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(71) Applicant: AU OPTRONICS CORPORATION
[CN/CN]; No.1, Li-Hsin Road II, Science-Based Industrial
Park, Hsin-Chu, Taiwan 30078 (CN).

(72) Inventors: LIU, Mengchang; c/o No.1, Li-Hsin Road II,
Science-Based Industrial Park, Hsin-Chu, Taiwan 30078
(CN). HSIAO, Mengjia; c/o No.1, Li-Hsin Road II, Sci-
ence-Based Industrial Park, Hsin-Chu, Taiwan 30078
(CN).

(74) Agent: LUNGTIN INTERNATIONAL INTELLECTU-
AL PROPERTY AGENT LTD.; 18th Floor, Tower B,
Grand Place, No. 5 Huizhong Road, Chaoyang District,
Beijing 100101 (CN).

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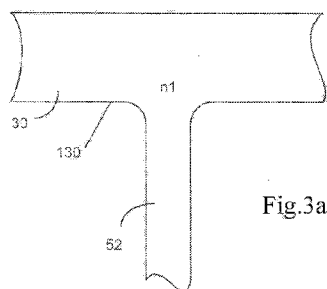


Fig.3a

(57) Abstract: A method for providing a supporting structure in a flat-plate display is disclosed. The display has a display panel, a diffuser panel, a reflector panel to reflect light from a backlight unit towards the diffuser panel in order to illuminate the display panel. The supporting structure has a plurality of support pins located in that gap between the diffuser panel and the reflector panel for supporting the diffuser panel. The support pins are either molded with the diffuser panel, fused into the diffuser panel or attached to the diffuser panel using an index matching optical adhesive.



WO 2014/005437 A1

SUPPORTING STRUCTURE IN A FLAT-PLATE DISPLAY AND METHOD FOR MAKING SAME

5 Technical Field

The present invention relates to a flat-plate display and, in particular, to the supporting structure in the flat-plate display.

Background of the Invention

10 A flat-plate display, in general, has a display panel where a layer of thin-film transistors is used to control a plurality of display elements illuminated by a backlight source. Between the backlight source and the display panel, a diffuser panel is used to diffuse the light provided by the backlight source. Furthermore, a reflector is placed adjacent to the backlight source to reflect the light provided by the backlight source to the diffuser panel. The diffuser panel is spaced from
15 the reflector and the backlight source, leaving a gap therebetween.

The present invention is concerned with providing a supporting structure in the flat-plate display. In particular, the supporting structure is located in the gap between the diffuser panel and the backlight source/reflector.

20 Summary of the Invention

The present invention provides a flat-plate display with a supporting structure. If the supporting structure includes a plurality of support pins placed in the gap between the diffuser panel and the backlight source to support the diffuser panel, dark spots usually appear on the display panel at the locations above the support pins due to the reflection losses between the
25 diffuser panel and the support pins. According to various embodiments of the present invention, the dark spots associated with the supporting pins are reduced or eliminated.

Thus, the first aspect of the present invention is a method for use in a display. The method comprises:

30 providing a supporting structure in the display, the display comprising a diffuser panel and a reflector panel spaced from the diffuser panel, defining a gap therebetween, wherein the supporting structure comprises a plurality of support pins located in the gap; and

joining the support pins to the diffuser panel such that the absolute value of a refractive index difference, if existing, between the diffuser panel and the support pins is smaller than 0.3.

According to some embodiments of the present invention, when the diffuser panel and the

support pins are made of the same material, said joining comprises molding the support pins with the diffuser panel and the molding comprises injection molding.

According to some embodiments of the present invention, the joining comprises fusing one end of the support pins onto the diffuser panel and the fusing comprises applying ultrasonic waves to the one end of the support pins.

According to some embodiments of the present invention, the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index different from the first refractive index.

According to some embodiments of the present invention, the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index.

According to some embodiments of the present inventions, the joining comprises providing an optical adhesive between the diffuser panel and one end of the support pins. When the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index, and the optical adhesive comprises a third refractive index, the method further comprises:

selecting the optical adhesive such that the third refractive index has a value between the first refractive index and the second refractive index.

According to some embodiments of the present invention, when the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index, and the optical adhesive comprises a third refractive index, the method further comprises:

selecting the optical adhesive such that the absolute difference between the first refractive index and the third refractive index is smaller than 0.02.

The second aspect of the present invention is a display comprising:
a diffuser panel;

a reflector panel configured to reflect light towards the diffuser panel, the reflector panel spaced from the diffuser panel defining a gap therebetween; and

a supporting structure located in the gap, the supporting structure comprising a plurality of support pins attached to the diffuser panel such that the absolute value of a refractive index difference, if existing, between the diffuser panel and the support pins is smaller than 0.3.

According to some embodiments of the present invention, when the diffuser panel and the support pins are made of the same material, the support pins are molded with the diffuser panel.

According to one embodiment of the present invention, in the support pins are molded with the diffuser panel by injection molding.

According to some embodiments of the present invention, one end of the support pins is fused onto the diffuser panel.

According to one embodiment of the present invention, the support pins are fused onto the diffuser panel by ultrasonic welding.

5 According to various embodiments of the present invention, the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index different from or substantially equal to the first refractive index.

10 According to some embodiments of the present invention, the support pins are attached to the diffuser panel by an optical adhesive provided between the diffuser panel and one end of each of the support pins.

15 According to one embodiment of the present invention, when the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index, and the optical adhesive comprises a third refractive index, the optical adhesive is selected such that the third refractive index has a value between the first refractive index and the second refractive index.

20 According to another embodiment of the present invention, when the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index, and the optical adhesive comprises a third refractive index, the optical adhesive is selected such that the absolute difference between the first refractive index and the third refractive index is smaller than 0.02.

Brief Description of the Drawings

25 Figure 1 illustrates a flat display according to the present invention.

Figure 2a illustrates the interface between the diffuser panel and one of the support pins.

Figure 2b illustrates the losses in transmitted light due to multiple reflections.

Figure 3a illustrates a support pin molded with the diffuser panel, according to one embodiment of the present invention.

30 Figure 3b illustrates a support pin fused into the diffuser panel, according to another embodiment of the present invention.

Figure 3c illustrates a support pin attached to the diffuser panel using an optical adhesive, according to a different embodiment of the present invention.

35 Figure 3d illustrates the losses in transmitted light when the support pins are attached to the diffuser panel using an optical adhesive.

Detailed Description of the Invention

The present invention is concerned with providing a supporting structure in a flat-plate display. As shown in Figure 1, the flat-plate display 10 has a display panel 20, a diffuser or diffuser panel 30, a backlight unit 40. The display panel 20 comprises a plurality of picture elements controlled by a thin-film transistor layer (not shown). In a transmissive or transreflective display, the display panel 20 is illuminated by the backlight unit 40 through the diffuser panel 30. The diffuser panel 30 is spaced from the backlight unit 40 such that there is a gap 34 between the diffuser panel 30 and the backlight unit 40. The backlight unit 40 may comprise a backlight source 42 to provide the illuminating light and a reflector 44 to reflect part of the illuminating light toward the diffuser panel 30. The present invention is concerned with providing a supporting structure 50 in the gap 34. The supporting structure 50 comprises a plurality of support pins 52. Depending on the physical layout of the backlight unit 40, it is possible that one end of the support pin 52 is located on the surface 144 of the reflector 44 and the other end of the support pin 52 is touching the lower surface 130 of the diffuser panel 30. Let us assume that the diffuser panel 30 is made of a material having a refractive index n_1 and the support pins 52 are made of a material having a refractive index n_2 . In general, if the diffuser panel 30 is resting on the support pins 52 as shown in Figure 2a, the interface 150 between the upper surface 152 of the support pins 52 and the lower surface 130 of the diffuser panel 30 comprises an air gap as shown in Figure 2b. When a light beam 53 encounters the upper surface 152, part of the light beam 53 will be reflected due to the refractive index difference between n_2 and air ($n=1.0$). The transmitted portion through the upper surface 152 will also be reflected at the lower surface 130 of the diffuser panel 30 due to the refractive index difference between n_1 and air.

The present invention provides a method and a supporting structure configured to eliminate or reduce the losses in the transmitted light from the support pin 52 through the interface 150 into the diffuser panel 30. The losses in the transmitted light can be estimated using Fresnel reflection equation, which is well known. As shown in Figures 2a and 2b, the refractive index of the diffuser panel 30 is n_1 and the refractive index of the support pin 52 is n_2 . There will be two reflections R_1 and R_2 and the transmission coefficient T is approximately given by $T=1-R_1-R_2$, which is dependent on the incident angle θ .

For simplicity, let us assume $n_1=n_2=1.5$. With the refractive index of air being $n=1$, the refractive index difference is $\Delta n=\pm 0.5$. The reflection coefficient ($R_1=R_2=R$, approximately) and the transmission coefficient ($T=1-2R$) are given below:

Incident angle θ (degrees)	R	T
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0	0.04	0.92
25	0.075	0.85
35	0.17	0.66
40	0.39	0.22
> 41.8	R1=TIR	0

It should be noted that, when the incident angle is larger than 41.8 degrees, total-internal-reflection (TIR) occurs at the interface 152 (at the upper surface of the support pin 52). As such, the light beam does not reach the diffuser panel 30. The TIR angle is less than 45 degrees and, therefore, only a small part of the light beams from the reflector will be transmitted into the diffuser panel 30. Due to the reflection losses at the interface 150 between the diffuser panel 30 and the support pin 52, a darker spot appears on the display panel 20. The number of darker spots on the display panel 20 is dependent on the number of the support pins 52.

According to various embodiments of the present invention, the losses in the transmitted light can be eliminated or reduced by reducing the refractive index difference, Δn , at the interface 150 between the lower surface 130 of the diffuser panel 30 and the upper surface 152 of the support pin 52.

According to one embodiment of the present invention, the support pins 52 are produced in the same process as the diffuser panel 30. For example, if the diffuser panel 30 is made of plastic or polymer produced by injection molding, then the support pins 52 can be produced by injection molding in the same process. As such, there is no gap between the lower surface 130 of the diffuser panel 30 and each of the support pins 52 (see Figure 3a). Since there is no interface between the lower surface 130 of the diffuser panel 30 and each of the support pins 52, there are no reflection losses between the lower surface 130 of the diffuser panel 30 and the support pins 52.

According to another embodiment of the present invention, the support pins 52 are fused onto the lower surface 130 of the diffuser panel 30. For example, ultrasonic welding can be used to join the support pins 52 to the lower surface 130 of the diffuser panel 30 as shown in Figure 3b. Ultrasonic welding applies high-frequency ultrasonic acoustic vibrations to the upper end of each support pin 52 to create a solid-state weld. Since ultrasonic welding can be used to join dissimilar materials together, the refractive index n_2 of the support pins 52 can be the same as or different from the refractive index n_1 of the diffuser panel 30. In any case, the air gap at the interface 150 (see Figures 2b) is eliminated. It should be noted that ultrasonic welding is used here as an example. There may be many other joining techniques that can be used for joining the support pins 52 to the lower surface 130 of the diffuser panel 30 without resulting in an abrupt

change in the refractive index in the path of a light beam from a support pin to the diffuser panel. For example, there are methods that can be used to temporarily melt either the upper surface 152 of a support pin 52 or the lower surface 130 of the diffuser panel 30, or both, for the joining purpose.

5 According to yet another embodiment of the present invention, the support pins 52 are attached to the lower surface 130 of the diffuser panel 30 using a joining medium. For example, an optical adhesive 35 is used to join the support pins 52 to the lower surface 130 of the diffuser panel 30 as shown in Figure 3c. As shown in Figure 3c, the refractive index of the diffuser panel 30 is n_1 , the refractive index of the support pin 52 is n_2 and the refractive index of the optical
 10 adhesive 35 is n_3 . It is understood that, before the optical adhesive 35 is cured, it is a liquid or gel so that there are effectively no air gaps existing between the optical adhesive 35 and the diffuser panel 30 and between the optical adhesive 35 and the support pin 52. Thus, it is possible to substantially eliminate the losses in the transmitted light due to the reflections at an air gap. For example, if the refractive indices of the diffuser panel 30 and the support pins 52 are
 15 substantially the same, or $n_1=n_2$, it is possible to select an optical adhesive 35 with a refractive index n_3 which is substantially equal to n_1 .

If n_1 is not the same as n_2 , it is possible to select an optical adhesive 35 with a refractive index n_3 having a value between n_1 and n_2 to reduce the reflection losses. For example, if $n_1=1.50$ and $n_2=1.60$, it is possible to select an optical adhesive with a refractive index $n_3=1.55$
 20 such that $\Delta n=\pm 0.05$. In this particular case, the losses in the transmitted light can be estimated as follows:

Incident angle θ (degrees)	R	T
0	0.00025	0.9995
25	0.0004	0.9992
35	0.0006	0.9988
45	0.0010	0.998
60	0.005	0.99
>75.7	R=TIR	0

25 Thus, in this particular example, the transmission losses in this case are mainly due to reflections at very large incident angles and the total-internal-reflection.

It should be noted that most plastics have refractive indices between 1.3 and 1.7, and the refractive indices of the optical adhesive are between 1.32 and 1.57. If $n_1=1.7$ and $n_2=1.3$, it is possible to select an optical adhesive with $n_3=1.50$ so that $\Delta n=\pm 0.2$. The losses in the

transmitted light can be estimated as follows:

Incident angle θ (degrees)	R	T
0	0.0051	0.99
25	0.0071	0.984
35	0.010	0.98
45	0.016	0.978
60	0.043	0.91
No TIR		

5 The losses in the transmitted light can be greatly reduced even when there is a substantial refractive index difference between the optical adhesive 35 and the diffuser panel 30, and between the optical adhesive 35 and the support pin 52. For example, when $n_1=n_2=1.59$ and $n_3=1.32$ (with $\Delta n=\pm 0.27$), the losses in the transmitted light are estimated as follows:

Incident angle θ (degrees)	R	T
0	0.0086	0.983
25	0.014	0.972
35	0.024	0.952
45	0.057	0.886
55	0.38	0.24
>56.1	R=TIR	0

10 It should be understood that, there is no reason why one chooses such an optical adhesive with $\Delta n=\pm 0.27$. The above calculation is only used to demonstrate that it is possible to reduce the reflection losses by attaching a support pin to the diffuser panel such that the absolute value of a refractive index difference, if existing, between the diffuser panel and the support pins is smaller than 0.3.

15 In an extreme case when both the diffuser panel 30 and the support pins 52 are made of materials with $n_1=n_2=1.7$, it is possible to select the optical adhesive having the highest refractive index or $n_3=1.57$ (with $\Delta n=\pm 0.13$).

Incident angle θ (degrees)	R	T
0	0.0016	0.998
25	0.0024	0.995

35	0.0038	0.992
45	0.0075	0.985
55	0.0217	0.957
>67.5	R=TIR	0

When the refractive index of the plastic is $n_1=n_2=1.3$, an optical adhesive having a low refractive index such as 1.32 should be used, or $\Delta n=\pm 0.02$.

In the various embodiments of the present invention, the losses in the transmitted light can be reduced by choosing the refractive index difference, Δn , for the interface between the diffuser panel 30 and the support pin 52 to be smaller than, say, ± 0.3 . When the refractive index of the diffuser panel 30 and the support pin 52 is around 1.5, an optical adhesive having a refractive index between 1.48 and 1.52 should be used for attaching the support pin 52 to the lower surface 130 of the diffuser panel 30. As such, the absolute refractive index difference between the optical adhesive and the diffuser panel/support pins is equal to or smaller than 0.02.

In summary, when the support pins are molded with the diffuser panel, the losses in transmitted light can be effectively eliminated. When the support pins are fused with the diffuser panel, the losses in transmitted light are greatly reduced or eliminated. When the support pins are attached to the diffuser panel using an optical adhesive, the optical adhesive can be selected such that the absolute difference between the optical adhesive and the diffuser panel/support pins can be reduced to 0.3 or smaller. It is also possible to select the optical adhesive such that the absolute difference is reduced to 0.05 or 0.02 and smaller. With the various embodiments of the present invention, the darker spots on the display panel due to the losses in the transmitted light (from the reflector to the diffuser panel) can be eliminated or made less visible.

Although the present invention has been described with respect to one or more embodiments thereof, it will be understood by those skilled in the art that the foregoing and various other changes, omissions and deviations in the form and detail thereof may be made without departing from the scope of this invention.

What is claimed is:

1. A method for use in a display, comprising:

5 providing a supporting structure in the display, the display comprising a diffuser panel and a reflector panel spaced from the diffuser panel, defining a gap therebetween, wherein the supporting structure comprises a plurality of support pins located in the gap; and

joining the support pins to the diffuser panel such that the absolute value of a refractive index difference, if existing, between the diffuser panel and the support pins is smaller than 0.3.

10 2. The method according to claim 1, wherein the diffuser panel and the support pins are made of the same material and wherein said joining comprises molding the support pins with the diffuser panel.

3. The method according to claim 2, wherein said molding comprises injection molding.

4. The method according to claim 1, wherein said joining comprises fusing one end of the support pins onto the diffuser panel.

15 5. The method according to claim 4, wherein said fusing comprises applying ultrasonic waves to the one end of the support pins.

6. The method according to claim 4, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index different from the first refractive index.

20 7. The method according to claim 4, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index.

8. The method according to claim 1, wherein said joining comprises providing an optical adhesive between the diffuser panel and one end of the support pins.

25 9. The method according to claim 8, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index, and the optical adhesive comprises a third refractive index, said method further comprising:

30 selecting the optical adhesive such that the third refractive index has a value between the first refractive index and the second refractive index.

10. The method according to claim 8, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index, and the optical adhesive comprises a third refractive index, said method further comprising:

35 selecting the optical adhesive such that the absolute difference between the first refractive

index and the third refractive index is smaller than 0.02.

11. A display comprising:

a diffuser panel;

5 a reflector panel configured to reflect light towards the diffuser panel, the reflector panel spaced from the diffuser panel defining a gap therebetween; and

a supporting structure located in the gap, the supporting structure comprising a plurality of support pins attached to the diffuser panel such that the absolute value of a refractive index difference, if existing, between the diffuser panel and the support pins is smaller than 0.3.

10 12. The display according to claim 11, wherein the diffuser panel and the support pins are made of the same material and wherein the support pins are molded with the diffuser panel.

13. The display according to claim 12, wherein the support pins are molded with the diffuser panel by injection molding.

14. The display according to claim 11, wherein one end of the support pins is fused onto the diffuser panel.

15 15. The display according to claim 14, wherein the support pins are fused onto the diffuser panel by ultrasonic welding.

20 16. The display according to claim 14, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index different from or substantially equal to the first refractive index.

17. The display according to claim 11, wherein the support pins are attached to the diffuser panel by an optical adhesive provided between the diffuser panel and one end of each of the support pins.

25 18. The display according to claim 17, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index, and the optical adhesive comprises a third refractive index, and wherein the optical adhesive is selected such that the third refractive index has a value between the first refractive index and the second refractive index.

30 19. The display according to claim 17, wherein the diffuser panel is made of a first material comprising a first refractive index and the support pins are made of a second material comprising a second refractive index substantially equal to the first refractive index, and the optical adhesive comprises a third refractive index, and wherein the optical adhesive is selected such that the absolute difference between the first refractive index and the third refractive index is smaller than 0.02.

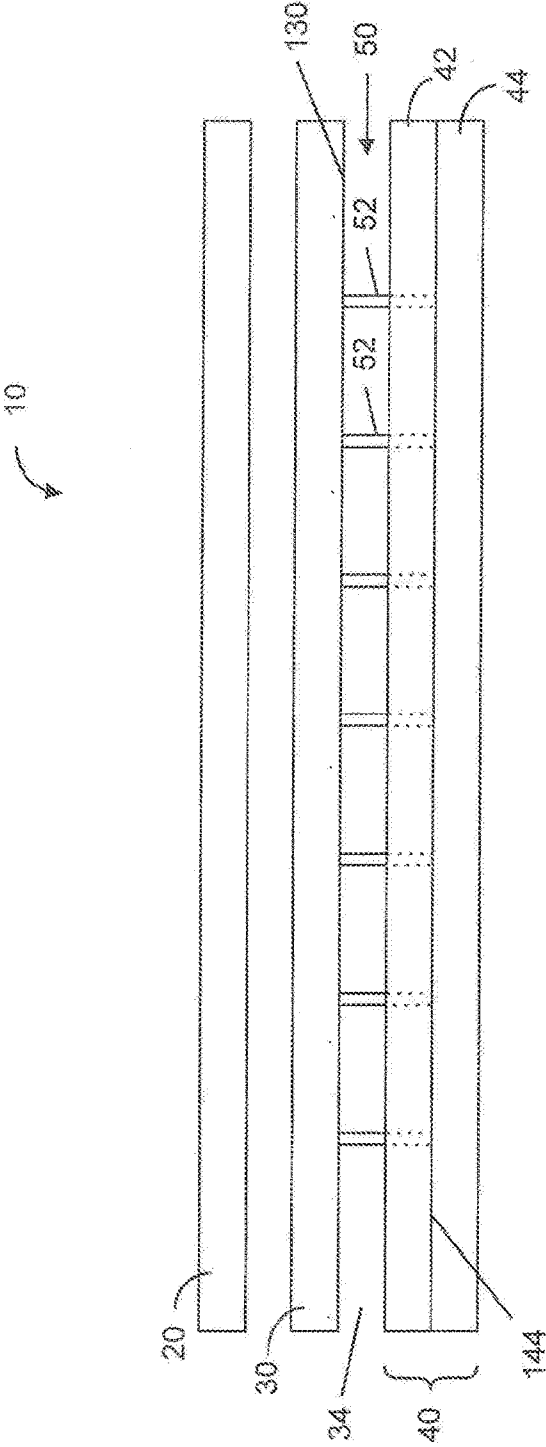


Fig.1

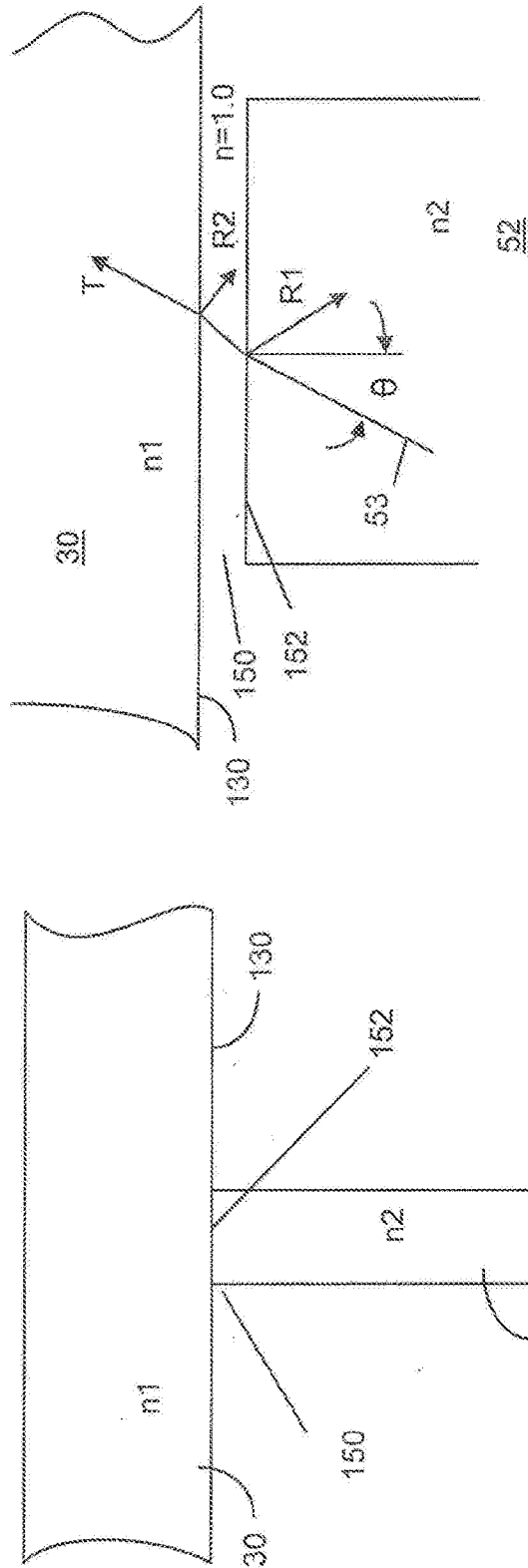


Fig.2b

Fig.2a

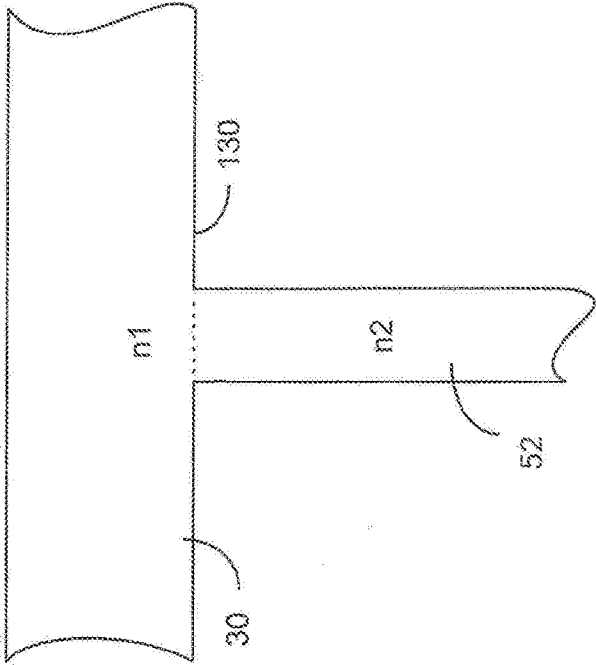


Fig.3b

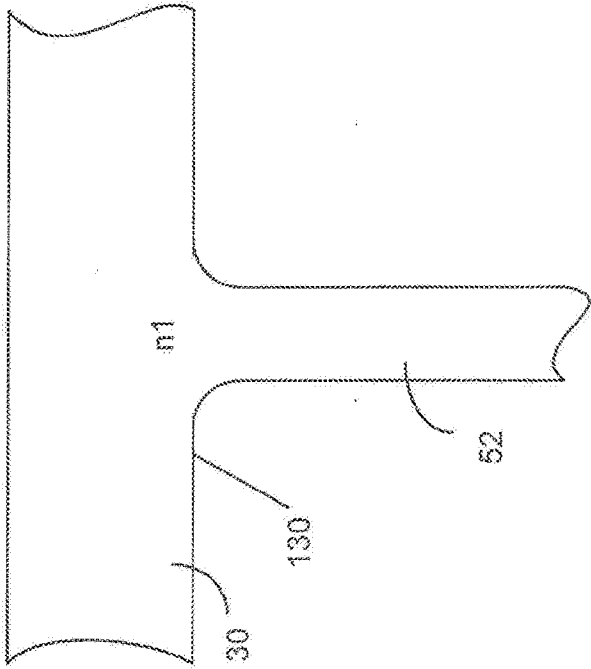


Fig.3a

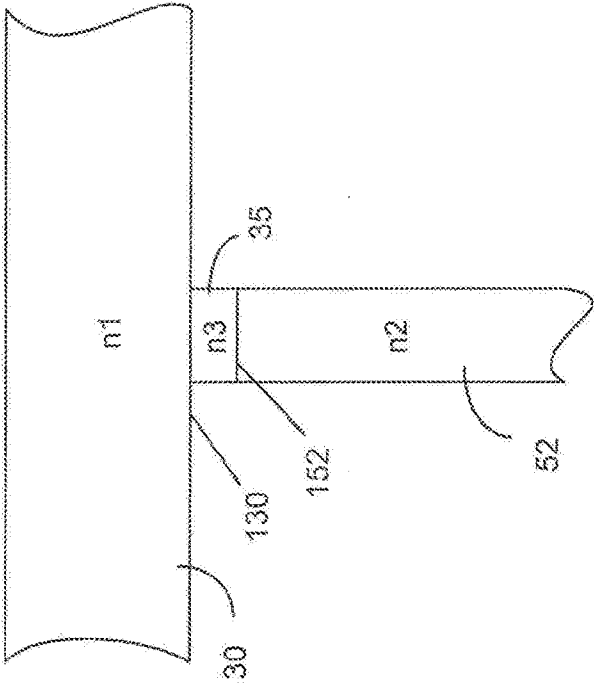


Fig.3c

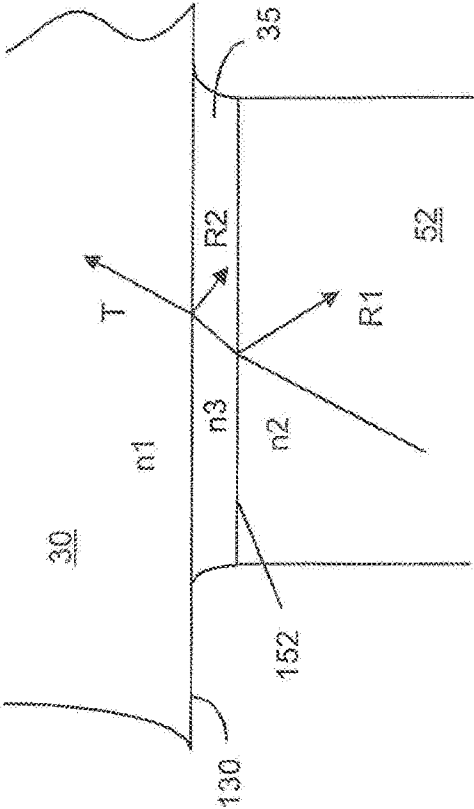


Fig.3d

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/072305

A. CLASSIFICATION OF SUBJECT MATTER

F21V 7/04 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F21V, G02B, G02F

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

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

WPI, EPODOC, CNPAT, CNKI: diffuser, diffusion, diffusing, reflector, refractive, refraction, refract, index, rate, ratio, support, panel, plate, layer, difference, gap, space

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0158904 A1 (AU OPTRONICS CORP.) 20 Jul. 2006 (20.07.2006) description, paragraphs 0001, 0023, 0027, figures 1a, 3a, 5a, 5b	1-19
Y	US 2007/0058250 A1 (FUJI PHOTO FILM CO., LTD.) 15 Mar. 2007 (15.03.2007) description, paragraphs 0069, 0073	1-19
A	CN 101819289 A (AU OPTRONICS CORP.) 01 Sept. 2010 (01.09.2010) the whole document	1-19

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search
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