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### Journal of Physics: Conference Series 675 (2016) 042013

# Research of work stability of diamond detectors used in SCR DDIR

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Abstract. In this work we study influence of various factors on stability of ionizing radiation detectors installed in the cosmic ray spectrometer (SCR) based on diamond detectors of ionization radiation (DDIR). Diamond detectors for SCR are made of single crystals of synthetic diamond type IIa. Diamond detectors were studied successively in three different experiments. Checking detector stability with ambient temperature increased up to 70 degrees Celsius was the first experiment. At next we change the geometry of detector irradiation by rotating nuclear source around it and measuring changes in detector count rate. And last one experiment was about checking the phenomenon of polarization by prolonged detector irradiation by ionizing radiation of various types and energies. The study revealed the presence of the strong influence of the polarization effect on the work of diamond detectors for registration of ionizing particles with short mean free path (in our experiment they were the alfa-particles of <sup>238</sup>Pu). In this work correspondence of the experimental results of the "rotation" the source around the detector with the data obtained by simulation in GEANT-4 was shown.

### 1. Introduction

The detectors of ionizing radiation (IR) based on the diamond sensitive elements are getting more popular in various spheres of human activity in recent years. The idea to use diamond as a sensitive element for the detectors of ionizing radiation appeared in the 1960s, and has been determined by such properties of diamond as high radiation, temperature and chemical resistance [1]. However, difficulty with choosing the crystals with desired properties (mainly due to the different degrees of natural diamond purity) has impeded the intensive development of this direction, and therefore use of diamonds was very costly. Currently advances in growing the artificial diamond single crystals by chemical vapour deposition process (CVD) led to simplification of using diamonds in various applications in science and technology. For example, thanks to its high velocity of charge carriers and radiation resistance, diamond is now widely used as a replacement for silicon sensitive elements in devices monitoring the position of the beam of charged particles in accelerators, preventing the deflection of a beam from a predetermined path [2]. High radiation resistance and its stability at temperatures up to 200 degrees Celsius enabled to use diamond detectors in the vertical neutron chamber in the International Thermonuclear Experimental Reactor (ITER) [3]. This work is devoted to the use of diamond detectors of

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ionizing radiation in space technology, in particular in the Cosmic Ray Spectrometer developed by the Industrial - Technology Center "UralAlmazInvest". It is expected that the spectrometer will allow to study the cosmic radiation of following types: electrons, protons and heavy ions.

## 2. Experement setup

In this work we studied the DDIR ELSC-1 based on artificial type IIa diamond for saving stability of it characteristics under various conditions. The following conditions for the detector had been considered: increased ambient temperature; the detector irradiation at different angles of incidence by the IR on the surface of DDIR (that was checked with a simulation of diamond detectors, made by GEANT-4); a long irradiation time of the detector by different types of IR (checking the influence of polarization). Brief description of the ionizing radiation sources used in this study is shown in table 1.

Table 1. Radiation sources.	
Name of the nucleus and type of radiation	Energy spectrum
<sup>238</sup> Pu, alfa-particle	One line with energy near to 5499.9 $\rm keV$
<sup>90</sup> Sr- <sup>90</sup> Y, beta-particle	Continued energy range with maximum value near to 2.28 MeV, and energy of maximum of activity near to 545.9 keV.

# 3. The heating of the detector and changing the geometry of irradiation

ELSC-1 with a <sup>238</sup>Pu was placed in special heater, where temperature was up to 70 degrees Celsius. Then twelve spectra (300 seconds in duration each) were recorded with PC-compatible board, while decreasing detector and source temperature by every 5 degrees Celsius. We studied the changes in the total count rate of the detector and in the count rate at the peak of total absorption. The results of data obtained during several series of such measurements are shown in figure 1. Statistics of pulses set has made main contribution to the measurement error.



**Figure 1.** Influence of different temperature on the count rate of DDIR ELSC-1, <sup>238</sup>Pu (lines connecting points are guide to the eyes only).



Figure 2. Influence of different experiment geometry on the count rate of DDIR,<sup>90</sup>Sr-<sup>90</sup>Y, (lines connecting points are guide to the eyes only).

As we can see, there are no changes in count rate of ELSC-1 by detecting ionizing radiation of  $^{238}$ Pu, even with ambient temperature near to 70 degrees Celsius.

The study of ELSC-1 detector behavior in a changing geometry of irradiation was the next experiment. The angle between the incident flux of IR and the surface of ELSC-1 varied in increments of 10 degrees, and after each change the spectrum of ionizing source <sup>90</sup>Sr-<sup>90</sup>Y was recorded. Also, a mathematical model was created in the GEANT-4 environment, which imitates a similar experiment. Comparison of the results is shown in figure 2.

As seen from the experimental results, there is a slight decrease in the count rate when the angle of incidence on the detector surface reaches the value of 70 degrees. This means that a decrease in detection efficiency due to reduction of the effective area of the detector under the influence of radiation, prevails over the increase of efficiency, which is caused by increasing of the thickness of the detector. Comparison of experimental results with mathematical models showed similar results, and in this connection we can make one conclusion: a mathematical model of a diamond detector created in GEANT-4 is fully confirmed by the behavior of the detector in the real world.

## 4. Checking the polarization phenomena

The most significant drawback of diamond detectors today, is their susceptibility to the influence of the polarization effect. This effect is manifested as a decrease in charge collection efficiency of the detector (which reduces the counting rate and the distortion of the spectrum [4]). Checking of the polarization effect in ELSC-1 detector was carried out using a long irradiation of the detector by two types of ionizing radiation. There was continuous recording of twelve spectra, 300 seconds in duration each (total time of measurement is one hour). Comparison of the ELSC-1 readings at the beginning and at the end of the measurement cycle allows us to see whether there is any polarization. The comparison of the results for different radiation sources are shown in figures 3 and 4.



**Figure 3.** Influence of different temperature on the count rate of DDIR ELSC-1, <sup>238</sup>Pu.



Figure 4. Influence of different experiment geometry on the count rate of DDIR, <sup>90</sup>Sr-<sup>90</sup>Y.

We saw noticeable effect of polarization in case of registration of radiation with short mean free path. We investigated some ways to eliminate polarization (currently known method of turning off the power supply of detector and a method of changing the polarity of the bias voltage [5]). It was found that turning off the power supply of the ELSC-1 for 30 seconds is the better way to eliminate the polarization than reversing polarity of the bias voltage for the same time. In this regard the special scheme for CRS was made that allowed spectrometer to work in the following measurement mode: 60 seconds of measurement, 10 seconds depolarization by turning off the bias voltage. Currently, CRS is at the final stage of manufacturing.

# 5. Conclusion

It has been found that the DDIR ELSC-1 remains stable when the ambient temperature increases up to 70 degrees Celsius.

We have found a slight change in the counting rate by increasing the angle of incidence of electron radiation on the surface of a diamond detector from 0 to 70 degrees, which confirmed the legitimacy of the use of a mathematical model of the detector set up in GEANT-4.

It is shown that with the help of periodic power outage from the detector for short periods of time (about 30 seconds) the instability of the diamond detector associated with the effect of polarization is almost entirely eliminated.

# Acknowledgments

This work was partially supported by MEPhI Academic Excellence Project (contract No. 02.a03.21.0005, 27.08.2013).

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