

TEMPERATURE DEPENDENCIES OF CHARGE COLLECTION EFFICIENCY OF THE SENSORS BASED ON GAAS:CR STRUCTURES

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Keywords: GaAs:Cr sensors, temperature dependencies, charge collection efficiency, lifetime of free charge carriers.

Abstract. This article is devoted to the study of the temperature dependencies of the charge collection efficiency of the GaAs:Cr sensors. These sensors are widely used in the experiments in modern physics. The article also shows the dependence of the lifetime on temperature.

ТЕМПЕРАТУРНАЯ ЗАВИСИМОСТЬ ЭФФЕКТИВНОСТИ СБОРА ЗАРЯДА СЕНСОРОВ НА ОСНОВЕ GAAS:CR СТРУКТУР

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Ключевые слова: сенсоры на основе GaAs:Cr структур, температурная зависимость, эффективность сбора зарядов, время жизни свободных носителей заряда.

Аннотация. Данная статья посвящена исследованию температурных зависимостей эффективности сбора зарядов сенсоров на основе GaAs:Cr структур. Данные сенсоры активно используются при проведении экспериментов в современной физике. Также в статье приведена зависимость времени жизни свободных электронов от температуры.

1. Introduction

Semiconductor radiation detectors are widely used in modern high-energy physics. Currently, more than 90% of all semiconductor devices are being produced on the basis of silicon and germanium. However, the usage of sensors based on these very foundations is limited by low operating temperatures and low coefficient of the absorbed radiation at the energies above 20 Kev for germanium and silicon sensors. Therefore, the compound semiconductors come at the forefront, e.g. gallium arsenide (GaAs), which has a number of such advantages as a large energy band gap (1.4 eV), high coefficient of the absorbed radiation of gamma-rays (10-60 Kev). However, gallium arsenide has significant drawbacks, such as a small value of the lifetime of charge carriers (10-8 ns) and the conductivity depth of penetration of the electric field in the material (1 mm), due to the presence of intrinsic point defects (deep EL2-centers) [1]. One of the way to reduce the influence of EL2 centers is to compensate GaAs with chromium [2].

Charge collection efficiency is the main characteristics of the detectors which depend on the production of mobility and lifetime of the charge carriers. In this project, we study the dependence of charge collection efficiency on the temperature conditions of work of the GaAs sensors.

2. Experimental setup and samples

Structure of the Me-GaAs:Cr-Ni Me and CrNi contacts were the studied samples. The amplitude spectra were taken in the temperature range of 25-50°C when the voltage on the sensor from 10 to 150 V in order to obtain the dependencies. Temperature control is done by a Peltier element. The ²⁴¹Am was

used as the gamma radiation source. Measurement equipment (figure 1) included a preamplifier (PA) and the driver amplifier (SA), the data were transferred to digital format by ADC and displayed on the computer.

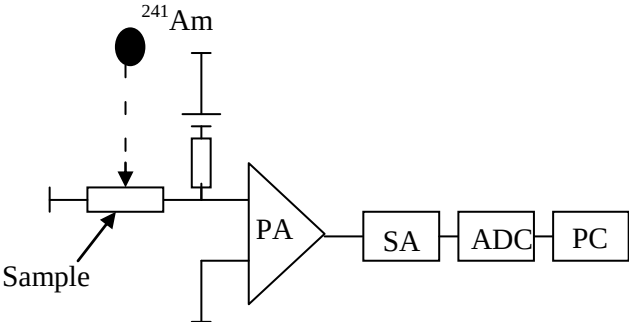


Fig. 1. The scheme of the experiment

3. Result and discussion

Amplitude spectra, obtained at different temperatures and constant voltage (U =120 V) shown in figure 2.

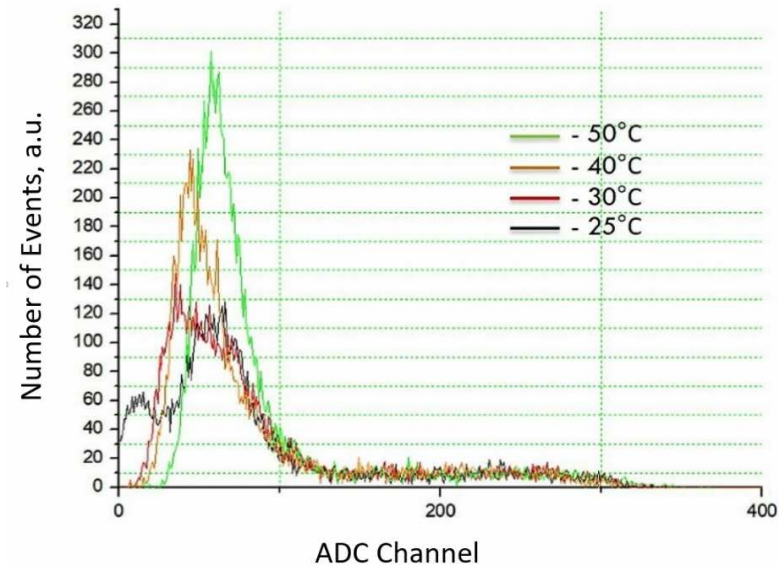


Fig. 2. The amplitude spectrum of GaAs:Cr at different temperatures T°C and the voltage applied to the sample 120 V

To calculate CCE of each sample, the ADC channel from amplitude spectrum which corresponded to the maximum of the distribution of events was found. For GaAs:Cr the channel is determined from the decay «of the shelf» which corresponds energy of 60 Kev. Previously was experimentally determined that the number of the ADC channel which corresponds to 100% charge collection efficiency, is equal to 319 (1).

$$CCE = \frac{N_{ADC}}{N_{319}} \cdot 100\% . \tag{1}$$

Figure 3 shows the temperature dependence of the charge collection efficiency on the electric field in table 1 from the voltage.

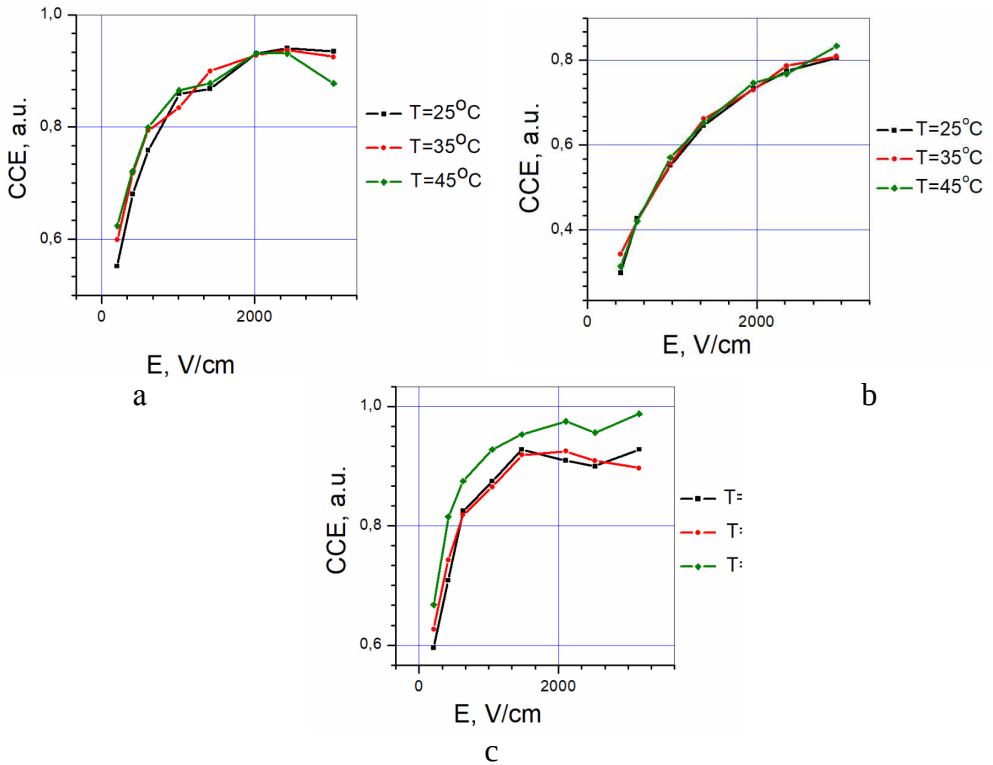


Fig. 3. The temperature dependence of charge collection efficiency on the electric field: a) for the sample № 1, b) for the sample № 2, c) for the sample № 3

For the samples № 1 and № 3 we can observe increased charge collection efficiency while the temperature is increasing, which is clearly visible at low bias voltages of 10-50 V. For both samples the character of the dependency becomes nonmonotonic at higher voltages. However, for the sample № 2 there is no CCE(T) dependence.

Tab. 2. The temperature dependence of the lifetime of the charges

T, °C	$\mu_e \tau_e, \text{cm}^2/\text{V}$		
	№ 1	№ 2	№ 3
25	159500	40250	175500
30	173750	39250	164500
35	18400	41750	190250
40	180250	42000	269750
50	211750	42750	279250

Using Hecht equation [1], the mobility-lifetime product of electrons ($\mu_e \tau_e$) was calculated for the studied samples (table 2). For the sample № 2 the $\mu_e \tau_e$ value remains constant, i.e. there's no temperature dependence, however, for samples № 1

and № 3 with the temperature increase we can clearly observe the rise of electron lifetime.

4. Conclusions

Based on everything we said before, the following conclusions can be made. For the samples with a large lifetime (60 - 70 ns) the dependence of charge collection efficiency on the temperature is being observed, which is connected with the increase of the $\mu_e\tau_e$ value with temperature. But, at the same time for the samples with a low lifetime (16 ns) the temperature dependence is not observed.

Thus the dependence of charge collection efficiency has complex behavior and should be studied further.

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