US 20060057765A1

(19) **United States**
(12) **Patent Application Publication**
Hsu et al.
(10) **Pub. No.: US 2006/0057765 A1**
(43) **Pub. Date: Mar. 16, 2006**

(54) IMAGE SENSOR INCLUDING MULTIPLE LENSES AND METHOD OF MANUFACTURE THEREOF

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(21) Appl. No.: **10/939,894**

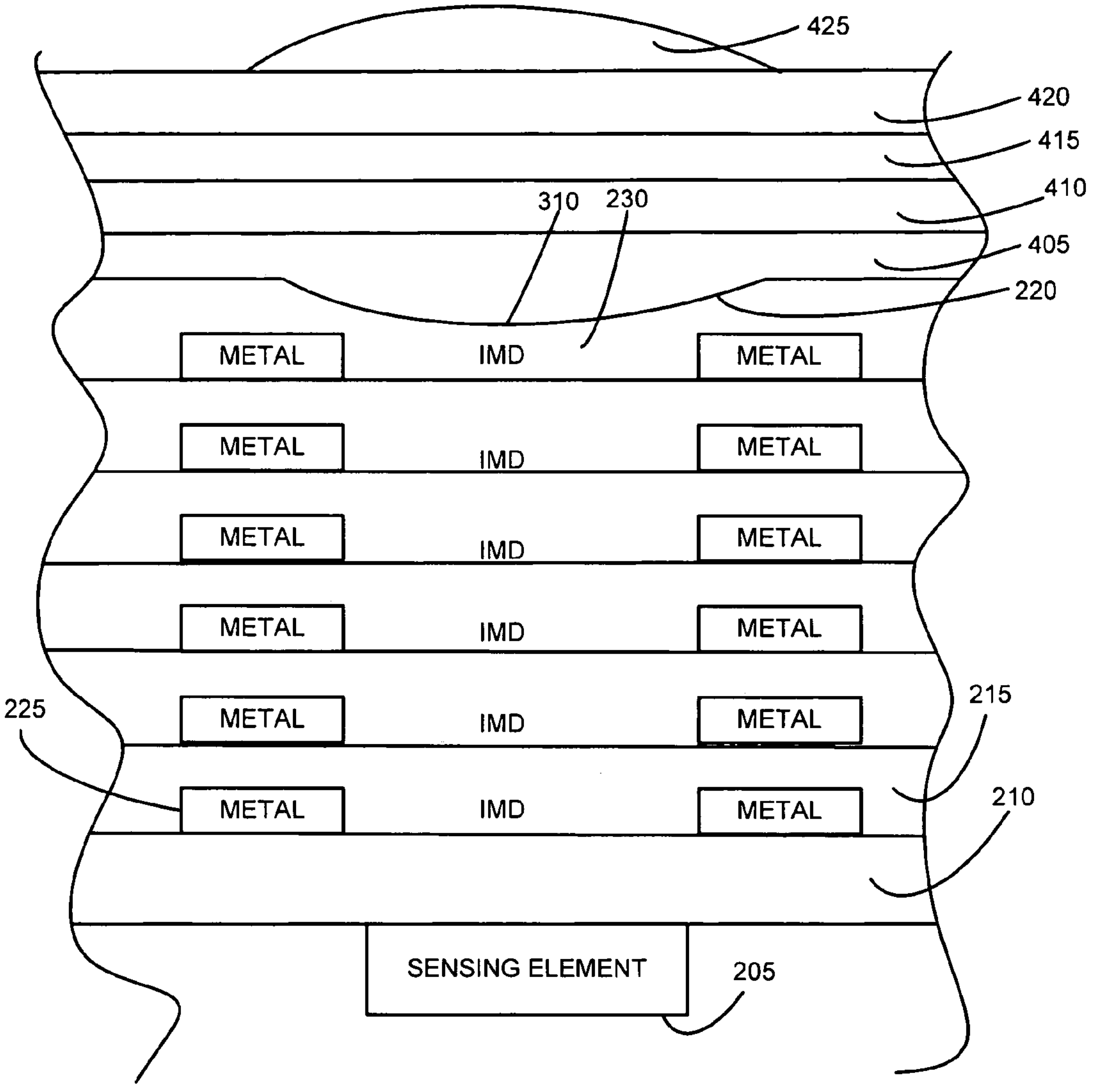
(22) Filed: **Sep. 13, 2004**

Publication Classification

(51) **Int. Cl.**
H01L 21/00 (2006.01)
(52) **U.S. Cl.** **438/70**; 438/73

(57) ABSTRACT

A device includes an image sensing element. The device also includes a Silicon Dioxide (SiO_2) layer, located over the image sensing element, exhibiting a first index of refraction. The device further includes a first lens, located over the SiO_2 layer, exhibiting a second index of refraction greater than the first index of refraction. The device still further includes a color filter located over the first lens and a second lens located over the color filter.



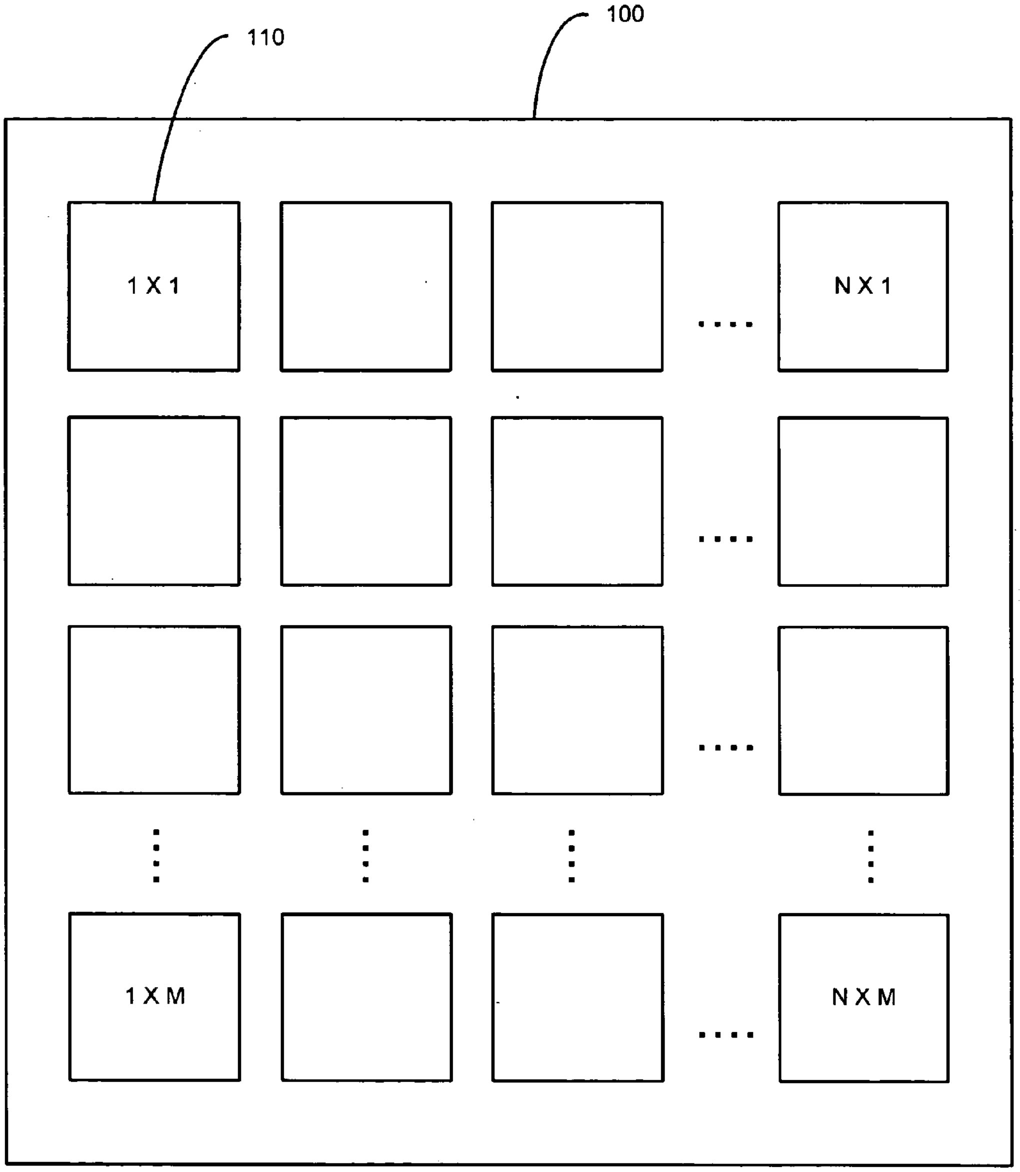


Fig. 1

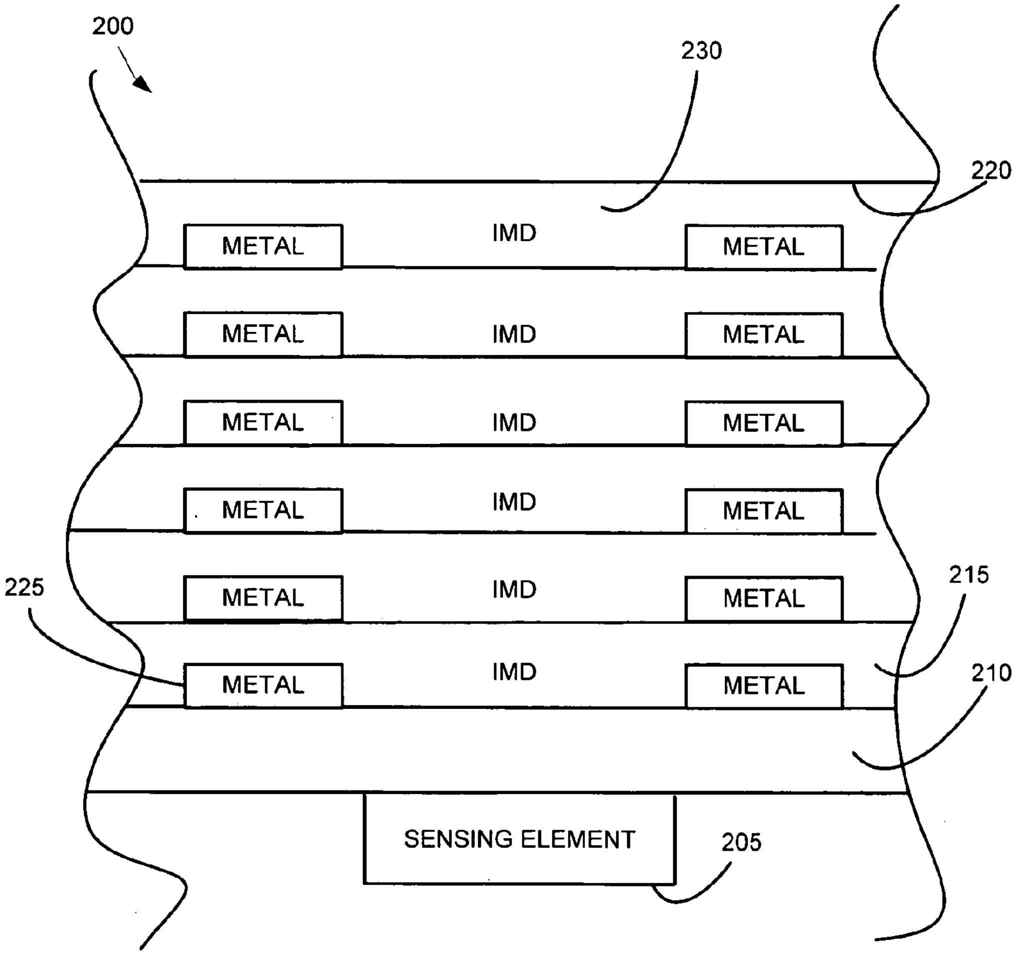

200
230
220
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
225
METAL
IMD
METAL
215
METAL
IMD
METAL
210
SENSING ELEMENT
205

Fig. 2

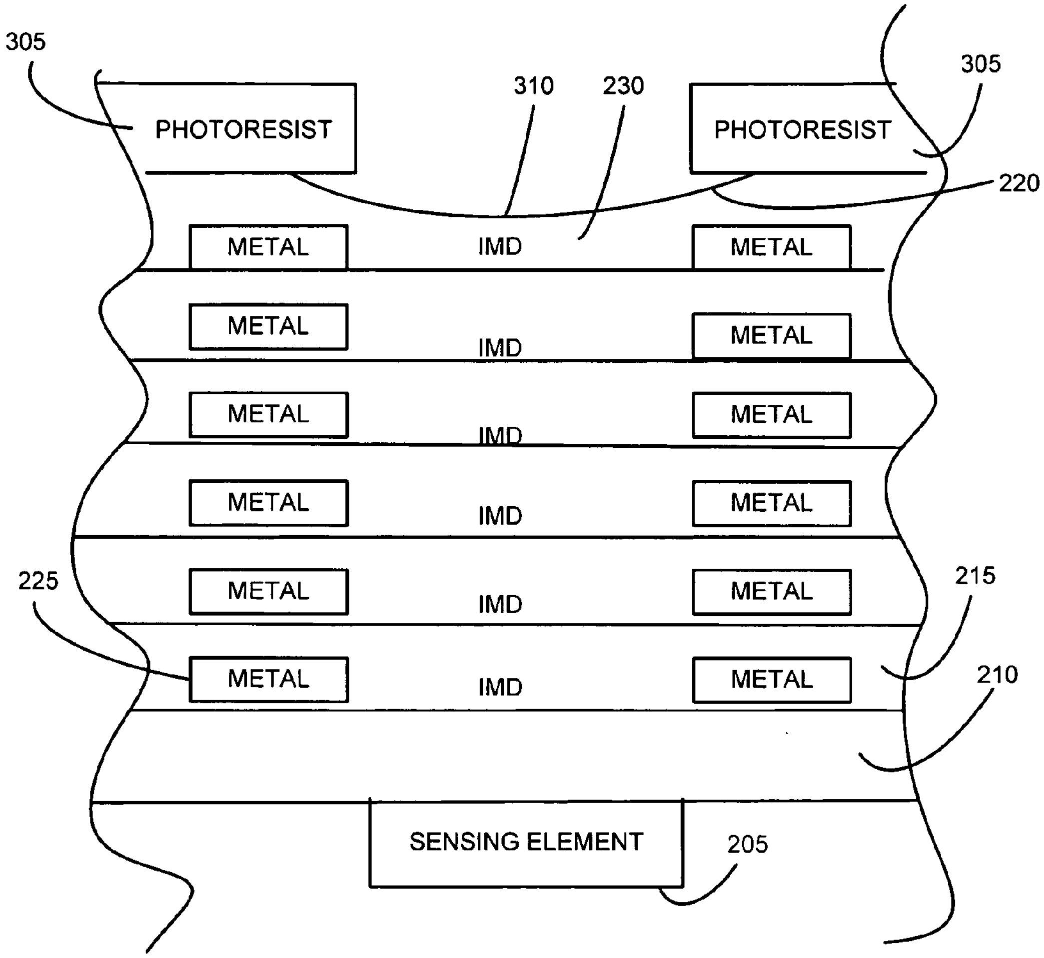

305
PHOTORESIST
310
230
PHOTORESIST
305
220
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
225
METAL
IMD
METAL
215
METAL
IMD
METAL
210
SENSING ELEMENT
205

Fig. 3

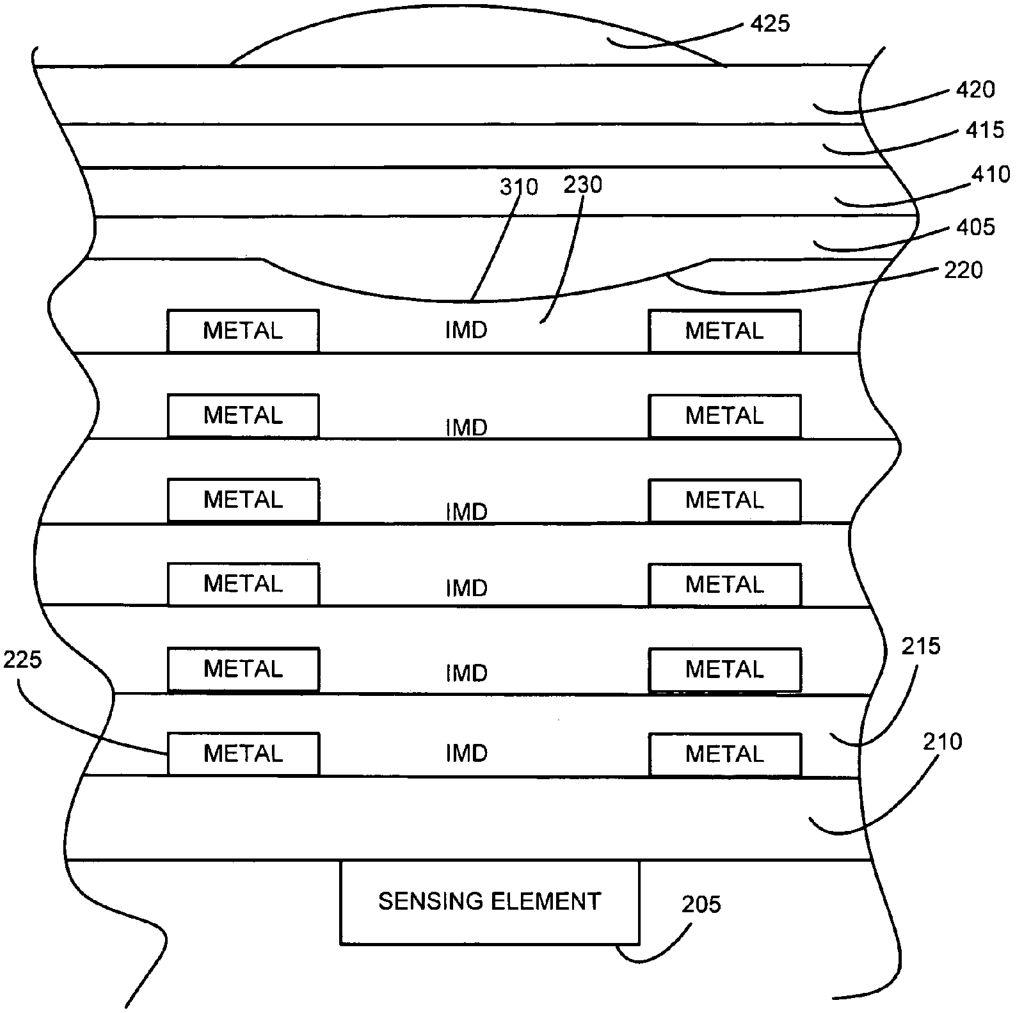

425
420
415
410
405
310
230
220
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
METAL
IMD
METAL
225
METAL
IMD
METAL
215
METAL
IMD
METAL
210
SENSING ELEMENT
205

Fig. 4

IMAGE SENSOR INCLUDING MULTIPLE LENSES AND METHOD OF MANUFACTURE THEREOF

FIELD OF DISCLOSURE

[0001] The present disclosure relates generally to the field of microelectronic devices and, more particularly, an image sensor including multiple lenses and method of manufacture thereof.

BACKGROUND

[0002] Various digital imaging devices (e.g., digital cameras) use image sensors, such as charge-coupled device ("CCD") imaging sensors and complementary metal oxide semiconductor ("CMOS") image sensors. Such image sensors include a two dimensional array of photo-receptor devices (e.g., photodiodes), each of which is capable of converting a portion of an image to an electronic signal (e.g., representing a "pixel"). Some devices (e.g., a display device) are capable of receiving one or more signals from multiple photo-receptor devices of an image sensor and forming (e.g., reconstructing) a representation of the image.

[0003] A photo-receptor device stores a signal in response to intensity or brightness of light associated with an image. Thus, for an image sensor, sensitivity to light is important.

[0004] Accordingly, what is needed is an image sensor with improved sensitivity to light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] In the accompanying figures, in accordance with the standard practice of the industry, various features are not drawn to scale. In fact, dimensions of the various features may be shown to have increased or reduced for clarity.

[0006] **FIG. 1** is a block diagram of an image sensor according to the illustrative embodiment.

[0007] **FIGS. 2-4** are successive sectional views of a photo-receptor device according to the illustrative embodiment.

DETAILED DESCRIPTION

[0008] The following discussion references various embodiments, and/or examples for implementing different features of the various embodiments. Also, specific examples of components and arrangements are described for clarity, and are not intended to limit the scope this disclosure. Moreover, the following discussions repeat reference numerals and/or letters in the various examples, and such repetitions are also for clarity and does not itself indicate a relationship between the various embodiments and/or configurations discussed. Still further, references indicating formation of a first feature over or on a second feature include embodiments in which the features are formed in direct contact, and also embodiments in which one or more additional features are formed, interposing the first and second features, such that the first feature and the second feature are not in direct contact.

[0009] **FIG. 1** is a block diagram of an image sensor **100** according to the illustrative embodiment. In the illustrative embodiment, the image sensor **100** is a charged coupled device ("CCD") image sensor. However in other embodiments, the image sensor **100** is another type of image sensor, such as a complementary metal oxide semiconductor ("CMOS") image sensor.

[0010] The image sensor **100** includes photo-receptor devices (e.g., photodiodes) **110**. Each of the photo-receptor devices **110** is substantially similar to one another. The photo-receptor devices **110** are organized according to a two dimensional array. As shown, the array includes N columns and M rows. Accordingly, the quantity of photo-receptor devices **110** included by the image sensor **100** is represented by a number resulting from multiplying N by M. Information (e.g., electronic signal) stored by each of the photo-receptor devices **110** is capable of representing a "pixel" of an image (e.g., an image displayed by a display device). Thus, the number resulting from multiplying N by M is also capable of representing a resolution (e.g., screen resolution) for such an image.

[0011] **FIG. 2** is a sectional view of a photo-receptor device (e.g., one of the photo-receptor devices **110**), indicated generally at **200**, in an initial stage of manufacture according to the illustrative embodiment. The photo-receptor device **200** includes a sensing element **205** that reacts to light (e.g., a light beam). In one embodiment, the sensing element **205** includes a pn-junction device (e.g., a diode). The photo-receptor device **200** also includes at least one dielectric layer **210**, and one or more inter-metal-dielectric ("IMD") layers **215**. Moreover, the photo-receptor device **200** includes a "top" (e.g., upper most) IMD layer **220**, which is one of the layers included by the IMD layers **215**. Each of the IMD layers **215** includes a metal layer **225** as shown. Also, each of the IMD layers **215** includes a dielectric layer. For example, the IMD layer **220** includes a dielectric layer **230**, which is a part of the IMD layer **220**.

[0012] In the illustrative embodiment, the dielectric layer **230** includes SiO_2. The dielectric layer **230** is formed by atomic layer deposition ("ALD"), chemical vapor deposition ("CVD"), such as plasma-enhanced CVD ("PECVD"), high density plasma CVD ("HDP-CVD"), and low pressure CVD ("LPCVD"), evaporation, or any other suitable technique. Notably, with PECVD, tetraethoxysilane ("TEOS") is used to form the SiO_2 dielectric layer **230**.

[0013] After its formation, the dielectric layer **230** is planarized. Examples of planarizing techniques include thermal flow, sacrificial resist etch-back, spin-on glass, and chemical-mechanical planarization ("CMP"). In particular, CMP is a technique for planarizing various disparate types of materials, such as dielectric and metal materials. CMP is capable of selectively removing materials from a layer (e.g., a layer of a wafer) by mechanical polishing that is assisted by one or more chemical reactions.

[0014] In more detail, with conventional CMP, a wafer is mounted with its face down on a carrier. The carrier is pressed against a moving platen that includes a polishing surface (e.g., a polishing pad). While the carrier is rotated about its axis, aqueous material including abrasive elements is dripped onto the polishing pad so that the centrifugal force formed by rotating the carrier distributes the aqueous material on the polishing pad. Accordingly, via a combination of mechanical polishing and chemical reaction, CMP selectively removes a portion of a layer of the wafer.

[0015] **FIG. 3** is a sectional view of the of the photo-receptor device **200**, in a subsequent stage of manufacture according to the illustrative embodiment. At this stage, a curved recess **310** is formed on the dielectric layer **230**. The curved recess **310** is formed by using conventional photolithography and etching techniques. In one example, the curved recess is formed by patterning the dielectric layer **230** with a sequence of processes that includes: photo-resist patterning, wet etching, and photo-resist stripping. Also, the photo-resist patterning includes: photo-resist coating, "soft baking", mask alignment, pattern exposure, photo-resist development, and "hard baking". Moreover, wet etching is isotropic etching, and accordingly, suitable for forming the curved recess **310**.

[**0016**] In more detail, in forming the curved recess **310**, a photo-resist layer **305** is formed over the dielectric layer **230** as shown in **FIG. 3**. After forming the photo-resist layer **305**, wet etching is performed on the dielectric layer **230**. Subsequently, the photo-resist layer **305** is removed. Although in the illustrative embodiment, the curved recess **310** is formed using photo-lithography/wet-etching, in other embodiments, the curved recess **310** is formed using one or more other suitable techniques such as maskless lithography.

[**0017**] **FIG. 4** is a sectional view of the of the photo-receptor device **200**, in a subsequent stage of manufacture according to the illustrative embodiment. At this stage of manufacture, the photo-receptor device **200** includes the dielectric layer **230**, which includes the curved recess **310**. Over the dielectric layer **230** and its curved recess **310**, a lens **405** is formed. In the illustrative embodiment, the lens **405** includes SiN, SiON, or any other suitable material. Also, examples of techniques used to form the lens **405** include ion implantation of N, sputtering, ALD, and CVD such as PECVD, LPCVD, and HDP-CVD. In one example, NH3 and HCD are used in association with LPCVD to form the lens **405** that includes SiN. As shown, the lens **405** is a convex lens.

[**0018**] The photo-receptor device **200** also includes a spacer **410**, which is formed over the lens **405**. In the illustrative embodiment, the spacer **410** includes SiO_2, polymer or any other material suitable for electrical insulation and planarization. Moreover, the photo-receptor device **200** includes a color filter layer **415** formed over the spacer **410**. In the illustrative embodiment, the color filter layer **415** includes a resin, such as a pigment-dispersed resin or polymer. A spacer **420**, which is substantially similar to the spacer **410**, is formed over the color filter layer **415** as shown in **FIG. 4**.

[**0019**] In addition to the lens **405**, the photo-receptor device **200** includes a lens **425**. The lens **425** is substantially similar to the lens **405**. Accordingly, techniques used to form the lens **425** are substantially similar to the techniques used for forming the lens **405** as discussed above. Materials used to form lens **425** include a resin, such as a pigment-dispersed resin or polymer. The various layers between the lens **425** and the sensing element **205** are sufficiently transparent to pass light from lens **425** to the sensing element **205**.

[**0020**] As discussed above, the photo-receptor device **200** is capable of forming (e.g., converting) a portion of an image as an electronic signal. The photo-receptor device **200** forms such electronic signal in response to light (e.g., a light beam), from an optical image, that is received through the lenses **405** and **425**, the color filter layer **415**, and the IMD layers **215**.

[**0021**] A light beam passing from one type of medium (e.g., the lens **405**) to another medium (e.g., the dielectric layer **230**) is typically affected by refraction. An example of refraction can be observed when a light beam passes from air to water. An amount of refraction for a specified medium is characterized by its index of refraction. In one example, index of refraction is characterized by the following mathematical expression.

$$n=c/v_{phase}$$

[**0022**] In the above expression, c is the speed of light and v_{phase} is the phase velocity.

[**0023**] As discussed above, for the photo-receptor device **200**, light sensitivity of the image sensing element **205** is important. It has been observed that, in general, light sensitivity can be improved by receiving light from a large pixel area and focusing the light on a small image sensing element. For improving the light sensitivity of the image sensing element **205**, the photo-receptor device **200** includes the lenses **405** and **425** as discussed above. Also for improving the light sensitivity of the image sensing element **205**, an index of refraction for the lens **405** is greater than an index of refraction for the dielectric layer **230**.

[**0024**] For example, in one version of the illustrative embodiment, the lens **405** includes SiN and the dielectric layer **230** includes SiO_2. According to one measured value, an index of refraction for SiN is approximately 2.01 and an index of refraction for SiO_2 is 1.46. Thus, the index of refraction for the lens **405** (2.01) is greater than the index of refraction for the dielectric layer **230** (1.46).

[**0025**] Although illustrative and alternative embodiments have been shown and described, a wide range of modification, change, and substitution is contemplated in the foregoing disclosure and, in some instances, some features of the embodiments may be employed without a corresponding use of other features. Accordingly, broad constructions of the appended claims in manners consistent with the scope of the embodiments disclosed are appropriate.

1. A method for manufacturing an image sensor, the method comprising: forming an image sensing element; forming over the image sensing element, a Silicon Dioxide (SiO_2) layer exhibiting a first index of refraction; forming over the SiO_2 layer, a first lens exhibiting a second index of refraction greater than the first index of refraction; forming a color filter over the first lens; and forming a second lens over the color filter.

2. The method of claim 1, wherein the first lens includes Silicon Nitride (SiN).

3. The method of claim 1, wherein the second index of refraction is approximately 2.01.

4. The method of claim 1, wherein the first index of refraction is approximately 1.46.

5. The method of claim 1, wherein the SiO_2 layer is formed by chemical vapor deposition ("CVD")

6. The method of claim 1, wherein the first lens is formed by CVD.

7. The method of claim 1, wherein the SiO_2 layer is planarized.

8. The method of claim 7, wherein the SiO_2 layer is planarized by chemical-mechanical planarization ("CMP").

9. The method of claim 1, wherein the SiO_2 layer is wet-etched.

10. The method of claim 1, wherein the color filter includes a resin.

11. The method of claim 1, wherein the color filter includes a polymer.

12. A device comprising: an image sensing element; a Silicon Dioxide (SiO_2) layer, located over the image sensing element, exhibiting a first index of refraction; a first lens, located over the SiO_2 layer, exhibiting a second index of refraction greater than the first index of refraction; a color filter located over the first lens; and a second lens located over the color filter.

13. The device of claim 12, wherein the first lens includes Silicon Nitride (SiN).

14. The device of claim 12, wherein the second index of refraction is approximately 2.01.

15. The device of claim 12, wherein the first index of refraction is approximately 1.46.

16. The device of claim 12, wherein the SiO_2 layer is formed by chemical vapor deposition ("CVD").

17. The device of claim 12, wherein the first lens is formed by CVD.

18. The device of claim 12, wherein the SiO_2 layer is planarized.

19. The device of claim 18, wherein the SiO_2 layer is planarized by chemical-mechanical planarization ("CMP").

20. The device of claim 12, wherein the SiO_2 layer is wet-etched.

21. The device of claim 12, wherein the color filter includes a resin.

22. The device of claim 12, and comprising:

one or more inter-metal-dielectric ("IMD") layers.

23. A device comprising:

an image sensing element;

a first convex lens, located over the image sensing element;

a color filter located over the first convex lens; and

a second convex lens located over the color filter.

24. The device of claim 1 wherein the first convex lens comprises a curved surface curving toward the image sensing element.

25. The device of claim 1 wherein the second convex lens comprises a curved surface curving away from the first convex lens.

26. The device of claim 1 wherein the first and second convex lenses each comprises a material selected from the group consisting of silicon nitride and silicon oxynitride.

27. The device of claim 1 wherein the first and second convex lenses each comprises an index of refraction greater than that of surrounding materials.

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