INVESTIGATION OF THE APPLIED VOLTAGE INFLUENCE ON THE IONIZING RADIATION PARTICLES DETECTING BY DIAMOND DETECTORS

V.V. Okhotnikov, S.A. Linnik, A.V. Gaydaychuk
Scientific Supervisor: Dr. S.A. Linnik
Language advisor: A.K. Ustyuzhanina
Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050
E-mail: vvohotnikov@yandex.ru

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПРИКЛАДЫВАЕМОГО НАПРЯЖЕНИЯ НА ДЕТЕКТИРОВАНИЕ ЧАСТИЦ ИОНИЗИРУЮЩЕГО ИЗЛУЧЕНИЯ АЛМАЗНЫМИ ДЕТЕКТОРАМИ

В.В. Охотников, С.А. Линник, А.В. Гайдайчук
Научный руководитель: к.т.н. С.А. Линник
Лингвистический руководитель: А.К. Устюжанина
Национальный исследовательский Томский политехнический университет,
Россия, г. Томск, пр. Ленина, 30, 634050
E-mail: vvohotnikov@yandex.ru

Аннотация. *Мы сообщаем об исследовании влияния приложенного напряжения на способность алмазных детекторов улавливать и передавать пригодный для считывания сигнал ионизирующего излучения. Измерения проводились на образцах детекторов поликристаллического алмаза детекторного качества (5 мм × 5 мм × 500 мкм) в диапазоне напряжений от -1000 В до 1000 В путем облучения β-частицами Sr.*

Introduction. The one of the problems of modern technologies for the calculation and determination of a wide range of particles that are studied in the field of space, fundamental physics and nuclear technologies is a process of fast high-energy ionizing particles detection with large volumes and for a long time. Particle detectors, which are used to detect, track, or identify high energy particles typically consist of a detection volume and an amplifier. The ionizing particle is crossing the detection volume and creating charge carriers that are read and amplified to the level of the measurable signal. In this case, silicon and similar detectors suffer from the high degree of degradation with prolonged exposure of ionizing radiation. Therefore, it is urgent to research and develop a new technologies for the application of a wide range of materials that could expand the technological capabilities of using detectors in different environments and for various purposes.

The diamond combines several outstanding properties, such as the highest hardness, thermal conductivity, chemical inertness and exceptional strength. Consequently, the diamond is attractive not only for jewelry, but also it is interesting for scientific and technological purposes throughout the world. As a wide-gap semiconductor, diamond has a low density of charge carriers, it has the highest radiation resistance and high detection rate due to the high mobility of charge carriers of both electronic and hole conductivity [1]. At the same time, the higher the applied voltage to the detector mean the greater the detection rate, which makes it possible to read a high volume of incoming data. It is to determine the optimal parameters of the applied voltage.

Materials and research methods. The diamond detectors usually consist of parallel plate with two metallized surfaces as electrodes. The new developments of diamond detectors use 3D geometry, where the electrodes are located inside a bulk material. In the work, industrial samples of diamond detectors of detector quality (5mm X 5mm X 500mkm) were used, contacts were made by W / Ti layers with a summary thickness around 150μm. The principle of operation: a high voltage is applied to the electrodes for electric field creation inside the diamond volume. The ionizing particle (β-particle Sr), passing through the diamond bulk and creates an electron-hole pairs by ionization. The average ionization energy of a diamond is about 13.2 eV [2], which leads to the creation of 36 electron-hole pairs per 1 μm diamond thickness for a minimal ionizing particle (MIP) [3]. The electric field forces the charge carriers to drift to the electrodes. This drift of the charge carriers causes directly the current in the reading circuit after the Ramos law [4]. The measurements were carried out on a Keithley 6485 picaampermeter for 8000 seconds in a range from -1000V to 1000V in 200V increments.

Результаты. The results of measurements are shown in Fig. 1. In ideal conditions, the graphs should be identical for different applied voltages and differ only in the output current and be a straight line with uniform periodic oscillations with an amplitude of the order of 100 pA.

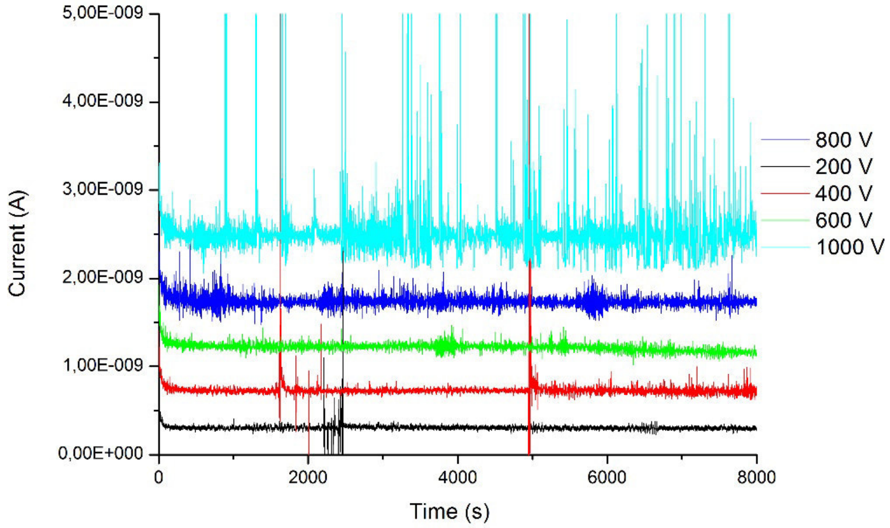

Fig. 1. The measurements of the produced current when the detectors are irradiated by β-particles of Sr with a positive voltage applying.

With the voltage decreasing, the stability of the measurements increases. At the same time, in the range of more than 600 and below -600 volts there are large fluctuations in the signal, this is do not allow the signal to be read sufficiently cleanly and correctly.

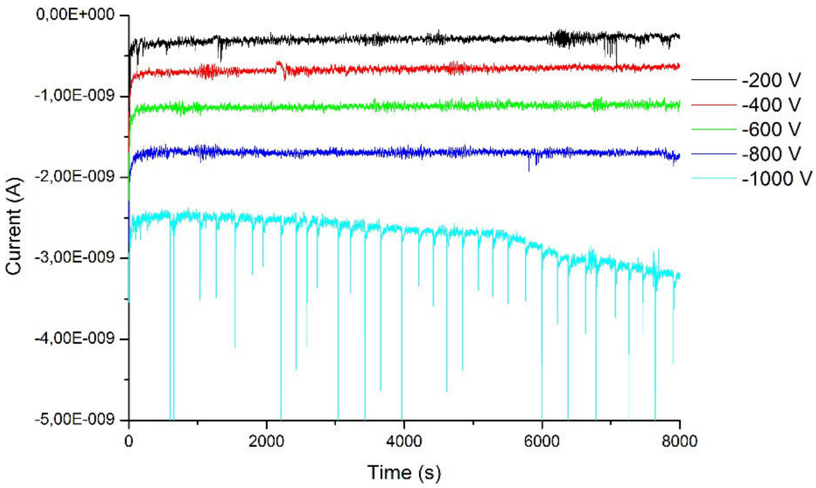

Fig. 2. The measurements of the produced current when the detectors are irradiated by β-particles of Sr with a negative voltage applying.

A stable and readable signal is observed in the range from -600 to 600 volts, which is nevertheless contains a rather significant amount of noise, which should be filtered out during the measurements. It is also worth noting that with an irradiation time more than 5500 s the signal degradation is observed, this is happened by the internal degradation of the material and is unstable due to the heterogeneity of the material and the structure of the defects in the detectors lattice.

Conclusion. The most successful voltage application is order of -600 V, which corresponds to an approximately 1 V/μm of detecting material. Such a voltage makes it possible to increase the rate of recombination in the semiconductor detector volume and to increase the rate of ionizing particles reading which cause the creation of electron-hole pairs. At the same time, it is possible to filter noise from the measured parameters and introduce an allowable error in the overall measurements.

REFERENCES

1. Spear K. (1994) Synthetic diamond: Emerging CVD Science and Technology. Wiley Interscience Publication.
2. Canali C. (1997) Electrical properties and performances of natural diamond nuclear radiation detectors // Nuclear Instruments and Methods, no. 160. – pp. 73–77.
3. Pomorskiy M. (2009) Electronic Properties of Single Crystal CVD Diamond and its Suitability for Particle Detection in Hadron Physics Experiments: Ph. D. thesis – Johann Wolfgang Goethe University in Frankfurt am Main.
4. Ramo S. (2003) Currents Induced by Electron Motion // Proceedings of the I.R, no. 27, pp. 584–585.