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(54) **Title:** METHOD FOR REDUCING INTERFERENCE FRINGES IN A DISPLAY DEVICE

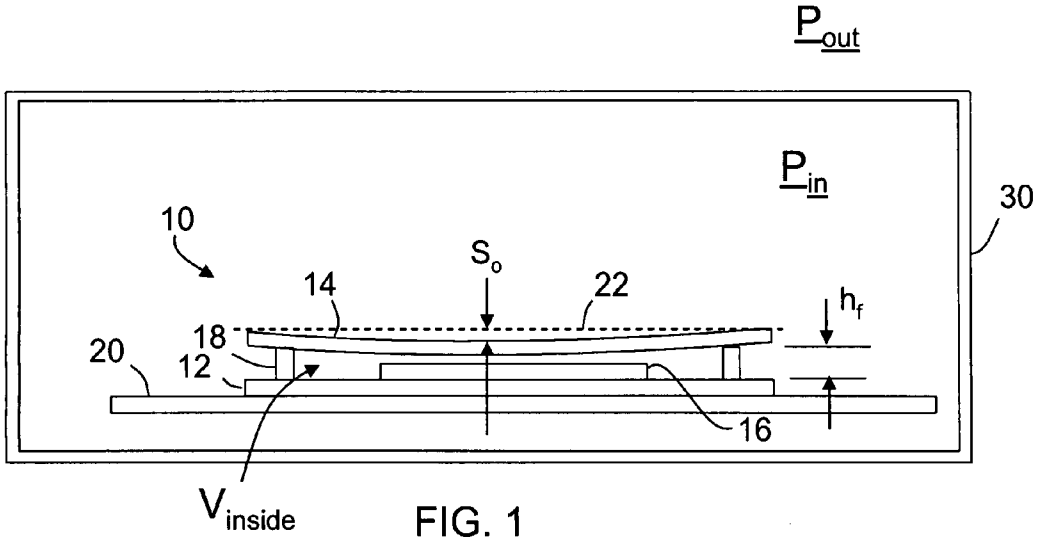


FIG. 1

(57) **Abstract:** A method of minimizing the formation of interference fringes in an OLED display device is disclosed comprising sealing the upper and lower glass substrates comprising the display device to one another within an enclosure wherein a pressure of the atmosphere within the enclosure is greater than the pressure of the atmosphere outside the enclosure.

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METHOD FOR REDUCING INTERFERENCE FRINGES IN A DISPLAY DEVICE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention is directed to a method of reducing sag-induced Newton's rings in a display device, and in particular, Newton's rings in an organic light emitting diode (OLED) display device.

TECHNICAL BACKGROUND

[0002] Organic light emitting diodes (OLEDs) hold considerable promise as an alternative display device technology to, for example, liquid crystal or plasma displays. Advantages to OLED displays include a thin form factor, low power consumption, wide color gamut, high contrast ratio, wide viewing angle, fast response time and low temperature manufacturing.

[0003] An OLED display device typically comprises a first, backplane substrate and a second, cover substrate. An OLED element comprising one or more layers of organic light emitting material and one or more electrodes is disposed on the backplane substrate, and sandwiched between the backplane and cover substrates. The backplane substrate is hermetically sealed to the cover substrate, thus encapsulating the OLED element between the two substrates. The backplane substrate may be sealed to the cover substrate using a variety of methods, including the use of an adhesive, such as an epoxy adhesive, or by forming a frit seal. The use of a frit is a favored approach due to the long-lived hermeticity of the resultant seal. Frit seals tend to require less separation between the backplane and cover substrates, and are self supporting during the sealing process, whereas adhesive seals tend to require spacers to maintain a consistent separation between the backplane and cover substrates.

[0004] One drawback to having a small distance between the cover substrate and the OLED element is the potential for forming interference fringes on the viewing surface of the display device under fluorescence light if the cover substrate exhibits sag. In some cases, the magnitude of the sag may be sufficient to cause contact between the cover and the OLED element, which may damage the OLED element. The formation of

interference fringes is a well-known optical phenomenon which occurs in the gas film between closely spaced transparent media having a varying separation, such as, for example, the air film between the convex spherical surface of a lens and a planar glass surface in contact with the lens. It is known more popularly by the name Newton's rings. The rings or interference fringes form alternating light (constructive interference) and dark (destructive interference) fringes about the point of contact between the lens and the planar surface.

[0005] Newton's rings appear in an OLED display device when a glass substrate which serves as a transparent window for the display sags into close proximity of an organic electroluminescent element within the device. This sagging may result from the manufacturing process. For example, in some processes a force may be applied to the cover substrate when sealing the cover substrate to the backplane substrate having the OLED element disposed thereon in order to obtain a good seal. If this sealing force is applied unevenly, creating a depressed region in the center portion of the cover substrate, interference fringes may appear. A display device which exhibits interference fringes is commercially unacceptable.

[0006] What is needed is a method of forming a hermetic seal in an OLED device while minimizing sag and avoiding the formation of interference fringes in the sealed device.

SUMMARY

[0007] In accordance with an embodiment of the present invention, a method of minimizing interference fringes in a display device is provided comprising providing first and second substrates, the first substrate comprising an organic light emitting diode (OLED) element disposed thereon, sealing the second substrate to the first substrate, the OLED element being disposed between the first and second substrates, and wherein the sealing is performed in an enclosure comprising an atmosphere with a pressure P_{in} greater than a pressure P_{out} of an ambient atmosphere outside the enclosure.

[0008] It is desirable that the pressure (P_{in}) of the atmosphere inside the enclosure during the sealing is greater than the pressure (P_{out}) outside the enclosure by at least about 10 mbar. That is, wherein $P_{in} - P_{out} \geq 10$ mbar. Put another way, it is desirable that P_{in} is equal to or greater than about $1.01*P_{out}$. In some embodiments, it may be desirable to have $P_{in} \geq 1.013*P_{out}$.

[0009] In another embodiment, a method of minimizing interference fringes in a display device is disclosed comprising providing first and second substrates, the first substrate comprising an organic light emitting diode (OLED) element disposed thereon, sealing the second substrate to the first substrate, the OLED element being disposed between the first and second substrates, and wherein the sealing is performed in an enclosure comprising an atmosphere with a pressure P_{in} equal to or greater than $(S_0/8h_f)/(1-(S_0/8h_f))$ times the pressure P_{out} of an ambient atmosphere outside the enclosure, where h_f is the separation between the first and second substrates by frit and S_0 is a maximum sag of the second substrate.

[0010] It is to be understood that both the foregoing general description and the following detailed description present embodiments of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention, and are incorporated into and constitute a part of this specification. The drawings illustrate an exemplary embodiment of the invention and, together with the description, serve to explain the principles and operations of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a side cross sectional view of an OLED device exhibiting sag. The OLED device is shown disposed in an enclosure.

[0012] FIG. 2 is a side cross sectional view of a glass envelope (an LED device without an OLED element), showing several forms of cover substrate sag.

[0013] FIG. 3 is a plot of the minimum differential pressure desired between the inside of the enclosure (e.g. glove box) as a function of the number of fringes by which the visible fringe pattern is desired to be reduced.

Detailed Description

[0014] In the following detailed description, for purposes of explanation and not limitation, example embodiments disclosing specific details are set forth to provide a thorough understanding of the present invention. However, it will be apparent to one having ordinary skill in the art, having had the benefit of the present disclosure, that the present invention may be practiced in other embodiments that depart from the specific details disclosed herein. Moreover, descriptions of well-known devices, methods and materials may be omitted so as not to obscure the description of the present invention. Finally, wherever applicable, like reference numerals refer to like elements.

[0015] Shown in FIG. 1 is an OLED device **10** that exhibits sag. OLED device **10** comprises first (backplane) substrate **12**, second (cover) substrate **14**, and OLED element **16** disposed therebetween. OLED element **16** in turn comprises one or more organic electroluminescent layers, as well as metal oxide electrode layers. First and second substrates **12**, **14** are separated by frit wall **18** having a height h_F and arranged about a periphery of the substrates in the form of a closed circuit or frame. The parameter h_f is equivalent to the separation between the first and second substrates after sealing the substrates.

[0016] Backplane substrate **12** is assumed to be flat. Flattening of the backplane substrate may be accomplished, for example, by supporting it with a flat, hard supporting fixture **20**. As illustrated in FIG. 1, cover substrate **14** exhibits an inward sag, where S_0 is the sag amplitude at the center of the cover substrate (relative to the frit wall height), and L_{x0} (or L_{y0}) is the x-(or y-)dimension of the frit wall, and V_{Inside} is the volume confined by the first and second substrates and the frit wall after sealing (see FIG. 2). Dashed line **22** represents a plane parallel to backplane substrate **12**, and therefore a reference position for cover substrate **14** (the position of substrate **14** if sag were not present).

[0017] In a simplified form (e.g. not considering internal stress in the cover sheet, or a non-uniform frit wall height h_f), cover substrate sag can be represented as a parabolic or sine function. In FIG. 2, reference numeral **14a** identifies a parabolic sag in the cover substrate, and reference numeral **14b** identifies a sine-function sag in the cover substrate. (FIG. 2 is shown without OLED element **16** for clarity.) Since backplane substrate **12** is

assumed flat, the backplane substrate can be represented by the equation $f_{Bottom}(x,y) = 0$. For an assumed parabolic sag, the cover substrate can be represented by the equation,

$$f_{Parabolic}(x,y) = h_F - S_0 \cdot \left\{ \left(\frac{16}{L_{x0}^2 L_{y0}^2} \right) \cdot \left(x^2 - L_{x0} x \right) \cdot \left(y^2 - L_{y0} y \right) \right\} \quad (1)$$

where h_F is the frit wall height after sealing, S_0 is the maximum sag amplitude, and L_{x0} and L_{y0} are the dimensions of the frit perimeter in the x- and y-directions, respectively.

[0018] Similarly, for a sine-shaped sag, the cover substrate can be represented by the equation

$$f_{Sine-shape}(x,y) = h_F - S_0 \cdot \sin^2\left(\frac{\pi x}{L_{x0}} \right) \cdot \sin^2\left(\frac{\pi y}{L_{y0}} \right) \quad (2)$$

where the parameters are the same as in (1) above.

[0019] The volume confined after laser frit sealing, V_{Inside}, is calculated by integrating the above sag-shape functions such that they may be expressed as a simple equation with a parameter α

$$V_{Inside} = A \cdot \left(h_F - \alpha \cdot S_0 \right) \quad (3)$$

where A is the sealed area on the bottom plate (that is, $A = L_{x0} \cdot L_{y0}$ for a rectangular backplane substrate) and α is the sag volume parameter. By sealed area what is meant is the area of backplane substrate **12** enclosed by frit wall **18**. The sag volume parameter α, determined by the sag shape, is equal to 4/9 for the parabolic sag and 1/4 for the sine-function sag.

[0020] Equation (3) can be used to express the pressure differential between the pressure inside of the glove box and the pressure outside the glove box according to

$$\Delta P = P_{in} - P_{out} = P_{out} \cdot \frac{\alpha \left(S_0 / h_F \right)}{1 - \alpha \left(S_0 / h_F \right)} \quad (4)$$

[0021] FIG. 3 depicts plotted curves for several different scenarios of cover substrate sag. Curve **24** represents the desired pressure differential ΔP between the glove box inside pressure P_{in} and the ambient atmospheric pressure P_{out} outside the glove box as a function of the number of interference fringes in the instance of a cover substrate having a parabolic-shaped sag. Curve **26** represents the desired pressure differential ΔP between the glove box inside pressure P_{in} and the ambient atmospheric pressure P_{out} outside the glove box as a function of the number of interference fringes in the instance of a cover substrate having a sine-shaped shaped sag. Finally, curve **28** represents the desired pressure differential ΔP between the glove box inside pressure P_{in} and the ambient atmospheric pressure P_{out} outside the glove box as a function of the number of interference fringes based on experimental data collected from an experiment described below. The data from FIG. 3 suggest the desirability of sealing the display device in an atmosphere having a pressure at least ΔP equal to or greater than that represented by curve **28** in FIG. 3. As described herein, this can most easily be accomplished by performing the sealing process within the confines of an enclosure (glove box) **30**, such as that shown in FIG. 1. Enclosure **30** should be connected to a pressure control system (not shown) capable of providing the enclosure with an atmosphere comprised of substantially inert gases, and at a pressure greater than the pressure of the ambient atmospheric pressure outside the enclosure. Suitable pressure control systems for maintaining a pre-determined pressure within an enclosure are well understood, and no further description should be necessary.

Example

[0022] In an example of the above described process, two frit-sealed glass sample envelopes were manufactured in accordance with an embodiment of the present invention. For the first envelope, sample A, a first SiO_2-based glass substrate having dimensions of 50.8 mm x 50.8 mm was hermetically sealed with a frit to a second SiO_2-based glass substrate having the same dimensions. Both substrates were approximately 0.7 mm in thickness. The glass envelope did not contain an OLED element within its interior. To form the envelope, a frit wall was formed by dispensing a glass frit paste onto the second substrate in a closed circuit or frame pattern having dimensions of 40 mm x 40 mm. The second substrate comprising the frit frame was then heated in an oven

to pre-sinter the frit wall. The frit wall had a height of about 14 μm within ± 1 μm. The first substrate was placed on a steel plate in a glove box comprising a substantially nitrogen atmosphere. Subsequent to the pre-sintering, the second substrate was placed on the first substrate in the glove box with the frit wall disposed between the first and second substrates, and a small magnet was placed on top of the second substrate within the perimeter of the frit frame. The pressure of the inert atmosphere within the glove box was raised to a pressure of about 1.4 mbar above the ambient atmospheric pressure outside the glove box, where atmospheric pressure was about 1013 mbar. The frit was the heated and melted by irradiating the frit wall through the second substrate with a laser beam, which was traversed over the frit wall to heat and melt the frit wall and seal the substrates together. The height of the frit wall after sealing was approximately 12 μm. The first sample was then removed from the glove box and inspected for Newton rings. The number of rings was counted from the inside boundary of the frit wall to the center fringe. Approximately 49 fringes were counted.

[0023] The same process was used to form a second sample envelope, Sample B, with the exception that the pressure of the atmosphere within the glove box prior to sealing was adjusted to approximately 13 mbar (about 1.28 %) above the ambient atmospheric pressure outside the glove box. Again, subsequent to the sealing process, the second sample was removed from the glove box and the number of fringes counted, with approximately 39 fringes counted for the second sample.

[0024] To simplify calculations, it was assumed the fringes resulted from the interference of light at a wavelength of about 500 nm, approximately the center of the visible wavelength band. Consequently, one fringe interval (the distance from one constructive fringe to the adjacent constructive fringe) represented a 250 nm change in sag. Since the fringes were counted from the perimeter of the envelope to the center of the envelope, the counted number represented only one half of the total number of fringes across the entire envelope from frit boundary to frit boundary. Thus, the maximum sag for the first, 1.4 mbar ΔP sample was approximately 6 μm and the maximum sag for the second, 13 mbar ΔP sample was approximately 5 μm, resulting in a reduction in sag of about 1 μm.

[0025] Assuming a sine-function sag in the samples, the inner volume of sample A, V_A is equal to 16.8 mm^3 and the inner volume of sample B, V_B, was 17.2 mm^3, representing a

0.4 mm^3 change in inner volume, or an approximately 2.3% change. Using equation (4), a minimum pressure differential between the pressure of the atmosphere inside the glove box and the pressure of the atmosphere outside the glove box according to the present experiment is $\Delta P \geq P_{out}*(S_0/8h_f)/(1-S_0/8h_f)$. That is, $\alpha = 1/8$.

[0026] It is believed these experimental results differ from those predicted from theory due to factors such as frit height variation and internal glass stress.

[0027] It should be emphasized that the above-described embodiments of the present invention, particularly any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiments of the invention without departing substantially from the spirit and principles of the invention. For example, although the present invention is described in terms of an embodiment employing a frit seal, the teaching of the present invention may be applied in other embodiments where a sufficiently small distance separates the encapsulating substrates, and sag is formed in one of the substrates, resulting in the formation of interference fringes. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present invention and protected by the following claims.

What is claimed is:

1. A method of encapsulating an organic light emitting diode (OLED) device comprising:

providing first and second substrates, the first substrate comprising an OLED element disposed thereon;

sealing the second substrate to the first substrate, the OLED element being disposed between the first and second substrates; and

wherein the sealing is performed in an enclosure comprising an atmosphere with a pressure P_{in} greater than a pressure P_{out} of an ambient atmosphere outside the enclosure.

2. The method according to claim 1 wherein $P_{in} - P_{out} \geq 10$ mbar.

3. The method according to claim 1 wherein P_{in} is equal to or greater than about $1.01*P_{out}$.

4. The method according to claim 1 wherein the second substrate comprises a frit wall disposed thereon.

5. The method according to claim 4 wherein the sealing comprises heating the frit wall with a laser beam.

6. The method according to claim 1 wherein $P_{in} - P_{out} \geq P_{out}*(S_0/8h_f)/(1-(S_0/8h_f))$ where h_f is a height of a frit wall disposed between the first and second substrates and S_0 is a maximum sag of the second substrate.

7. The method according to claim 1 wherein the sealing comprises heating a glass frit disposed between the first and second substrates to melt the frit, thereby forming a hermetic seal between the first and second substrates.

8. The method according to claim 7 wherein the heating is performed by traversing a laser beam over the glass frit.

9. A method of method of encapsulating an organic light emitting diode (OLED) device comprising:

providing first and second substrates, the first substrate comprising an OLED element disposed thereon;

sealing the second substrate to the first substrate such that the OLED element is disposed between the first and second substrates; and

wherein the sealing is performed in an enclosure comprising an atmosphere with a pressure P_{in} equal to or greater than $(S_0/8h_f)/(1-(S_0/8h_f))$ times the pressure P_{out} of an ambient atmosphere outside the enclosure, where h_f is the separation between the first and second substrates and S_0 is a maximum sag of the second substrate.

10. The method according to claim 9 wherein $P_{in} \geq P_{out}*(S_0/4h_f)/(1-(S_0/4h_f))$.

11. The method according to claim 9 wherein $P_{in} \geq P_{out}*(4S_0/9h_f)/(1-(4S_0/9h_f))$.

12. The method according to claim 9 wherein the sealing comprises heating a glass frit with a laser beam.

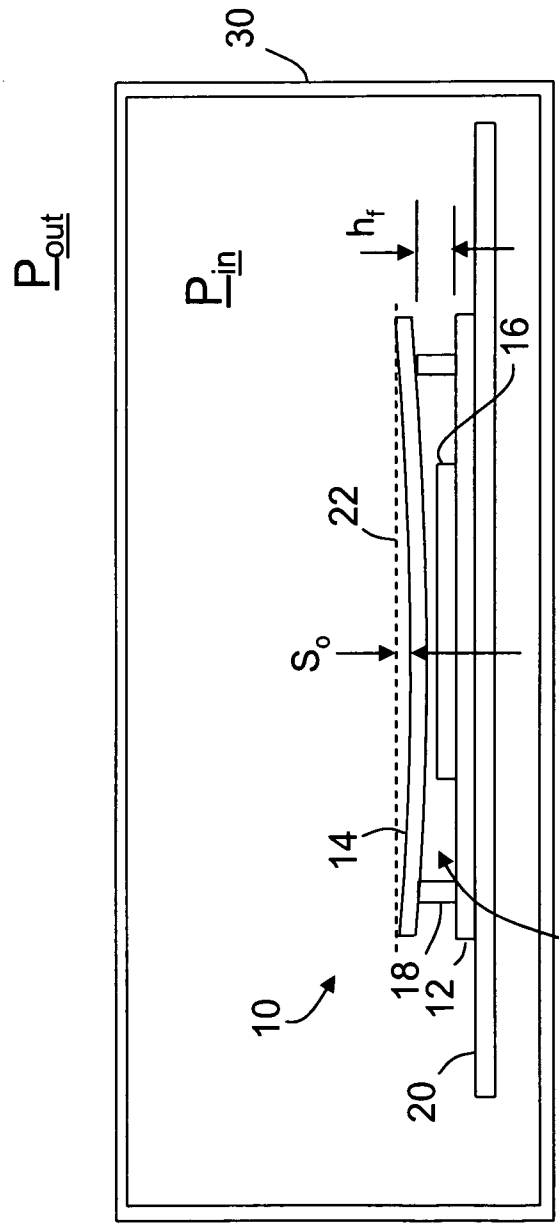

30
P_{out}
P_{in}
h_f
16
22
S_o
14
18
12
10
20
V_{inside}

FIG. 1

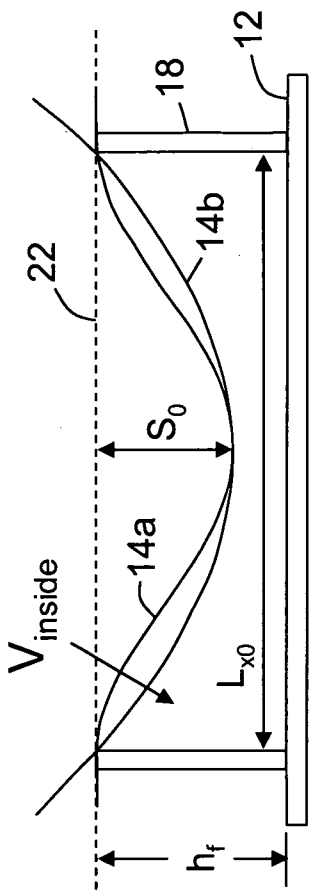

12
18
14b
22
S_0
14a
V_{inside}
L_{x0}
h_f

FIG. 2

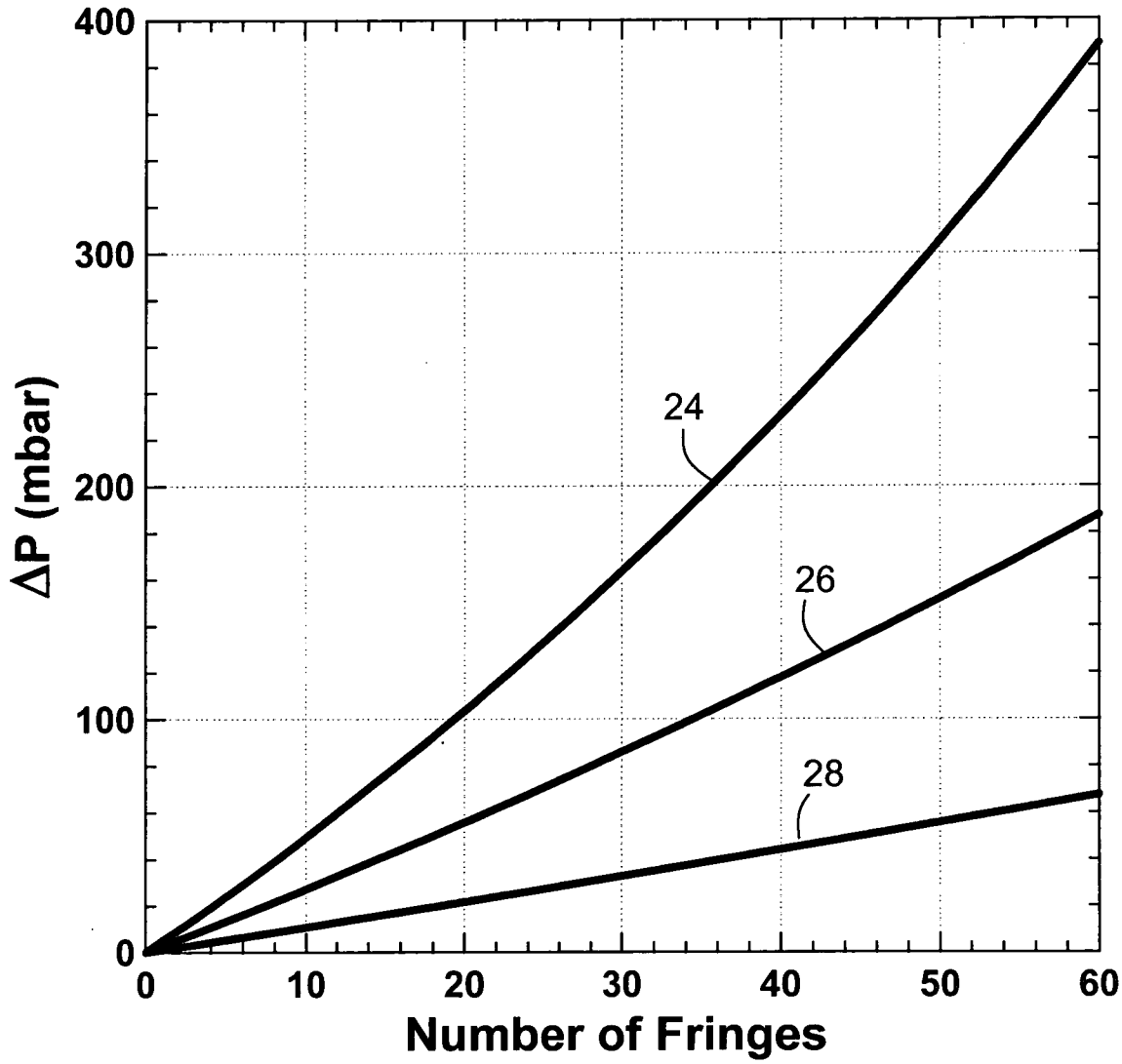

400
300
200
100
0
ΔP (mbar)
24
26
28
0
10
20
30
40
50
60
Number of Fringes

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/001661

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L51/52

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)
H01L H05B

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 practical, search terms used)
EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2006 202610 A (PIONEER TOHOKU CORP) 3 August 2006 (2006-08-03) paragraphs [0042], [0049], [0050]; figures 1b,2	1-3,6, 9-11
Y		4,5,7,8, 12
X	US 2005/248270 A1 (GHOSH AMALKUMAR P [US] ET AL) 10 November 2005 (2005-11-10) paragraphs [0009], [0010], [0060]	1,4,5,7, 8
Y		4,5,7,8, 12
P,X	EP 1 821 354 A (SAMSUNG SDI CO LTD [KR]) 22 August 2007 (2007-08-22) paragraphs [0007] - [0009], [0048], [0049], [0052] claims 14,17	1,4,5,7, 8

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 June 2008	02/07/2008

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/001661

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2006202610 A	03-08-2006	NONE	
US 2005248270 A1	10-11-2005	WO 2005119803 A2	15-12-2005
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