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(54) **APPARATUS AND METHOD FOR REDUCING OPTICAL CROSS-TALK IN IMAGE SENSORS**

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Related U.S. Application Data

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(51) **Int. Cl.**

H01L 31/0232 (2014.01)
H04N 9/04 (2006.01)
H01L 27/146 (2006.01)

(52) **U.S. Cl.**

CPC ***H04N 9/045*** (2013.01); ***H01L 27/1464*** (2013.01); ***H01L 27/14621*** (2013.01); ***H01L 27/14623*** (2013.01); ***H01L 27/14627*** (2013.01); ***H01L 27/14685*** (2013.01)

(58) **Field of Classification Search**

USPC 257/432, E31.127; 438/69
See application file for complete search history.

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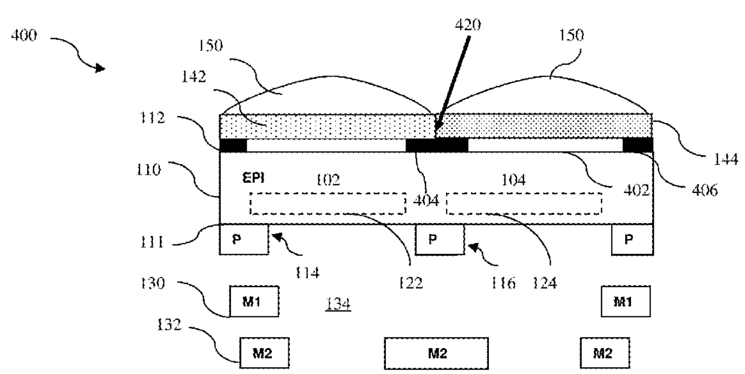
(57) **ABSTRACT**

An image sensor device includes a semiconductor substrate having a front surface and a back surface; an array of pixels formed on the front surface of the semiconductor substrate, each pixel being adapted for sensing light radiation; an array of color filters formed over the plurality of pixels, each color filter being adapted for allowing a wavelength of light radiation to reach at least one of the plurality of pixels; and an array of micro-lens formed over the array of color filters, each micro-lens being adapted for directing light radiation to at least one of the color filters in the array. The array of color filters includes structure adapted for blocking light radiation that is traveling towards a region between adjacent micro-lens.

20 Claims, 8 Drawing Sheets



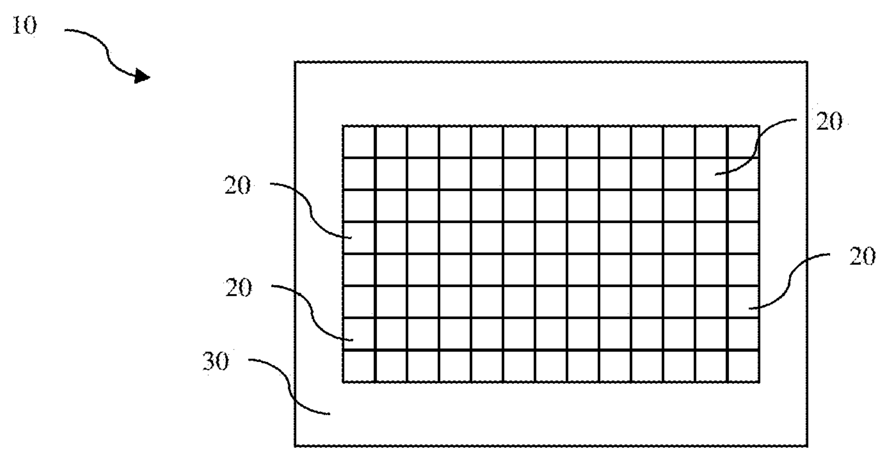


Fig. 1

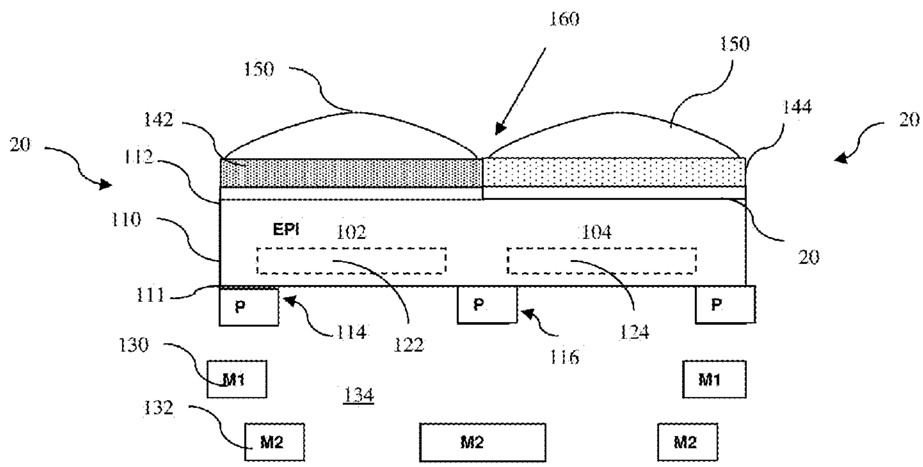

160
150
150
142
144
20
20
112
110
EPI
102
104
20
111
P
P
P
114
122
124
116
130
M1
M1
134
132
M2
M2
M2

Fig. 2A

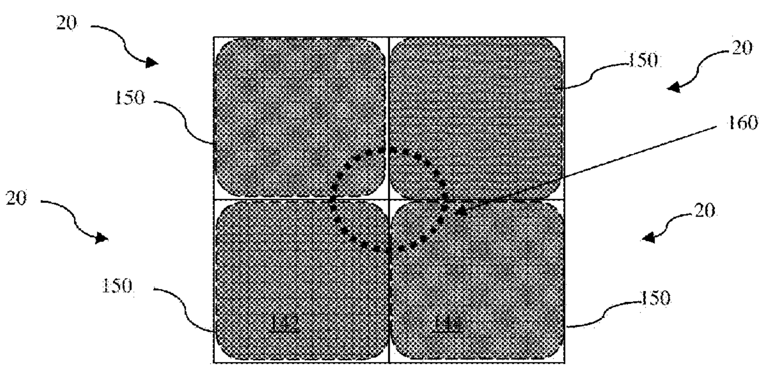

20
150
20
150
160
20
20
150
142
144
150

Fig. 2B

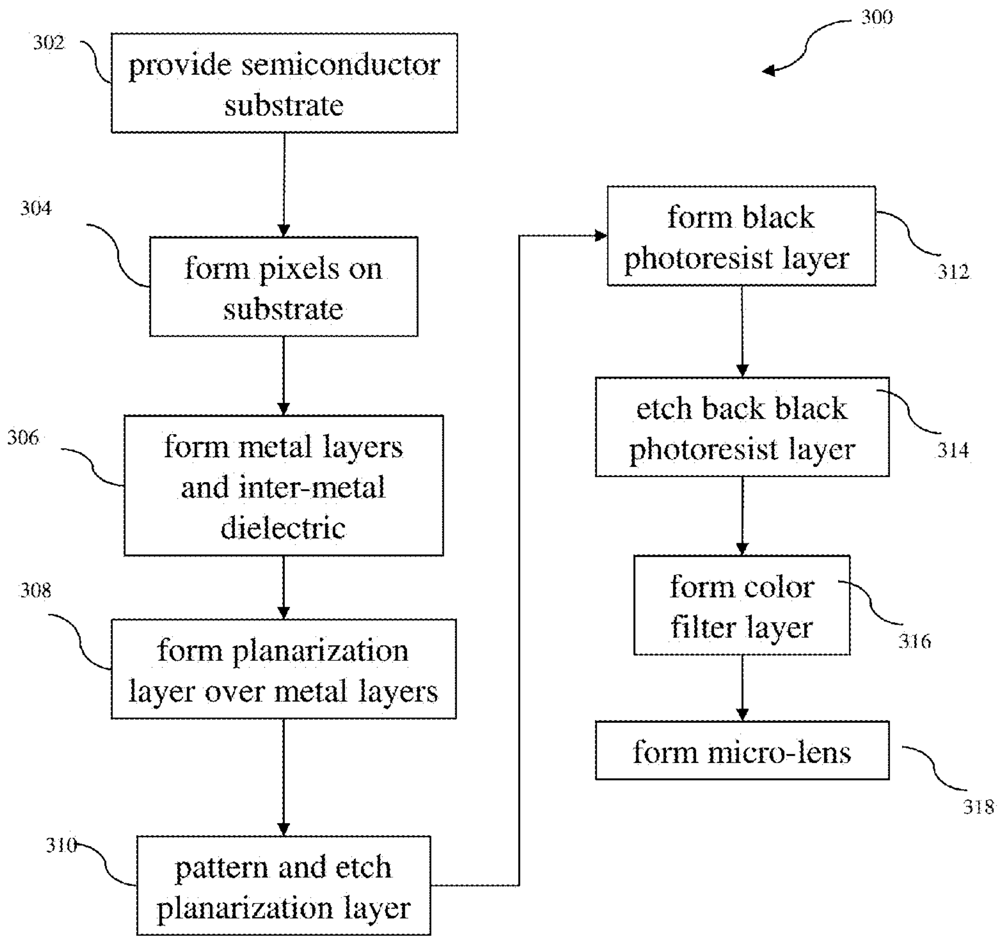

300
302
provide semiconductor substrate
304
form pixels on substrate
306
form metal layers and inter-metal dielectric
308
form planarization layer over metal layers
310
pattern and etch planarization layer
form black photoresist layer
312
etch back black photoresist layer
314
form color filter layer
316
form micro-lens
318

Fig. 3

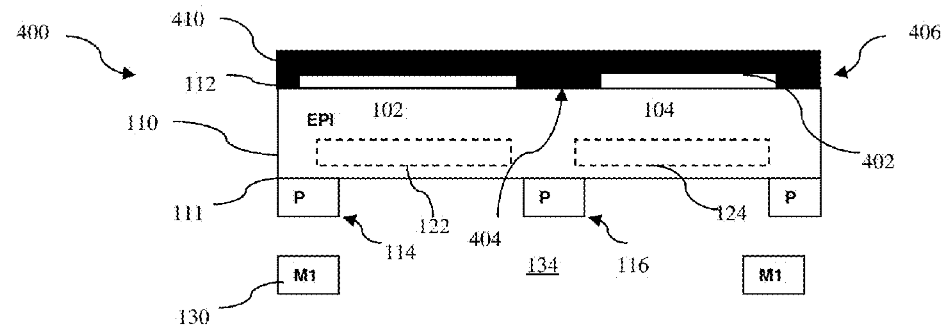

400
410
406
112
EPI
102
104
110
402
111
P
P
P
122
404
124
114
134
116
M1
M1
130

Fig. 4A

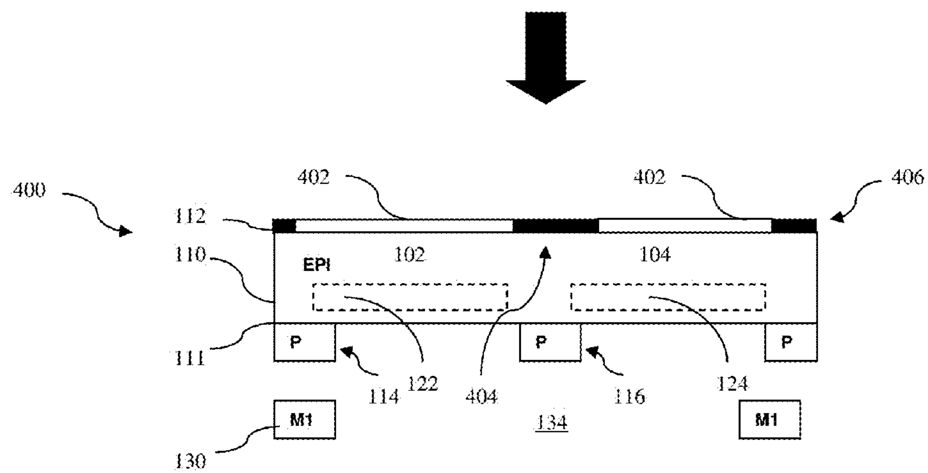
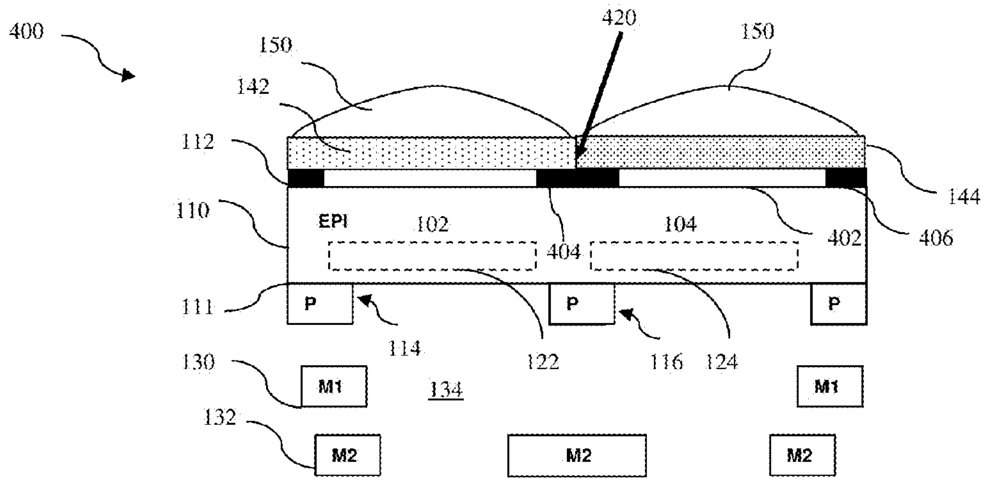

402
402
406
400
112
110
EPI
102
104
111
P
P
P
114
122
404
116
124
M1
134
M1
130

Fig. 4B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420
150
150
142
112
144
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EPI
102
104
402
406
404
111
P
P
P
114
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124
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132
M2
M2
M2

Fig. 4C

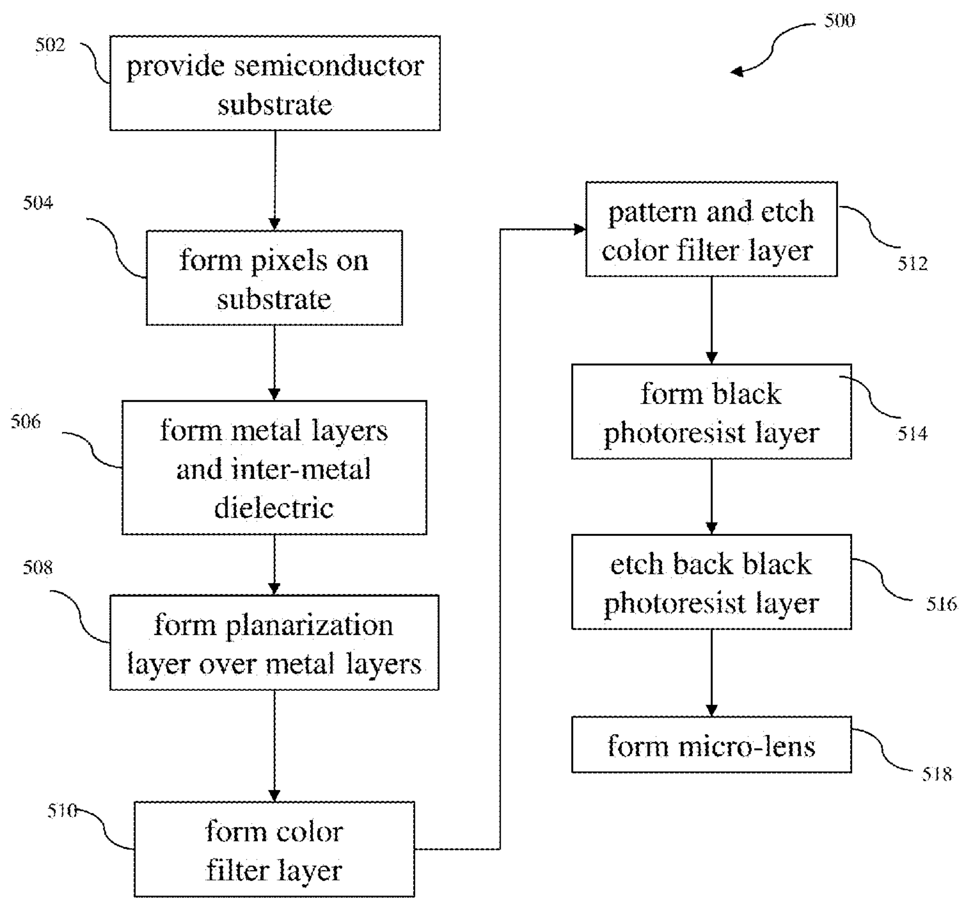
500
502
provide semiconductor substrate
504
form pixels on substrate
506
form metal layers and inter-metal dielectric
508
form planarization layer over metal layers
510
form color filter layer
pattern and etch color filter layer
512
form black photoresist layer
514
etch back black photoresist layer
516
form micro-lens
518

Fig. 5

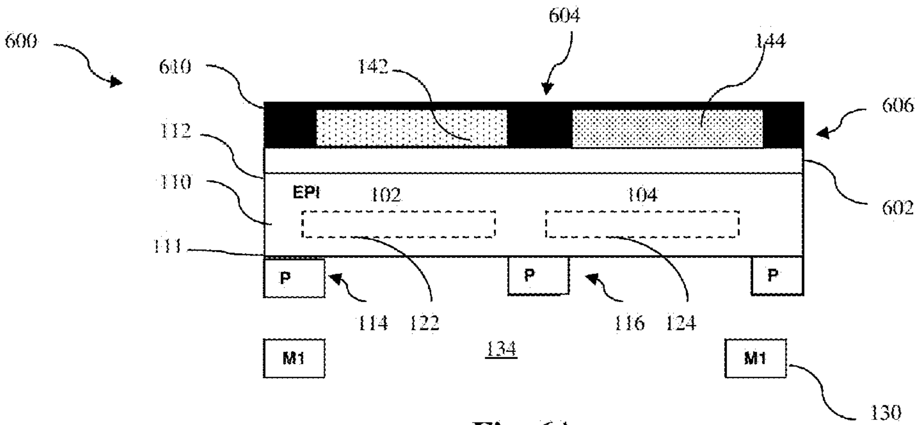
600
610
142
604
144
606
112
602
110
EPI
102
104
111
P
P
P
114
122
116
124
134
M1
M1
130

Fig. 6A

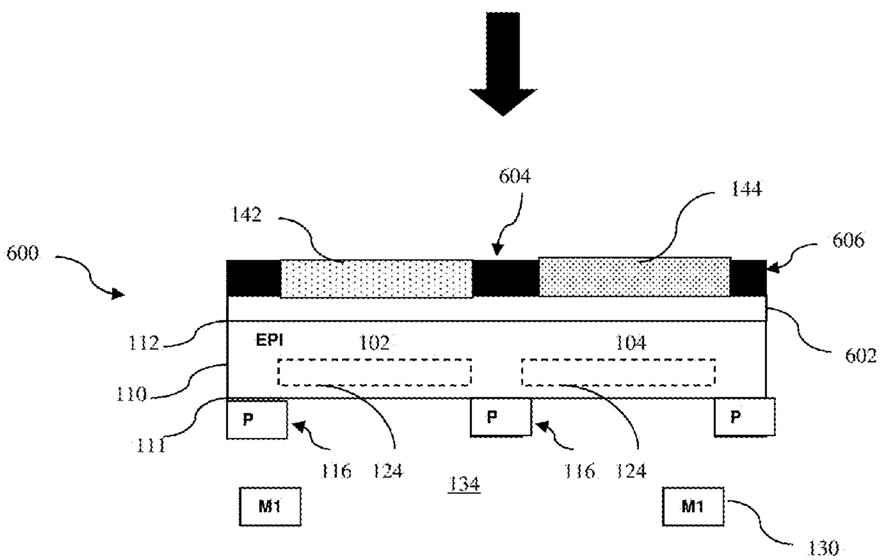
604
144
142
606
600
112
EPI
102
104
602
110
111
P
P
P
116
124
116
124
134
M1
M1
130

Fig. 6B

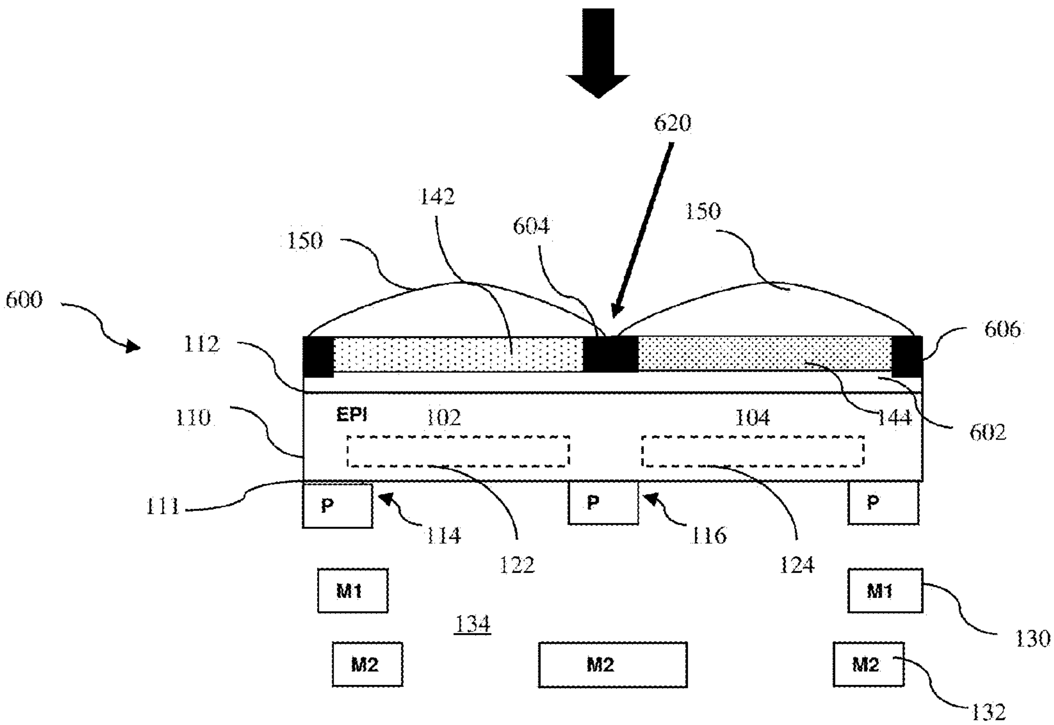
620
142
604
150
150
600
606
112
EPI
102
104
144
602
110
111
P
P
P
114
116
122
124
M1
M1
130
134
M2
M2
M2
132

Fig. 6C

APPARATUS AND METHOD FOR REDUCING OPTICAL CROSS-TALK IN IMAGE SENSORS

CROSS-REFERENCE

This application is a continuation of U.S. Non-provisional patent application Ser. No. 11/779,122, filed on Jul. 17, 2007, which is hereby incorporated by reference in its entirety.

BACKGROUND

The present disclosure relates generally to image sensor devices and, more particularly, to an apparatus and method for reducing optical crosstalk in image sensor devices.

An image sensor provides a grid of pixels which may contain photosensitive diodes or photodiodes, reset transistors, source follower transistors, pinned layer photodiodes, and/or transfer transistors for recording intensity or brightness of light. The pixel responds to the light by accumulating photo-charges—the more light, the more the photo-charges. The charges can then be used by another circuit so that a color and brightness can be used for a suitable application, such as a digital camera. Common types of pixel grids include a charge-coupled device (CCD), a complimentary metal oxide semiconductor (CMOS) image sensor (CIS), an active-pixel sensor (APS), and a passive-pixel sensor.

In order to capture color information, image sensors may employ a color filter layer that incorporates several different color filters (e.g., red, green, and blue), and are positioned such that the incident light is directed through the filter via an array of micro-lens. However, the micro-lens may exhibit poor light control ability at a region between adjacent micro-lens. That is, incident light traveling through this region may not be directed to the appropriate pixel for processing. This may result in optical cross-talk between adjacent pixels and thus, may lead to poor device performance.

Therefore, what is needed is a simple and cost-effective apparatus and method for reducing optical cross-talk in image sensor devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1** is a top view of an image sensor including a plurality of pixels.

FIGS. **2**A & **2**B are cross-sectional and top views, respectively, of part of the image sensor of FIG. **1**.

FIG. **3** is a flowchart of a method of making a back-side illuminated sensor that embodies various aspects of the present disclosure.

FIGS. **4**A-**4**C are cross-sectional views of the back-side illuminated image sensor being processed according to the method of FIG. **4**.

FIG. **5** is a flowchart of a method of making a back-side illuminated sensor according to an alternative embodiment of the present disclosure.

FIGS. **6**A-**6**C are cross-sectional views of the back-side illuminated image sensor being processed according to the method of FIG. **5**.

DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

Referring to FIG. **1**, illustrated is a top view of an image sensor **10** including a plurality of pixels **20**. Additional circuitry and input/outputs **30** are typically provided adjacent to the grid of pixels **20** for providing an operation environment for the pixels and for supporting external communications with the pixels. The image sensor **10** may include a charge-coupled device (CCD), complimentary metal oxide semiconductor (CMOS) image sensor (CIS), an active-pixel sensor (APS), and a passive-pixel sensor.

Referring to FIGS. **2**A and **2**B, illustrated are cross-sectional and top views, respectively, of two adjacent pixels **20** of the image sensor **10** FIG. **1**. In the present example, the adjacent pixels include a first pixel **102** and a second pixel **104** for sensing visible light. It is understood that the use of visible light is a mere example and that other types of radiation such as infrared (IR), microwave, X-ray, and ultraviolet (UV) may be used in other types of applications. The pixels **102** and **104** may be formed on a semiconductor substrate **110**. The substrate **110** may include a front surface **111** and a back surface **112**. The substrate **110** may comprise an elementary semiconductor such as silicon, germanium, and diamond. Alternatively, the substrate **110** may optionally comprise a compound semiconductor such as silicon carbide, gallium arsenic, indium arsenide, and indium phosphide. Additionally, semiconductor substrate types such as silicon-on-insulator (SOI) and/or an epitaxial layer may be utilized.

The pixels **102** and **104** may each comprise of a photodiode and at least one transistor **114** and **116** for sensing and recording an intensity of light. An example of a photodiode that can be used in this embodiment is shown in U.S. patent application Ser. No. 11/291,880, filed on Dec. 1, 2005, which is hereby incorporated by reference. For example, the substrate **110** may comprises a P-type silicon. A silicon epitaxial layer (epilayer or epi) may be grown on the substrate **110** by a method such as chemical vapor deposition (CVD). The epilayer may have a lower concentration of dopant than that of the heavily doped P-type silicon substrate **110**. The photodiode includes a light-sensing region which in the present embodiment is an N-type doped region **122** and **124** having dopants formed in the silicon epilayer. All doping may be implemented using a process such as ion implantation or diffusion in various steps and techniques. It is understood that all doping may be reversed accordingly such as providing an N-type silicon substrate having an epilayer with a P-type light-sensing region.

The substrate **110** may also comprise lateral isolation features (not shown) such as shallow trench isolation (STI) features to separate the pixels and/or other devices formed on the substrate. These other devices may include various doped regions each having an N-type or P-type, such as an N-well or P-well. Even though the present example describes a photodiode, it is understood that other types of pixels may be used. Other types of pixels include, but are not limited to, pinned photodiodes, photo transistors (e.g., p/n/p or n/p/n), and photogates. Additionally, configurations such as a 4T active pixel including a photodiode and four transistors (e.g., transfer gate transistor, reset transistor, source follower transistor, and select transistor) or pixel types using 4T operating concepts (e.g., sharing reset transistor and source follower transistor for several pixels) may be used for the pixels. Additional circuitry also exists to provide an appropriate functionality to handle the type of pixels **100** being used and the type of light being sensed.

The image sensor **10** includes a plurality of interconnect metal layers including first and second interconnect metal layers **130** and **132**, respectively, overlying the pixels **102** and **104**. The metal layers **130** and **132** may be used for interconnecting various devices formed on the substrate **110**. The metal layers **130** and **132** may comprise of conductive materials such as aluminum, aluminum alloy, copper, copper alloy, titanium, titanium nitride, tungsten, polysilion, metal silicide, and/or combinations thereof. The image sensor **10** may further include an inter-metal dielectric **134** for insulating the interconnecting metal layers **130** and **132** disposed therein. The inter-metal dielectric **134** may comprise of a low-k dielectric material such as a material having a dielectric constant (k) less than about 3.5. The inter-metal dielectric **134** may comprise of carbon-doped silicon oxide, fluorine-doped silicon oxide, silicon nitride, silicon oxynitride, polymide, spin-on glass, amorphous fluorinated carbon, and/or other suitable materials. Even though two metal layers **130** and **132** and inter-metal dielectric **134** is disclosed herein for clarity and simplicity, it is understood that multiple metal layers and inter-metal dielectric are typically used in an image sensor device.

The image sensor **10** further includes a color filter layer overlying the back surface **112** of the substrate **110**. In the present example, the color filter layer includes a first color filter **142** for filtering through visible light of a first wavelength (e.g., red, blue, green light) to the first pixel **102**, and a second color filter **144** for filtering through visible light of a second wavelength (e.g., red, blue, green light) to the second pixel **104**. The color filters **142** and **144** may comprise of a dye-based (or pigment-based) polymer for filtering out a specific frequency band (e.g., desired wavelength of light). Alternatively, the color filters **142** and **144** may optionally comprise of a resin or other organic-based material having color pigments.

The image sensor **10** further includes a plurality of micro-lens **150**. The micro-lens **150** may be positioned in various arrangements overlying the color filters **142** and **144** and pixels **102** and **104**. The micro-lens **150** may have a variety of shapes depending on the refractive index of material used for the micro-lens and the distance from the sensor surface to the micro-lens.

In operation, the image sensor **10** is designed to receive light radiation traveling towards the back surface **112** of the semiconductor substrate **110**. The visible light is directed towards the color filters **142** and **144** by the micro-lens **150**. The light passing through to the color filters **142** and **144** and

pixels **102** and **104** may be maximized since the light is not obstructed by various device features (e.g., gates electrodes) or metal features (e.g., the metal layers **130** and **132**) overlying the front surface **111** of the substrate **110**. The desired wavelength of light (e.g., red, green, blue light) that is allowed to pass through to the respective pixel **102** and **104**, induces a photocurrent which may be recorded and processed. However, there is a region **160** between adjacent micro-lens **150** where the micro-lens exhibit poor light control ability. That is, light traveling through this region **160** may not be directed to the appropriate pixel for processing. As such, optical cross-talk between adjacent pixels may occur and thus, may lead to poor device performance.

Referring to FIGS. **3**, and **4**A through **4**C, illustrated are a flowchart of a method **300** for making a back-side illuminated image sensor device **400**, and cross-sectional views of the image sensor **400** being processed at various stages according to the method **300**. The image sensor **400** of FIG. **4** is similar to the image sensor **10** of FIGS. **1-2** except for the features disclosed below. Similar features in FIGS. **4** and **1-2** are numbered the same for clarity. In FIG. **3**, the method **300** begins with step **302** in which a semiconductor substrate **110** may be provided with a front surface **111** and a back surface **112**. The substrate **110** may include an epilayer formed thereon. The method **300** continues with step **304** in which a plurality of pixels **102** and **104** may be formed on the substrate **110**, each pixel having a light-sensing element **122** and **124** such as a photodiode, and at least one transistor **114** and **116**. The process of forming the pixels is known in the art and thus, not described in detail here.

The method **300** continues with step **306** in which interconnect metal layers **130** and **132** and an inter-metal dielectric **134** may be formed over the substrate **110**. The process of forming the interconnect metal layers and inter-metal dielectric is known in the art and thus, not described in detail here. The method **300** continues with step **308** in which a planarization layer **402** may be formed over the back surface **112** of the substrate **110**. The planarization layer **402** may include silicon oxide. Alternatively, the planarization layer **402** may optionally include silicon nitride, silicon oxynitride, or other suitable material. The planaraization layer **402** may be formed by a suitable deposition or spin-coating process known in the art. The method **300** continues with step **310** in which the planarization layer **402** may be patterned by photolithography and etched to define open regions **404** and **406** within the planarization layer. The open regions **404** and **406** may have a width of about 0.2 μm. Alternatively, the open regions **404** and **406** may optionally have a width smaller than 0.2 μm.

In FIG. **4**A, the method **300** continues with step **312** in which a black photoresist layer **410** may be formed over the patterned planarization layer **402**. Accordingly, the black photoresist layer **410** may fill in the regions **404** and **406** within the planarization layer **402**. The black photoresist layer **410** may be formed by a deposition process, spin-coating process, or other suitable process. Alternatively, other suitable opaque materials may optionally be used instead of the black photoresist. In FIG. **4**B, the method **300** continues with step **314** in which the black photoresist layer **410** may be etched back until the planarization layer **402** is exposed. The etch back process includes an etching species that selectively removes the black photoresist layer **410** and uses the planarization layer **402** as an etch stop layer.

In FIG. **4**C, the method **300** continues with step **316** in which a color filter layer including color filters **142** and **144** may be formed over the patterned planarization layer **402**. The color filter layer may be configured such that a region between adjacent color filters **142** and **144** substantially overlies the regions **404** and **406** within the planarization layer **402** that are filled with the black photoresist. The method **300** continues with step **318** in which a plurality of micro-lens **150** may be formed over the color filter layer. The micro-lens **150** are configured to direct light radiation traveling towards the back surface **112** of the substrate **110** to the corresponding pixels **102** and **104**. The micro-lens **150** may be configured such that a region between adjacent micro-lens **150** substantially overlies the regions **404** and **406** within the planarization layer **402** that are filled with the black photoresist.

In operation, the image sensor **400** is designed to receive light radiation traveling towards the back surface **112** of the semiconductor substrate **110**. The light is directed towards the color filters **142** and **144** by the micro-lens **150**. The light passing through to the color filters **142** and **144** and pixels **102** and **104** may be maximized since the light is not obstructed by various device features (e.g., gates electrodes) or metal features (e.g., the metal layers **130** and **132**) overlying the front surface **111** of the substrate **110**. The desired wavelength of light (e.g., red, green, blue light) that is allowed to pass through to the respective pixel **102** and **104**, induces a photocurrent which may be recorded and processed. There is a region **420** between adjacent micro-lens **150** where the micro-lens exhibit poor light control ability. That is, light traveling through this region **420** may not be directed to the appropriate pixel for processing. However, in the present embodiment, the light traveling through this region **420** may be shielded or blocked by the regions **404** and **406** within the planarization layer **402** that are filled with the black photoresist. As such, the regions **404** and **406** within planarization layer **402** may minimize optical cross-talk between adjacent pixels.

Referring to FIGS. **5**, and **6**A through **6**C, illustrated are a flowchart of a method **500** for making a back-side illuminated image sensor device **600**, and cross-sectional views of the image sensor **600** being processed at various stages according to the method **500**. The image sensor **600** of FIG. **6** is similar to the image sensor **10** of FIGS. **1-2** except for the features disclosed below. Similar features in FIGS. **6** and **1-2** are numbered the same for clarity. In FIG. **5**, the method **500** begins with step **502** in which a substrate **110** may be provided with a front surface **111** and a back surface **112**. The substrate **110** may include an epilayer formed thereon. The method **500** continues with step **504** in which a plurality of pixels **102** and **104** may be formed on the substrate **110**, each pixel having a light-sensing element **122** and **124** such as a photodiode, and at least one transistor **114** and **116**. The process of forming the pixels is known in the art and thus, not described in detail here.

The method **500** continues with step **506** in which interconnect metal layers **130** and **132** and an inter-metal dielectric **134** may be formed over the substrate **110**. The process of forming the interconnect metal layers and inter-metal dielectric is known in the art and thus, not described in detail here. The method **500** continues with step **508** in which a planarization layer **602** may be formed over the back surface **112** of the substrate **110**. The planarization layer **602** may include silicon oxide. Alternatively, the planarization layer **602** may optionally include silicon nitride, silicon oxynitride, or other suitable material. The planaraization layer **602** may be formed by a suitable deposition or spin-coating process known in the art.

The method **500** continues with step **510** in which a color filter layer may be formed over the planarization layer **602**. The color filter layer includes a first color filter **142** for filtering through visible light of a first wavelength (e.g., red, blue, green light) to the first pixel **102**, and a second color filter **144** for filtering through visible light of a second wavelength (e.g., red, blue, green light) to the second pixel **104**. The color filters **142** and **144** may comprise of a dye-based (or pigment-based) polymer for filtering out a specific frequency band (e.g., desired wavelength of light). Alternatively, the color filters **142** and **144** may optionally comprise of a resin or other organic-based material having color pigments. The process of forming the color filter layer is known in the art, and thus, not described in detail here.

The method **500** continues with step **512** in which the color filter layer may be patterned by photolithography and etched to define open regions **604** and **606** within the color filter layer. The open regions **604** and **606** are located between adjacent color filters **142** and **144**. The open regions **604** and **606** may have a width of about 0.2 μm. Alternatively, the open regions **604** and **606** may optionally have a width smaller than 0.2 μm. In FIG. **6**A, the method **500** continues with step **514** in which in which a black photoresist layer **610** may be formed over the patterned color filter layer. Accordingly, the black photoresist layer **610** may fill in the regions **604** and **606** between adjacent color filters **142** and **144**. The black photoresist layer **610** may be formed by a deposition process, spin-coating process, or other suitable process. Alternatively, other suitable opaque materials may optionally be used instead of the black photoresist.

In FIG. **6**B, the method **500** continues with step **516** in which the black photoresist layer **610** may be etched back until the color filters **142** and **144** are exposed. The etch back process includes an etching species that selectively removes the black photoresist layer **110** and uses the color filter layer as an etch stop layer. In FIG. **6**C, the method **500** continues with step **518** in which a plurality of micro-lens **150** may be formed over the color filter layer. The micro-lens **150** are configured to direct light radiation traveling towards the back surface **112** of the substrate **110** to the corresponding pixels **102** and **104**. The micro-lens **150** may be configured such that a region between adjacent micro-lens **150** substantially overlies the regions **604** and **606** within the color filter layer that are filled with the black photoresist.

In operation, the image sensor **600** is designed to receive light radiation traveling towards the back surface **112** of the semiconductor substrate **110**. The light is directed towards the color filters **142** and **144** by the micro-lens **150**. The light passing through to the color filters **142** and **144** and pixels **102** and **104** may be maximized since the light is not obstructed by various device features (e.g., gates electrodes) or metal features (e.g., the metal layers **130** and **132**) overlying the front surface **111** of the substrate **110**. The desired wavelength of light (e.g., red, green, blue light) that is allowed to pass through to the respective pixel **102** and **104**, induces a photocurrent which may be recorded and processed. There is a region **620** between adjacent micro-lens **150** where the micro-lens exhibit poor light control ability. That is, light traveling through this region **620** may not be directed to the appropriate pixel for processing. However, in the present embodiment, the light traveling through this region **620** may be shielded or blocked by the regions **604** and **606** within the color filter layer that are filled with the black photoresist. As such, the regions **604** and **606** between adjacent color filters **142** and **144** may minimize optical cross-talk between adjacent pixels **102** and **104**.

Thus, provided is an image sensor and method for making the same. In one embodiment, an image sensor device includes a semiconductor substrate having a front surface and a back surface; a plurality of pixels formed on the front surface of the semiconductor substrate, each pixel being adapted for sensing light radiation; an array of color filters formed over the plurality of pixels, each color filter being adapted for allowing a wavelength of light radiation to reach at least one of the plurality of pixels; and a plurality of micro-lens formed over the array of color filters, each micro-lens being adapted for directing light radiation to at least one of the color filters in the array. The array of color filters further includes structure adapted for blocking light radiation that is traveling towards a region between adjacent micro-lens. In some embodiments, the array of color filters is formed over the back surface of the substrate. In some other embodiments, the structure includes a black photoresist disposed in a space between adjacent color filters in the array.

In other embodiments, the image sensor device further includes a planarization layer formed between the back surface of the substrate and the array of color filters. In still other embodiments, the structure includes a planarization layer having a transparent portion and an opaque portion, the planarization layer being disposed between the back surface of the substrate and a bottom surface of the array of color filters, the opaque portion being disposed underneath an area between adjacent color filters. In some other embodiments, the opaque portion includes a black photoresist. In other embodiments, the transparent portion is one of a silicon oxide, a silicon nitride, a silicon oxynitride, or combinations thereof. In other embodiments, the structure has a width that is equal to about 0.2 μm. In still other embodiments, the device further includes a plurality of interconnect metal layers formed over the front surface of the substrate; and an inter-metal dielectric disposed between each of the plurality of metal layers.

Also provided is one embodiment of a method for making an image sensor device. The method includes the steps of: providing a semiconductor substrate having a front surface and a back surface; forming a plurality of pixels on the front surface of the semiconductor substrate, each pixel being adapted for sensing light radiation; forming an array of color filters over the plurality of pixels, each color filter being adapted for allowing a wavelength of light radiation to reach at least one of the plurality of pixels; and forming a plurality of micro-lens over the array of color filters, each micro-lens being adapted for directing light radiation to at least one of the color filters in the array. The step of forming the array of color filters further includes forming the array of color filters with structure adapted for blocking light radiation traveling towards a region between adjacent micro-lens.

In some embodiments, the step of forming the array of color filters with the structure includes: forming a planarization layer on the back surface of the substrate; patterning the planarization layer to define a space within the planarization layer; forming a layer of an opaque material over the patterned planarization layer; etching back the opaque material until the planarization layer is exposed; and forming a color filter layer over the planarization layer such that the space filled with the opaque material is disposed underneath an area between adjacent color filters. In some embodiments, the step of forming the layer of opaque material includes forming a layer of a black photoresist.

In some other embodiments, the step of forming the array of color filters with the structure includes: forming a planarization layer on the back surface of the substrate; forming a color filter layer over the planarization layer; patterning the color filter layer to define a space between adjacent color filters; forming a layer of an opaque material over the patterned color filter layer; and etching back the opaque material until the color filter layer is exposed. In some embodiments, the step of forming the layer of opaque material includes forming a layer of a black photoresist. In still other embodiments, the method further includes: forming a plurality of metal layers over the front surface of the substrate; and forming an intermetal dielectric between each of the plurality of metal layers.

Also provided is a semiconductor device including a substrate having a front surface and a back surface; a plurality of pixels formed on the front surface of the substrate, each pixel being adapted to sense light radiation directed towards the back surface of the substrate; an array of color filters formed over the back surface of the substrate, each color filter being aligned with one of the plurality of pixels for allowing a wavelength of light radiation to pass through to the one of the plurality of pixels; a plurality of micro-lens formed over the array of color filters, each micro-lens being adapted to direct light radiation to each color filter in the array; and a blocking structure disposed between the back surface of the substrate and the plurality of micro-lens, the blocking structure being adapted to block light radiation traveling towards a region between adjacent micro-lens from reaching the pixels.

In some embodiments, the blocking structure includes a black photoresist disposed in a region between adjacent color filters. In some other embodiments, the blocking structure includes a planarization layer formed between the back surface of the substrate and a bottom surface of the array of color filters, the planarization layer having a black photoresist disposed underneath an area between adjacent color filters. In still other embodiments, the wavelength of light is one of a red light, a green light, and a blue light. In other embodiments, each pixel includes a photodiode and at least one transistor.

The foregoing has outlined features of several embodiments so that those skilled in the art may better understand the detailed description that follows. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. For example, the color filters disclosed may be configured to filter through other colors such as cyan, yellow, and magenta, or other types of light radiation such as infrared (IR), microwave, X-ray, and ultraviolet (UV). Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

Several different advantages exist from these and other embodiments. In addition to providing an efficient and cost-effective apparatus and method for reducing optical cross-talk in image sensors, the apparatus and method disclosed herein can easily be integrated with current semiconductor processing equipment and techniques. In addition, the apparatus and method disclosed herein utilizes a black photoresist material that does not exhibit good resolution in photolithography for small feature sizes. As such, the apparatus and method disclosed herein may be implemented even as pixel sizes continue to decrease with emerging technologies.

What is claimed is:

1. An image sensor device, comprising:

a semiconductor substrate having a front surface and a back surface;

a plurality of pixels formed on the front surface of the semiconductor substrate, each pixel being adapted for sensing light radiation;

a first layer including an array of color filters formed over the plurality of pixels, each color filter being adapted for allowing a wavelength of light radiation to reach at least one of the plurality of pixels;

a plurality of micro-lens formed over the array of color filters, each micro-lens being adapted for directing light radiation to at least one of the color filters in the array; and

a second layer between the pixels and the color filters that includes transparent material;

wherein the second layer further includes a structure adapted for blocking light radiation that is traveling towards a region between adjacent micro-lens, further wherein the plurality of micro-lens are in contact with the array of color filters, and wherein the structure and the transparent material are coplanar at respective top surfaces and bottom surfaces thereof, and further wherein the structure directly contacts a bottom surface of at least one of the color filters.

2. The device of claim **1**, wherein the array of color filters is formed over the back surface of the substrate.

3. The device of claim **2**, wherein the structure includes a black photoresist disposed in a space between portions of the transparent material.

4. The device of claim **3**, wherein the transparent material comprises a planarization layer formed between the back surface of the substrate and the array of color filters.

5. The device of claim **3**, wherein the micro-lens are configured such that a region between adjacent micro-lens overlies the structure.

6. The device of claim **1**, wherein the structure has a width that is less than or equal to about 0.2 μm.

7. The device of claim **1**, further comprising:

a plurality of interconnect metal layers formed over the front surface of the substrate; and

an inter-metal dielectric disposed between each of the plurality of metal layers.

8. A semiconductor device, comprising:

a substrate having a front surface and a back surface;

a plurality of pixels formed on the front surface of the substrate, each pixel being adapted to sense light radiation directed towards the back surface of the substrate;

an array of color filters formed over the back surface of the substrate, each color filter being aligned with one of the plurality of pixels for allowing a wavelength of light radiation to pass through to the one of the plurality of pixels;

a plurality of micro-lens formed over the array of color filters, each micro-lens being adapted to direct light radiation to each color filter in the array;

a layer between the pixels and the color filters that includes a transparent portion; and

a blocking structure within the layer and disposed between the back surface of the substrate and the plurality of micro-lens, the blocking structure being adapted to block light radiation traveling towards a region between adjacent micro-lens from reaching the pixels, further wherein the plurality of micro-lens are in contact with the array of color filters, and wherein the blocking structure and the transparent portion are coplanar at respective top surfaces and bottom surfaces thereof, and further wherein the blocking structure directly contacts a bottom surface of at least one of the color filters.

9. The device of claim **8**, wherein the blocking structure includes a black photoresist disposed in the layer.

10. The device of claim **8**, wherein the layer comprises a planarization layer formed between the back surface of the substrate and a bottom surface of the array of color filters, the planarization layer having a black photoresist disposed underneath an area between adjacent color filters.

11. The device of claim **8**, wherein the wavelength of light is one of a red light, a green light, and a blue light.

12. The device of claim **11**, wherein each pixel includes a photodiode and at least one transistor.

13. The device of claim **8**, wherein the array of color filters are adjacent and the plurality of micro-lens are adjacent.

14. The device of claim **13**, wherein the micro-lens are configured such that a region between adjacent micro-lens overlies the structure.

15. The device of claim **8**, wherein the transparent portion is one of a silicon oxide, a silicon nitride, a silicon oxynitride, or combinations thereof.

16. An image sensor device, comprising:

a semiconductor substrate having a front surface and a back surface;

a plurality of pixels on the front surface of the semiconductor substrate, each pixel being adapted for sensing light radiation;

an array of color filters over the plurality of pixels, each color filter being adapted for allowing a wavelength of light radiation to reach at least one of the plurality of pixels;

a plurality of micro-lens over the array of color filters, each micro-lens being adapted for directing light radiation to at least one of the color filters in the array; and

a structure disposed in a layer of transparent material between the pixels and the color filters and positioned for blocking light radiation traveling towards a region between adjacent micro-lens, wherein the layer of transparent material and the structure are coplanar at a top surface and a bottom surface thereof, and further wherein the structure directly contacts a bottom surface of at least one of the color filters.

17. The device of claim **16**, wherein the array of color filters includes a space filled with an opaque material disposed underneath an area between adjacent color filters.

18. The device of claim **17**, wherein the opaque material includes a black photoresist.

19. The device of claim **16**, wherein the micro-lens are configured such that a region between adjacent micro-lens overlies the structure.

20. The device of claim **16**, further comprising:

a plurality of metal layers over the front surface of the substrate; and

an intermetal dielectric between each of the plurality of metal layers.

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