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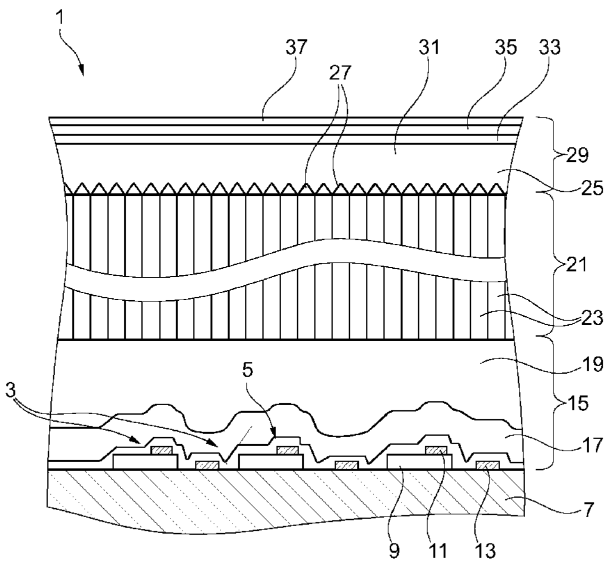

Fig. 1

(57) Abstract: An indirect radiation detector as it can be used e.g. in X-ray radiology employs a scintillator layer (21) comprising needle-grown scintillating crystals in order to convert incoming X-rays into light. The textured, uneven surface (25) of the needle-grown scintillator layer (21) is planarized by a planarizing layer (31), which is preferably made of benzocyclobutene (BCB) and which serves to planarize, equalize the rough surface (25) before depositing a moisture protection layer (37) and, possibly, further layers such as a mirror layer (35) and an adhesion layer (33) on top thereof. Due to the planarizing layer (31), the moisture protection layer (37) does not need to follow the contour of the textured surface (25) of the scintillator layer (21) and the risk for cracks within the moisture protection layer is significantly reduced.

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RADIATION DETECTOR AND METHOD FOR PREPARING SAME

FIELD OF THE INVENTION

The present invention relates to a radiation detector and a method for preparing such radiation detector. Particularly, the present invention relates to an indirect radiation detector in which a scintillator layer comprises needle-grown scintillating crystals wherein the scintillator layer is arranged on top of a sensor array and wherein the scintillator layer is protected against environmental influences by a moisture protection layer.

BACKGROUND OF THE INVENTION

In indirect radiation detectors, also referred to as indirect digital radiology detectors, a scintillator material is applied to convert for example X-rays into visible light. The visible light might then be captured by sensors such as photodiodes arranged in a sensor array of the detector. A frequently used material for the scintillator is caesium-iodide doped with thallium-iodide. Crystals of such scintillator material may be frequently grown in a needle-like structure. The scintillator material might be sensitive to moisture such that a protection must be provided for the detector and particularly for the scintillator.

It is known to protect the scintillator by a coating including for example silicon oxide or parylene. Conventionally, such coating has been applied directly on top of the scintillator layer in order to protect the scintillator layer against water or moisture. However, it has been found that in such conventional way to protect the scintillator layer, much care must be taken when applying the protection coating onto the scintillator material and that, furthermore, degradation of the scintillator layer over time is frequently observed..

SUMMARY OF THE INVENTION

Accordingly, there might be a need for a radiation detector and a method for preparing such radiation detector wherein inter alia shortcomings of the above-mentioned prior approaches are at least partially overcome. Particularly, there might be a need for a radiation detector and a method for preparing same wherein the scintillator layer is easily, effectively and reliably protected against environmental impact such as degradation by incoming moisture or water.

These needs may be met by the subject-matter according to one of the independent claims. Advantageous embodiments of the present invention are described in the dependent claims.

According to a first aspect of the present invention, a radiation detector is proposed. The radiation detector comprises a sensor array, a scintillator layer comprising a textured surface in a direction away from the sensor array and being arranged on top of the sensor array, a planarizing layer arranged on top of the textured surface of the scintillator layer, and a moisture protection layer arranged on top of a surface of the planarizing layer away from the scintillator layer.

A gist of the present invention may be seen as based on the following idea:

The inventor of the present invention has found that in conventional indirect radiation detectors comprising a scintillator layer, degradation over the time frequently occurred and that such degradation might be attributed to voids or cracks occurring in a protection layer of the scintillator layer through which voids or cracks moisture might pass and enter into the scintillator layer. Furthermore, the inventor found that the occurrence of cracks might be attributed to the fact that conventional moisture protection layers are usually deposited directly on top of the scintillator layer. The scintillator layer, however, does normally not have a flat, even surface but, due to the fact that the crystals of scintillating material are normally grown in a needle-shape such that a plurality of longitudinal needles are arranged adjacent to one another, the surface of the scintillator layer is textured, i.e. very rough and uneven, and comprises sharp edges or tips. At such edges or tips, a conventional moisture protection layer deposited on the scintillator layer and following the contours of such edges or tips might easily crack or peel off at exposed regions of the surface of the scintillator layer.

It is proposed herein that such problems could have been overcome by interposing a planarizing layer between the scintillator layer and the moisture protection layer. Herein, a “planarizing layer” might be understood as a layer which at least partially planarizes the rough, textured surface of a scintillator layer. In other words, when the scintillator layer has a rough surface comprising sharp pointed structures, the planarizing layer arranged on top of such surface of the scintillator layer does not completely follow the contour of the surface of the scintillator layer but planarizes such contour which might mean that a surface of the planarizing layer which is directed away from the scintillator layer does preferably not have sharply pointed structures but has at most smooth structures and is more preferably substantially even. On such substantially even surface of the planarizing layer, a moisture protection layer might then be arranged without having the risk of cracks occurring at any sharply pointed structures.

In the following, further possible features, details and advantages of embodiments of the present invention are mentioned.

The radiation detector might be adapted to detect any kind of electromagnetic radiation, particularly X-ray radiation. Such radiation detector might be suitably adapted for medical applications such as X-ray examination devices given the highest sensitivities and MTF-values.

The sensor array comprised in the radiation detector might comprise a plurality of radiation sensors. The radiation sensors might be arranged in a matrix arrangement. Each sensor might be sensitive to detect electromagnetic radiation having energies below the energy of the radiation to be detected by the entire radiation detector. In other words, the sensors might be adapted to detect for example visible light whereas the entire radiation detector might be adapted to detect X-rays. For example, the sensors might be photodiodes.

In order to convert the incoming high-energy radiation into low-energy radiation to be detected by the sensors in the sensor array, a scintillator layer is arranged on top of the sensor array. Such scintillator layer comprises a scintillating material which is able to convert photons of high-energy electromagnetic radiation into photons of low-energy electromagnetic radiation. A typical scintillating material is for example caesium-iodide (CsI) doped with thallium-iodide (TlI). Such scintillating material is usually grown in a needle-like structure wherein longitudinal sharp needles are arranged adjacent to each other along their longitudinal surfaces. Narrow spaces in the order of a few μm or less might be present between adjacent crystal needles. A typical thickness of a scintillator layer used on top of a sensor array is about a few hundred μm, for example

400 μm or more. The width of the needles typically is about 7 μm and the tip is conically shaped.

Accordingly, the roughness of the textured surface of a scintillator layer comprising needle-grown crystals might be in the range of a few μm wherein the surface roughness corresponds approximately to the length of the conical tips of the crystal needles.The distance from the top of a tip of a needle-grown crystal to the deepest "valley", i.e. through the space between adjacent needles down to a substrate or neighbouring layer, might be in the range of the height of the needles, for example 400 μm or more.

The planarizing layer, which might have properties as described further above, is arranged on top of the textured surface of the scintillator layer, i.e. a surface of the scintillator layer away from the sensor array. In other words, when the sensor array is arranged on one side of the scintillator layer, the planarizing layer is arranged on the opposing other side of the scintillator layer. The planarizing layer might but does not necessarily need to cover the entire surface of the scintillator layer. The planarizing layer might have a maximum thickness which is in the same order of magnitude or larger than the magnitude of the surface roughness of the scintillator layer e.g. at the tips of the crystal needles. For example, the maximum thickness of the planarizing layer might be between 1 and 20 μm, preferably between 3 and 10 μm. Expressed in relative values, the maximum thickness of the planarizing layer might be between 10 and 300 %, preferably between 50 and 200 % of the thickness of the conically shaped tips of the scintillator layer.

The moisture protection layer is arranged on top of a surface of the planarizing layer away from the scintillator layer. In other words, when the scintillator layer is arranged on one side of the planarizing layer, the moisture protection layer is arranged on the other opposite side thereof. The moisture protection layer might be a layer which seals or protects the underlying scintillator layer against water or moisture. Preferably, the moisture protection layer should have a thickness, structure and density such as to be leak-proof and water-impermeable. For example, the thickness of the moisture protection layer might be between about 10 nm and 1 μm. Materials, which might be used are for example silicon oxides (SiO, SiO_2) or silicon nitrides (Si_xN_y) or combinations or stacks thereof. Also reflecting materials such as Al, Cr or Ag which can form a mirror layer can act as moisture-protection layer,

It is to be noted that, herein, the expression "a first layer being arranged on top of a surface of a second layer" might be interpreted in a way such that the first layer is arranged over, i.e. above, the second layer. This might but does not necessarily involve that the first and second layers are in direct contact.

According to an embodiment of the present invention, the textured surface (25) of the scintillator layer is formed by needle-like crystals forming the scintillator layer (21). Such needle-like structure is typical for certain scintillating materials such as CsI doped with TlI.

According to a further embodiment of the present invention, the planarizing layer comprises a material which can be obtained by solidifying a liquid material. As described further below with respect to the inventive method for preparing a radiation detector, such material might be applied onto the textured surface of the scintillator layer and, due to its liquid nature, might equalize/planarize the surface of the scintillator layer. Subsequently, the liquid material may be solidified for example by curing of a resin or by polymerisation of an organic polymeric material thereby forming the solid planarizing layer.

According to a further embodiment of the present invention, the planarizing layer comprises benzocyclobutene, also referred to as BCB. This material has been found as being suitable for forming the planarizing layer because it does not affect the scintillating properties of the CsI doped with TlI. Such material might be obtained under the name Cyclotene CRC 3022-35 from Dow Chemicals. Alternatively, other organic materials such as PBO (PolyBisbenzOxazole) or acrylic or epoxy or silicone resins might also be used for the planarizing layers. Such materials might be originally provided in a liquid form having a more or less high viscosity and can be applied to the rough surface of the scintillator layer for example by spin coating or slit coating. Subsequently, the material can be cured to form the planarizing layer.

According to a further embodiment of the present invention, the radiation detector further comprises a mirror layer arranged on top of a surface of the planarizing layer away from the scintillator layer.

Herein, a mirror layer may be defined as reflecting the electromagnetic radiation to which the sensors of the sensor array are sensitive. For example, the mirror layer can be reflective for low-energy radiation such as visible light but be transmissive for high-energy radiation such as X-rays. Accordingly, X-rays can be transmitted through the mirror layer and into the underlying scintillator layer where the X-rays are converted into visible light which is then emitted isotropically and reflected back by the mirror layer onto the sensor array. Thereby, the efficiency of the radiation detector can be significantly increased. The mirror layer can be made from a metallic material such as for example aluminium (Al) or chromium (Cr) and might have a typical thickness value of between 10 nm and 1 micron. As, according to this embodiment, the mirror layer is arranged on top of the planarizing layer, the mirror layer itself is substantially planar. This might advantageously improve its reflection properties. The mirror layer might at the same time serve as moisture protection layer.

According to an alternative embodiment of the present invention, the mirror layer is arranged between the scintillator layer and the planarizing layer. In other words, the mirror layer might be arranged directly on top of the scintillator layer. This might be possible as the mirror layer is not as sensitive to cracks as for example the moisture protection layer. Such layer arrangement might simplify the process of production of the radiation detector.

According to a further embodiment of the present invention, the radiation detector further comprises an adhesion layer disposed between the planarizing layer and the mirror layer. Such adhesion layer might promote the adhesion between the planarizing layer and the mirror layer or, alternatively, the adhesion between the planarizing layer and the moisture protection layer. The adhesion layer might be made for example from silicon oxide or silicon nitride.

According to a second aspect of the present invention, a method for preparing a radiation detector, particularly a radiation detector as described above with respect to the first aspect of the invention, is proposed. The method comprises: providing a scintillator layer on top of a sensor array, the scintillator layer comprising a textured surface in a direction away from the sensor array, forming a planarizing layer on top of the textured surface of the scintillator layer; and forming a moisture protection layer on top of a surface of the planarizing layer away from the scintillator layer.

The scintillator layer may be prepared by crystal-growing of a scintillating material such as caesium-iodide doped with thallium-iodide into a needle-like structure.

According to an embodiment of the present invention, the planarizing layer is formed with a liquid material. The method then further comprises subsequently solidifying the liquid material. For example, the planarizing layer might be formed using BCB which is subsequently, after applying same to the textured surface of the scintillator layer, cured in order to form the solid planarizing layer. The curing process might be performed by a heat treatment at elevated temperature e.g. 180 – 250°C for between 1 and 10 hours, typically 4 hours.

According to a further embodiment of the present invention, the planarizing layer is formed by a spin coating technique or a slit coating technique. The spin coating technique might comprise dropping a viscous, liquid material onto the rotating surface of the scintillator layer whereby the liquid material is homogeneously distributed over the textured surface of the scintillator layer by the occurring centrifugal forces. Accordingly, a thin film of liquid material is deposited onto the scintillator layer wherein this thin film might subsequently be cured. Alternatively, in the slit coating technique, a viscous, liquid material is pressed through a slit wherein the slit is moved over the surface of the scintillator material thereby depositing a thin film onto the surface of the scintillator material. The thin film can then subsequently be cured. As in such techniques, the material forming the planarizing layer is applied to the surface of the scintillator layer in a liquid form, the roughness of the surface of the scintillator layer can be easily equalized/planarized before subsequently curing the material for forming the solid planarizing layer.

The moisture protection layer might be formed on top of the surface of the planarizing layer e.g. by way of physical or chemical vapour deposition (PVD, CVC). For example, a silicon oxide-layer or a silicon nitride-layer might be formed by plasma enhanced chemical vapour deposition (PECVD) or low pressure CVD (LPCVD).

It has to be noted that aspects and embodiments of the invention have been described with reference to different subject-matters. In particular, some embodiments have been described with reference to the detector, i.e. the apparatus type claims, whereas other embodiments have been described with reference to the method for preparing such detector, i.e. the method type claims. However, a person skilled in the art will gather from the above and the following description that, unless other notified, in addition to any combination of features belonging to one type of subject-matter also any combination between features relating to different subject-matters, in particular between features of the apparatus type claims and features of the method type claims, is considered to be disclosed with this application.

BRIEF DESCRIPTION OF THE DRAWINGS

The aspects and embodiments defined above and further details of the present invention may be apparent from an exemplary embodiment to be described hereinafter with reference to the figure but to which the invention is not limited.

Fig. 1 shows a radiation detector according to an embodiment of the present invention.

The illustration in the drawing is only schematically and not to scale.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

In Fig. 1, an exemplary embodiment of a radiation detector 1 according to the present invention is depicted. A sensor array 3 comprising a plurality of sensors 5 arranged in a matrix structure is provided on an insulating substrate 7. Each sensor 5 comprises a photosensitive element 9 such as a photodiode which is electrically contacted by a column conductor 11 and a row conductor 13.

On top of the sensor array 3, a barrier layer 15 encompassing an inorganic water-blocking layer 17 and an organic layer 19 is provided.

On top of the sensor array 3 and the barrier layer 15, a scintillator layer 21 is arranged. The scintillator layer 21 comprises elongated crystal needles 23 arranged longitudinally adjacent to each other. At a surface away from the sensor array 3, the scintillator layer 21 comprises a textured, uneven, rough surface 25 due to the sharp tips 27 of the crystal needles 23. The scintillator layer 21 is made from caesium-iodide (CsI) doped with thallium iodide (TlI).

On top of the textured surface 25 of the scintillator layer 21, a protection layer 29 is arranged. The protection layer 29 comprises a planarizing layer 31 made from benzocyclobutene (BCB) which effectively planarizes the textured surface 25 of the scintillator layer 21. On top of the planarizing layer 31, a thin adhesion layer 33 made from silicon oxide and then a mirror layer 35 made from aluminium are deposited. Finally, a further silicon oxide layer acting as a moisture protection layer 37 is arranged on top of the planarizing layer 31 and the intermediate adhesion layer 33 and mirror layer 35.

According to alternative embodiments (not shown) the existence and sequence of the different layers might be varied. For example, in the simplest mode, there are no adhesion layers 33 and no separate mirror layers 35 and the moisture protection layer 37 is directly arranged onto the planarizing layer 31. Therein, the moisture protection layer 37 might be formed with a reflecting material such as a metal such that it also acts as mirror layer 35. Alternatively, an aluminium mirror layer 35 is deposited directly onto the planarizing layer 31 and then the moisture protection layer 37 is deposited on top of the mirror layer 35 without any adhesion layers 33 in between. In a further alternative, the mirror layer 35 is deposited directly adjacent to the scintillator layer 21, optionally including an additional adhesion layer 33 between the scintillator layer 21 and the mirror layer 35, and then the planarizing layer 31 is arranged on top of the mirror layer 35, again optionally with an adhesion layer 33 in between before the moisture protection layer 37 follows on top of the planarizing layer 31.

In order to get an overview of possible sequences of the scintillator layer 21, the planarizing layer 31, the adhesion layers 33, the mirror layer 35 and the moisture protection layer 37, the possible sequences are once more indicated with reference to the respective reference signs:

21 → 31 → 37 (or 35)

21 → 31 → 35 → 37 (or 35)

21 → 31 → 33 → 35 → 37

21 → 35 → 31 → 37

21 → 35 → 33 → 31 → 37

21 → 33 → 35 → 33 → 31 → 37

Finally, important aspect of the present invention might be summarized as follows:

An indirect radiation detector as it can be used e.g. in X-ray radiology employs a scintillator layer 21 comprising needle-grown scintillating crystals in order to convert incoming X-rays into light. The textured, uneven surface 25 of the needle-grown scintillator layer 21 is planarized by a planarizing layer 31, which is preferably made of benzocyclobutene (BCB) and which serves to planarize/equalize the textured surface 25 before depositing a moisture protection layer 37 and, possibly, further layers such as a mirror layer 35 and an adhesion layer 33 on top thereof. Due to the planarizing layer 31, the moisture protection layer 37 does not need to follow the contour of the textured surface 25 of the scintillator layer 21 and the risk for cracks within the moisture protection layer 37 is significantly reduced.

Finally, it should be noted that the terms "comprising", "including", etc. do not exclude other elements or steps and the term "a" or "an" does not exclude a plurality of elements. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

CLAIMS:

1. A radiation detector (1) comprising:
a sensor array (3);
a scintillator layer (21) comprising a textured surface (25) in a direction away from the sensor array, wherein the scintillator layer (21) is arranged on top of the sensor array (3);
a planarizing layer (31) arranged on top of the textured surface (25) of the scintillator layer (21);
a moisture protection layer (37) arranged on top of a surface of the planarizing layer (31) away from the scintillator layer (21).

2. The radiation detector according to claim 1, wherein
the textured surface (25) is formed by needle-like crystals (23) forming the scintillator layer (21).

3. The radiation detector according to claim 1 or 2, wherein
the planarizing layer (31) comprises a material which can be obtained by solidifying a liquid material.

4. The radiation detector according to claim 1, 2 or 3, wherein
the planarizing layer (31) comprises benzocyclobutene.

5. The radiation detector according to one of claims 1 to 4, further comprising
a mirror layer (35) arranged on top of a surface of the planarizing layer (31) away from the scintillator layer (21).

6. The radiation detector according to one of claims 1 to 4, further comprising
a mirror layer (35) arranged between the scintillator layer (21) and the planarizing layer (31).

7. The radiation detector according to claim 5 or 6, further comprising
an adhesion layer (33) disposed between the planarizing layer (31) and the mirror layer (35).

8. A method for preparing a radiation detector, the method comprising:
providing a scintillator layer (21) on top of a sensor array (3), the scintillator layer (21) comprising a textured surface (25) in a direction away from the sensor array;
forming a planarizing layer (31) on top of the textured surface (25) of the scintillator layer (21);
forming a moisture protection layer (37) on top of a surface of the planarizing layer (31) away from the scintillator layer (21).

9. The method according to claim 8, wherein
the planarizing layer (31) is formed with a liquid material and wherein the method further comprises subsequently solidifying the liquid material.

10. The method according to claim 8 or 9, wherein
the planarizing layer (31) is formed by one of a spin coating technique and a slit coating technique.

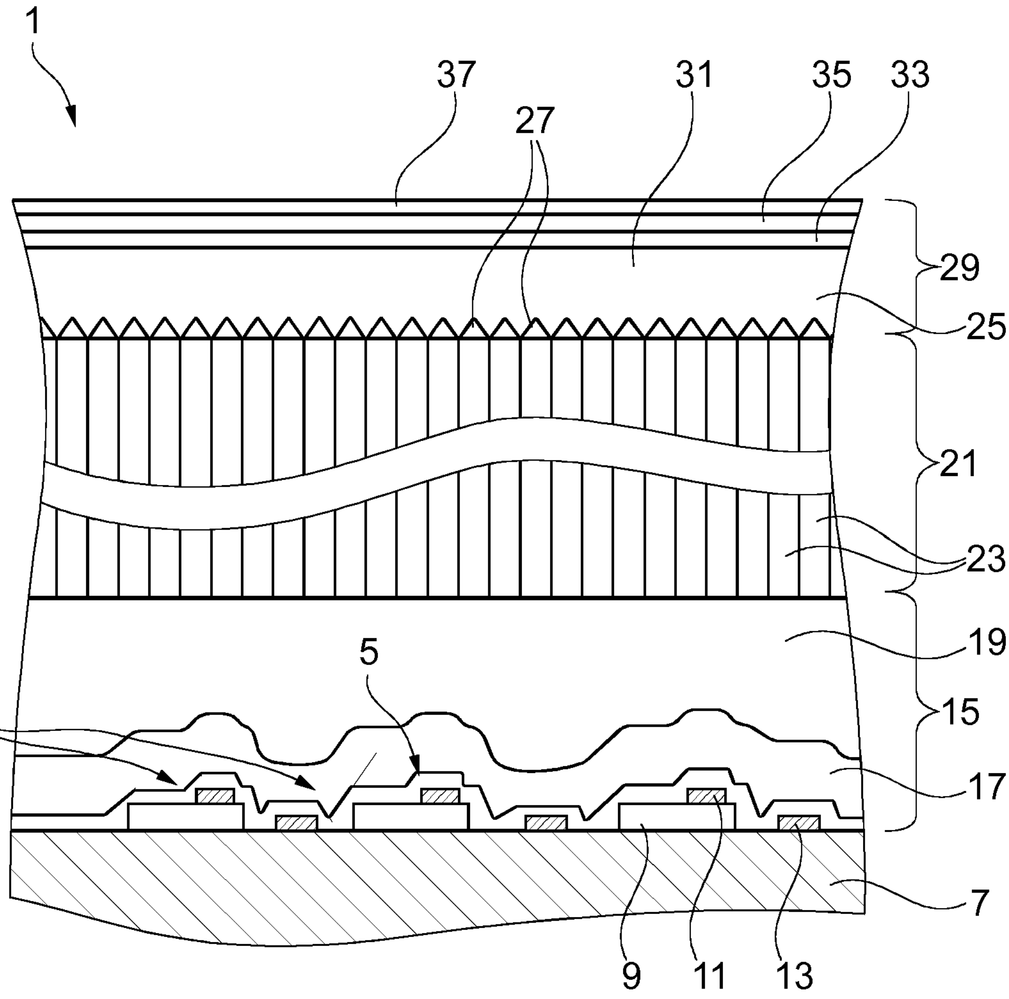

Fig. 1