On the Gamma-ray Irradiation Effects of Lead Sulphide Photoconductive Cell

(further report)

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Abstract

The gamma-ray irradiation effects of lead sulphide photoconductive cell have been obtained experimentally.

The gamma-ray source used was 10000 curie Cobalt-60, and total irradiation dose was 10^7 roentgen～10^8 roentgen. The irradiation was carried out at room temperature.

The results obtained are summarized as follows:

(1) Coloring of the cell vessel due to the gamma-ray irradiation does not deteriorate the characteristics of the lead sulphide photoconductive cell as a near infrared detector to any appreciable degree.

(2) Decrease in dark impedance of the cell due to the gamma-ray irradiation shows only a slight recovery.

(3) Value of the activation energy is changed by the gamma-ray irradiation.

(4) Dark current is increased, photocurrent is decreased and time constant is also decreased. Increase in dark current is due to the decrease in dark impedance of the cell, and shows little recovery.

The cause of the decrease in photocurrent and time constant may be the formation of current carrier recombination centers created by the gamma-ray irradiation.

(5) Current noise is increased by the gamma-ray irradiation, but recovers almost completely. Photocurrent and time constant also recover almost completely.

(6) The time needed for the complete recovery of the cell photoelectric characteristics seems to be proportional to the irradiation dose.

(7) From the results obtained above, it may be concluded that the lead sulphide photoconductive cell is not damaged so easily by the gamma-ray irradiation dose which was used in this experiment.

1 Introduction

Since January 1959, the author has been engaged in the study of lead sulphide photoconductive cell,[1),2),3),4)] and has completed several kinds of optical instruments using lead sulphide photoconductive cell as a light detector, such as near infrared microspectrophotometer,[5)] near infrared auto-recording spectrophotometer,[6)] self recording spectroradiometer,[7)] and so on.[8)]

Of late, the author has made the experiment on the gamma-ray irradiation effects of lead sulphide photoconductive cell and the results of this experiment have been reported briefly in author's recently published paper.[9)]

In the present report, subsequent data are incorporated and the further discussion over the whole results is given.

2 Experiment and Results

The sample used in author's experiment was the high impedance type lead sulphide photoconductive cell manufactured by the method that was originally established by the author.

The gamma-ray irradiation process was carried out at the Cobalt-60 irradiation laboratory of JAERI (Japan Atomic Energy Research Institute).

According to Kutzscher's report,[10] lead sulphide photoconductive cell shows no any variation of optical and electrical characteristics, when the gamma-ray irradiation dose is bellow 10^4 roentgens.

In author's experiment, the irradiation doses used were 1.2×10^7 roentgens (first exposure) and 10^8 roentgens (second exposurer), second exposure was carried out three monthes after first exposure. Optical and electrical characteristics were measured after both exposures.

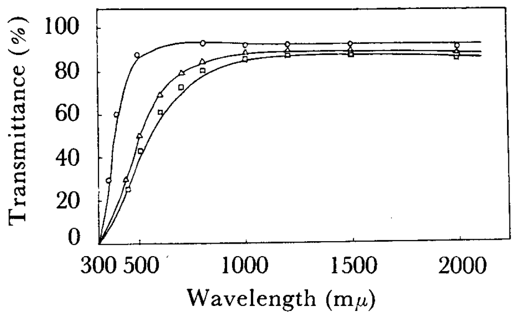
In this report the expression "before exposure" means the state of no irradiation, namely the state before first exposure.

The gamma-ray source used was a 10000 curie Cobalt-60 unit, and the energy of the gamma-ray used was approximately 1.17 to 1.33 MeV.

Irradiation was carried out at room-temperature (approximately 300 degree K). Time constant and noise of the cell were measured by the noise analyzer[11] and the resistor which has the same resistance value with the sample cell at room temperature was used as the load resistance of the cell.

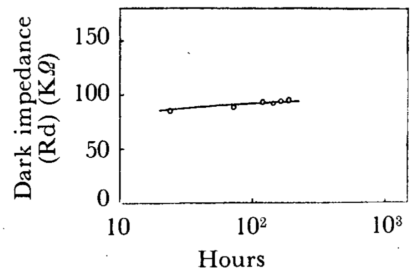
Fig. 1 shows the spectral transmittance characteristics of the gamma-ray irradiated cell vessel, comparing with non-irradiated one no any variation is seen except between 300 milli-microns∼800 milli-microns.

Variation of the spectral transmittance characteristics seems to be proportional to the irradiation dose, but from the spectral response characteristics of lead sulphide cell, it may be concluded that coloring of the cell vessel due to the irradiation doses



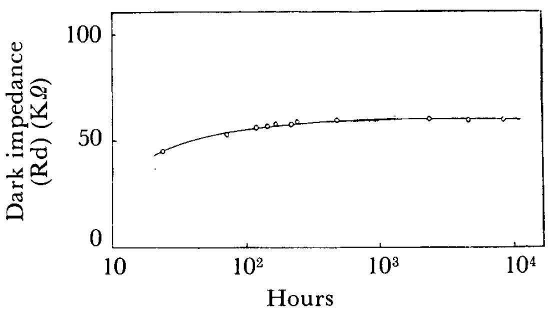
○ : No ray irradiation
△ : After 1st exposure (24 hours)
□ : After 2nd exposure (24 hours)
At room temperature
Cell vessel : hard glass

Fig. 1. Spectrol transmittance of cell vessel



Before 1st exposure Rd = 140KΩ
At room temperature

Fig. 2. Variation of dark impedance (after 1st exposure)



Before 2nd exposure Rd = 95KΩ
At room temperature

Fig. 3. Variation of dark impedance (after 2nd exposure)

used do not deteriorate the capability of the cell as an infrared detector to any appreciable degree.

No time dependence of variation of the cell vessel coloring was observed.

Fig. 2 shows the time dependence of the recovery of the cell dark impedance after first exposure.

Fig. 3 shows that after second exposure.

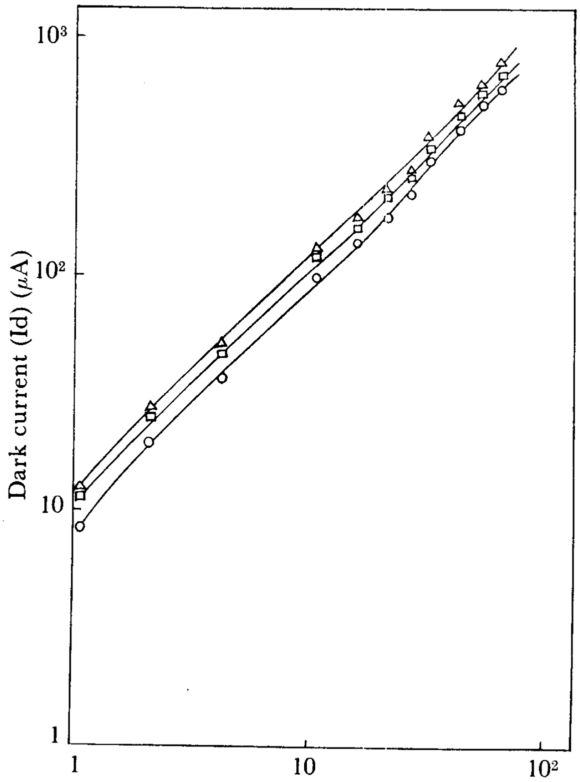
Table 1 Variation of activation energy

First exposure

	Before exposure	After exposure (hrs)					
		24	120	168	240	360	408
Eg (eV)	0. 26	0. 20	0. 24	0. 27	0. 26	0. 27	0. 27

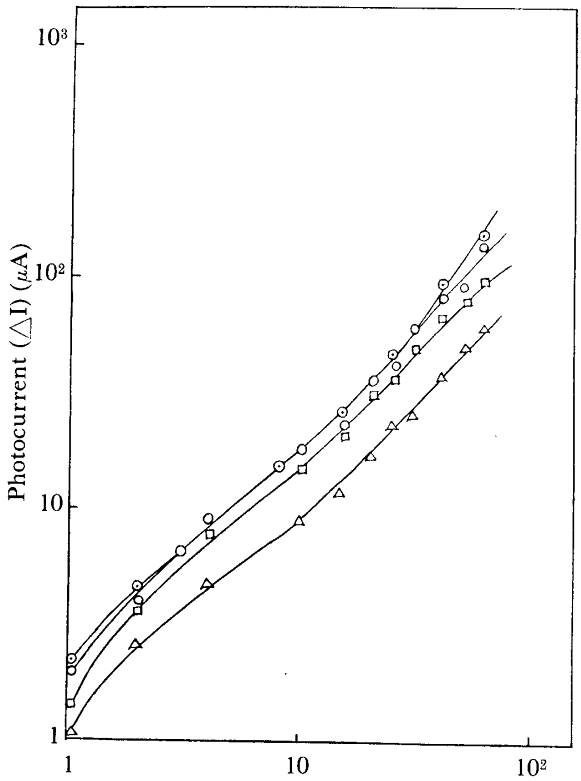
Second exposure

	Before exposure	After exposure (hrs)							
		24	120	168	240	360	408	2190	8760
Eg (eV)	0. 27	0. 34	0. 28	0. 26	0. 32	0. 30	0. 29	0. 28	0. 29



○ : Before 1st exposure
△ : 24 hours after exposure
□ : 168 hours after exposure
At room temperature

Fig. 4. Dark current *vs.* bias voltage (1st exposure)



Incident energy : 310.2μW
○ : Before 1st exposure
△ : 24 hours after exposure
□ : 360 hours after exposure
⊙ : 408 hours after exposure
Recovery : 408 hours
At room temperature

Fig. 5. Photocurrent *vs.* bias voltage (1st exposure)

As shown in Fig. 2 and Fig. 3, decrease in dark impedance of the cell shows little recovery.

The relation between conductivity and activation energy of semiconductor is given by the Eq. (1) where σ is conductivity, Eg is activation energy, k is Boltzmann constant, and T is absolute temperature.

$$\sigma = \sigma_0 \exp\left(-\frac{Eg}{2kT}\right) \tag{1}$$

Using Eq. (1), values of the activation energy of the cell were calculated before exposure and after first and second exposure, the results obtained are shown in Table. 1.

Fig. 4 and Fig. 5 show the recovery of the bias voltage characteristics of the dark current and photocurrent of the cell after first exposure.

Fig. 6 and Fig. 7 show those after second exposure.

For the measurement of photocurrent, a tungsten lamp was used as a light source with Toshiba infrared filter IR-DIA.

The value of the incident energy falling on the photosensitive area of the cell was measured directly by the vacuum thermocouple.

Table. 2 shows the variation of the cell time constant due to to the gamma-ray

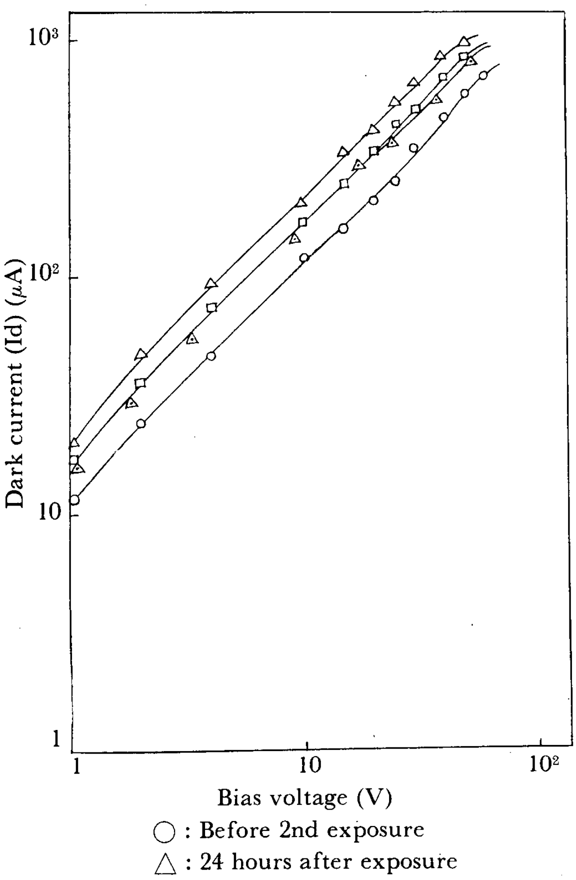


Fig. 6. Dark current *vs.* bias voltage (2nd exposure)

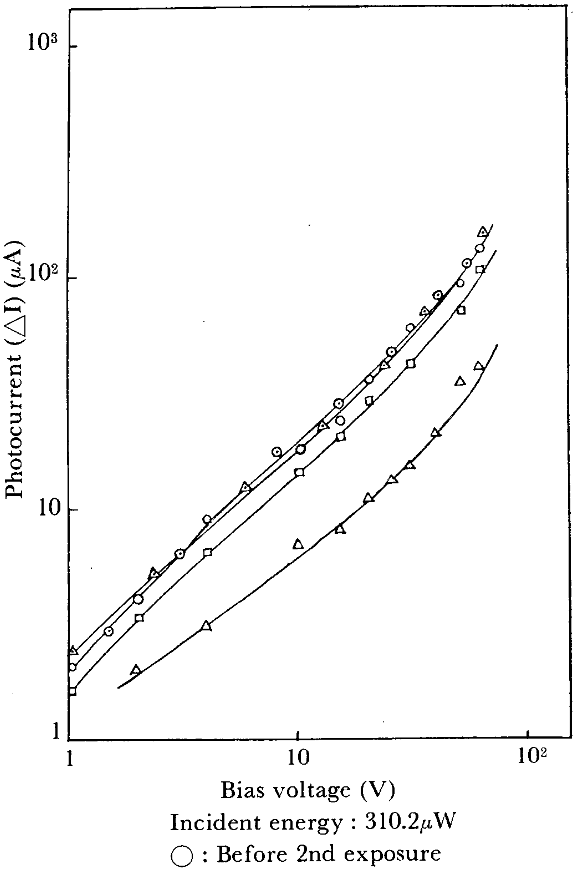


Fig. 7. Photocurent *vs.* bias voltage (2nd exposure)

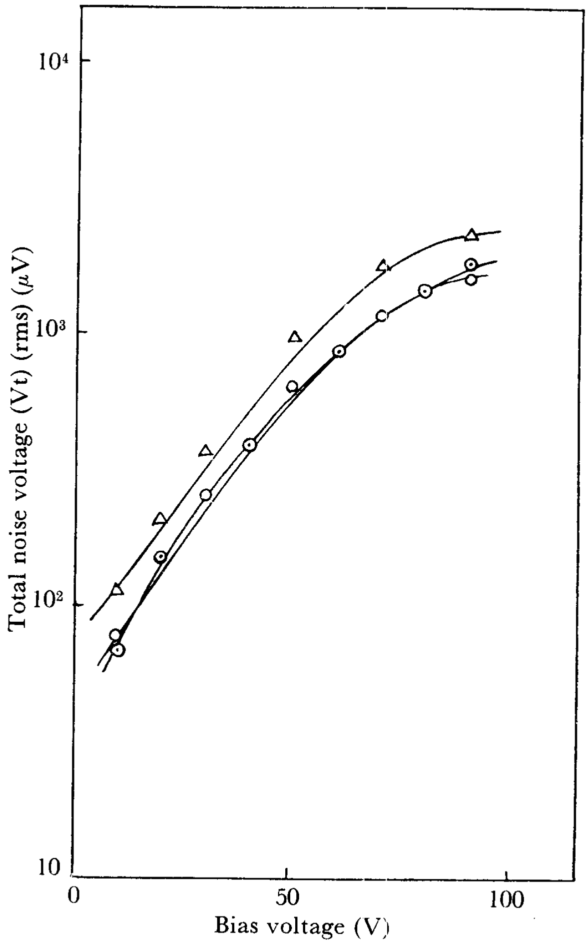
Table 2 Variation of time constant

First exposure

	Before exposure	After exposure (hrs)					
		24	72	168	264	360	432
τ (μS)	72	48	50	53	60	68	73

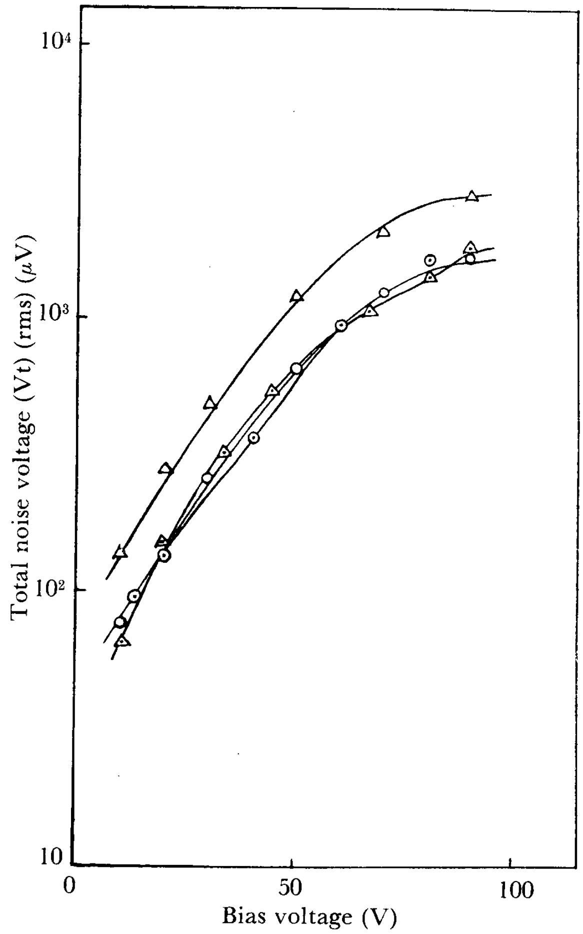
Second exposure

	Before exposure	After exposure (hrs)							
		24	74	168	288	408	552	2190	8760
τ (μS)	73	41	43	49	57	64	71	69	68



f = 200 c/s
○ : Before 1st exposure
△ : 24 hours after exposure
⊙ : 456 hours after exposure
Recovery : 456 hours
At room temperature

Fig. 8. Total noise *vs.* bias voltage (1st exposure)



f = 200 c/s
○ : Before 2nd exposure
△ : 24 hours after exposure
⊙ : 528 hours after exposure
▲ : 8760 hours after exposure
Recovery : 528 hours
At room temperature

Fig. 9. Total noise *vs.* bias voltage (2nd exposure)

irradiation and the recovery of it after exposure.

Fig. 8 shows the recovery of the bias voltage characteristics of the cell total noise voltage after first exposure, and Fig. 9 shows that after second exposure.

Non-current noise showed no variation after the gamma-ray irradiation.

3 Discussion

The results obtained in this experiment are approximately in agreement with those reported by Kutzscher except the variation of dark impedance of the cell.

According to Kutzscher's report, dark impedance of the cell was increased by the gamma-ray irradiation and returned to normal approximately one month after exposure.

In author's experiment, contrary to Kutzscher's report dark impedance of the cell was decreased by the gamma-ray irradiation and showed no return to normal after exposure.

Though it is already a year and a month after second exposure, dark impedance of the cell shows no return to normal.

Decrease in dark impedance of the cell shows the formation of trapping centers contributing to the thermal excitation at room temperature.

Decrease in photocurrent and time constant may be due to the creation of the current carrier recombination centers.

The change of activation energy indicates a complex change of depth of this energy level as the results of the creation of some imperfection centers due to the gamma-ray irradiation.

4 Summary

The gamma-ray irradiation effects of lead sulphide photoconductive cell were observed and summarized as follows.

(1) Coloring of the cell vessel due to the gamma-ray irradiation does not deteriorate the characteristics of the lead sulphide photoconductive cell as a near infrared detector.

(2) Decrease in dark impedance of the cell due to the gamma-ray irradiation shows little recovery.

(3) Decrease in dark impedance of the cell shows the formation of the trapping centers which contribute to the thermal excitation at room temperature.

(4) Value of the activation energy is changed by the gamma-ray irradiation.

(5) Dark current is increased and photocurrent is decreased.

(6) Time constant is also decreased.

(7) Increase in dark current is due to the decrease in dark impedance and shows little recovery.

(8) The cause of decrease in photocurrent and time constant may be the formation of current carrier recombination centers created by the gamma-ray irradiation.

(9) Current noise is increased by the gamma-ray irradiation, but recovers completely after exposure. Photocurrent and time constant also recover completely.

(10) The time needed for the recovery of the cell photolectric characteristics seems to be proportional to the irradiation dose.

(11) From the results obtained above, it may be concluded that the lead sulphide photoconductive cell is not damaged so easily by the gamma-ray irradiation dose which was used in this experiment.

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