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(54) **CT DETECTOR FABRICATION PROCESS**

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(58) **Field of Search** ..... 250/370.01, 370.09, 250/370.13, 370.14; 378/19, 98.8

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

6,473,486 B2 10/2002 Hoffman

6,480,562 B2	11/2002	Jiang et al.
6,480,563 B2	11/2002	Hoffman et al.
6,654,443 B1	11/2003	Hoffman
6,704,391 B2	3/2004	Hoffman et al.
6,864,484 B1 *	3/2005	Zur ..... 250/370.09
2003/0161437 A1	8/2003	Hoffman

\* cited by examiner

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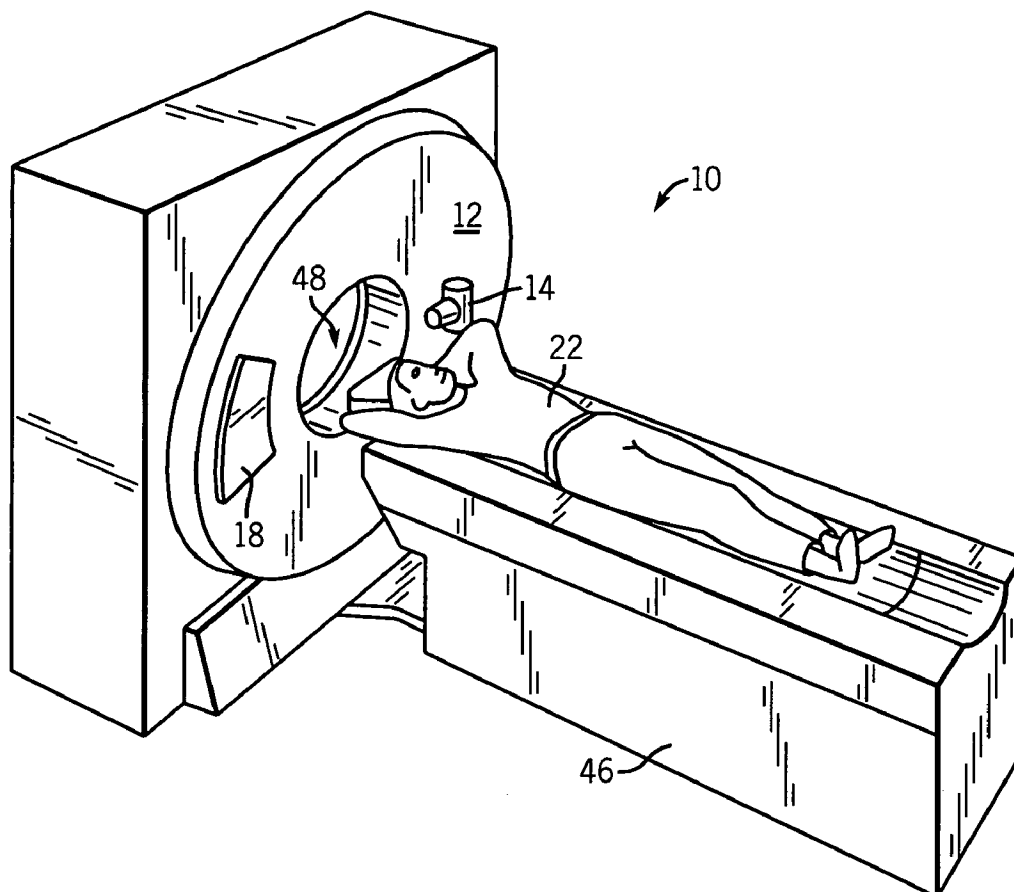
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(57) **ABSTRACT**

A CT detector capable of energy discrimination and direct conversion is disclosed. The detector includes multiple layers of semiconductor material with the layers having varying thicknesses. The detector is constructed to be segmented in the x-ray penetration direction so as to optimize count rate performance as well as avoid saturation.

**20 Claims, 6 Drawing Sheets**



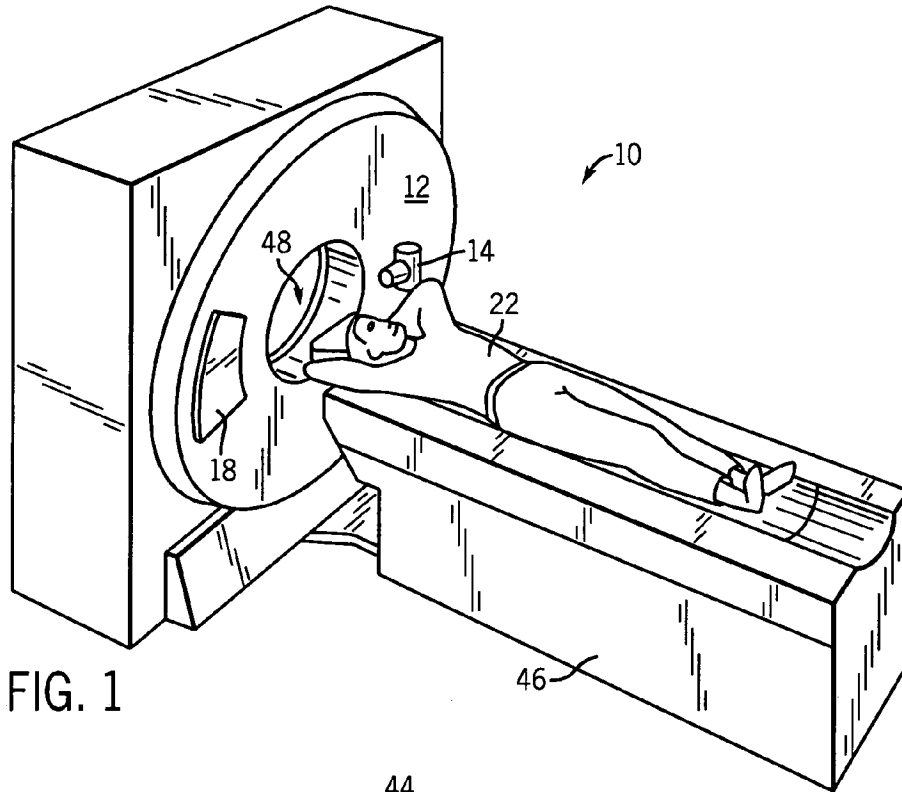


FIG. 1

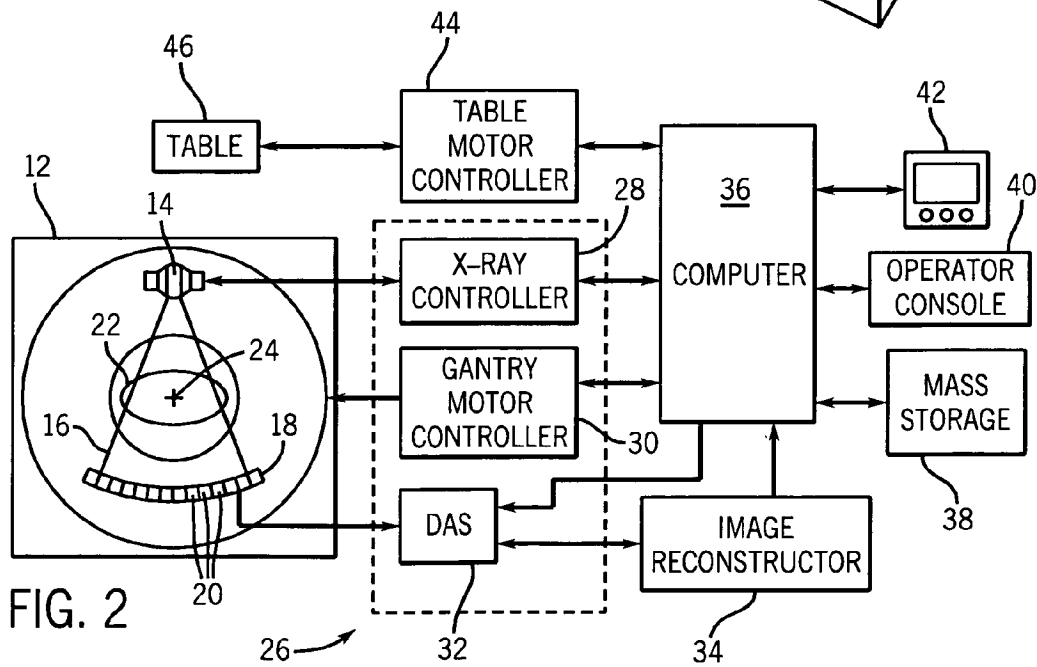


FIG. 2

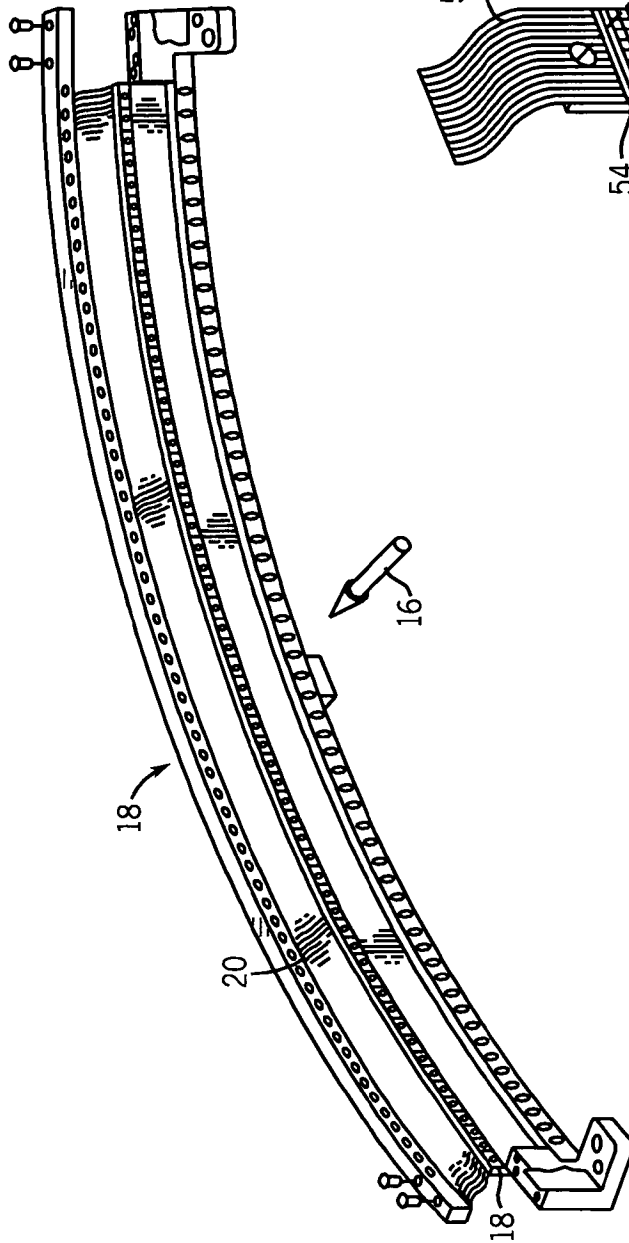


FIG. 3

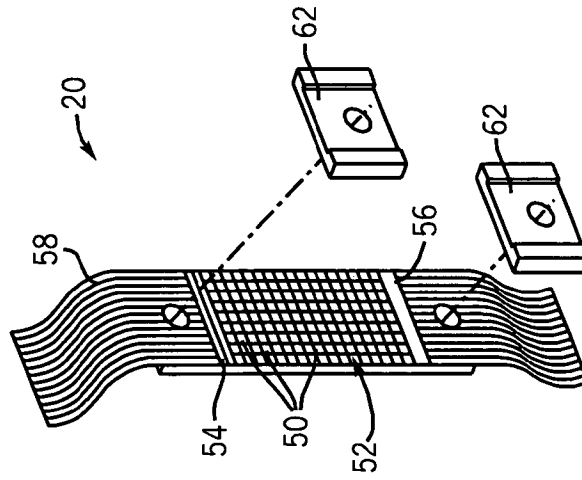


FIG. 4

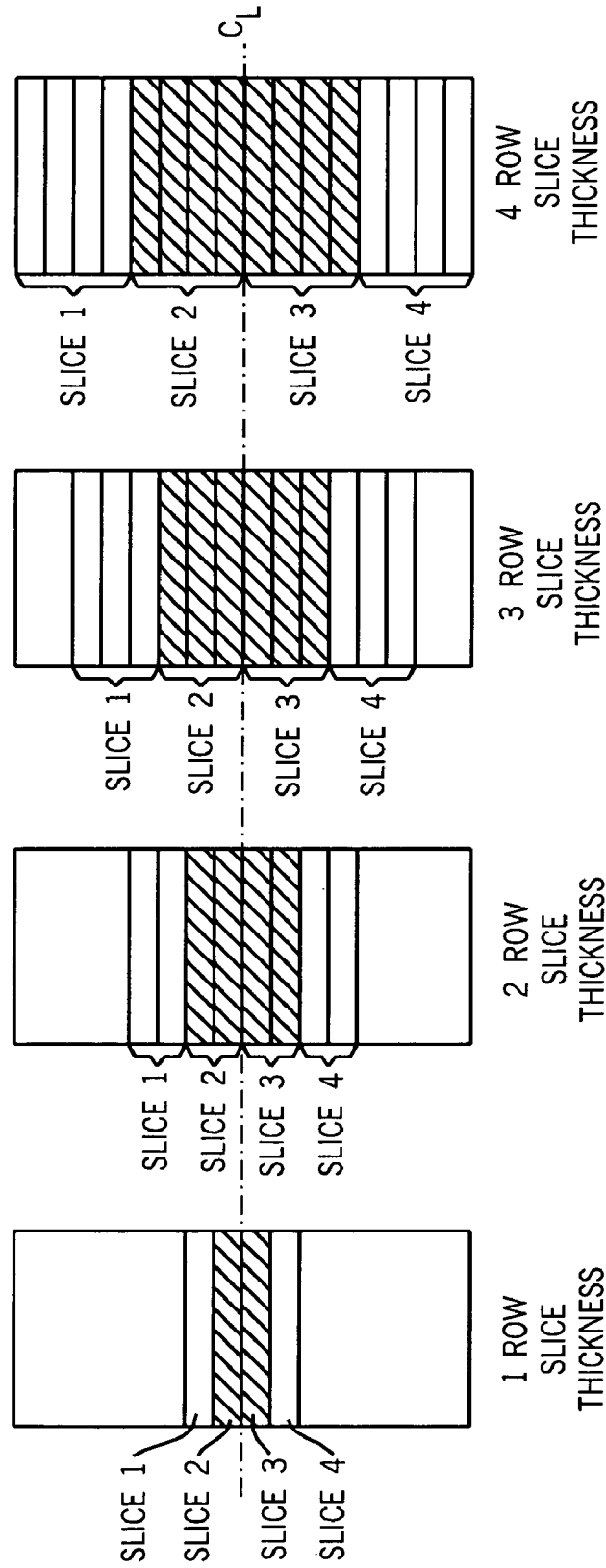


FIG. 5

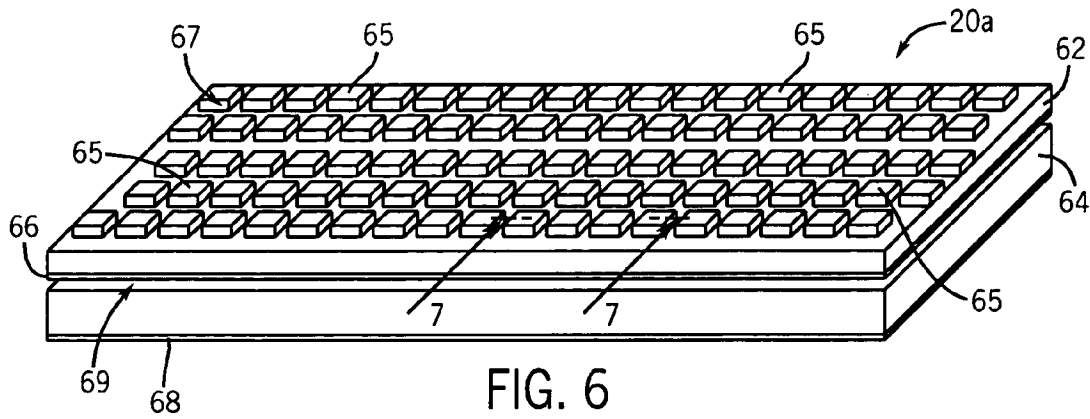


FIG. 6

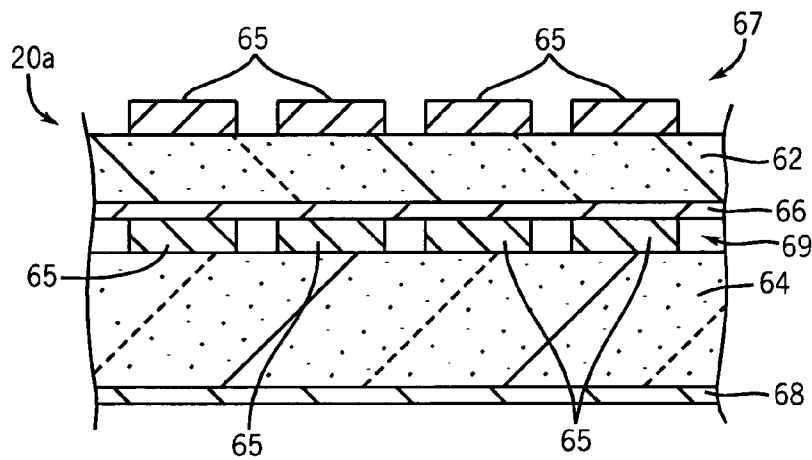


FIG. 7

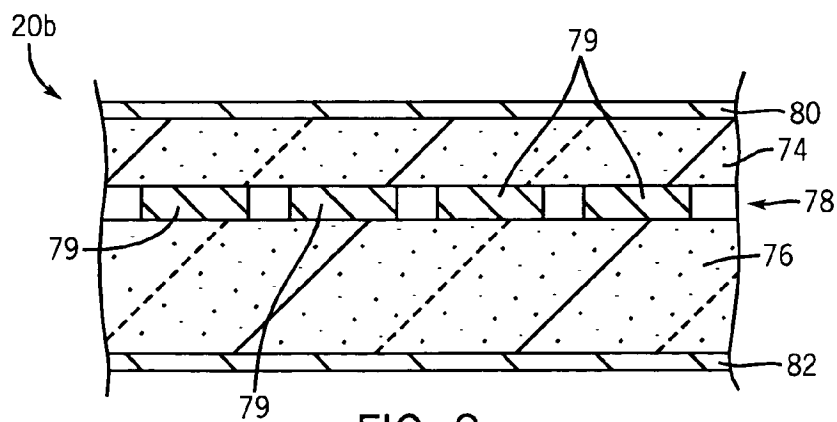
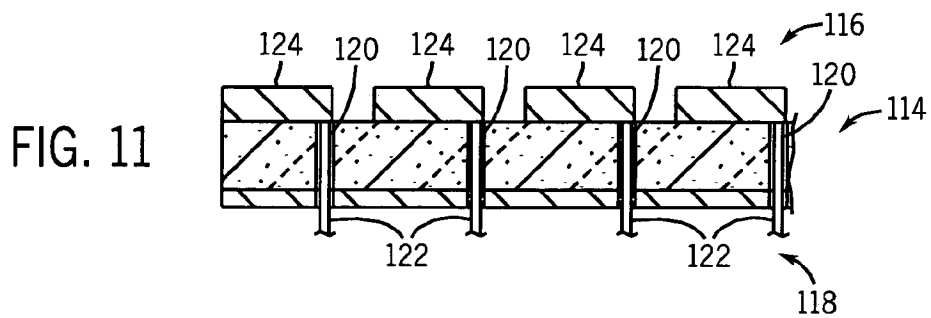
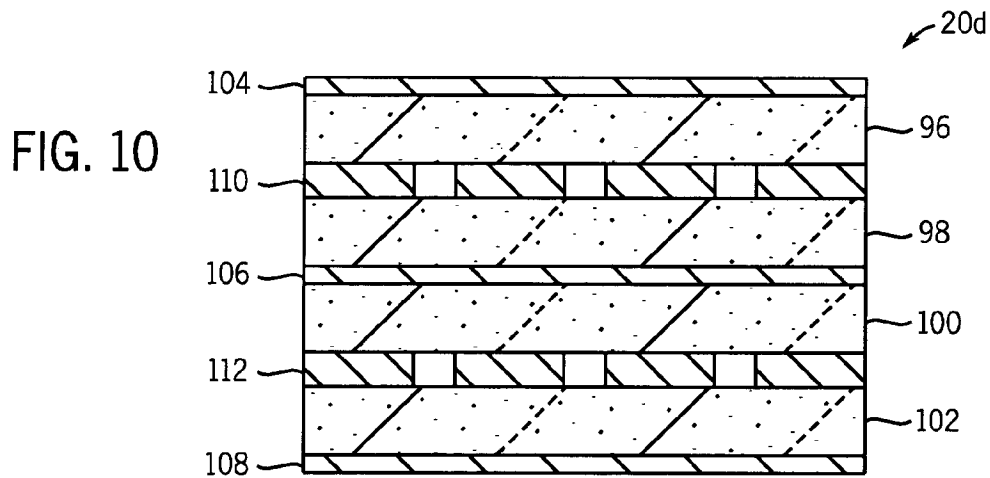
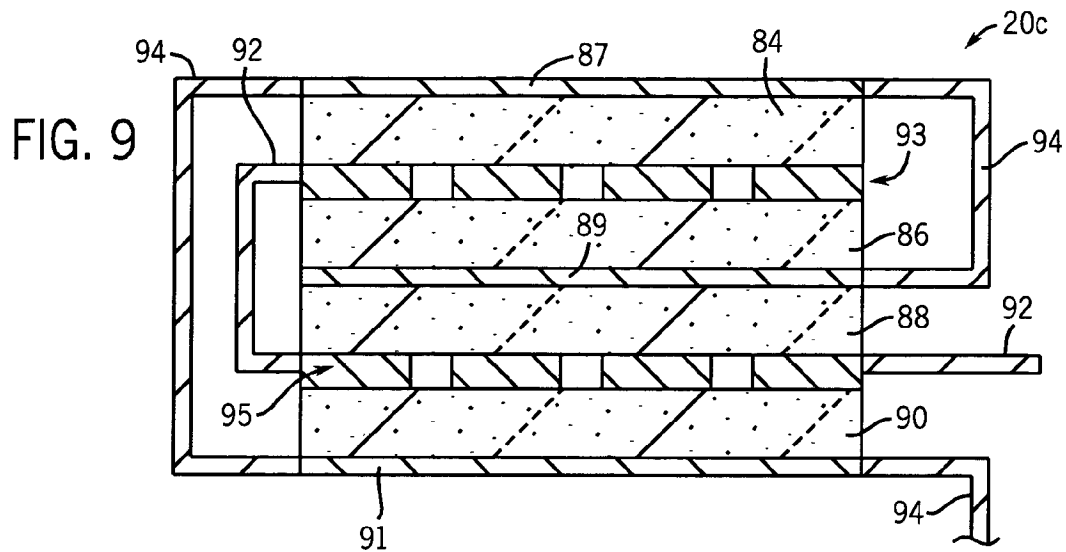


FIG. 8



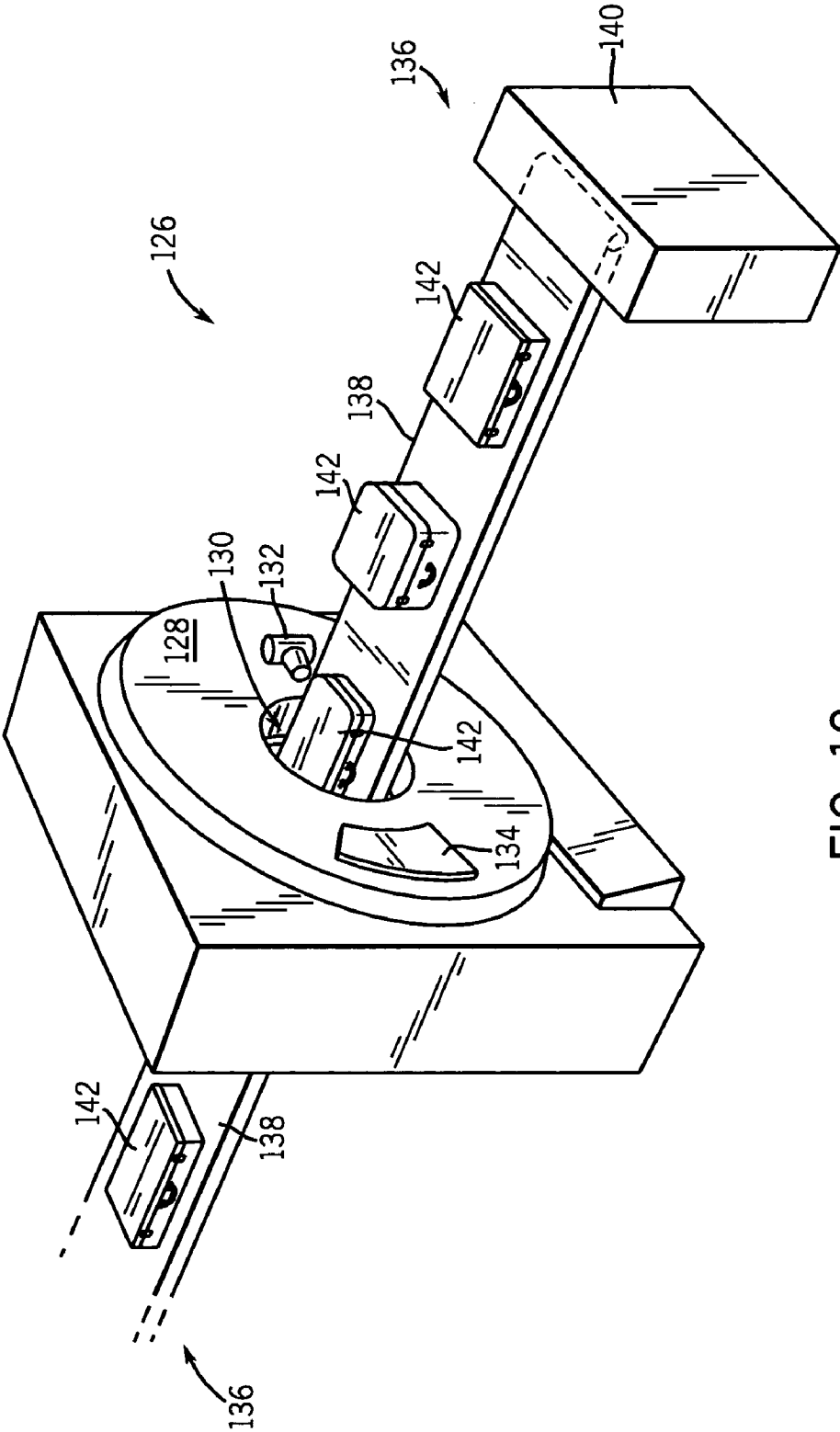


FIG. 12

**CT DETECTOR FABRICATION PROCESS****BACKGROUND OF THE INVENTION**

The present invention relates generally to diagnostic imaging and, more particularly, to a method of constructing and otherwise fabricating a direct conversion CT detector capable of providing photon count and/or energy data.

Typically, in radiographic imaging systems, an x-ray source emits x-rays toward a subject or object, such as a patient or a piece of luggage. Hereinafter, the terms "subject" and "object" may be interchangeably used to describe anything capable of being imaged. The beam, after being attenuated by the subject, impinges upon an array of radiation detectors. The intensity of the attenuated beam radiation received at the detector array is typically dependent upon the attenuation of the x-rays. Each detector element of the detector array produces a separate electrical signal indicative of the attenuated beam received by each detector element. The electrical signals are transmitted to a data processing system for analysis which ultimately produces an image.

In some computed tomography (CT) imaging systems, the x-ray source and the detector array are rotated about a gantry within an imaging plane and around the subject. X-ray sources typically include x-ray tubes, which emit the x-rays as a beam at a focal point. X-ray detectors typically include a collimator for collimating x-ray beams received at the detector, a scintillator for converting x-rays to light energy adjacent the collimator, and a photodiode for receiving the light energy from an adjacent scintillator and producing electrical signals therefrom. Typically, each scintillator of a scintillator array converts x-rays to light energy. Each photodiode detects the light energy and generates a corresponding electrical signal. The outputs of the photodiodes are then transmitted to the data processing system for image reconstruction.

Conventional CT imaging systems utilize detectors that convert radiographic energy into current signals that are integrated over a time period, then measured and ultimately digitized. A drawback of such detectors is their inability to provide data or feedback as to the number and/or energy of photons detected. That is, conventional CT detectors have a scintillator component and photodiode component wherein the scintillator component illuminates upon reception of radiographic energy and the photodiode detects illumination of the scintillator component and provides an electrical signal as a function of the intensity of illumination. While it is generally recognized that CT imaging would not be a viable diagnostic imaging tool without the advancements achieved with conventional CT detector design, a drawback of these detectors is their inability to provide energy discriminatory data or otherwise count the number and/or measure the energy of photons actually received by a given detector element or pixel. Accordingly, recent detector developments have included the design of an energy discriminating, direct conversion detector that can provide photon counting and/or energy discriminating feedback. In this regard, the detector can be caused to operate in an x-ray counting mode, an energy measurement mode of each x-ray event, or both.

These energy discriminating, direct conversion detectors are capable of not only x-ray counting, but also providing a measurement of the energy level of each x-ray detected. While a number of materials may be used in the construction of a direct conversion energy discriminating detector, semiconductors have been shown to be one preferred material. A drawback of direct conversion semiconductor detectors,

however, is that these types of detectors cannot count at the very high x-ray photon flux rates typically encountered with conventional CT systems. The very high x-ray photon flux rate ultimately leads to detector saturation. That is, these detectors typically saturate at relatively low x-ray flux levels. This saturation can occur at detector locations wherein small subject thickness is interposed between the detector and the radiographic energy source or x-ray tube. It has been shown that these saturated regions correspond to paths of low subject thickness near or outside the width of the subject projected onto the detector fan-arc. In many instances, the subject is more or less circular or elliptical in the effect on attenuation of the x-ray flux and subsequent incident intensity to the detector. In this case, the saturated regions represent two disjointed regions at extremes of the fan-arc. In other less typical, but not rare instances, saturation occurs at other locations and in more than two disjointed regions of the detector. In the case of an elliptical subject, the saturation at the edges of the fan-arc is reduced by the imposition of a bowtie filter between the subject and the x-ray source. Typically, the filter is constructed to match the shape of the subject in such a way as to equalize total attenuation, filter and subject, across the fan-arc. The flux incident to the detector is then relatively uniform across the fan-arc and does not result in saturation. What can be problematic, however, is that the bowtie filter may not be optimum given that a subject population is significantly less than uniform and not exactly elliptical in shape. In such cases, it is possible for one or more disjointed regions of saturation to occur or conversely to over-filter the x-ray flux and create regions of very low flux. Low x-ray flux in the projection will ultimately contribute to noise in the reconstructed image of the subject.

A number of imaging techniques have been developed to address saturation of any part of the detector. These techniques include maintenance of low x-ray flux across the width of a detector array, for example, by using low tube current or current that is modulated per view. However, this solution leads to increased scanned time. That is, there is a penalty that the acquisition time for the image is increased in proportion to the nominal flux needed to acquire a certain number of x-rays that meet image quality requirements. Other solutions include the implementation of an over-range algorithm that is used to generate replacement data for the saturated data. However, these algorithms may imperfectly replace the saturated data as well as contribute to the complexity of the CT system.

It would therefore be desirable to design a direct conversion, energy discriminating CT detector that does not saturate at the x-ray photon flux rates typically found in conventional CT systems.

**BRIEF DESCRIPTION OF THE INVENTION**

The present invention is directed to a multilayer CT detector that can be made to perform at very high count rates that overcomes the aforementioned drawbacks.

A CT detector capable of energy discrimination and direct conversion is disclosed. The detector includes multiple layers of semiconductor material of varying thicknesses throughout the detector. In this regard, the detector is constructed so as to be segmented in the x-ray penetration direction to optimize count rate performance as well as avoid saturation.

The CT detector supports not only x-ray photon counting, but energy measurement or tagging as well. As a result, the present invention supports the acquisition of both anatomical



cal detail as well as tissue characterization information. In this regard, the energy discriminatory information or data may be used to reduce the effects of beam hardening and the like. Further, these detectors support the acquisition of tissue discriminatory data and therefore provide diagnostic information that is indicative of disease or other pathologies. For example, detection of calcium in a plaque in a view is possible. This detector can also be used to detect, measure, and characterize materials that may be injected into a subject such as contrast agents and other specialized materials such as targeting agents. Contrast materials can, for example, include iodine that is injected into the blood stream for better visualization. A method of fabricating such a detector is also disclosed.

Therefore, in accordance with one aspect of the present invention, a method of manufacturing a direct conversion detector for radiographic imaging is provided. The method includes the steps of providing multiple layers of semiconductor material designed to directly convert x-rays to electrical signals and affixing an electrically conductive film layer to at least an x-ray penetration surface of each layer of semiconductor material. The method further includes arranging the multiple layers of semiconductor material in a stack such that each layer is in contact with at least two electrically conductive film layers.

In accordance with another aspect of the present invention, a direct conversion detector for radiographic imaging having multiple layers of semiconductor material and interstitial electrically conductive layers is formed by depositing a metallized layer on at least an x-ray penetration surface of each of a plurality of semiconductor layers. The detector is further formed by stacking the plurality of semiconductor layers in an x-ray penetration direction such that each semiconductor layer is sandwiched between a pair of metallized layers.

According to yet another aspect of the present invention, a CT detector fabrication process is provided and includes a metallization stage whereupon a metallized layer is affixed to each of a plurality of CZT substrates. Each CZT substrate is designed to convert x-rays directly to electrical signals. The fabrication process further includes an arrangement stage whereupon the plurality of CZT substrates is arranged to form a CZT detector stack with each CZT substrate sandwiched between a pair of metallized layers. A composite stage is also provided whereupon the plurality of CZT substrates is connected to one another to form a singular composite structure.

Various other features, objects and advantages of the present invention will be made apparent from the following detailed description and the drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The drawings illustrate one preferred embodiment presently contemplated for carrying out the invention.

In the drawings:

FIG. 1 is a pictorial view of a CT imaging system.

FIG. 2 is a block schematic diagram of the system illustrated in FIG. 1.

FIG. 3 is a perspective view of one embodiment of a CT system detector assembly.

FIG. 4 is a perspective view of a CT detector.

FIG. 5 is illustrative of various configurations of the detector in FIG. 4 in a four-slice mode.

FIG. 6 is a partial perspective view of a two-layer director in accordance with the present invention.

FIG. 7 is a cross-sectional view of FIG. 6 taken along lines 7—7 thereof.

FIGS. 8—10 illustrate cross-sectional views of direct conversion detectors in accordance with several additional embodiments of the present invention.

FIG. 11 is a cross-sectional schematic view of that shown in FIG. 10 illustrating signal feedthroughs that are created in another embodiment of the invention.

FIG. 12 is a pictorial view of a CT system for use with a non-invasive package inspection system.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The operating environment of the present invention is described with respect to a four-slice computed tomography (CT) system. However, it will be appreciated by those skilled in the art that the present invention is equally applicable for use with single-slice or other multi-slice configurations. Moreover, the present invention will be described with respect to the detection and conversion of x-rays. However, one skilled in the art will further appreciate that the present invention is equally applicable for the detection and conversion of other radiographic energy.

Referring to FIGS. 1 and 2, a computed tomography (CT) imaging system 10 is shown as including a gantry 12 representative of a "third generation" CT scanner. Gantry 12 has an x-ray source 14 that projects a beam of x-rays 16 toward a detector assembly 18 on the opposite side of the gantry 12. Detector assembly 18 is formed by a plurality of detectors 20 which together sense the projected x-rays that pass through a medical patient 22. Each detector 20 produces an electrical signal that represents not only the intensity of an impinging x-ray beam but is also capable of providing photon or x-ray count data, and hence the attenuated beam as it passes through the patient 22. During a scan to acquire x-ray projection data, gantry 12 and the components mounted thereon rotate about a center of rotation 24.

Rotation of gantry 12 and the operation of x-ray source 14 are governed by a control mechanism 26 of CT system 10. Control mechanism 26 includes an x-ray controller 28 that provides power and timing signals to an x-ray source 14 and a gantry motor controller 30 that controls the rotational speed and position of gantry 12. A data acquisition system (DAS) 32 in control mechanism 26 reviews data from detectors 20 and converts the data to digital signals for subsequent processing. An image reconstructor 34 receives sampled and digitized x-ray data from DAS 32 and performs high speed reconstruction. The reconstructed image is applied as an input to a computer 36 which stores the image in a mass storage device 38.

Computer 36 also receives commands and scanning parameters from an operator via console 40 that has a keyboard. An associated cathode ray tube display 42 allows the operator to observe the reconstructed image and other data from computer 36. The operator supplied commands and parameters are used by computer 36 to provide control signals and information to DAS 32, x-ray controller 28 and gantry motor controller 30. In addition, computer 36 operates a table motor controller 44 which controls a motorized table 46 to position patient 22 and gantry 12. Particularly, table 46 moves portions of patient 22 through a gantry opening 48.

As shown in FIGS. 3 and 4, detector assembly 18 includes a plurality of detectors 20, with each detector including a number of detector elements 50 arranged in a cellular array. A collimator (not shown) is positioned to collimate x-rays 16

before such beams impinge upon the detector assembly **18**. In one embodiment, shown in FIG. **3**, detector assembly **18** includes **57** detectors **20**, each detector **20** having an array size of  $16 \times 16$ . As a result, assembly **18** has 16 rows and 912 columns ( $16 \times 57$  detectors) which allows 16 simultaneous

Switch arrays **54** and **56**, FIG. **4**, are multi-dimensional semiconductor arrays coupled between cellular array **52** and DAS **32**. Switch arrays **54** and **56** include a plurality of field effect transistors (FET) (not shown) arranged as multi-dimensional array and are designed to combine the outputs of multiple cells to minimize the number of data acquisition channels and associated cost. The FET array includes a number of electrical leads connected to each of the respective detector elements **50** and a number of output leads electrically connected to DAS **32** via a flexible electrical interface **58**. Particularly, about one-half of detector element outputs are electrically connected to switch **54** with the other one-half of detector element outputs electrically connected to switch **56**. Each detector **20** is secured to a detector frame **60**, FIG. **3**, by mounting brackets **62**.

It is contemplated and recognized that for some applications, the count rate limitation of the FET arrays may make them less desirable. In this regard, as will be described, each detection pixel or cell is connected to a channel of electronics.

Switch arrays **80** and **82** further include a decoder (not shown) that enables, disables, or combines detector element outputs in accordance with a desired number of slices and slice resolutions for each slice. Decoder, in one embodiment, is a decoder chip or a FET controller as known in the art. Decoder includes a plurality of output and control lines coupled to switch arrays **54** and **56** and DAS **32**. In one embodiment defined as a 16 slice mode, decoder enables switch arrays **54** and **56** so that all rows of the detector assembly **18** are activated, resulting in 16 simultaneous slices of data for processing by DAS **32**. Of course, many other slice combinations are possible. For example, decoder may also select from other slice modes, including one, two, and four-slice modes.

As shown in FIG. **5**, by transmitting the appropriate decoder instructions, switch arrays **54** and **56** can be configured in the four-slice mode so that the data is collected from four slices of one or more rows of detector assembly **18**. Depending upon the specific configuration of switch arrays **54** and **56**, various combinations of detectors **20** can be enabled, disabled, or combined so that the slice thickness may consist of one, two, three, or four rows of detector elements **50**. Additional examples include, a single slice mode including one slice with slices ranging from 1.25 mm thick to 20 mm thick, and a two slice mode including two slices with slices ranging from 1.25 mm thick to 10 mm thick. Additional modes beyond those described are contemplated.

As described above, each detector **20** is designed to directly convert radiographic energy to electrical signals containing energy discriminatory data. The present invention contemplates a number of configurations for these detectors. Notwithstanding the distinctions between each of these embodiments, each detector does share two common features. One of these features is the multilayer arrangement of semiconductor films or layers. In a preferred embodiment, each semiconductor film is fabricated from Cadmium Zinc Telluride (CZT). However, one skilled in the art will readily recognize that other materials capable of the direct conversion of radiographic energy may be used. The other common feature between the various embodiments is the use of

interstitial or intervening metallized films or layers separating the semiconducting layers. As will be described, these metallized layers are used to apply a voltage across a semiconductor layer as well as collect electrical signals from a semiconductor layer.

It is generally well known that photon count rate performance of a semiconductor is a function of the square of the thickness of the detector and the radiographic energy deposition process is exponential. The count rate performance for a CZT detector may be defined by:

$$T_{TR} = \frac{L^2}{V\mu_e}$$

From this definition, assuming a thickness of  $L=0.3$  cm and an electric field  $V$  of 1000 V/cm, and with a  $\mu_e$  of about 1000, a maximum count rate of 1.0 megacounts may be achieved. In other words, the count rate of a CZT semiconductor layer that is 3 mm thick may have a count rate performance in the range of 1.0 megacounts/sec. However, as will be described, constructing a direct conversion semiconductor detector with multiple layers as opposed to a single thicker layer can improve count rate performance.

Referring now to FIG. **6**, a portion of a two-layered CZT or direct conversion detector **20a** in accordance with one embodiment of the present invention is shown in perspective. Detector **20a** is defined by a first semiconductor layer **62** and a second semiconductor layer **64**. During the fabrication process, each semiconductor layer **62**, **64** is constructed to have a number of electronically pixilated structures or pixels to define a number of detection elements **65**. This electronic pixilation is accomplished by applying a 2D array **67**, **69** of electrical contacts **65** onto a layer **62**, **64** of direct conversion material. Moreover, in a preferred embodiment, this pixilation is defined two-dimensionally across the width and length of each semiconductor layer **62**, **64**.

Detector **20a** includes a contiguous high voltage electrode **66**, **68** for semiconductor layers **62**, **64**, respectively. Each high voltage electrode **66**, **68** is connected to a power supply (not shown) and is designed to power a respective semiconductor layer during the x-ray or gamma ray detection process. One skilled in the art will appreciate that each high voltage connection layer should be relatively thin so as to reduce the x-ray absorption characteristics of each layer and, in a preferred embodiment, is a few hundred angstroms thick. As will be described in greater detail below, these high voltage electrodes may be affixed to a semiconductor layer through a metallization process.

Referring now to FIG. **7**, a cross-sectional view of FIG. **6** taken along line **7—7** thereof illustrates the relative thickness of each semiconductor layer **62**, **64**. Similar to the high voltage electrode layers **66**, **68**, the 2D arrays **67**, **69** should also be minimally absorbent of radiographic energy. Each array or signal collection layer is designed to provide a mechanism for outputting the electrical signals created by the semiconductor layers to a data acquisition system or other system electronics. One skilled in the art will appreciate that several hundred interconnects (not shown) are used to connect each contact **65** with the CT system electronics.

In addition, as shown in FIG. **7**, the thickness of the semiconductor layers **62**, **64** is different from one another. In this regard, more x-rays are deposited in semiconductor layer **62** than in semiconductor layer **64**. For example, assuming that semiconductor layer **62** has a thickness of one

millimeter (mm) and semiconductor **64** has a thickness of 2 mm, semiconductor layer **62** is expected to absorb about 78% of the x-rays whereas the second semiconductor layer **64** is expected to absorb about 22% of the x-rays. Further, it is expected that the first semiconductor layer **62** is to experience a maximum count rate that is approximately nine times faster than that of a single layer semiconductor 3 mm thick. However, the first semiconductor layer **62** measures only approximately 78% of the total flux thereby providing an 11.5 times increase in effective max count rate performance compared to a single semiconductor layer 3 mm thick. The second semiconductor layer **64** is expected to have a count rate that is 2.25 times faster than that of a single 3 mm thick semiconductor but measures only approximately 22% of the total flux, thereby, providing an equivalent or effective max count rate that is approximately 10.2 times that expected to be experienced with a single layer of semiconductor material 3 mm thick. As a result of the improved count rates of the segmented detector described above relative to a single layer of semiconductor material, detector **20a** may be constructed to provide a tenfold increase in count rate performance.

The above dimensions are illustrative of the improvement in maximum count rate that may be experienced with a two layer detector. However, it is contemplated that more than two layers may be used to construct a CT detector with improved count rate characteristics. For example, a single 0.43 mm layer is expected to absorb about 54% of x-rays received and, as such, has a maximum count rate of approximately 40 times that of a single layer, 3.0 mm thick semiconductor. However, a 0.43 mm layer absorbs only approximately 54% of the total flux to provide an equivalent or effective max count rate of approximately 92 times that of a single semiconductor layer that is 3 mm thick. Additional layers may be added to provide an overall count rate increase of 9200%.

Referring now to FIG. 8, another contemplated design for a CZT or direct conversion detector is shown. In this embodiment, detector **20b** also includes a pair of semiconductor layers **74, 76**. In contrast to the previously described embodiment, detector **20b** includes a single, common signal collection layer or 2D contact array **78**. This single, yet common array **78** is designed to collect electrical signals from both semiconductor layers **74, 76** and output those electrical signals to a DAS or other system electronics. In addition, detector **20b** includes a pair of high voltage electrodes **80, 82**. Each high voltage electrode effectively operates as a cathode whereas the contacts of the 2D array **78** operate as an anode. In this regard, the voltage applied via high voltage connections **80, 82** creates a circuit through each semiconductor layer to the signal collection contacts array **78**.

Yet another contemplated embodiment is illustrated in FIG. 9. As shown in this embodiment, detector **20c** includes four semiconductor layers **84, 86, 88, and 90**. Detector **20c** further includes two electrically conductive lines or paths **92, 94** that are electrically connected to high voltage electrodes **87, 89, 91** as well as collection contact arrays **93, 95**. Electrically conductive path **92** receives and translates electrical signals from contact arrays **93, 95**. In this regard, a single data output is provided to the CT system's electronics. Similar to a single signal collection lead, a single high voltage connection **94** is used to power the four semiconductor layers **84-90** via electrodes **87, 89, 91**. Detector **20c** only requires a single high voltage connection.

Referring to FIG. 10, a monolithic embodiment of the present invention is shown. Similar to the embodiment of

FIG. 7, detector **20d** includes four semiconductor layers **96-102**. Each semiconductor layer **96-102** is connected to a pair of electrically conductive layers. In this regard, one electrically conductive layer is used for application of a voltage whereas the other electrically conductive layer is used for collection of the electrical signals generated by the respective semiconductor layers. To minimize the number of electrically conductive layers, detector **20d** utilizes an alternating electrically conductive layer architecture. That is, every other electrically conductive layer is used for high voltage connection with the other electrically conductive layers used for signal collection. In this regard, electrically conductive layers **104, 106, and 108** are used for application of a relatively high voltage whereas layers **110 and 112** include contacts for signal collection. As such, high voltage collection layers **104 and 108** are used to apply a voltage to semiconductor layers **96 and 102**, respectively. High voltage connection layer **106** is used to apply a voltage to semiconductor layers **98 and 100**.

As described above, in a preferred embodiment, each semiconductor layer is constructed from CZT material. One skilled in the art will appreciate that there are a number of techniques that may be used to construct such a semiconductor. For example, molecular beam epitaxy (MBE) is one method that may be used to grow each thin layer of CZT material. One skilled in the art will appreciate that a number of techniques may be used to metallize the semiconductor layers to provide the electrically conductive connections heretofore described.

Further, metallization may also be used to provide signal feedthroughs for the collection contacts as illustrated in FIG. 11. As shown, a single layer of semiconductor material **114** is sandwiched between an array **116** of collection contacts and a high voltage electrode layer **118**. Prior to metallization of the semiconductor layer **114** to form collection contact array **116** and high voltage electrode layer **118**, holes **120** may be etched or otherwise formed in semiconductor **114**. The holes **120** may then be metallized to provide a signal feed path **122** from a respective collection contact **124**. The signal feed-throughs or conductive paths **122** are constructed within holes **120** so as to not be in contact with the near-contiguous high voltage electrode layer **118**. In this regard, signal runs may extend vertically or in the x-ray reception direction throughout the detector to a bus (not shown) designed to translate the electrical signals emitted by the individual collection contacts **124** to the CT system's electronics. As a result, a stacked arrangement of a series of thin stacked layers in the x-ray direction is formed.

Referring now to FIG. 12, package/baggage inspection system **126** includes a rotatable gantry **128** having an opening **130** therein through which packages or pieces of baggage may pass. The rotatable gantry **128** houses a high frequency electromagnetic energy source **132** as well as a detector assembly **134**. A conveyor system **136** is also provided and includes a conveyor belt **138** supported by structure **140** to automatically and continuously pass packages or baggage pieces **142** through opening **130** to be scanned. Objects **142** are fed through opening **130** by conveyor belt **138**, imaging data is then acquired, and the conveyor belt **138** removes the packages **142** from opening **130** in a controlled and continuous manner. As a result, postal inspectors, baggage handlers, and other security personnel may non-invasively inspect the contents of packages **142** for explosives, knives, guns, contraband, etc.

Therefore, in accordance with one embodiment of the present invention, a method of manufacturing a direct conversion detector for radiographic imaging is provided. The

method includes the steps of providing multiple layers of semiconductor material designed to directly convert x-rays to electrical signals and affixing an electrically conductive film layer to at least an x-ray penetration surface of each layer of semiconductor material. The method further includes arranging the multiple layers of semiconductor material in a stack such that each layer is in contact with at least two electrically conductive film layers.

In accordance with another embodiment of the present invention, a direct conversion detector for radiographic imaging having multiple layers of semiconductor material and interstitial electrically conductive layers is formed by depositing a metallized layer on at least an x-ray penetration surface of each of a plurality of semiconductor layers. The detector is further formed by stacking the plurality of semiconductor layers in an x-ray penetration direction such that each semiconductor layer is sandwiched between a pair of metallized layers.

According to yet another embodiment of the present invention, a CT detector fabrication process is provided and includes a metallization stage whereupon a metallized layer is affixed to each of a plurality of CZT substrates. Each CZT substrate is designed to convert x-rays directly to electrical signals. The fabrication process further includes an arrangement stage whereupon the plurality of CZT substrates is arranged to form a CZT detector stack with each CZT substrate sandwiched between a pair of metallized layers. A composite stage is also provided whereupon the plurality of CZT substrates is connected to one another to form a singular composite structure.

The present invention has been described in terms of the preferred embodiment, and it is recognized that equivalents, alternatives, and modifications, aside from those expressly stated, are possible and within the scope of the appending claims.

What is claimed is:

1. A method of manufacturing a direct conversion detector for radiographic imaging, the method comprising the steps of:

providing multiple layers of semiconductor material designed to directly convert x-rays to electrical signals; affixing an electrically conductive film layer to at least an x-ray penetration surface of each layer of semiconductor material; and arranging the multiple layers of semiconductor material in a stack such that each layer is in contact with at least two electrically conductive film layers.

2. The method of claim 1 wherein the step of affixing includes the step of metallizing the at least an x-ray penetration surface of each layer of semiconductor material.

3. The method of claim 1 wherein the step of providing includes the step of growing each layer of semiconductor material from a CZT bulk.

4. The method of claim 3 wherein the step of growing includes utilizing molecular beam epitaxy to grow each CZT layer.

5. The method of claim 1 further comprising the step of affixing an electrically conductive film on an x-ray penetration surface and an opposite surface of one layer of semiconductor material.

6. The method of claim 5 wherein the step of arranging the multiple layers in a stack includes the step of joining the multiple layers to one another such that the layer having two surfaces of electrically conductive film thereon is placed farthest from an x-ray source.

7. The method of claim 1 wherein the step of arranging includes the step of positioning the multiple layers with

respect to one another such that each layer is in contact with an HV connection film layer and a signal collection film layer.

8. The method of claim 1 wherein the step of arranging includes the steps of:

forming at least one bore in each of the multiple layers along a common axis; and metallizing the at least one bore to join the multiple layers in the stack.

9. A direct conversion detector for radiographic imaging, the detector having multiple layers of semiconductor material and interstitial electrically conductive layers, and formed by:

depositing a metallized layer on at least an x-ray penetration surface of each of a plurality of semiconductor layers; and

stacking the plurality of semiconductor layers in an x-ray penetration direction such that each semiconductor layer is sandwiched between a pair of metallized layers.

10. The detector of claim 9 further formed by growing the plurality of semiconductor layers from CZT bulk.

11. The detector of claim 10 further formed by growing the plurality of semiconductor layers via molecular beam epitaxy.

12. The detector of claim 9 further formed by etching a hole through the plurality of semiconductor layers and filling the hole with a joining compound to secure the plurality of semiconductor layers to one another in a single stacked arrangement.

13. The detector of claim 9 configured to directly convert x-rays into electrical signals that may be processed into a single image that provides anatomical detail and tissue characterization.

14. The detector of claim 9 having at least three semiconductor layers.

15. The detector of claim 9 further formed by arranging the plurality of semiconductor layers in pairs having a common signal collection electrode.

16. A CT detector fabrication process comprising:

a metallization stage whereupon a metallized layer is affixed to each of a plurality of CZT substrates, each CZT substrate designed to convert x-rays directly to electrical signals;

an arrangement stage whereupon the plurality of CZT substrates is arranged to form a CZT detector stack with each CZT substrate sandwiched between a pair of metallized layers; and

a composite stage whereupon the plurality of CZT substrates is connected to one another to form a singular composite structure.

17. The CT detector fabrication process of claim 16 further comprising a CZT substrate fabrication stage whereupon each CZT substrate is grown by molecular beam epitaxy.

18. The CT detector fabrication process of claim 16 wherein the composite stage includes etching a hole through the CZT detector stack and filling the hole with a joining metal.

19. The CT detector fabrication process of claim 16 wherein the arrangement stage includes positioning the plurality of CZT substrates such that each CZT substrate is connected to an anode layer and a cathode layer.

20. The CT detector fabrication process of claim 19 wherein each anode layer is disposed to receive signals from two CZT substrates.