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(54) **IMAGE SENSOR AND METHOD FOR MANUFACTURING THE SAME**

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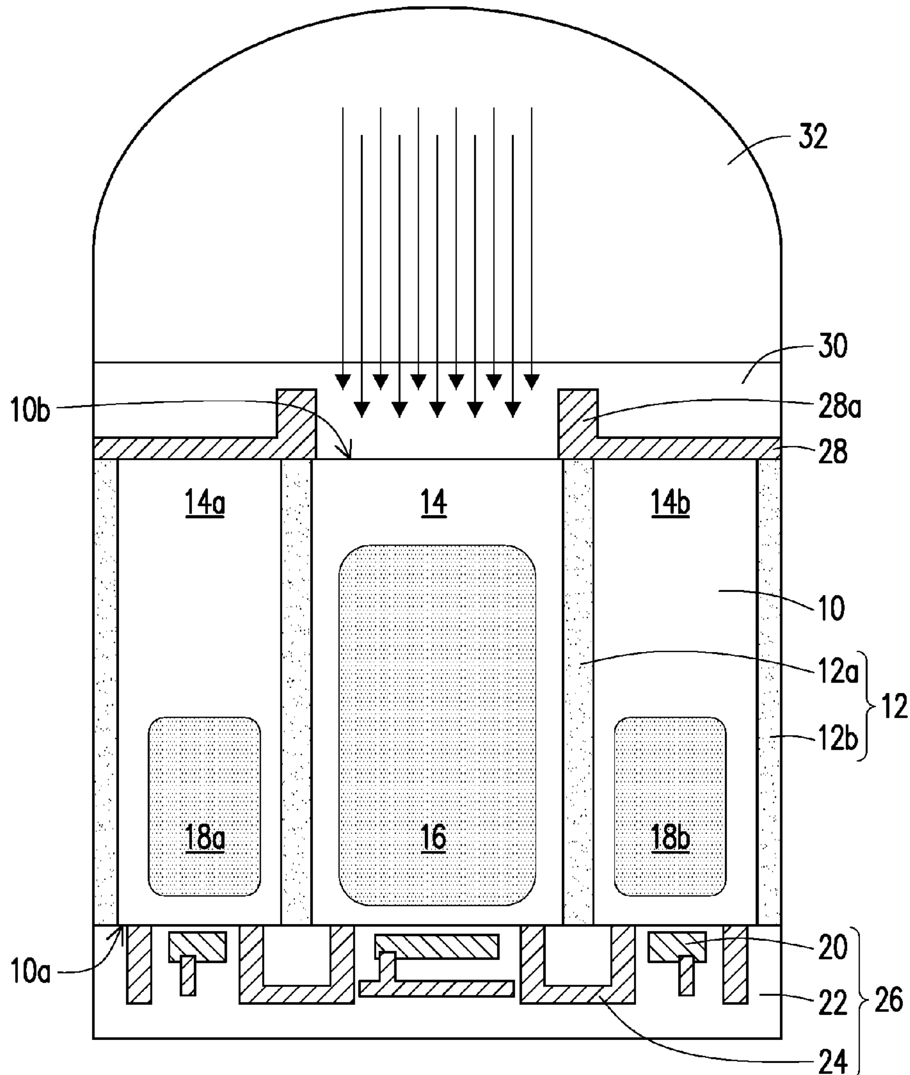
(57) **ABSTRACT**

An image sensor that includes a substrate is provided. A photodiode is formed in the substrate and in a pixel region. Storage devices are formed in the substrate and adjacent to the photodiode. Deep trench isolation walls penetrate the substrate to isolate the photodiode from the storage devices. A circuit layer is disposed on a first surface of the substrate and connected to the photodiode and the storage devices. A shielding structure is disposed on a second surface of the substrate to shield of the storage devices. A material layer is disposed above the second surface of the substrate. A lens is disposed on the material layer and configured to receive incident light and transmit the incident light to the photodiode.



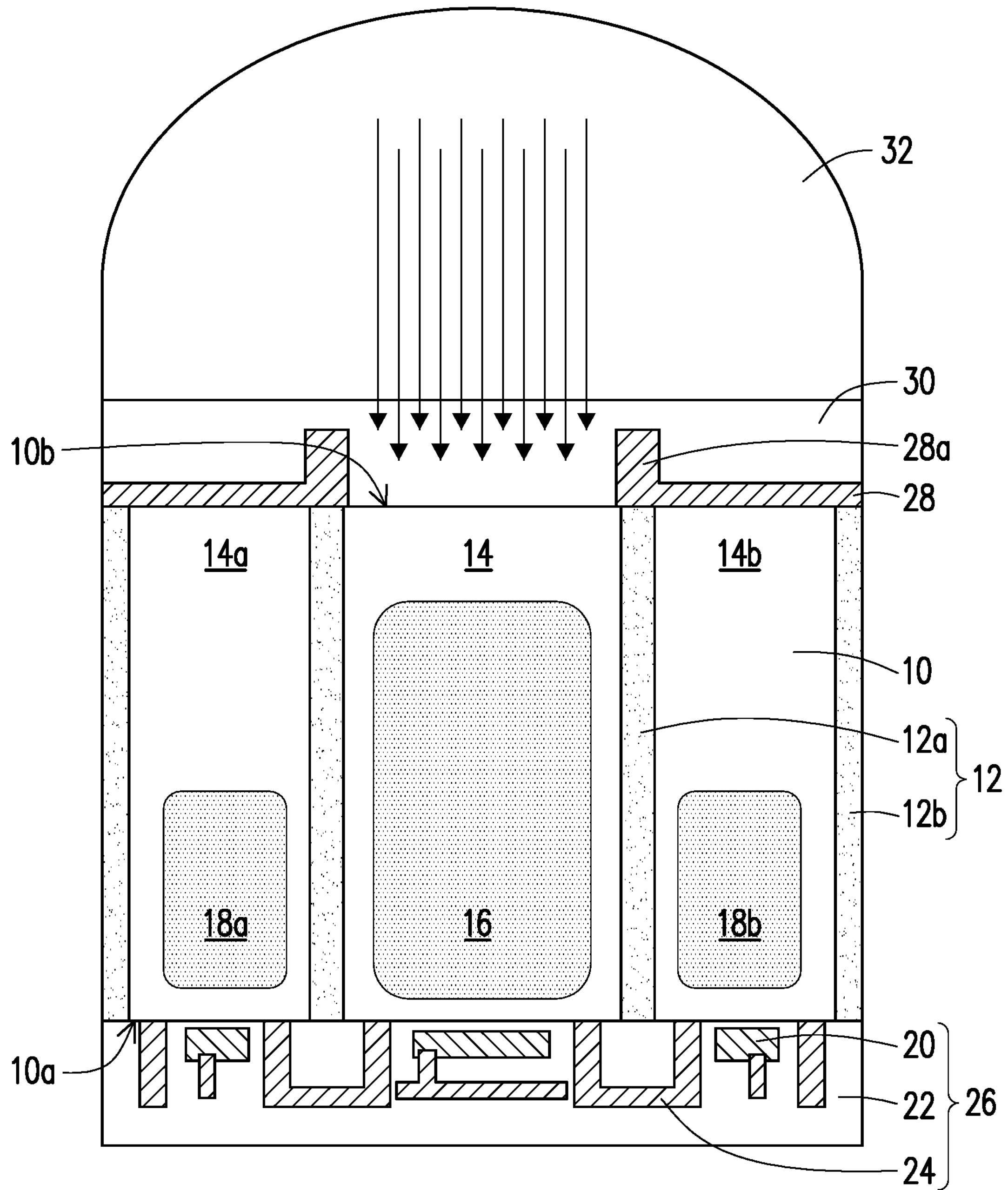


FIG. 1

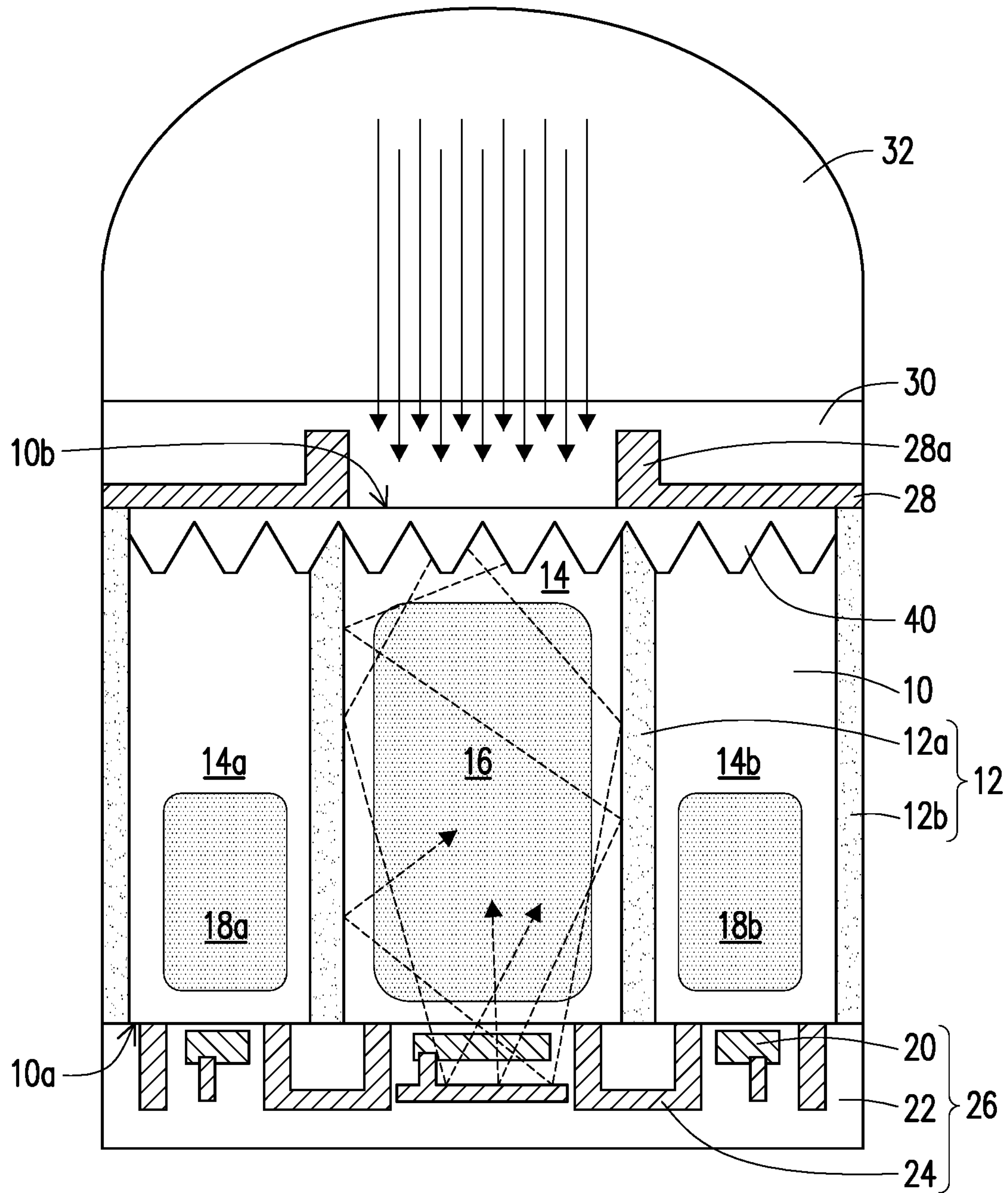


FIG. 2

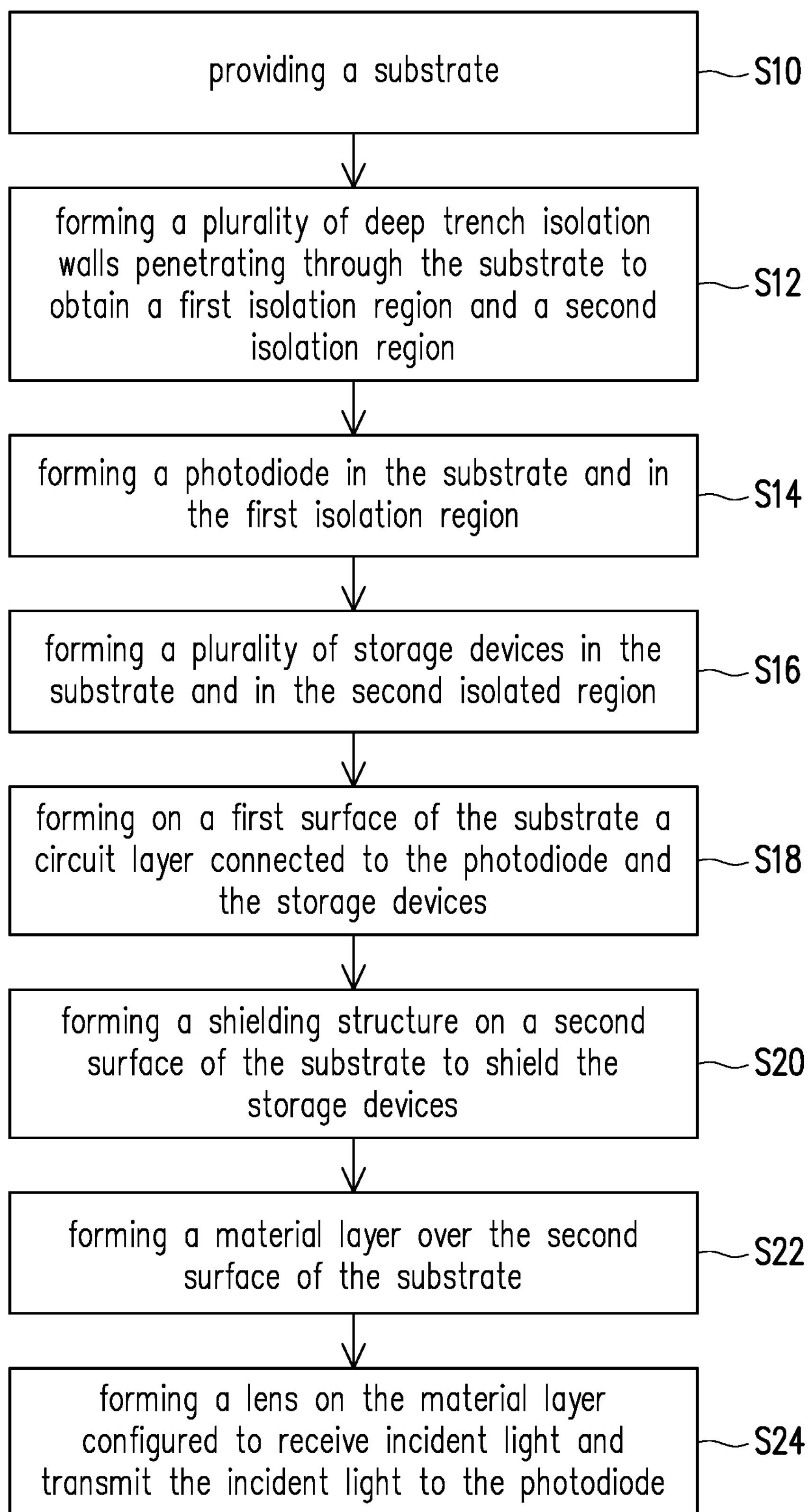


FIG. 3

IMAGE SENSOR AND METHOD FOR MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of Chinese patent application serial no. 201910870948.5, filed on Sep. 16, 2019. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND

Technical field

[0002] The disclosure relates to a semiconductor manufacturing technology, and in particular to an image sensor and a method for manufacturing the same.

Description of Related Art

[0003] An image sensor is a device that acquires images. It is compatible with modern electronic datafication products and has a wide range of applications in daily lives. For instance, digital images can be obtained while the image sensor is applied in a camera or a camcorder. The digital images are generally formed by combining a plurality of pixels in an array, and the images indicated here may be images of visible light or infrared light.

[0004] The image sensor includes a photo-sensing array composed of a plurality of photodiodes, and the photo-sensing effect depends on the photo-sensing efficiency of the photodiodes. The light source to be sensed can be visible light or infrared light.

[0005] In order to improve the quality of the sensor, the quality of the photodiode device is required to be improved, and it is also necessary to prevent the photodiodes from interfering with other adjacent devices. On the other hand, the storage of electrical signals converted by the photo-sensing operation of the photodiodes should also be protected from environmental interference. Any of the aforementioned factors may pose a negative impact on the quality of the acquired images.

[0006] Hence, the factors that play a role in the improvement of the overall photo-sensing efficiency of the image sensor should be considered in research and development.

SUMMARY

[0007] The disclosure is directed to an image sensor and a method for manufacturing the same, which can at least ensure the photodiode to be placed in an isolation space and reduce the possibility of interference, and also increase the number of times of a light path passing through the photodiode and enhance the light receiving amount according to an embodiment. As a whole, the photo-sensing efficiency of the image sensor can be improved.

[0008] According to an embodiment, an image sensor that includes a substrate is provided. A photodiode is formed in the substrate and in a pixel region. Storage devices are formed in the substrate and adjacent to the photodiode. Deep trench isolation walls penetrate through the substrate to isolate the photodiode and the storage devices. A circuit layer is disposed on a first surface of the substrate and connected to the photodiode and the storage devices. A shielding structure is disposed on a second surface of the substrate to shield the storage devices. A material layer is disposed over the second surface of the substrate. A lens is disposed on the material layer and configured to receive incident light and transmit the incident light to the photodiode.

[0009] In an embodiment, the deep trench isolation walls include an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, and the storage devices are located between the inner wall and the outer wall.

[0010] In an embodiment, the shielding structure further includes a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

[0011] In an embodiment, the circuit layer includes a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

[0012] In an embodiment, the electrical signal is directed to one of the storage devices or all of the storage devices.

[0013] In an embodiment, the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer includes a color filter layer.

[0014] According to an embodiment, an image sensor including a substrate is provided. A photodiode is formed in the substrate and in a pixel region. Storage devices are formed in the substrate and adjacent to the photodiode. Deep trench isolation walls penetrate through the substrate to isolate the photodiode and the storage devices. A circuit layer is disposed on a first surface of the substrate and connected to the photodiode and the storage devices. A surface texture pattern layer is formed on a second surface of the substrate, wherein the surface texture pattern layer includes a plurality of surface protruding structures extending toward the substrate. The shielding structure is disposed on the surface texture pattern layer to shield the storage devices. A material layer is disposed above the second surface of the substrate. A lens is disposed on the material layer and configured to receive incident light and transmit the incident light into the photodiode.

[0015] In an embodiment, the deep trench isolation walls include an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, wherein the storage devices are located between the inner wall and the outer wall.

[0016] In an embodiment, the shielding structure further includes a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

[0017] In an embodiment, the circuit layer includes a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

[0018] In an embodiment, the electrical signal is directed to one of the storage devices or all of the storage devices.

[0019] In an embodiment, the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer includes a color filter layer.

[0020] According to an embodiment, a method for manufacturing an image sensor is provided, and the method includes providing a substrate. Deep trench isolation walls penetrate through the substrate to obtain a first isolated region and a second isolated region. A photodiode is formed in the substrate and in the first isolated region. Storage devices are formed in the substrate and in the second isolated region. A circuit layer is formed on a first surface of the

substrate and connected to the photodiode and the storage devices. A shielding structure is formed on a second surface of the substrate to shield the storage devices. A material layer is formed above the second surface of the substrate. A lens is formed on the material layer and configured to receive incident light and transmit the incident light to the photodiode.

[0021] In an embodiment, the deep trench isolation walls include an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, wherein the storage devices are located between the inner wall and the outer wall.

[0022] In an embodiment, the shielding structure further includes a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

[0023] In an embodiment, the circuit layer includes a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

[0024] In an embodiment, the electrical signal is directed to one of the storage devices or all of the storage devices.

[0025] In an embodiment, the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer includes a color filter layer.

[0026] In an embodiment, the method further includes forming a surface texture pattern layer on the second surface of the substrate before forming the shielding structure, wherein the surface texture pattern layer includes a plurality of surface protruding structures extending toward the substrate.

[0027] In an embodiment, the step of forming the surface texture pattern layer includes etching the second surface of the substrate to form a plurality of recessed structures and forming a dielectric layer on the second surface of the substrate and filling the recessed structures with the dielectric layer to obtain the surface texture pattern layer.

[0028] In order to make the disclosure more comprehensible, several embodiments accompanied with figures are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure.

[0030] FIG. **1** is a schematic view of a cross-sectional structure of an image sensor according to an embodiment of the disclosure.

[0031] FIG. **2** is a schematic view of a cross-sectional structure of an image sensor according to an embodiment of the disclosure.

[0032] FIG. **3** is a schematic flowchart of a method for manufacturing an image sensor according to an embodiment of the disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0033] The disclosure relates to a structure of an image sensor and a method for manufacturing the same. In one or more embodiments of the disclosure, for instance, deep trench isolation walls are applied to isolate light for a photodiode device and reduce the interference between adjacent pixels in the corresponding photodiode device. In addition, the storage devices can be effectively isolated to reduce the possibility of interference with stored signals by the environment.

[0034] Some embodiments are provided below to illustrate the disclosure, but the disclosure is not limited to the embodiments provided herein.

[0035] FIG. **1** is a schematic view of a cross-sectional structure of an image sensor according to an embodiment of the disclosure. With reference to FIG. **1**, deep trench isolation walls **12** are formed in a substrate **10**. The deep trench isolation walls **12** penetrate through the substrate **10** to obtain an isolation region **14** at a central position and isolation regions **14***a* and **14***b* at the peripheries of the isolation region **14**. A photodiode **16** is predetermined to be formed in the isolation region **14** of the substrate **10**, and the isolation region **14** can also be considered as a pixel region.

[0036] The deep trench isolation walls **12** include, for instance, an inner wall **12***a* to isolate the photodiode **16** and an outer wall **12***b* surrounding the inner wall **12***a*. Storage devices **18***a* and **18***b* are located between the inner wall **12***a* and the outer wall **12***b*.

[0037] Regarding the manufacture of the deep trench isolation walls **12**, for instance, deep trench isolation walls having a predetermined depth are formed on one side of the substrate **10**, and in the subsequent manufacturing process, the other side of the substrate **10** is ground to expose an end portion of the deep trench isolation walls **12**. The resultant deep trench isolation walls **12** penetrate through the substrate **10** and can divide a sensing cell into the isolated region **14** including the photodiode **16** and the isolated regions **14***a* and **14***b* including the storage devices **18***a* and **18***b*. It can be observed from the cross-sectional structure that the isolated regions **14***a* and **14***b* are separated. From the top view structure, the isolated regions **14***a* and **14***b* may, for instance, also be connected and surround the isolated region **14** at the central position in response to the shape of a lens. That is, in an embodiment, the outer wall **12***b* may surround the inner wall **12***a*.

[0038] In an embodiment, the initial deep trench isolation walls **12** are formed on one surface **10***a* of the substrate **10**. In addition, the required photodiode **16** and the storage devices **18***a* and **18***b* may also be formed in the substrate **10**, for instance.

[0039] After the formation of the initial deep trench isolation walls **12**, the photodiode **16**, and the storage devices **18***a* and **18***b*, the circuit layer **26** can be formed on the surface **10***a* of the substrate **10**. The circuit layer **26** includes, for instance, at least a transistor device **20**, an interconnect structure **22**, and an inner-layer dielectric layer **24**. According to the semiconductor manufacturing technology, the inner-layer dielectric layer **24** is a structure that is required for supporting the transistor device **20** and the interconnect structure **22**. The actual circuit in the circuit layer **26** is fabricated according to the control circuit required by the image sensor, and the circuit layer **26** provided in the disclosure is not limited to what is provided in the embodiment nor limited to any other specific circuit.

[0040] In an embodiment, the circuit layer **26** may include a first circuit part and a second circuit part. The first circuit part includes the transistor **20** and the relevant components and may convert a sensor signal generated by the photodiode **16** into an electrical signal. The second circuit part includes

the interconnect structure **22** that receives the electrical signal to be stored in the storage devices **18***a* and **18***b*.

[0041] In an embodiment, the electrical signal can be directed to one of the storage devices **18***a* and **18***b* or all of the storage devices **18***a* and **18***b*, which is determined by the control mechanism of the storage and should not be construed as a limitation in the disclosure.

[0042] In an embodiment, the other surface **10***b* of the substrate **10** can be ground, so that the other end of the deep trench isolation walls **12** is exposed, and the surface **10***b* can be flattened by grinding. Here, the grinding operation can be performed on the surface **10***b* of the substrate **10** after the circuit layer **26** is completely formed according to an embodiment. In another embodiment, the grinding operation can be performed on the surface **10***b* of the substrate **10** before the circuit layer **26** is completely formed. The disclosure is not limited to the order of performing the grinding operation.

[0043] After the grinding operation is completed, the surface **10***b* of the substrate **10** is in a flat state, and a variety of required optical devices can be continuously formed on the surface **10***b*. In the current manufacturing state, none of the photodiode **16** and the storage devices **18***a* and **18***b* have any shielding structure for shielding light, and the photodiode **16** receives the incident light as indicated by the arrow. The storage devices **18***a* and **18***b* should be protected from the ambient light during operation, and note that the ambient light may cause changes to the stored signal and thus lead to image errors.

[0044] In an embodiment, the shielding structure **28** is disposed on the surface **10***b* of the substrate **10** and above the storage devices **18***a* and **18***b*, so as to shield the storage devices **18***a* and **18***b*. After the isolation spaces **16***a* and **16***b* are shielded by the shielding structure **28**, the deep trench isolation walls **12** and the shielded isolation spaces **16***a* and **16***b* can achieve the light shielding effect on the side and the top, and loss of the stored electrical signal can be better prevented. Since the photodiode **16** is required to receive the incident light, the shielding structure **28** does not shield the photodiode **16**. The side of the isolation region **14** is isolated by the deep trench isolation walls **12** and as a result can achieve a relatively better isolation effect.

[0045] A material of the shielding structure **28** is a metallic material according to an embodiment. The deep trench isolation walls **12** are, for instance, made of a dielectric material or other materials that can reflect light. In addition, in an embodiment, the shielding structure **28** includes, for instance, a vertical grid structure **28***a* disposed on an end portion of the inner wall **12***a* of the deep trench isolation walls **12** and surrounding the photodiode **16**.

[0046] The material layer **30** covers the substrate **10**, and the shielding structure **28** is also covered by the material layer **30**. A lens **32** can be disposed on the material layer **30**. In an embodiment, the incident light provided herein may be visible light or infrared light. If the incident light is the visible light, the material layer **30** may include, for instance, a color filter layer corresponding to red, green, or blue light. The structure of the material layer **30** is designed according to actual needs, and the material layer **30** provided herein is not limited to what is described in the embodiment. After the material layer **30** is completely formed, the lens **32** can be disposed on the material layer **30** to receive the incident light and gather the received light into the isolation space **14**, and then the gathered light enters the photodiode **16**. After receiving the light, the photodiode **16** converts the amount of the received light into an electrical signal and stores the electrical signal in the storage devices **18***a* and **18***b* through the circuit layer **26**. In an embodiment, the circuit layer **26** can include a control device which determines the way to store the storage devices **18***a* and **18***b*.

[0047] The image sensor described above can be further modified to increase the amount of light that can be received by the photodiode **16**. FIG. **2** is a schematic view of a cross-sectional structure of an image sensor according to an embodiment of the disclosure.

[0048] With reference to FIG. **2**, the image sensor provided in this embodiment is similar to the image sensor described in FIG. **1**, while a surface texture pattern layer **40** is additionally disposed on the surface **10***b* of the substrate according to the present embodiment. Here, the surface texture pattern layer **40** includes, for instance, a plurality of surface protruding structures extending toward the substrate **10**. The surface texture pattern layer **40** scatters the incident light, and the scattered light is reflected by the inner wall **12***a* of the deep trench isolation walls **12** and metal elements of the circuit layer **26**, allowing the light path to pass through the photodiode **16** multiple times and to be absorbed. This increases the amount of the absorbed light.

[0049] In an embodiment, a method of manufacturing a surface texture pattern layer includes, for instance, performing a wet etching process on the surface **10***b* of the substrate **10** to some extent, so as to form a plurality of recessed structures. A dielectric layer is then formed on the surface **10***b* of the substrate **10**. The recessed structures are filled with the dielectric layer to form a structure protruding toward the substrate **10**, so as to obtain a surface texture pattern layer **40**. The method of manufacturing the surface texture pattern layer is not limited to what is described in the embodiment, given that a structure capable of scattering the incident light on the surface **10***b* of the substrate **10** can be formed through performing the corresponding forming process.

[0050] Manufacturing steps of the manufacturing method provided herein are further described in an embodiment below. FIG. **3** is a schematic flowchart of a method for manufacturing an image sensor according to an embodiment of the disclosure.

[0051] With reference to FIG. **3**, the method for manufacturing an image sensor includes providing a substrate in step S**10**. In step S**12**, deep trench isolation walls penetrating through the substrate are formed to obtain a first isolation region and a second isolation region. In step S**14**, a photodiode is formed in the substrate and in the first isolated region. In step S**16**, storage devices are formed in the substrate and in the second isolated region. In step S**18**, a circuit layer is formed on a first surface of the substrate and connected to the photodiode and the storage devices. In step S**20**, a shielding structure is formed on a second surface of the substrate to shield the storage devices. In step S**22**, a material layer is formed above the second surface of the substrate. In step S**24**, a lens is formed on the material layer and configured to receive the incident light and transmit the incident light to the photodiode.

[0052] In addition, to form the surface texture pattern layer **40** shown in FIG. **2**, for instance, a wet etching process is performed on the surface **10***b* of the substrate **10** to some extent, so as to form a plurality of recessed structures. A dielectric layer is then formed on the surface **10***b* of the

substrate **10**, and the recessed structures are filled with the dielectric layer to form protruding structures extending toward the substrate **10**, so as to obtain the surface texture pattern layer **40**.

[0053] According to the choice of different manufacturing processes, the protruding structures of the surface texture pattern layer **40** may be regular or irregular cone-shaped structures according to an embodiment of the disclosure.

[0054] To sum up, in one or more embodiments herein, the structure of the image sensor and the method for manufacturing the same are provided. Here, the deep trench isolation walls are applied to isolate light for the photodiode device and reduce the interference between adjacent pixels in the corresponding photodiode device. In addition, the storage devices can be effectively isolated to reduce the possibility of interference with the stored signals by the environment. The surface texture pattern layer increases the light reflection path and increases the amount of the absorbed light of the photodiode.

[0055] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present disclosure without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the present disclosure cover modifications and variations of this disclosure provided they fall within the scope of the following claims and their equivalents.

1. An image sensor comprising:

a substrate;

a photodiode formed in the substrate and in a pixel region;

a plurality of storage devices formed in the substrate and adjacent to the photodiode;

a plurality of deep trench isolation walls penetrating whole through the substrate to isolate the photodiode and the storage devices;

a circuit layer disposed on a first surface of the substrate and connected to the photodiode and the storage devices;

a shielding structure disposed on a second surface of the substrate to shield the storage devices;

a material layer disposed above the second surface of the substrate; and

a lens disposed on the material layer and configured to receive incident light and transmit the incident light to the photodiode.

2. The image sensor according to claim **1**, wherein the deep trench isolation walls comprise an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, wherein the storage devices are located between the inner wall and the outer wall.

3. The image sensor according to claim **2**, wherein the shielding structure further comprises a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

4. The image sensor according to claim **1**, wherein the circuit layer comprises a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

5. The image sensor according to claim **4**, wherein the electrical signal is directed to one of the storage devices or all of the storage devices.

6. The image sensor according to claim **1**, wherein the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer comprises a color filter layer.

7. An image sensor, comprising:

a substrate;

a photodiode formed in the substrate and in a pixel region;

a plurality of storage devices formed in the substrate and adjacent to the photodiode;

a plurality of deep trench isolation walls penetrating through the substrate to isolate the photodiode and the storage devices;

a circuit layer disposed on a first surface of the substrate and connected to the photodiode and the storage devices;

a surface texture pattern layer formed on a second surface of the substrate, wherein the surface texture pattern layer comprises a plurality of surface protruding structures extending toward the substrate;

a shielding structure disposed on the surface texture pattern layer to shield the storage devices;

a material layer disposed above the second surface of the substrate; and

a lens disposed on the material layer and configured to receive incident light and transmit the incident light into the photodiode.

8. The image sensor according to claim **7**, wherein the deep trench isolation walls comprise an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, and the storage devices are located between the inner wall and the outer wall.

9. The image sensor according to claim **8**, wherein the shielding structure further comprises a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

10. The image sensor according to claim **7**, wherein the circuit layer comprises a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

11. The image sensor according to claim **10**, wherein the electrical signal is directed to one of the storage devices or all of the storage devices.

12. The image sensor according to claim **7**, wherein the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer comprises a color filter layer.

13. A method for manufacturing an image sensor, comprising:

providing a substrate;

forming a plurality of deep trench isolation walls penetrating whole through the substrate to obtain a first isolation region and a second isolation region;

forming a photodiode in the substrate and in the first isolation region;

forming a plurality of storage devices in the substrate and in the second isolated region;

forming a circuit layer on a first surface of the substrate, the circuit layer being connected to the photodiode and the storage devices;

forming a shielding structure on a second surface of the substrate to shield the storage devices;

forming a material layer over the second surface of the substrate; and

forming a lens on the material layer configured to receive incident light and transmit the incident light to the photodiode.

14. The method according to claim **13**, wherein the deep trench isolation walls comprise an inner wall to isolate the photodiode and an outer wall surrounding the inner wall, and the storage devices are located between the inner wall and the outer wall.

15. The method according to claim **14**, wherein the shielding structure further comprises a vertical grid structure disposed on an end portion of the inner wall and surrounding the photodiode.

16. The method according to claim **13**, wherein: the circuit layer comprises a first circuit part and a second circuit part, the first circuit part converts a sensor signal generated by the photodiode into an electrical signal, and the second circuit part receives the electrical signal to be stored in the storage devices.

17. The method according to claim **16**, wherein the electrical signal is directed to one of the storage devices or all of the storage devices.

18. The method according to claim **17**, wherein the incident light is visible light or infrared light, and if the incident light is the visible light, the material layer comprises a color filter layer.

19. The method according to claim **13**, further comprising forming a surface texture pattern layer on the second surface of the substrate before forming the shielding structure, wherein the surface texture pattern layer comprises a plurality of surface protruding structures extending toward the substrate.

20. The method according to claim **19**, wherein the step of forming the surface texture pattern layer comprises:

wet-etching the second surface of the substrate to form a plurality of recessed structures; and

forming a dielectric layer on the second surface of the substrate and filling the recessed structures with the dielectric layer to obtain the surface texture pattern layer.

* * * * *