

Porous Silicon-Integrated Germanium Quantum Dots for Advanced Radiation Detector Applications

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Abstract: - The porous silicon and the porous silicon doped with germanium (Ge) powder were prepared electrochemically, inspired by the mentioned parameters. The proportion of Hydrogen fluoride (HF) to ethanol was 4:1. Field emission scanning electron microscopy (FESEM) and energy dispersive X-ray spectroscopy (EDX) were used to characterize the sample structure, and it was observed that Ge is present in the sample. We studied the sample current-voltage (I-V) characteristics to observe at which bias voltage on the source the measured current is increasing. Furthermore, fully utilizing the readout capabilities, pulses of X-rays were successfully measured and compared in the investigation of different parameters of X-ray illumination on the sample detector. The porous silicon (PS) and Ge -PS parameters that yield the best results are (90V, 100mA, 1s) and (100V, 10mA, 0.5s).

Key-Words: - porous silicon; X-ray detector, Quantum dots, EGFET, Ge/PS, radiation, sensitivity.

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1 Introduction

Radiation is the process of energy being transmitted in the form of waves or particles (as Electromagnetic waves or subatomic particles such as electrons, neutrons, etc.) through any material medium or space. Radiation comes in two forms: ionizing and non-ionizing. Ionizing radiation is a type of radiation that causes atomic particles to become ionized, which makes electrons leave their orbitals. It comes up when energy is moving through waves or particles. Ionizing exposure is formed by types of radiation such as X-rays, gamma rays, and neutrons. Non-ionizing radiation is radiation that does not have sufficient energy to ionize atoms, including radio waves and microwaves, [1], [2].

There are two main types of X-ray detectors: indirect ionizing radiation detectors and direct ionizing radiation detectors. A scintillator is utilized in an X-ray detector to convert X-rays into visible light, which is then detected by a visible light detector. An X-ray detector utilizes the photoelectric conversion effect of semiconductor materials to directly convert X-rays into electrical signals. Directly There are generally two kinds of X-ray detectors: direct ionization radiation detectors and indirect ionization radiation detectors. This X-ray detector utilizes scintillation to convert light and visible rays into electric signals and then processes such visible light with the visible light detector X-ray detectors use the photoelectric conversion characteristic of certain semiconductors to convert X-

rays directly to an electric signal. Directly ionizing radiation is a kind of 'wash' of highly charged particles, shoving their energy as they tear through any of the atoms' outer shells like bullets. Regarding indirectly ionizing radiation, in which a beam of X-rays or gamma rays interacts with an atom, and an electron is ejected (which in turn deposits its energy in tissues), [3].

X-ray detectors are one of the most popular devices used in many fields due to their excellent image quality. Industrial product testing, scientific research, and damage-free transportation of medicine, which is not nondestructible is a few of these fields, [4], [5], [6], [7], [8]. Using Figure 1 (Appendix), it is evident that not only is the solid-state semiconductor X-ray detector of simple and compact form factor, lightweight, and maximal robustness but also the flexibility it provides, even further is evident by the capability to generate imaging detector slices, [5], [6], [7]. They provide the potential to construct relatively effective detectors with excellent reliability and sensitivity over the entire range of scales in the human body. Efficiency, sensitivity, and peak-to-background are important parameters when assessing X-ray detectors.

They provide the potential to construct relatively effective detectors with excellent reliability and sensitivity over the entire range of scales in the human body. Efficiency, sensitivity, and peak-to-background are important parameters when assessing X-ray detectors. These two quantities are important for reducing the radiation dose to patients in X-ray examinations and for detecting weak X-ray signals. These are almost entirely determined by the charge carrier mobility-lifetime product ($\mu\tau$), which is closely associated with Material Atomic number Z . Along with the progress in semiconductor technology, the selection of materials for use as the X-ray detector has become wider. Most of the materials used are crystalline, such as silicon, germanium, cadmium zinc telluride, and so forth, [8], [9], [10]. And now the programmers are also interested in nanoparticles because of this amazing technological age. To expand the focus of the nanoscale investigation, we will exchange these modified particles for the solution-synthesized materials, such as crystalline and amorphous nanomaterials. Various techniques have been used for the synthesis of nanomaterials and are adapted to the different approaches to the synthesis of the

material, [11]. For instance, the process of chemical vapor decomposition (CVD), chemical exfoliation of graphene oxide, and graphitic oxide reduction methods are employed to produce graphene or carbon nanotube (CNT). Quantum dots (QDs) are a class of nanoparticles that have a few atoms and can carry electrons. Woggon has extensively investigated their optical properties, especially their absorption properties. A quantum dot semiconductor senses UV, and it emits a definite wavelength; hence, we observe a specific color, [12]. The electronic, magnetic, and optical properties of QDs doped with other atoms can be strongly shaped by their sizes and shapes.

PSs are generally formulated with open void silicones, [13]. It was discovered by the Uhlirs at Bell in the early 1950s. At the time, the Uhlirs were studying electrochemical procedures for shaping silicon wafers, which were used to produce microelectronic circuits. It won't work. Expected in electrochemical, silicon wafers should not dissolve uniformly, given the right electrochemical conditions. But in the 100> direction, holes were observed on the waferplate that can be explained only as the result of drilling in the wrong place a foot without taking care to keep connections valid.

This material fell out of use, as it was largely forgotten until the 1980s. But when they discovered that its incredibly high surface area was beneficial for spectroscopy experiments, there were two new applications to explore. A Ge quantum dot sample was selected for PS doping, since it can affect detection. Although the electron number is higher, the sword will still be obtained with lower irradiation, [14]. It has not yet been reported whether this element can be used as a dopant for irradiation. We will carry out I-V characterization of a sample post-synthesis to uncover the influence of irradiation on the detector. There are two commonly employed types of dosimeters in the semiconductor field, namely, silicon diodes and metal-oxide-semiconductor field-effect transistor (MOSFETs). However, it has to be taken into account that extended gate field effect transistors (EGFETs), besides having small detector sizes, have many more attractive features in terms of ease of preparation and in use. More broadly, it is highly versatile, can be positioned anywhere in a system, and presents capabilities that might be thought of as low-sensitivity detection with surprising sensitivity for monitoring during irradiation. So I could give good ideas for how to make a radiation detector more

efficient for material research. The radiation detection result of each dosimeter's type, pros, and cons will be displayed immediately after installation. Semiconductor detectors were emphasized in this study since it is their response to this radiation is more pronounced as compared to that of ionization chamber detectors, [14], [15]. Some examples of ionizing radiation include X-ray and gamma ray, while non-ionizing radiation encompasses radio waves, microwaves, infrared, visible light, and lower energy ultraviolet (UV) radiation. Given its widespread use in medical devices, X-ray photons are typically selected to irradiate the sample detector connected as an EGFET.

2 Methodology

Preparation of PS: Electrochemical etching was adopted due to its low cost and high yield. The preparation can be divided into four steps: cutting, washing, electrochemical treatment, and cleaning. A silicon wafer is first cut into a 2×2 cm square box, with an ATV RV-129 diamond scribe machine. The sections cut thus were then cleaned by the Radio Corporation of America (RCA) standard method, a technique developed by Werner Kern and co-workers at RCA Laboratory in the late 1960s. This comprises removal of currents originated from organic and particle cleaning (RCA-1), stripping oxides, and using ionics cleans (RCA-2). The wafer was then placed into a Teflon cell bottom against a metal plate. Taking deposition of Ge on PS as an example, 0.05 g Ge powder was added into the mixed solution of HF and ethanol (4:1). The work voltage 20 F(w) B(Ge is oxidized in the solution, the electrochemical reaction is started by 20 mA current and 20 min etching time, the solution was decanted and the PS was rinsed several times with ethanol. The weight of the sample will be measured and recorded after etching. For the examination of the production technique of the stone material and the standard topography, we apply a FESEM. This method is appropriate to study a material at its surface and detect structures as small as 1 nm, [16]. In contrast to X-ray spectrometry (XPS) or X-ray diffraction (XRD) representing no information about the spatial distribution of the sample, FESEM utilizes tungsten heated filaments as the source of high velocity electrons, which are bombarded onto a sample. The produced secondary electrons will be caught by a detector and enlarged in

electric signal. The signals will further be reported as the image, [17].

A finger mask is placed over the sample and sputtered after the samples are characterized. A silver RF sputtering equipment is applied as a target. The sample is then covered with a finger electrode with a width of 0.35 mm, a length of 3.4 mm, and a gap of 0.40 mm in space. Using a tungsten lamp as a light source, the intensity of the light on the sample detector relative to no light is compared. I-V curve parameters were measured, recorded, analysed, and discussed in experimental work. The sample detector is investigated as such by an EGFET (Extended Gate FET). The experiment is aimed at investigating how radiation behaves with the samples.

3 Results and Discussion

3.1 FESEM/EDX Result

Following synthesis, the samples were subjected to FESEM/EDX. Approximate the average pore size of the powder. The average PS pore size is approximately 420.88 nm. 'Branches' are formed on the PS surface. FESEM and EDX are like twins; we can also say that we can determine the chemical composition from them. The samples in which detail deposits are formed are noted in the Ge (011). Because of the low mass of deposits applied during the electrochemical process (0.05g of deposits in the sample), searching for any deposits in the sample is difficult. The powder samples are contaminated with particles of boron (B), copper (Cu), and fluoride (F) impurities.

As seen in Figure 2 (Appendix), the highest peaks of Si and O can be observed on PS, indicating the presence of an oxide layer on the surface. The fraction of Ge in the Ge-PS is 0.18% wt (0.07% at).

3.2 I-V Characteristic Result

The I-V curve is measured for the sample exposed to the interdigitated finger electrode deposition. This work was undertaken to investigate how the presence of light in the range of wavelengths from 380 nm to 700 nm influenced the sample detector. The applied voltage is swept from drain to source and is fixed between -5 V and 5 V, while the bias voltage set on the gate is 0 V or 0.3 V. As shown in Figure 3 (Appendix), bias voltage gives a significant variation in all sample detectors; any increase in bias voltage up to 0.3 V leads to the maximum current. It is seen,

for example, that for the PS at 5V without light or bias 0V, the current is only seen at about 2.0×10^{-5} A, and at bias 0.3V, the current is about 7.0×10^{-4} A.

This may be responsible for the fact that when the bias voltage applied to the gate is removed, the electrons on the surface of the gate will be repelled. As a result, the drain is allowed more current. Therefore, it follows that the current increases with the increase of bias voltage. This is consistent with the report in [18], [19], in which a bias voltage is applied on the gate, and the current for fixed drain voltage as a function of increasing gate voltage V_g .

With respect to the first type of study, it is clear to see (in this part of the study) that in light, the current rises up at the same voltage value (except for Ge-PS at bias 0.3V). Except for Ge-PS at 0.3V bias, the difference between the two curves under this condition can be an indication that recombination of electron-hole pair will be increases (Table 1, Appendix). The phenomenon arises due to the effect of light in these semiconductors. When a photon of light from a radiation source is exert on semiconductor casing, certain of the electrons in the valence band will absorb energy from photons of light. And frequencies in the form of light are then propelled to the conduction band, creating more holes in the valence the potential between the two sides of the semiconductor as shown in Figure 4 (Appendix).

To provide a deeper physical understanding of the detector's performance, the charge collection efficiency (η) of the Ge-PS matrix was analyzed using the modified Hecht equation, [20]. The relationship between the induced photocurrent (I_{ph}) and the applied bias voltage (V) can be expressed as:

$$\eta(V) = \frac{I_{ph}}{I_0} = \frac{\mu\tau V}{L^2} [1 - e^{-L^2/\mu\tau V}] \quad (1)$$

where L is the thickness of the active layer, and $\mu\tau$ represents the mobility-lifetime product of the charge carriers. By fitting our experimental I-V data under X-ray illumination to this model, the $\mu\tau$ product for the Ge-doped porous silicon was estimated. The integration of Ge quantum dots into the porous silicon structure enhances the $\mu\tau$ product by reducing the recombination rate at the surface states of the PS pores. This mathematical correlation explains the significant increase in sensitivity observed in the Ge-PS samples compared to the pure PS samples, as the Ge dots act as efficient centers for carrier generation and transport under high-energy photon interaction.

3.3 X-ray Detector Results

The sample detector is exposed to X-rays and recorded. Various X-ray parameters will be tested and compared for each detector sample, and the results will be presented as current-time and voltage-time graphs. The purpose of this paper is to establish and compare the effects of (chemical) irradiation on sample detectors. For the following parameters, the curve of each sample detector will be examined as write down in Table 2 (Appendix).

Another X-ray-based research is called 5-pulse research, which is the use of 5 pulses on the sample detector irradiations with a constant X-ray parameter. This article is concentrated on a set of pulses in a current vs. time and voltage vs time plot. The applied voltage was 3 V and 5s for the sample detectors. Similar to the I-V characteristic study, with the increase of bias voltage at the gate, the current increases, that results I value for a 0.5 V bias mode that is larger than for a 0.1 V mode. In the IVT graph, we can see that the irradiated curve takes a longer period to measure the same current as in the case of non-irradiated curve. For the current-time curve for PS at the bias of 0.3 V displayed in Figure 5 (Appendix), it took 2.87 s and 4.26 s for NPS and IPS (90, 100, and 1) samples, respectively, to reach 0.0002 A.

In the case of no sample irradiation, it was found that the applied voltage at 2s was around 1V for PS. Current begins to rise from 0A at 2s, but the applied voltage in the irradiated samples is delayed from the pulse. This pulse can be seen from both the voltage vs time and the current vs time characteristics. Graph of voltage vs time and current vs time fluctuating and small pulses. For (90, 100, 1) and (100, 100, 1), a pellet irradiation pulse is observed at 0.45s with a measured current of 12.7 μ A, whereas a 0.45s pulse for (90, 100, 0.5) has a measured current of 16.4 μ A. The voltage vs time graph shows that for (90, 100, 1) and (100, 100, 1), 0.572V and 0.465V are measured after 2 s, while 0.444V before 2 s is measured for (90, 100, 0.5). The pulses resolved for current and voltage, as are for the biased condition (0.5 V), are more (Table 3, Appendix).

The profiles of the current-time graph and voltage-time graph of all samples are almost similar. The detected pulse during irradiation is the only difference. Some changes in pulse are less clear, however, in some samples. One such example is Ge-PS at a bias of 0.5V with parameter (90, 100, 1) in the graph of voltage vs time as shown in Figure 6

(Appendix). Pulses which can be detected in this study might be different from those for the reason of human error, such as concurrent functioning of irradiation and the system. Accordingly, the irradiation time may not always be the same, in that the X-ray irradiation and the operation of the I-V system may not proceed simultaneously. Furthermore, there is a large difference between the data of pulses and the original data, and the program for the smoothing curve method needs to be applied. Therefore, the pulses measured are the mean pulses. By the variations of seed irradiation parameters, attention can make Fascicuate researches be seen. For voltage variation, any changes in the I-V characteristic are noted during irradiation. This is to test the effect of the high-energy X-ray on the sample detector. Variation in the current of X-ray means to vary and control the number of electrons ejected from the electron gun to the anode target. Research on this parameter is to help to clarify the effect of additional X-ray photons upon the sample detector. Finally, regulating the length of irradiation involves studying the number of pulses in the findings that can be detected by the sample detector.

CGAM parameter study. However, other parameters study does not show much difference in parameters between sets. In theory, the ionizing X-ray and delivery energy that the camera may have been higher in voltage and in current for a short duration. This is because upon irradiation, higher energy is provided to the electron in the valence band to excite it to the conduction band. Rather, the recorded results are exactly the opposite. More time was used than after irradiation for voltage and current. Therefore, the only possible inference is that the measured data could represent results of the reverse bias voltage. For pulses, there with more complex pulse sequences and more set parameters, the difference under study is not easy to observe, as the range of parameters might be too narrow and the data is obtained without a clear difference. Thus, this investigation shows that the sample detector synthesized affects the irradiation. To investigate further into the effect of continuous five-beam irradiation on the sample detector on the current and voltage, another experiment was carried out.

3.3.1 Five-Pulses Study

In the following section of the methodology, five fixed continuous X-rays are exposed on a sample detector, and the data is illustrated in a graph. From

Figure 7 and Figure 8 in Appendix, the metrical mode of the peaks becomes more significant with each higher order. (lower than the pulse).

The maximum and minimum peaks are randomly taken to compute the mean peak difference for current and voltage. The formula is as follows:

$$\text{average peak difference} = \frac{\text{total highest peak} - \text{total lowest peak}}{\text{total peak selected}} \quad (2)$$

From Table 4 (Appendix), the calculated value of the average pulse difference of current and voltage of PS is increasing in each parameter. Nevertheless, for I in each of the parameters, the second pulse is smaller than the first pulse. This result could be attributed to the fact that the sample detector electrons relaxed before irradiation, or the sample was not preheated before irradiation.

From the results, it is also estimated that irradiation with X-rays exerts an effect on current, voltage, and time change. Most of the detected pulse duration does not correspond to the irradiation duration, however. For any set of graphs that are measured with the same samples but a different length of one irradiation time between 0.5 s and 1 s, the recorded pulse length of the irradiated pulse does not correspond to the length of the irradiated period. This can be inferred as the sample detector starts to recover to its initial current or voltage after irradiation, giving rise to pulses longer than the irradiation time.

There should be a rise in voltage and current against time if the sample detector of the crystal is irradiated by X-rays in the sense of principle. This is due to higher energy being given to electrons in the valence band to be excited and provide an increase in carrier density when X-ray photons are irradiated in the sample, [21]. The voltage in the gate would be read and should rise quickly, since there is a sudden increase of electrons in the conduction band after the radiation passes. This applied gate voltage serves to push the electrons away from the surface of the gate. Meanwhile, the voltage on the current across the drain will multiply. But there was a sudden loss of counting pulses, which is not supposed to happen. As follows from Figure 7 (Appendix), the behavior for only the first two pulses is enhanced. Hence, these two pulses work as they describe.

The observed pulses under X-ray illumination (Figure 8, Appendix) exhibited a transient "opposite"

behavior before reaching a steady state. While this might initially appear as a timing discrepancy, a formal sensitivity analysis reveals that it is a physical phenomenon related to Transient Displacement Current. In the Ge-PS heterostructure, the high density of surface states at the interfaces of the porous silicon and the Ge quantum dots acts as temporary charge traps.

Upon X-ray interaction, a rapid generation of electron-hole pairs occurs. However, a portion of these carriers is instantaneously captured by these localized surface states, creating an internal screening field that opposes the applied bias. This leads to the observed initial dip or "opposite" pulse morphology. As the bias voltage overcomes this screening effect (de-trapping mechanism), the current stabilizes. This interpretation is consistent with the electronic relaxation time constants calculated for nanostructured semiconductors, where the competition between carrier generation and trapping dictates the pulse shape. Consequently, the "optimum parameters" identified are those that balance the bias voltage required to minimize these trapping effects while maximizing the signal-to-noise ratio.

On the contrary, observed a decrease in the current after irradiation, [22]. There would be a cut-off voltage that makes the current initially rise and then fall after a few irradiations. Similarly, there is a possibility that irradiation causes the time to break down to decrease in a device geometry-independent manner.

The impact of X-ray irradiation parameters on the current and voltage pulses cannot be analyzed. Wondering why? It's because the parameters are different in the 4 samples you have. For instance, increasing the current of X-rays could indicate an increase in the electrons produced by the electron gun accelerated to the anode target. There should be more X-ray photons emitted and incident on the sample detector. With the sudden rise of the electron, the voltage of the gate increases, and the current decreases. Similarly, the current pulse difference is thereby increased. But the pulse difference of the PS and the Ge-PS sample decreases.

Even if the best sample detector parameter can be suggested, it may be subject to change depending on the irradiation timing and operation of the I-V system by hand. The effective parameter used to contrapose the pulse-difference of airlines detector is recommended in Table 5 (Appendix).

As a significant spread is observed in the level of the current and voltage pulses, these parameters are selected as the best choice. Not all observed pulse differences can be compared because X-ray impinges late on the sample detector. On the other hand, further investigations are needed in order to determine the best parameter values for sample detectors (Table 6, Appendix).

4 Conclusion

This study represents an initial use of nanotechnology in radiation dosimeters. Because of the low price of the EGFET, a measuring system exhibiting this element has indisputable advantages. The PS and Ge/PS extended gates were prepared by way of the electrochemical process with 4:1 HF/ethanol and 0.05g PCI3 doping powders. Doping material is well confirmed by FESEM-EDX analysis, and the image is obtained as well. The IV characteristic was obtained by the method shown, which is different from the other papers. In another experiment, the X-ray irradiation of a sample EGFET detector was studied. Results are also reported and quantified appropriately. With regard to the PS sample detector, the Ge-PS sample detector is the one with the greatest current-voltage pulse differential. Suggested optimal parameters for each sample detector are likewise, (90 V, 100 mA, 1 s) for PS and (100 V, 10 mA, 0.5 s) for Ge-PS.

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The authors wrote, reviewed and edited the content as needed and they have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Natheer A. Algadri (first author, corresponding author) conceived the research idea, developed the theoretical framework, supervised all stages of the work, contributed to data analysis, and led the writing of the final manuscript.
- Ahmad M. Al-Diabat contributed to the experimental design, performed physical calculations, and participated in the interpretation of theoretical results.
- Naser M. conducted laboratory experiments, collected data, and assisted in data analysis.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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APPENDIX

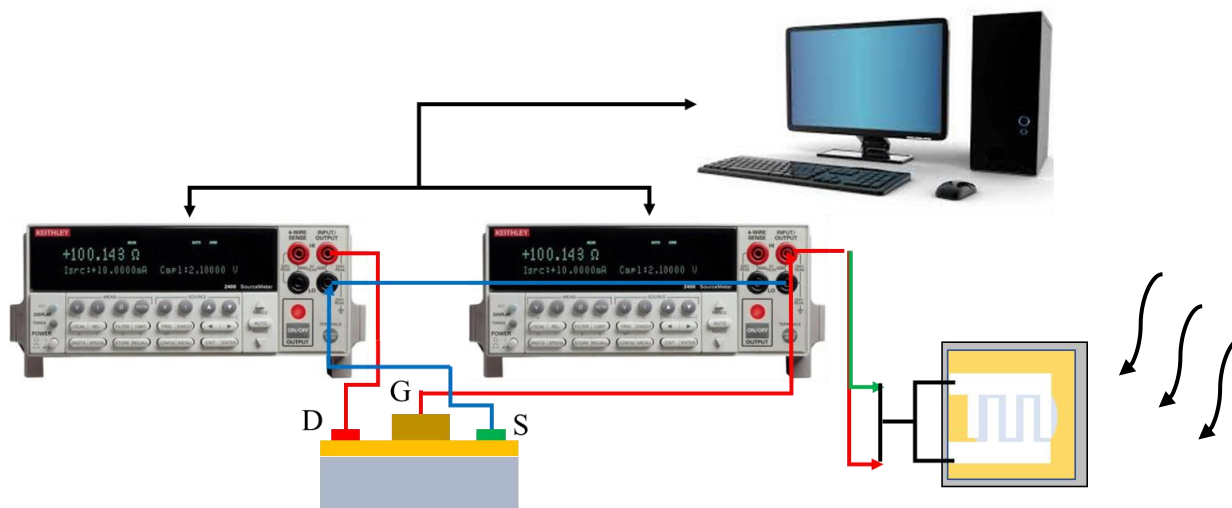


Fig. 1: Experimental setup for X-ray detector
Source: created by the authors

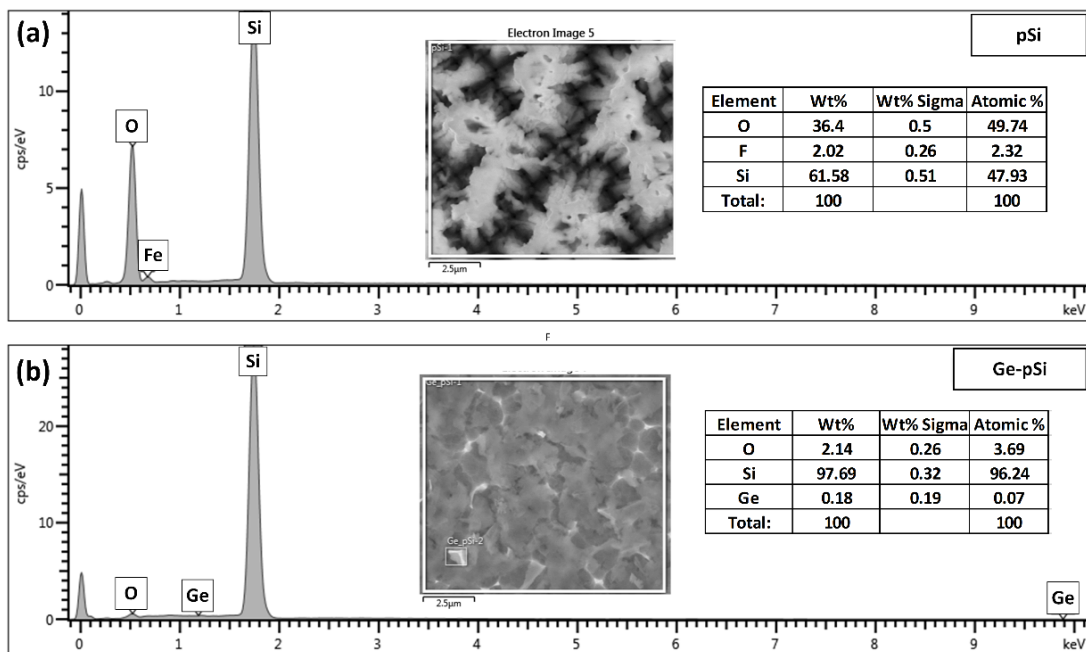


Fig. 2: FESEM/EDX result of (a) PS (b) Ge-PS.
Source: created by the authors.

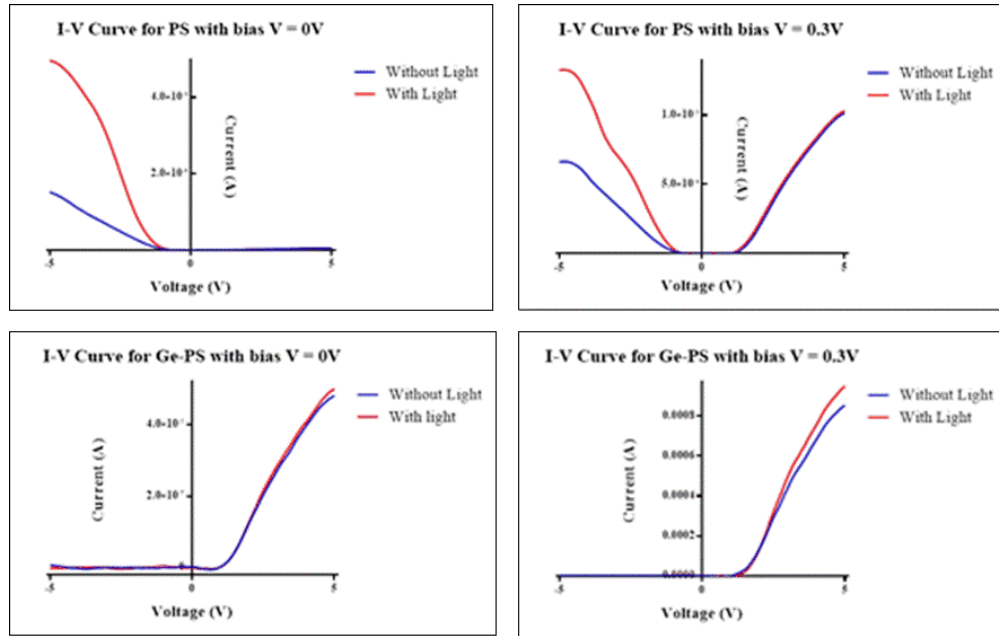


Fig. 3: I-V curve of PS, and Ge-PS at bias $V = 0V$ & $0.3V$
Source: created by the authors

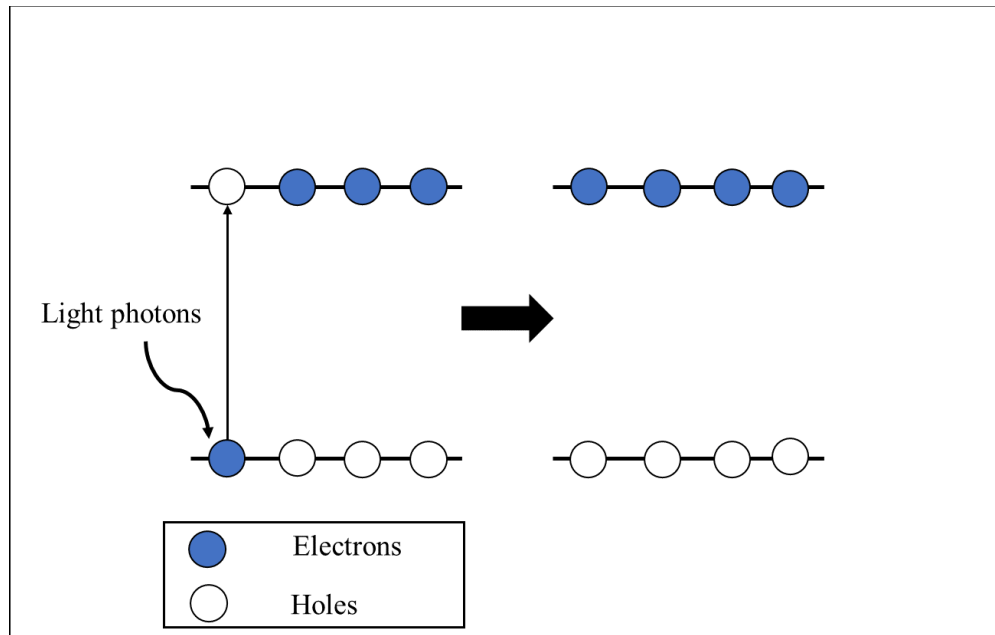


Fig. 4: Effects of light photons on energy band gap
Source: created by the authors.

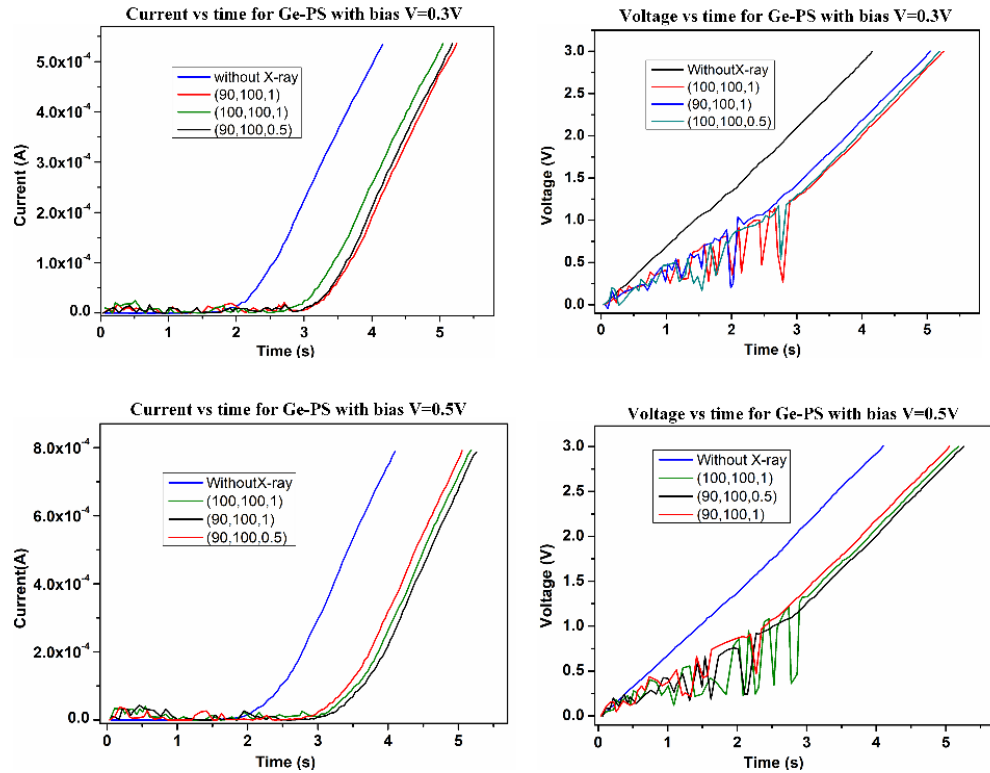


Fig. 5: Graph for PS with different parameters of X-ray irradiation
Source: created by the authors

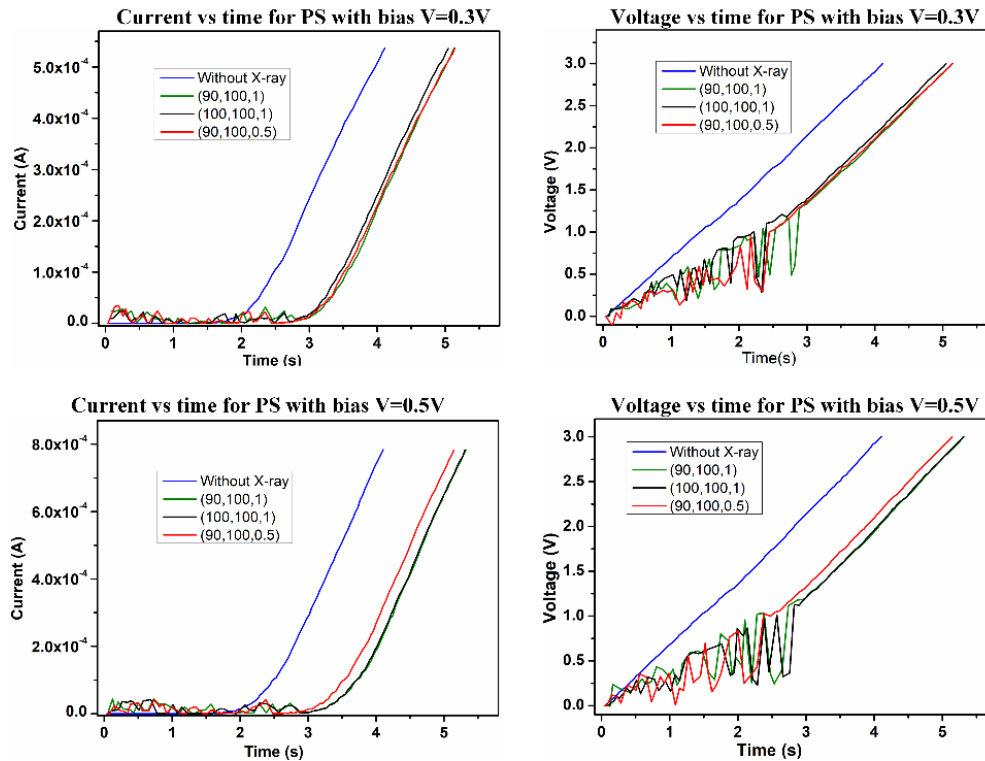


Fig. 6: Graph for Ge-PS with different X-ray parameters
Source: created by the authors.

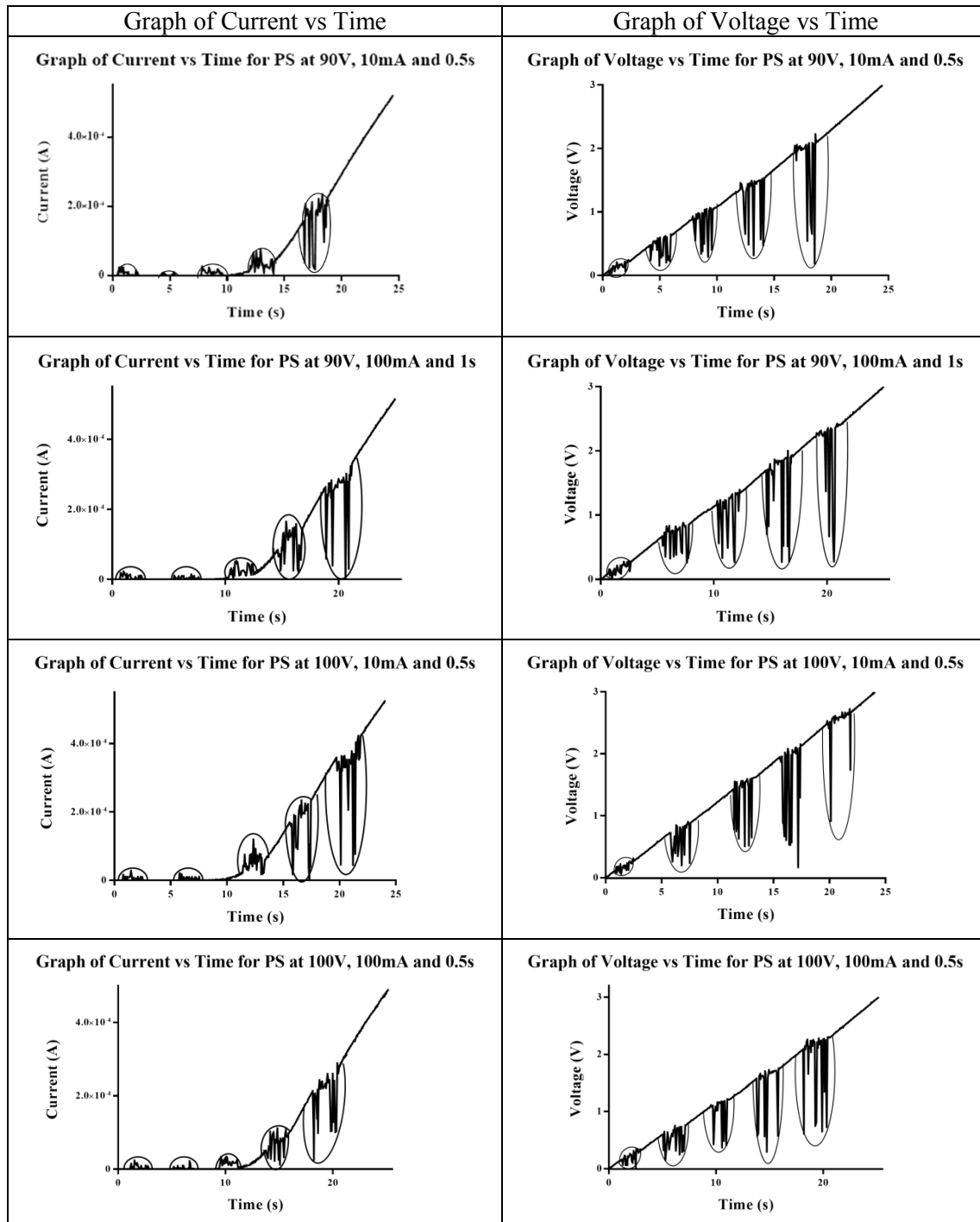


Fig. 7: Graph for PS with five pulses of X-ray irradiation

Source: created by the authors

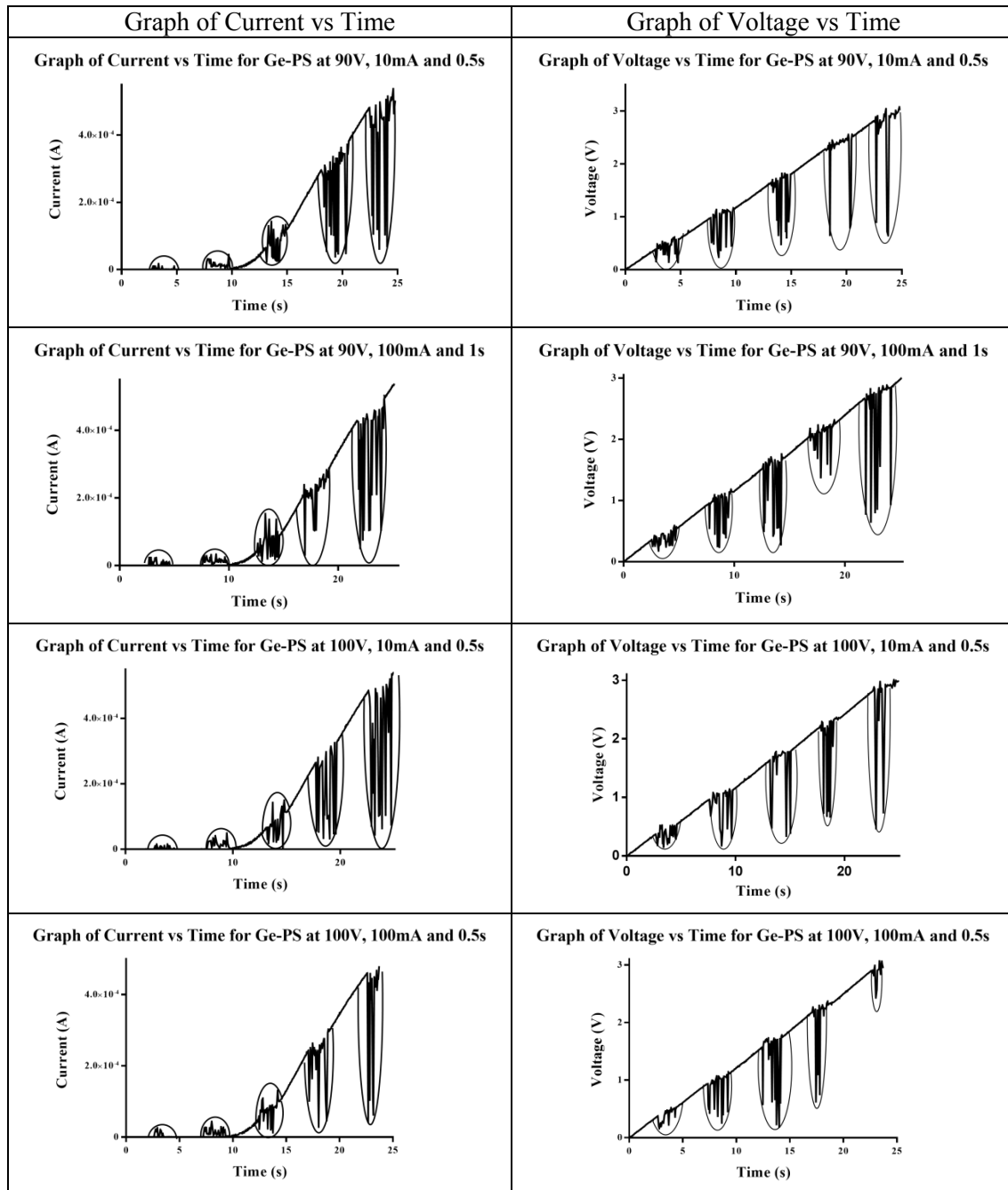


Fig. 8: Graph for Ge-PS with five pulses of X-ray irradiation
Source: created by the authors

Table 1. Maximum and minimum current measured for applied voltage (-5V and 5V) at bias 0V and 0.3 V

Sample	Bias 0V				Bias 0V			
	V=-5 V		V=5 V		V=-5 V		V=5 V	
Light	Presence	Absence	Presence	Absence	Presence	Absence	Presence	Absence
PS	4.90×10^{-5}	1.60×10^{-5}	5.27×10^{-7}	4.99×10^{-7}	1.35×10^{-3}	6.23×10^{-4}	1.05×10^{-3}	1.04×10^{-3}
Ge-PS	7.34×10^{-9}	8.73×10^{-9}	5.13×10^{-7}	4.85×10^{-7}	1.73×10^{-9}	4.74×10^{-9}	9.68×10^{-4}	8.70×10^{-4}

Source: created by the authors.

Table 2. Parameters used for irradiated samples

Short name	Description
Without X-ray	Samples are not irradiated with X-ray/ normal conditions.
(90, 100, 1)	Samples irradiated at 90 V, 100mA, and 1s.
(100, 100, 1)	Samples irradiated at 100 V, 100mA, and 1s.
(90, 100, 0.5)	Samples irradiated at 90 V, 100mA, and 0.5s.

Source: created by the authors.

Table 3. Current and voltage pulses measured for PS at bias 0.3V and 0.5V

Sample	Pulses measured		
	Parameters	Current vs time (μ A)	Voltage vs time (V)
PS (bias 0.3V)	(90, 100, 1)	12.7	0.572
	(100, 100, 1)	12.7	0.465
	(90, 100, 0.5)	16.4	0.444
PS (bias 0.5V)	(90, 100, 1)	15.9	0.177, 0.775, 0.657
	(100, 100, 1)	26.6	0.956, 0.583
	(90, 100, 0.5)	26.6	0.7, 0.337

Source: created by the authors.

Table 4. Average pulse difference for PS

$\Delta I/\Delta V$	Average Pulse Difference for PS					Parameters
	1	2	3	4	5	
$\Delta I(\mu A)$	19.52	8.81	19.9	48.55	166.35	90V, 10mA, 0.5s
$\Delta V(V)$	0.13	0.32	0.49	0.87	1.39	
$\Delta I(\mu A)$	14.15	9.66	28.38	107.54	254.89	90V, 100mA, 1s
$\Delta V(V)$	0.15	0.44	0.74	1.36	1.59	
$\Delta I(\mu A)$	15.87	12.68	59.42	178.89	238.03	100V, 10mA, 0.5s
$\Delta V(V)$	0.10	0.49	0.93	1.59	0.97	
$\Delta I(\mu A)$	12.59	11.53	15.60	81.92	174.04	100V, 100mA, 0.5s
$\Delta V(V)$	0.22	0.43	0.74	1.21	1.31	

Source: created by the authors.

Table 5. Average pulse difference for Ge-PS

$\Delta I/\Delta V$	Average Pulse Difference for Ge-PS					Parameters
	1	2	3	4	5	
$\Delta I(\mu A)$	11.48	22.16	103.99	264.33	407.79	90V, 10mA, 0.5s
$\Delta V(V)$	0.39	0.71	0.98	1.78	1.61	
$\Delta I(\mu A)$	18.93	28.93	92.51	164.56	374.75	90V, 100mA, 1s
$\Delta V(V)$	0.23	0.71	1.16	0.68	2.02	
$\Delta I(\mu A)$	11.13	34.21	127.24	258.04	428.26	100V, 10mA, 0.5s
$\Delta V(V)$	0.16	0.71	1.35	1.62	2.32	
$\Delta I(\mu A)$	19.30	24.83	84.23	165.95	347.56	100V, 100mA, 0.5s
$\Delta V(V)$	0.23	0.69	1.28	1.34	0.56	

Source: created by the authors.

Table 6. Optimized operating parameters for the Ge-PS detector

Sample detector	Suggested optimum parameters
PS	90 V, 100mA, 1s
Ge-PS	100 V, 10mA, 0.5s

Source: created by the authors.