

COLOR FILTER SHAPING

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relates to a method and apparatus for capturing an image. More specifically, embodiments of the present disclosure relate to a photoactive device for an apparatus.

Description of the Related Art

[0002] An image sensor is a sensor that detects and conveys the information that constitutes an image. For example, an image sensor converts incoming radiation into signals that subsequently convey information. Image sensors may be used in electronic imaging devices such as digital cameras, camera modules, medical imaging equipment, and the like.

[0003] Color filters that are used in image sensors aid in selectively allowing a pre-defined wavelength of light to pass through, while blocking all other wavelengths of light. For example, a color filter may be capable of resolving red, green, blue, and white light. In the case of red light, the respective red color filter will only allow for the red wavelength of light to pass through, while blocking the green, blue, and white light wavelengths.

[0004] Accordingly, there is a continual need for an improved image sensor in image capturing apparatuses.

SUMMARY

[0005] Embodiments described herein generally relate to an apparatus for capturing an image and a photoactive device for that apparatus. In one embodiment, the apparatus for capturing an image includes a lens and a photoactive device. The photoactive device is positioned adjacent the lens. The photoactive device includes a substrate, one or more photodiodes, and a color filter array. The one or more photodiodes are formed in the substrate. The color filter array is positioned over the substrate. The color filter array has

one or more color filters. Each color filter has a radiation receiving surface that is shaped to re-direct radiation to a respective photodiode.

[0006] In another embodiment, a photoactive device is disclosed herein. The photoactive device includes a substrate, one or more photodiodes, and a color filter array. The one or more photodiodes are formed in the substrate. The color filter array is positioned over the substrate. The color filter array has one or more color filters. Each color filter has a radiation receiving surface that is shaped to re-direct radiation to a respective photodiode.

[0007] In another embodiment, a color filter array is disclosed herein. The color filter array includes a plurality of color filters. Each color filter has a radiation receiving surface and a radiation exiting surface. The radiation receiving surface of each filter is shaped to re-direct radiation entering the radiation receiving surface and exiting the radiation exiting surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] Figure 1 illustrates an apparatus, such as a camera, according to one embodiment.

[0010] Figures 2A illustrates a first side cross-sectional view of a photoactive device within the camera, according to one embodiment.

[0011] Figures 2B illustrates a second side cross-sectional view of a photoactive device within the camera, according to one embodiment.

[0012] Figure 3 is a logical diagram of the photoactive device of Figure 2A, according to one embodiment.

[0013] Figures 4 is a flow diagram illustrating a method of forming a photoactive device, according to one embodiment.

[0014] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

[0015] It is to be noted, however, that the appended drawings illustrate only exemplary embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

DETAILED DESCRIPTION

[0016] Figure 1 is a schematic view of an apparatus 100 for capturing an image. In one example, the apparatus 100 may be a camera. In some examples, the camera may be for use in a mobile device. For example, the camera may be a rear-facing camera in a mobile device.

[0017] The apparatus 100 generally includes a photoactive device 102 and a lens 104. For example, the photoactive device 102 may be an image sensor. The photoactive device 102 is configured to capture an image in response to a user positioning the apparatus 100 in front of an object, and transmitting a signal to the apparatus 100 to capture the image. The lens 104 may comprise one or more objective lenses. The one or more objective lenses are configured to aid in focusing on the object.

[0018] Figure 2 is a side cross-sectional view of the photoactive device 102, according to one embodiment. The photoactive device 102 may comprise a photoactive feature 202. In one embodiment, the photoactive feature 202 may be an image sensor. In another embodiment, the photoactive feature 202 may be display pixels. For example, Figure 2 illustrates a photoactive device 102 comprising a photoactive feature 202 that is a metal-oxide semiconductor (CMOS) image sensor.

[0019] The photoactive device 102 includes an array of photodiodes 206 formed in a substrate 201. For example, as illustrated, the photoactive device 102 includes three photodiodes 206₁, 206₂, 206₃ (generically, 206_i, although the number of photodiode 206_i may vary). In one embodiment, the substrate 201 may be formed of silicon. Alternatively, the substrate 201 may be formed of any suitable material, such as, but not limited to, gallium arsenide, germanium, silicon-germanium, and the like. The substrate 201 may further include auxiliary circuitry 208 disposed therein. In one example, the substrate 201 may include auxiliary circuitry 208 between each photodiode 206_i. For example, the substrate 201 includes auxiliary circuitry 208 between photodiode 206₁ and 206₂ and between photodiode 206₂ and 206₃.

[0020] The photoactive device 102 may further include a metal layer 210 positioned on a top surface of the substrate 201. The metal layer 210 may include one or more stacks of metal features 212. Each metal feature 212 may be aligned the photodiodes 206_i. For example, as shown, a first stack of metal features 212 is shown overlapping with photodiodes 206₁ and 206₂, and a second stack of metal features 212 is shown overlapping with photodiodes 206₂ and 206₃. Each stack of metal features 212 may serve, for example as electrodes, guard rings, and light gates.

[0021] The photoactive device 102 may further include a color filter array 214 positioned on a top surface of the metal layer 210. The color filter array 214 comprises a plurality of color filters 216. For example, as illustrated in Figure 2, the color filter array 214 includes a color filter 216_r, 216_g, and 216_b (generically, 216_i). Each color filter 216_i is configured to receive radiation from a first surface (radiation receiving surface 218) and filter the radiation such each color filter 216_i only allows a pre-selected wavelength of light emitted from a second surface (radiation exiting surface 220) to pass through. For example, color filter 216_r is configured to only allow light corresponding to the red wavelength of light to pass therethrough. For example, color filter 216_g is configured to only allow light corresponding to the green wavelength of light to pass therethrough. For example, color filter 216_b is configured to only allow light corresponding to the blue wavelength of light to pass therethrough. In some embodiments, a coating

layer 215 is positioned between the color filter array 214 and the metal layer 210 to protect the color filter array 214 from the metal layer 210.

[0022] In some techniques, a microlens array (MLA) (not shown) is used to aid in capturing a larger amount of radiation. The MLA is also used for directing the radiation towards the photodiode. For example, the MLA may be arranged such that the MLA directs light to each color filter 216_i positioned in the photoactive device 102. Directing the light towards each color filter 216_i aids in reducing the amount of light that may stray from the individual color filters 216_i and towards a light shield (e.g., a stack of metal features 212).

[0023] Embodiments of the photoactive device 102 do not implement, however, a traditional MLA. Rather, each color filter 216_i in the photoactive device 102 is shaped to aid in receiving a greater amount of radiation, and directing that radiation directly to a photodiode 206_i, thus reducing or eliminating the need for an MLA. In one embodiment, the radiation receiving surface 218 of each color filter 216_i may be shaped to control the direction of radiation exiting the filter through the radiation exiting surface 220. For example, the radiation receiving surface 218 of each color filter 218_i may be shaped to re-direct the incoming radiation such that the radiation is directed towards a respective photodiode. Shaping the radiation receiving surface 218 means that an entirety of the radiation receiving surface 218 is not flat. In one embodiment, the radiation receiving surface 218 may be etched. For example, the radiation receiving surface 218 may be etched such that the color filter 216_i mimics a meta-lens comprising a plurality of nanofeatures.

[0024] Figure 3 is a logical diagram 300 illustrating components of the photoactive device 102, according to one embodiment. Logical diagram 300 illustrates three color filters 216_r, 216_g, and 216_b. Below the color filters 216_i are one or more light shields 302. For example, the one or more light shields 302 may be a stack of metal features 212. As shown, each light shield 302 partially overlaps one or more color filters 216_i. The light shields 302 are configured to shield light emitted from each color filter 216_i from mixing prior to reaching the photodiodes 206_i positioned thereunder.

[0025] As shown, each color filter 216_i includes a shaped radiation receiving surface 218_i. For example, the color filter 216_r has the shaped radiation receiving surface 218_r, the color filter 216_g has the shaped radiation receiving surface 218_g, and the color filter 216_b has the shaped radiation receiving surface 218_b. In one embodiment, each radiation receiving surface 218_i may include the same patterning. In another embodiment, each radiation receiving surface 218_i may include a unique patterning. As discussed above, the patterning may be in a form that mimics a meta-lens. For example, as shown, the radiation receiving surface 218_g is configured to be patterned such that it mimics a meta-lens comprising a plurality of nanofeatures. As shown, the radiation receiving surface 218_g includes a plurality of nanofeatures 304 etched therein.

[0026] In another embodiment, the shaped radiation receiving surface 218_i may mimic a micro-lens element in an MLA. For example, as illustrated, the radiation receiving surface 218_r is shaped to mimic a micro-lens element, e.g., the radiation receiving surface 218_r has an arc shape. In another embodiment, the radiation receiving surface 218_i may be partially planarized. For example, as shown in the radiation receiving surface 218_b, the radiation receiving surface 218_b is planarized to form a flat polished surface.

[0027] The logical diagram 300 further illustrates radiation paths 306 of incoming radiation 308. For example, the logical diagram 300 includes radiation paths 306₁-306₃ passing through the color filter 216_r, radiation paths 306₄-306₆ passing through the color filter 216_g, and radiation paths 306₇-306₉ passing through the color filter 216_b. As shown, the radiation receiving surface 218_r is arc shaped, such that the color filter 216_r directs the radiation 308 towards the photodiode 206₁. The radiation receiving surface 218_g mimicking a meta-lens directs the radiation 308 towards the photodiode 206₂. The radiation receiving surface 218_b fails, however, in directing the radiation towards the photodiode 206₃, as the radiation receiving surface 218_b is not shaped to change the direction of the radiation paths 306₇-306₉. Accordingly, the radiation 308 is lost as the light shield 302 absorbs the incoming radiation 308.

[0028] Thus, shaping the radiation receiving surfaces 218_i of each color filter 216_i enables the photoactive device 102 to receive a greater amount of radiation, while reducing the overall size of the photoactive device 102 with elimination of the need for an MLA.

[0029] In some embodiments, as shown in Figure 2B, the photoactive device 102 may include a back-illuminated image sensor 250. In this embodiment, the metal layer 210 having the one or more metal features 212 is positioned beneath the substrate 201. For example, the metal layer 210 is covered by the one or more photodiodes 206₁-206₃.

[0030] Figure 4 is a flow diagram illustrating a method 400 of forming a photoactive device, such as the photoactive device 102, according to one example. The method 400 begins at block 402. At block 402 one or more photodiodes are formed on a substrate. For example, one or more photodiodes 216_i are formed on substrate 201. As illustrated in the above examples, the photodiodes 216₁-216₃ are formed on the substrate 201.

[0031] At block 404, a metal layer is deposited on a top surface of the substrate 201 having the one or more photodiodes formed thereon. For example, as illustrated above, the metal layer 210 is deposited on the substrate 201. The metal layer includes one or more metal features formed therein.

[0032] At block 406, a coating layer may be deposited on a top surface of the metal layer. For example, referring to Figure 2A above, the coating layer 215 is deposited on the top surface of the metal layer 210. The coating layer 215 is configured to protect the color filters (positioned in block 408) from the underlying metal layer.

[0033] At block 408, a color filter array is positioned on a top surface of the coating layer 215. For example, the color filter array 214 is positioned on the top surface of the coating layer 215. The color filter array contains a plurality of color filters. Each color filter 216 is configured to allow a pre-defined wave length of radiation to pass therethrough, while blocking all other wave lengths of radiation.

[0034] At block 410, each color filter in the color filter array is shaped. For example, each color filter may undergo a shaping process in which a radiation receiving surface of the color filter is shaped to help direct light towards one of the one or more photodiodes. In one embodiment, each color filter is shaped similarly to one another. In another embodiment, each color filter has a unique shape relative to one another. In yet another embodiment, two or more color filters may have the same shape. Shaping may be in the form of arcing, planarizing, etching, etc., of the radiation receiving surface of the color filter. For example, in one embodiment a shape of the radiation receiving surface 218 may be in the form of a metalens having a plurality of features etched therein. In another example, a shape of the radiation receiving surface 218 may be in the form of an arc. In yet another example, a shape of the radiation receiving surface 218 may be in the form of a partially planarized surface. Generally, a shape of the radiation receiving surface 218 may be any shape that re-directs incoming radiation.

[0035] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

What is claimed is:

1. An apparatus for capturing an image, comprising:
a lens; and
a photoactive device positioned adjacent the lens, the photoactive device comprising:
a substrate;
one or more photodiodes formed in the substrate; and
a color filter array positioned over the substrate, the color filter array having a plurality of color filters, wherein each color filter has a radiation receiving surface that is shaped to re-direct radiation to a respective photodiode.
2. The apparatus of claim 1, wherein the photoactive device further comprises a metal layer positioned between the substrate and the color filter array.
3. The apparatus of claim 2, wherein the metal layer comprises one or more stacks of metal features shielding re-directed radiation from a first color filter from mixing with re-directed radiation from a second color filter.
4. The apparatus of claim 2, wherein the photoactive device further comprises a coating layer positioned between the metal layer and the color filter array.
5. The apparatus of claim 1, wherein one color filter of the color filter array has one radiation receiving surface that comprises a plurality of nanofeatures etched therein.
6. The apparatus of claim 1, wherein one color filter of the color filter array has one radiation receiving surface that is partially planarized.

7. The apparatus of claim 1, wherein one color filter of the color filter array has one radiation receiving surface that is arc-shaped.
8. The apparatus of claim 1, wherein the lens comprises one or more objective lenses.
9. A photoactive device, comprising:
 - a substrate;
 - one or more photodiodes formed in the substrate; and
 - a color filter array positioned over the substrate, the color filter array comprising a plurality of color filters, wherein each color filter has a radiation receiving surface that is shaped to re-direct radiation to a respective photodiode.
10. The photoactive device of claim 9 further comprising a metal layer positioned between the substrate and the color filter array.
11. The photoactive device of claim 10, wherein the metal layer comprises one or more stacks of metal features shielding re-directed radiation from a first color filter from mixing with re-directed radiation from a second color filter.
12. The photoactive device of claim 10, further comprising a coating layer positioned between the metal layer and the color filter array.
13. The photoactive device of claim 9, wherein one color filter of the color filter array has one radiation receiving surface comprises a plurality of nanofeatures etched therein.
14. The apparatus of claim 9, wherein one color filter of the color filter array has one radiation receiving surface that is partially planarized.

15. The photoactive device of claim 9, wherein one color filter of the color filter array has one radiation receiving surface that is arc-shaped.

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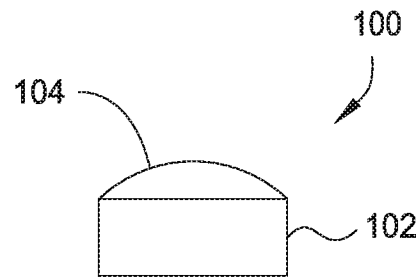


FIG. 1

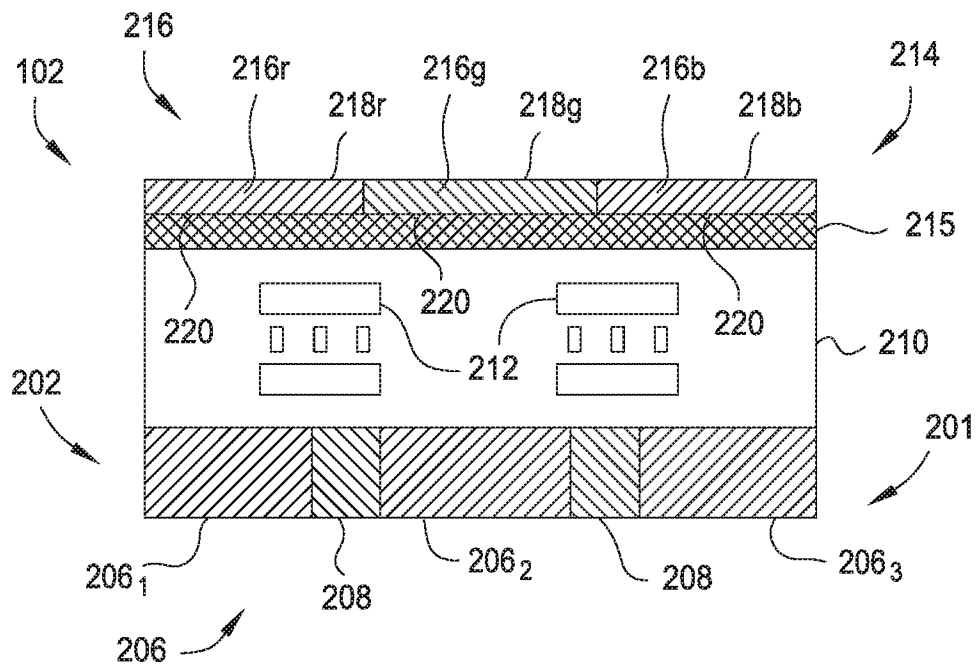


FIG. 2A

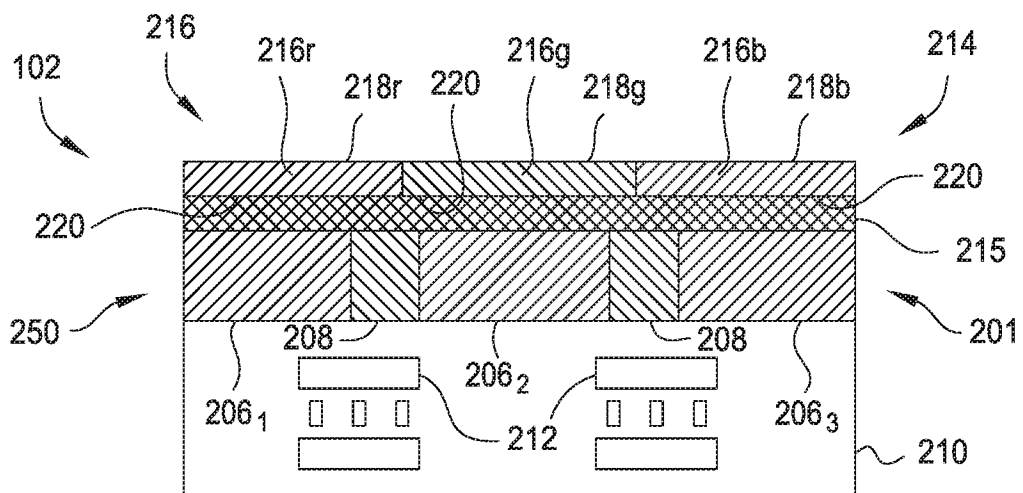
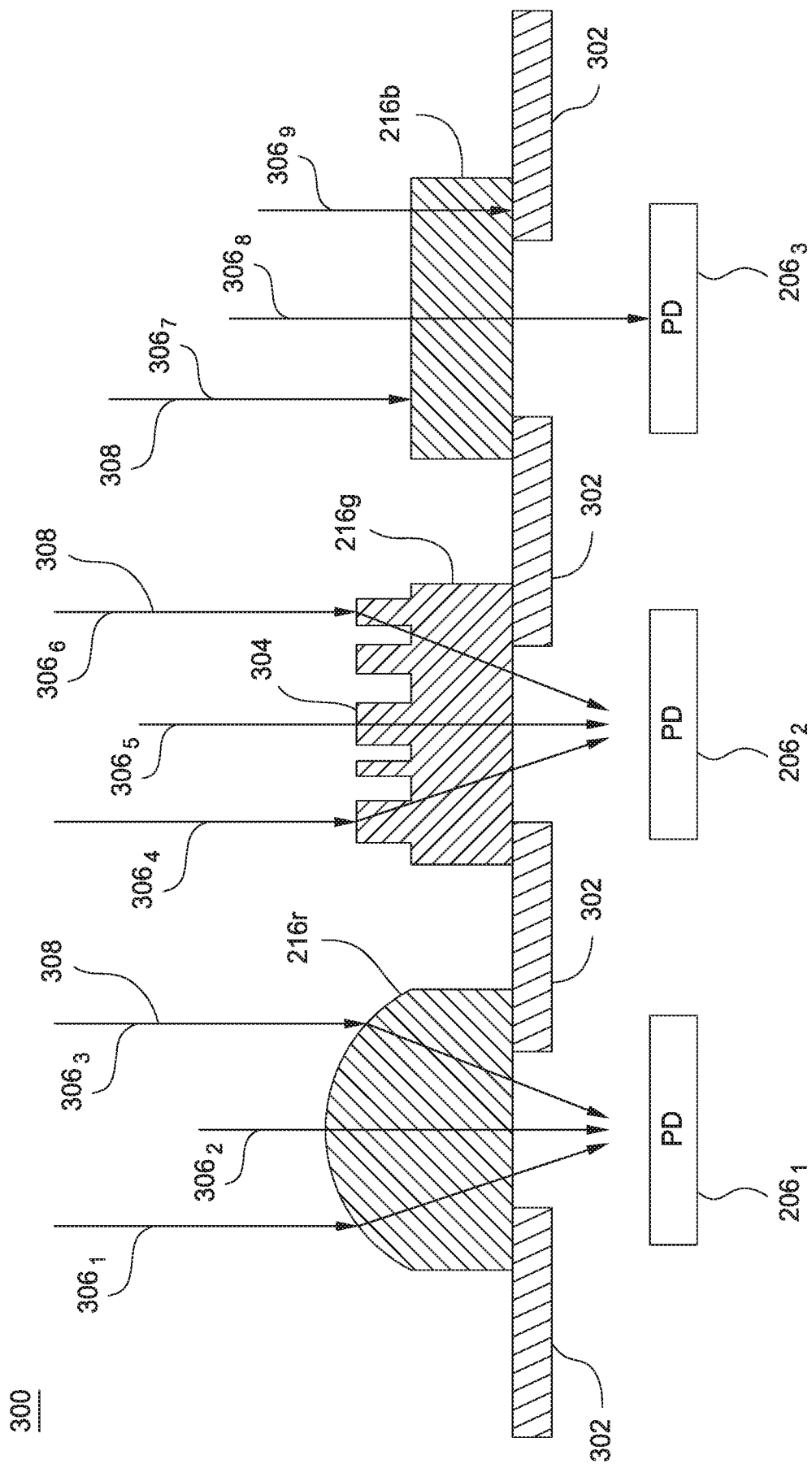


FIG. 2B



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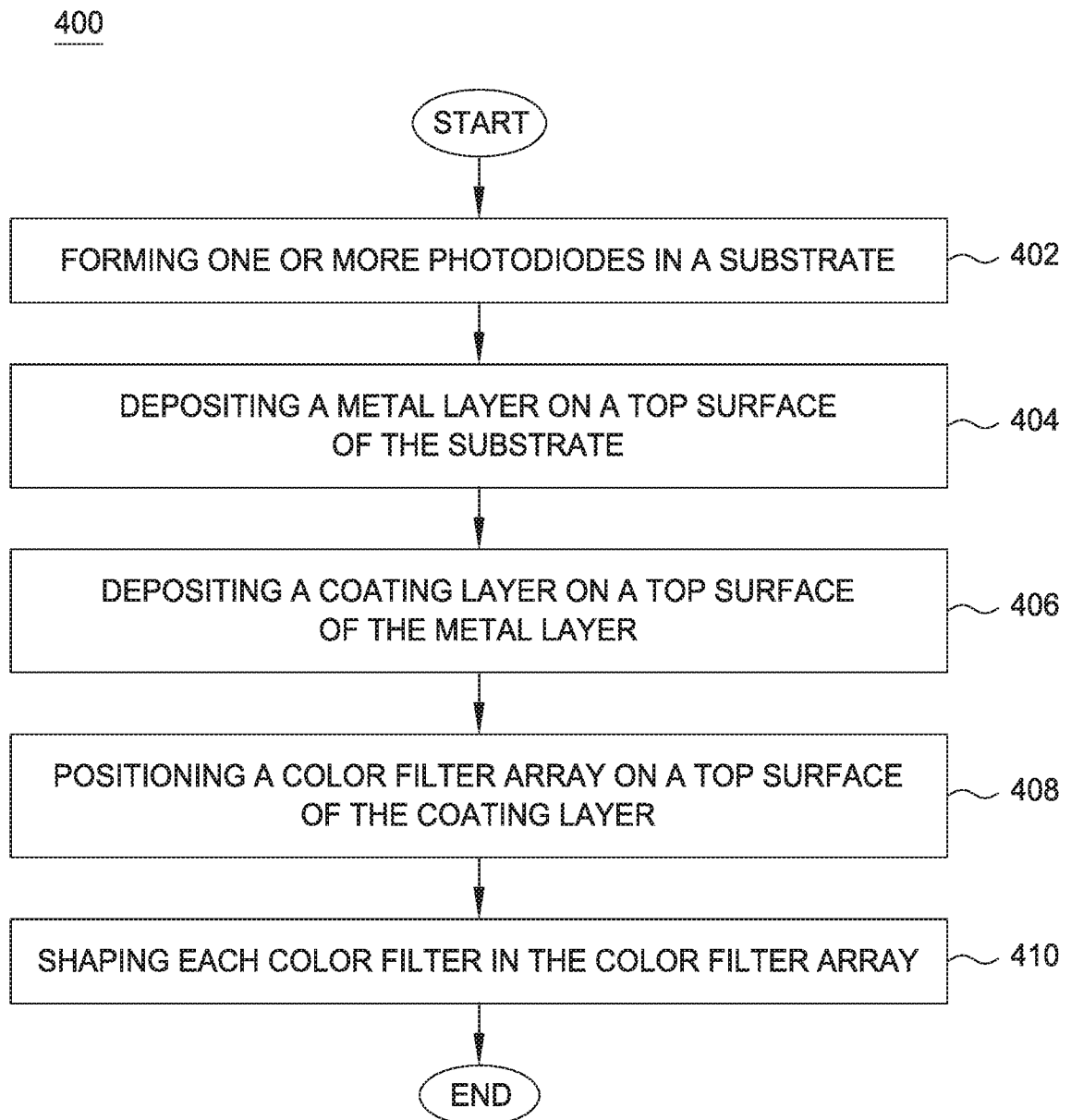


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/041659**A. CLASSIFICATION OF SUBJECT MATTER****H01L 27/146(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 27/146; G02B 3/00; G03F 7/00; H01L 21/00; H01L 31/0216; H01L 31/113; H04N 5/232

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: lens, photodiode, substrate, color, filter, metal, image, sensor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2016-0106337 A (SAMSUNG ELECTRONICS CO., LTD.) 12 September 2016 See paragraphs [0022]-[0049] and figures 1a-1b.	1-15
Y	US 2006-0138485 A1 (MENG AN JUNG) 29 June 2006 See paragraphs [0028]-[0032] and figure 2D.	1-15
A	US 2010-0108866 A1 (CHI-XIANG TSENG et al.) 06 May 2010 See paragraphs [0029]-[0043] and figures 4-10.	1-15
A	US 2015-0062390 A1 (SILICONFILE TECHNOLOGIES INC.) 05 March 2015 See paragraphs [0028]-[0063] and figures 1-6.	1-15
A	US 2008-0090323 A1 (YI-TYNG WU) 17 April 2008 See paragraphs [0040]-[0052] and figures 1-9.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/041659

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-2016-0106337 A	12/09/2016	US 2016-0260762 A1 US 9653501 B2	08/09/2016 16/05/2017
US 2006-0138485 A1	29/06/2006	CN 1794463 A CN 1794463 B KR 10-0672660 B1 KR 10-2006-0073185 A US 2009-0325338 A1 US 7579639 B2	28/06/2006 05/05/2010 24/01/2007 28/06/2006 31/12/2009 25/08/2009
US 2010-0108866 A1	06/05/2010	CN 101740588 A CN 101740588 B TW 201018969 A TW I481912 B US 8164042 B2	16/06/2010 28/12/2011 16/05/2010 21/04/2015 24/04/2012
US 2015-0062390 A1	05/03/2015	CN 104425635 A JP 2015-050467 A KR 10-1373132 B1	18/03/2015 16/03/2015 14/03/2014
US 2008-0090323 A1	17/04/2008	None	