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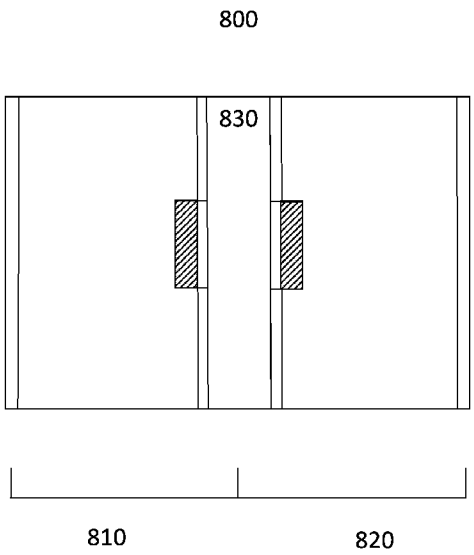


Fig. 8

(57) Abstract: A radiation detection system, comprising first (810) and second (820) semiconductor detectors each arranged to output respective detection signals wherein the first and second detectors (810, 820) are separated by a neutron reactive material(830), wherein the neutron reactive material (830)is arranged, in response to neutron capture, to emit at least two charged reaction products in generally opposing directions such that a first reaction product is detected by the first detector (810) and a second reaction product is detected by the second detector(820), a control unit coupled to the detector, the control unit (110) being arranged to apply a bias voltage to the first and second detectors (810, 820) and to receive the detection signals output from the first and second detectors(810, 820), wherein the control unit (110) is arranged to apply a first bias voltage to the first and second detectors (810, 820) and to store information indicative of detection signals received from the first and second detectors (810, 820) at the first bias voltage, to apply a second bias voltage to the first and second detectors (810, 820) and to store information indicative of detection signals at the second bias voltage, and wherein the control unit (110) is arranged to determine whether detection signals corresponding to detection of the first and second reaction products are received within a predetermined period.

WO 2016/203265 A1

Apparatus and Method for Radiation Detection

Embodiments of the present invention relate generally to a radiation detection system and a radiation detection method. In particular, embodiments of the present invention relate generally to a radiation detection system and a radiation detection method for discriminating between first and second radiation types.

Background

It is often desired to monitor radiation, such as, but not limited to, providing personal dose monitoring for workers exposed to radiation sources.

However due to the different types of radiation, such as gamma and neutron, monitoring exposure to mixed radiation fields is problematic.

It is an object of embodiments of the invention to at least mitigate one or more of the problems of the prior art.

It is an object of embodiments of the invention to provide an apparatus and method for radiation discrimination.

Statements of Invention

According to aspects of the present invention there is provided embodiments of the invention as set forth in the appended claims.

According to an aspect of the present invention there is provided a radiation detection system, comprising a semiconductor detector arranged in relation to one or more regions of a neutron-reactive material for emitting at least one charged particle in response to neutron capture, the detector being arranged to output a detection signal, a control unit coupled to the detector, the control unit being arranged to apply a bias voltage to the detector and to receive the detection signal output from the detector, wherein the control unit is arranged to apply a first bias voltage to the detector and to receive detection signals at the first bias voltage, and to apply a second bias voltage to

the detector and to receive detection signals at the second bias voltage. Further bias voltages may be applied. The bias voltages may be applied up to a full depletion of the semiconductor detector. The skilled person will appreciate how a full depletion voltage may be calculated for parameters of the semiconductor detector, such as thickness, semiconductor material etc.

According to an aspect of the present invention there is provided a radiation detection system, comprising a semiconductor detector arranged in relation to one or more regions of a neutron-reactive material for emitting at least one charged particle in response to neutron capture and the detector being arranged to output a detection signal, a control unit coupled to the detector, the control unit being arranged to apply a bias voltage to the detector and to receive the detection signal output from the detector, wherein the control unit is arranged to apply a first bias voltage to the detector and to store information indicative of detection signals at the first bias voltage, and to apply a second bias voltage to the detector and to store information indicative of detection signals at the second bias voltage.

According to an aspect of the present invention there is provided a radiation detection system, comprising a semiconductor detector arranged in relation to one or more regions of a neutron-reactive material for emitting at least one charged particle in response to neutron capture and the detector being arranged to output a detection signal, a control unit coupled to the detector, the control unit being arranged to control a volume of a sensitive region of the detector and to receive the detection signal output from the detector, wherein the control unit is arranged to configure the sensitive region of the detector at a first volume and to store information indicative of detection signals at the first volume, and to configure the sensitive region of the detector at a second volume and to store information indicative of detection signals at the second volume.

According to an aspect of the present invention there is provided a radiation detection method, comprising configuring a sensitive volume of a semiconductor detector to be a first volume, wherein the detector is associated with one or more regions of a neutron-reactive material for emitting at least one charged particle in response to neutron capture, receiving detection signals from the detector at the first volume,

configuring the sensitive volume to be a second volume and receiving detection signals from the detector at the second volume.

A radiation detection system, comprising first and second semiconductor detectors each arranged to output respective detection signals wherein the first and second detectors are separated by a neutron reactive material, wherein the neutron reactive material is arranged, in response to neutron capture, to emit at least two charged reaction products in generally opposing directions such that a first reaction product is detected by the first detector and a second reaction product is detected by the second detector, a control unit coupled to the detector, the control unit being arranged to apply a bias voltage to the first and second detectors and to receive the detection signals output from the first and second detectors, wherein the control unit is arranged to apply a first bias voltage to the first and second detectors and to store information indicative of detection signals received from the first and second detectors at the first bias voltage, to apply a second bias voltage to the first and second detectors and to store information indicative of detection signals at the second bias voltage, and wherein the control unit is arranged to determine whether detection signals corresponding to detection of the first and second reaction products are received within a predetermined period. The predetermined period may be a period between detection of the first reaction product and the second reaction product. The first and second bias voltages are between a first voltage and a full depletion voltage for the first and second semiconductor detector.

According to an aspect of the present invention, there is provided a radiation detection method, comprising applying a first bias voltage to first and second semiconductor detectors separated by a neutron-reactive material, wherein the neutron reactive material is arranged, in response to neutron capture, to emit at least two charged reaction products in generally opposing directions such that a first reaction product is detected by the first detector and a second reaction product is detected by the second detector, receiving detection signals output from the first and second detectors at the first bias voltage, applying a second bias voltage to the first and second detectors, receiving detection signals from the first and second detectors at the second bias voltage, and determining whether detection signals corresponding to detection of the first and second reaction products are received within a predetermined period.

According to another aspect of the present invention, there is provided computer software which, when executed by a computer, is arranged to perform a method according to an aspect of the invention. The computer software may be stored on a computer-readable medium. The computer software may be tangibly stored on a computer-readable medium.

Brief Description of the Drawings

Embodiments of the invention will now be described by way of example only, with reference to the accompanying figures, in which:

Figure 1 shows a radiation detection system according to an embodiment of the invention;

Figure 2 shows a radiation detector according to an embodiment of the invention;

Figure 3 is a flowchart illustrating a method of radiation detection according to an embodiment of the invention;

Figure 4 is an illustration of count rate against bias voltage for a detector according to an embodiment of the invention;

Figure 5 is a further illustration of count rate against bias voltage for a detector according to an embodiment of the invention;

Figure 6 is a yet further illustration of count rate against bias voltage for a detector according to an embodiment of the invention; and

Figure 7 a still further illustration of count rate against bias voltage for a detector according to an embodiment of the invention.

Detailed Description of Embodiments of the Invention

Figure 1 illustrates a radiation detection system 100 according to an embodiment of the invention. The system 100 is provided for discriminating between neutron and gamma radiation, as will be explained.

The system 100 comprises a control unit 110 coupled to a detector 150. The detector 150 is provided for detecting radiation and outputing detection signals in response thereto. The detector 150 is sensitive to charged particles. The detector 150 is a semiconductor detector. The detector 150 may be a silicon-based semiconductor detector, although it will be realised that other semiconducting materials may be used. In some embodiments the detector 150 comprises at least one diode. It will be realised that the system 100 may comprise more than one detector 150. The detection signal output by the detector may be indicative of charge deposited in the detector 150.

The control unit 110 is coupled to the detector 150 to apply a bias voltage to the detector 150. In some embodiments the control unit 110 is arranged to apply a reverse bias voltage to the diode to enhance a depletion region of the diode. The bias voltage may be between 1 and 100 Volts, although it will be realised that other voltages may be used. The bias voltage may be up to the full depletion voltage for the semiconductor. In some embodiments the control unit 110 comprises a processor 120 for operatively executing computer software instructions and a memory 130 for storing data. The processor 120 may be arranged to store in the memory 130 data indicative of received detection signals and information indicative a bias voltage applied to the detector 150 corresponding to the detection signals. The processor 120 may be arranged to operatively execute a method as described below in connection with Figure 3.

The detector 150 is arranged to output a detection signal in response to a detection of a charged particle. The charged particle may, for example, be one or more of an electron, an alpha particle, a ^{3}H (triton), or a ^{7}Li particle. The detection signal is output responsive to ionisation within the depletion region. The detection signal is received by the control unit 110.

Figure 2 illustrates a cross section through a detector 200 according to an embodiment of the invention. The detector 200 may be the detector 150 shown in Figure 1. In some embodiments of the invention the detector 200 is formed by at least one diode 200.

Figure 2 illustrates a cross-section through a diode 200 formed by a junction of first and second type semiconductor materials, as will be appreciated. In the exemplary diode 200 illustrated in Figure 2, a bulk layer of first-type material 210, such as n-type silicon 210, is provided. In contact with the first-type material 210 is a second-type material 220, such as p-type silicon material 220. In the exemplary structure illustrated in Figure 2 the p-type material 220 forms an isolated region proximal to a first surface of the n-type material 210. The first surface of the n-type material 210 is covered with an insulating layer 233 which may be silicon dioxide 233. The silicon dioxide layer 233 has a thickness less than a penetrating depth of charged particles such as alpha, triton and ^{7}Li particles, as will be appreciated from the description below. In order to provide electrical contact to the p-type material 220 a metal contact 232, such as aluminium, is arranged through the insulating layer 233 to contact the p-type material 220. At a second side of the n-type material 210 a second electrical contact 231, which may be aluminium, is arranged to electrically contact the n-type material 210. In this way a potential difference applied between the contacts 231, 232 forms, or increases, a depletion region in the diode 200. The depletion region represents a sensitive volume of the detector 150. Thus the increase in potential difference controls the volume of the sensitive region of the diode. As will be appreciated, a depth from the first surface of the n-type material 210 of the depletion region is controlled by a voltage applied between the contacts 231, 232. The depletion region is formed initially proximal to the first surface of the n-type layer 210 and extends toward the second surface with increasing applied voltage. As will be appreciated, the depletion region is a region in which mobile charge carriers are removed or depleted due to the electric field.

At least a portion of the diode 200 is in contact, or close proximity, with a neutron-reactive material 240 for emitting at least one charged particle in response to neutron capture. The neutron-reactive material 240 is arranged to output at least one charged particle responsive to neutron capture. The at least one charged particle may be one

or more of an alpha particle, a triton or a ^{7}Li particle. The neutron-reactive material 240 may be formed from ^{6}Li or ^{10}B or one of their compounds.

In the illustration of Figure 2 the neutron-reactive material 240 is arranged proximal to the first surface of the n-type material of the diode 200. The neutron-reactive material 240 may form a layer separated from the n-type material 210 generally by the insulating layer 233. That is, the neutron-reactive material 240 may be arranged upon the insulating layer 233 covering the first surface of the diode 200. In some embodiments the neutron-reactive material 240 is arranged only proximal to the first surface. However in other embodiments it will be realised that the neutron-reactive material 240 may also be arranged upon other surfaces of the diode, such as other faces, and may cover more than one surface of the diode 200. The insulating layer 233 is of a thickness that charged particles emitted from the neutron reactive material 240 are able to pass through the insulating layer 233 to the depletion region of the diode.

Figure 3 illustrates a method 300 according to an embodiment of the invention. The method may be implemented by a system 100 as illustrated and described with reference to Figures 1 and 2.

The method 300 comprises a step of applying a first bias voltage to a detector 150, 200. The first bias voltage may be, for example, 2 Volts. The bias voltage may be applied to the detector 150, 200 by the control unit 110. The bias voltage is applied to the detector 150, 200 to increase a depletion region of the detector 150, 200 (it will be understood that a depletion region however small may already exist without an applied voltage).

In step 320 signal information indicative of the detection signals received from the detector 150, 200 is stored. The signal information may be stored in the memory 130 of the apparatus 100. The signal information is associated with voltage information indicative of the bias voltage applied to the detector 150, 200 corresponding to the detection signal. For example, the signal information may be stored in step 320 in an area of memory 130 associated with the first bias voltage. Alternatively the signal information corresponding to each detection signal may be stored with a respective

item of voltage information indicative of the applied bias voltage. For example, the stored information may have the form [signal:voltage], although it will be realised that this is merely exemplary.

In step 330 it is determined whether the first bias voltage has been applied for a sufficient period according to one or more conditions. The one or more conditions may be one or more of a temporal condition or a condition based upon the recorded detection signals. For example the temporal condition may define a predetermined duration for which the first bias voltage is applied, such as a predetermined number of seconds. The predetermined number of seconds may be one second intervals, although it will be realised that other durations may be used. The condition based upon the recorded detection signals may define a number of detection signals to be recorded in step 320. If the one or more conditions are not met the method returns to step 320. If, however, the one or more conditions are met, then the method moves to step 340.

Step 340 comprises applying a second bias voltage to the detector 150, 200. The second bias voltage is greater than the first bias voltage. For example the second bias voltage may be, for example, 60 Volts. The second bias voltage is applied to increase a size of the depletion region with respect to the first applied bias voltage.

In step 350 signal information indicative of the detection signals received from the detector 150 is stored, as in step 320. The signal information may be stored in the memory 130 of the apparatus 100. The signal information is associated with voltage information indicative of the applied second bias voltage.

As in step 330, in step 360 it is determined whether the second bias voltage has been applied for a sufficient period according to one or more conditions. The one or more conditions may be one or more of a temporal condition or a condition based upon the recorded detection signals. If the one or more conditions are not met the method returns to step 350. If, however, the one or more conditions are met, then the method moves to step 370.

A third and more bias voltages may be applied to the detector, as will be appreciated.

In step 370 a radiation environment to which the detector 150, 200 has been subjected is discriminated. In particular, discrimination is made between detection signals received from the detector 150, 200 due to neutron radiation and due to gamma radiation. The discrimination between radiation types is made on the basis of the bias voltage applied to the detector 150.

Figure 4 is a graph illustrating detection signal rate (counts per second) against bias voltage applied to the detector 150, 200. As can be appreciated from the solid and dashed lines representing all pulses and those due to gamma radiation, an increase in bias voltage causes a corresponding increase in pulse rate. This is due to the increased bias voltage causing a corresponding increase in depletion region size. The increased size of the depletion region allows an increase in energy deposition within the depletion region by gamma rays, particularly by electrons ionised within the depletion region, thus causing an increase in gamma sensitivity with increasing bias voltage as shown in Figure 4 which causes an overall increase in count output rate of the detector 150 in a mixed gamma-neutron field. However, since neutrons do not interact directly with the semiconductor material of the detector 150, 200, detection of neutron radiation is via secondary charged particle energy deposition. For example, energy is deposited in the depletion region by alpha or triton particles. Such charged particles have a relatively short range in the material of the detector of up to around 10μm and more likely around 6μm. Even a relatively small depletion region is likely to capture a majority of the energy deposited by such highly ionising charged particles when such particles are emitted in the depletion region. Therefore the bias voltage has little effect on the output rate of detection signals responsive to neutron radiation. This is shown in Figure 4 as the dotted line which is relatively flat against bias voltage.

Figures 5 to 7 illustrate a response of a system according to an embodiment of the invention to various radiation fields and bias voltages.

Figure 5 illustrates a response of the system 100 at various bias voltages to a neutron and gamma mixed radiation field. The mixed radiation field is produced in this

example by a 1Ci Am/Be source, water moderated. The *x* axis of Figures 5-7 corresponds to counts output by an analogue-to-digital convertor (ADC), thus representing an arbitrary unit indicative of signal amplitude output by the detector 150, 200. The increase in signal count rate corresponds to increasing bias voltage.

Figure 6 illustrates a response of the system 100 at various bias voltages to the radiation field used in Figure 5 but including a neutron absorber proximal to the detector 150 which reduces a neutron component of the radiation field at the detector 150, 200. The influence of bias voltage on the response of the detector 150, 200 to the gamma component can be appreciated from Figure 6.

Figure 7 illustrates a difference between the responses shown in Figures 5 and 6 i.e. corresponding substantially to the neutron component of the radiation field. The insensitivity of the detector 150, 200 to the bias voltage with respect to the neutron component can be appreciated from Figure 7.

Whilst the method 300 has been illustrated with respect to first and second bias voltages it will be realised that more than two bias voltages may be applied to the detector 150, 200. The method 300 may be extended such that a third or third and fourth bias voltages are applied to the detector 150, 200 and signal information stored corresponding to detection signals output by the detector 150, 200.

Figure 8 illustrates a detector 800 according to a further embodiment of the invention. The detector 800 may be used in the system 100 illustrated in Figure 1 as detector 150, 200. The detector 800 comprises first 810 and second 820 semiconductor detectors arranged in proximal relation. The first 810 and second 820 semiconductor detectors may be first and second diodes as described above, although it will also be realised that each detector 810, 820 may comprise more than one diode. In particular the first 810 and second 820 detectors are arranged to be interposed or separated by neutron-reactive material 830, corresponding to material 240 in Figure 2. The first 810 and second 820 detectors are arranged back-to-back separated by the neutron-reactive material 830. In this way, the sensitive region of each detector 810, 820, corresponding to the depletion region, is proximal to the neutron-reactive material 830

for detecting charged particles emitted there-from. Each of the first and second detectors 810, 820 is arranged to output a corresponding detection signal

In some embodiment the neutron-reactive material 830 emits at least two charged particles of different types in response to neutron capture. For example, where the neutron-reactive material 830 is ^{6}Li an alpha particle and a ^{3}H (triton) particle are emitted in response to neutron capture. These particles are emitted in generally opposing directions. The first detector 810 is arranged to output a first detection signal and the second detector 820 is arranged to output a second detection signal. The first and second detectors 810, 820 output detection signals of different amplitudes corresponding to the detection of the alpha and triton particles respectively. The first and second detection signals are output generally coincidentally i.e. at the same time. The control unit 110 operably coupled to the detector 800 is arranged to determine substantially coincidental detection of neutron reaction products from the neutron-reactive material 830.

Advantageously embodiments of the present invention suppress or at least reduce a gamma-ray background to allow neutron detection. Embodiments of the invention allow a change in size of a detection signal arising from gamma rays by applying varying bias voltages, whilst keeping neutron detection signals generally unchanged.

As will be appreciated, embodiments of the present invention provide a radiation detection system and a radiation detection method capable of discriminating between gamma and neutron radiation detection. The system and method utilise a semiconductor-based detector which may be small and low-power. Thus embodiments of the invention may provide a small, portable radiation detection system. Such system may be integrated in a hand-held device, such as mobile telephone or computing device.

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of volatile or non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, RAM, memory chips, device or integrated

circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic tape. It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

CLAIMS

1. A radiation detection system, comprising:

first and second semiconductor detectors each arranged to output respective detection signals wherein the first and second detectors are separated by a neutron reactive material;

wherein the neutron reactive material is arranged, in response to neutron capture, to emit at least two charged reaction products in generally opposing directions such that a first reaction product is detected by the first detector and a second reaction product is detected by the second detector;

a control unit coupled to the detector, the control unit being arranged to apply a bias voltage to the first and second detectors and to receive the detection signals output from the first and second detectors;

wherein the control unit is arranged to apply a first bias voltage to the first and second detectors and to store information indicative of detection signals received from the first and second detectors at the first bias voltage, to apply a second bias voltage to the first and second detectors and to store information indicative of detection signals at the second bias voltage; and

wherein the control unit is arranged to determine whether detection signals corresponding to detection of the first and second reaction products are received within a predetermined period.

2. The system of claim 1, wherein the control unit is arranged to discriminate between first and second radiation types based on the detection signals at the first and second bias voltages.

3. The system of claim 1 or 2, wherein the first and second bias voltages are applied for one or both of a predetermined period of time and a predetermined number of detection signals.

4. The system of claim 1, 2 or 3, wherein the control unit is arranged to apply one or more further bias voltages and to store information indicative of detection signals at the one or more further bias voltages.

5. The system of any preceding claim, wherein the first and second bias voltages are between 1 Volt and a full depletion voltage for the first and second semiconductor detector.

6. The system of any preceding claim, wherein the neutron-reactive material comprises one or more of ^{6}Li and ^{10}B.

7. The system of any preceding claim, wherein an active volume of one or both of the first and second semiconductor detectors is located proximal to a surface of the respective detector having the neutron-reactive material formed thereon.

8. The system of any preceding claim, wherein one or both of the first and second semiconductor detectors are semiconductor diodes.

9. The system of any preceding claim, wherein the bias voltage is arranged to control a volume of a depletion region of one or both of the first and second semiconductor detectors.

10. The system of claim 2 or any claim dependent thereon, wherein the first radiation type is gamma radiation and the second radiation type is neutron radiation.

11. The system of any preceding claim, wherein the control unit is arranged to determine first and second components of the radiation field from the information indicative of the detection signals at the first and second bias voltages.

12. The system of any preceding claim, wherein the information indicative of the detection signals at the first and second bias voltages is indicative of a magnitude of the detection signals.

13. The system of claim 12, wherein one or both of: the first and second detectors are arranged in back-to-back relation, and the first and second detectors are arranged to have a respective sensitive volume proximal to the neutron reactive material.

14. A radiation detection method, comprising:

applying a first bias voltage to first and second semiconductor detectors separated by a neutron-reactive material, wherein the neutron reactive material is arranged, in response to neutron capture, to emit at least two charged reaction products in generally opposing directions such that a first reaction product is detected by the first detector and a second reaction product is detected by the second detector;

receiving detection signals output from the first and second detectors at the first bias voltage;

applying a second bias voltage to the first and second detectors;

receiving detection signals from the first and second detectors at the second bias voltage; and

determining whether detection signals corresponding to detection of the first and second reaction products are received within a predetermined period.

15. The method of claim 14, comprising discriminating between first and second radiation types based on the detection signals at the first and second bias voltages.

16. The method of claim 15, wherein the first and second radiation types are gamma and neutron radiation, respectively.

17. The method of claim 14, 15 or 16, comprising storing information in a memory indicative of the detection signals at the first and second bias voltages.

18. The method of any of claims 14 to 17, comprising applying one or more further bias voltages to the first and second detectors, and receiving detection signals from the first and second detectors at the one or more further bias voltages.

19. The method of any of claims 14 to 18, wherein the first and second bias voltages are applied for one or both of a predetermined period of time and a predetermined number of detection signals.

20. The method of any of claims 14 to 19, wherein the first and second bias voltages are between 1 Volt and a full depletion voltage for the first and second detectors.

21. The method of any of claims 14 to 20, wherein the first and second bias voltages cause a change in volume of a sensitive region of one or both of first and second detectors.

22. The method of any of claims 14 to 21, wherein one or both of the first and second semiconductor detectors are semiconductor diodes.

23. Computer software which, when executed by a computer, is arranged to perform a method as in any of claims 14 to 22.

24. The computer software of claim 23 stored on a computer-readable medium.

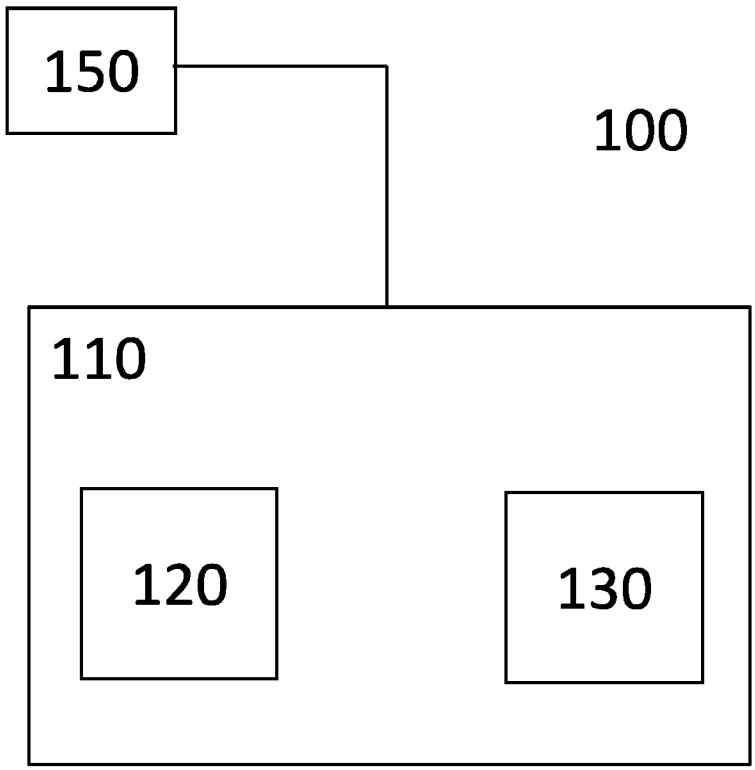


Fig. 1

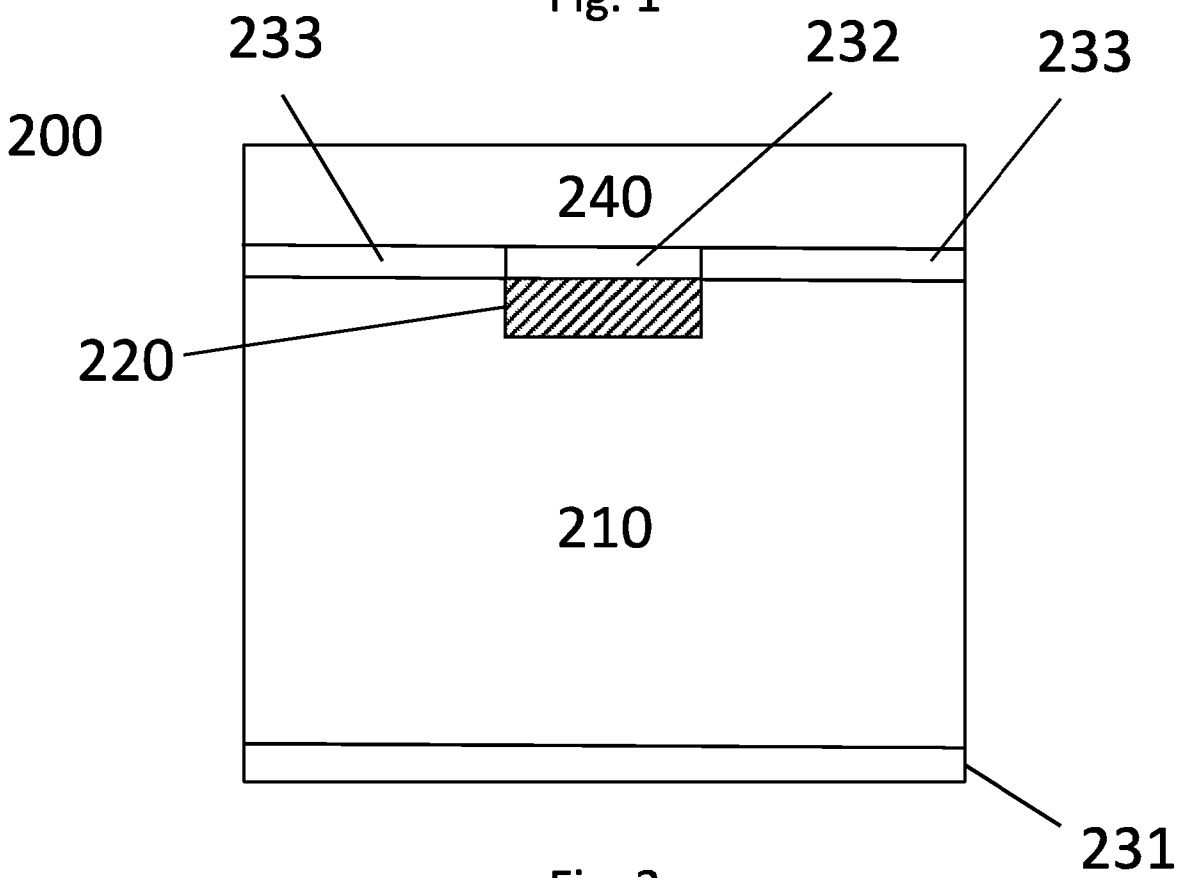


Fig. 2

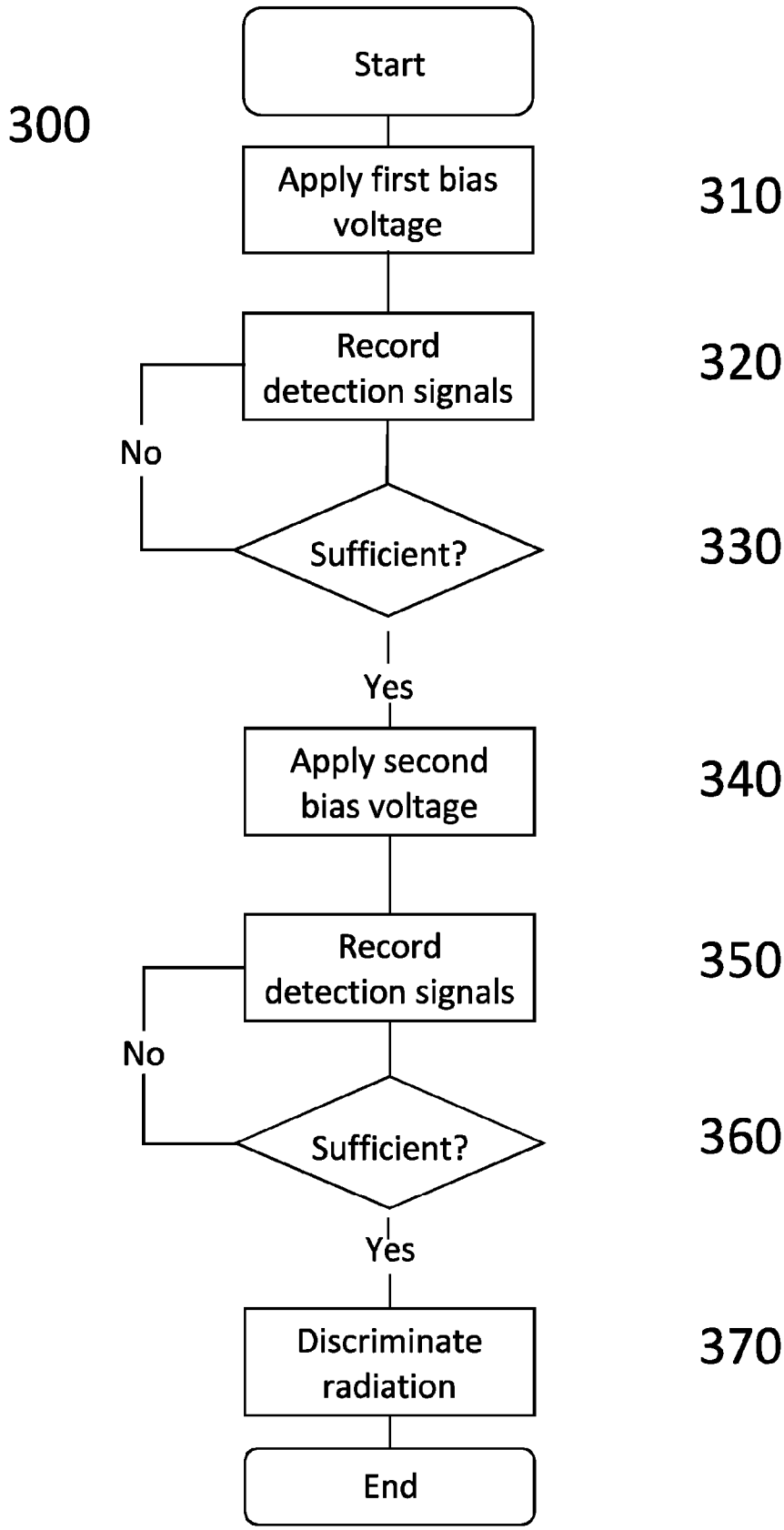

300
Start
Apply first bias voltage
310
Record detection signals
320
No
Sufficient?
330
Yes
Apply second bias voltage
340
Record detection signals
350
No
Sufficient?
360
Yes
Discriminate radiation
370
End

Fig. 3

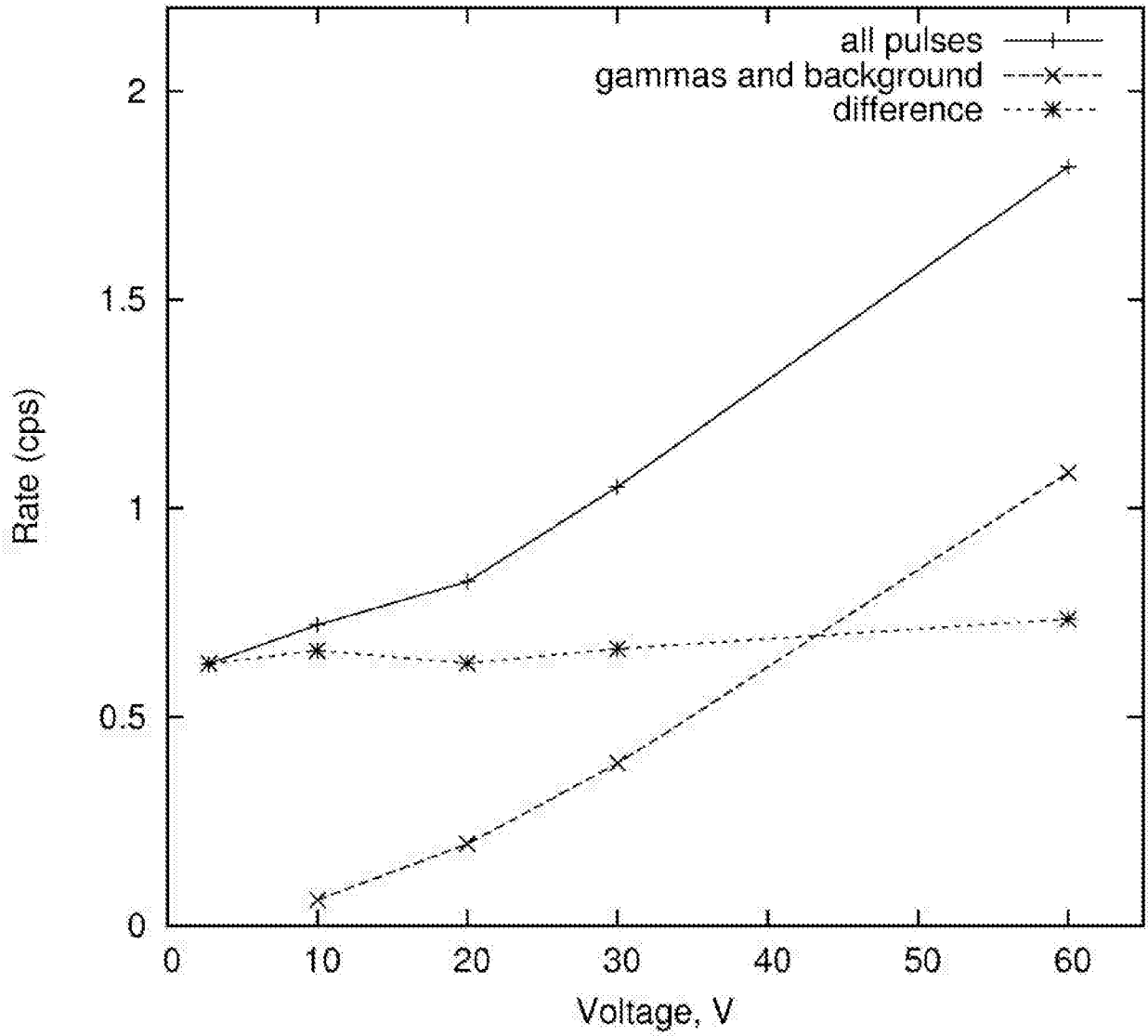

all pulses
gammas and background
difference
Rate (cps)
Voltage, V
0
0.5
1
1.5
2
0
10
20
30
40
50
60

Fig. 4

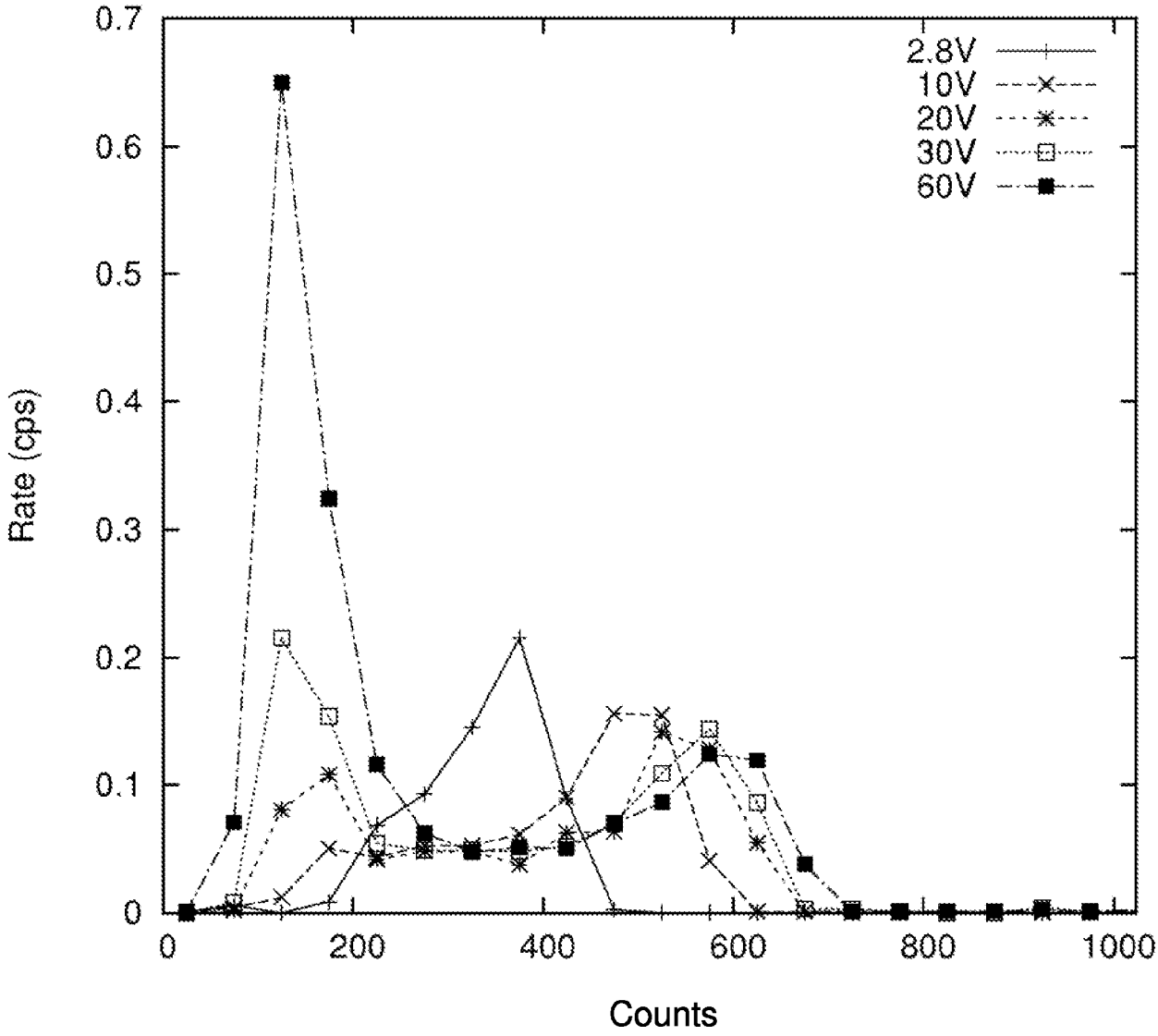

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Rate (cps)
0
200
400
600
800
1000
Counts
2.8V
10V
20V
30V
60V

Fig. 5

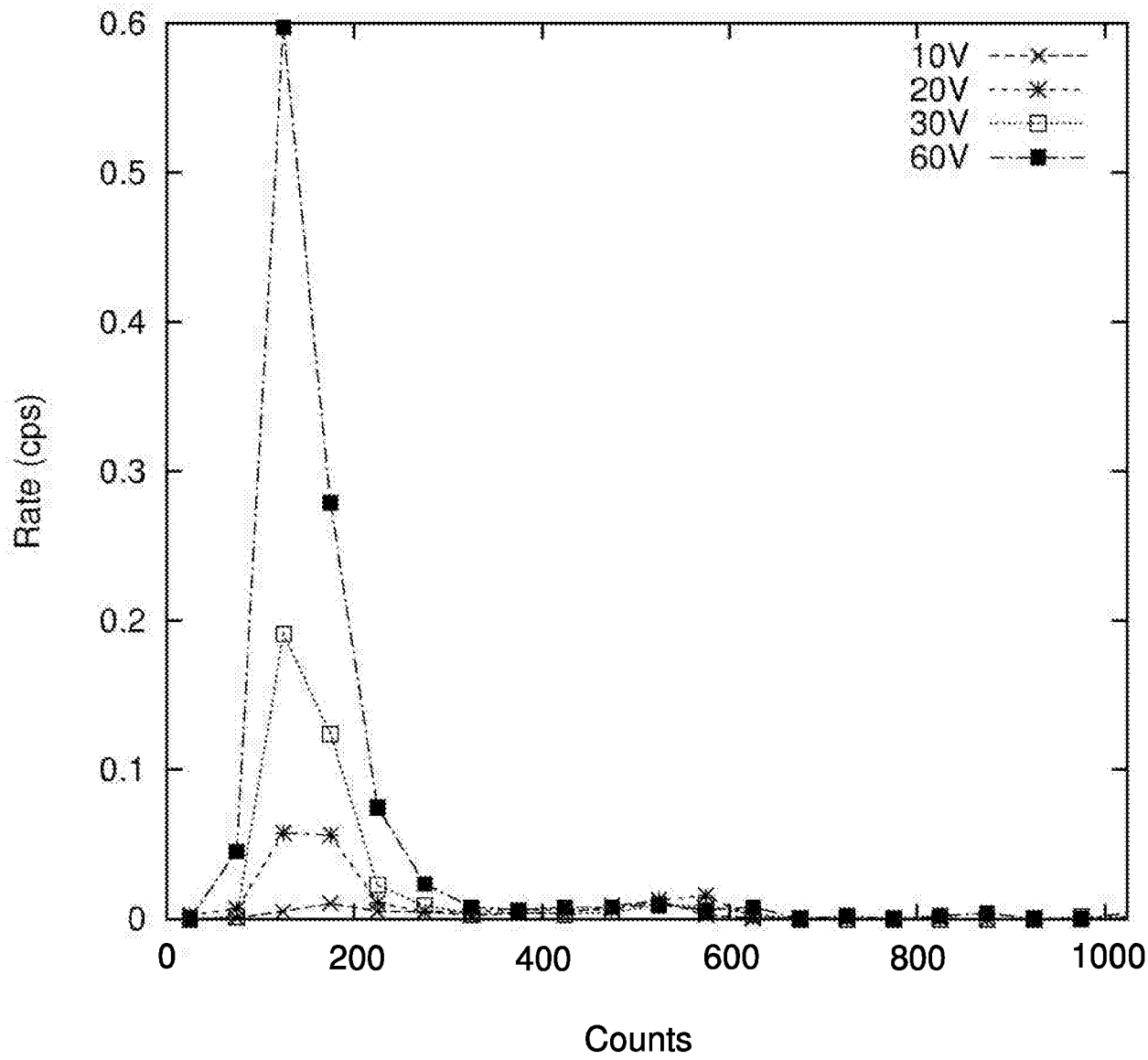

0.6
0.5
0.4
0.3
0.2
0.1
0
Rate (cps)
0
200
400
600
800
1000
Counts
10V
20V
30V
60V

Fig. 6

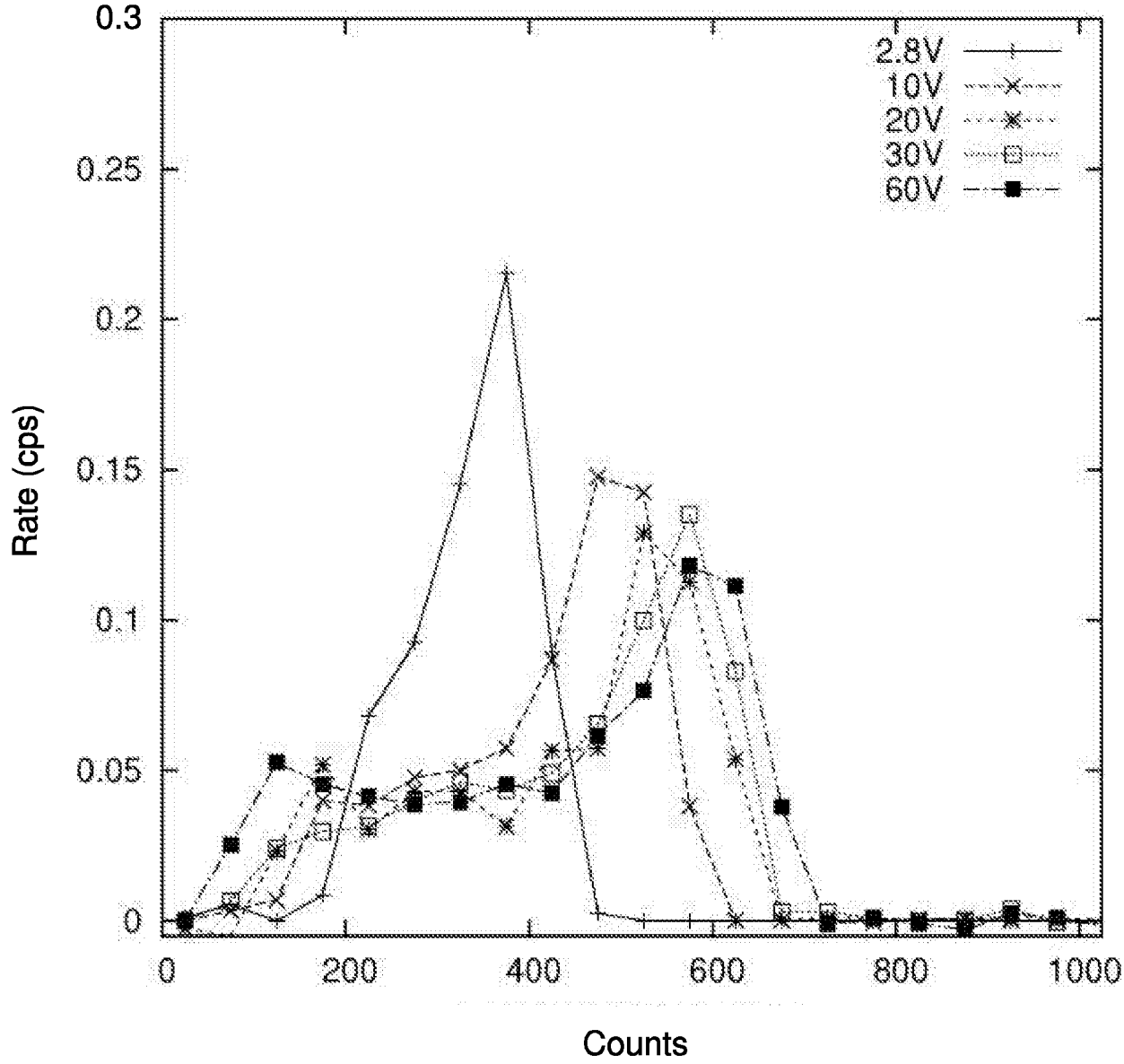

0.3
0.25
0.2
0.15
0.1
0.05
0
Rate (cps)
0
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400
600
800
1000
Counts
2.8V
10V
20V
30V
60V

Fig. 7

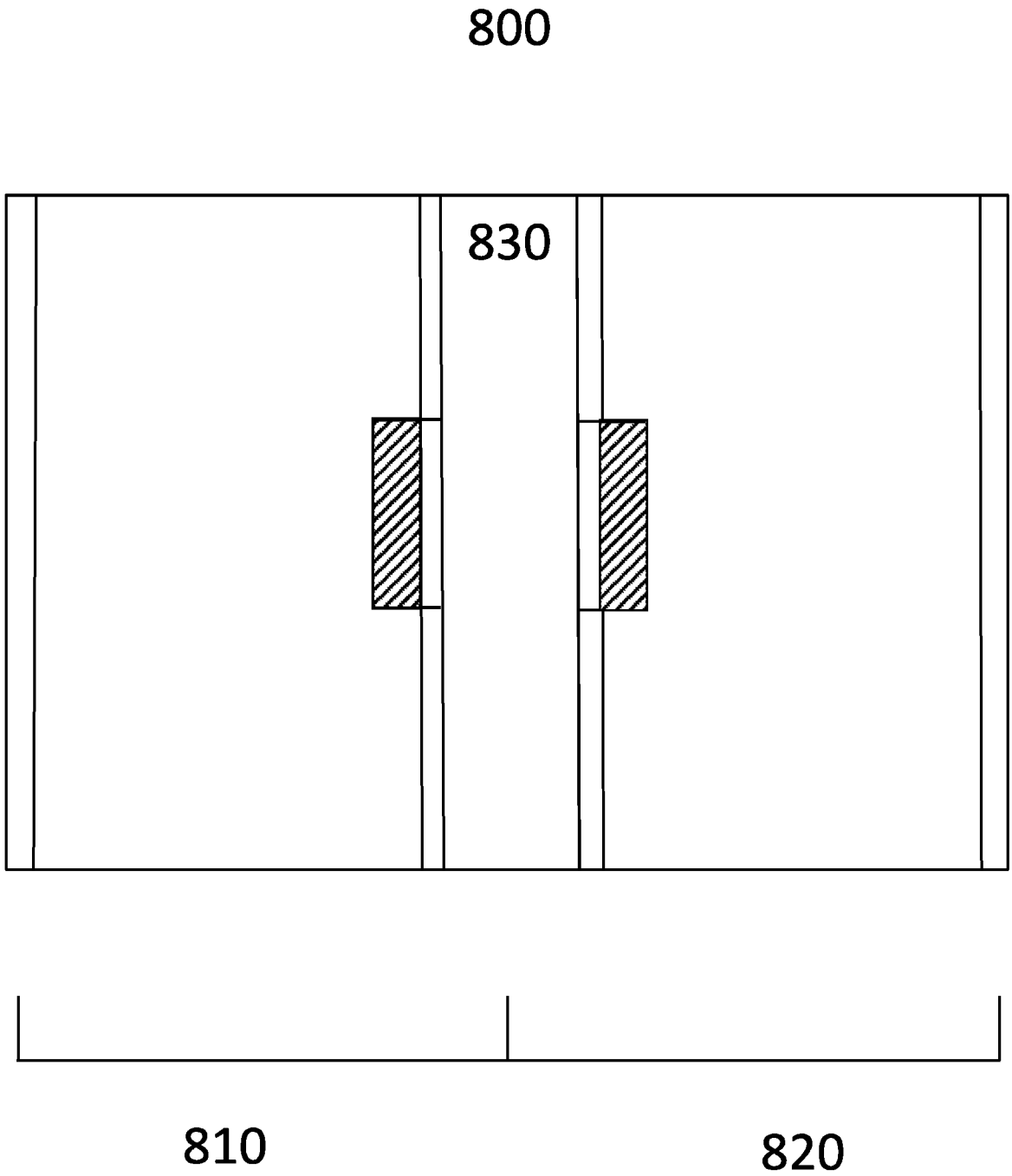


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/051828

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01T3/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	NDOYE A ET AL: "Neutron radiation of an electronic sensor using coincidence method for an active dosimeter", NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH. SECTION A: ACCELERATORS, SPECTROMETERS, DETECTORS, AND ASSOCIATED EQUIPMENT, ELSEVIER BV * NORTH-HOLLAND, NL, vol. 423, no. 2-3, 1 March 1999 (1999-03-01), pages 414-420, XP004160874, ISSN: 0168-9002, DOI: 10.1016/S0168-9002(98)01314-X	1,3-9, 12-14, 17-24
A	abstract figures 1, 2, 3 section 2 section 4	2,10,11, 15,16

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 September 2016	14/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Santen, Nicole

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/051828

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 336 890 A (KITAGUCHI HIROSHI [JP] ET AL) 9 August 1994 (1994-08-09)	1,3-9, 12-14, 17-24
A	abstract figures 1, 6, 7, 11 column 4, lines 22-52 column 5, lines 23-28 column 6, lines 16-56 column 8, lines 28-32 column 13, lines 7-27	2,10,11, 15,16

A	DE 100 42 076 A1 (IFG INST FUER GERAETEBAU GMBH [DE]) 10 May 2001 (2001-05-10) abstract figure 3 column 2, lines 10-24 column 4, line 34 - column 5, line 28	1-24

A	US 6 479 826 B1 (KLANN RAYMOND T [US] ET AL) 12 November 2002 (2002-11-12) abstract figures 1a, 7 column 1, lines 47-51 column 3, line 13 - column 5, line 9 column 8, lines 18-40 column 9, lines 1-10	1-24

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2016/051828

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5336890 A	09-08-1994	JP H053337 A	08-01-1993
		US 5336890 A	09-08-1994
		US 5457322 A	10-10-1995
DE 10042076 A1	10-05-2001	NONE	
US 6479826 B1	12-11-2002	NONE	