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(54) **DISPLAY DEVICE**

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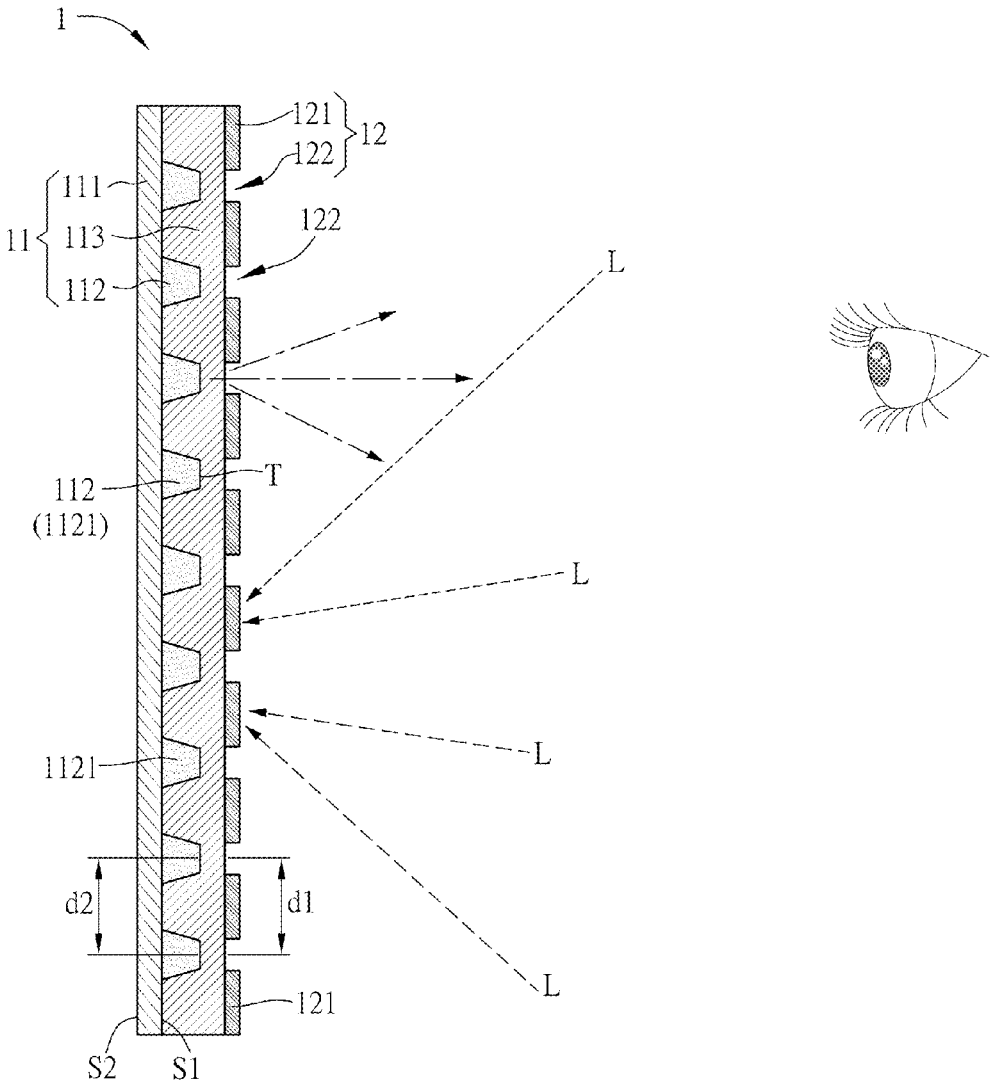
(57) **ABSTRACT**

A display device includes a display module and a light-shielding structure. The display module has a substrate, a plurality of photoelectric units and a protective layer. The substrate defines with a first surface and a second surface. The photoelectric units are arranged on the first surface of the substrate, and each photoelectric unit has at least one photoelectric element. The protective layer is arranged on the first surface of the substrate and is filled between the photoelectric elements. The light-shielding structure is arranged on and connected to the protective layer. The light-shielding structure has a light-shielding layer including light-absorption materials and a plurality of windows defined in the light-shielding layer. The windows respectively correspond to the photoelectric units, and the photoelectric units are viewed through the corresponding windows in the direction perpendicular to the first surface of the substrate.



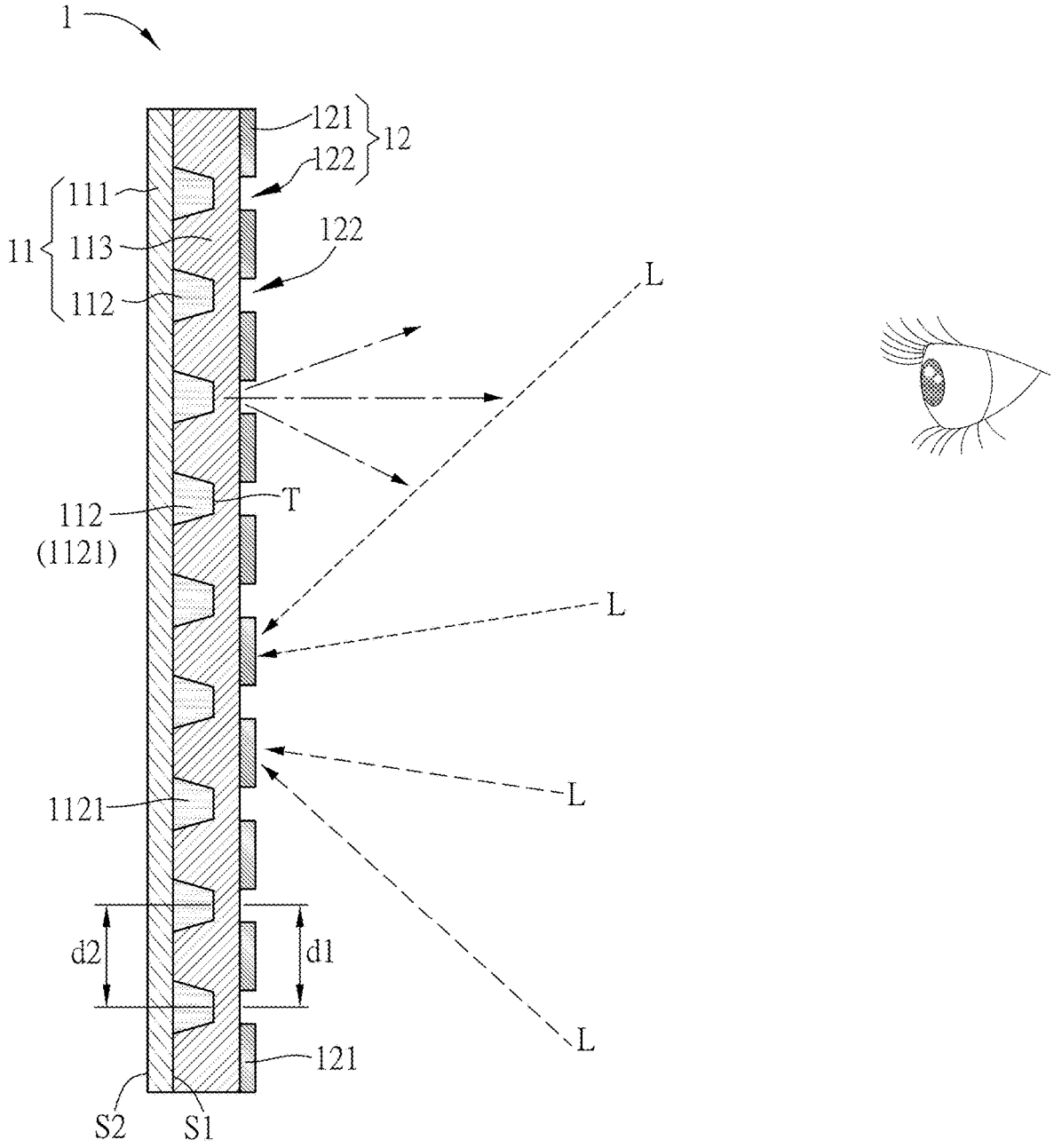

1
121
12
122
111
11
113
122
112
L
T
112
(1121)
L
1121
L
d2
d1
L
121
S2
S1

FIG. 1

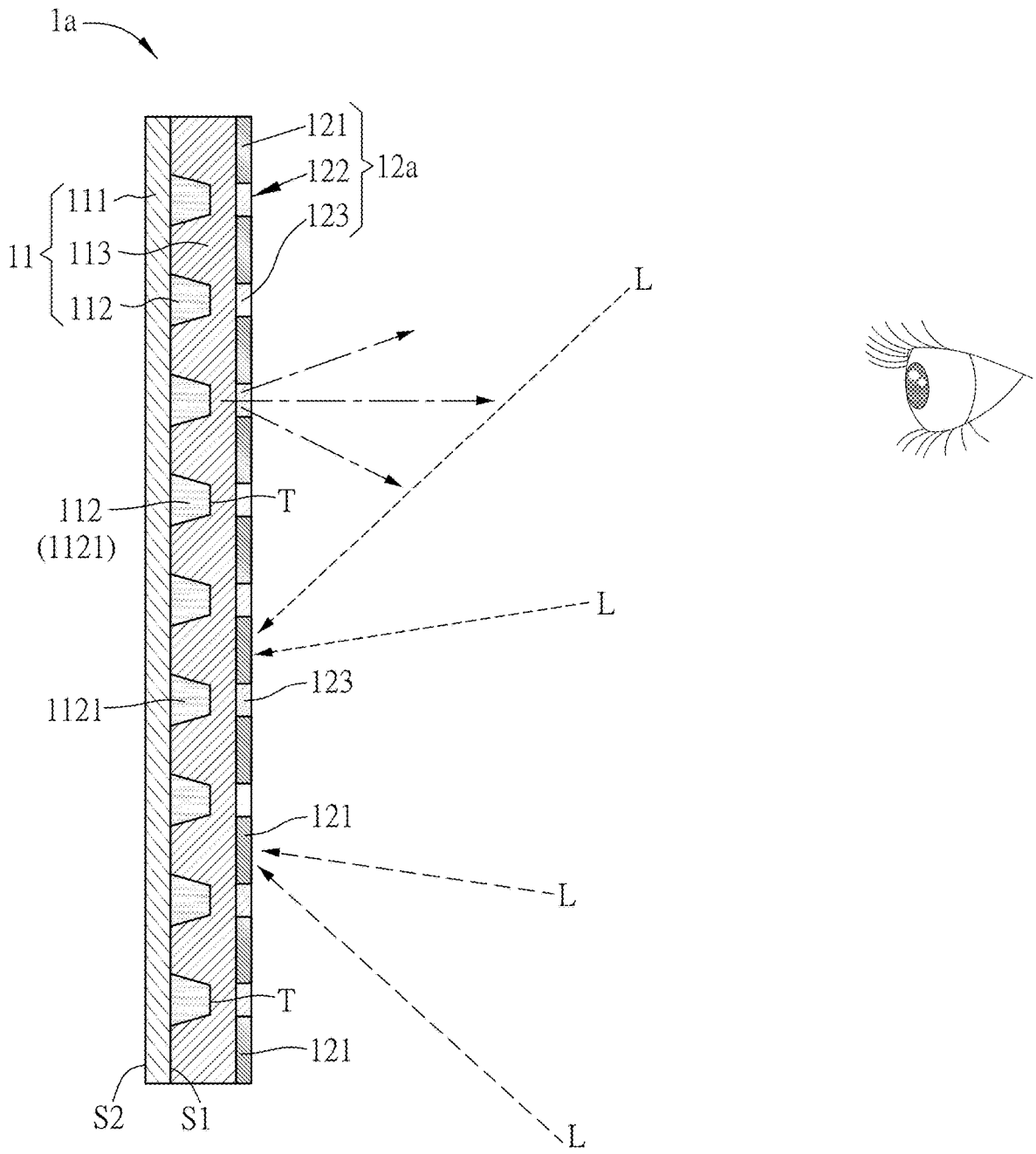

1a
121
122
12a
123
111
11
113
112
L
112
(1121)
T
L
123
1121
121
L
T
121
S2
S1
L

FIG. 2

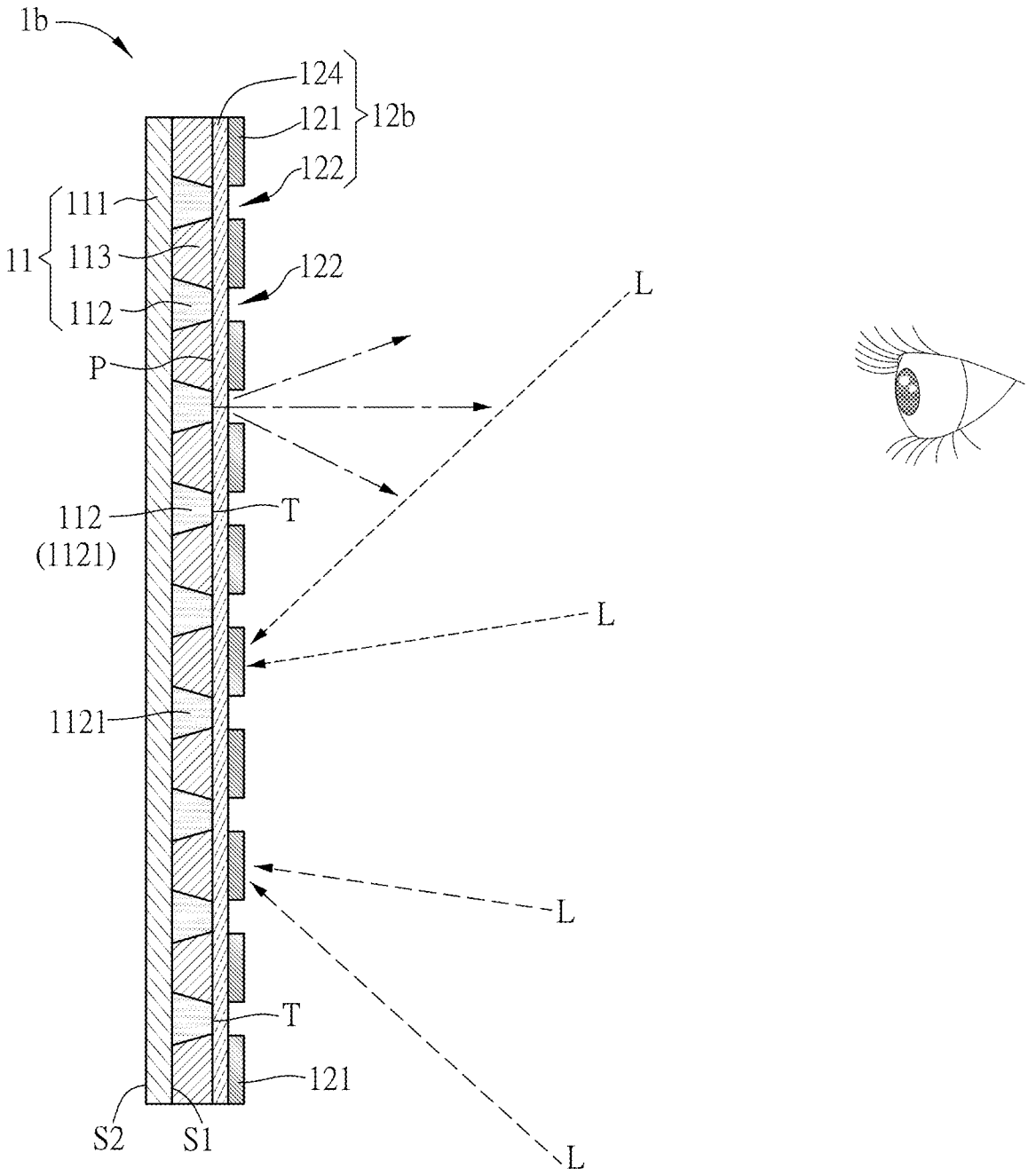
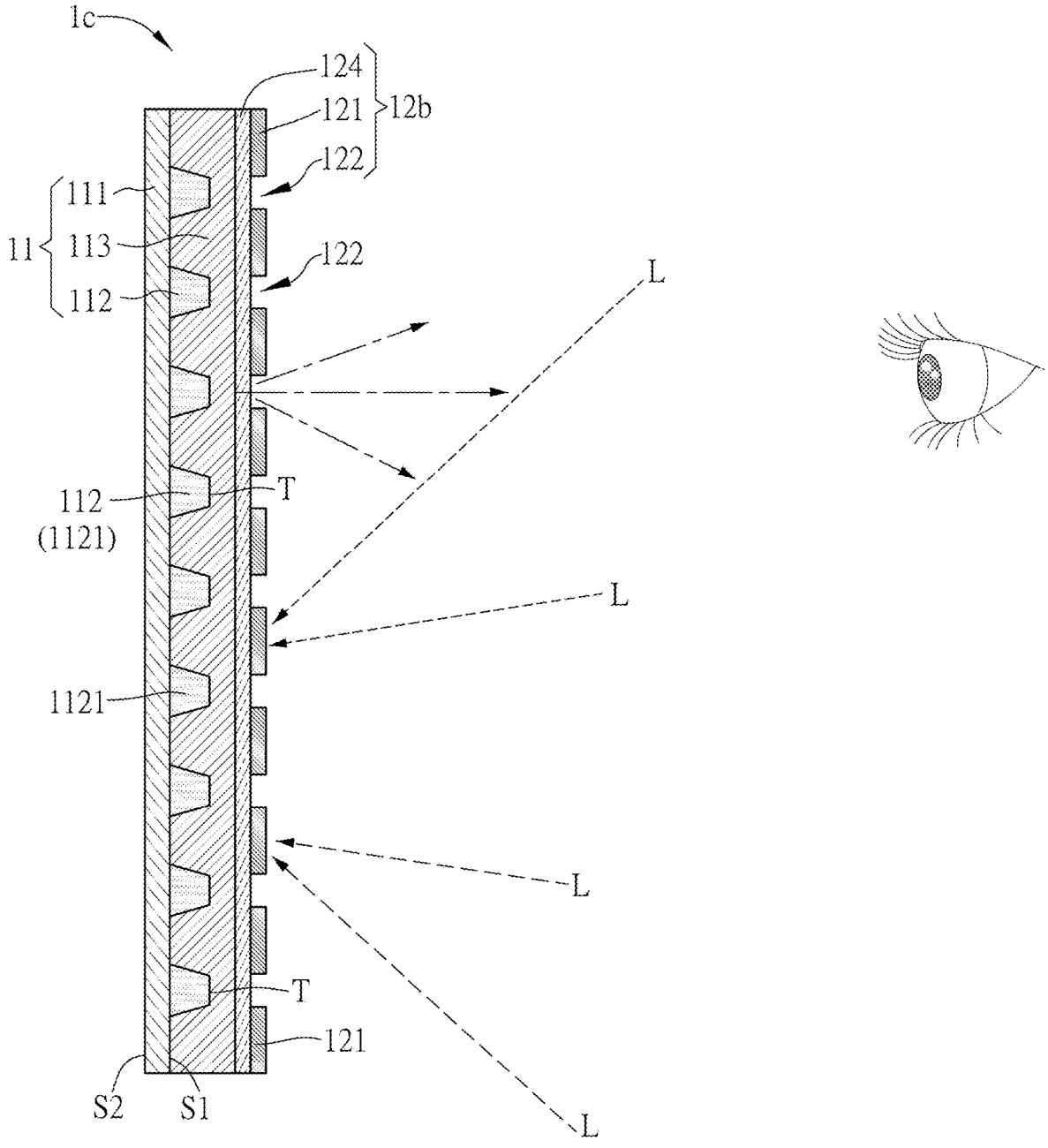

1b
124
121
12b
122
111
11
113
122
112
L
P
112
(1121)
T
L
1121
L
T
121
S2
S1
L

FIG. 3


1c
124
121
12b
122
111
11
113
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122
L
112
(1121)
T
L
1121
L
T
121
S2
S1
L

FIG. 4

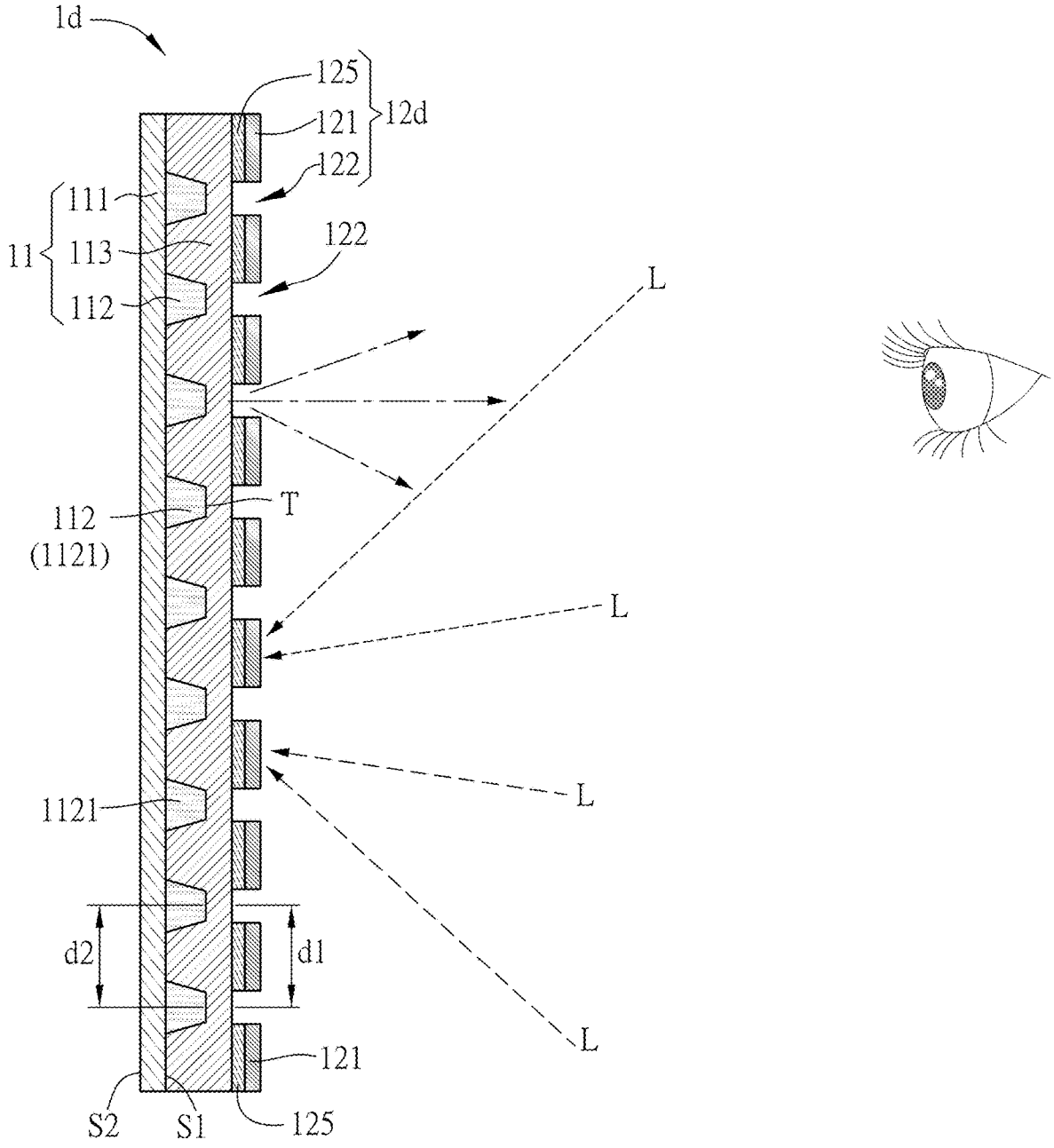
1d
125
121
12d
122
111
11
113
112
122
L
112
(1121)
T
L
L
1121
d2
d1
L
121
S2
S1
125

FIG. 5

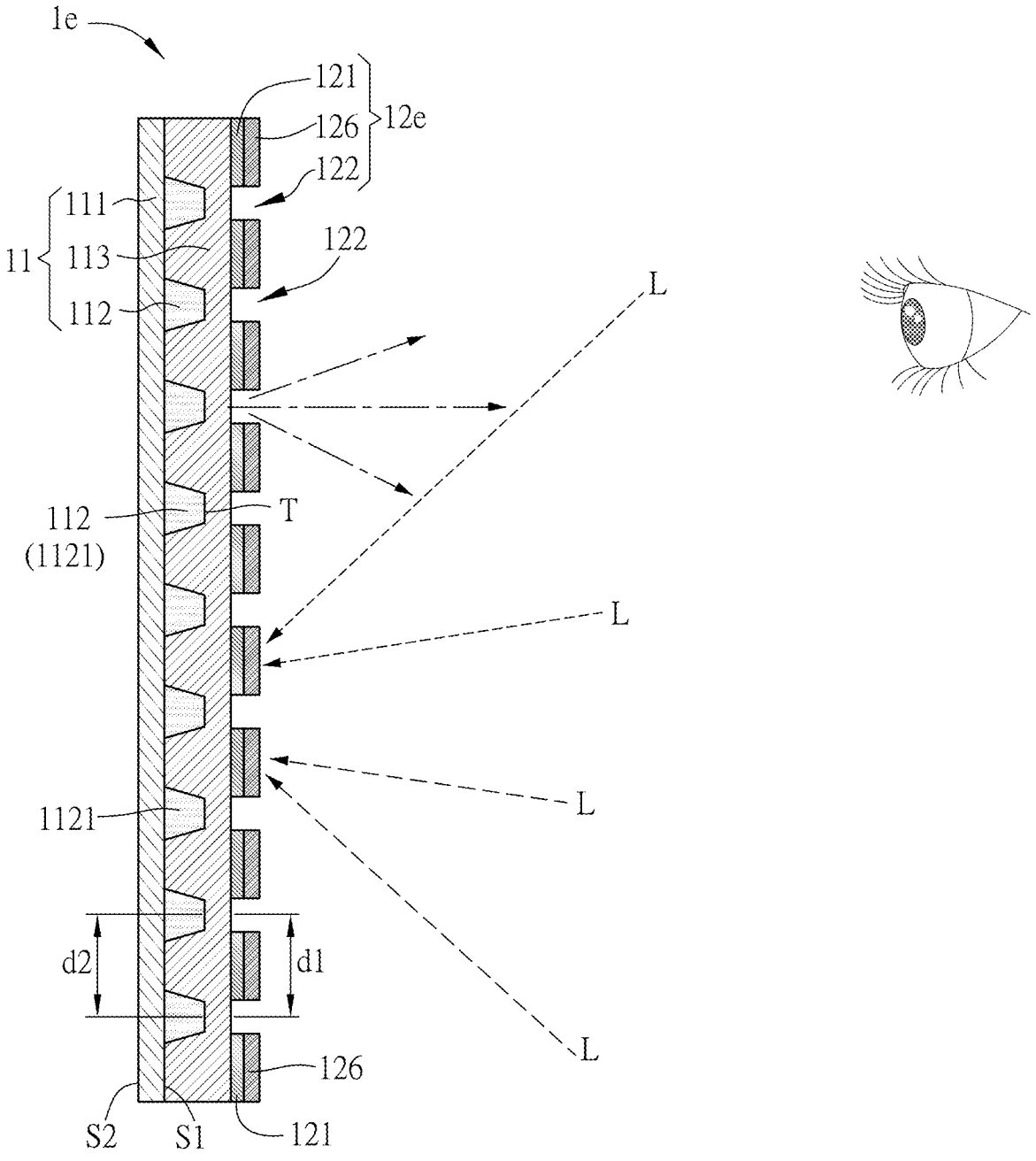
1e
121
126
12e
122
111
11
113
112
122
L
112
(1121)
T
L
L
1121
L
d2
d1
126
S2
S1
121

FIG. 6

DISPLAY DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Non-provisional application claims priority under 35 U.S.C. § 119(a) on Patent Application No(s). 110129143 filed in Taiwan, Republic of China on Aug. 6, 2021, the entire contents of which are hereby incorporated by reference.

BACKGROUND

Technology Field

[0002] The present disclosure relates to a display device and, in particular, to a display device that can improve the display quality degradation caused by ambient light.

Description of Related Art

[0003] The light-emitting diode (LED) is a lighting component made of semiconductor materials. The LED has two electrode terminals. When a voltage is applied between the electrode terminals, the electrons and electric holes can be combined in the semiconductor layers, and the remaining energy can be converted into light so as to output light. Different from the general incandescent light bulbs, LEDs are a cold light source, which has the advantages of low power consumption, long component life, no warm-up time, fast response speed, compact size, vibration durable, and suitable for mass production. Accordingly, the LED can be manufactured into a tiny or matrix module based on the needs in applications, so it can be widely used in lighting equipment, indicators of information, communication or consumer electronic products, backlight modules of display devices, display devices per se. Therefore, LEDs have become one of the essential components in our lives.

[0004] Taking the display device as an example, the ambient light source often causes the reflection of ambient images, thereby leading to the display quality degradation, especially in the outdoors. Therefore, it is desired to provide a display device that can solve the issue of the reflection of ambient images caused by the ambient light source, thereby improving the display quality degradation.

SUMMARY

[0005] Embodiments of the present invention are directed to a display device that can improve the display quality degradation caused by the ambient light source.

[0006] Embodiments of the present invention provide a display device, which includes a display module and a light-shielding structure. The display module has a substrate, a plurality of photoelectric units and a protective layer. The substrate defines with a first surface and a second surface, and the photoelectric units are arranged on the first surface of the substrate. Each photoelectric unit has at least one photoelectric element. The protective layer is arranged on the first surface of the substrate and is filled between the photoelectric elements. The light-shielding structure is arranged on and connected to the protective layer. The light-shielding structure has a light-shielding layer including light-absorption materials, and a plurality of windows defined in the light-shielding layer. The windows respectively correspond to the photoelectric units, and the photoelectric units are viewed through the corresponding windows in a direction perpendicular to the first surface of the substrate.

[0007] In one embodiment, the protective layer is a light-permeable layer.

[0008] In one embodiment, the windows respectively correspond to the photoelectric elements, and the photoelectric elements are viewed through the windows in the direction perpendicular to the first surface of the substrate.

[0009] In one embodiment, the pitch between adjacent two windows is equal to the pitch between adjacent two photoelectric units.

[0010] In one embodiment, the pitch between adjacent two windows is equal to the pitch between adjacent two photoelectric elements.

[0011] In one embodiment, the top surface of the protective layer and the top surfaces of the photoelectric elements together define a coplanar surface.

[0012] In one embodiment, the protective layer covers the top surfaces of the photoelectric elements.

[0013] In one embodiment, the light-shielding layer directly connects the protective layer.

[0014] In one embodiment, the light-shielding structure further has a transparent substrate connecting the protective layer, and the light-shielding layer is arranged on the surface of the transparent substrate away from the protective layer.

[0015] In one embodiment, the transparent substrate defines a light-emitting surface away from the substrate, and areas of the light-emitting surface corresponding to the windows are roughened.

[0016] In one embodiment, each of the windows is an opening defined through the light-shielding layer.

[0017] In one embodiment, the light-shielding structure further has a light-permeable element filling a corresponding one of the openings.

[0018] In one embodiment, the light-permeable element defines a refractive index matching decreasing away from the protective layer.

[0019] In one embodiment, in the direction perpendicular to the first surface of the substrate, the geometric dimension of each window is greater than or equal to the geometric dimension of the corresponding photoelectric unit.

[0020] In one embodiment, the light-shielding structure further includes a reflective layer arranged along the light-shielding layer, and the reflective layer is located between the protective layer and the light-shielding layer.

[0021] In one embodiment, the contour of the reflective layer is not greater than the contour of the light-shielding layer in the direction perpendicular to the first surface of the substrate.

[0022] In one embodiment, the light-shielding layer includes a light absorption material.

[0023] In one embodiment, the light-shielding structure further includes a light absorption layer arranged along the light-shielding layer, and the light absorption layer is located at one side of the light-shielding layer away from the protective layer.

[0024] In one embodiment, the light-shielding structure further defined plural of window areas corresponding to the windows respectively, and a non-window area representing a remaining area other than the window areas, an ambient-light reflectivity of the non-window area is less than that of at least one of the window areas.

[0025] In one embodiment, the protective layer defines a light-emitting surface away from the substrate, and the light-emitting surface is a roughened surface.

[0026] As mentioned above, in the display device of this disclosure, the light-shielding structure is arranged on and connected to the protective layer of the display module, and has a light-shielding layer and a plurality of windows defined in the light-shielding layer, the windows respectively correspond to the photoelectric units, and the photoelectric units are viewed through the corresponding windows in a direction perpendicular to the first surface of the substrate. Accordingly, when the ambient image light caused by the ambient light source is reflected to the display device, it can be absorbed by the light-shielding layer. As a result, the display device of this disclosure can improve the display quality degradation caused by the ambient light source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The disclosure will become more fully understood from the detailed description and accompanying drawings, which are given for illustration only, and thus are not limitative of the present disclosure, and wherein:

[0028] FIG. **1** is a schematic diagram showing a display device according to an embodiment of this disclosure; and

[0029] FIGS. **2** to **6** are schematic diagrams showing display devices according to different embodiments of this disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0030] The present disclosure will be apparent from the following detailed description, which proceeds with reference to the accompanying drawings, wherein the same references relate to the same elements.

[0031] Each of the display devices in the following embodiments can be an active matrix (AM) display device or a passive matrix (PM) display device, and this disclosure is not limited thereto.

[0032] FIG. **1** is a schematic diagram showing a display device **1** according to an embodiment of this disclosure. As shown in FIG. **1**, the display device **1** includes a display module **11** and a light-shielding structure **12** connecting to the display module **11**. The light-shielding structure **12** is configured to absorb the reflective light L from the ambient light source to the display device **1**, so that the viewer can be free from the interference of the ambient light source when viewing the display device **1**, thereby improving the display quality degradation caused by the ambient light source.

[0033] The display module **11** includes a substrate **111**, a plurality of photoelectric units **112**, and a protective layer **113**.

[0034] The substrate **111** is defined with a first surface S**1** and a second surface S**2** opposite to each other, the photoelectric units **112** are arranged on the first surface S**1** of the substrate **111**. In this case, the first surface S**1** is the surface of the substrate **111** facing the light-shielding structure **12** (as well as the viewer), and the second surface S**2** is the surface of the substrate **111** away from the light-shielding structure **12**. The photoelectric units **112** are separately distributed one the first surface S**1** of the substrate **111** and facing the light-shielding structure **12**. In some embodiments, the substrate **111** can be a rigid substrate, a resilient substrate or a composite substrate. For example, if the substrate **111** is a resilient substrate, the display device **1** can be manufactured as a rollable and flexible display device, which is convenient for storage.

[0035] Each of the photoelectric units **112** has at least one photoelectric element **1121**. In this embodiment, each photoelectric unit **112** has, for example, one photoelectric element **1121**. In some embodiments, the photoelectric element **1121** can be a photoelectric chip or a photoelectric package of millimeter or micrometer level. In some embodiments, the photoelectric element **1121** can include, for example but not limited to, a LED chip, a Mini LED chip, a Micro LED chip or a package, or a photoelectric chip or package on or under the level of micrometer or millimeter scale. In this case, the package on or under the level of millimeter scale should include the chip of micrometer level.

[0036] In some embodiments, the photoelectric unit **112** may have one photoelectric element **1121**, which means that the photoelectric unit **112** or the photoelectric element **1121** can be realized as one single pixel. In some embodiments, the photoelectric unit **112** may have a plurality of photoelectric elements **1121**, which means that the multiple photoelectric units **112** or the multiple photoelectric elements **1121** can be realized as a plurality of pixels. In some embodiments, the photoelectric unit **112** or photoelectric element **1121** can include, for example, one or more of red, blue, or green LED, Mini LED, or Micro LED chips, or LED, Mini LED, or Micro LED chips or packages of other colors. When the plurality of photoelectric chips or packages included in the photoelectric unit **112** or the photoelectric element **1121** are red, blue and green LED, Mini LED, or Micro LED chips, the display device **1** can be manufactured as a full-color LED, Mini LED, or micro LED display. In some embodiments, the photoelectric unit **112** or photoelectric element **1121** can include a chip having horizontal electrodes, flip-chip electrodes, or vertical electrodes, which are electrically connected to the circuit layer (not shown) arranged on the substrate **11** by wire bonding or flip-chip bonding. The aforementioned package is not limited to a package with active components or a passive package without active components. The active components can be, for example but not limited to, thin-film transistors (TFTs), silicon ICs, or the like. In some embodiments, the display module **11** may further include one or more driving elements corresponding to the aforementioned photoelectric units **112** or photoelectric elements **1121**, so as to drive the photoelectric units **112** or photoelectric elements **1121** to emit light correspondingly. In this case, the above-mentioned driving elements can be arranged on the first surface S**1** or/and the second surface S**2** of the substrate **111**, and this disclosure is not limited thereto. Each of the aforementioned driving elements can include at least one thin-film transistor (TFT), a silicon-semiconductor-based IC, or the like. In some embodiments, in addition to the TFT, the driving element can also include any of other thin-film elements or circuits, such as thin-film resistors, capacitors, or insulating films, and the disclosure is not limited thereto. In practice, the driving elements can be optionally selected depending on the driving method of the photoelectric unit **112** or the photoelectric element **1121**.

[0037] The protective layer **113** is arranged on the first surface S**1** of the substrate **111** and is filled between the photoelectric units **112** (or photoelectric elements **1121**). Moreover, the protective layer **113** of this embodiment also

covers the top surfaces T of the photoelectric units **112** (photoelectric elements **1121**) facing the light-shielding structure **12**. Since the protective layer **113** is filled between the photoelectric units **112** and covering the photoelectric units **112**, the photoelectric units **112** (photoelectric elements **1121**) can be protected from the intrusion of moisture or dusts, which may damage the characteristics thereof. In different embodiments, the protective layer **113** can only be filled between the photoelectric elements **1121** and be leveled with the top surfaces T of the photoelectric units **112** (photoelectric elements **1121**). In this embodiment, the protective layer **113** is a light-permeable layer, and it can be a structural layer made of, for example but not limited to, an optical clear adhesive (OCA), an optical clear resin (OCR), or any of other light-permeable materials. For example, the light-permeable material can include inorganic light-permeable materials, light-permeable polymer materials, or light-transmitting composite materials, and this disclosure is not limited thereto.

[0038] The light-shielding structure **12** is arranged on and connected to the protective layer **113**. The light-shielding structure **12** has a light-shielding layer **121** and a plurality of windows **122** defined in the light-shielding layer **121**. In this embodiment, the light-shielding layer **121** is arranged on the protective layer **113** and directly connected to the protective layer **113**, and the photoelectric units **12** can be viewed through (seen through) the corresponding windows in the direction perpendicular to the first surface S**1** of the substrate **111**. In addition, in order to avoid affecting the luminous efficiency of the photoelectric units **112**, the geometric dimension of each window **122** must be greater than or equal to the geometric dimension of the corresponding photoelectric unit **112** in the direction perpendicular to the first surface S**1** of the substrate **111**. In other words, when the viewer views the display device **1** from the side of the light-shielding structure **12** away from the display module **11**, the photoelectric unit **112** (or the photoelectric element **1121**) can be seen through the window **122**, and the light-shielding layer **121** will not affect the light outputted from the photoelectric unit **112** (or the photoelectric element **1121**). Even if the light-shielding layer **121** and the photoelectric unit **112** are not completely aligned due to the process factors, once the geometric size of each window **122** is greater than that of the corresponding photoelectric unit **112**, the light emitted from the photoelectric unit **112** will not be blocked by the light-shielding layer **121**, thereby avoiding to affect the luminous efficiency.

[0039] In this embodiment, each window **122** is an opening defined through the light-shielding layer **121** (without filling any material in the openings), and in the direction perpendicular to the first surface S**1** of the substrate **111**, the light-shielding pattern formed by the light-shielding layer **121** surrounds the peripheries of the photoelectric units **112**, so that the light emitted from the photoelectric units **112** can be outputted through the windows **122** respectively. The light-shielding layer **121** per se is made of light-absorption material(s), or at least includes a light absorption material, such as a black or dark ink or photoresist, for absorbing the ambient light reflected from the outside to the display device **1** and thus improving the contrast of the display device **1**.

[0040] In some embodiments, the pitch between two adjacent windows **122** can be equal to the pitch between two adjacent photoelectric units **112**. In some embodiments, the pitch between two adjacent windows **122** can be equal to the pitch between two adjacent photoelectric elements **1121**. In this embodiment, the windows **122** respectively correspond to the photoelectric elements **1121** (in the one-on-one manner), the photoelectric elements **1121** are viewed through (seen through) the corresponding windows **122** in the direction perpendicular to the first surface S**1**, and the pitch d**1** between two adjacent windows **122** is equal to the pitch d**2** between two adjacent photoelectric elements **1121** (d**1**=d**2**). Herein, "the pitch between two adjacent windows **122**" is defined as the distance between the middle line of one window **122** and the middle line of the next window **122**, and "the pitch between two adjacent photoelectric elements **1121**" is defined as the distance between the middle line of one photoelectric element **1121** and the middle line of the next photoelectric element **1121**.

[0041] In one embodiment, the protective layer **113** defines a light-emitting surface away from the substrate **11**, and the light-emitting surface is roughened after the surface treatment process. There are some benefits of the roughened surface, first, it would reduce the possibility of total reflection while the light is travelled from the photoelectric units **112** or the photoelectric element **1121** forward the protective layer **113**, and the lighting traveling efficiency of the photoelectric units **112** or the photoelectric element **1121** is consequently increased; second, it would reduce the possibility of reflection from the ambient light source; third, it would clarify the pixel to improve the image quality, while the roughened surface of the protective layer **113**, which includes light-absorption materials, improve the light-absorption efficiency.

[0042] In some embodiment, the light-shielding structure **12** further defined plural of window areas corresponding to the windows **122** respectively, and a non-window area representing a remaining area other than the widow areas, an ambient-light reflectivity of the non-window area is less than that of at least one of the window areas.

[0043] As mentioned above, in the display device **1** of this embodiment, the light-shielding structure **12** is arranged on and connected to the protective layer **113** of the display module **11**, and has a light-shielding layer **121** and a plurality of windows **122** defined in the light-shielding layer **121**, the windows **122** respectively correspond to the photoelectric units **112**, and the photoelectric units **112** are viewed through (seen through) the corresponding windows **122** in the direction perpendicular to the first surface S**1** of the substrate **111**. Accordingly, when the ambient image light L caused by the ambient light source is reflected to the display device **1**, it can be absorbed by the light-shielding layer **121**. As a result, the display device **1** of this embodiment can improve the display quality degradation caused by the ambient light source.

[0044] The display devices according to different embodiments of this disclosure will be described hereinafter with reference to FIGS. **2** to **6**.

[0045] As shown in FIG. **2**, the component configurations and connections of the display device **1***a* of this embodiment are mostly the same as those of the display device **1** of the previous embodiment. Unlike the display device **1** of the previous embodiment, in the display device **1***a* of this embodiment, each window **122** is an opening defined through the light-shielding layer **121**, and the light-shielding structure **12** further includes a light-permeable element **123**, which fills the openings. The material of the light-permeable element **123** can be, for example but not limited to, an

optical clear adhesive (OCA), an optical clear resin (OCR), or any of other light-permeable materials. For example, the light-permeable material can include inorganic light-permeable materials, light-permeable polymer materials, or light-transmitting composite materials, and this disclosure is not limited thereto. Moreover, it is desired, for decreasing the risks of possible scratching and damaging to the light-shielding structure **12** caused by external stresses, to provide an additional cover layer (not shown) at one side of the light-shielding structure **12** close to the viewer, and this disclosure is not limited. In some cases, the light-permeable element **123** defines a refractive index matching decreasing away from the protective layer **113**, which means the refractive index matching of the light-permeable element **123** decreases from a side adjacent to the protective layer **113** to an opposite side adjacent to the air therearound, to improve the image quality.

[0046] As shown in FIG. **3**, the component configurations and connections of the display device **1***b* of this embodiment are mostly the same as those of the display device **1** of the previous embodiment. Unlike the display device **1** of the previous embodiment, in the display device **1***b* of this embodiment, the protective layer **113** is only filled between and around the photoelectric units **112** (the photoelectric elements **1121**) without covering the top surfaces T of the photoelectric units **112** (the photoelectric elements **1121**). In this embodiment, the top surface of the protective layer **113** and the top surfaces T of the photoelectric units **112** (the photoelectric elements **1121**) are leveled and together define a coplanar surface P. Furthermore, the light-shielding structure **12***b* of this embodiment further includes a transparent substrate **124** connecting the protective layer **113**, and the light-shielding layer **121** is arranged on a surface of the transparent substrate **124** away from the protective layer **113**. In this case, since the protective layer **113** is leveled with the top surfaces T of the photoelectric units **112** (the photoelectric elements **1121**), the transparent substrate **124** can connect the coplanar surface P defined by the top surface of the protective layer **113** and the top surfaces T of the photoelectric units **112** (the photoelectric elements **1121**). In this case, the openings of the light-shielding structure **12** would be further through the transparent substrate **124** for communicating therethrough, or the transparent substrate **124** would close the openings of light-shielding layer **121**. In the case of closure of the openings of light-shielding layer **121**, the transparent substrate **124** defines a light-emitting surface away from the substrate **11**, and areas of the light-emitting surface corresponding to the windows **122** are roughened, so as to improve the image quality.

[0047] As shown in FIG. **4**, the component configurations and connections of the display device **1***c* of this embodiment are mostly the same as those of the display device **1** of the previous embodiment. Unlike the display device **1** of the previous embodiment, in the display device **1***c* of this embodiment, the light-shielding structure **12***c* further includes a transparent substrate **124**, which connects the protective layer **113**, and the light-shielding layer **121** is arranged on a surface of the transparent substrate **124** away from the protective layer **113**.

[0048] As shown in FIG. **5**, the component configurations and connections of the display device **1***d* of this embodiment are mostly the same as those of the display device **1** of the previous embodiment. Unlike the display device **1** of the previous embodiment, in the display device **1***d* of this embodiment, the light-shielding structure **12***d* further includes a reflective layer **125** arranged along the light-shielding layer **121**, and the reflective layer **125** is located between the protective layer **113** and the light-shielding layer **121**. Based on this design, the light emitted from the photoelectric unit **112** toward the light-shielding layer **121** can be reflected by the reflective layer **125**, thereby improving the light utilization rate of the photoelectric units **112**. The contour of the reflective layer **125** can be not greater than that of the light-shielding layer **121** in the direction perpendicular to the first surface of the substrate. In other words, in the direction parallel to the first surface S1 of the substrate **111**, the present embodiment does not limit the width of the reflective layer **125** to be the same as that of the light-shielding layer **121**. For example, the width of the reflecting layer **125** can be equal to or less than the width of the light-shielding layer **121**. In this embodiment, the contour of the reflective layer **125** is equal to the contour of the light-shielding layer **121** as an example.

[0049] As shown in FIG. **6**, the component configurations and connections of the display device **1***e* of this embodiment are mostly the same as those of the display device **1** of the previous embodiment. Unlike the display device **1** of the previous embodiment, in the display device **1***e* of this embodiment, the light-shielding layer **12***e* includes a light absorption layer **126** arranged along the light-shielding layer **121**, and the light absorption layer **126** is located at one side of the light-shielding layer **121** away from the protective layer **113**. In this embodiment, the light absorption layer **126** is connected with one side of the light-shielding layer **121** away from the protective layer **113**. In this case, the light-shielding layer **121** can include a light absorption material, and the light absorption material of the light absorption layer **126** can be the same as or different from that of the light-shielding layer **121**. This disclosure is not limited thereto.

[0050] To be noted, the light-permeable element **123** of the display device **1***a* as shown in FIG. **2** can be applied to any of the display devices **1***b*~**1***e* as shown in FIGS. **3** to **6**.

[0051] To be understood, in the conventional art, the light-shielding structure (light-shielding layer) is directly formed inside the display module (for example, the black matrix (BM) is arranged on the substrate and is located at the periphery of the photoelectric unit), but it may have non-uniform refractive indexes due to the non-uniform material distribution after the molding process, which will cause the reflection of external light source. To solve this problem of the conventional art, the present disclosure arranges the light-shielding structure (light-shielding layer) outside the display module, which can effectively reduce the interference of the displayed image caused by the reflection of external light source, thereby avoiding to induce the problem of display quality degradation.

[0052] In summary, in the display device of this disclosure, the light-shielding structure is arranged on and connected to the protective layer of the display module, and has a light-shielding layer and a plurality of windows defined in the light-shielding layer, the windows respectively correspond to the photoelectric units, and the photoelectric units are viewed through the corresponding windows in a direction perpendicular to the first surface of the substrate. Accordingly, when the ambient image light caused by the ambient light source is reflected to the display device, it can be absorbed by the light-shielding layer. As a result, the

display device of this disclosure can improve the display quality degradation caused by the ambient light source.

[0053] Although the disclosure has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments, will be apparent to persons skilled in the art. It is, therefore, contemplated that the appended claims will cover all modifications that fall within the true scope of the disclosure.

What is claimed is:

1. A display device, comprising:

a display module having a substrate, a plurality of photoelectric units and a protective layer, wherein the substrate defines with a first surface and a second surface opposite to each other, the photoelectric units are arranged on the first surface of the substrate, each of the photoelectric units has at least one photoelectric element, and the protective layer is arranged on the first surface of the substrate and is filled between the photoelectric elements; and

a light-shielding structure arranged on and connected to the protective layer, wherein the light-shielding structure has a light-shielding layer including light-absorption materials, and a plurality of windows defined in the light-shielding layer; the windows respectively correspond to the photoelectric units, and the photoelectric units are viewed through the corresponding windows in a direction perpendicular to the first surface of the substrate.

2. The display device of claim **1**, wherein the protective layer is a light-permeable layer.

3. The display device of claim **1**, wherein the windows respectively correspond to the photoelectric elements, and the photoelectric elements are viewed through the windows in the direction perpendicular to the first surface of the substrate.

4. The display device of claim **1**, wherein a pitch between adjacent two of the windows is equal to a pitch between adjacent two of the photoelectric units.

5. The display device of claim **1**, wherein a pitch between adjacent two of the windows is equal to a pitch between adjacent two of the photoelectric elements.

6. The display device of claim **1**, wherein a top surface of the protective layer and top surfaces of the photoelectric elements together define a coplanar surface.

7. The display device of claim **1**, wherein the protective layer covers top surfaces of the photoelectric elements.

8. The display device of claim **1**, wherein the light-shielding layer directly connects the protective layer.

9. The display device of claim **1**, wherein the light-shielding structure further has a transparent substrate connecting the protective layer, and the light-shielding layer is arranged on a surface of the transparent substrate away from the protective layer.

10. The display device of claim **1**, wherein each of the windows is an opening defined through the light-shielding layer.

11. The display device of claim **10**, wherein the light-shielding structure further has a light-permeable element filling a corresponding one of the openings.

12. The display device of claim **11**, wherein the light-permeable element defines a refractive index matching decreasing away from the protective layer.

13. The display device of claim **1**, wherein, in the direction perpendicular to the first surface of the substrate, a geometric dimension of each of the windows is greater than or equal to a geometric dimension of corresponding one of the photoelectric units.

14. The display device of claim **1**, wherein the light-shielding structure further includes a reflective layer arranged along the light-shielding layer, and the reflective layer is located between the protective layer and the light-shielding layer.

15. The display device of claim **14**, wherein a contour of the reflective layer is not greater than a contour of the light-shielding layer.

16. The display device of claim **1**, wherein the light-shielding layer comprises a light absorption material.

17. The display device of claim **1**, wherein the light-shielding structure further comprises a light absorption layer arranged along the light-shielding layer, and the light absorption layer is located at one side of the light-shielding layer away from the protective layer.

18. The display device of claim **1**, wherein the light-shielding structure further defined plural of window areas corresponding to the widows respectively, and a non-window area representing a remaining area other than the widow areas, an ambient-light reflectivity of the non-window area is less than that of at least one of the window areas.

19. The display device of claim **1**, wherein the protective layer defines a light-emitting surface away from the substrate, and the light-emitting surface is a roughened surface.

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