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INFLUENCE OF LOW ENERGY α-PARTICLE FLUXES ON THE PHOTOCONDUCTIVITY OF GaAs

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Abstract. In the present work, we study the influence of small energy α-particles (0.96 MeV) on the photoconductivity in order to construct a detector for small fluxes of low energy α-particles irradiation. Photocurrent measurements were carried out at room temperature (T=300K), before and after irradiation, on Semi-insulated (SI) GaAs specimens, with epilayer of low resistivity Si doped GaAs. Analyzing, by the Origin 7.0 Pro program, the experimental data $I_{ph} = f(E_{photons})$, where I_{ph} is the difference between the current under illumination and the dark current, we found three Gaussian curves. We irradiated the specimen, using Am^{241} as a source of α-particles, in equal time intervals succeeding small differences in the α-particles fluxes. We measured the photocurrent using photons of energies corresponding to the peaks of the above referred curves before and after each irradiation. We repeated the measurements for total duration of 6 hours corresponding to $119.88 \cdot 10^7$ α-particles/cm^2. We observed that the relation $I_{ph} = f(N)$ is linear for all specimens, where with N we denote the flux.

1. INTRODUCTION

Few papers refer to the effect of α-particle irradiation on GaAs at temperatures around the boiling point of nitrogen, for the far infrared (6 -15 μm) and for high fluxes (10^{10} -10^{16} α-particles/cm^2) [1,2]. Other papers [3-5] studied this effect by the DLTS method for very low (5 keV), middle (2.0 MeV), and high enough (5.4 MeV) α-particle energies for temperatures from near absolute zero up to 350K.

In this paper we use the photoconductivity method in order to study the effect of low energy (0.96 MeV) α-particles on the photoconductivity of Semi-insulated (SI) GaAs with epilayer of low resistivity Si doped GaAs with concentration 10^{16} ions/cm^3 at room temperature (T=300K). Since our interest is to study the effect for small fluxes of the above referred low energy, we irradiated the specimen in equal time intervals and repeated the measurements for total irradiation duration of 6 hours corresponding to a total flux of $119.88 \cdot 10^7$ α-particles/cm^2, i.e. $19.98 \cdot 10^7$ α-particles/h$\cdot$cm^2.

As the energy gap of GaAs at room temperature, given by the bibliography is 1.42 eV, we measured the current in the photons energy region 1.36 -1.55 eV and plotted the spectra $I_{ph} = f(E_{photons})$, where I_{ph} is the difference between the current under illumination and the dark current.

Analyzing the spectra by the Origin 7.0 Pro program, we found three Gaussian curves with their peaks located at the photon energies 1.519 eV,

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1.422 eV, and 1.399 eV as we have published in our previous work [6].

We measured the I_{ph} using photons of energies 1.519 eV and 1.422 eV before and after each irradiation.

2. EXPERIMENTAL TECHNIQUES

Photocurrent measurements have been carried out on three specimens of SI-GaAs with 1 μm epilayer of Si doped GaAs (10^{16} ions/cm^3). All specimens were pieces of the same wafer made by the LEC (Liquid Encapsulated Czochralski) method. Two orthogonal AuGe contacts were made at a distance of 100 μm. The specimens were enclosed in a cryostat whose window was covered with a Mylar sheet of 12.5 μm thickness.

The illuminating system consisted of a small 250 W halogen lamp with an external semi-spherical reflector and an Oriel Optics monochromator. The light beam did struck the surface, on which the contacts were made, vertically. We used photons with energies 1.519 eV and 1.422 eV.

For the irradiation with α-particles we used a source of Am^{241} of special radioactivity 1.5 mC/cm^2 and of energy 4,7 MeV. The special radioactivity is $5.55 \cdot 10^7$ particles/cm^2.sec and it corresponds to a flux of of $19.98 \cdot 10^7$ particles/cm^2 hour.

As the distance between the radioactive source and the specimen is 0.5 cm the radiation beam strikes vertically on the sample's surface. The surface of the contacts on the specimen is 2 mm^2 so the incident α-particles' beam is 39.96 10^5 particles/hour.

In order to reduce the energy of α-particles to 0.96 MeV, we added to the existing Mylard sheet, which closes the window of the cryostat, a second one of the same thickness (12.5 mm) as, every sheet reduces the energy by 1.87 MeV [7].

The current was measured with a programmable electrometer (Keithley 617) using a software package which was developed for our equipment. The whole measuring system was shielded against external fields with copper sheets.

The cryostat is a part of the cooling system consisting of an air He circulating machine of Air Products and a temperature controller of Scientific Instruments which are used for temperature stabilisation.

All measurements were carried out at the temperature of 300K.

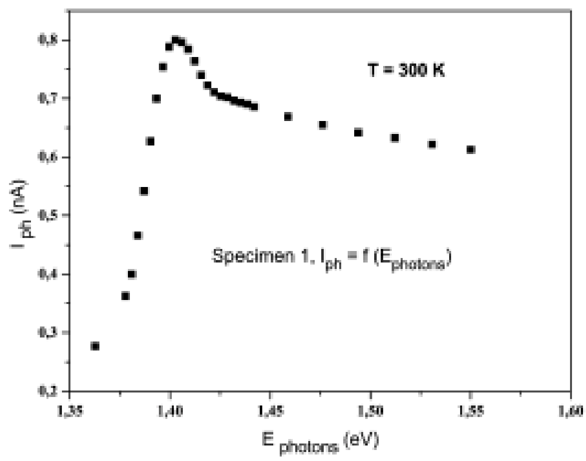

Fig. 1. I_{ph} as a function of $E_{photons}$ for the specimen No. 1 at T=300K.

3. RESULTS AND DISCUSSION

The I_{ph} as a function of $E_{photons}$ is plotted in Fig. 1 for the specimen No. 1 at the temperature T=300K. The applied voltage used to obtain the spectrum was 20 mV. Similar spectra were taken for the other two specimens.

The analysis of the spectrum plotted in Fig. 1, is shown in Fig. 2. Three Gaussian curves were obtained with their peaks P1, P2, and P3 located at the energies 1.519 eV, 1.422 eV, and 1.399 eV correspondingly. As the three specimens were pieces of the same wafer and their spectra were similar, we thought that there was no reason to follow the same procedure for the other two specimens.

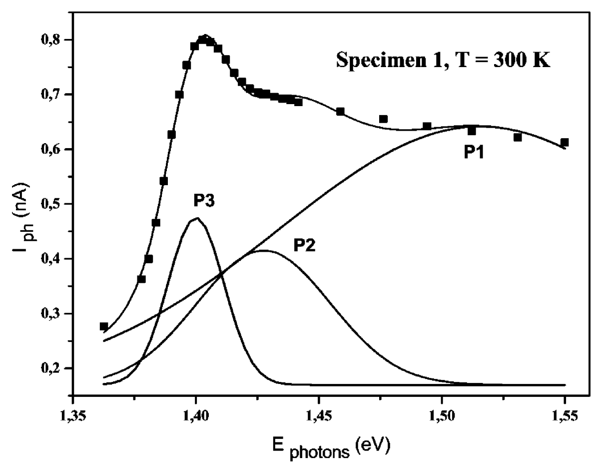

Fig. 2. Analysis of the spectrum plotted in Fig. 1.

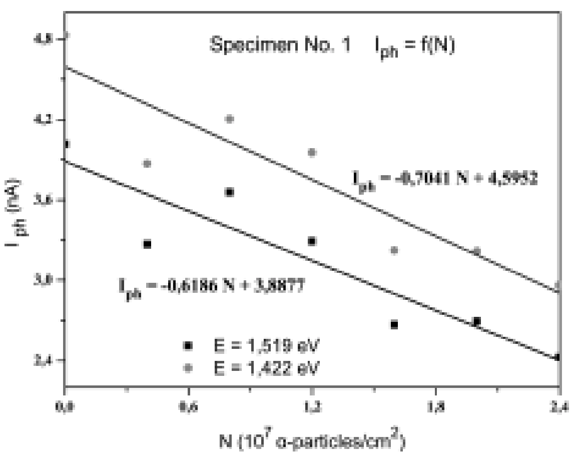

Fig. 3. I_{ph} vs irradiation flux for specimen No. 1.

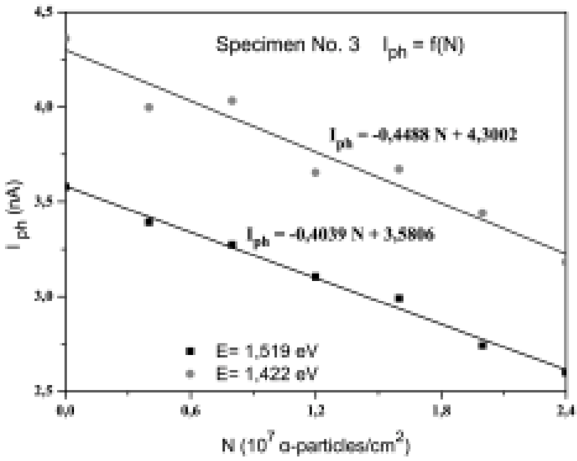

Fig. 5. I_{ph} vs irradiation flux for specimen No. 3.

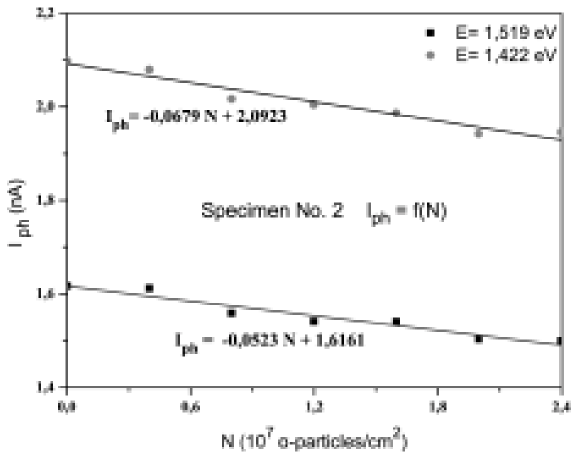

Fig. 4. I_{ph} vs irradiation flux for specimen No. 2.

The I_{ph} as a function of the number of α-particles/cm^2 for the specimens No. 1, 2, and 3 are plotted in Figs. 3, 4, and 5. The applied voltage, for all cases, was 100 mV.

We have not taken into account the measurements referred to the photon energy of 1.399 eV because the results were not satisfactory.

We observed that for all specimens the behavior of the I_{ph} as a function of N (number of α-particles per cm^2) is the same for both photon energies. This function is almost linear, as it results from the values of the correlation factor given by the least square method.

The values of the I_{ph} are decreased as the flux increases. This decrease is due to the increase of the defects produced by the α-particles irradiation such as Frenkel pairs and Schottky imperfections [5,8].

The observed differences in the slopes and pre-irradiation values of the I_{ph} of the three specimens are due to the different location of each specimen on the surface of the wafer.

The I_{ph} corresponding to the lower energy photons is higher than that corresponding to the photons of higher energy, as it is expected from the spectrum of Fig. 1. This may be due to the higher probability of this kind of transitions.

The specimens were annealed for 2 hours at the temperature of 370K without any remarkable recovery. We did not use higher temperature for the annealing procedure as we used silver paint for the ohmic contacts.

4. CONCLUSION

In this work we measured the photocurrent I_{ph} as a function of the flux of α-particles irradiation for two photon energies (1.519 eV and 1.422 eV) at the temperature of 300K and found that this relation is linear. By this method we can distinguish small differences in fluxes of low energy α-particles irradiation.

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