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(54) **CMOS IMAGE SENSOR AND METHOD FOR FABRICATING THE SAME**

Publication Classification

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(57) **ABSTRACT**

A CMOS image sensor and method for fabricating the same improve image characteristics by eliminating the thickness of a planarization layer. The CMOS image sensor includes a semiconductor substrate; a plurality of active devices, provided in a predetermined surface of the semiconductor substrate, for generating electrical charges according to an amount of incident light; an insulating interlayer formed on an entire surface of the semiconductor substrate including the plurality of active devices; a color filter layer formed on the insulating interlayer, the color filter layer comprised of red, green, and blue color filter patterns for respectively filtering light according to wavelength, the color filter patterns arranged to correspond to the plurality of active devices; and a plurality of microlenses formed on the color filter layer, wherein the color filter layer is planarized so that each color filter pattern of the color filter layer is imparted with an equal height for receiving the plurality of microlenses.

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(63) Continuation of application No. 11/319,184, filed on Dec. 28, 2005, now Pat. No. 7,341,885.

Foreign Application Priority Data

(30) Dec. 29, 2004 (KR) 2004-0114658

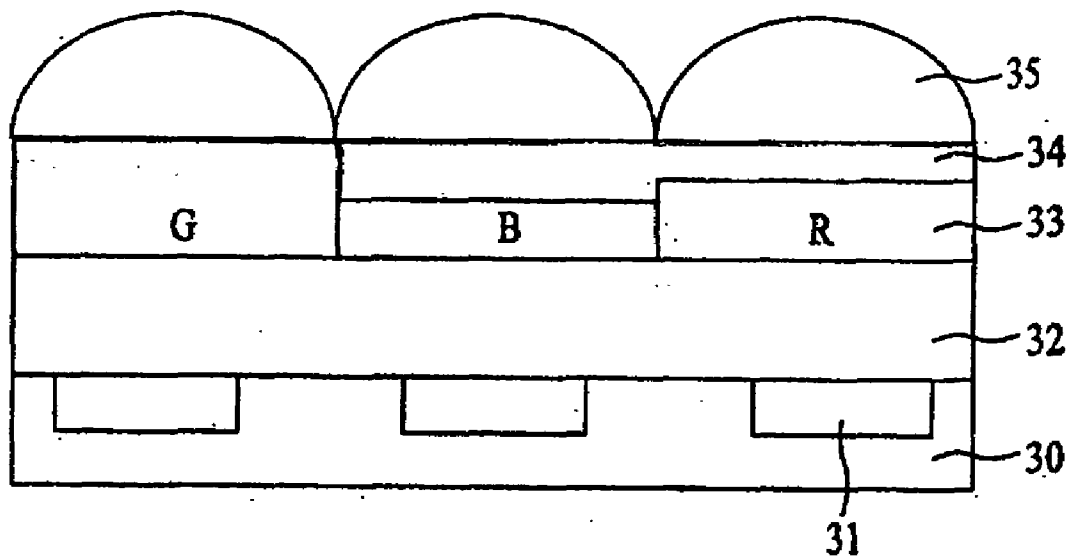


FIG. 1
Related Art

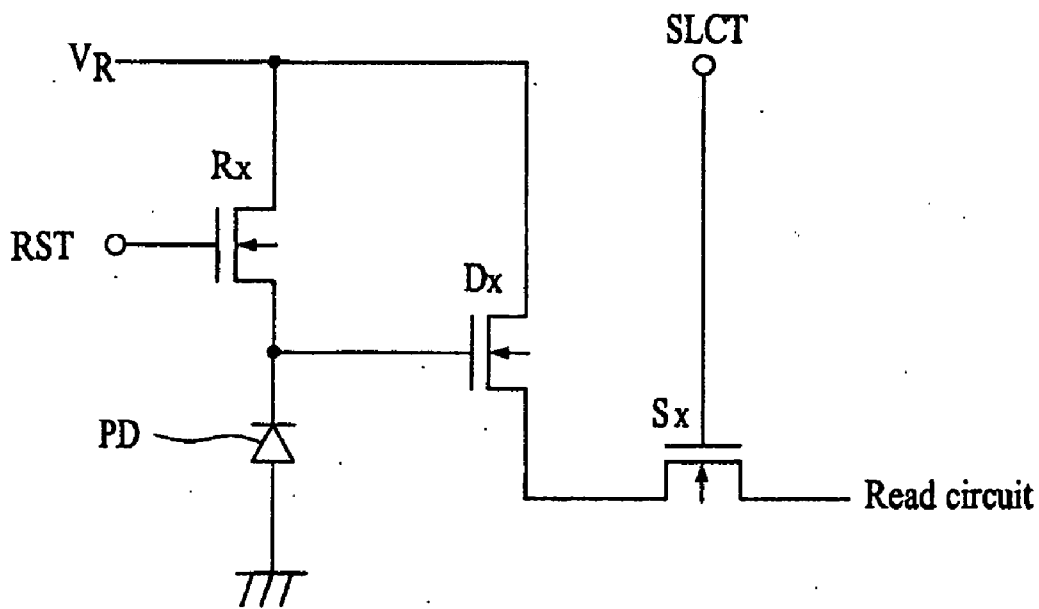


FIG. 2
Related Art

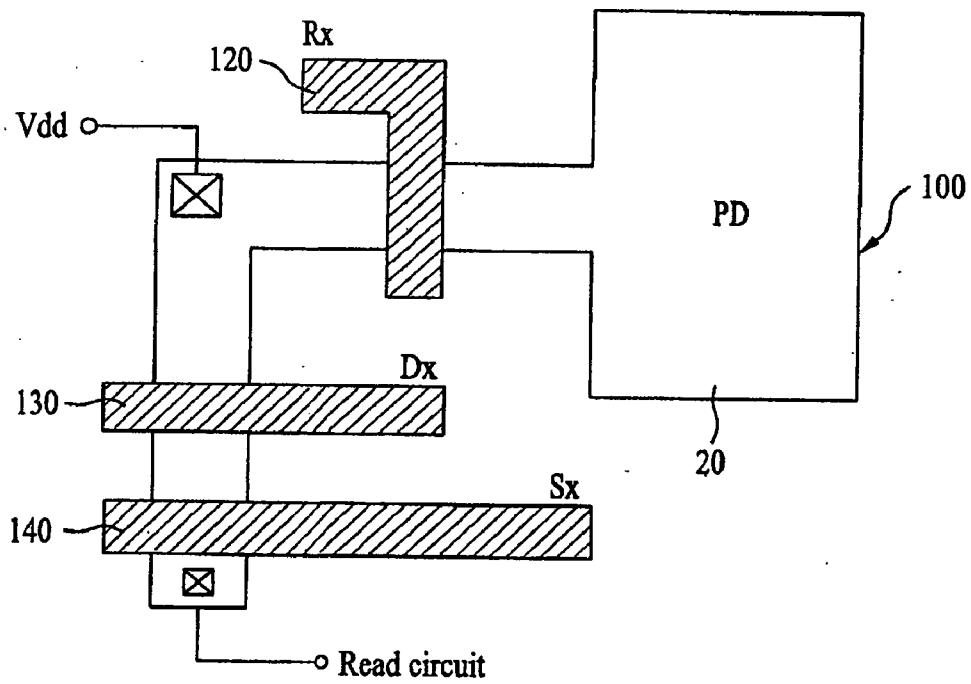


FIG. 3
Related Art

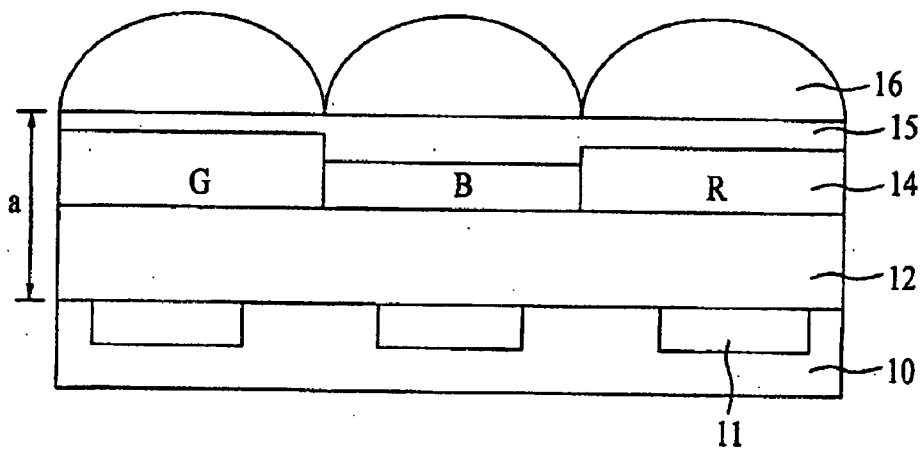


FIG. 4A

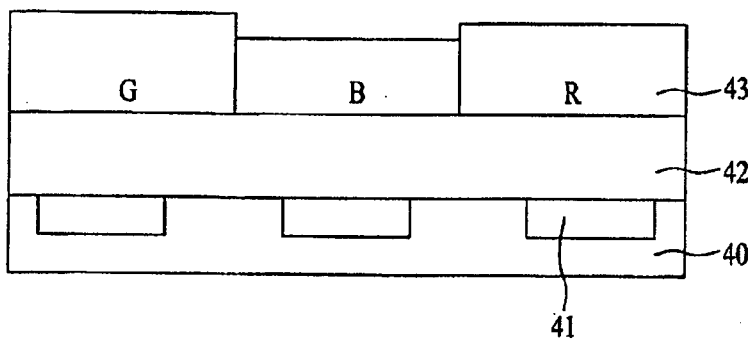


FIG. 4B

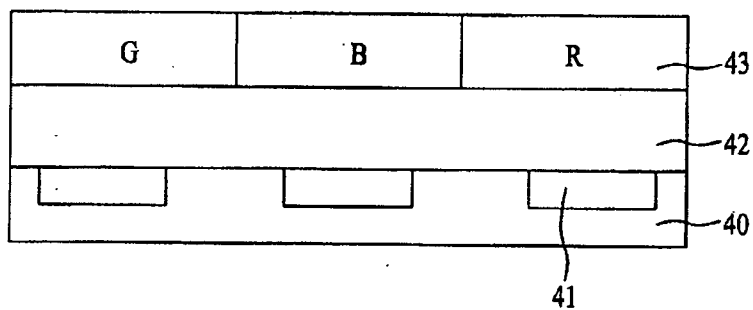


FIG. 4C

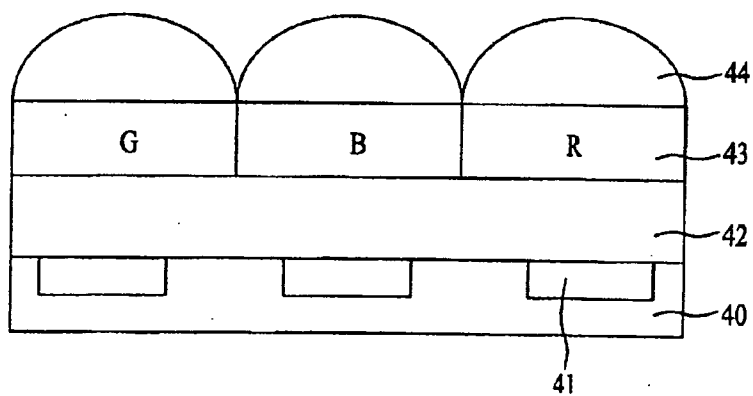


FIG. 5A

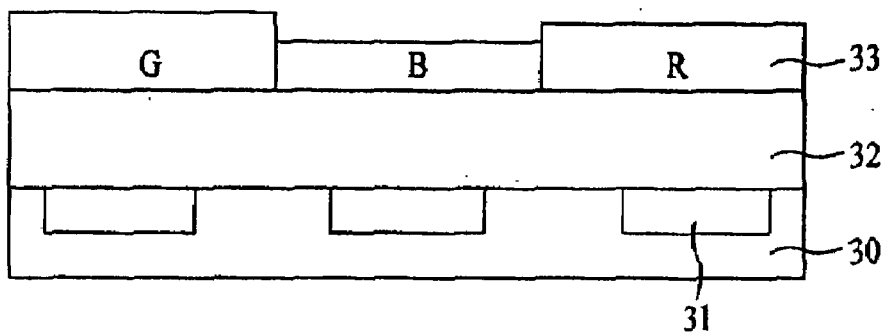


FIG. 5B

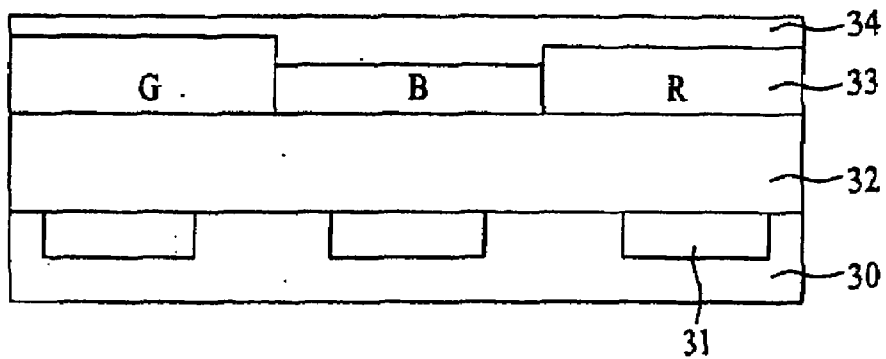


FIG. 5C

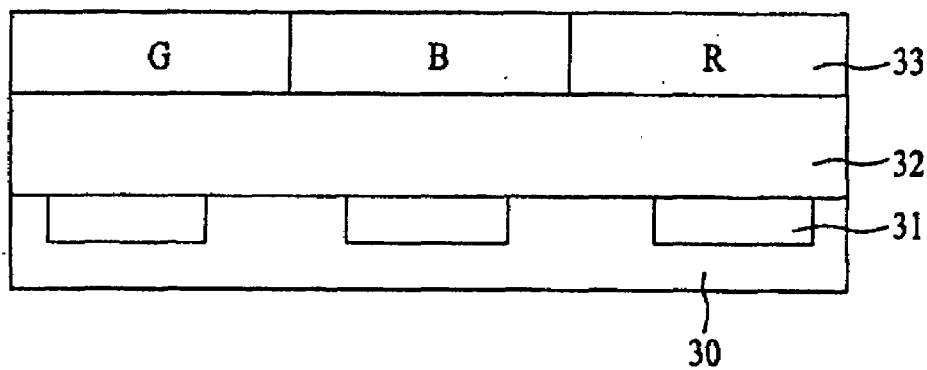


FIG. 5D

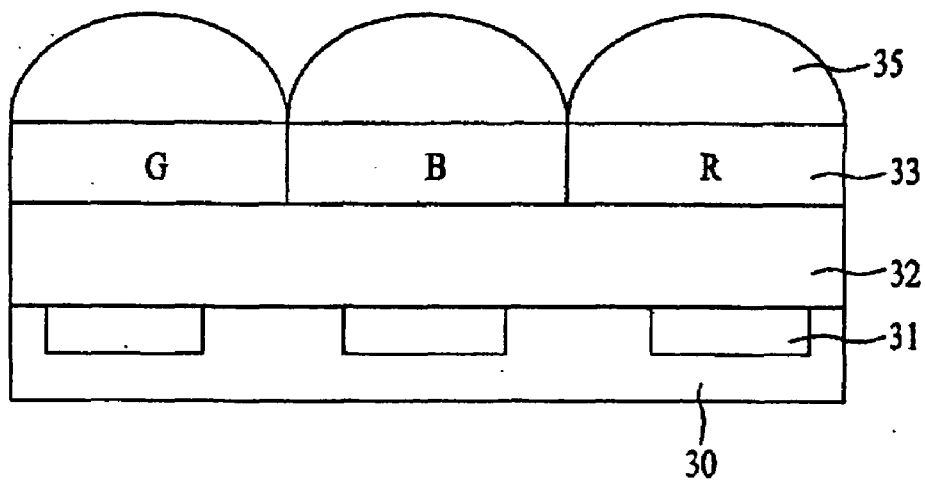


FIG. 6A

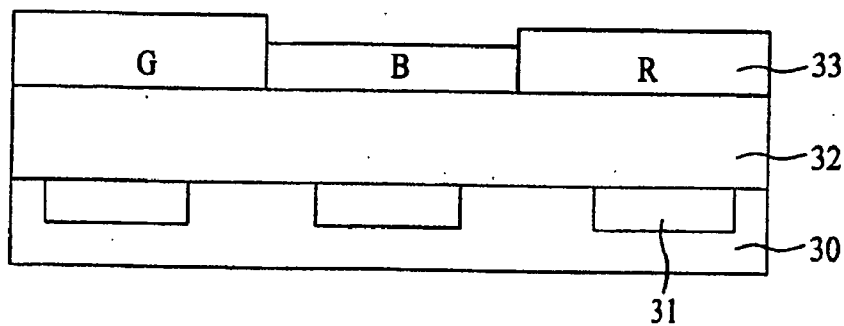


FIG. 6B

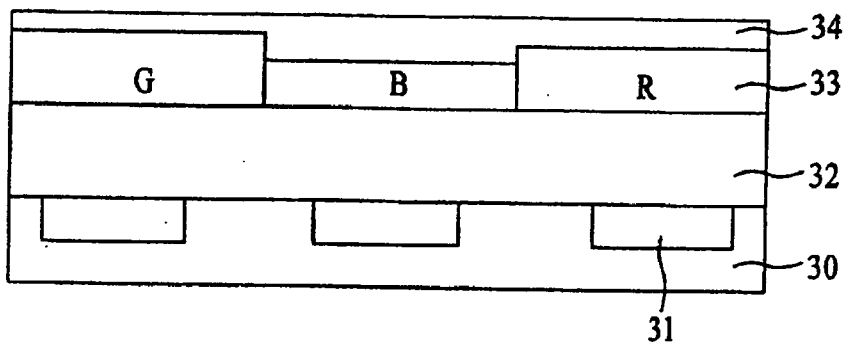


FIG. 6C

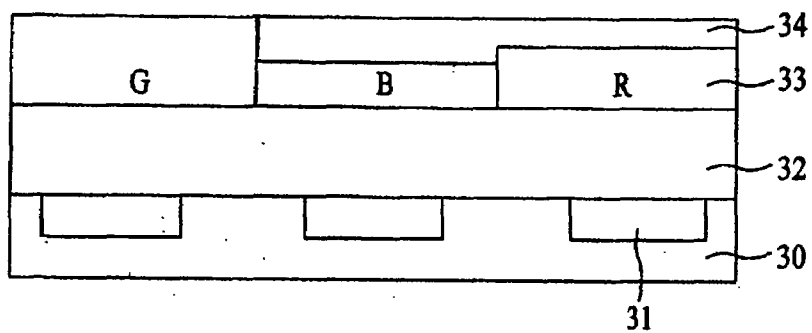
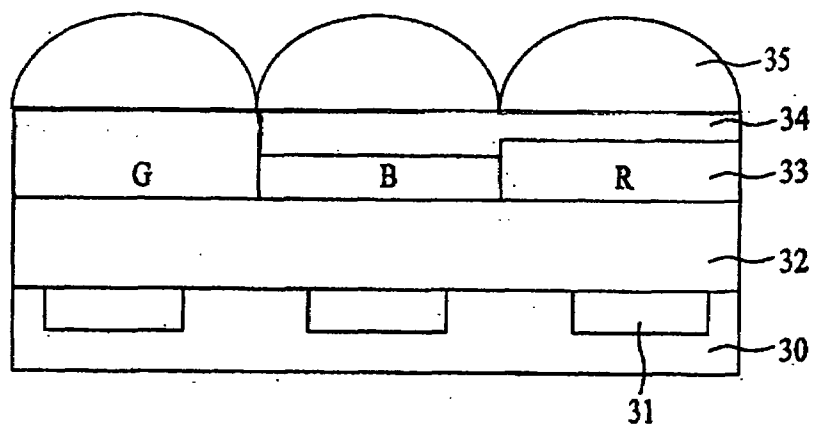


FIG. 6D



CMOS IMAGE SENSOR AND METHOD FOR FABRICATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 10-2004-0114658 filed on Dec. 29, 2004, which is hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an image sensor, and more particularly, to a CMOS image sensor and a method for fabricating the same, which improves the sensor's image characteristics.

[0004] 2. Discussion of the Related Art

[0005] Image sensors are semiconductor devices for converting an optical image into an electrical signal and include charge-coupled devices and complementary metal-oxide-semiconductor (CMOS) image sensors. A general charge-coupled device includes an array of photodiodes converting light signals into electrical signals. Disadvantages of a charge-coupled device include a complicated driving method, high power consumption, and a complicated fabrication process requiring a multi-phased photo process. In a charge-coupled device, integration of complementary circuitry such as a control circuit, a signal processor, and an analog-to-digital converter into a single-chip device is difficult. Thus, development of compact-sized or thin products using such image sensors is hindered. Examples of compact-sized or thin products include digital still cameras and digital video cameras.

[0006] CMOS image sensors, on the other hand, adopt CMOS technology using a control circuit and a signal processing circuit as a peripheral circuit. CMOS image sensors also adopt switching technology which allows outputs to be sequentially detected using MOS transistors corresponding to a number of arrayed pixels. This allows an image to be detected. Accordingly, a CMOS image sensor uses CMOS fabrication technology, i.e., a simple fabrication method using fewer photolithography steps, thereby enabling an advantageous device exhibiting low power consumption.

[0007] In the aforementioned CMOS image sensor of the related art, the photodiode is the active device for forming an optical image based on incident light signals. The optical image is formed by generating electrical signals according to the intensity and wavelength or color of incident light. In such a CMOS image sensor, each photodiode senses incident light and the corresponding CMOS logic circuit converts the sensed light into an electrical signal according to input wavelength. The photosensitivity of the photodiode increases as more light is able to reach the photodiode. In this instance, enhanced photosensitivity results from an increase in the levels of sensed light and corresponds to the light-receiving capability of the active device. One way of enhancing the photosensitivity of a CMOS image sensor is to improve its "fill factor," i.e., the degree of surface area covered by the photodiodes versus the entire surface area of the image sensor. The fill factor is improved by increasing the area responsive to incident light, i.e., the photo-sensing portion. However, there is a limit to increasing the photo-sensing portion due to the required presence of the logic circuit portion.

[0008] Therefore, a device of a material exhibiting excellent light transmittance, such as a convex microlens having a predetermined curvature for refracting incident light, may be provided to redirect any light that may be incident on the image sensor outside the immediate area of the photodiodes. The device may also be provided to concentrate or focus the incident light on one or more of the photodiodes themselves. That is, the incident light, striking the surface of the convex structure of the microlens while in parallel to the optical axis of the microlens, is refracted by the microlens according to the curvature of the convex structure. The incident light is thereby focused at a predetermined point along the optical axis. Accordingly, in a color image sensor, such a microlens may be provided over a color filter layer including red (R), blue (B), and green (G) filter elements for passing the light of each color or wavelength to be disposed over a photodiode area.

[0009] Meanwhile, CMOS image sensors are classified according to a number of transistors. For example, a 3T-type CMOS image sensor consists of one photodiode and three transistors and a 4T-type CMOS image sensor consists of one photodiode and four transistors. An equivalent circuit and layout of a unit pixel of a 3T-type CMOS image sensor of the related art are shown in FIG. 1 and FIG. 2, respectively.

[0010] Referring to FIG. 1, a CMOS image sensor of the related art comprises one photodiode PD and three NMOS transistors including a reset transistor Rx, a drive transistor Dx, and a select transistor Sx. The cathode of the photodiode PD is commonly connected to the drain of the reset transistor Rx and the gate of the drive transistor Dx, whose drain is connected to the source of the select transistor Sx, whose drain is in turn connected to a read circuit. With the anode of the photodiode PD grounded, a reference voltage VR is applied via a power line to the source of each of the reset and drive transistors Rx and Dx. A reset signal RST is applied via a reset line to the gate of the reset transistor Rx and a select signal SLCT is applied via a column select line to the gate of the select transistor Sx.

[0011] Referring to FIG. 2, an active area 100 is defined for each unit pixel of the CMOS image sensor of FIG. 1. The active area 100 includes a photodiode area 20 comprising the bulk of the active area, which is overlapped by gate electrode areas 120, 130, and 140 of the three NMOS transistors, respectively. The source/drain region of each transistor is formed by an ion-implantation process with respect to the active area 100. Power (Vdd) is applied to the source/drain regions of the reset transistor Rx and drive transistor Dx. The source/drain region of the select transistor Sx is connected to the read circuit. Each of the gate electrodes 120, 130, and 140 is connected to external circuitry (not shown) via a corresponding signal line having a pad provided at one end.

[0012] As shown in FIG. 3, a CMOS image sensor of the related art includes a plurality of photodiodes 11 formed in a surface of a semiconductor substrate 10, an insulating interlayer 12 formed on the entire surface of the semiconductor substrate 10 including the photodiodes 11, a first planarization layer (not shown) formed on the insulating interlayer 12, a color filter layer 14 formed on the first planarization layer, a second planarization layer 15 formed on the entire surface of the semiconductor substrate 10 including the color filter layer 14, and a plurality of microlenses 16 provided on the second planarization layer 15 corresponding to the respective photodiodes 11, each microlens being formed as convex structure and having a predetermined curvature. The microlenses 16

focus incident light onto the corresponding photodiodes **11** through the color filter layer **14**. The color filter layer **14** is comprised of red (R), green (G), and blue (B) color filter patterns for respectively filtering light according to wavelength. Each of the photodiodes **11** is disposed below one of the color filter patterns and generates an electrical charge according to the amount of incident light that reaches the photodiode.

[0013] The curvature and height of the microlens, which is a critical component of an image sensor, are determined in due consideration of the desired focus of incident light. Generally, the microlens is made of polymer-based resin enabling a completed microlens to be formed using only a photolithography patterning process of exposure and development followed by a reflowing process. The pattern profile or shape of the microlens tends to vary according to exposure conditions, for example, the conditions of a thin film on the semiconductor substrate, which are rather unstable. This results in degraded focusing characteristics. The microlens is nevertheless formed to have the optimal size, thickness, and curvature radius, which are determined with due regard to such parameters as shape, size, and positioning of a unit pixel, photodiode thickness, and physical characteristics (e.g., dimensions) of a light-shielding layer.

[0014] Meanwhile, the respective color filter patterns have different heights since each is formed by its own individual photolithography processing. Therefore, the planarization layer **15** provides a level surface, above the upper surfaces of the color filter patterns, for receiving the microlens array. Accordingly, as shown in FIG. 3, the traveling distance of light, which passes through the microlens **16** to be incident on the photodiode **11**, is inherently increased due to the thickness of the planarization layer **15**. Since the light-receiving efficiency of the CMOS image sensor of the related art depends on the amount of light reaching the photodiode, light sensitivity is lowered due to the greater traveling distance, thereby deteriorating the capacity of the CMOS image sensor.

SUMMARY OF THE INVENTION

[0015] Accordingly, the present invention is directed to a CMOS image sensor and a method for fabricating the same that substantially obviates one or more problems due to limitations and disadvantages of the related art.

[0016] An advantage of the present invention is to provide a CMOS image sensor and a method for fabricating the same that improves image characteristics by eliminating the thickness of a planarization layer.

[0017] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0018] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, there is provided a CMOS image sensor comprising a semiconductor substrate; a plurality of active devices, provided in a predetermined surface of the semiconductor substrate, for generating electrical charges according to an amount of incident light; an insulating interlayer formed on an entire surface of the semiconductor substrate including the plurality of active devices; a color filter layer formed on the insulating interlayer, the color filter layer

comprised of red, green, and blue color filter patterns for respectively filtering light according to wavelength, the color filter patterns arranged to correspond to the plurality of active devices; and a plurality of microlenses formed on the color filter layer, wherein the color filter layer is planarized so that each color filter pattern of the color filter layer is imparted with an equal height for receiving the plurality of microlenses.

[0019] In another aspect of the present invention, there is provided a method for fabricating a CMOS image sensor. The method comprises forming a plurality of photodiodes in a predetermined surface of a semiconductor substrate; forming an insulating interlayer on an entire surface of the semiconductor substrate including the plurality of photodiodes; forming a color filter layer including red, green, and blue color filter patterns on the insulating interlayer; planarizing the color filter layer so that each color filter pattern of the color filter layer is imparted with an equal height; and forming a plurality of microlenses on the planarized color filter layer.

[0020] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention. In the drawings:

[0022] FIG. 1 is an equivalent circuit view of a 3T-type CMOS image sensor of the related art;

[0023] FIG. 2 is a layout of a unit pixel in a 3T-type CMOS image sensor of the related art;

[0024] FIG. 3 is a cross-sectional view of a CMOS image sensor of the related art;

[0025] FIGS. 4A-4C are cross-sectional views illustrating a method for fabricating a CMOS image sensor according to an embodiment of the present invention; and

[0026] FIGS. 5A-5D are cross-sectional views illustrating a method for fabricating a CMOS image sensor according to another embodiment of the present invention.

[0027] FIGS. 6A-6D are cross-sectional views illustrating a method for fabricating a CMOS image sensor according to another embodiment of the present invention

DETAILED DESCRIPTION OF THE INVENTION

[0028] Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, like reference designations will be used throughout the drawings to refer to the same or similar parts.

[0029] An embodiment of the present invention will be described with reference to FIG. 4A-5C. As shown in FIG. 4A, a plurality of photodiodes **41**, which may be in the form of a plurality of photo-gates, are formed at fixed intervals in a predetermined surface of a semiconductor substrate **40**. Then, an insulating interlayer **42** of an oxide such as undoped silicate glass is formed on an entire surface of the semiconductor substrate **40** including the plurality of photodiodes **41**. The insulating interlayer **42** may be formed as a multi-layered structure, including a light-shielding layer (not shown) for

preventing light from reaching areas other than the photodiodes **41**, and another insulating interlayer (not shown) formed on the light-shielding layer.

[0030] Subsequently, respective resist layers of green (G), blue (B), and red (R) are coated on the insulating interlayer **42**, and then an exposure and development process is performed with respect to each layer of resist, thereby forming a color filter layer **43** including the green (G), blue (B), and red (R) color filter patterns. The color filter patterns are arranged to correspond to a plurality of active devices, such as photodiodes **41**, for filtering light according to wavelength. The respective color filter patterns have different heights since each is formed by its own individual photolithography processing.

[0031] Referring to FIG. **4B**, a chemical-mechanical polishing process or an etching process is performed with respect to the entire surface of the color filter layer **43** including each of the color filter patterns, thereby forming a planarized color filter layer **43**. That is, the polishing process or the etching process serves to planarize the surface of the color filter layer **43**. As a result, each color filter pattern is imparted with an equal height for receiving an array of microlenses.

[0032] In FIG. **4C**, a sacrificial layer (not shown) for microlens formation is coated on the planarized color filter layer **43**, and an exposure and development process is performed with respect to the sacrificial layer, thereby forming a microlens pattern corresponding to an array of microlenses. The sacrificial layer may be formed as a resist layer or an oxide layer of tetra-ethyl-ortho-silicate. A plurality of microlenses **44** is formed by reflowing the microlens pattern. The reflowing process may employ a hot plate or a furnace. The curvature of the microlenses **44** can be varied to control focusing according to an application of a heat shrinkage method. Subsequently, the microlenses **44** are irradiated with ultraviolet light, thereby curing each microlens to maintain its optimal curvature radius.

[0033] Another embodiment of the present invention will be described with reference to FIG. **5A-5D**. As shown in FIG. **5A**, a plurality of photodiodes **31**, which may be in the form of a plurality of photo-gates, are formed at fixed intervals in a predetermined surface of a semiconductor substrate **30**. Then, an insulating interlayer **32** of an oxide such as undoped silicate glass is formed on an entire surface of the semiconductor substrate **30** including the plurality of photodiodes **31**. The insulating interlayer **32** may be formed as a multi-layered structure, including a light-shielding layer (not shown) for preventing light from reaching areas other than the photodiodes **31**, and another insulating interlayer (not shown) formed on the light-shielding layer.

[0034] Subsequently, respective resist layers of green (G), blue (B), and red (R) are coated on the insulating interlayer **32**, and then an exposure and development process is performed with respect to each layer of resist, thereby forming a color filter layer **33** including the green (G), blue (B), and red (R) color filter patterns. The color filter patterns are arranged to correspond to the plurality of active devices, such as photodiodes **31**, for filtering light according to wavelength. The respective color filter patterns have different heights since each is formed by its own individual photolithography processing.

[0035] As shown in FIG. **5B**, a planarization layer **34** is formed on the entire surface of the semiconductor substrate **30**, including the color filter patterns, to fill any crevices in the color filter layer **33** that may be present in the underlying

surface, for example, between the color filter patterns. The planarization layer **34** should cover the highest surface among the respective color filter patterns and will serve as a sacrificial layer.

[0036] Referring to FIG. **5C**, a chemical-mechanical polishing process or an etching process is performed with respect to the entire surface of the planarization layer **34**. The planarization layer **34** and the respective color filter patterns of the color filter layer **33** are simultaneously polished or simultaneously etched. The planarization layer **34** enables less removal of one or more of the color filter patterns of the color filter layer **33**. Thereby an excessive reduction in filter layer thickness, which may occur in striving for full planarization by polishing or etching the color filter layer directly, is avoided. That is, there may be remnants of the planarization layer **34** left after the polishing step or etching step, such that material of the planarization layer **34** is disposed between the color filter patterns of the color filter layer **33**. Thus, with minor portions (not shown) of the planarization layer **34** remaining as necessary, each color filter pattern is imparted with an equal height for receiving an array of microlenses.

[0037] In FIG. **5D**, a sacrificial layer for microlens formation is coated on the planarized color filter layer **33**, and then an exposure and development process is performed with respect to the sacrificial layer, thereby forming a microlens pattern corresponding to an array of microlenses. The sacrificial layer may be formed as a resist layer or an oxide layer of tetra-ethyl-ortho-silicate. A plurality of microlenses **35** is formed by reflowing the microlens pattern. The reflowing process may employ a hot plate or a furnace. The curvature of the microlenses **35** can be varied to control focusing according to an application of a heat shrinkage method. Subsequently, the microlenses **35** are irradiated with ultraviolet light, thereby curing each microlens to maintain its optimal curvature radius.

[0038] Another embodiment of the present invention will be described with reference to FIG. **6A-6D**. As shown in FIG. **6A**, a plurality of photodiodes **31**, which may be in the form of a plurality of photo-gates, are formed at fixed intervals in a predetermined surface of a semiconductor substrate **30**. Then, an insulating interlayer **32** of an oxide such as undoped silicate glass is formed on an entire surface of the semiconductor substrate **30** including the plurality of photodiodes **31**. The insulating interlayer **32** may be formed as a multi-layered structure, including a light-shielding layer (not shown) for preventing light from reaching areas other than the photodiodes **31**, and another insulating interlayer (not shown) formed on the light-shielding layer.

[0039] Subsequently, respective resist layers of green (G), blue (B), and red (R) are coated on the insulating interlayer **32**, and then an exposure and development process is performed with respect to each layer of resist, thereby forming a color filter layer **33** including the green (G), blue (B), and red (R) color filter patterns. The color filter patterns are arranged to correspond to the plurality of active devices, such as photodiodes **31**, for filtering light according to wavelength. The respective color filter patterns have different heights since each is formed by its own individual photolithography processing.

[0040] As shown in FIG. **6B**, a planarization layer **34** is formed on the entire surface of the semiconductor substrate **30**, including the color filter patterns, to fill any crevices in the color filter layer **33** that may be present in the underlying surface, for example, between the color filter patterns. The

planarization layer 34 should cover the highest surface among the respective color filter patterns and will serve as a sacrificial layer.

[0041] Referring to FIG. 6C, a chemical-mechanical polishing process or an etching process is performed to partially remove the planarization layer 34. The planarization layer 34 and one of the respective color filter patterns, such as the green color filter pattern, of the color filter layer 33 are simultaneously polished or simultaneously etched. The planarization layer 34 enables less removal of one or more of the color filter patterns of the color filter layer 33. Thereby an excessive reduction in filter layer thickness, which may occur in striving for full planarization by polishing or etching the color filter layer directly, is avoided. That is, there may be remnants of the planarization layer 34 left after the polishing step or etching step, such that material of the planarization layer 34 is disposed between the color filter patterns of the color filter layer 33. Thus, with minor portions (not shown) of the planarization layer 34 remaining as necessary, each color filter pattern is imparted with an equal height for receiving an array of microlenses.

[0042] In FIG. 6D, a sacrificial layer for microlens formation is coated on the planarized color filter layer 33, and then an exposure and development process is performed with respect to the sacrificial layer, thereby forming a microlens pattern corresponding to an array of microlenses. The sacrificial layer may be formed as a resist layer or an oxide layer of tetra-ethyl-ortho-silicate. A plurality of microlenses 35 is formed by reflowing the microlens pattern. The reflowing process may employ a hot plate or a furnace. The curvature of the microlenses 35 can be varied to control focusing according to an application of a heat shrinkage method. Subsequently, the microlenses 35 are irradiated with ultraviolet light, thereby curing each microlens to maintain its optimal curvature radius.

[0043] By adopting the CMOS image sensor and method for fabricating the same according to the present invention, no planarization layer is needed between the color filter layer and the microlens since the color filter layer itself is imparted with a planarized upper surface. Accordingly, because the thickness of the planarization layer is eliminated, the traveling distance of light passing through the microlens to be incident on the photodiode can be decreased, thereby improving the image characteristics of the sensor.

[0044] It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

- 1. A CMOS image sensor comprising:
 - a semiconductor substrate;
 - a plurality of active devices, provided in a predetermined surface of said semiconductor substrate, for generating electrical charges according to an amount of incident light;
 - an insulating interlayer formed on an entire surface of said semiconductor substrate including said plurality of active devices;
 - a color filter layer formed on said insulating interlayer, said color filter layer comprised of red, green, and blue color

filter patterns for respectively filtering light according to wavelength, the color filter patterns arranged to correspond to said plurality of active devices; and

a plurality of microlenses formed on said color filter layer, wherein said color filter layer is planarized so that each color filter pattern of said color filter layer is imparted with an equal height for receiving said plurality of microlenses.

2. The CMOS image sensor of claim 1, wherein the planarization of said color filter layer is performed by one of a chemical-mechanical polishing process and an etching process.

3. The CMOS image sensor of claim 2, wherein the planarization of said color filter layer is performed with respect to the entire surface of said color filter layer, including each of the filter patterns.

4. The CMOS image sensor of claim 1, further comprising: a sacrificial layer formed on the entire surface of said semiconductor substrate including said color filter layer.

5. The CMOS image sensor of claim 4, wherein said sacrificial layer is disposed between the color filter patterns of said color filter layer.

6. The CMOS image sensor of claim 5, wherein said sacrificial layer is partially removed from said color filter layer.

7. The CMOS image sensor of claim 5, wherein said sacrificial layer is completely removed from said color filter layer.

8. A method for fabricating a CMOS image sensor comprising:

forming a plurality of photodiodes in a predetermined surface of a semiconductor substrate;

forming an insulating interlayer on an entire surface of the semiconductor substrate including the plurality of photodiodes;

forming a color filter layer including red, green, and blue color filter patterns on the insulating interlayer;

planarizing the color filter layer so that each color filter pattern of the color filter layer is imparted with an equal height; and

forming a plurality of microlenses on the planarized color filter layer.

9. The method of claim 8, wherein the planarization of the color filter layer is performed by one of a chemical-mechanical polishing process and an etching process.

10. The method of claim 9, wherein the planarization of the color filter layer is performed with respect to the entire surface of the color filter layer, including each of the color filter patterns.

11. The method of claim 8, further comprising: forming a sacrificial layer on the entire surface of the semiconductor substrate including said color filter layer.

12. The method of claim 11, wherein said sacrificial layer is formed to cover a highest surface among the color filter patterns of said color filter layer.

13. The method of claim 11, wherein said sacrificial layer and said color filter layer are simultaneously planarized.

14. The method of claim 12, wherein said sacrificial layer is partially removed from said color filter layer.

15. The method of claim 12, wherein said sacrificial layer is completely removed from said color filter layer.