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EFFECTS OF GAMMA IRRADIATION ON ELECTRIC CHARACTERISTICS OF POWER DIODES

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ABSTRACT

In this work we presented the preliminary results of a systematic study of direct voltage and cut-off frequency variations of power diodes under different gamma irradiation doses. The samples were irradiated at a gamma facility, ^{60}Co-Gammacell 220 (dose rate of 2.31 kGy/h), in the Radiation Technology Center (CTR) at IPEN-CNEN/SP. The temperature during exposure was typically 25 ºC. The values of direct voltage and the temporal response of the devices were studied for an accumulated dose of 1350 kGy. The results have shown an improvement of the reverse recovery behavior of this type of diode, as well as a 10% decrease in its direct voltage.

1. INTRODUCTION

In power semiconductor devices, the minority carrier lifetime is reduced by introducing efficient recombination centers either by diffusion of metallic impurities such as gold and platinum immediately before metallization, or by high energy irradiation, which is usually the last step in the processing sequence [1]. Irradiation of semiconductors with electrons, protons and gamma radiation plays a vital role in modifying the electrical characteristics and controlling the carrier life time effectively by creating lattice defects [2].

Therefore, the irradiation of diodes is one of the most widely technique used in the power electronic industry to reduce of the time interval for the transition between conduction and non-conduction states of theses diodes. In fact, the irradiation of such devices normally can modify the mean-lifetime carriers, locally or in the whole irradiated region [3]. Until now, the behavior of this mechanism is not completely understood and many researches have been carried out in order to clarify the carriers recombination process.

The aim of this work is to evaluate the behavior of direct voltage and cut-off frequency of power diodes under different gamma irradiation doses.

2. MATERIALS AND METHODS

2.1. Samples and irradiation

The commercial diode used in this work (Fig. 1) was manufactured for power circuits and gently supplied by Semikron do Brasil. The sample used in this study had a diameter of 10 mm and was irradiated in the central position of a ^{60}Co-Gammacell 220 (MDS Nordion) in the Radiation Technology Center (CTR) at IPEN-CNEN/SP. Once the dose rate of this gamma facility was 2.31 kGy/h, the exposure times were selected to achieve doses from 5kGy up to 1350 kGy. The temperature during the irradiation was typically 25 ºC.

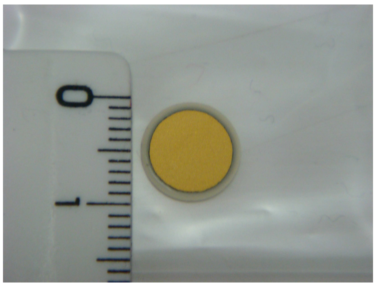

Figure 1. Semikron power diode used in this work.

2.2. Instrumentation and methods

The direct voltage of the diode was determined through the *IxV* curves, with the device polarized by a DC source HPE36/0A. A Fluke 89 digital multimeter was used to measure the forward currents.

The temporal response of the diode related to its reverse recovery behavior was investigated with a homemade half-wave rectifier circuit. The sine wave generator used (Minipa MFG 4220) had a maximum frequency of 10 MHz and the corresponding waveforms were acquired and registered in a 300 MHz bandwidth Digital Oscilloscope (Tektronix TDS 3034B). The experimental setup can be viewed in Fig. 2.

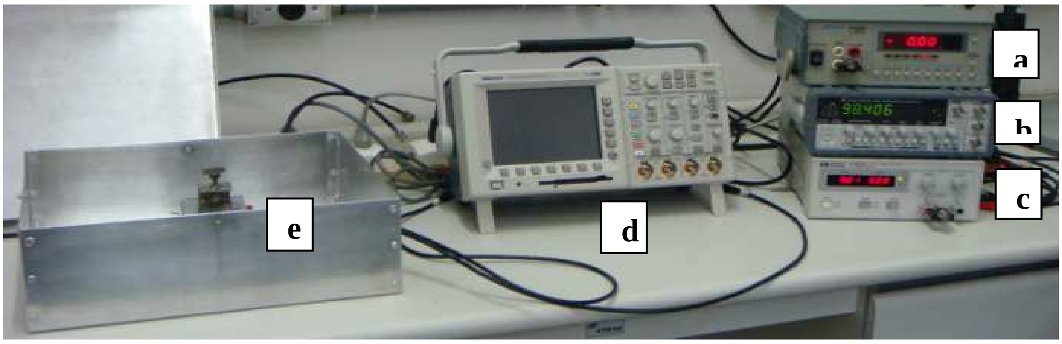

Figure 2. Experimental setup: a- digital multimeter; b – sine wave generator; c- DC source; d- digital oscilloscope and e- measuring circuit.

3. RESULTS

In Fig. 3 are presented the results for the direct voltage as a function of accumulated dose for the diode polarized at 5 V. From this Figure it can be observed a decrease of ≅10% in the direct voltage after an accumulated dose of 1 MGy.

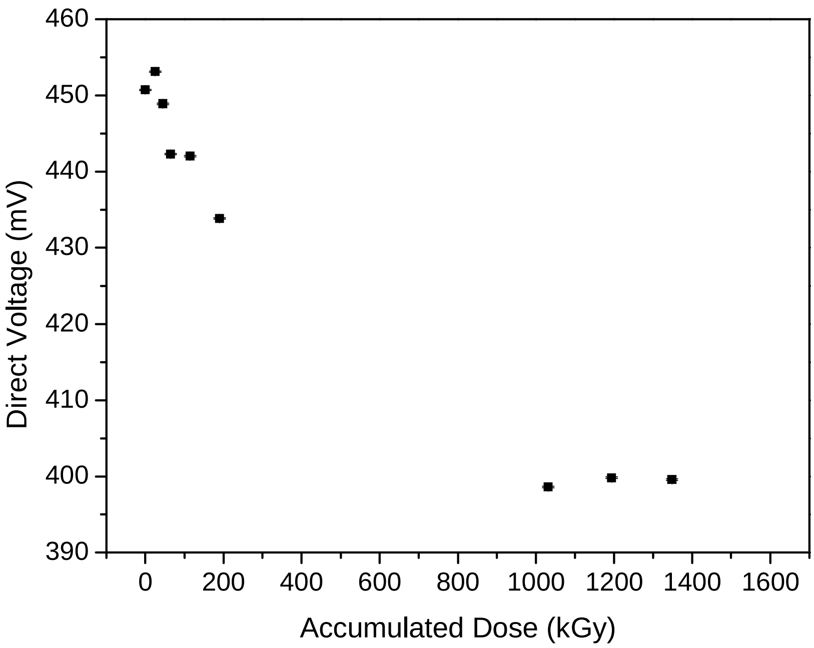

Figure 3. Direct voltage as a function of accumulated dose (diode bias = 5 V).

The behavior of a voltage characteristic of the reverse recovery process of the diode irradiated with an accumulated dose of 1350 kGy for a 40 kHz sine waveform is shown in Fig. 4, where the area under the positive part of the signal is assigned as V_+ and the negative one as V_-. The related curve of (V_-/V_+) ratio versus frequency for the sample (Fig. 5) allowed the estimation of the cut-off frequency, which exhibited a significant increase from 96 kHz, without irradiation, to 4.4 MHz for 1350 kGy of accumulated dose (Fig. 6). It is worth to note that, up to now, there is no a theoretical model to explain the exponential growth of the cut-off frequency as a function of accumulated dose observed in Figure 6. Some studies are under way to clarify this point.

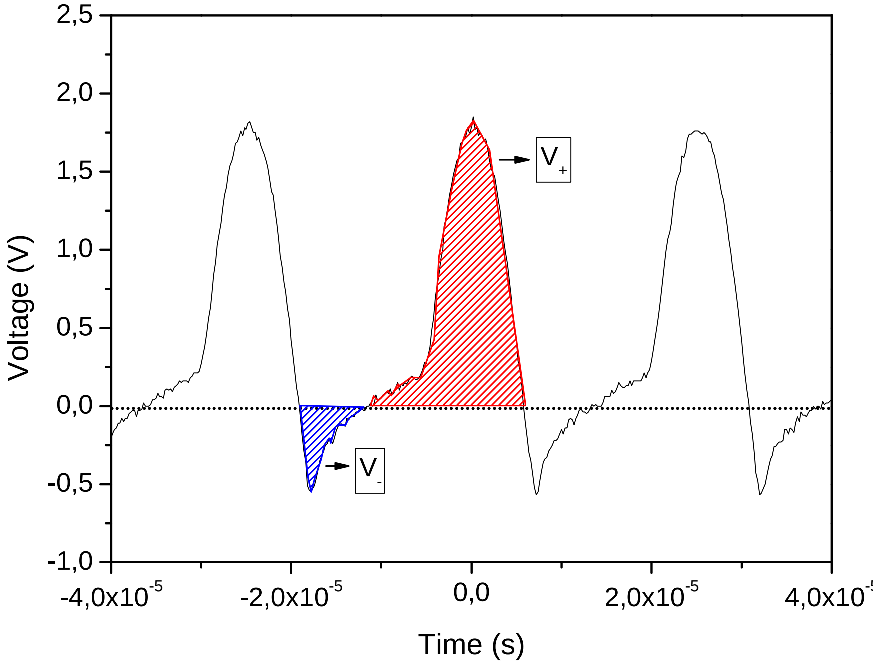

Figure 4. Voltage characteristic of the diode for reverse recovery process with a sine wave.

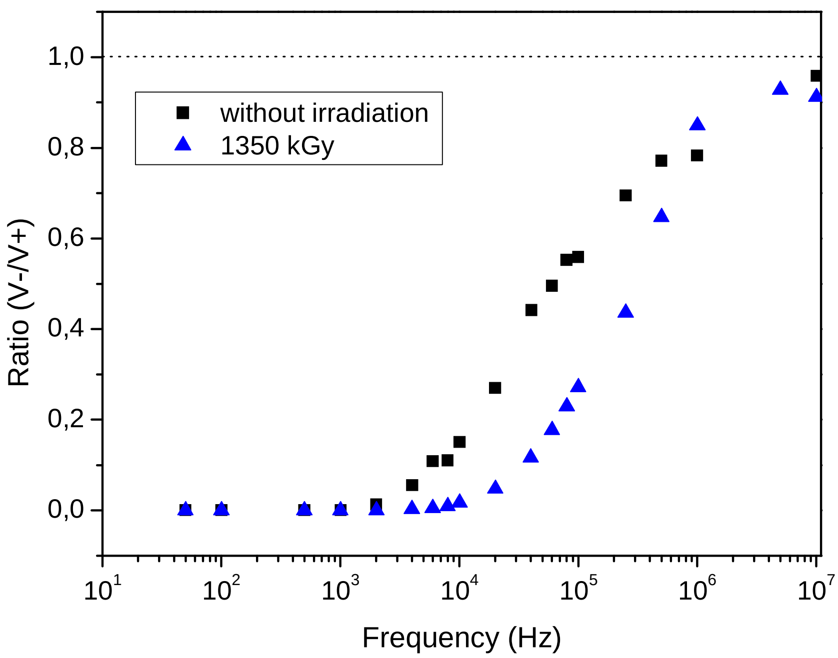

Figure 5. Ratio (V-/V+) *versus* sine wave frequency.

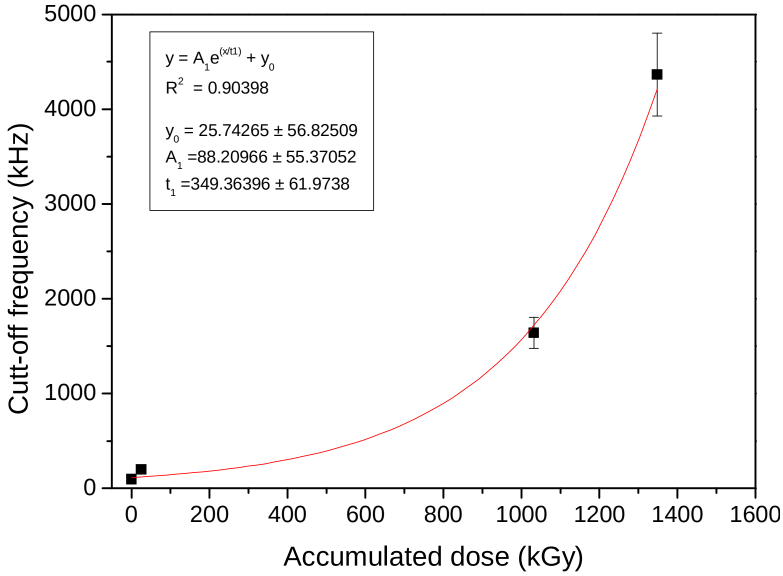

Figure 6. Cut-off frequency as a function of accumulated dose.

Table 1 summarizes the direct voltage and the cut-off frequency as function of accumulated dose obtained for the sample used.

Table 1. Direct voltage and cut-off frequency of the diode with gamma irradiation.

Accumulated Dose (kGy)	Direct Voltage (mV)	Cut-off Frequency (kHz)
0	427.6 ± 0.1	96 ± 10
25	406.8 ± 0.1	199 ± 20
1032	382.2 ± 0.1	1641 ± 164
1348.6	380.6 ± 0.1	4367 ± 437

4.CONCLUSIONS

As expected, the preliminary results obtained for gamma irradiation in power diodes shown an improvement of the reverse recovery behavior of this device, as well as a decrease of 10% in its direct voltage for doses up to 1 MGy. A study of the reverse recovery time for a square wave, as done in the electronic industry, is under way.

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