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PHOTOTRANSISTOR RESPONSE UNDER A NEUTRON FLUENCE

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ABSTRACT

The purpose of this communication is to show some effects on a bipolar phototransistor after it has been under a neutron fluence. Unlike a transistor, a phototransistor is designed so that the collector has a large area and consequently it has a higher radiation detection probability. Then, it is possible to have a certain number of interactions so that any changes in the internal structure of the phototransistor can be observed after a neutron irradiation. If a phototransistor is under a certain spectra of neutron fluence the interaction depends on the cross section of the either silicon chip or its encapsulation, and recoil protons could be the charged particle responsible for changes in the semiconductor structure. Furthermore, neutron irradiation could give to the device a state of vanishing in its electrical characteristic which can be performed tracing the current versus voltage curve (I×V). The experimental arrangement basically consists of a photonic device, a neutron-gamma radiation source and a Flip-Flop electrometer second generation (EFF-2G). One of the main parameters of evaluation was the phototransistor dark current. In fact, the first results demonstrate that when the phototransistor is neutron irradiated there is a significant variation in its I×V characteristic curve.

1. INTRODUCTION

Data describing the behaviour of some electronic devices in the neutron-gamma radiation fluence are already known [1-3], but there is not sufficient information about neutron-irradiated phototransistors. Silicon based photonic devices can be normally used as charged particle, gamma and X-ray detectors for ionizing radiation monitoring or real time dosimetry. In the case of a bipolar phototransistor the principle of operation is the Compton or photoelectric interaction that yields an electrical current flowing from the collector to the emitter terminal, and this current is proportional to the radiation beam intensity. If a phototransistor is under a certain spectra of neutron fluence the interaction depends on the cross section of the either silicon chip or its encapsulation, and recoil protons could be the charged particle responsible for changes in the semiconductor structure. Thus, changes in the photonic device can be correlated to its dark current variation. Such a result could be used for monitoring the neutron fluence in a certain nuclear reactor or another type of neutron source. Actually, the neutron indirectly induces some defects in the semiconductor structure altering the leakage current of the device after irradiation. The damage to the phototransistor can also depend on the energy fluence, exposure time, dose rate and its encapsulation (hermetically or plastic). These results will indicate how the device can be used in the neutron fluence and it may also give information about its life time.

2. MATERIALS AND METHODS

2.1. Detectors and readout system

TEKT5400S (Vishay) [4] (Figure 1) was the phototransistor chosen to be tested under a neutron fluence. The devices were used for tracing their characteristic curves before and after irradiation. Such a result is known as the current versus voltage (I×V) curve and it can be traced connecting the photonic device to a semiconductor parameter analizer [5] in a black box to avoid light. A Flip Flop electrometer second generation (EFF-2G) [6] was used as the readout system, *i.e.*, it works acquiring the characteristic curve corresponding to the device dark current.

Figure 1. TEKT5400S Phototransistor.

2.2. Radiation Sources and Irradiation Procedures

An Am-Be source which it has an activity of 7.4 10^{11} Bq was used. At the present time it yields a thermal neutron fluence about 10^6 neutrons per second in a certain volume of paraffin (the experimental arrangement illustrated in Figure 2). Two irradiation procedures were chosen to test the photonic device response in a time interval of 115 h: 1) Insert it in a thermal neutron fluence at 0.15 m detector-source distance; 2) Insert it close to the radiation source (without paraffin) to verify how fast neutrons can cause changes in the semiconductor. Basically, a set of four devices for each irradiation procedure were used as passive mode detectors, and consequently they had no bias, *i.e.*, no voltage to the collector and the emitter pins. Similar to the TLD method, three devices were set to detect radiation and the fourth one was not irradiated at all. The reading procedure was repeated twice and a representative statistics was obtained with a sample size of 5 readings per point.

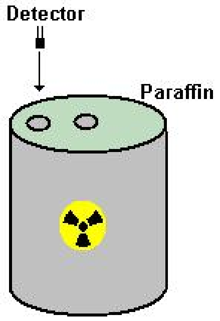

Figure 2. Experimental Arrangement.

3. RESULTS AND DISCUSSIONS

The characteristic curve for the devices inserted in a thermal neutrons fluence is illustrated in Figure 3. The black curve represents an acquired curve before irradiation. After 115 h the device under a cloud of neutrons, the red curve indicated that the TEKT5400S phototransistor had its parametric curve shifted up, *i.e.*, the device dark current was multiplied by a factor. Such a result was similarly obtained to other electronic semiconductor devices [1-3] meaning that the semiconductor structure was altered when the neutrons interact with the photonic device. The curve number 2 (yellow) is the one day after acquired curve and the number 3 (green) is one week after acquired curve. These curves demonstrate that neutron irradiation could give to the device a state of vanishing in its electrical characteristic. It suggests that the neutron-gamma irradiation process could be used to electrically equalizer some devices, *i.e.*, to become them so-called matched devices.

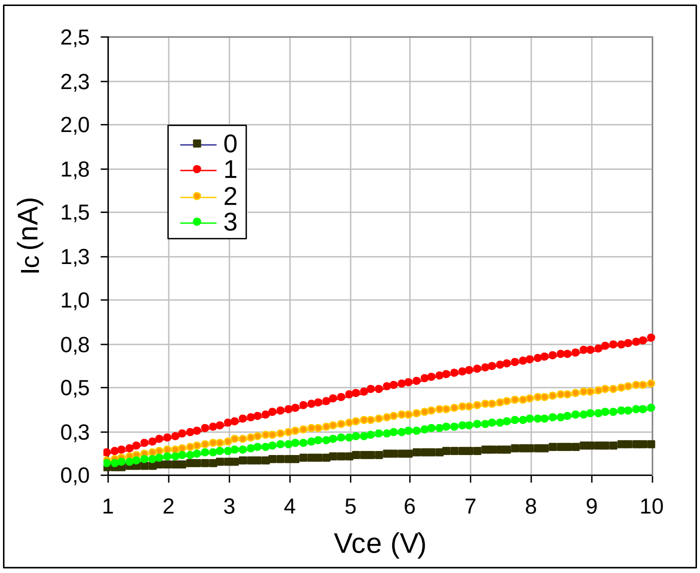

Figure 3. Characteristic curves for the phototransistors irradiated during 115 h in a thermal neutron fluence. The reading 0 and 1 mean before and after irradiation, respectively. The reading 2 and 3 correspond to after one day and one week after irradiation, respectively.

Figure 4 shows the characteristic curve for the devices inserted in a fast neutron fluence. One can see the similarity between two graphs, however when the device is under a fast neutron flux the changing is more significant than the thermal neutron irradiation. Also the one day after acquired curve indicates that the characteristic curve of the device vanishes by the time, however, the last curve obtained after one week (green) also suggests that the device rest at a new electrical state. Then, based on these results, one can conclude that a neutron irradiation can become a method to produce matched electronic devices.

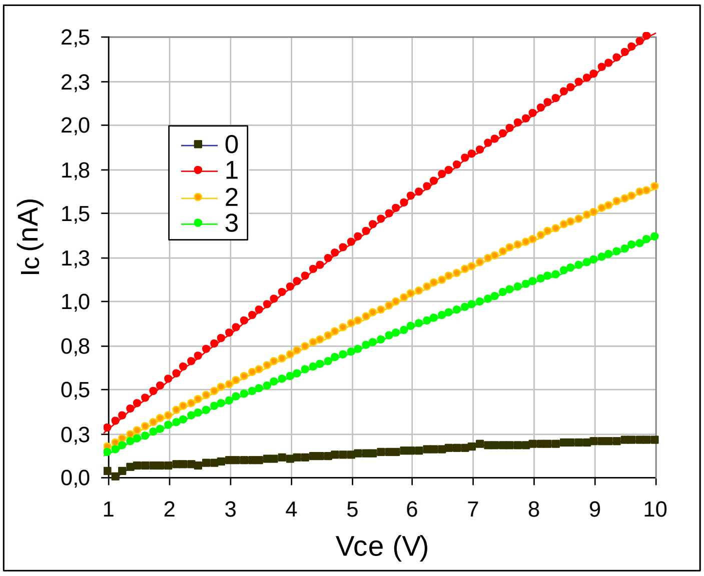

Figure 4. Characteristic curves for the phototransistors irradiated during 115 h in a fast neutron fluence. The reading 0 and 1 mean before and after irradiation, respectively. The reading 2 and 3 correspond to after one day and one week after irradiation, respectively.

4. CONCLUSIONS

A TEKT5400S phototransistor was tested to be irradiated under a thermal and fast neutron fluence. After an 115 h time interval of irradiation the electrical characteristic curves of the devices were acquired to compare with the curves before irradiation. The results demonstrated that both thermal and fast neutrons interact with the device multiplying the characteristic curves by a factor. Such a result could be used for monitoring the neutron fluence in a certain nuclear reactor or another type of neutron source. In this case, a calibration parametric curve could be calculated to fit the phototransistor response with the neutron flux. Another application could be to identify if the phototransistor is under a slow or fast neutron fluence because the photonic device provides different responses for each one. Furthermore, a changing in the semiconductor material suggests that a neutron irradiation can be used to perform devices with the same electrical characteristic, so-called matched devices. The last application is a very important method for electronics because it provides to build materials and devices in electrical engineering for sophisticated circuitry design.

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REFERENCES

1. V. A. Varlachev and E. S. Solodovnikov, A Fast-Neutron Detector Based on Single-Crystalline Silicon, *Instruments and Experimental Techniques*, **51**, No. 2, pp. 171–174 (2008).
2. V. A. Sahakyan, Influence of Different Type Irradiation on the Parameters of Silicon Semiconductor Devices, *Journal of Contemporary Physics*, **43**, No. 5, pp. 226–230, (2008).
3. H.P. Hjalmarson, R.L. Pease, R.M. Van Ginhoven, P.A. Schultz, N.A. Modine, Electrical effects of transient neutron irradiation of silicon devices, *Nuclear Instruments and Methods in Physics Research B*, **255**, pp. 114–119 (2007).
4. TEKT5400S datasheet http://www.vishay.com/ (2009).
5. 4156C Semiconductor Parameter Analizer http://www.home.agilent.com/ (2009).
6. L. A. P. Santos, A semiconductor parameter analyzer for ionizing radiation detectors, *INAC 2009 Proceedings*, Rio de Janeiro, in this book (2009).