US 20160013229A1

(19) **United States**

(12) **Patent Application Publication**

TU et al.

(10) **Pub. No.: US 2016/0013229 A1**

(43) **Pub. Date: Jan. 14, 2016**

(54) **IMAGE SENSOR AND MANUFACTURING METHOD THEREOF**

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(21) Appl. No.: **14/326,912**

(22) Filed: **Jul. 9, 2014**

Publication Classification

(51) **Int. Cl.**

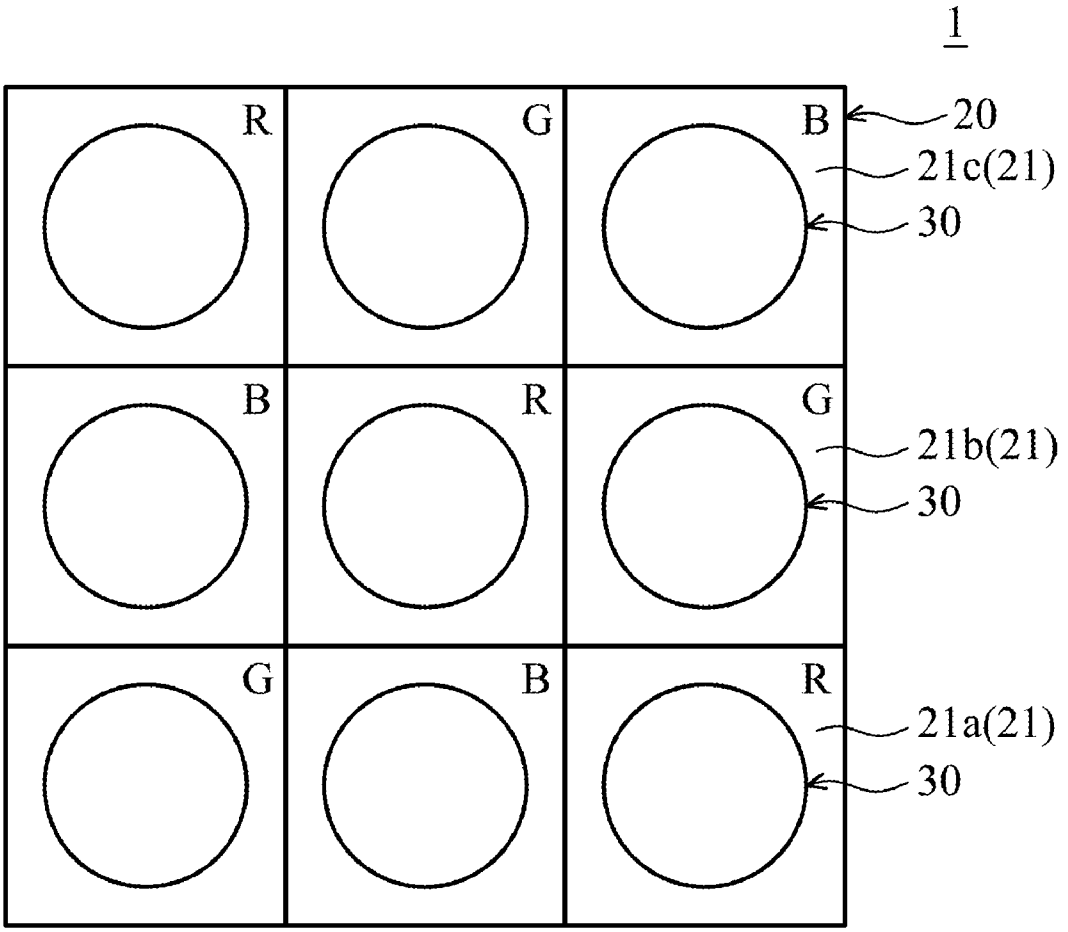
H01L 27/146	(2006.01)
H04N 9/04	(2006.01)
H04N 5/243	(2006.01)

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

CPC ***H01L 27/14621*** (2013.01); ***H04N 5/243*** (2013.01); ***H04N 9/045*** (2013.01); ***H01L 27/14627*** (2013.01); ***H01L 27/14685*** (2013.01)

(57) **ABSTRACT**

Embodiments of an image sensor are provided. The image sensor includes a sensing layer, a filter unit and a microlens. The filter unit is disposed on the sensing layer, and the microlens is disposed on the filter unit. The filter unit has a gradient refractive index. Therefore, the sensitivity of the image sensor is improved.



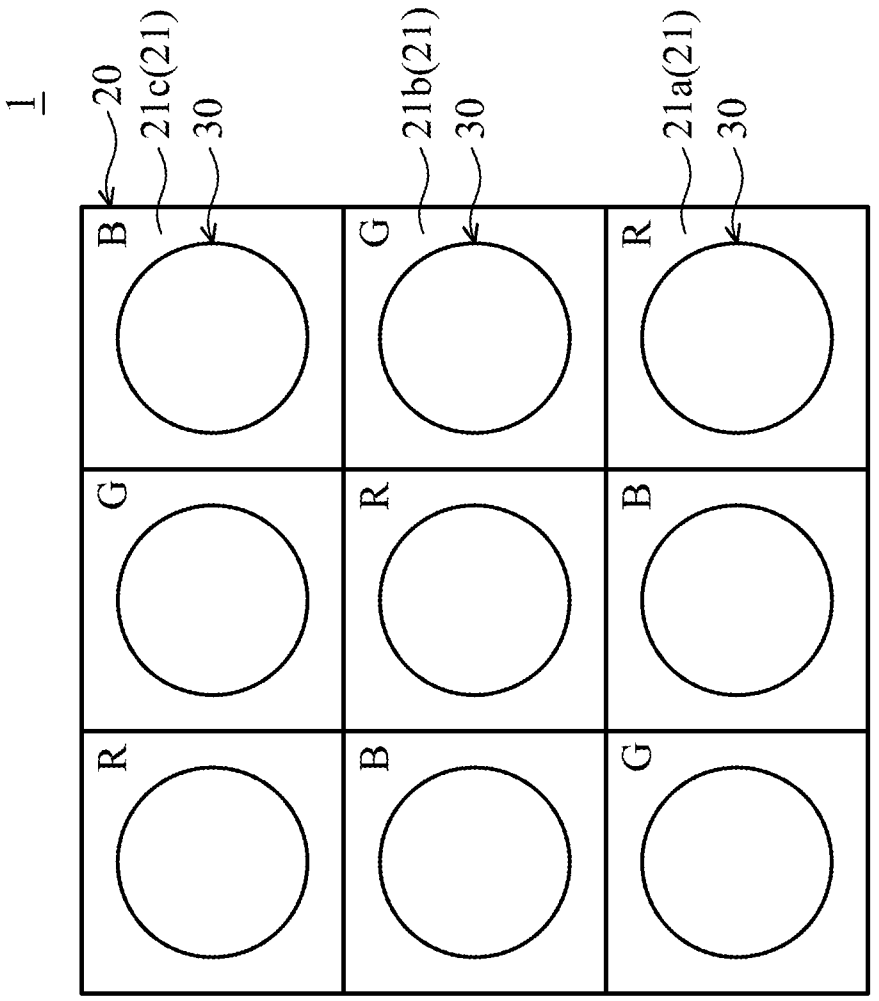


FIG. 1

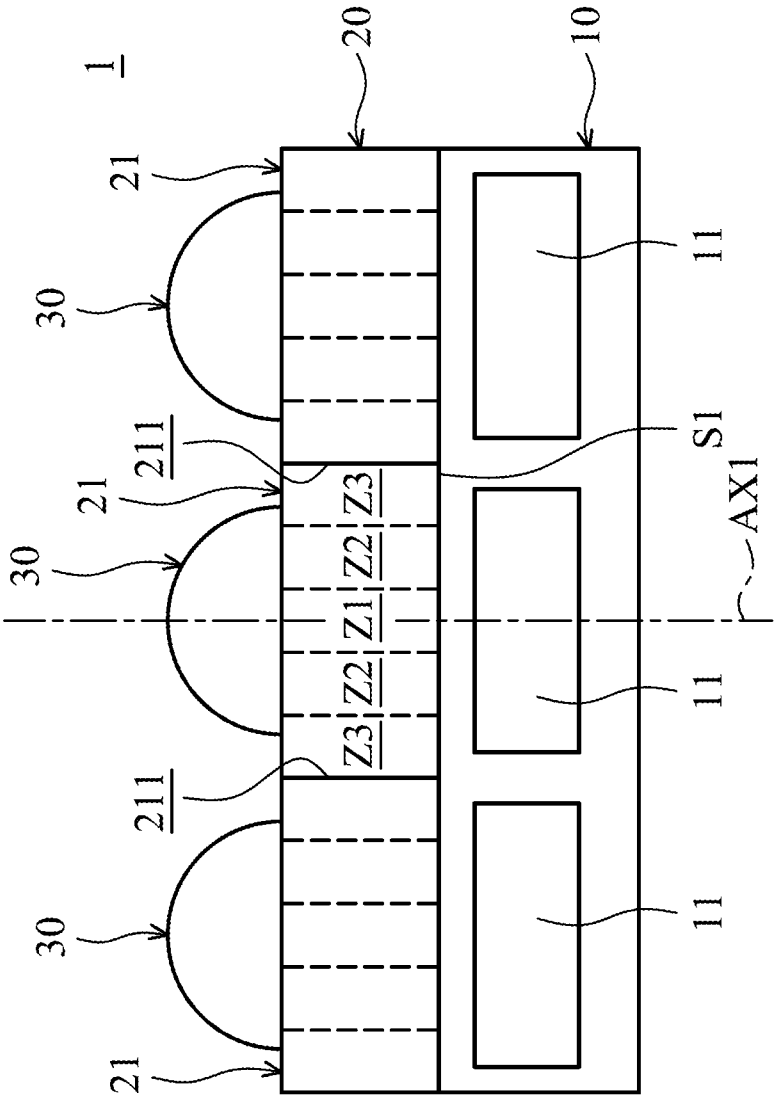


FIG. 2

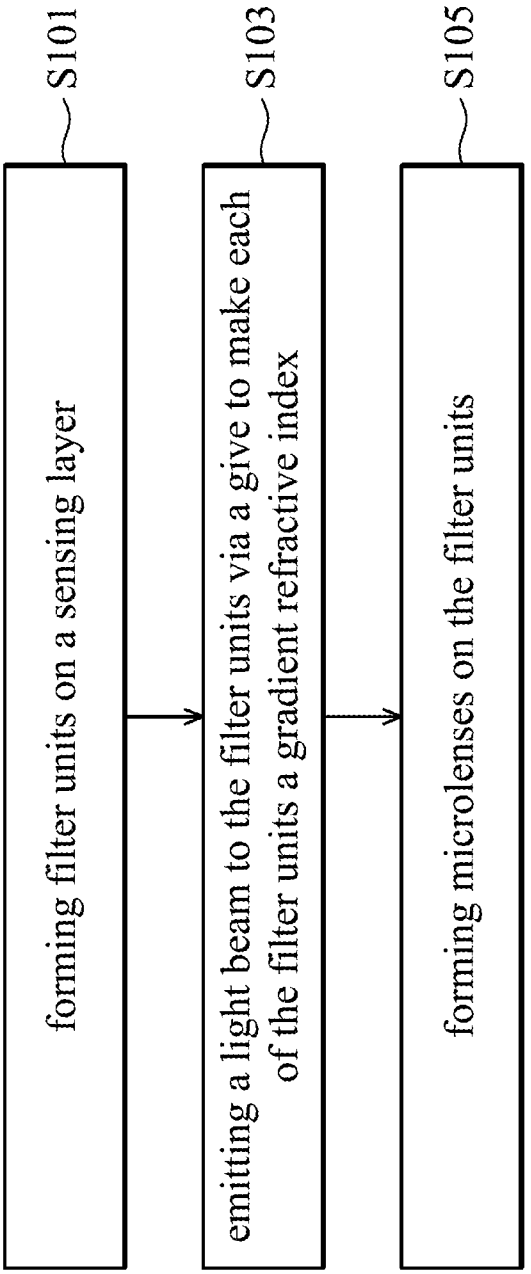

S101
forming filter units on a sensing layer
S103
emitting a light beam to the filter units via a give to make each of the filter units a gradient refractive index
S105
forming microlenses on the filter units

FIG. 3

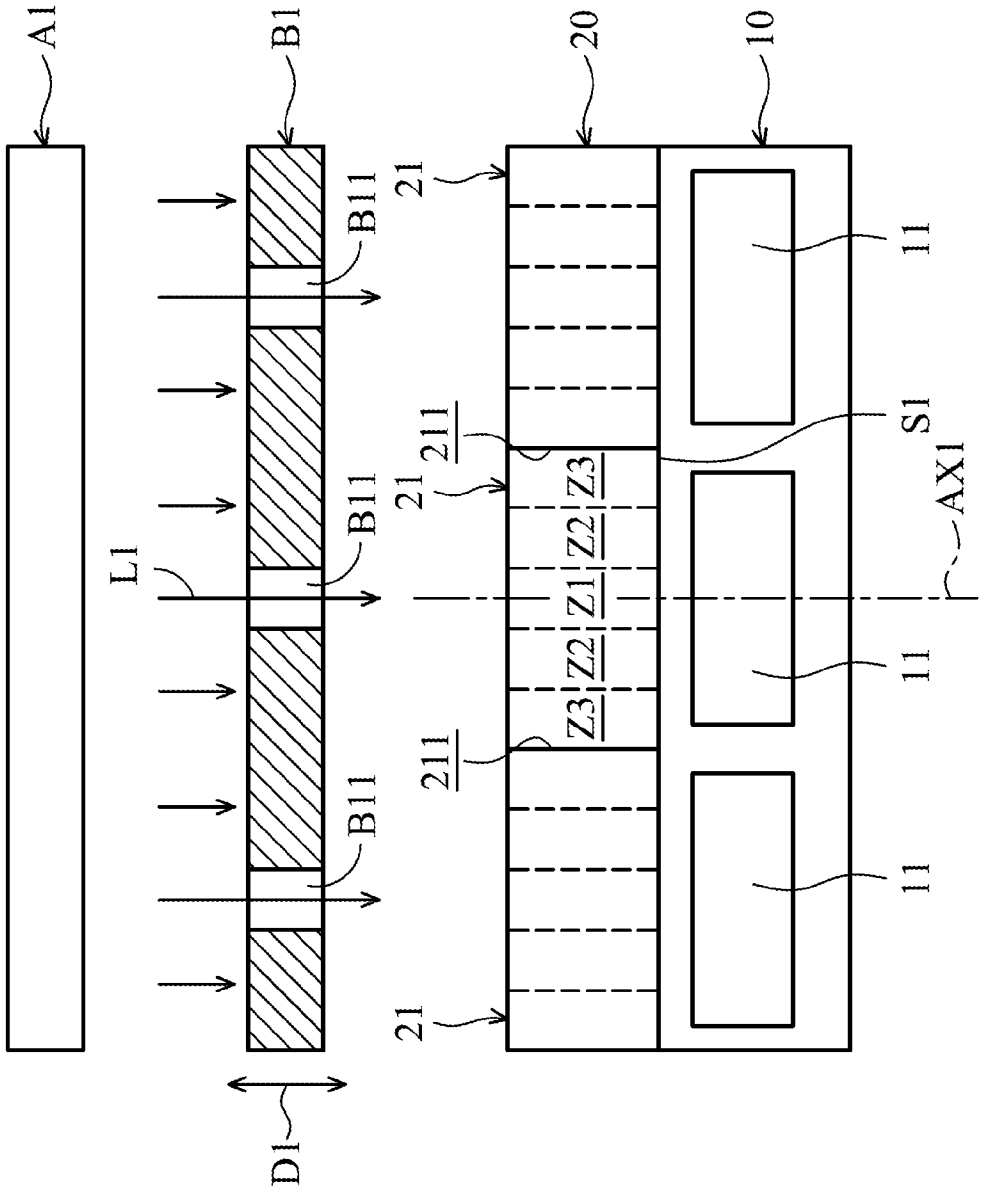


FIG. 4

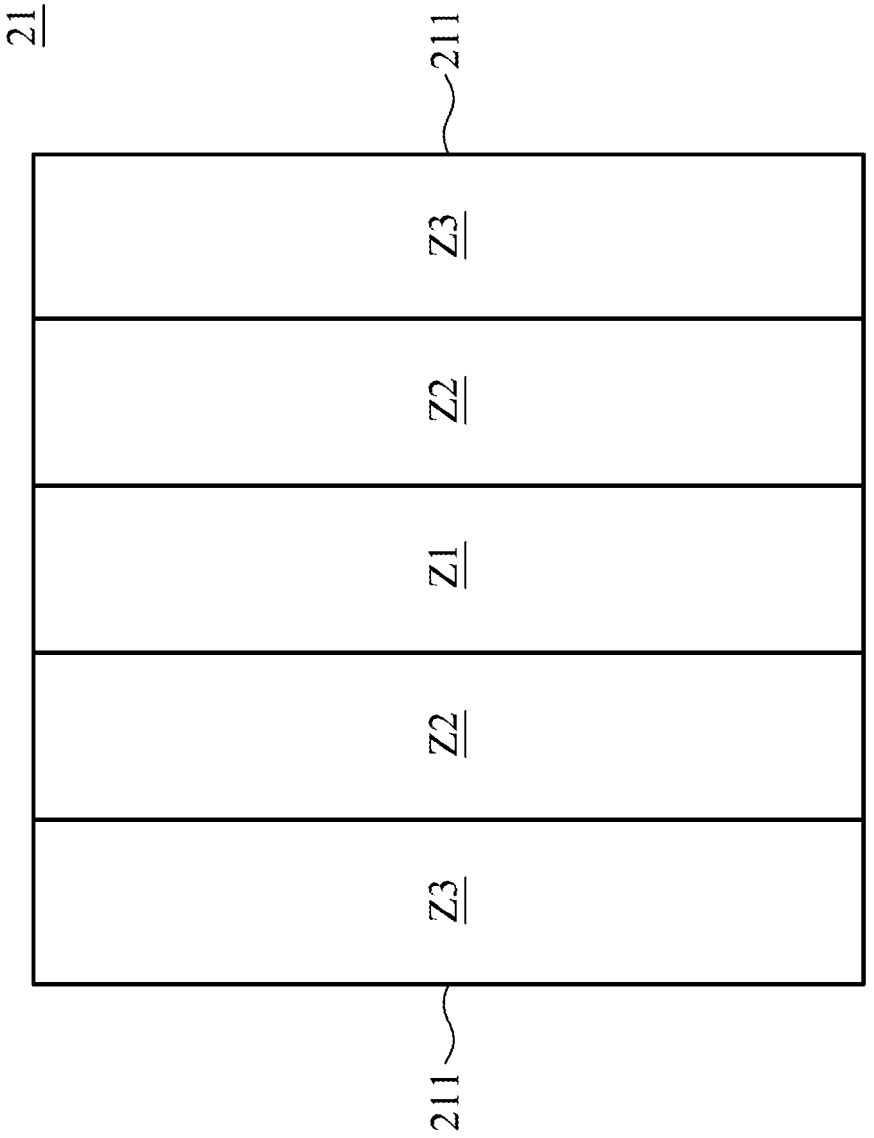


FIG. 5

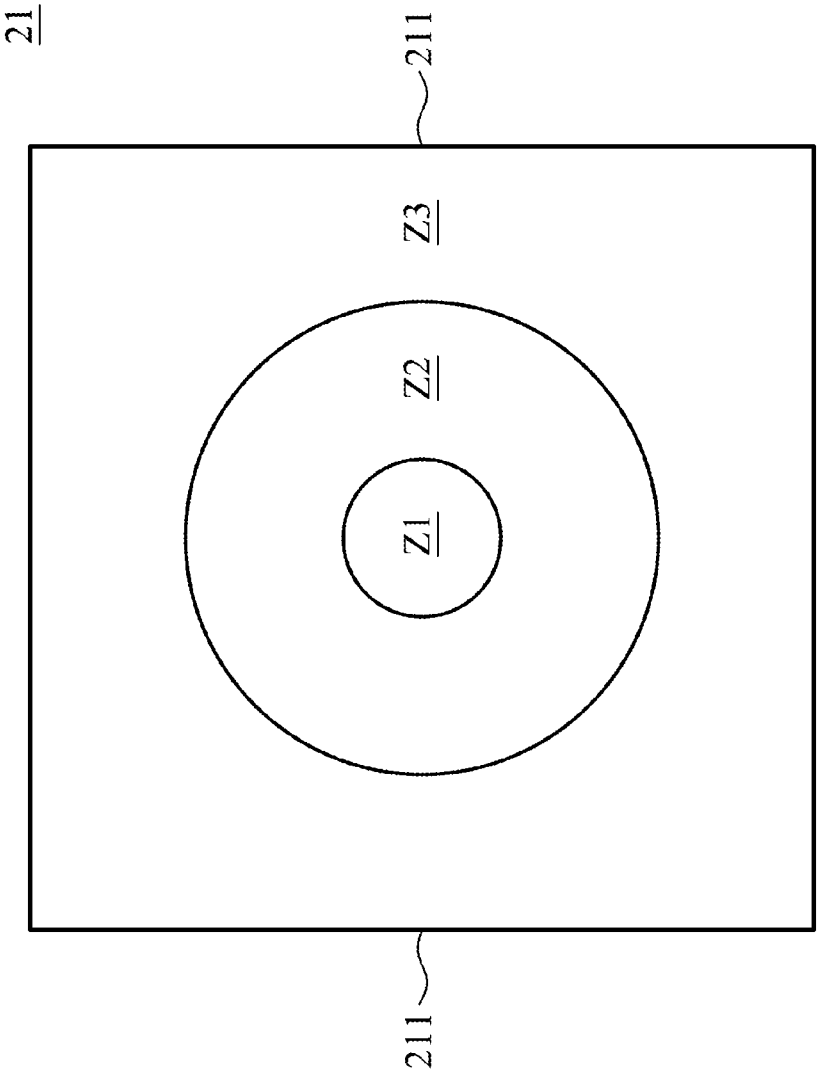


FIG. 6

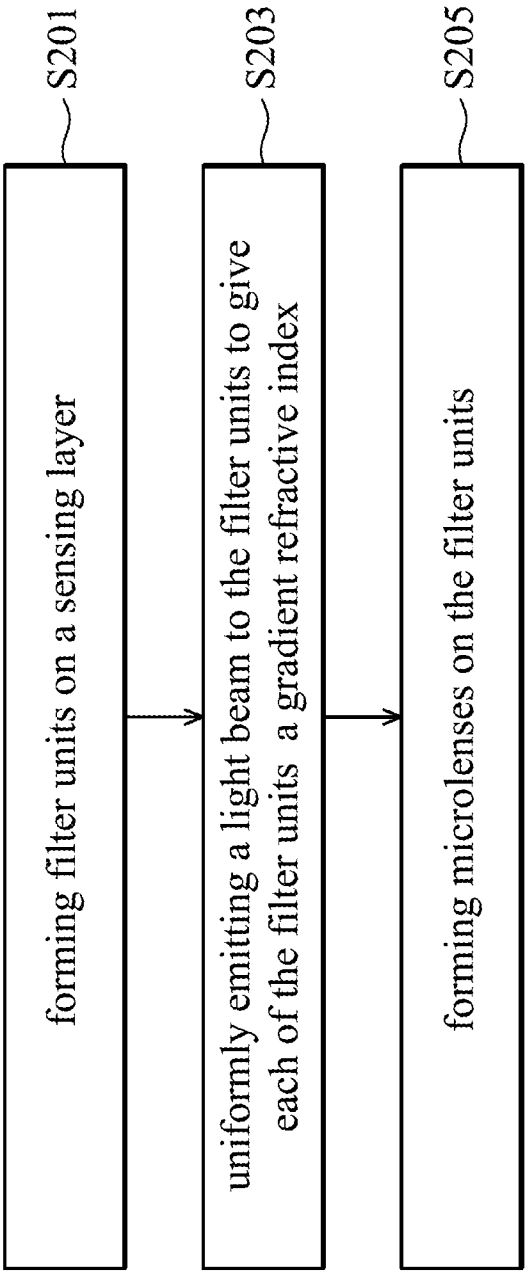

S201
forming filter units on a sensing layer
S203
uniformly emitting a light beam to the filter units to give each of the filter units a gradient refractive index
S205
forming microlenses on the filter units

FIG. 7

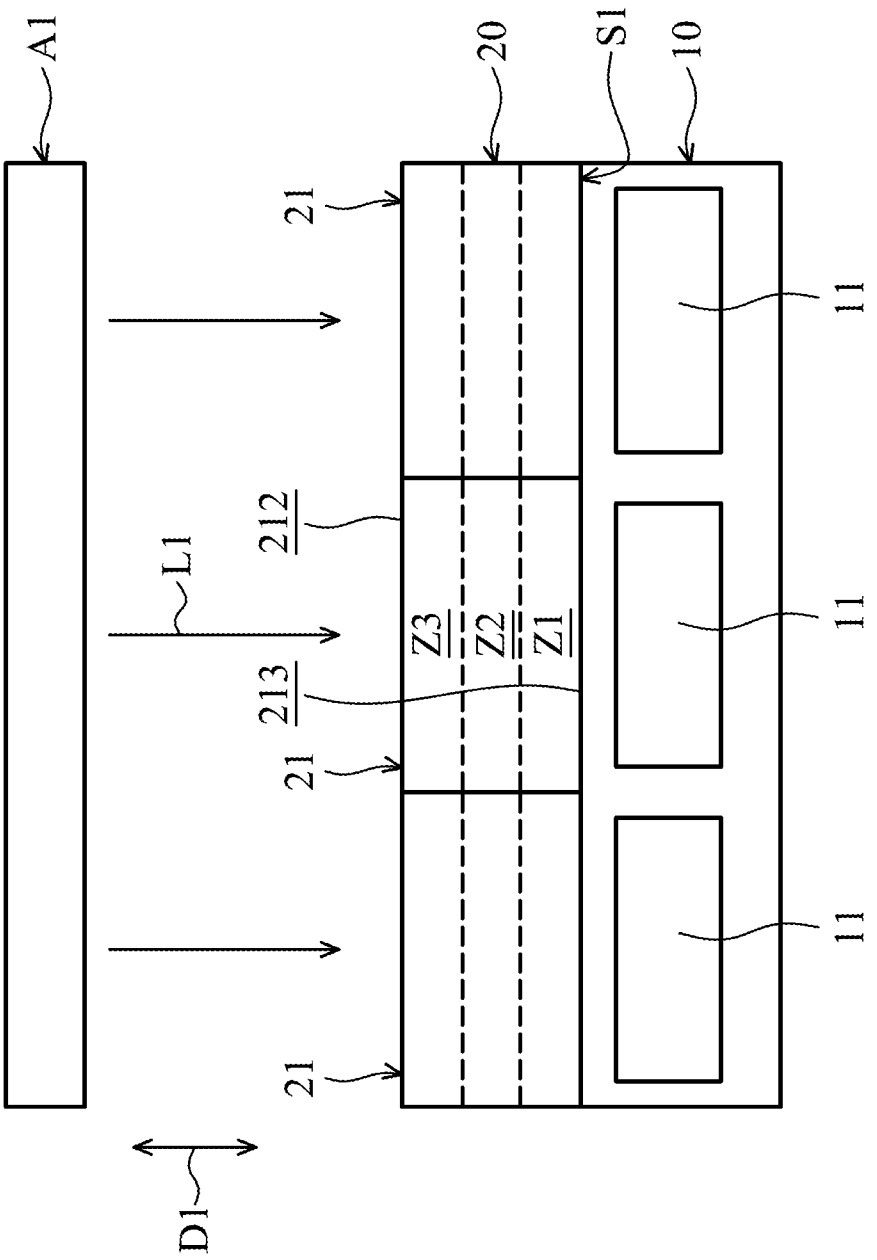


FIG. 8

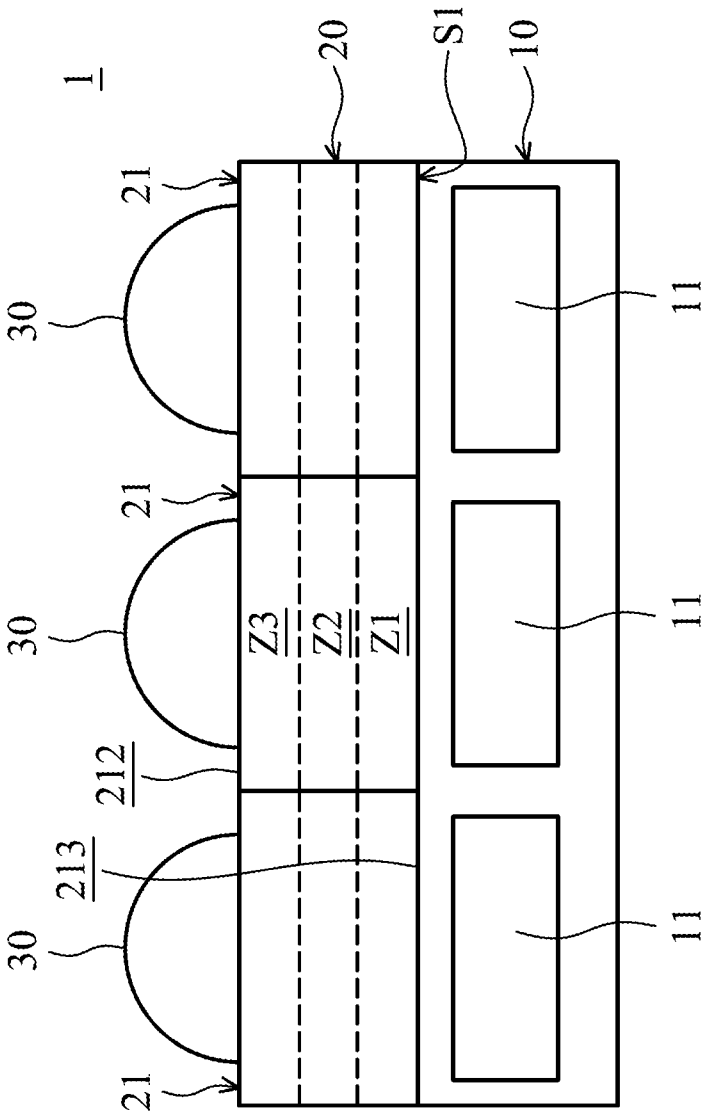


FIG. 9

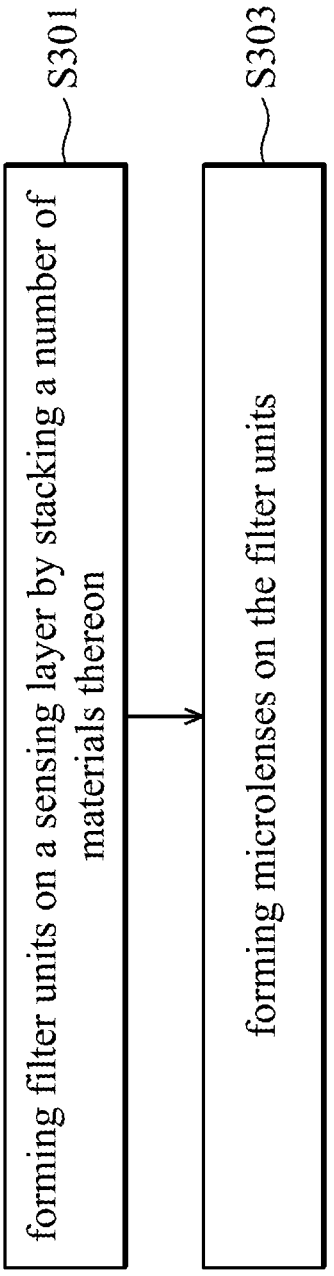

S301
forming filter units on a sensing layer by stacking a number of materials thereon
S303
forming microlenses on the filter units

FIG. 10

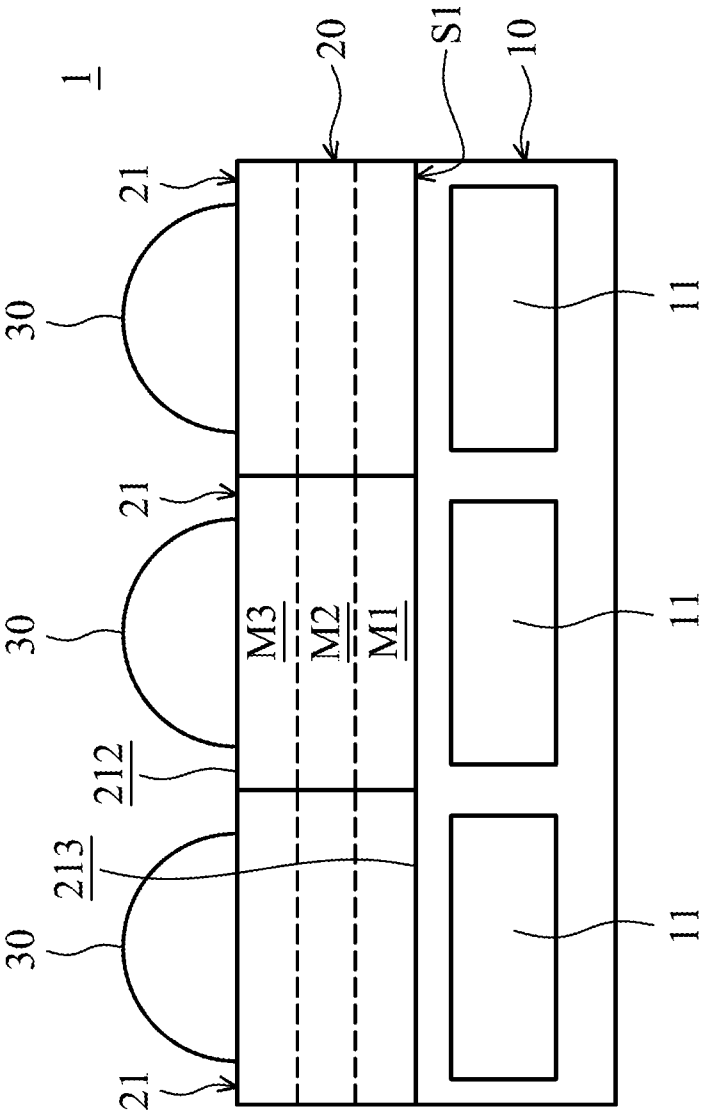


FIG. 11

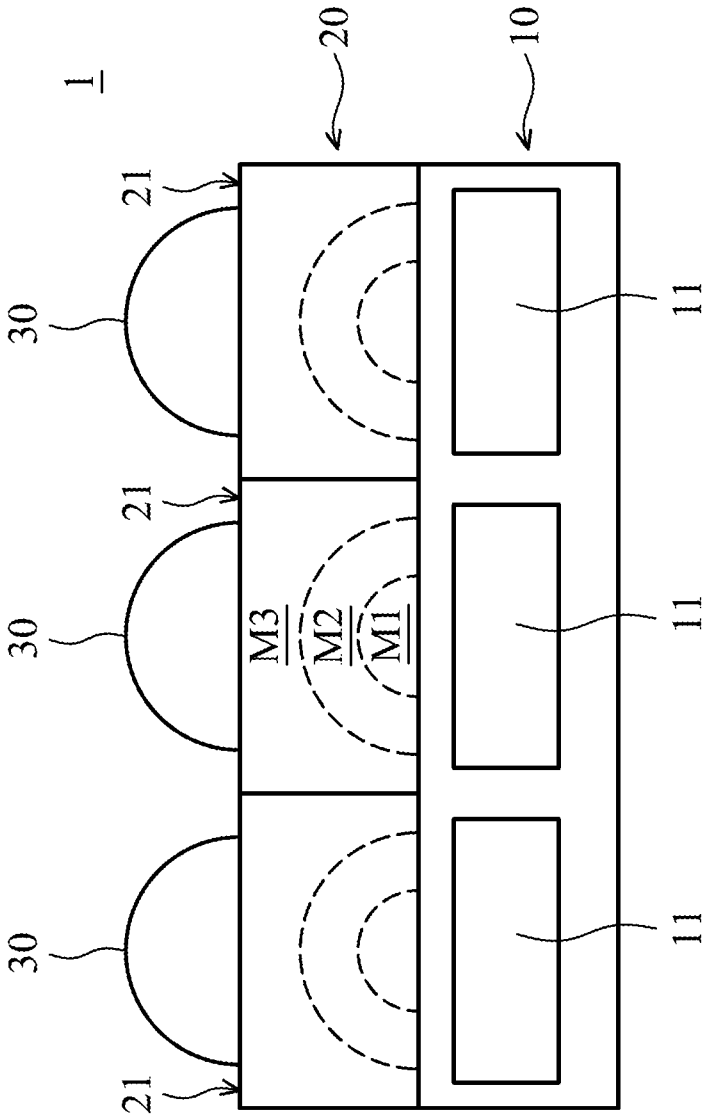


FIG. 12

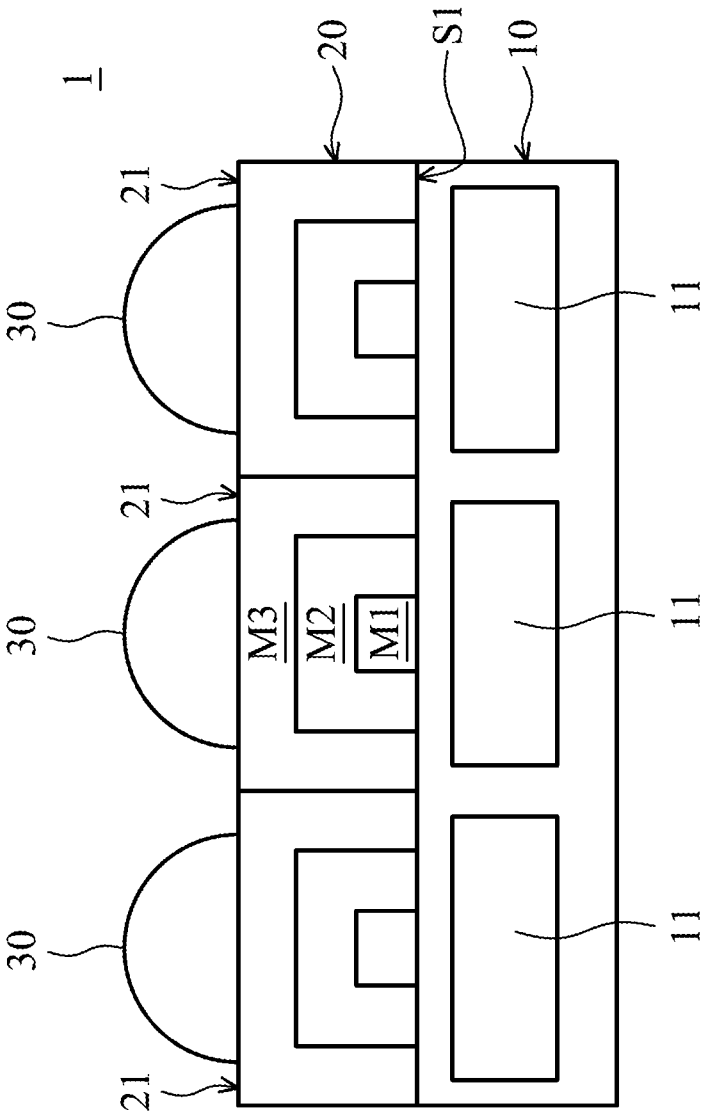


FIG. 13

IMAGE SENSOR AND MANUFACTURING METHOD THEREOF

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present disclosure relates to an image sensor, and in particular to an image sensor having a filter unit.

[0003] 2. Description of the Related Art

[0004] In general, a digital camera utilizes an image sensor to sense light and generate an image signal, and thus a picture taken by the digital camera can be generated according to the image signal.

[0005] With the development of digital cameras, a high quality of image signals is requested. The quality of image signals is important, especially when the digital camera is used in a low-luminance environment.

[0006] Although image sensors have been generally adequate for their intended purposes, they have not been entirely satisfactory in all respects. Consequently, it would be desirable to provide a solution for improving image sensors.

BRIEF SUMMARY OF THE INVENTION

[0007] The present disclosure provides an image sensor and a manufacturing method for improving the quality of image signals generated by the image sensor.

[0008] The present disclosure provides an image sensor including a sensing layer, a filter unit and a microlens. The filter unit is disposed on the sensing layer, and the microlens is disposed on the filter unit. The filter unit has a gradient refractive index.

[0009] The present disclosure provides a manufacturing method of image sensors that includes forming a filter unit on a sensing layer and emitting a light beam to the filter unit to give the filter unit a gradient refractive index. The manufacturing method also includes forming a microlens on the filter unit.

[0010] The present disclosure also provides a manufacturing method of image sensors includes forming a filter unit on a sensing layer by stacking a plurality of materials thereon and forming a microlens on the filter unit. The filter unit has a gradient refractive index. Each of the materials has a refractive index lower than the refractive index of the material below it.

[0011] In conclusion, the sensitivity of the image sensor of the present disclosure is improved by the filter unit having a gradient refractive index. Therefore, the image signals generated by the image sensor are improved, especially in a low-luminance environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

[0013] FIG. **1** is a top view of an image sensor in accordance with the present disclosure;

[0014] FIG. **2** is a cross-sectional view of the image sensor in accordance with a first embodiment of the present disclosure;

[0015] FIG. **3** is a flow chart of the manufacturing method of the image sensor in accordance with the first embodiment of the present disclosure;

[0016] FIG. **4** is a schematic view of the manufacturing method of the image sensor during an intermediate stage in accordance with the first embodiment of the present disclosure;

[0017] FIG. **5** is a top view of a filter unit during an intermediate stage in accordance with the first embodiment of the present disclosure;

[0018] FIG. **6** is a top view of a filter unit during an intermediate stage in accordance with a second embodiment of the present disclosure;

[0019] FIG. **7** is a flow chart manufacturing method of the image sensor in accordance with a third embodiment of the present disclosure;

[0020] FIG. **8** is a schematic view of the manufacturing method of the image sensor during an intermediate stage in accordance with the third embodiment of the present disclosure;

[0021] FIG. **9** is a cross-sectional view of the image sensor in accordance with the third embodiment of the present disclosure;

[0022] FIG. **10** is a flow chart manufacturing method of the image sensor in accordance with a fourth embodiment of the present disclosure;

[0023] FIG. **11** is a cross-sectional view of the image sensor in accordance with the fourth embodiment of the present disclosure;

[0024] FIG. **12** is a cross-sectional view of the image sensor in accordance with a fifth embodiment of the present disclosure; and

[0025] FIG. **13** is a cross-sectional view of the image sensor in accordance with a sixth embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0026] FIG. **1** is a top view of an image sensor **1** in accordance with the present disclosure. FIG. **2** is a cross-sectional view of the image sensor **1** in accordance with a first embodiment of the present disclosure. The image sensor **1** can be applied to an image apparatus, such as a digital camera. The image sensor **1** is used to sense light and generate an image signal according to the light falling on the image sensor **1**.

[0027] The image sensor **1** includes a sensing layer **10**, a filter layer **20** and a number of microlenses **30**. The filter layer **20** is disposed on the sensing layer **10**. The microlenses **30** are disposed on the filter layer **20** in an array.

[0028] Furthermore, the sensing layer **10** includes a number of sensing units **11** arranged in an array. In some embodiments, the sensing units **11** are photodiode. In some embodiments, the sensing layer **10** further includes an anti-leakage layer, an anti-reflection layer, and/or other optional layers (not shown in figures). The filter layer **20** includes a number of filter units **21** arranged in an array. Each of the filter units **21** is disposed over one of the sensing units **11**, and each of the microlenses **30** is disposed on one of the filter units **21**.

[0029] When a light falls on the image sensor **1**, the light passes through the microlenses **30** and the filter units **21** to the sensing units **11**. The light is focused by the microlenses **30**. Each of the filter units **21** allows a predetermined range of wavelengths of the light to pass. Each of the sensing units **11** generates an intensity signal according to the intensity of the light falling thereon, and the image signal is formed by the intensity signals.

[0030] The filter units **21** are color filter units **21**. For example, the filter units **21** include a number of red filter units

21*a*, a number of green filter units **211**), and a number of blue filter units **21***c* as shown in FIG. **1**. The red filter units **21***a*, the green filter units **21***b*, and the blue filter units **21***c* are alternately arranged. The red filter units **21***a* allow wavelengths of light in a range from 620 nm to 750 nm to pass. The green filter units **21***b* allow wavelengths of light in a range from 495 nm to 570 nm to pass. The blue filter units **21***c* allow wavelengths of light in a range from 476 nm to 495 nm to pass.

[0031] The filter unit **21** includes photopolymer. Each of the filter units **21** has a gradient refractive index. The gradient refractive index is in a range from about 1.4 to about 1.9. The gradient refractive index has a maximum value and a minimum value, and the difference between the maximum value and the minimum value is in a range from about 0.07 to about 0.5. In some embodiments, the maximum value is in a range from about 1.5 to about 1.9, and the minimum value is in range from about 1.4 to about 1.8.

[0032] As shown in FIG. **2**, the gradient refractive index is symmetric at a distance from a central vertical axis AX**1** of the filter unit **21**. The central vertical axis AX**1** is perpendicular to a boundary surface S**1** between the sensing layer **10** and the filter layer **20**. The sensing layer **10** and the filter layer **20** are parallel to boundary surface S**1**.

[0033] The gradient refractive index adjacent to the central vertical axis AX**1** is greater than the gradient refractive index adjacent to a side wall **211** of the filter unit **21**. The side wall **211** is perpendicular to the boundary surface S**1**. In other words, the gradient refractive index at or adjacent to the central vertical axis AX**1** has the maximum value. The gradient refractive index at or adjacent to the side wall **211** has the minimum value.

[0034] For example, the filter unit **21** has a first area Z**1**, a second area Z**2** and a third area Z**3**. The first area Z**1** (center area) is located at the central vertical axis AX**1** (or the center of the filter unit **21**), and has a first mean refractive index. The second area Z**2** is located between the first area Z**1** and the third area Z**3**, and has a second mean refractive index. The third area Z**3** is adjacent to the side wall **211** of the filter unit **21**, and has a third mean refractive index.

[0035] The first mean refractive index is greater than the second mean refractive index, and the second mean refractive index is greater than the third mean refractive index. For example, the first mean index is about 1.7, the second mean index is about 1.65, and the third mean index is about 1.60.

[0036] The microlens **30** includes photopolymer. The microlens **30** has a single refractive index. The refractive index of the microlens **30** is in a range from about 1.4 to about 1.9.

[0037] FIG. **3** is a flow chart of the manufacturing method of the image sensor **1** in accordance with the first embodiment of the present disclosure. FIG. **4** is a schematic view of the manufacturing method of the image sensor **1** during an intermediate stage in accordance with the first embodiment of the present disclosure. In step S**101**, the filter units **21** of the filter layer are formed on the sensing layer **10**. In step S**103**, a light beam L**1** is emitted on the filter units **21** via a mask B**1** to give each filter unit **21** a gradient refractive index. In step S**105**, the microlens **30** is formed on the filter units **21** as shown in FIGS. **1** and **2**.

[0038] Regarding step S**103**, as shown in FIG. **4**, the light source A**1** is disposed upon the filter layer **20**. The mask B**1** is disposed upon the filter layer **20**, and located between the light source A**1** and the filter layer **20**. The light source A**1** emits the light beam L**1** along an emitting direction D**1**. The emitting direction D**1** is parallel to the central vertical axis AX**1**, and perpendicular to the boundary surface S**1**.

[0039] The mask B**1** is perpendicular to emitting direction D**1**, and parallel to the boundary surface S**1**. The mask B**1** has a number of holes B**11** extended along the emitting direction D**1**. Each of the holes B**11** corresponds to one of the center areas Z**1** (first area) of the filter units **21**. As shown in FIG. **4**, the holes B**11**, the center areas Z**1** are located at the central vertical axis AX**1**.

[0040] The light beam L**1** is emitted to the mask B**1** and passes through the holes B**11**, and than is emitted to the filter units **21** of the filter layer **20**.

[0041] In some embodiments, since the filter unit **21** includes photopolymer, when the filter unit **21** is irradiated by the light beam L**1**, a chemical reaction occurs at the photopolymer, and the refractive index of the filter unit **21** is changed according to the intensity of the light beam L**1**.

[0042] As shown in FIG. **4**, the intensity of the light beam L**1** emitted to the filter unit **21** is gradually decreased from the central area Z**1** to the side wall **211**, and thus the filter unit **21** has the gradient refractive index, which is symmetric at a distance from the central vertical axis AX**1** of the filter unit **21**. Furthermore, the gradient refractive index is gradually decreased from the central vertical axis AX**1** to the side wall **211** of the filter unit **21**. In other words, since the intensity of the light beam L**1** emitted to the first area Z**1** is greater, and the intensity of the light beam L**1** emitted to the third area Z**3** is lower, the first mean refractive index of the first area Z**1** is greater than the third mean refractive index of the third area Z**3**.

[0043] FIG. **5** is a top view of one filter unit **21** during an intermediate stage in accordance with the first embodiment of the present disclosure. In this embodiment, the hole B**11** is a narrow shape or a rectangle shape. As shown in FIGS. **4** and **5**, the first area Z**1**, the second area Z**2**, and the third area Z**3** are rectangles, and parallel to each other.

[0044] FIG. **6** is a top view of one filter unit **21** during an intermediate stage in accordance with a second embodiment of the present disclosure. In this embodiment, the hole is a circular shape. As shown in FIGS. **4** and **6**, the first area Z**1** is a cylindrical shape extending along the central vertical axis AX**1**. The second area Z**2** is around the first area Z**1**, and the third area Z**3** is around the second area Z**2**.

[0045] FIG. **7** is a flow chart manufacturing method of the image sensor **1** in accordance with a third embodiment of the present disclosure. FIG. **8** is a schematic view of the manufacturing method of the image sensor **1** during an intermediate stage in accordance with the third embodiment of the present disclosure. FIG. **9** is a cross-sectional view of the image sensor **1** in accordance with the third embodiment of the present disclosure.

[0046] In step S**201**, the filter units **21** of the filter layer **20** are formed on the sensing layer **10**. In step S**203**, a light beam L**1** is uniformly emitted to the filter units **21** to give each filter unit **21** a gradient refractive index.

[0047] As shown in FIG. **8**, the light source A**1** is disposed upon the filter layer **20**. The light source A**1** uniformly emits the light beam L**1** to the filter units **21** of the filter layer **20** along the emitting direction D**1**.

[0048] Each the of filter units **21** has a top surface **212** and a bottom surface **213** opposite to the top surface **212**. The top surface **212** faces the light source A**1** and is parallel to the boundary surface S**1**. The bottom surface **213** is located at the boundary surface S**1**, and is disposed on the sensing layer **10**.

Since the intensity of the light beam L1 emitted to the filter unit **21** is gradually decreased from the top surface **212** to the bottom surface **213**, the gradient refractive index is gradually increased from the bottom surface **213** to the top surface **212**.

[0049] In step S**205**, as shown in FIG. **9**, the microlens **30** is formed on the filter units **21**. The top surface **212** is connected to the microlens **30**. The first area Z**1** is adjacent to the sensing layer **10**. The third area Z**3** is adjacent to the microlens **30**. The third area Z**3** is between the first area Z**1** and the second area Z**2**. The first area Z**1**, the second area Z**2**, and the third area Z**3** are layered shapes and stacked on each other. The first area Z**1**, the second area Z**2**, and the third area Z**3** are parallel to the boundary surface S**1** and parallel to each other.

[0050] The first mean refractive index of the first area Z**1** is greater than the second mean refractive index of the second area Z**2**, and the second mean refractive index is greater than the third mean refractive index of the third area Z**3**.

[0051] FIG. **10** is a flow chart manufacturing method of the image sensor **1** in accordance with a fourth embodiment of the present disclosure. FIG. **11** is a cross-sectional view of the image sensor **1** in accordance with the fourth embodiment of the present disclosure.

[0052] In step S**301**, the filter units **21** of the filter layer **20** are formed on the sensing layer **10** by stacking a number of materials M**1**, M**2** and M**3** on the filter layer **20**. In some embodiments, the materials M**1**, M**2** and M**3** are made by a chemical vapor deposition (CVD) process. In step S**302**, the microlenses **30** are formed on the filter units **21**.

[0053] As shown in FIG. **11**, the filter unit **21** includes the stacked materials M**1**, M**2** and M**3**, and the materials M**1**, M**2** and M**3** are layered. The material M**2** is stacked on the material M**1**, and the material M**3** is stacked on the material M**2**. The material M**1** connected to the filter layer **20**, the material M**3** connected to the microlens **30**, and the material M**2** is between the material M**1** and the material M**3**.

[0054] Each of the materials M**1**, M**2** and M**3** has a refractive index different from the adjacent material. In this embodiment, each of the refractive indexes of the materials M**2** and M**3** is lower than the refractive index of the material below it. For example, the refractive index of the material M**1** is about 1.7, the refractive index of the material M**2** is about 1.65, and the refractive index of the material M**3** is about 1.6. In some embodiments, the materials M**1**, M**2** and M**3** are different.

[0055] FIG. **12** is a cross-sectional view of the image sensor **1** in accordance with a fifth embodiment of the present disclosure. As shown in FIG. **12**, the material M**1** is a bump-shaped material arranged under the materials M**2** and M**3**, and thus the shape of the materials M**2** and M**3** correspond to a contour of the bump-shaped material M**1**. In the embodiment, the materials M**1**, M**2** and M**3** have curved profiles.

[0056] FIG. **13** is a cross-sectional view of the image sensor **1** in accordance with a sixth embodiment of the present disclosure. The difference between the sixth embodiment and the fifth embodiment is that the materials M**1**, M**2** and M**3** have polygonal profiles.

[0057] By the filter unit **21**, for example, the QE (Quantum Efficiency) peak is improved about 2.7% to 5.4% when the difference between the maximum value and the minimum value of the gradient refractive index is about 0.1. In general, the quantum efficiency may apply to the incident photon to converted electron (IPCE) ratio of the image sensor, and greater quantum efficiency corresponds to greater sensitivity of the image sensor. The sensitivity of the green filter unit **21***b* to a light at 3200K is improved about 0.3%, for example. Therefore, the sensitivity of the image sensor **1** is improved.

[0058] Moreover, the cross talk of the green filter unit **21***b* irradiated by a blue light is improved about 5% to 9%, for example. The cross talk of the red filter unit **21***a* irradiated by a green light is improved about 1% to about 2%. The cross talk of the blue filter unit **21***c* irradiated by a green light is improved about 0.6% to about 2%. Therefore, the quality of the image signal generated by the image sensor **1** is improved.

[0059] In conclusion, the sensitivity of the image sensor of the present disclosure is improved by the filter unit having a gradient refractive index. Therefore, the image signals generated by the image sensor are improved, especially in a low-luminance environment.

[0060] While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. On the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

1. An image sensor, comprising:
a sensing layer;
a filter unit disposed on the sensing layer; and
a microlens disposed on the filter unit,
wherein the filter unit includes a single material having a gradient refractive index.

2. The image sensor as claimed in claim **1**, wherein the gradient refractive index is in a range from 1.4 to 1.9.

3. The image sensor as claimed in claim **1**, wherein the gradient refractive index has a maximum value and a minimum value, and the difference between the maximum value and the minimum value is in a range from 0.07 to 0.5.

4. The image sensor as claimed in claim **1**, wherein the microlens comprises photopolymer and comprises a single refractive index.

5. The image sensor as claimed in claim **1**, wherein the filter unit comprises photopolymer.

6. The image sensor as claimed in claim **1**, wherein the gradient refractive index is symmetric and decreases from the central vertical axis to a side wall of the filter unit.

7. The image sensor as claimed in claim **1**, wherein the filter unit has a bottom surface disposed on the sensing layer and has a top surface opposite to the bottom surface and connected to the microlens, and the gradient refractive index gradually increases the bottom surface to the top surface.

8. (canceled)

9. (canceled)

10. A manufacturing method of image sensors, comprising:
forming a filter unit on a sensing layer;
emitting a light beam to the filter unit to give the filter unit a gradient refractive index; and
forming a micro lens on the filter unit.

11. (canceled)

12. The manufacturing method of image sensors as claimed in claim **10**, comprising emitting the light beam to the filter unit via a mask, wherein the mask has a hole corresponding to a center area of the filter unit.

13. The manufacturing method of image sensors as claimed in claim **12**, wherein the gradient refractive index is symmetric and decreases from the central vertical axis to a side wall of the filter unit.

14. The manufacturing method of image sensors as claimed in claim **10**, comprising uniformly emitting the light beam to the filter unit.

15. The manufacturing method of image sensors as claimed in claim **10**, wherein the gradient refractive index increases from a bottom surface of the filter unit to a top surface of the filter unit, and the bottom surface is disposed on the sensing layer.

16. (canceled)

17. (canceled)

18. (canceled)

19. (canceled)

20. The image sensor as claimed in claim **1**, wherein the sensing layer includes a substrate having sensing units embedded therein.

21. The image sensor as claimed in claim **1**, wherein the filter unit is a color filter.

* * * * *