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Effect of γ Radiation on Gate Trigger Current of Thyristors

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Experimental study on the γ-radiation effect in gate trigger current, I_{GT}, of small current thyristors (2A class) has been performed. The gate trigger current is sensitively increased by γ radiation and the stability of the thyristor is improved. The increase in I_{GT} is proportional to the γ-radiation dose and is not deteriorated by heat treatment at 200°C for 1000 h.

It is well known that many types of semiconductor devices are radiation sensitive. The radiation effect on semiconductor devices usually appears at 10^3 R and by irradiation of $10^8 \sim 10^{10}$ R, they become out of use.[1,2] The change in their electrical properties is caused by the structural deffect produced by irradiations. Electron beams or γ rays of about 1 MeV give rise to the Frenkel deffect, *i.e.*, one electron removes one atom in the crystal structure involved. This deffect forms impurity levels in the forbidden band of semiconductor crystal, resulting in change in carrier concentration, in decrease in minority carrier lifetime and mobility, and in change of optical or other physical properties.[3] Among these effects, the most sensitive one is the decrease of the lifetime of minority carriers, which is proportional to the the irradiation dose.[4]

In the present work, the γ-ray radiation effect on the electrical properties of thyristors was examined. The thyristor is the most practical *pnpn* 4-layer switching device and the function is equivalent to a pair of *pnp* and *npn* transistors interconnected through the collectors.

In the actual use of thyristors, operations should be done at a certain standard value of I_{GT}. However, at the present stage of manufacturing process, it is rahter difficult to produce thyristors with a desirable value of I_{GT} for stable functioning. Since the thyristor operating with a small standard value of I_{GT} is electrically too sensitive, misoperations may take place. Therefore, it is desired to get the thyrisotrs with a large I_{GT}. The purpose of the present work is to obtain the thyristors with a large I_{GT} without giving deteriorations to other electrical characteristics.

The principle of gate-turn on of the thyristors ($p_1n_1p_2n_2$) is as followings; (a) when p_2 (gate) is plus-biased and n_2 (cathode) is minus-biased, there appears the current from p_2 to n_2, (b) then electrons flow in from junction J_3 and reach junction J_2, and (c) this leads to current of holes from junction J_1. When the thyristor is irradiated by γ rays, recombination centers of carriers are produced in the layer p_2, making electrons from n_2 difficult to reach J_2 and resulting in increase of I_{GT}.

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The specimen used in the experiment is the diffused, glass passivated, mold-type thyristor (commercial name is 2PO5M~2P4M, NEC). The base material is n-type (P-doped) silicon made by the Floating Zone method. The concentration of phosphor is about 10^{15} atoms/cm^3. Ga is diffused in p_1 and p_2 layers and P in n_2. The sample was irradiated in a 2000 Ci γ-ray irradiation facility (6.7×10^4 R/h) at room temperature.[5] The irradiation dose was controlled by changing irradiation time. The method of testing electrical characteristics is JIS (c-7051).

In Table I are listed relative changes of items studied before and after γ radiation (2×10^6 R). Numerical values are obtained by averaging values of 14 thyristors sampled at random. As seen in the table, the most sensitive item for γ radiation is I_{GT}/I_{GTO}, where I_{GTO} and I_{GT} are the gate trigger current before and after γ radiation, respectively, but the others are not very much changed by γ radiation.

Table I. Relative Changes in Electrical Characteristics of Thyristors Caused by γ Radiation (2×10^6 R). Suffix O means Initial Values

I_{GT}/I_{GTO}	I_H/I_{HO}	V_{GT}/V_{GTO}	I_D/I_{DO}	I_R/I_{RO}	V_D/V_{DO}	V_R/V_{RO}	V_T/V_{TO}
4.6	1.7	1.1	1.6	1.1	0.92	0.94	1.1

I_{GT} : Gate Trigger Current. I_H : Holding Current.
V_{GT} : Gate Trigger Voltage. I_D : Foward Saturation Current.
I_R : Reverse Saturation Current. V_D : Foward Blocking Voltage.
V_R : Reverse Blocking Voltage. V_T : Foward Voltage Drop.

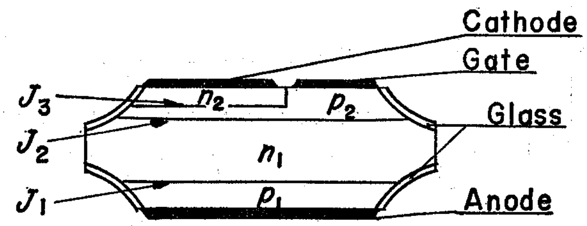

Fig. 1. Cross-sectional view of a glass passivated thyristor.

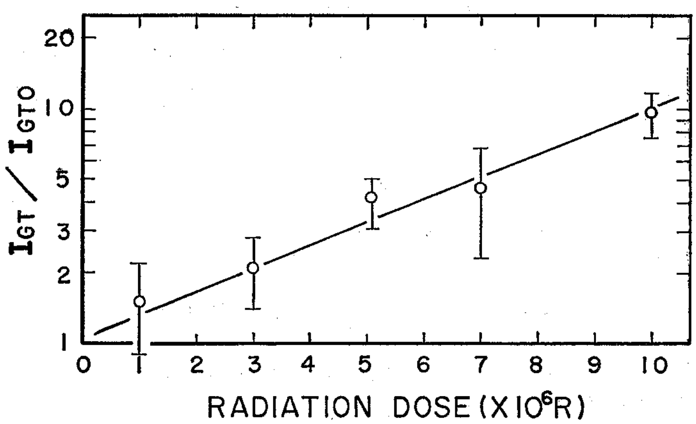

Fig. 2. Relative change in the gate trigger current, I_{GT}/I_{GTO}, *versus* γ-irradiation dose.

The relation between γ-radiation dose and relative change in I_{GT} was also studied, of which result is shown in Fig. 2. In this measurements, we used several decades thyristors divided into three groups with different I_{GTO}. However, the γ-radiation effect on I_{GT} did not show appreciable dependence on the initial value of gate trigger current, I_{GTO}. From these observations, we concluded that the γ-radiation effect on I_{GT}/I_{GTO} is proportional to the γ-radiation dose and does not depend on I_{GTO}.

It is of importance to know if the improved characteristics (increased I_{GT}) by γ radiation do not deteriorate during actual use of thyristors. To see this, the thyristors treated by γ radiation were annealed at 200°C for 1000 h. As shown in Fig. 3, reverse annelaing[4] occurs within the first several hours, but after that, the improved characteristics are stable at that temperature. Since this temperature is higher than the operation temperature of thyristors, the γ-radiation effect can be considered to be useful to improve the characteristics of thyristors.

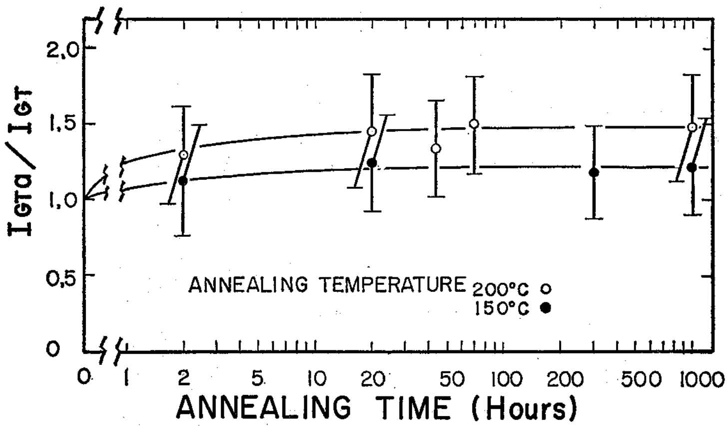

Fig. 3. Relative change in the gate trigger current in annealing treatment. I_{GTa} denotes the gate trigger current after the annealing.

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