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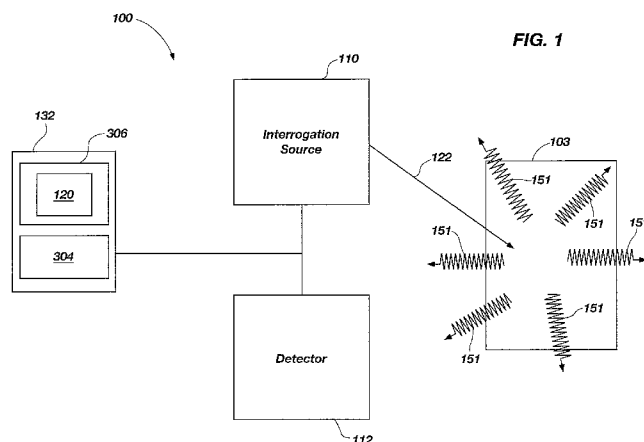
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(54) Title: **SYSTEMS, METHODS, AND COMPUTER-READABLE MEDIA FOR EXPLOSIVE DETECTION**



(57) Abstract: Systems and methods relating to explosive detection are disclosed. A method of detecting a possible explosive material may include measuring gamma ray energy emitted from a target object. The method may further include determining whether the target object includes a first element and, if so, determining whether the target object includes a second, different element. Additionally, the method may include identifying the target object as a possible explosive material if the target object includes each of the first element and the second element. Computer-readable media storing instructions for carrying out the methods are also disclosed.

SYSTEMS, METHODS, AND COMPUTER-READABLE MEDIA FOR EXPLOSIVE DETECTION

5 CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of and priority to U.S. Non-provisional Patent Application Serial No. 12/572,457, filed October 2, 2009, entitled SYTEMS, METHODS, AND COMPUTER-READABLE MEDIA FOR EXPLOSIVE DETECTION which is incorporated herein by reference in its entirety.

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GOVERNMENT RIGHTS

This invention was made with government support under Contract Number DE-AC07-05ID14517 awarded by the United States Department of Energy. The government has certain rights in the invention.

15

TECHNICAL FIELD

Embodiments of the present invention relate generally to explosive detection and, more specifically, to systems, methods, and computer-readable media for detecting a possible explosive material.

20

BACKGROUND

There is an ever-increasing need to conduct quick, non-invasive, and non-destructive analysis of harmful materials, especially when such materials are concealed within a container such as, for example, a container used in commerce for shipping freight. Various methods have
25 been proposed for inspecting sealed containers for purposes of identifying a material, which may indicate the presence of an explosive that may be used for terrorism or for other unlawful activities.

Such methods have included interrogating a vehicle or container with neutrons provided by a neutron generator or isotopic source and thereafter collecting gamma rays generated by the
30 presence of a material by utilizing a gamma ray detector. Specifically, conventional methods of detecting an explosive material include detection of nitrogen, which is common to most explosives. However, because some non-explosive materials, such as ammonia or liquid nitrogen, contain nitrogen, detection of nitrogen by itself does not positively identify an

explosive material. Therefore, by using these conventional methods, non-explosive materials may be falsely identified as possible explosive materials at a high-rate. Furthermore, upon identification of a possible explosive material, additional methods, such as physical inspection of the material, may be required to determine whether the material is in fact an explosive material. Accordingly, due to high false-positive rates, conventional methods relating to explosive material detection have proven to be costly and time-consuming.

There is a need to enhance methods relating to detection of an explosive using element detection technologies. Specifically, there is a need for systems, methods and computer-readable media for providing enhanced detection of an explosive by reducing false-positive rates.

BRIEF SUMMARY

An embodiment of the present invention comprises a method of detecting a possible explosive material. The method may comprise measuring gamma ray energy emitted from a target object and determining whether the target object includes a first element. The method may further include determining whether the target object includes a second, different element if the target object includes the first element. Additionally, the method may include identifying the target object as a possible explosive material if the target object includes each of the first element and the second element.

Another embodiment of the present invention includes another method of detecting a possible explosive material. The method may comprise measuring background energy emitted from a detection environment and measuring energy emitted from the detection environment having a target object positioned therein. Furthermore, the method may include comparing the measured background energy to the measured energy to determine whether the target object includes a first element. In addition, the method may include comparing the measured background energy to the measured energy to determine whether the target object includes oxygen if the target object includes the first element. Furthermore, the method may comprise classifying the target object as a possible explosive material if the target object includes each of the first element and oxygen.

Another embodiment of the present invention includes a method of identifying a possible explosive material. The method may comprise identifying a target object as a possible explosive material if the target object comprises each of nitrogen and oxygen.

Another embodiment of the present invention includes yet another method of detecting a possible explosive material. The method may comprise measuring background energy emitted from a detection environment. The method may also include positioning a target object within the detection environment, subjecting the target object to an interrogation process, and determining whether the target object includes nitrogen. Further, the method may include determining whether the object includes oxygen if the target object includes nitrogen. Additionally, the method may comprise identifying the target object as a possible explosive material if the target object includes each of nitrogen and oxygen.

Another embodiment of the present invention includes a detection system. The detection system may comprise an interrogation source configured to transmit neutrons toward a detection environment and a detector configured to detect gamma rays emitted from the detection environment. The detection system may further comprise a computer operably coupled to each of the interrogation source and the detector. The detection system may be configured to determine whether a target object positioned within the detection environment includes a first element and, if so, determine whether the target object includes a second, different element. Additionally, the detection system may be configured to identify the target object as a possible explosive material if the target object includes each of the first element and the second, different element.

Yet another embodiment of the present invention includes a computer-readable storage medium storing instructions that, when executed by a processor, cause the processor to perform instructions for detecting a possible explosive material according to an embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a detection system including an interrogation source, a detector, a detection environment, and a computer, in accordance with an embodiment of the present invention;

FIG. 2 illustrates the detection system of FIG. 1 further including a target object, which may include an explosive material to be detected;

FIG. 3 is a flow chart illustrating a method of detecting a possible explosive material, in accordance with an embodiment of the present invention;

FIG. 4 depicts a portion of a gamma ray spectrum illustrating counts of detected background gamma rays at energies between 10,000 keV and 11,000 keV;

FIG. 5 depicts another portion of the gamma ray spectrum of FIG. 4 illustrating counts of detected background gamma rays at energies between 4,800 keV and 6,400 keV;

FIG. 6 depicts a portion of a gamma ray spectrum illustrating counts of gamma rays at energies between 10,000 keV and 11,000 keV detected upon interrogation of a target object;

5 FIG. 7 depicts another portion of the gamma ray spectrum of FIG. 6 illustrating counts of detected gamma rays at energies between 4,800 keV and 6,400 keV; and

FIG. 8 is a flow chart illustrating another method of detecting a possible explosive material, in accordance with an embodiment of the present invention.

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DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings which form a part hereof and, in which is shown by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those of ordinary skill in the art to practice the invention, and it is to be understood that
15 other embodiments may be utilized, and that structural, logical, and electrical changes may be made within the scope of the disclosure.

In this description, functions may be shown in block diagram form in order not to obscure the present invention in unnecessary detail. Furthermore, specific implementations shown and described are only examples and should not be construed as the only way to
20 implement the present invention unless specified otherwise herein. Block definitions and partitioning of logic between various blocks represent a specific, non-limiting implementation. It will be readily apparent to one of ordinary skill in the art that the various embodiments of the present invention may be practiced by numerous other partitioning solutions. For the most part, details concerning timing considerations, and the like, have been omitted where such details are
25 not necessary to obtain a complete understanding of the present invention in its various embodiments and are within the abilities of persons of ordinary skill in the relevant art.

When executed as firmware or software, the instructions for performing the methods and processes described herein may be stored on a computer readable medium. A computer readable medium includes, but is not limited to, magnetic and optical storage devices such as
30 disk drives, magnetic tape, CDs (compact disks), DVDs (digital versatile discs or digital video discs), and semiconductor devices such as RAM, DRAM, ROM, EPROM, and Flash memory.

Referring in general to the following description and accompanying drawings, various aspects of the present invention are illustrated to show its structure and method of operation.

Common elements of the illustrated embodiments are designated with like numerals. It should be understood that the figures presented are not meant to be illustrative of actual views of any particular portion of the actual structure or method, but are merely idealized representations, which are employed to more clearly and fully depict the present invention.

5 As will be understood by a person having ordinary skill in the art, a detection environment may include background energy (i.e., energy that is present in a detection environment without a target object being positioned therein) that may be measured upon interrogation of the detection environment. Accordingly, a gamma ray spectrum illustrating the background energy detected within a detection environment may be generated and analyzed
10 prior to interrogation of a target object. As used herein, the term “count” means a number of detected gamma rays at a specific energy emitted from a detection environment. Furthermore, as used herein, the term “background level” means an amount of an element (e.g., nitrogen) existing within a detection environment without a target object being positioned therein.

As described more fully below, various embodiments of the present invention include
15 systems, methods, and computer-readable media for explosive detection. More specifically, various embodiments of the present invention are related to systems, methods, and computer-readable media for detecting a possible explosive material. A method of detecting a possible explosive material may include measuring gamma ray energy emitted from a target object, determining whether the target object includes a first element and, if so, determining whether
20 the target object includes a second element. Further, the method may include classifying the target object as a possible explosive material if the target object includes each of the first element and the second element. A detection system, according to one or more embodiments of the present invention, will first be described. Thereafter, various contemplated methods of detecting a possible explosive material, in accordance with one or more embodiments of the
25 present invention, will be described.

FIGS. 1 and 2 illustrate a detection system 100 used to detect the presence of an element, such as, for example only, carbon, hydrogen, nitrogen, or oxygen. Detection system 100 may also be commonly referred to hereinafter as an “interrogation system.” As illustrated in FIG. 1, detection system 100 includes a detection environment 103, an interrogation source
30 110, a detector 112, and a computer 132. As will be understood by a person having ordinary skill in the art, a detection environment may comprise, for example only, an area within an airport, a port-of-entry, a shipping port, or the like. For example, interrogation source 110 may comprise a neutron generator. Computer 132 may include a processor 304 and a memory 306.

Memory 306 may include a computer readable medium (e.g., data storage device 120), which may include, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact disks), DVDs (digital versatile discs or digital video discs), and semiconductor devices such as RAM, DRAM, ROM, EPROM, and Flash memory. As
5 illustrated, computer 132 may be operably coupled to interrogation source 110 and radiation detector 112.

FIG. 2 illustrates a target object 106 positioned within detection environment 103. Target object 106 is, or contains, the material with respect to which a determination is being made regarding its elemental components. For example, target object 106 may be any container
10 capable of transporting or smuggling explosives. As a more specific example, target object 106 may be a truck, a drum, or a shipping container such as those used by cargo container ships.

Interrogation source 110 may be configured to generate a stream of neutrons 122 which are directed toward, or travel in the direction of, detection environment 103 and its contents. The generated neutrons have the ability to pass through many different shielding configurations.

15 For example, the energy of interrogating source 110 may be selected in order to provide neutrons with energy spectra appropriate for optimal penetration of a given shield. Thus, the neutrons are able to pass through the walls of target object 106, as well as most shielding that may be used to conceal or smuggle an explosive material in a given object. The neutrons react with the contents within detection environment 103 to induce reactions that cause gamma rays
20 to be emitted from detection environment 103.

Detector 112 may be located in the proximity of detection environment 103, and may comprise, for example, an array of radiation detectors. As non-limiting examples, radiation detector 112 may comprise a high-purity germanium (HPGe) detector, a bismuth germanate detector or a sodium iodide detector. Gamma rays emitted from detection environment 103 may
25 be detected by radiation detector 112 and analyzed by electronics and other devices, such as computer 132 or any other computers (not shown) associated with radiation detector 112. It is noted that computer 132 may be configured to control the operation of each of interrogation source 110 and detector 112. It is further noted that for the contemplated embodiments described herein, interrogation source 110 may be operated in a pulse mode, as will be
30 understood by a person having ordinary skill in the art. Furthermore, as described more fully below, interrogation source 110 may comprise a neutron generator configured to transmit neutrons having an energy greater than 6,129 keV.

With reference to FIGS. 1-8, and in accordance with one or more embodiments of the present invention, various contemplated methods of detecting a possible explosive material will now be described. As illustrated in FIG. 3, a method 310 of detecting a possible explosive material may include measuring background gamma ray energy emitted from a detection environment (e.g. detection environment 103) (depicted by numeral 312 in FIG. 3). More specifically, with reference again to FIG. 1, interrogation source 110 may transmit a stream of neutrons 122 towards detection environment 103 and the transmitted neutrons 122 may interact with any elements existing within detection environment 103 to generate one or more gamma rays 151. Upon generation of gamma rays 151, detector 112 may detect gamma rays 151 and convey an electrical signal output responsive and corresponding to such detection to computer 132, which may then generate an associated gamma ray spectrum.

FIG. 4 depicts a portion 402 of a gamma ray spectrum 410 generated upon interrogation of a detection environment (e.g., detection environment 103) prior to a target object being positioned therein. Portion 402 of gamma ray spectrum 410 illustrates counts of detected background gamma rays at energies between 10,000 keV and 11,000 keV. Furthermore, FIG. 5 depicts another portion 404 of gamma ray spectrum 410 illustrating counts of detected background gamma rays at energies between 4,800 keV and 6,400 keV. As described more fully below, portions 402 and 404 of gamma ray spectrum 410 may be compared to associated portions of another gamma ray spectrum generated upon interrogation of a target object, which is positioned within the detection environment.

Method 310 may further include measuring gamma ray energy emitted from the detection environment (e.g., detection environment 103) having a target object (e.g. target object 106) positioned therein (depicted by numeral 314 in FIG. 3). More specifically, with reference again to FIG. 2, target object 106 may be positioned within detection environment 103 and, thereafter, a stream of neutrons may be transmitted at target object 106, which may contain or comprise an explosive material.

Upon penetration of target object 106, neutrons 122 may interact with target object 106, generating one or more gamma rays 150 responsive to such interaction via a neutron capture reaction or an inelastic scattering reaction. Neutron capture is a reaction in which a collision of a neutron with a target atom results in absorption of the neutron into the nucleus of the atom, which then emits energy (i.e., one or more gamma rays). A neutron capture reaction usually occurs in a finite number of microseconds. Furthermore, an inelastic scattering reaction may occur when a neutron and a target atom collide and a nucleus of the target atom receives energy,

thus leaving the nucleus in an excited state. When the nucleus decays to its original energy level, it emits energy in the form of one or more gamma rays. An inelastic scattering reaction usually occurs in a fraction of a microsecond.

As known by a person having ordinary skill in the art, when a neutron is captured by a nucleus of a nitrogen atom (i.e., a neutron capture reaction involving nitrogen), a gamma ray having an energy of substantially 10,829 keV may be released. Therefore, stimulated nitrogen may produce, as a result of a neutron capture reaction, a full energy gamma ray peak at substantially 10,829 keV in an associated gamma ray spectrum. Furthermore, a gamma ray detector may detect energy of substantially 10,318 keV released during a neutron capture reaction involving nitrogen corresponding to the full energy, less 511 eV of energy of a positron annihilation gamma ray which escaped the gamma ray detector without depositing its energy. Accordingly, the gamma ray spectrum may also include a first escape gamma ray peak at substantially 10,318 keV. Also a second escape gamma ray peak is possible at 9,807 keV.

Additionally, as understood by a person having ordinary skill in the art, when a neutron collides with a nucleus of an oxygen atom (i.e., an inelastic scattering reaction involving oxygen), a gamma ray having an energy of substantially 6,129 keV may be released. Therefore, stimulated oxygen may produce, as a result of an inelastic scattering reaction, a full energy gamma ray peak at substantially 6,129 keV in an associated gamma ray spectrum. Moreover, an inelastic scattering reaction involving oxygen may result in a gamma ray having an energy of substantially 5,618 keV or a gamma ray having an energy of substantially 5,107 keV being detected. Accordingly, the gamma ray spectrum may also include a single escape gamma ray peak at substantially 5,618 keV and a double escape gamma ray peak at substantially 5,107 keV.

With further reference to FIG. 2, gamma ray energy emitted from detection environment 103 including target object 106 may be detected by detector 112. Upon detection of gamma rays 150, detector 112 may convey a corresponding electrical signal to computer 132, which may then generate an associated gamma ray spectrum. FIG. 6 depicts a portion 602 of a gamma ray spectrum 610 generated upon interrogation of a target object (e.g., target object 106) positioned within a detection environment (e.g., detection environment 103). Portion 602 of gamma ray spectrum 610 illustrates counts of detected gamma rays at energies between 10,000 keV and 11,000 keV. Furthermore, FIG. 7 depicts another portion 604 of gamma ray spectrum 610 illustrating counts of detected gamma rays at energies between 4,800 keV and 6,400 keV.

Method 310 may further include determining whether the target object includes a first element that is common to most explosive materials (depicted by numeral 316 in FIG. 3). More specifically, to determine whether the target object includes a first element, gamma ray spectrum 410 (i.e., the gamma ray spectrum generated upon interrogation of a detection environment prior to positioning a target object therein) may be compared to gamma ray spectrum 610 (i.e., the gamma ray spectrum generated upon interrogation of the detection environment having the target object positioned therein). Yet more specifically, for example, gamma ray spectrum 410 and gamma ray spectrum 610 may be compared to determine whether the target object includes nitrogen, which is common to most explosives. As mentioned above, stimulated nitrogen may produce a full energy gamma ray peak at substantially 10,829 keV and a first escape gamma ray peak at substantially 10,318 keV in an associated gamma ray spectrum. With reference to FIGS. 4 and 6, in comparison to portion 402 of gamma ray spectrum 410, portion 602 of gamma ray spectrum 610 includes a gamma ray peak at each of 10,829 keV (depicted by numeral 614 in FIG. 6) and 10,318 keV (depicted by numeral 612 in FIG. 6). Accordingly, one of ordinary skill in the art would be able to conclude that the target object interrogated in an associated detection process includes nitrogen.

Additionally, method 310 may include determining whether the target object includes a second element if it is determined that the target object includes the first element (depicted by numeral 318 in FIG. 3). More specifically, if it is determined that the target object includes the first element (e.g., nitrogen), gamma ray spectrum 410 (i.e., the gamma ray spectrum generated upon interrogation of the detection environment not including a target object) may again be compared to gamma ray spectrum 610 (i.e., the gamma ray spectrum generated upon interrogation of the detection environment having the target object positioned therein) to determine whether the target object includes a second element. Yet specifically, for example, gamma ray spectrum 410 and gamma ray spectrum 610 may be compared to determine whether the target object includes oxygen, which all known explosives contain. As mentioned above, stimulated oxygen may produce a full energy gamma ray peak at substantially 6,129 keV, a single energy escape gamma ray peak at substantially 5,618 keV, and a double energy escape gamma ray peak at substantially 5,107 keV in an associated gamma ray spectrum. With reference to FIGS. 5 and 7, in comparison to portion 404 of gamma ray spectrum 410, portion 604 of gamma ray spectrum 610 includes a gamma ray peak at each of 6,129 keV (depicted by numeral 616 in FIG. 7), 5,618 keV (depicted by numeral 618 in FIG. 7) and 5,107 keV (depicted by numeral 620 in FIG. 7). Accordingly, one of ordinary skill in the art would be able

to conclude that the target object interrogated in an associated detection process includes oxygen. Upon establishing that the target object includes a first element that is common to most explosives (e.g. nitrogen) and a second element that all known explosives contain (e.g., oxygen), the target object may be identified as a possible explosive material (depicted by numeral 320 in FIG. 3).

It is noted that the gamma ray spectrums illustrated in FIGS. 4-7 were generated by a detection system (e.g., detection system 100 depicted in FIGS. 1 and 2) wherein a detector (e.g., detector 112) comprised a germanium detector. Further, an interrogating source (e.g., interrogating source 110) was operated for substantially the same amount of time for each interrogation process described above (i.e., the process of interrogating a detection environment without a target object, and the process of interrogating the detection environment having a target object positioned therein). Moreover, a detector (e.g., detector 112) was operated for substantially the same amount of time for each interrogation process described above (i.e., the process of interrogating a detection environment without a target object, and the process of interrogating the detection environment having a target object positioned therein).

It is further noted that the neutrons transmitted by interrogation source 110 must have an energy that is greater than an energy of an inelastic scatter gamma ray that is desired to be generated. For example, as noted above, an inelastic scattering reaction resulting from a collision of a neutron and an oxygen atom may produce a gamma ray having an energy of substantially 6,129 keV. Accordingly, to generate this gamma ray, a neutron transmitted by interrogation source 110 and colliding with a nucleus of an oxygen atom must have an energy greater than 6,129 keV. Therefore, to carry out the described embodiments of the present invention, interrogation source 110 should comprise an interrogation source configured to emit neutrons at energies above 6,129 keV. For example only, interrogation source 110 may comprise a Deuterium/Tritium (DT) Neutron Generator, which is configured to transmit neutrons at substantially 14.1 MeV.

As will be understood by a person of ordinary skill in the art, less expensive detectors, such as a sodium iodide detector, may have poorer energy resolution in comparison to a more expensive detector. As a result, an associated gamma ray spectrum may include improperly classified gamma rays (i.e., gamma rays classified at inaccurate energies), gamma rays that are imprecisely classified (i.e. gamma rays classified across multiple energies), or both. As such, according to an embodiment of the present invention, a detection system (e.g., detection system 100 of FIGS. 1 and 2) may be gated to enable neutron capture generated gamma rays to be

distinguished from inelastic scattering generated gamma rays. More specifically, as mentioned above, an inelastic scattering reaction may occur in a fraction of one microsecond (e.g., 0.2 microseconds) and a neutron capture reaction may take longer than one microsecond (e.g., 100 microseconds). Furthermore, in a pulse mode operation, a time duration of each pulse (i.e., during transmission of neutrons) of an interrogation source (e.g., interrogation source 110 of FIGS. 1 and 2) may be specified and a time duration between each pulse may be specified.

Therefore, to gate a detection system, a time duration of a pulse of an interrogation source and a time duration between each pulse may each be set accordingly so that inelastic scattering reactions are likely to occur during each pulse and neutron capture reactions are likely to occur between each pulse with a high probability. As a result, gamma rays detected during each pulse may be classified as gamma rays resulting from an inelastic scattering reaction and gamma rays detected between each pulse may be classified as gamma rays resulting from a neutron capture reaction.

On the other hand, a more expensive detector, such as a germanium detector, can more easily resolve gamma rays to their correct energy. As such, a detection system having a more expensive detector may properly classify detected gamma rays on an associated gamma ray spectrum without a need to gate the detection system.

FIG. 8 illustrates a flow diagram of another method 800 of detecting a possible explosive material in accordance with an embodiment of the present invention. Initially, background levels of both nitrogen and oxygen within a detection environment may be measured (depicted by numeral 802). Thereafter, a target object may be interrogated (depicted by numeral 804). More specifically, a target object may be introduced into the detection environment, a stream of neutrons may be transmitted towards the target object, and gamma rays emitted from both nitrogen and oxygen nuclei from the detection environment may be measured. A determination may then be made as to whether the target object includes nitrogen (depicted by numeral 806). Specifically, a measured background level of nitrogen may be compared to a level of nitrogen measured upon interrogation of the target object. If the level of nitrogen measured upon interrogation of the target object is greater than the measured background level of nitrogen, then it may be established that the target object includes nitrogen. If it is established that the target object does not include nitrogen, then it may be determined that the target object is not an explosive material (depicted by numeral 810). If it is established that the target object includes nitrogen, then a determination may be made as to whether the target object includes oxygen (depicted by numeral 808). Specifically, a measured background

level of oxygen may be compared to a level of oxygen measured upon interrogation of the target object. If the level of oxygen measured upon interrogation of the target object is greater than the measured background level of oxygen, then it may be established that the target object includes oxygen. If it is established that the target object does not include oxygen, then it may be
5 determined that the target object is not an explosive material (depicted by numeral 814). If it is established that the target object includes oxygen, then it may be determined that the target object is a possible explosive material (depicted by numeral 812).

Embodiments of the present invention, as described herein, may enable for identification of potentially explosive materials while reducing false-positive rates in comparison to
10 conventional methods. Accordingly, embodiments of the present invention may improve efficiency of a detection process as well as reduce costs associated with the detection process.

While the present invention has been described herein with respect to certain embodiments, those of ordinary skill in the art will recognize and appreciate that it is not so limited. Rather, many additions, deletions, and modifications to the described embodiments
15 may be made without departing from the scope of the invention as hereinafter claimed, including legal equivalents. In addition, features from one embodiment may be combined with features of another embodiment while still being encompassed within the scope of the invention as contemplated by the inventors.

CLAIMS

What is claimed is:

1. A method of detecting a possible explosive material, comprising:
measuring gamma ray energy emitted from a target object;
determining whether the target object includes a first element;
then, if the target object is determined to include the first element, determining whether the target object includes a second, different element ; and
identifying the target object as a possible explosive material if the target object includes each of the first element and the second element.
2. The method of claim 1, wherein determining whether the target object includes a first element comprises comparing gamma ray energy detected upon interrogation of a detection environment to gamma ray energy detected upon interrogation of the detection environment having a target object positioned therein.
3. The method of claim 1, wherein determining whether the target object includes the second, different element comprises comparing gamma ray energy detected upon interrogation of a detection environment to gamma ray energy detected upon interrogation of the detection environment having a target object positioned therein.
4. The method of claim 1, further comprising measuring gamma ray energy emitted from a detection environment prior to positioning the target object therein.
5. The method of claim 4, further comprising positioning the target object within the detection environment.
6. The method of claim 1, wherein determining whether the target object includes a first element comprises determining whether the target object includes nitrogen.
7. The method of claim 1, wherein determining whether the target object includes a second, different element comprises determining whether the target object includes oxygen.

8. The method of claim 1, further comprising transmitting neutrons at the target object with a neutron generator configured to emit neutrons at an energy greater than substantially 6,129 keV.

9. The method of claim 8, wherein transmitting neutrons at the target object with a neutron generator configured to emit neutrons at an energy greater than substantially 6,129 keV comprises transmitting neutrons at the target object with a Deuterium/Tritium (DT) Neutron Generator.

10. The method of claim 8, wherein transmitting neutrons at the target object with a neutron generator comprises transmitting neutrons at the target object with a neutron generator operated in a pulse mode.

11. The method of claim 1, wherein measuring comprises measuring gamma rays generated by at least one of an inelastic scattering reaction and a neutron capture reaction.

12. A computer-readable media storage medium storing instructions that when executed by a processor cause the processor to perform instructions for detecting a possible explosive material, the instructions comprising:
measuring gamma ray energy emitted from a target object;
determining whether the target object includes a first element;
determining whether the target object includes a second, different element if the target object includes the first element; and
identifying the target object as a possible explosive material if the target object includes each of the first element and the second, different element.

13. A method of detecting a possible explosive material, comprising:
measuring background energy emitted from a detection environment;
measuring energy emitted from the detection environment having a target object positioned therein;
comparing the measured background energy to the measured energy to determine whether the target object includes a first element;

comparing the measured background energy to the measured energy to determine whether the target object includes oxygen if the target object includes the first element;
classifying the target object as a possible explosive material if the target object includes each of the first element and oxygen.

14. The method of claim 13, wherein measuring background energy comprises transmitting neutrons toward the detection environment and collecting gamma ray energy emitted from the detection environment.

15. The method of claim 13, wherein measuring energy comprises transmitting neutrons toward the detection environment having the target object positioned therein and collecting gamma ray energy emitted from the detection environment having the target object positioned therein.

16. The method of claim 13, wherein comparing the measured background energy to the measured energy to determine whether the target object includes a first element comprises comparing a gamma ray spectrum generated upon interrogation of the detection environment and another gamma ray spectrum generated upon interrogation of the detection environment having the target object positioned therein.

17. The method of claim 13, wherein comparing the measured background energy to the measured energy to determine whether the target object includes oxygen comprises comparing a gamma ray spectrum generated upon interrogation of the detection environment and another gamma ray spectrum generated upon interrogation of the detection environment having the target object positioned therein.

18. The method of claim 13, wherein measuring background energy emitted from a detection environment comprises collecting gamma rays generated by an inelastic scattering reaction during a pulse of an associated interrogation source and collecting gamma rays generated by a neutron capture reaction between each pulse of the associated interrogation source.

19. The method of claim 13, wherein measuring energy emitted from the detection environment having a target object positioned therein comprises collecting gamma rays generated by an inelastic scattering reaction during a pulse of an associated interrogation source and collecting gamma rays generated by a neutron capture reaction between each pulse of the associated interrogation source.

20. A method of identifying a possible explosive material, the method comprising identifying a target object as a possible explosive material if the target object comprises each of nitrogen and oxygen.

21. A method of detecting a possible explosive material, comprising:
measuring background energy emitted from a detection environment;
positioning a target object within the detection environment;
subjecting the target object to an interrogation process;
determining whether the target object includes nitrogen;
determining whether the object includes oxygen if the target object includes nitrogen; and
identifying the target object as a possible explosive material if the target object includes each of nitrogen and oxygen.

22. The method of claim 21, wherein determining whether the target object includes nitrogen comprises comparing a measured background level of nitrogen to a level of nitrogen measured upon subjecting the target object to the interrogation process.

23. The method of claim 21, wherein determining whether the target object includes oxygen comprises comparing a measured background level of oxygen to a level of oxygen measured upon subjecting the target object to the interrogation process.

24. The method of claim 21, wherein subjecting the target object to an interrogation process comprises transmitting neutrons at the target object with a neutron generator configured to emit neutrons at an energy greater than substantially 6,129 keV.

25. The method of claim 24, wherein subjecting the target object to an interrogation process further comprises measuring gamma rays generated by at least one of an inelastic scattering reaction and a neutron capture reaction.

26. A detection system, comprising:
an interrogation source configured to transmit neutrons toward a detection environment;
a detector configured to detect gamma rays emitted from the detection environment; and
a computer operably coupled to each of the interrogation source and the detector;
wherein the detection system is configured to:
determine whether a target object positioned within the detection environment includes a first element;
determine whether the target object includes a second, different element if the target object includes the first element; and
identify the target object as a possible explosive material if the target object includes each of the first element and the second, different element.

27. The system of claim 26, wherein the detector is further configured to convey a signal to the computer corresponding to detection of the gamma rays emitted from the detection environment.

28. The system of claim 27, wherein the computer is configured to generate a gamma ray spectrum corresponding to the signal received from the detector.

29. The system of claim 26, wherein the computer is configured to compare a gamma ray spectrum corresponding to an interrogation of the detection environment and another gamma ray spectrum corresponding to an interrogation of the detection environment having the target object positioned therein.

30. The system of claim 26, wherein the interrogation source comprises a neutron generator configured to transmit neutrons at an energy greater than substantially 6,129 keV.

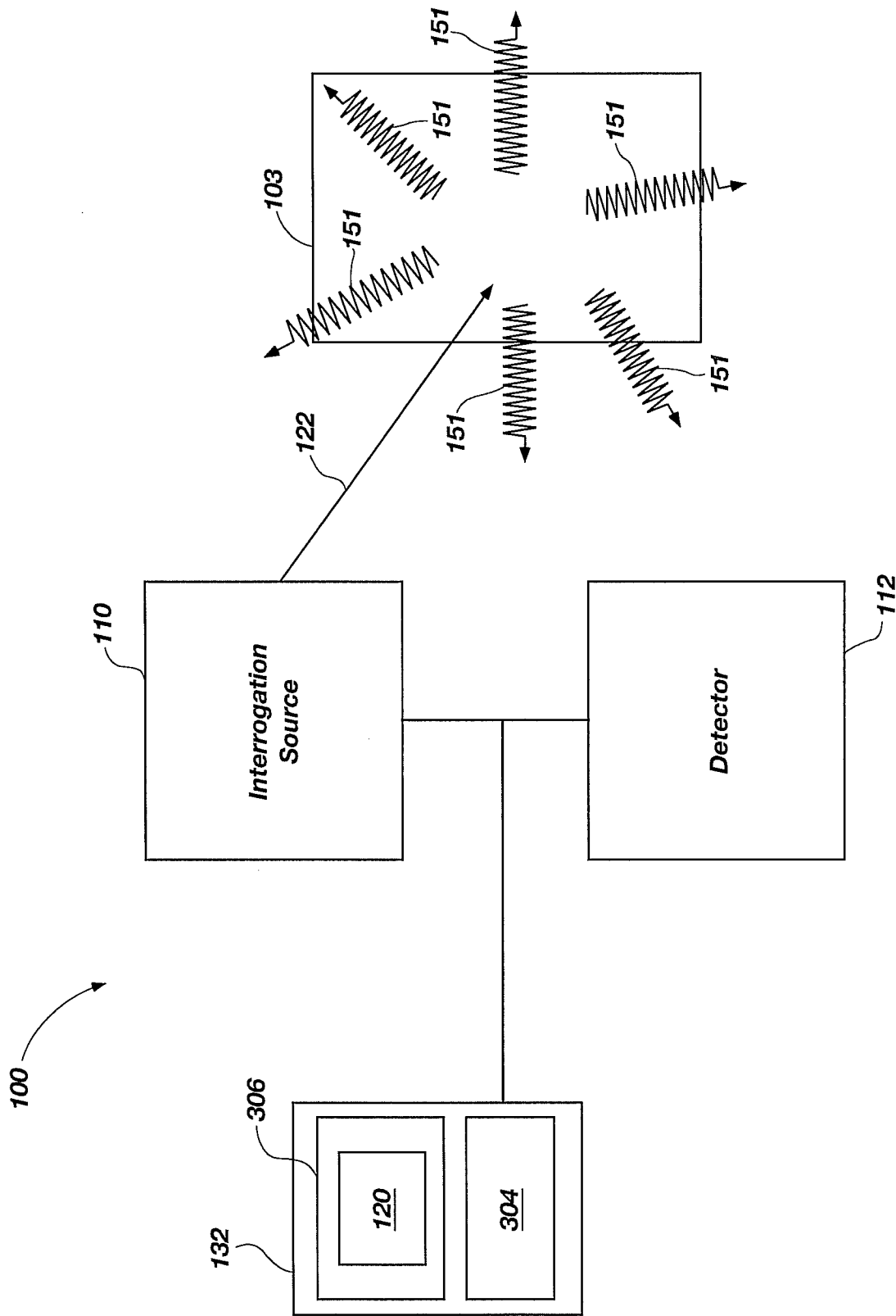
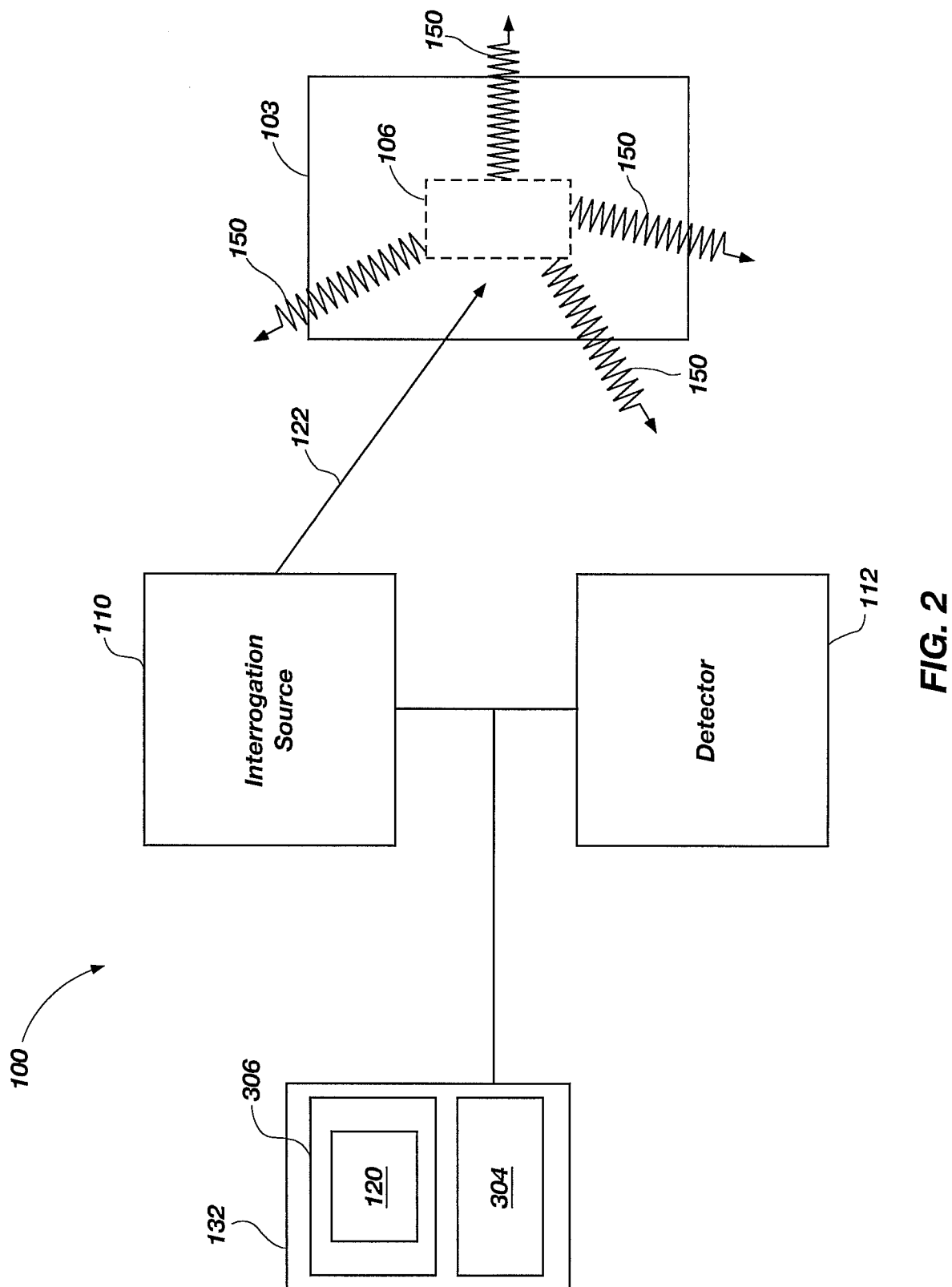
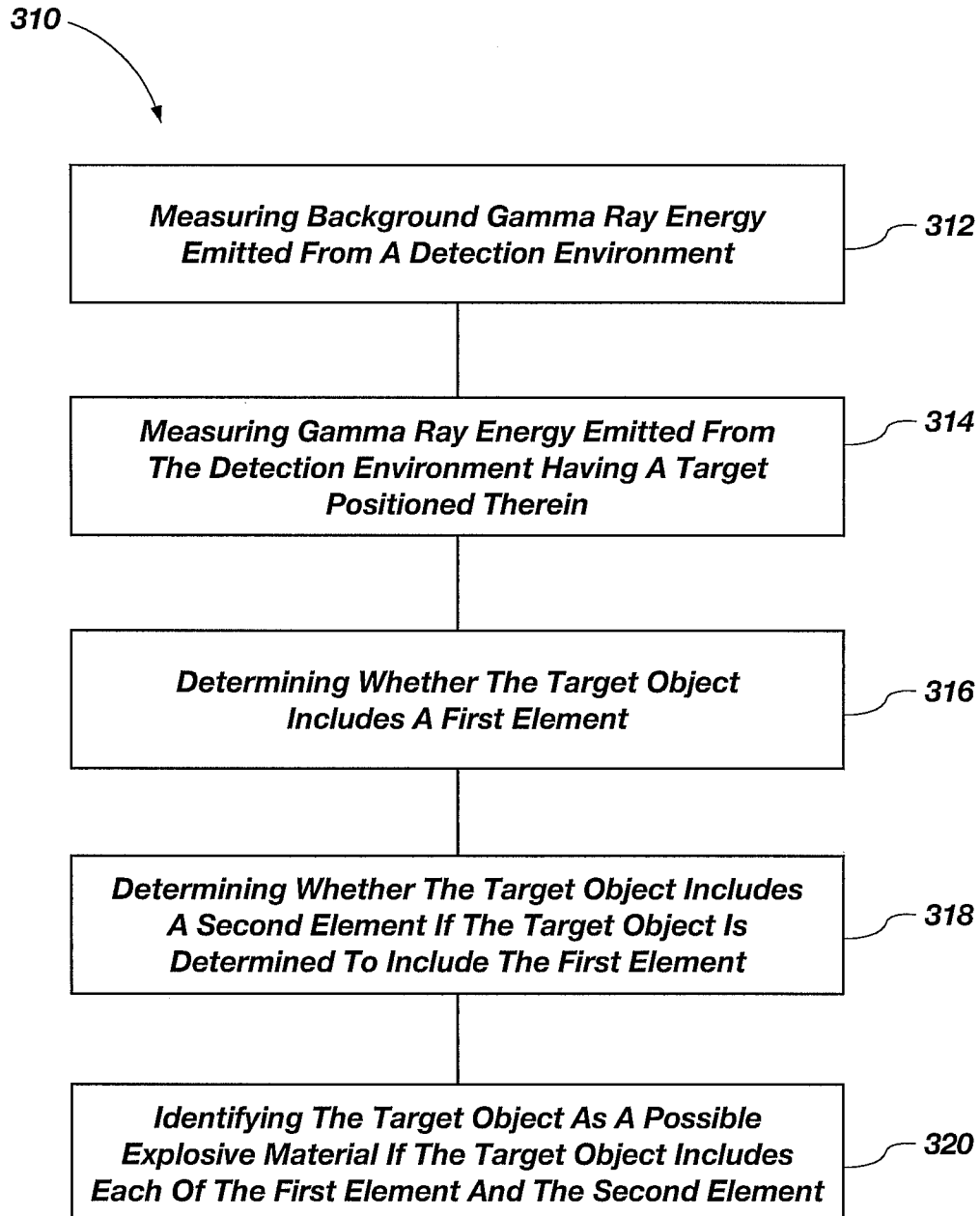


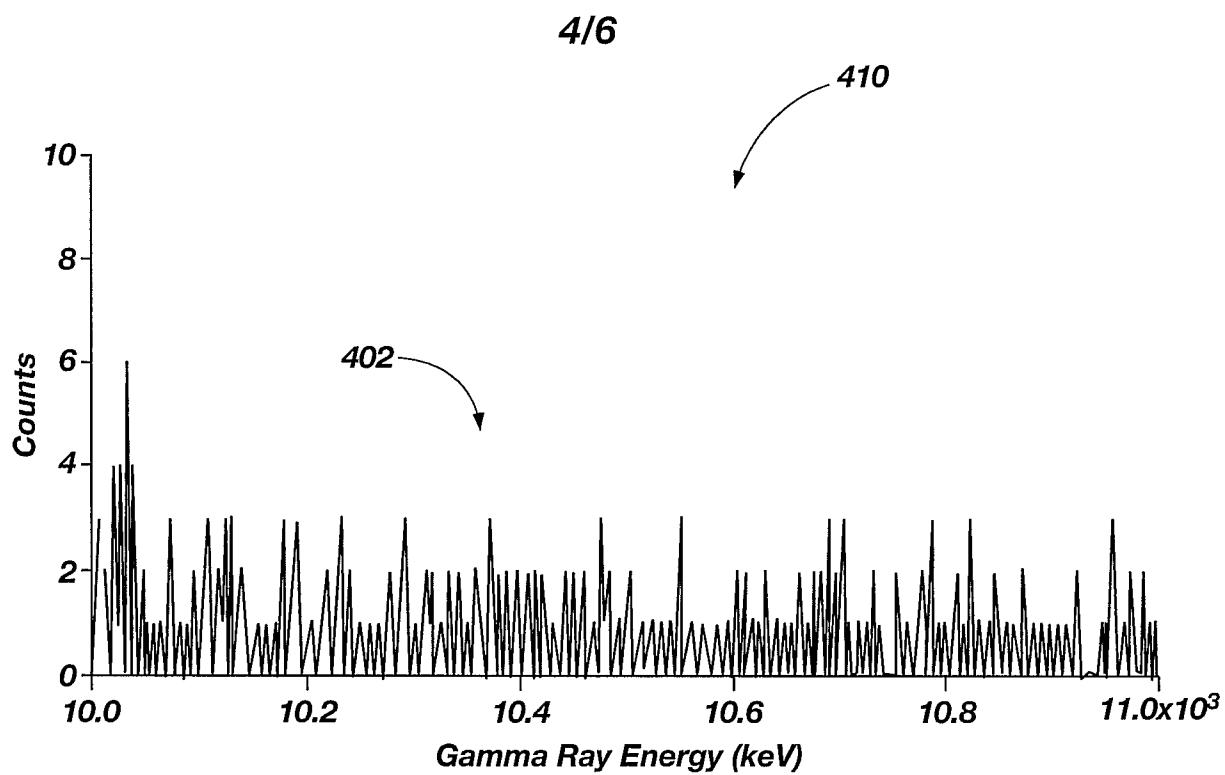
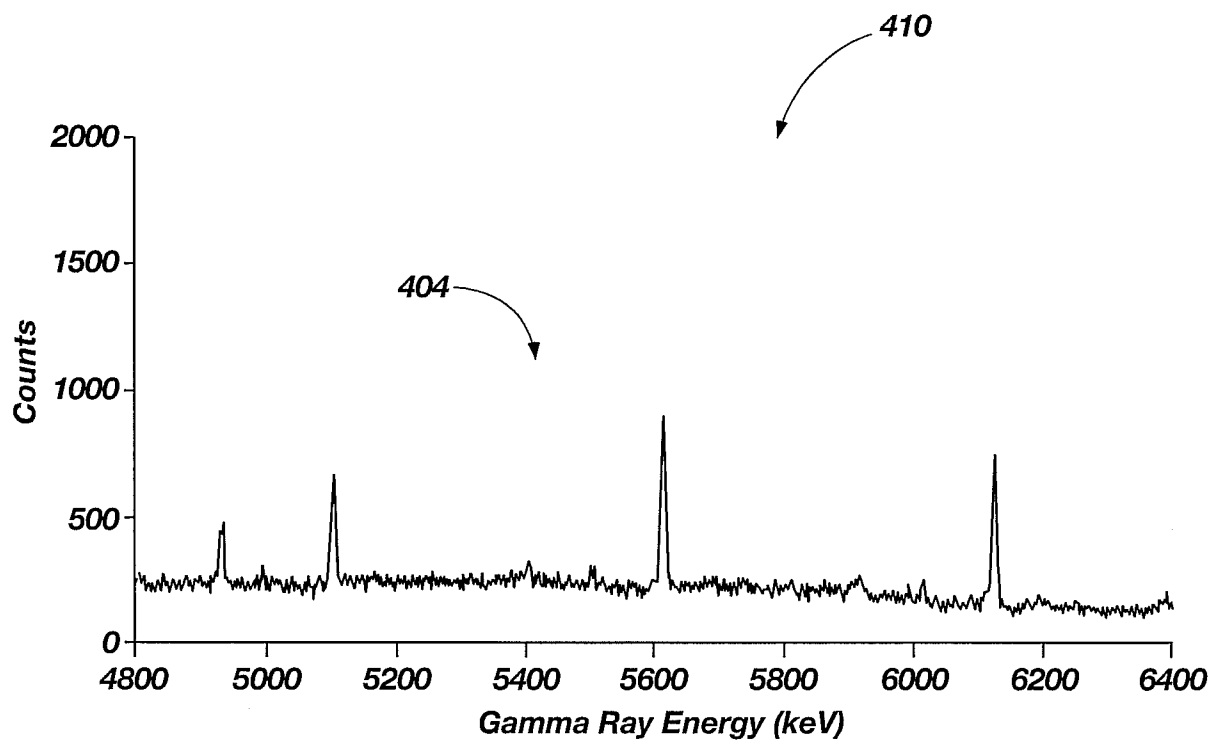
FIG. 1

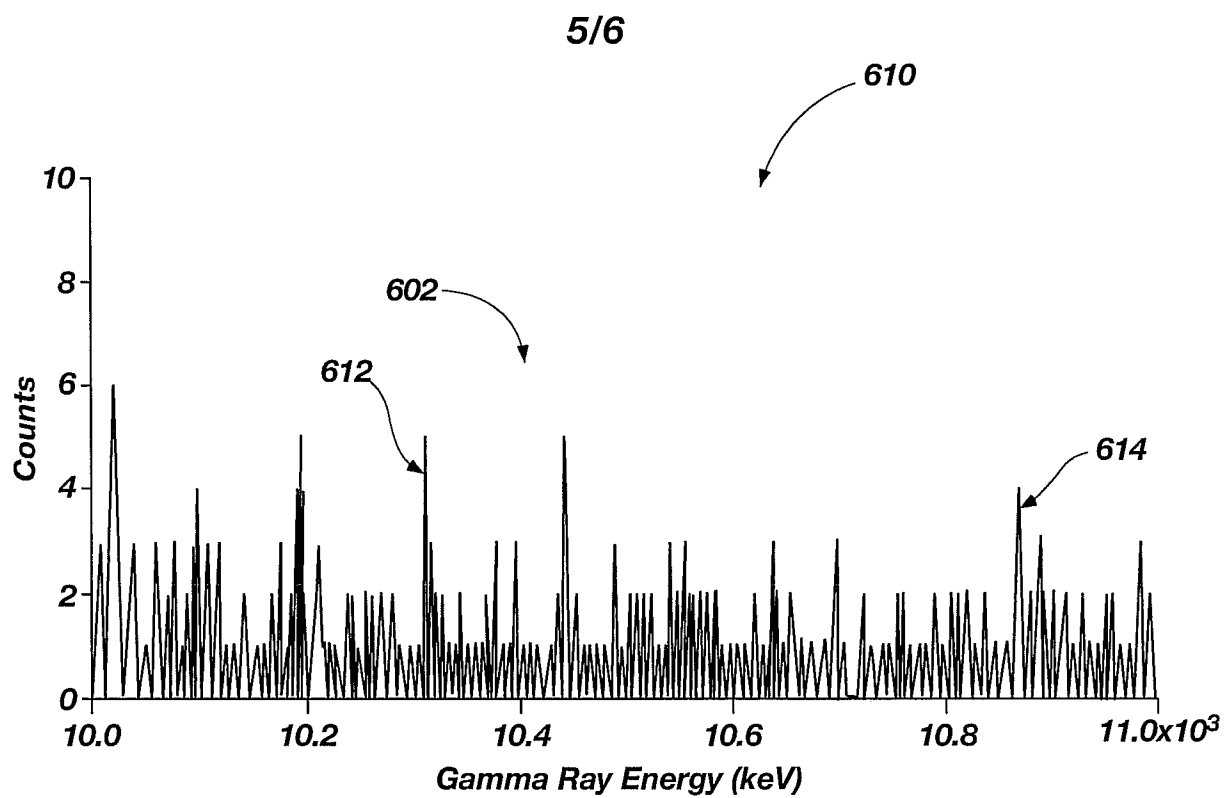
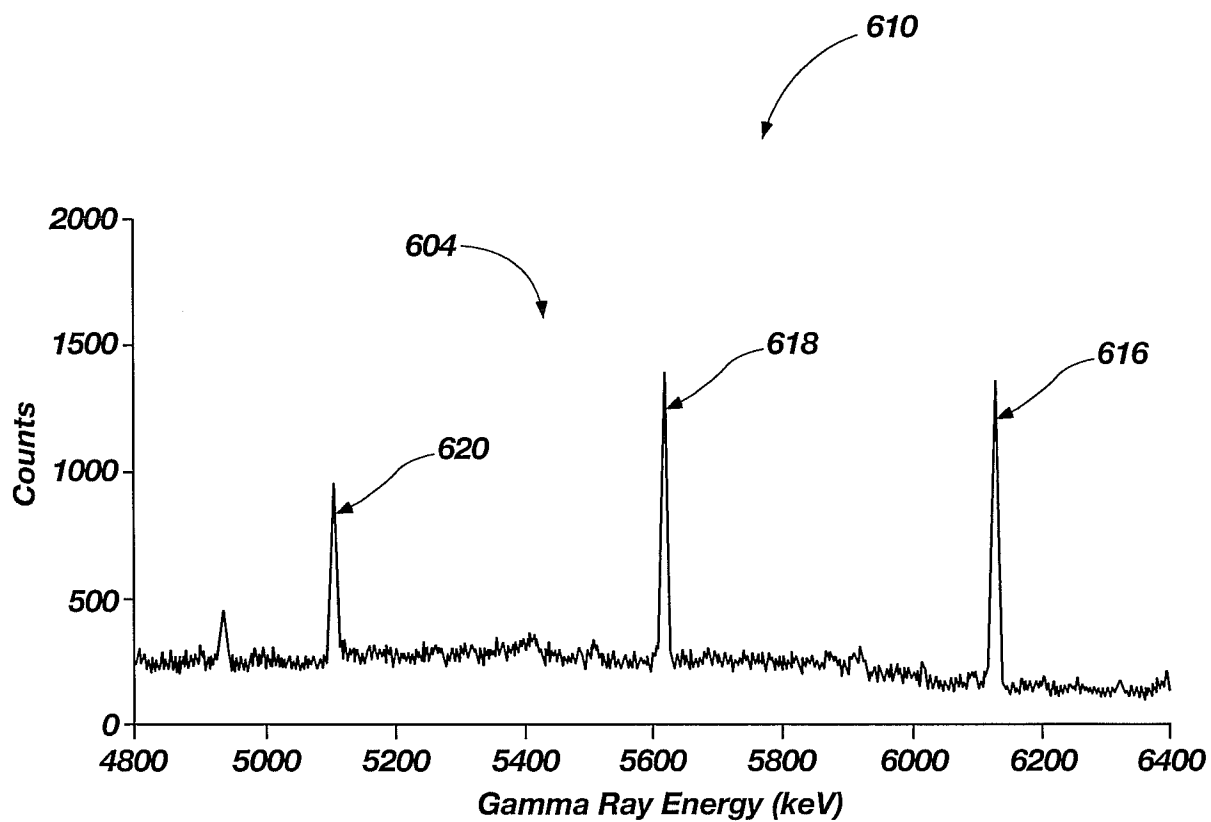
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**FIG. 3**

**FIG. 4****FIG. 5**

**FIG. 6****FIG. 7**

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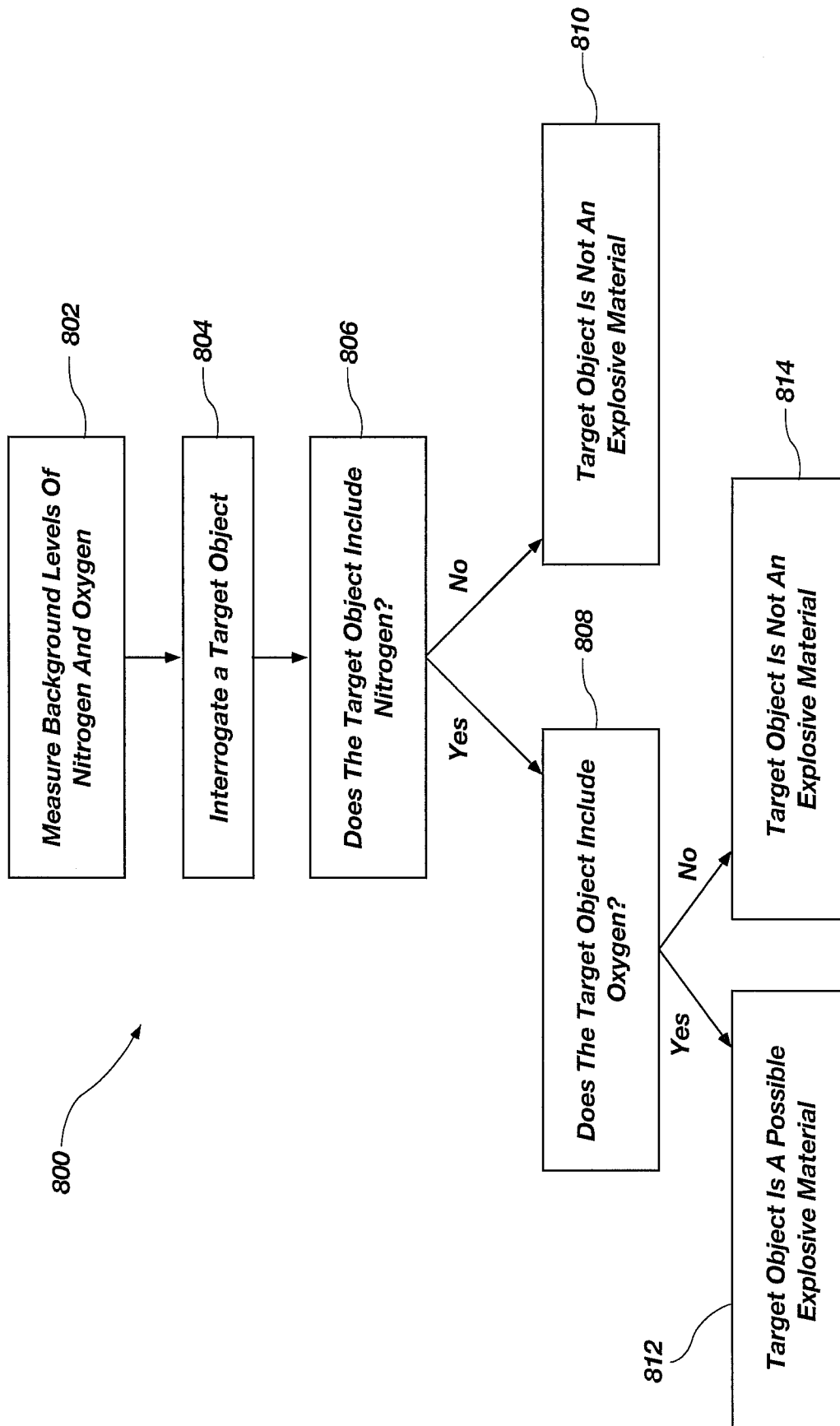


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/48700

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01J 5/02 (2011.01)

USPC - 250/390.07

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)
USPC: 250/390.07

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 250/390.01, 390.04, 390.07, 390.10, 391; 378/57 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST(USPT,PGPB,EPAB,JPAB); Google

Search Terms: gamma, neutron, explosive, oxygen, nitrogen, deuterium, tritium, background, pulse, inelastic scattering, neutron capture

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2007/0286339 A1 (ROTHSCHILD) 13 December 2007 (13.12.2007), entire document especially paras [0024], [0028]-[0034]	1, 5-9, 11-12, 20 ----- 2-4, 10, 13-19, 21-30
Y	US 2008/0224060 A1 (REBER et al.) 10 March 2009 (10.03.2009), entire document especially para [0069]	2-4
Y	US 2007/0295911 A1 (SVED) 27 December 2007 (27.12.2007), entire document especially para [0074]	10, 18
Y	US 6,563,898 B1 (VOURVOPOULOS et al.) 13 May 2003 (13.05.2003), entire document especially col 6, lns 29-67; col 7, lns 1-67; col 8, lns 1-32	13-19, 21-30
A	US 5,818,054 A (RANDERS et al.) 06 October 1998 (06.10.1998), entire document especially col 3, lns 46-54	1-30
A	US 5,606,167 A (MILLER) 25 February 1997 (25.02.1997), entire document	1-30
A	US 2008/0017806 A1 (NORRIS) 24 January 2008 (24.01.2008), entire document	1-30
A	US 5,818,054 A (RANDERS et al.) 06 October 1998 (06.10.1998), entire document	1-30
A	US 3,997,787 A (FEARON et al.) 14 December 1976 (14.12.1976), entire document especially	1-30

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"O" document referring to an oral disclosure, use, exhibition or other means

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

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later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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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

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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

04 May 2011 (04.05.2011)

Date of mailing of the international search report

11 MAY 2011

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