increase in field. For (50% HgO - 50% Fe₂O₃) and (100% HgO) samples the photoelectret charge first increases and then saturates in higher applied field region. The field is applied from 5kV/cm to 50 kV/cm. The Fig.2 shows that the photoelectret charge increases slowly with increasing field for 100% Fe₂O₃ sample.

In a photosensitive dielectric, illumination causes generation of charge carriers to be available for trapping polarizing field drifts these charge carriers through the dielectric giving rise to an accumulation of trapped carriers towards the surface of the photoconductor. When the field is increased, the spatial shift of the carriers increases which in turn decreases the recombination probability. This explains why Q_{ph} increases with polarizing field.

The saturation [16] in photoelectret charge versus field curves for (50% HgO - 50% Fe₂O₃) and (100% HgO) samples may be due to high potential barriers in layers near the electrodes, which may produce a homocharge at the sample surface and slow down the rise of polarization with increase in the polarizing field. It seems unlikely that the observed saturation is due to complete filling of all trapping levels.

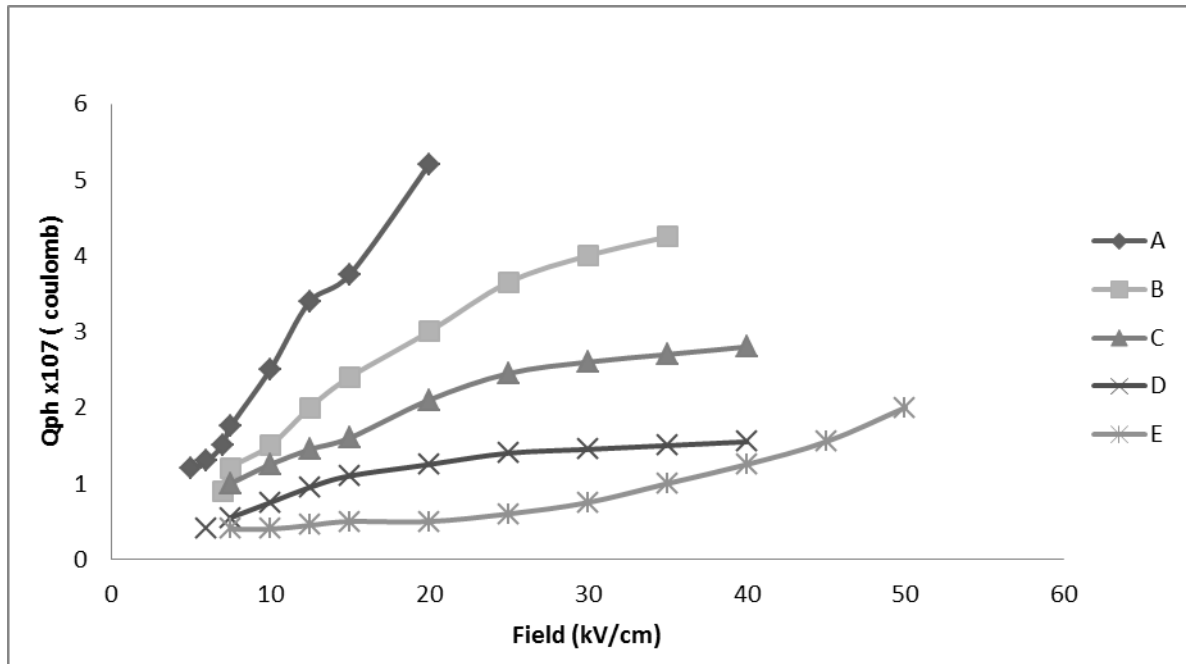


Figure 2: Variation of Photoelectret charge with applied field (Intensity =1800 lux, Polarization Time (t_{pp}) =30 sec, Dark depolarization Time (t_{dd})= 15 sec , Temp= 20 °C). A- (75%Hgo- 25% Fe₂O₃), B- (25%Hgo- 75% Fe₂O₃ and C- (50%Hgo- 50% Fe₂O₃),D-

3.3 Effect Of Polarization Time (Charging Time)

Figure.3 shows the variation of photoelectret charge as a function of charging time (t_{pp}). The measurements have been made for three compositions. The (25% HgO - 75% Fe₂O₃) sample retained more charge than (50% HgO - 50% Fe₂O₃) sample. For all the three samples photoelectret charge increases in the beginning and then tends to saturate. As the

polarization time increases, more and more charge carriers are generated due to which density of free carriers for trapping also increases. These carriers are subsequently released during photo-depolarization. At saturation, equilibrium is established between the rate of generation of carriers and the rate of trapping plus recombination.

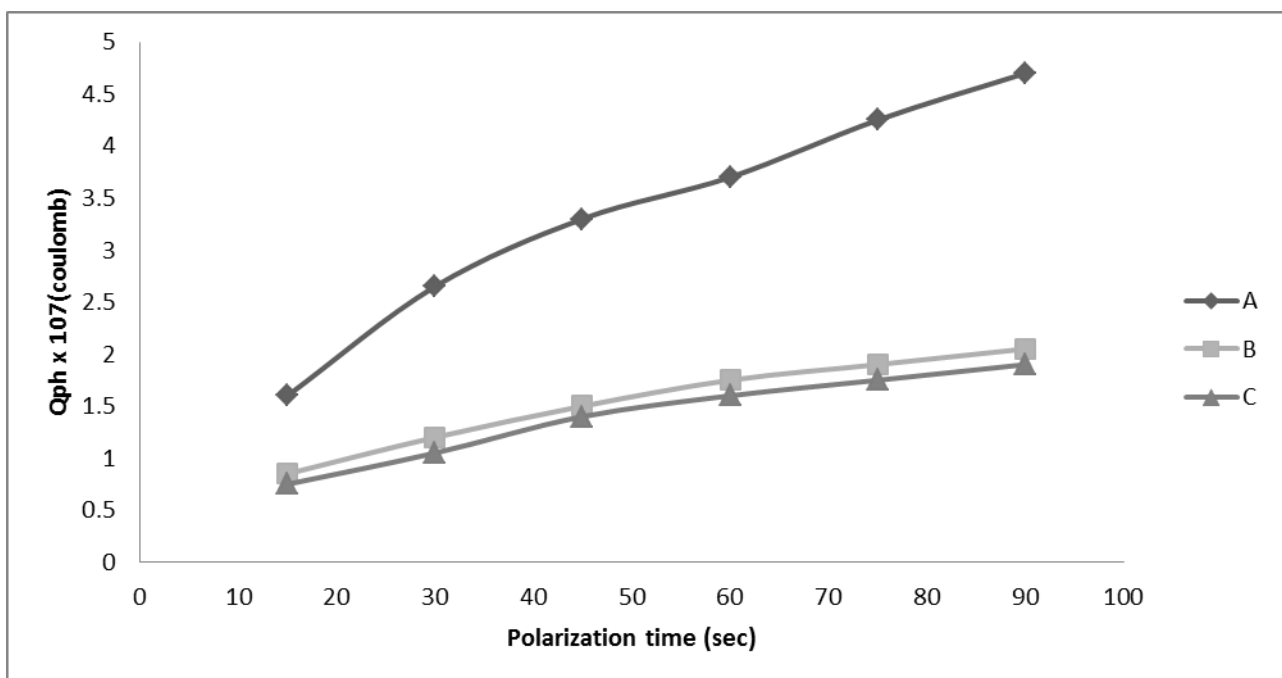


Figure 3: Variation of Photoelectret charge with time of polarization (Temperature =20 °C, Field = 10 kV/cm, intensity= 2100 lux, t_{dd} = 15 sec). A- (75%Hgo- 25% Fe₂O₃), B- (25%Hgo- 75% Fe₂O₃), C- (50%Hgo- 50% Fe₂O₃),

According to Kallmann and Rosenberg[17], the dependence of polarization (P) of photoelectret charge on the duration of polarization, t, obeys the following empirical law:

$$P = P_{\max} (1 - e^{-t/\tau})$$

Where τ is the response time. This has also been reported by Kallmann et al.

3.4 Effect Of Dark-Depolarization Time(t_{dd})

This variation has been shown in Figure .4.The measurements have been made for three samples. It is clear from the figure that the decreases in Qph with increasing dark –depolarization time is slow for (25% HgO - 75% Fe₂O₃) and (50% HgO - 50% Fe₂O₃) samples . For (75% HgO - 25% Fe₂O₃) sample photoelectret charge decreases

linearly with increases in dark –depolarization time. Dark depolarization of photoelectret charge arises due to charge carriers which belong to shallow trap levels. These charge carriers are released thermally at room temperature and recombine under the action of internal field in dark. With increased dark depolarization time, the charge carriers trapped at shallow levels have more chance to get released thermally. Charges trapped in deep levels only remained to be depolarized by illumination.

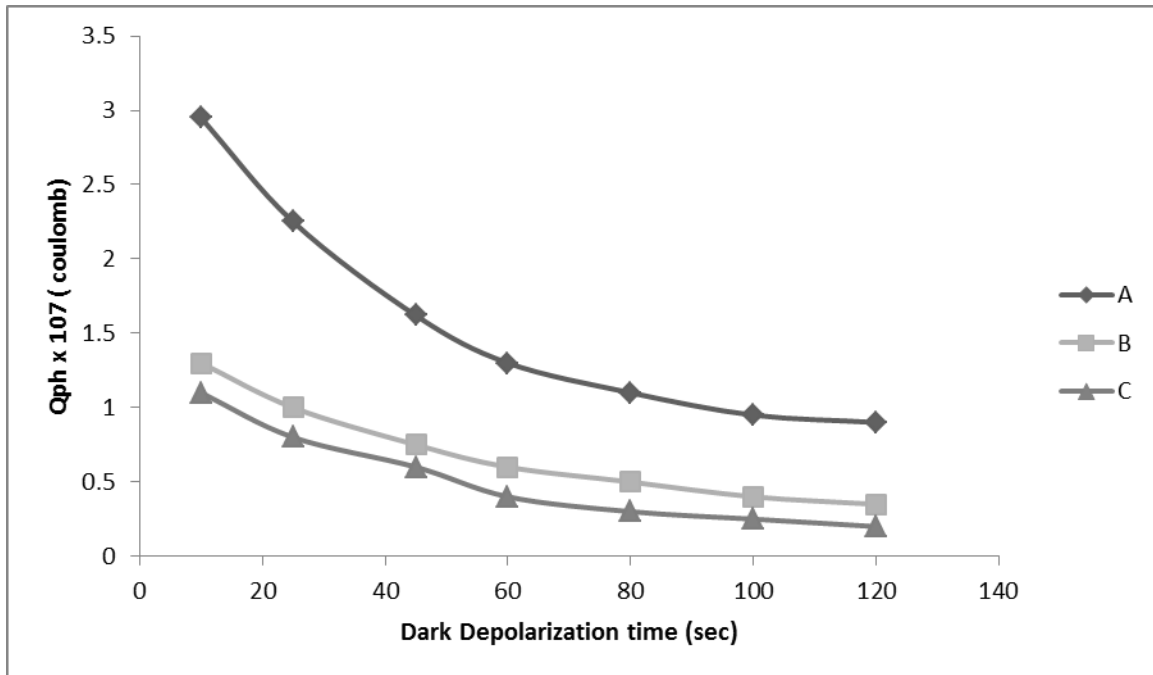


Figure 4: Variation of Photoelectret charge with dark depolarization time (Field = 10 kV/cm, Intensity =2000 lux, Polarization Time (t_{pp}) =30 sec, Dark depolarization Time (t_{dd})= 15 sec , Temp= 20 °C). A- (75%Hgo- 25% Fe₂O₃), B- (25%Hgo- 75% Fe₂O₃) and C- (50%Hgo- 50% Fe₂O₃).

3.5 Effect of Intensity of Illumination

The variation of photoelectret charge with changing intensity of illumination has been shown in Figure.5 .The observations have been taken for three mixed materials i.e. (75% HgO- 25% Fe₂O₃), (50% HgO - 50% Fe₂O₃) and (25% HgO -75% Fe₂O₃), For (50% HgO- 50% Fe₂O₃) and (25% HgO-75% Fe₂O₃) samples the variation of Qph with light intensity is very slow and tends to saturates at higher intensities. The Qph increases with increasing light intensity in beginning then tends to saturates for (75% HgO - 25% Fe₂O₃) sample . Similar variation of photoelectret charge with intensity of

illumination in BaTiO₃ – CdO has been reported by Devi et. al [16].

As the intensity increases, more and more charge carriers are generated, thereby, increasing the density of free carriers available for trapping which are subsequently released during photo depolarization. The saturation in photoelectret charge cannot be due to space charge accumulation. It is due to dynamical equilibrium established between the trapping levels and

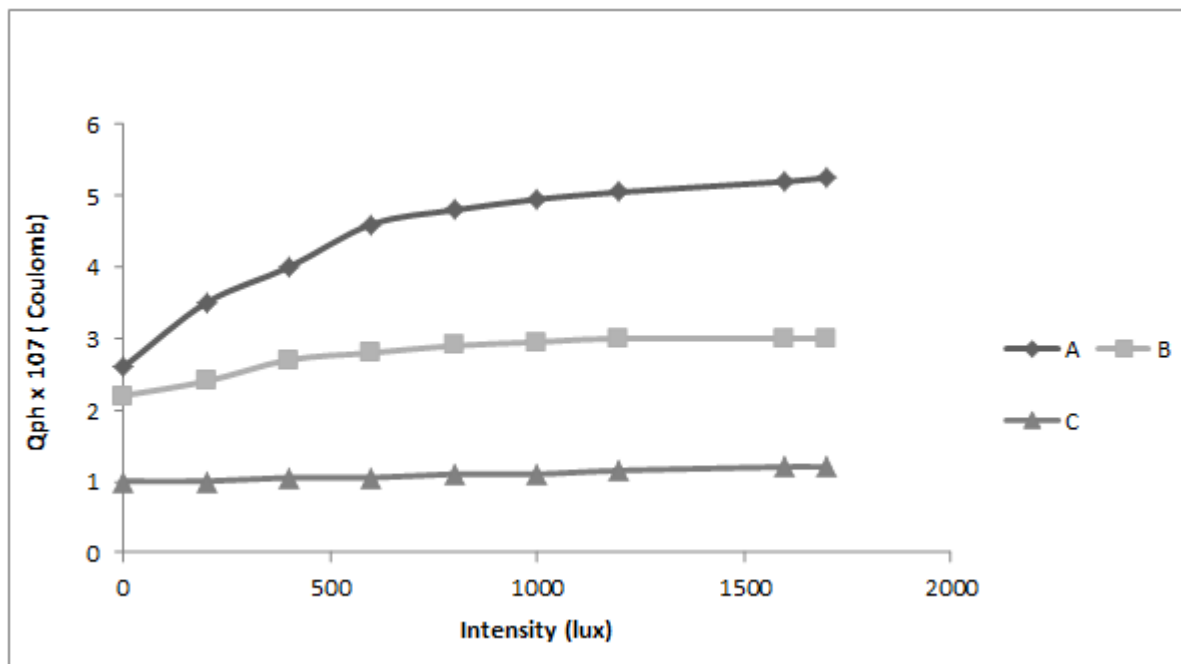


Figure 5: Variation of Photoelectret charge with Intensity of illumination (Field = 10 kV/cm, Polarization Time (t_{pp}) = 1 min., Dark depolarization Time (t_{dd}) = 15 sec, Temp = 2 °C). A- (75%HgO- 25% Fe₂O₃), B- (25%HgO- 75% Fe₂O₃) and C- (50%HgO- 50% Fe₂O₃)

the respective bands under the influence of light modified Fermi levels. At saturation only a small fraction of total number of trap levels are filled with the electrons [17].

4. Conclusions

The photoelectret state has been shown by (HgO - Fe₂O₃) Mixed materials. The Photoelectret charge is optimum for composition (75% HgO - 25% Fe₂O₃) heated at 400 °C for 35 min. This confirms that the resultant photoelectret charge is increased by mixing of two different materials. The Qph is found to be slightly larger for (75%HgO-25% Fe₂O₃) sample than (50%HgO-50% Fe₂O₃). The research on mechanism of electret formation in mixed materials is going on and in future it will play major role. There are large applications of electret technology in energy and health sensors.

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