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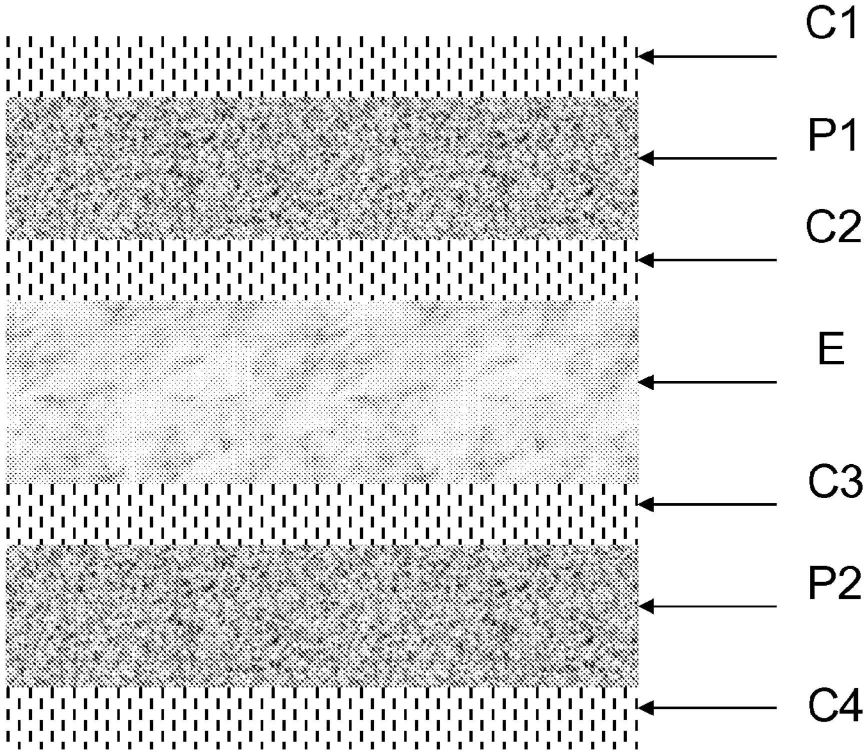
(54) Title: PIEZO ELECTROPHORETIC DISPLAY



(57) Abstract: The invention is directed to a variety of designs of piezo electrophoretic displays which may be driven without connecting to a power source. The piezo-electrophoretic display comprises an electrophoretic layer, a conductor layer, and a layer of piezo material. The processes for manufacturing the piezo electrophoretic displays are also provided.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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— *with international search report (Art. 21(3))*

PIEZO ELECTROPHORETIC DISPLAY

FIELD OF THE INVENTION

The present invention is directed to piezo electrophoretic displays which may be driven without connecting to a power source, and methods for their manufacture.

BACKGROUND OF THE INVENTION

The electrophoretic display (EPD) is a non-emissive device based on the electrophoresis phenomenon of charged pigment particles dispersed in a solvent or solvent mixture. The display typically comprises two plates with electrodes placed opposing each other. One of the electrodes is usually transparent. An electrophoretic fluid composed of a colored solvent with charged pigment particles dispersed therein is enclosed between the two plates. When a voltage difference is imposed between the two electrodes, the pigment particles migrate to one side or the other causing either the color of the pigment particles or the color of the solvent being seen from the viewing side.

Alternatively, an electrophoretic fluid may comprise two types of charged pigment particles of contrasting colors and carrying opposite charges, and the two types of the charged pigment particles are dispersed in a clear solvent or solvent mixture. In this case, when a voltage difference is imposed between the two electrode plates, the two types of the charged pigment particles would move to opposite ends (top or bottom) in a display cell. Thus one of the colors of the two types of the charged pigment particles would be seen at the viewing side of the display cell.

The driving of an electrophoretic display requires a power source, such as a battery to provide power to the display and/or its driving circuitry. The power source may be a driver IC in order to generate an electric field. The electric field may also need to be enhanced by a circuitry. In any case, a physical connection through wires is required to attach the power source to the electrophoretic display and its driving circuitry.

SUMMARY OF THE INVENTION

The present invention is directed to a piezo-electrophoretic display which comprises an electrophoretic layer, a conductor layer and a layer of piezo material. The electrophoretic layer and the layer of piezo material may share the conductor layer. The electrophoretic layer and the layer of piezo material may share the conductor layer through a conductor line.

In one embodiment, the display comprises (a) a first layer of piezo material sandwiched between a first conductor layer and a second conductor layer, (b) a second layer of piezo material sandwiched between a third conductor layer and a fourth conductor layer and (c) an electrophoretic layer sandwiched between the second conductor layer and the third conductor layer. The first conductor layer and the fourth conductor layer may be connected.

In one embodiment, the display comprises an electrophoretic layer sandwiched between a first conductor layer and a second conductor layer and a layer of piezo material sandwiched between a third conductor layer and a fourth conductor layer, wherein the first conductor layer and the third conductor layer are connected and the second conductor layer and the fourth conductor layer are connected.

In one embodiment, the display comprises an electrophoretic layer and a layer of piezo material, both of which are sandwiched between two conductor layers.

In one embodiment, the display comprises an electrophoretic layer sandwiched between a first conductor layer and a third conductor layer and a layer of piezo material sandwiched between a second conductor layer and the third conductor layer, wherein the first conductor layer and the second conductor layer are connected.

In one embodiment, the display comprises a layer of piezo material sandwiched between a first conductor layer and a second conductor layer and an electrophoretic layer sandwiched between the second conductor layer and a third conductor layer. The first conductor layer and the third conductor layer may be connected.

In one embodiment, a piezo-electrophoretic display comprises an electrophoretic layer sandwiched between two layers of piezo material.

In one embodiment, a piezo-electrophoretic display comprises an electrophoretic layer sandwiched between a first conductor layer and a second conductor layer and a layer of piezo material which on one side is in contact with the first conductor layer and the second conductor layer and on the other side is in contact with a third conductor layer, wherein the layer of the piezo material and the third conductor layer are folded into a U-shape. The electrophoretic layer may be unfolded or folded.

In one embodiment, the electrophoretic layer is microcup-based. In another embodiment, the electrophoretic layer is microcapsule-based.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-10 illustrate various structural designs of the present invention.

Figures 11a and 11b illustrate how a substrate-less electrophoretic film may be prepared.

Figure 12 depicts the forming of a film with alternating electrophoretic material and piezo material.

DETAILED DESCRIPTION OF THE INVENTION

The present inventors have now found certain piezo electrophoretic display structural designs which do not need a battery source or wired power supply in order for the electrophoretic display to operate. The assembly of such an electrophoretic display is therefore simplified.

Piezoelectricity is the charge which accumulates in a solid material in response to applied mechanical stress. Suitable materials for the present invention may include polyvinylidene fluoride (PVDF), quartz (SiO_2), berlinite ($AlPO_4$), gallium orthophosphate ($GaPO_4$), tourmaline, barium titanate ($BaTiO_3$), lead zirconate titanate (PZT), zinc oxide (ZnO), aluminum nitride (AlN), lithium tantalate, lanthanum gallium silicate, potassium sodium tartrate and any other known piezo materials.

Figures 1-10 illustrate various structural designs of the present invention.

In Figure 1, there are four conductor layers (C1-C4). A first layer of a piezo material (P1) is sandwiched between C1 and C2 and a second layer of a piezo material (P2) is sandwiched between C3 and C4. The electrophoretic layer (E) is sandwiched between C2 and C3. The piezo materials, P1 and P2, when applied mechanical stress, generate a voltage potential difference between C1 & C2 and C3 &C4, respectively. The voltage potential difference between C2 and C3, in turn, drives the electrophoretic layer E.

The “electrophoretic layer”, in the context of the present invention, may comprise micro-containers filled with an electrophoretic fluid. The micro-containers may be microcapsules (as described in US Patent No. 5,930,026) or microcups (as described in US Patent No. 6,930,818). The electrophoretic fluid comprises one, two or more types of charged pigment particles dispersed in a solvent or solvent mixture.

It is noted that the term “electrophoretic layer” or “electrophoretic film” does not include a plastic substrate layer (e.g., PET) or a conductor layer (e.g., ITO). Therefore, an “electrophoretic layer or film” may also be referred to as a “substrate-less electrophoretic layer or film". More details of the term "electrophoretic layer or film" are given in a section below.

The piezo-electrophoretic display of Figure 1 may be prepared in a variety of ways. For example, a layer of piezo material may be sandwiched between two conductor layers by lamination. Alternatively, a piezo material sandwiched between two conductor layers may be obtained commercially. An electrophoretic layer (E) may then be built on top of C3-P2-C4 and another layer of piezo material (P1) sandwiched between C1 and C2 is laminated over the electrophoretic layer (E). Alternatively, an electrophoretic layer may be sandwiched between the two sets of conductor-piezo-conductor layers, by lamination.

The design in Figure 2 is similar to that in Figure 1, except the conductor layers C1 and C4 are connected by a conductor line (C). In this case, C1 and C4 have the same voltage potential. The conductor line may be a connected line or a conductor sheet material which is folded to be in contact with both conductor layers C1 and C4.

Figure 3 depicts an alternative design. The electrophoretic layer (E) is sandwiched between conductor layers C1 and C2 and, separately, the piezo material layer (P) is sandwiched between conductor layers C3 and C4. But conductor layers C1 and C3 are connected through a conductor line C, and conductor layers C2 and C4 are connected through a conductor line C'. In this case, the voltage potential difference between C1 and C2 is the same as the voltage potential difference between C3 and C4 generated by the piezo material when it is applied mechanical stress.

As stated, a piezo material (P) sandwiched between two conductor layers (C3 and C4) is commercially available. An electrophoretic layer sandwiched between two conductor layers (C1 and C2) can be prepared by known methods.

In Figure 4, the electrophoretic layer E and the piezo material layer (P) share the conductor layers. As shown, both the electrophoretic layer (E) and the piezo material layer (P) are sandwiched between the conductor layers C1 and C2.

Therefore the voltage potential difference generated by the piezo material would be used to drive the electrophoretic layer E.

The piezo-electrophoretic structure of Figure 4 may be prepared in a number of ways. For example, a piezo material (P) and an electrophoretic layer (E) may be separately built on a conductor layer (C2) and finally another conductor layer (C1) is laminated over both the piezo material and the electrophoretic layer.

Alternatively, an electrophoretic layer may be built on C2 and part of the electrophoretic layer is then removed and the space previously occupied by the removed electrophoretic layer is then filled with a piezo material. A second conductor layer (C1) is then laminated over both the piezo material and the electrophoretic layer.

In the drawing, there appears to be a gap between the piezo material and the electrophoretic layer. However, the gap is not necessary. In other words, the electrophoretic layer may be in direct contact with the piezo material.

In Figure 5, the electrophoretic layer E and the piezo material layer (P) share a common bottom conductor layer C3. But the top conductor layers C1 and C2 are separate and as a result, a conductor line C is needed to connect the conductor layers C1 and C2. Because C1 and C2 are connected, the operation of this design is similar to that of Figure 4.

The structure of Figure 5 may be prepared in a similar manner as the structure of Figure 4, except two separate conductor layers (C1 and C2) are laminated over the electrophoretic layer (E) and the piezo material (P), respectively.

In Figure 6, there are three conductor layers C1-C3. The piezo material layer (P) is sandwiched between conductor layers C1 and C2 and the electrophoretic layer (E) is sandwiched between conductor layers C2 and C3. The electrophoretic layer is driven by the voltage potential difference between C2 and C3.

The electrophoretic layer (E) in this design may be built on the set of layers C2-P-C1 and another conductor layer C3 is laminated over the electrophoretic layer (E).

The design in Figure 7 is similar to that of Figure 6, except conductor layers C1 and C3 are connected through a conductor line (C). In this case, C1 and C3 have the same voltage potential.

In Figure 8, the electrophoretic layer (E) is sandwiched between two piezo material layers (P1 and P2). Under mechanical stress applied to the piezo layers, an electric field is generated to drive the electrophoretic layer.

Figures 9 and 10 depict U-shaped piezo-electrophoretic designs.

In Figure 9, initially a piezo material is sandwiched between one conductor layer C3 and, on the opposite side, two conductor layers C1 and C2. The conductor layers C1 and C2 are not in contact with each other. The electrophoretic layer (E) is placed only on top of one of the conductor layers (C1 or C2). To form the piezo-electrophoretic display, in this example, the C2-P-C3 side of the panel is folded over the electrophoretic layer (E). In this case, when mechanical stress is applied to the layer of the piezo material (P), a voltage potential difference is generated between the conductor layers C1 and C2 which drives the electrophoretic layer.

Figure 10 depicts a similar design, except that the electrophoretic layer (E) extends substantially throughout the length of the piezo material (P). In this example, when the panel is folded into a U-shaped structure, there is also a folded electrophoretic layer between the conductor layers C1 and C2. The folded electrophoretic layer can be driven in the same manner as that in Figure 9.

In any of the designs discussed above where there are more than one piezo material layer, the materials in different layers may be the same or different.

The preparation of an “electrophoretic layer or film” or “substrate-less electrophoretic layer or film” is shown in Figures 11a and 11b. As stated above, an “electrophoretic layer or film” or “substrate-less electrophoretic layer or film”, in the context of the present application, does not have a conductor layer and/or a substrate layer (such as a PET layer on which a conductor layer is laminated) attached to it.

The electrophoretic layer or film comprises an electrophoretic fluid filled within micro-containers (such as microcups as described in US Patent No. 6,930,818 or microcapsules as described in US Patent No. 5,930,026, which are incorporated herein by references) and any dielectric layers that support the electrophoretic fluid, including, for example, a binder material, a matrix material, an adhesive layer, a sealing layer, a primer layer or any other electrode-protecting layers to provide functional support.

In the case of a microcup-based electrophoretic layer, the microcups are formed on the substrate layer, which are then filled with an electrophoretic fluid and sealed. In the case of a microcapsule-based electrophoretic layer, the microcapsules, with an electrophoretic fluid enclosed within, are mixed with a binder material and the mixture is coated onto a substrate layer.

Both manufacturing processes for the microcup-based or microcapsule-based electrophoretic assembly described above may be carried out on a continuous format. The microcup-based electrophoretic layer may even be manufactured by a roll-to-roll continuous process. As a result, the electrophoretic layer formed by either the microcup or microcapsule technology is continuous along the web direction, or substantially continuous, which means that there is no intentional disruption of the electrophoretic layer along the web direction. If there is any disruption, usually it involves very small areas and exists as only a result of imperfection of the process.

As shown in Figure 11, an electrophoretic layer (110) is sandwiched between a substrate layer (112) and a release liner (111). The substrate layer (112) may comprise an electrode layer (not shown) and optionally other layers such as a release layer (112a). The release liner (111) is laminated over the electrophoretic layer optionally with an adhesive layer (111a).

To form a substrate-less electrophoretic layer or film, the substrate layer (112) and layers associated with the substrate layer are removed, which may be accomplished by mechanical means (such as scraping). The substrate layer itself may also have releasing property. If an optional release layer (112a) is present between the substrate layer (112) and electrophoretic layer (110), and in that case, the release layer (112a) may trigger release of the substrate layer (112), by laser, UV light, heat or the like. The release layer (112a) can be tuned to give enough hold for the formation of microcups during embossing, yet still be able to be released from them, when needed.

It is also possible to peel the substrate layer apart from the electrophoretic layer.

The release liner (111) may be peeled off. The adhesive layer (111a), if present, may remain on the electrophoretic layer. If there is no adhesive layer in the original assembly, the adhesive layer may be applied later when the separated electrophoretic layers are transferred.

After removal of the substrate layer (112) along with other optional layers and the release liner, the remaining electrophoretic layer may be cut into pieces of desired dimensions. The cutting may be accomplished by kiss cutting or the like.

Figure 11b shows an alternative sequence of manufacturing of a substrate-less electrophoretic layer or film. In this case, the cutting takes place before removal of the substrate layer (112) along with other optional layers and the release liner (111).

In Figure 12, the separated electrophoretic layers are transferred onto a conductor layer (123). The spaces between the electrophoretic layers (120) are then filled with a piezo material (121). The piezo material can be integrated into the empty spaces on a web by any coating, printing or converting process. The piezo material will occupy at least the areas where there is no electrophoretic material. Some section of it may superimpose with the non-continuous electrophoretic material. It is also possible for the piezo material to be deposited first before transfer of the electrophoretic layers. Either process can be carried out in a stop-and-go fashion or in a continuous manner. The finished product with a pattern of alternating piezo material and electrophoretic layer may then be cut to form a piezo-electrophoretic assembly such as those shown in Figures 3-5.

It is also possible to stack the substrate-less electrophoretic layer or film with conductor layer(s) and layer(s) of a piezo material to assemble a structure such as those shown in Figures 1, 2 and 6-8.

The processes as exemplified in Figures 11-12 enable the integration of a roll of film, on which the electrophoretic layer is repeatedly interrupted by a non-electrophoretic material (in this case, a piezo material) along the web direction. This interruption of the electrophoretic material is intentionally done in order to place a non-electrophoretic material adjacent to it. The separated electrophoretic layers can have a well-defined shape with sharp boundaries, for example, rectangular shape covers a strip across the web direction.

While the present invention has been described with reference to the specific embodiments thereof, it should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation, materials, compositions, processes, process step or steps, to the objective, spirit and scope of the present invention. All such modifications are intended to be within the scope of the claims appended hereto.

WHAT IS CLAIMED IS:

1. A piezo-electrophoretic display comprising an electrophoretic layer, a conductor layer, and a layer of piezo material.

2. The display of Claim 1, wherein the electrophoretic layer and the layer of piezo material share the conductor layer.

3. The display of Claim 2, wherein the electrophoretic layer and the layer of piezo material share the conductor layer through a conductor line.

4. The display of Claim 2, which comprises (a) a first layer of piezo material sandwiched between a first conductor layer and a second conductor layer, (b) a second layer of piezo material sandwiched between a third conductor layer and a fourth conductor layer and (c) the electrophoretic layer sandwiched between the second conductor layer and the third conductor layer.

5. The display of Claim 4, wherein the first conductor layer and the fourth conductor layer are connected.

6. The display of Claim 2, wherein the electrophoretic layer is sandwiched between a first conductor layer and a second conductor layer, the layer of piezo material is sandwiched between a third conductor layer and a fourth conductor layer, the first conductor layer and the third conductor layer are connected, and the second conductor layer and the fourth conductor layer are connected.

7. The display of Claim 1, wherein the electrophoretic layer and the layer of piezo material are both sandwiched between two conductor layers.

8. The display of Claim 2, wherein the electrophoretic layer is sandwiched between a first conductor layer and a third conductor layer, the layer of piezo material is sandwiched between a second conductor layer and the third conductor layer, and the first conductor layer and the second conductor layer are connected.

9. The display of Claim 2, wherein the layer of piezo material is sandwiched between a first conductor layer and a second conductor layer, and the electrophoretic layer sandwiched between the second conductor layer and a third conductor layer.

10. The display of Claim 9, wherein the first conductor layer and the third conductor layer are connected.

11. The display of Claim 1, wherein the electrophoretic layer is microcup-based.

12. The display of Claim 1, wherein the electrophoretic layer is microcapsule-based.

13. A piezo-electrophoretic display comprising an electrophoretic layer sandwiched between two layers of piezo material.

14. A U-shaped piezo-electrophoretic display comprising an electrophoretic layer sandwiched between a first conductor layer and a second conductor layer, and a layer of piezo material which on one side is in contact with the first conductor layer and the second conductor layer and on the other side is in contact with a third conductor layer, wherein the layer of the piezo material and the third conductor layer are folded into a U-shape.

15. The display of Claim 14, wherein the electrophoretic layer is unfolded.

16. The display of Claim 14, wherein the electrophoretic layer is folded.

17. The display of Claim 14, wherein the electrophoretic layer is microcup-based.

18. The display of Claim 14, wherein the electrophoretic layer is microcapsule-based.

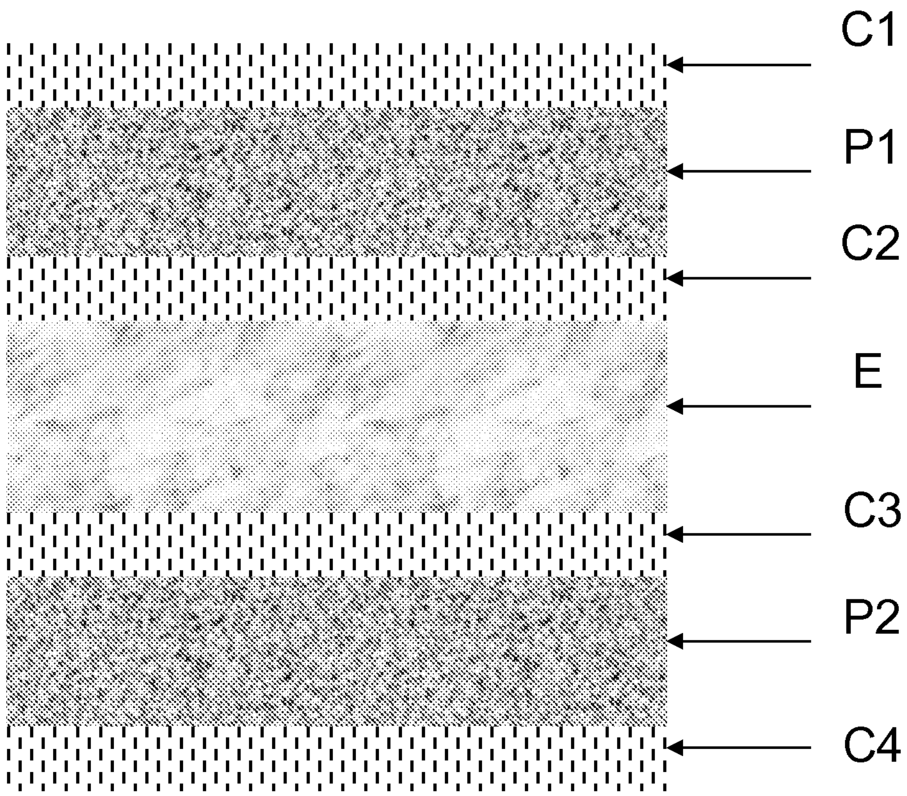

Figure 1

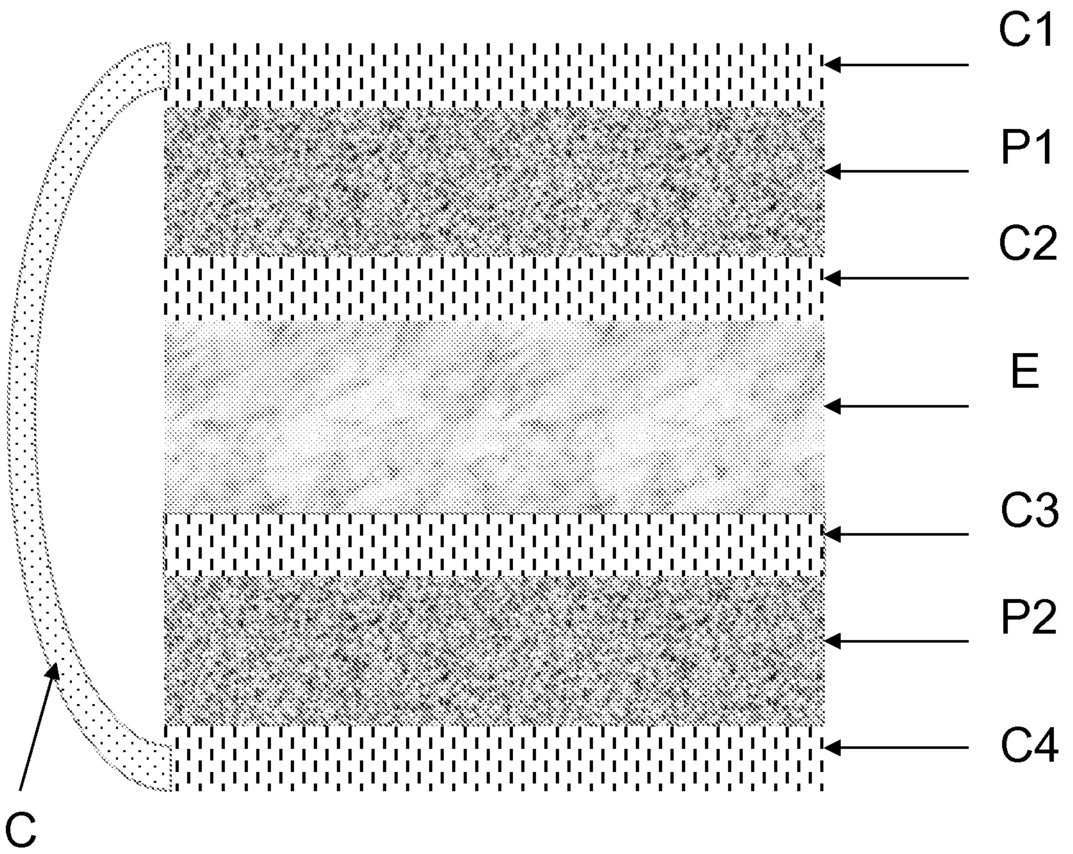

Figure 2

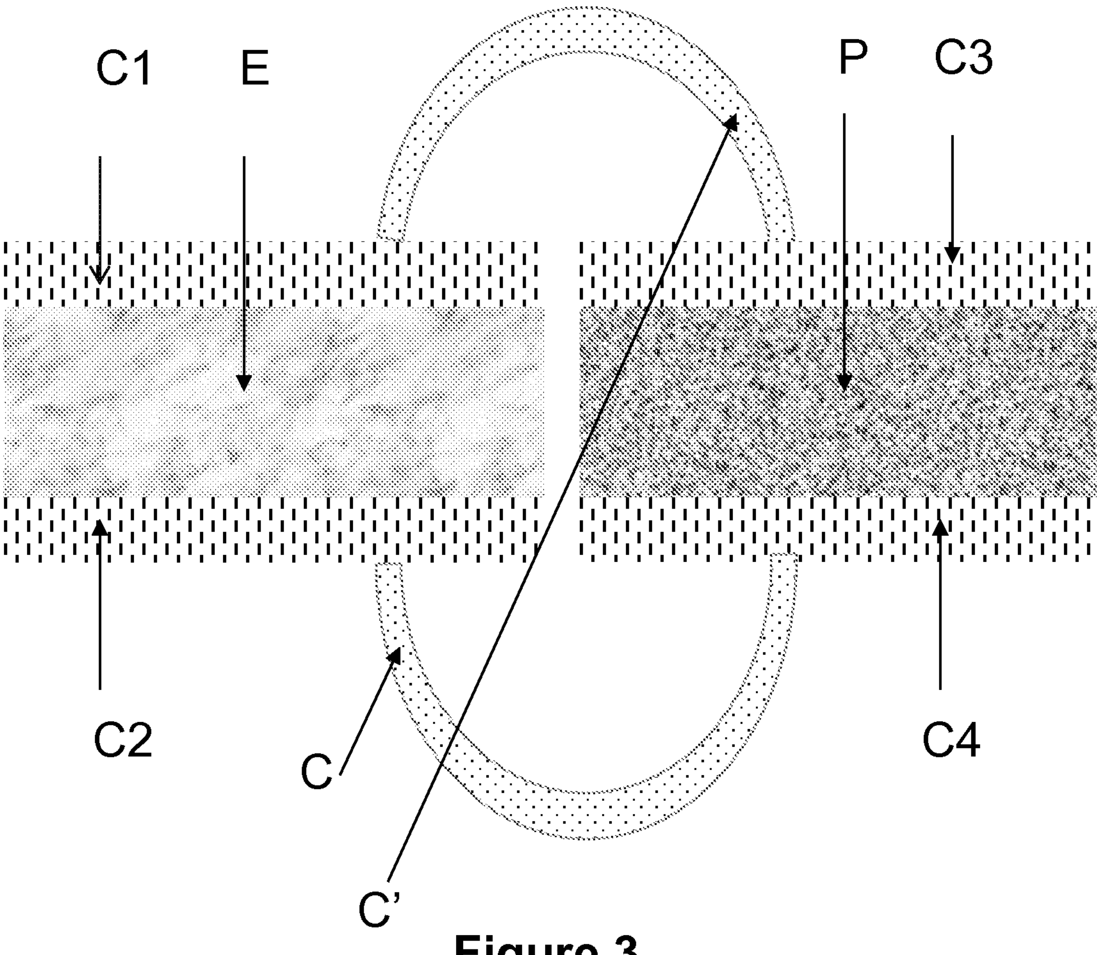

Figure 3

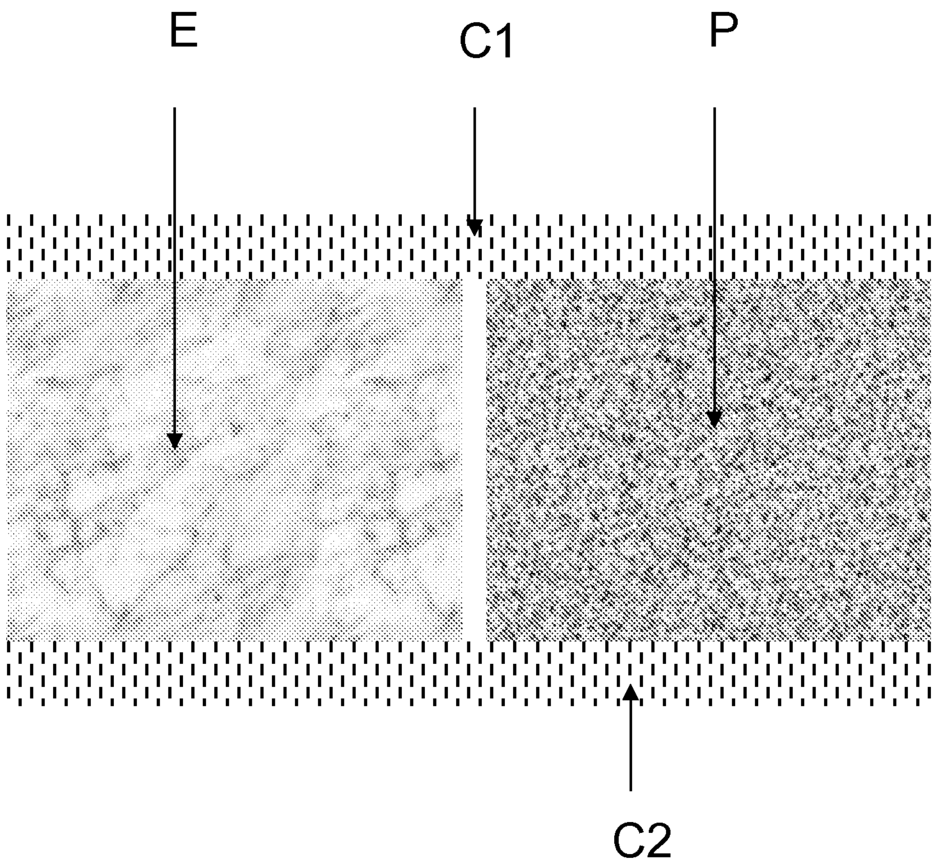

Figure 4

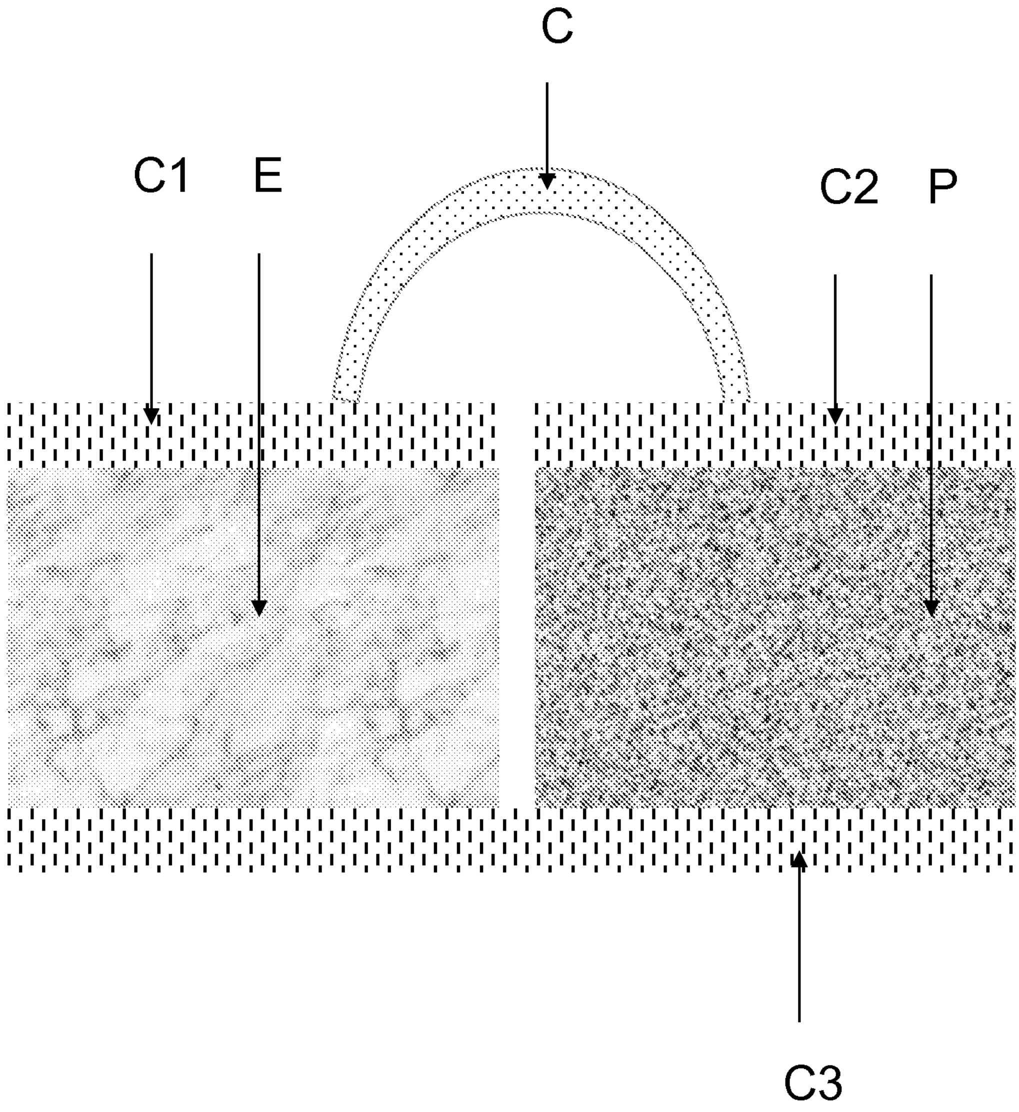

Figure 5

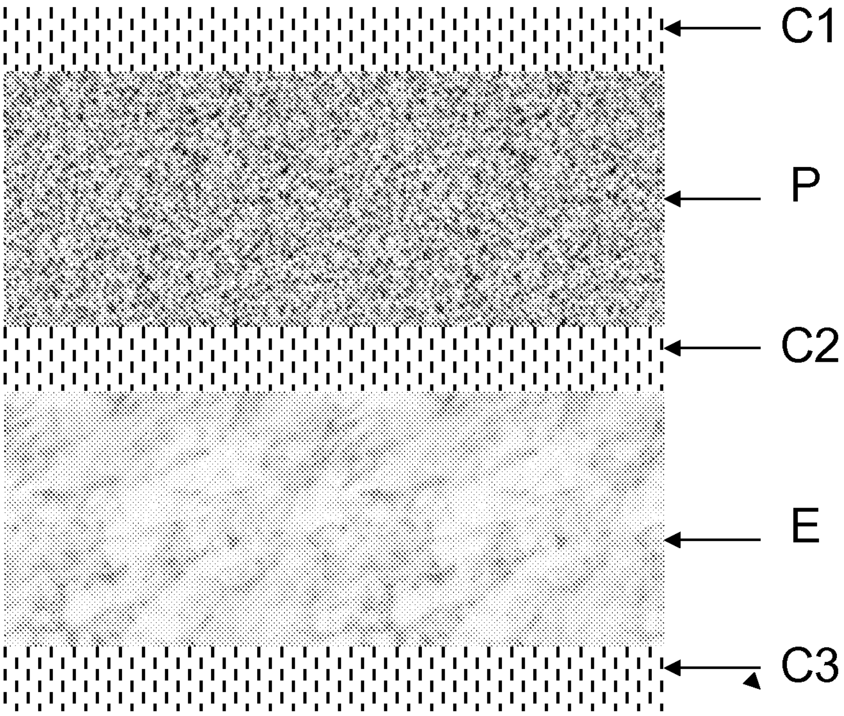

Figure 6

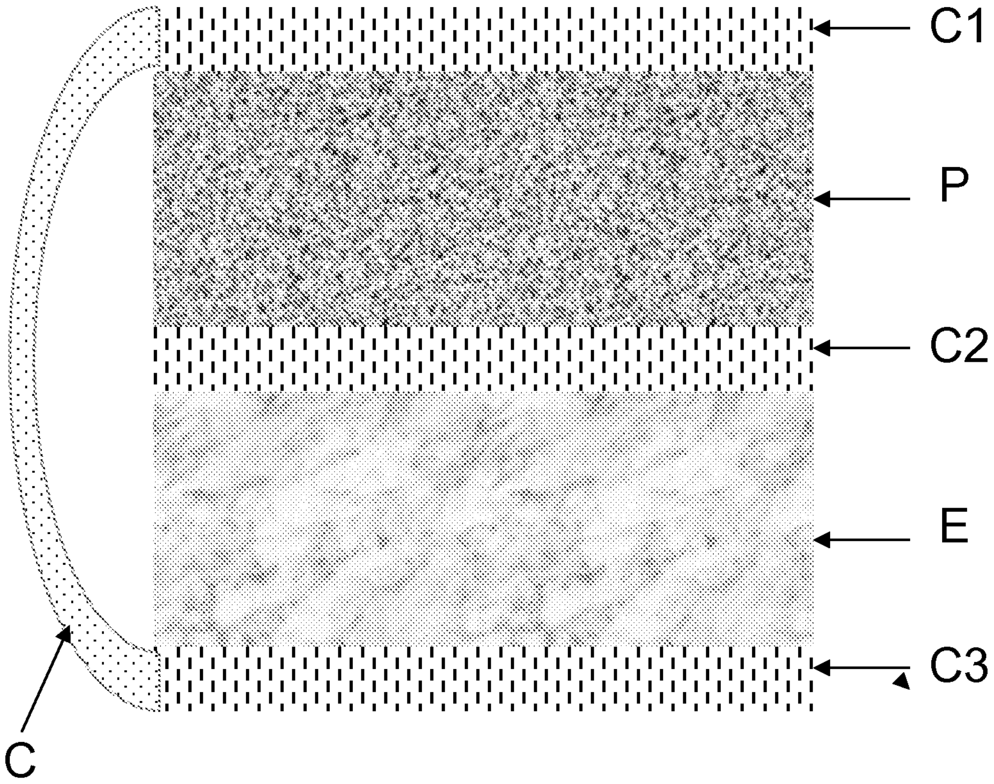

Figure 7

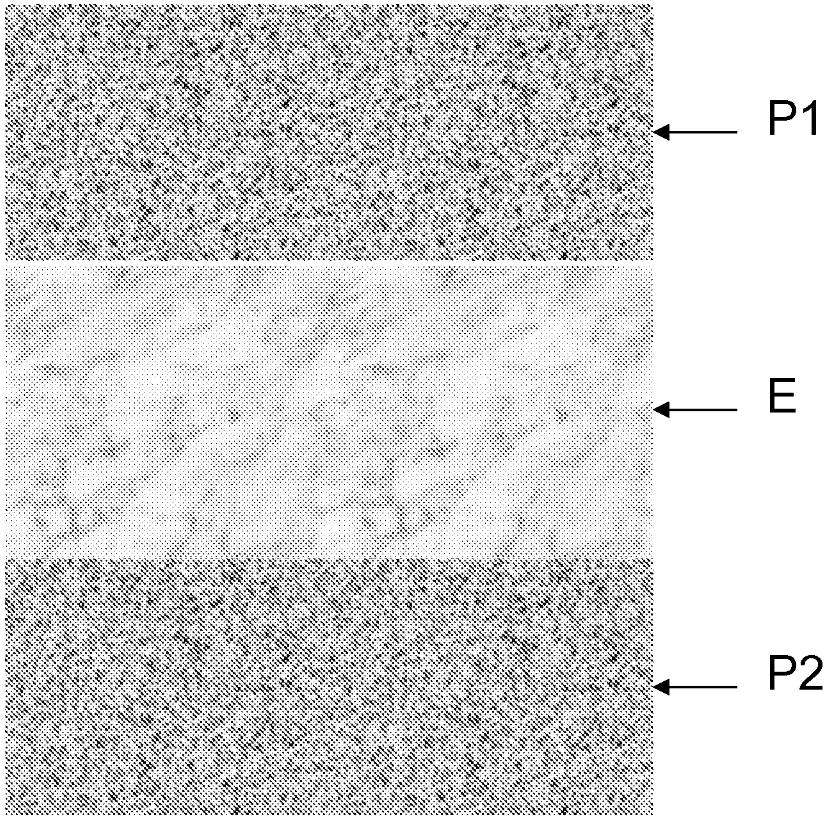

Figure 8

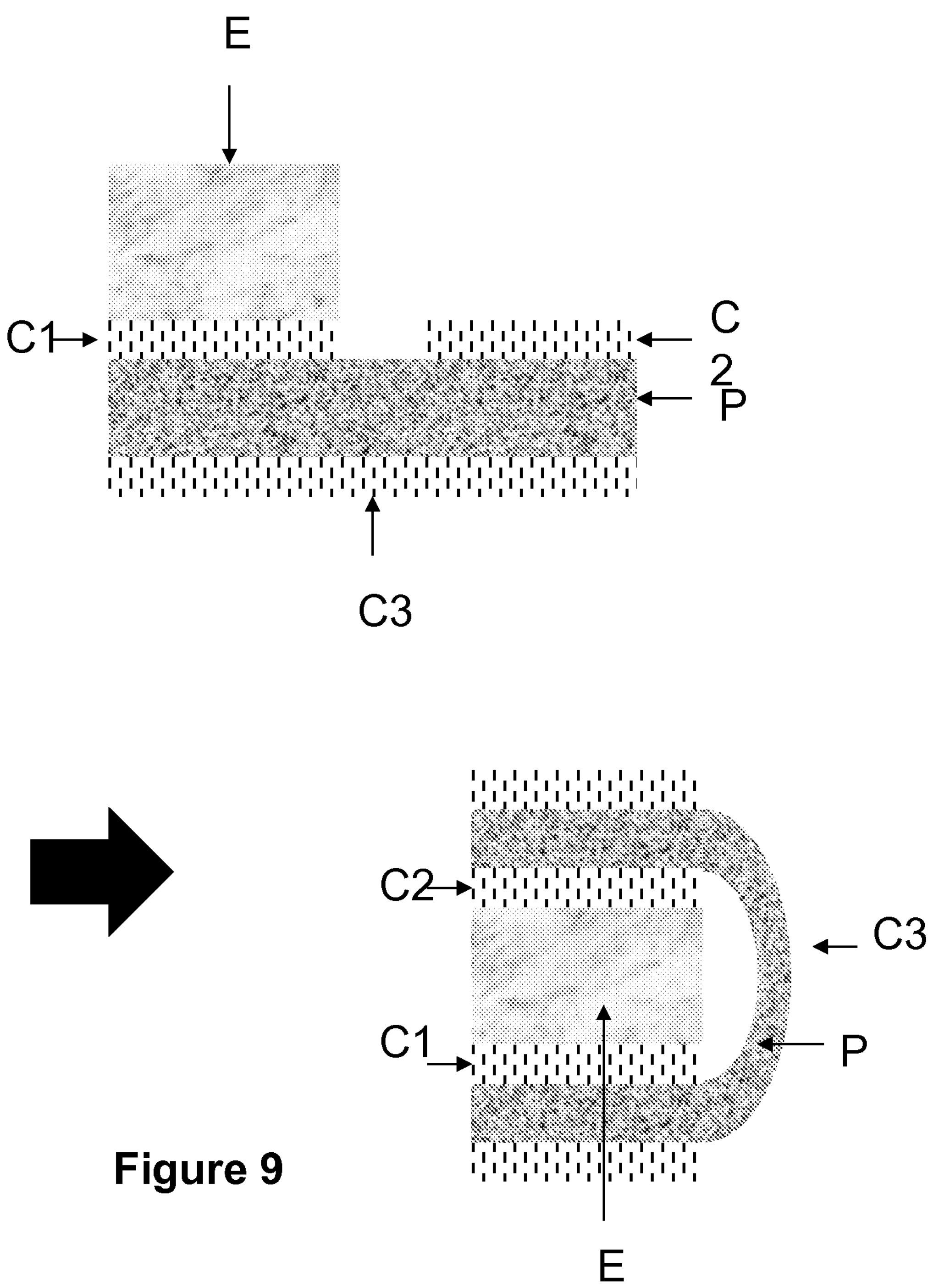

Figure 9

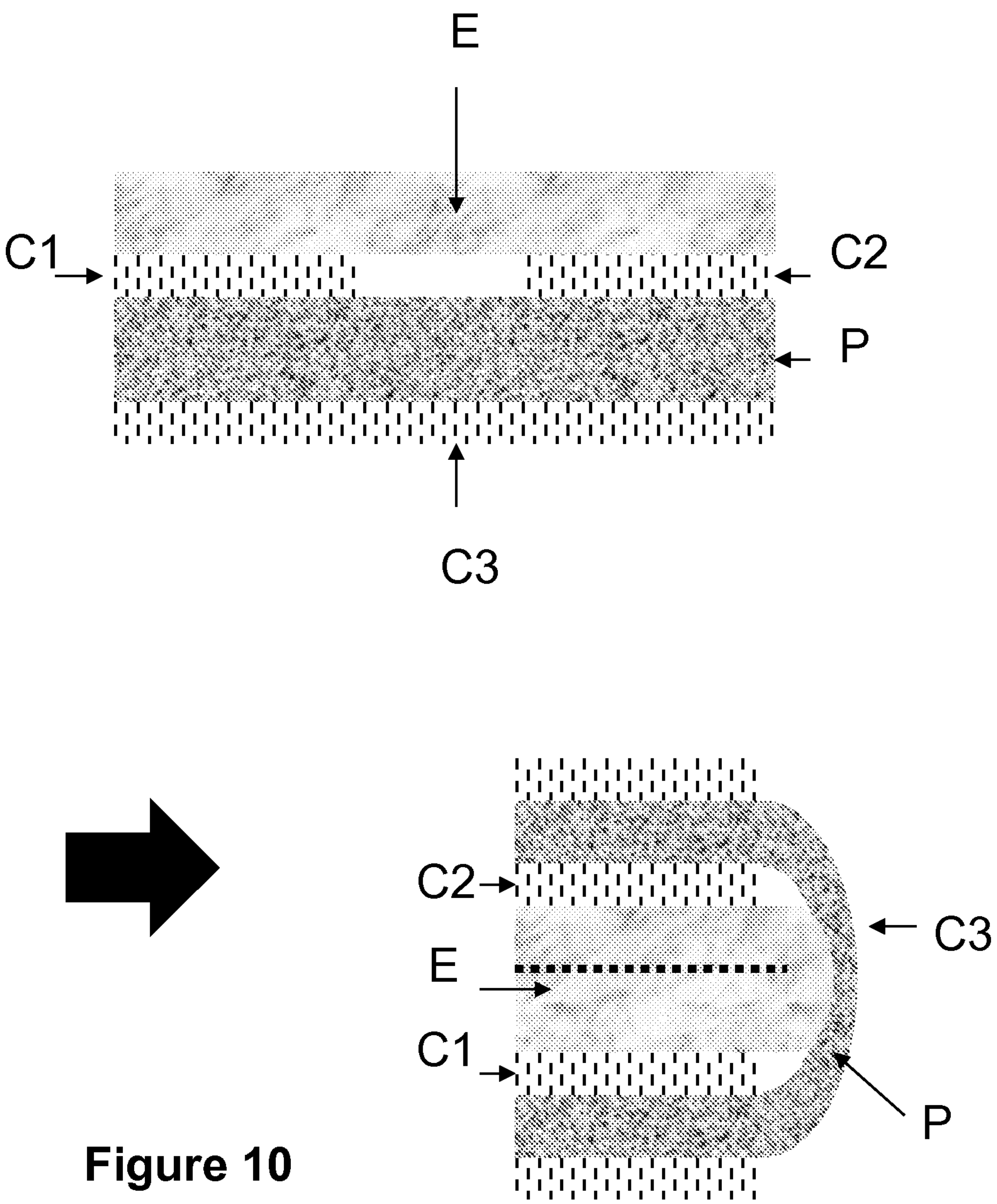

Figure 10

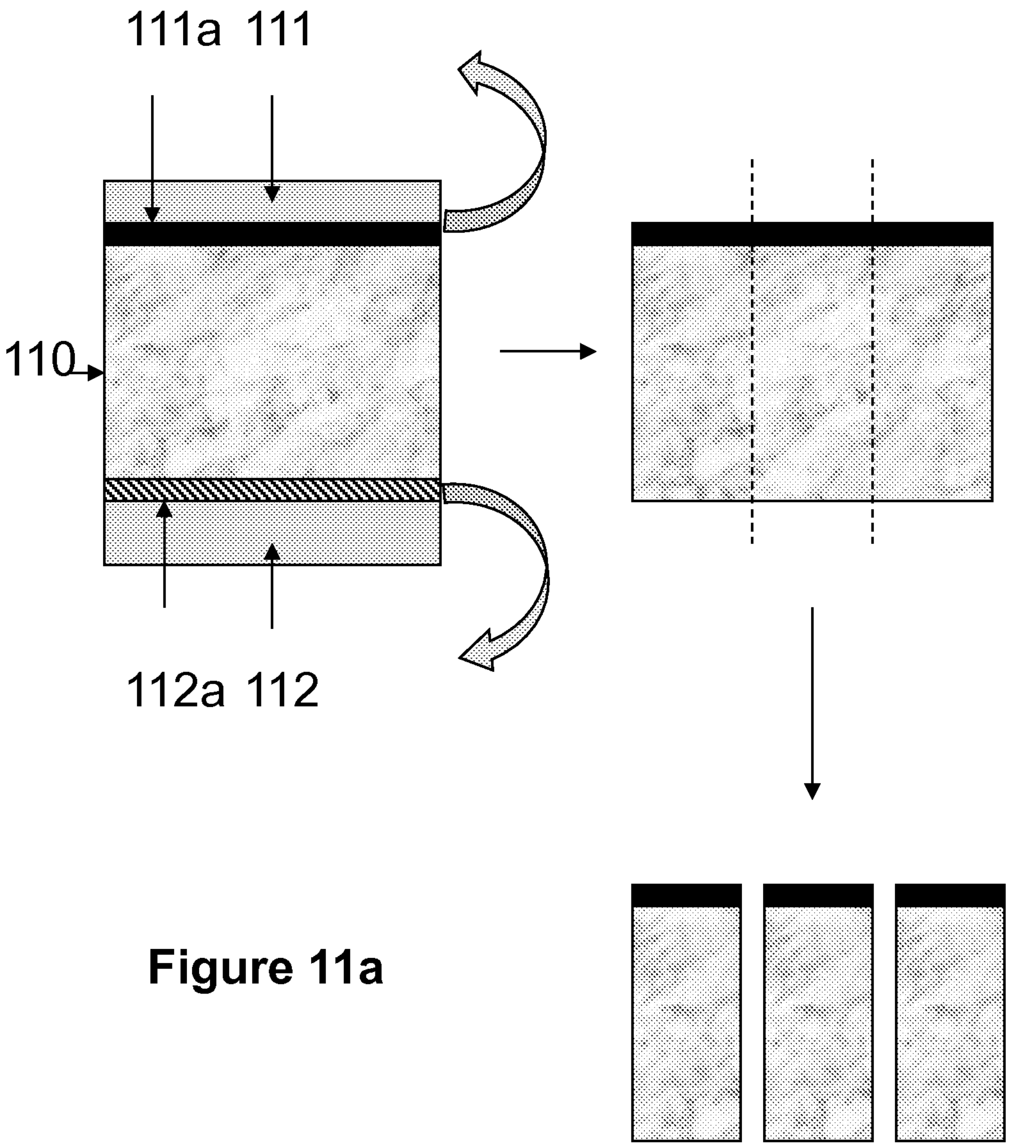

Figure 11a

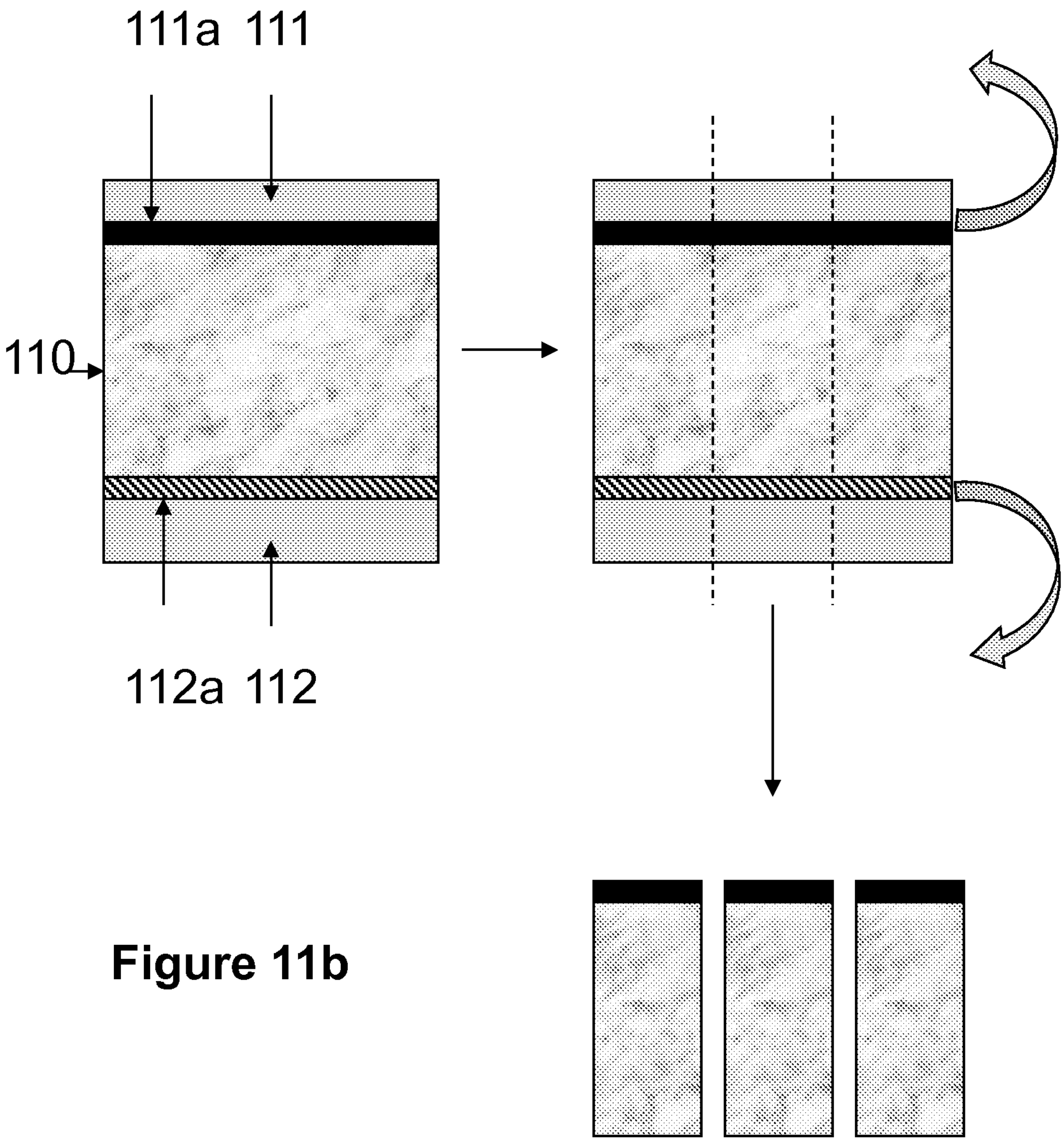

Figure 11b

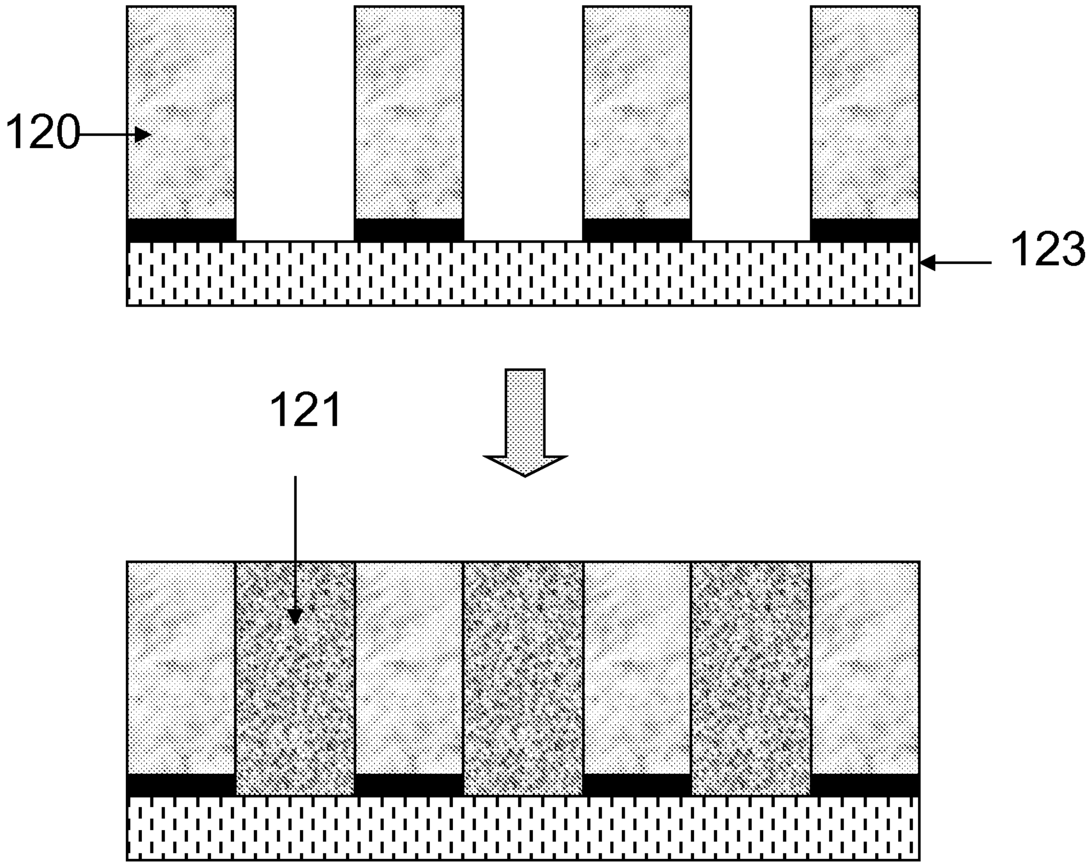

Figure 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/045394

A. CLASSIFICATION OF SUBJECT MATTER

G02F 1/167(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)
G02F 1/167; G09F 9/00; G09F 9/37; G06F 3/041

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: piezo-electrophoretic display, electrophoretic, piezo, conductor, U-shape, microcup, microcapsule

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2008-0094252 A (SK TELECOM CO., LTD.) 23 October 2008 See abstract; claims 1, 2, 5; paragraphs [0037], [0054]; and figures 3, 5.	1-5,11-13
A		6-10,14-18
A	JP 2010-085528 A (NIPPON HOSO KYOKAI) 15 April 2010 See abstract; claim 1; paragraphs [0039]-[0048]; and figures 1, 2.	1-18
A	JP 2004-004770 A (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 08 January 2004 See abstract; claims 1-3; paragraphs [0012]-[0026]; and figures 1A, 1B.	1-18
A	KR 10-2007-0082346 A (LG PHILIPS LCD CO., LTD.) 21 August 2007 See abstract; claims 1, 2; and figure 3.	1-18
A	US 2011-0242014 A1 (YAO-CHOU TSAI et al.) 06 October 2011 See abstract; claims 1, 2, 6, 7, 10; and figure 4A.	1-18

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

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2013 (17.09.2013)	**23 September 2013 (23.09.2013)**

Name and mailing address of the ISA/KR
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