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(71) Applicant (*for all designated States except US*): **MIORTECH HOLDING B.V.** [NL/NL]; High Tech Campus 9, NL-5656 AE Eindhoven (NL).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **FEIL, Hermanus** [NL/NL]; Dubloenhof 14, NL-5551 XN Valkenswaard (NL). **BORDES, Bente, Adriaan** [NL/NL]; Ekenrooisestraat 65, NL-5583 TE Waalre (NL). **VAN DER POLS, Eric, Paul** [NL/NL]; De Suikerbakker 16, NL-5506 EK Veldhoven (NL).

(74) Agents: **DOHMEN, Johannes, M., G.** et al.; Algemeen Octrooi- en Merkenbureau, P.O. Box 645, NL-5600 AP Eindhoven (NL).

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(54) **Title:** ELECTROWETTING ELEMENT

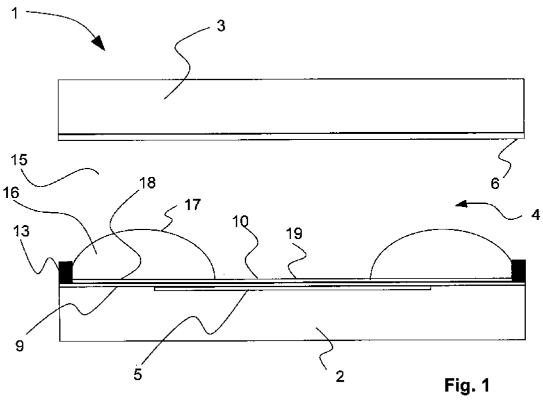

Fig. 1

(57) **Abstract:** The present invention is directed to an electrowetting element comprising a first electrode layer having a hydrophobic surface and a second electrode layer opposite said hydrophobic surface, a containment space formed between said first and said second electrode layer, and pixel walls mounted on said hydrophobic surface for forming at least one pixel element in said containment space between said pixel walls. The containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity. The polar and non-polar liquid are immiscible with each other. Said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state. In accordance with the invention, said hydrophobic surface has a surface tension such that said hydrophobic surface is oleophilic, and that porosity of said hydrophobic surface is such as to prevent penetration of said polar liquid into said hydrophobic surface.

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Title:

Electrowetting element

DESCRIPTION

Field of the Invention

The present invention relates generally to electrowetting elements, and in particular to an electrowetting element comprising a first electrode layer having a contact surface and a second electrode layer opposite said contact surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said contact surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state.

The present invention further relates to a method of manufacturing an electrowetting element comprising a first electrode layer having a contact surface and a second electrode layer opposite said contact surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said contact surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state.

Background of the Invention

Electrowetting technology is based on modification of an energy balance between on one hand surface tension forces of liquids and wetting properties of a solid surface, and on the other hand electrostatic forces induced by an applied voltage over a capacitor arrangement comprising said boundary layer.

An electrowetting element may subsequently from bottom to top be comprised of respectively a first electrode layer, an electrically insulating hydrophobic layer (i.e. having a hydrophobic surface on a side opposite the side adjacent or nearest to the first electrode layer), two liquids comprising at least a polar liquid and a non-polar liquid which are immiscible with each other, and a second electrode in contact with at least the polar liquid. In practice, the liquids are contained in between for example pixel walls forming a containment tray and a top glass plate.

Various materials can be used for the electrically insulating hydrophobic layer, e.g. teflon^{tm} (Polytetrafluoroethyline (PTFE)) is a suitable material having suitable optical and electrical properties. Materials which are to a large extend hydrophobic are considered preferable in the field of technology. As a non-polar liquid, one may use an oil such as decane. The selection criteria for selecting a suitable non-polar liquid include (apart from the liquid being non-polar), dielectric constant sufficiently large (the liquid is preferably a good isolator, or at least a poor conductor) and having an optical transmission coefficient that is suitable for the application wherein it is used (in practice the liquid will have low transmissibility, but in the present invention, a certain (small) degree of transmissibility may be advantageous, though not essential). Optical properties may be modified or adapted by introducing a small percentage of a dye in the non-polar liquid as an additive. The polar liquid preferably has good conductive properties, and should additionally be selected with respect to its optical properties. Preferably, the polar liquid is optically transmissive.

The principles of operation of an electrowetting element are as follows. In an unpowered state, i.e. when no voltage is applied over the first and second electrode, the lowest energetic state of the system is where the non-polar liquid forms a boundary layer between the polar liquid and the hydrophobic surface of the insulating layer. This is because the polar liquid is repelled by the hydrophobic layer. The poor transmissibility of the non-polar liquid then forms an obstruction to light that penetrates the system. When a voltage is applied over the electrodes, the lowest energetic state of the system becomes the situation wherein the (poorly conductive or insulating) non-polar liquid is pushed aside by the (conductive) polar liquid, and the polar liquid thereby being in direct contact with the insulating hydrophobic layer. Note that the voltage must be large enough for the electrostatic forces to overcome the repellent and surface tension forces that separate the polar liquid from the hydrophobic surface. In this situation, light that penetrates the system has rather unobstructed access to the insulating hydrophobic layer because of the well transmissibility of the polar liquid and the non-polar liquid being pushed aside.

Upon switching the electrodes from the powered state back to the unpowered state, by taking away the voltage that is applied to the electrodes, the equilibrium of forces present in the powered state is destroyed and the system will commence to turn back to the lowest energetic state of the system that was present before the electrodes were powered. A problem experienced with prior art electrowetting elements is that pixels of the system may not close after being opened. This problem is in the prior art resolved by increasing the porosity of the hydrophobic contact surface of the element. By increasing the porosity, the non-polar and often oily liquid is able to entrain the pores or microvoids in the hydrophobic contact layer, enabling the oil in each pixel to open and close more easily such as to prevent the above problem to occur.

A disadvantage of this method is that the porosity of the surface cannot be controlled efficiently in the manufacturing process. Therefore, the quality of electrowetting elements produced based on porous hydrophobic surface layers is variable. In case the porosity of the surface layer is too low, e.g. in some regions of the surface of the electrowetting elements, the probability of non-closing pixels of the electrowetting element produced, is larger in such an area and the produced electrowetting element may in that case be defective.

Another disadvantage is that by increasing the porosity of the hydrophobic contact surface, during use the polar liquid (e.g. water) may quite easily fill the pores or microvoids of the surface once a voltage is applied to the electrodes of the electrowetting elements and the polar liquid is in contact with the contact surface. The polar liquid may remain in the pores once the voltage is again turned off. This will deteriorate the electrowetting element, because the contact surface becomes hydrophilic in those areas of the surface wherein the polar liquid has entrained the microvoids. Therefore, over time it may occur that an electrowetting element that used to function perfectly directly after it was manufactured, deteriorates over time, leading to more and more non-closing pixels over time. This deteriorates the display quality of the electrowetting element and shortens the lifetime thereof.

Summary of the Invention

The present invention has for its objects to resolve the above-mentioned problems of the prior art, and provide an improved electrowetting element.

This and other objects is achieved in that there is provided an electrowetting element comprising a first electrode layer having a hydrophobic surface and a second electrode layer opposite said hydrophobic surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said hydrophobic surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state, characterized in that, said hydrophobic surface having a surface tension such that said hydrophobic surface is oleophilic, and that a porosity of said hydrophobic surface is such as to prevent penetration of said polar liquid into said hydrophobic surface.

The present invention is based on the insight that the contact angle between the non-polar liquid and the hydrophobic contact surface can be influenced by proper selection of the chemical properties of the surface, viz. by proper selection of the substance comprised by the hydrophobic contact surface. In particular, the surface tension of the hydrophobic surface is a critical parameter and should be chosen such that not only the surface is hydrophobic, but also the hydrophobic surface is oleophilic. This provides suitable wettability properties for a wide range of liquids that may be used as non-polar liquid for the present invention. Such liquids include, but are not limited to, various hydrocarbon oils, as will be explained below.

At the same time, the porosity level of the hydrophobic surface can be minimized (ideally the hydrophobic surface is not porose at all) such as to prevent penetration of the hydrophobic surface by polar liquid over time.

According to a preferred embodiment of the present invention, the hydrophobic contact surface is comprised of a substance having chemical properties such that an interfacial tension between the non-polar liquid and the hydrophobic surface is approximately equal to the difference between an interfacial tension between the polar liquid and the hydrophobic surface and interfacial tension between the polar liquid and the non-polar liquid for minimizing a contact angle of an interface between the non-polar liquid and the polar liquid relative to the hydrophobic surface.

The invention is based on the insight that the problem of non-closing pixels is created by a local energetic minimum caused by an equilibrium of surface tension forces between the interfaces surface-polar liquid, surface non-polar liquid and polar liquid-non-polar liquid. By properly selecting the chemical composition of the surface such that the interfacial tension between the non-polar liquid and the surface substantially equals the difference between the interfacial tensions between the polar liquid and the hydrophobic surface on one hand and the interfacial tension between the polar liquid and the non-polar liquid on the other hand, the establishing of a local force equilibrium between the surface tension forces will not occur until the non-polar liquid covers the complete hydrophobic surface of the pixel element of the electrowetting element. This is regardless of whether or not the pores or microvoids are present in het hydrophobic surface.

According to another preferred embodiment of the invention, the hydrophobic surface is comprised of a substance having chemical properties such that an interfacial tension between said non-polar liquid and said hydrophobic surface is at least one order of a magnitude smaller than at least one of an interfacial tension between said non-polar liquid and said polar liquid and an interfacial tension between said polar liquid and said hydrophobic surface.

It has been observed that proper selection of the substance to be comprised in the hydrophobic surface which matches this criterium, i.e. it matches with the chemical properties of the non-polar liquid to such an extend that the interfacial tension is relatively small (at least one order of a magnitude smaller) compared to the other interfacial tensions involved, the effects of the present invention can be achieved easily.

Good results have been achieved with an embodiment wherein the surface tension of the hydrophobic surface is within a range between 0,020 N/m and 0,035 N/m. Within this range, the hydrophobic surface is not only hydrophobic but also oleophilic, and therefor enables the non-polar liquid to easily spread across the hydrophobic surface under conditions wherein the electrodes are not charged. The porosity level can be reduced to a minimum, e.g. below 10% (ideally, the porosity level is 0%), such that penetration of the hydrophic surface by the polar liquid can be effectively prevented. This extends the lifetime of the electrowetting element according to the present invention, whilst at the same time the problem of non-closing pixels as described hereinabove is effectively resolved.

According to another embodiment of the present invention, the chemical properties of the hydrophobic surface match with chemical properties of said non-polar liquid for enabling said non-polar liquid to spread across said hydrophobic surface upon switching said electrode layers from a powered to an unpowered state. In particular, where the non-polar liquid is an oily substance, the hydrophobic surface may be particularly oleophilic.

Surprisingly good results have been achieved by a hydrophobic contact surface comprising a organosilane layer. Organosilane molecules are comprised of a silane group which readily adheres or bonds to e.g. a silica insulating layer, and at the same time the rest of the molecule may be matched to the molecular structure of the non-polar liquid used. If for example the non-polar liquid comprises a hydrocarbon compound, such as decane, the organosilane layer may comprise an organosilane molecular structure which comprises said hydrocarbon compound, such as decylsilane. More generally, for alkane-based oils, the use of an alkylsilane coating or surface layer is preferred in accordance with the invention.

The non-polar liquid used in the electrowetting element according to the present invention, may be selected from a group comprising mineral oils, animal and vegetable oils, esters, high-boiling hydrocarbons, higher fatty acids, higher alcohols and polyolefins, in particular alkanes such as decane, vaseline, spindle oil, castor oil, olive oil, liquid paraffin and polybutene. Oleophilic coatings, or surface layers, such as an alkylsilane surface layer or another silane layer matching with the molecular structure of the non-polar liquid use, can be applied in order to achieve the effects of the present invention.

According to a second aspect of the present invention there is provided a Method of manufacturing an electrowetting element comprising a first electrode layer having a hydrophobic surface and a second electrode layer opposite said hydrophobic surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said hydrophobic surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state, characterized in that said method comprises a step of selecting a substance for forming said hydrophobic surface such that the chemical properties of said substance enable said non-polar liquid to spread across said hydrophobic surface upon switching said electrode layers from a powered to an unpowered state.

Brief Description of the Drawings

The invention is further explained by means of specific embodiments and examples thereof, with reference to the enclosed drawings, wherein:

figure 1 illustrates a pixelelement in an electrowetting element according to the present invention;

figure 2 Illustrates a molecule of an alkylsilane monolayer coating present on a silica substrate surface; and

figure 3 is a diagram illustrating the wettability properties of a surface at various surface tension values.

Detailed description of Embodiments of the Invention

The invention is directed to an electrowetting element and a method for manufacturing thereof. The enclosed figure 1 discloses a pixel element (generally indicated by 1), comprising a containment space 4 between a first substrate 2 and a second substrate 3. Substrate 3 may for example be comprised of a glass layer, while substrate 2 may be a reflective substrate or another glass layer, which may be contiguous to backlighting means of a display. Substrate 2 may also comprise a specular reflective surface such that the electrowetting element may be applied to a mirror for dimming the reflectivity thereof. This may for example be advantageous for use in self-dimming car mirrors. The invention is however not limited to this application, and the teachings may be applied to electrowetting elements in general, regardless of their specific application and use.

Contiguous to substrate 2 and 3 electrodes 5 and 6 may be present at either side of containment space 4. Between electrodes 5 and 6 a voltage may be applied such as to switch the pixel element 1 on and off, as will be explained below.

On top of electrode 5 insulating layer 9 provides electric insulation between the containment space and said electrode. On top of insulating layer 9 a hydrophobic contact layer 10 is provided which is selected such that in an unpowered state the polar liquid is repelled from the hydrophobic surface, enabling the non-polar liquid to cover the complete surface of the pixel element 1.

In containment space 4, on top of insulating layer 9, pixel walls 13 separates pixel element 1 from contiguous pixel elements (not shown) of the electrowetting element. The pixel walls are preferrably of hydrophilic nature. The containment space 4 is filled with polar liquid 15. Every suitable polar liquid may be applied, however being a popular and readily available low-cost polar liquid, water is used as the polar liquid of the present embodiment of the invention. In addition to the polar liquid, the pixel element further comprises a non-polar liquid 16. The polar liquid and non-polar liquid are immissible forming a polar - non-polar liquid interface 17. The interface between the non-polar liquid and the hydrophobic contact surface is indicated with reference numeral 18. The interface between the polar liquid and the hydrophobic contact layer is generally indicated by reference numeral 19.

The pixel element 1 illustrated in figure 1 is in a transitional mode wherein, after being switched on, it has just been switched off (by releasing the voltage applied to electrodes 5 and 6), and the pixel element is closing, transiting to the unpowered equilibrium state wherein the pixel element is optically not transmissive. The non-polar liquid 16 is turning back to the 'off' state wherein the non-polar liquid fully covers the hydrophobic contact surface 10, separating surface 10 from polar liquid 15.

In the embodiment disclosed in figure 1, insulating layer 9 is comprised of a silica material layer, which is covered with a monolayer coating of an alkylsilane, for example decylsilane. The oil used as non-polar liquid 16 may be decane, while, as mentioned above, the polar liquid is water.

A schematic enlargement of a silica-based hydrophobic surface layer 10 of a pixel element 1, comparable to the embodiment illustrated in figure 1, is illustrated in figure 2. The enlargement is at microscopic level, disclosing two individual decylsilane molecules 25 which are attached to the silica substrate layer 9 of the pixel element. As can be seen, a decylsilane molecule comprises a silane group 27 which easily adheres to the silica layer 9. A decyl-group 28 of the molecule forms the interface between the non-polar liquid and the surface 10. The hydrophobic (oleophilic) surface thus comprises a molecular structure which is similar to the molecular structure of decane. Because of this property, the wetting properties of hydrophobic contact layer 10 are dominated by the wetting properties of decane because of the similarity of the molecular structure at the surface. Bonding forces between decane molecules are thus comparable to the bonding forces between the decane molecules and the decylsilane surface molecules. Therefore, if decane is used as non-polar liquid 16, the interfacial tension between the decane and the alkylsilane mono layer of hydrophobic surface layer 10 will be negligible such that the non-polar liquid easily spreads across the surface of the pixel element 1, after the pixel element is switched off to the unpowered state. This enables the pixel element to easily turn back into its unpowered equilibrium state wherein the non-polar liquid fully covers the hydro-phobic surface layer en separates this layer from the polar liquid 15.

In the embodiment described, since the wetting properties of layer 10 are determined by the decyl-group in the decylsilane film, the interfacial tension between the polar liquid and the surface 10 (interface 19) are comparable to the interfacial tension at interface 17, between the non-polar liquid and the polar liquid. Therefore, the interfacial tension between the polar liquid and the non-polar liquid is substantially equal to the interfacial tension of between the polar liquid and the hydrophobic surface. It has been discovered that such an interfacial tension renders the contact surface 10 sufficiently oleophilic for the electrowetting element to be operable. In addition, due to these comparable surface tension forces and the negligible surface tension between the non-polar liquid and the hydrophobic surface, the problem of non-closing pixel elements is effectively resolved since an equilibrium of surface tension forces will not occur until the non-polar liquid fully covers the hydrophobic surface. This is even the case when the hydrophobic surface is smooth, without microvoids or pores.

If θ is the contact angle of the non-polar liquid on the hydrophobic surface, and the roughness parameter R provides an indication of the roughness (such as porosity) of the surface (wherein R=1 for a smooth surface), and the interfacial tensions between the non-polar liquid (O), the surface (S), and the polar liquid (W) are respectively given by γ_{OS}, γ_{SW} , and γ_{OW}, the contact angle at which surface tension equilibrium may occur is provided by:

$$R \cos\theta = \frac{\gamma_{SW} - \gamma_{OS}}{\gamma_{OW}}$$

For the above described case, the contact angle will thus be close to 0°, i.e. the non-polar liquid will fully cover the hydrophobic surface, thereby achieving the effects of the invention.

Figure 3 provides a diagram illustrating the wettability properties of a surface at various surface tension levels. On the horizontal axis 30, the surface tension σ is illustrated in N/m. Above these values, various ranges 33, 34, 35 and 36 for various wettability properties are schematically illustrated.

If the surface tension is above 0,04 N/m, as indicated by range 33, the surface is observed to have hydrophilic properties. In case the surface tension σ drops below 0,035 N/m, the surface is observed to have hydrophobic properties. In material studies, a surface is said to be hydrophilic if the contact angle of a water droplet on the surface is 30° or smaller. On the other side, if a water droplet on a surface forms a contact angle larger than 90°, the surface is designated hydrophobic.

If the surface tension of the surface drops below 0,020 N/m, then besides being hydrophobic, the surface is observed to be oleophobic i.e. an oil droplet on such a surface will not spread easily across this surface. The corresponding range for an oilphobic surface is provided by range 35. For surface tensions between 0,020 N/m and 0,035 N/m the surface is observed to be oleophilic, while it is at the same time hydrophobic. In other words, a water droplet on the surface will not easily spread across the surface but a droplet of a hydrocarbon or oil will have a small contact angle and will easily spread across the surface. The corresponding range in figure 3 is range 36.

In table 1 below a number of chemical substances is provided having a critical surface tension within a range between 0,020 N/m, 0,035 N/m (range 36).

Table 1

octadecyltrichlorosilane	20-24
methyltrimethoxysilane	22.5

nonafluorohexyltrimethoxysilane	23.0
vinyltriethoxysilane	25
paraffin wax	25.5
ethyltrimethoxysilane	27.0
propyltrimethoxysilane	28.5
poly(chlorotrifluoroethylene)	31.0
poly(propylene)	31.0
poly(propylene oxide)	32
polyethylene	33.0
trifluoropropyltrimethoxysilane	33.5
3-(2-aminoethyl)-aminopropyltrimethoxysilane	33.5
poly(styrene)	34
p-tolyltrimethoxysilane	34
cyanoethyltrimethoxysilane	34
aminopropyltriethoxysilane	35

Although the invention has been described with reference to the embodiments disclosed in the figures, the invention may be practised differently, as will be apparent to the skilled reader. The scope of the invention is not limited by the embodiments disclosed, but is determined by the scope of the appended claims.

CLAIMS

1. Electrowetting element comprising a first electrode layer having a hydrophobic surface and a second electrode layer opposite said hydrophobic surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said hydrophobic surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state, characterized in that, said hydrophobic surface having a surface tension such that said hydrophobic surface is oleophilic, and that a porosity of said hydrophobic surface is such as to prevent penetration of said polar liquid into said hydrophobic surface.

2. Electrowetting element according to claim 1, wherein said hydrophobic surface is comprised of a substance having chemical properties such:

that an interfacial tension between said non-polar liquid and hydrophobic surface is approximately equal to the difference between an interfacial tension between said polar liquid and hydrophobic surface and an interfacial tension between said polar liquid and said non-polar liquid for minimizing a contact angle of an interface between said non-polar liquid and said polar liquid relative to said hydrophobic surface; or

that an interfacial tension between said non-polar liquid and said hydrophobic surface is at least one order of a magnitude smaller than at least one of an interfacial tension between said non-polar liquid and said polar liquid and an interfacial tension between said polar liquid and said hydrophobic surface.

3. Electrowetting element according to any of the previous claims, wherein said hydrophobic surface having a surface tension between 0.020 N/m and 0.035 N/m.

4. Electrowetting element according to any of the previous claims, wherein said chemical properties of said hydrophobic surface match with chemical

properties of said non-polar liquid for enabling said non-polar liquid to spread across said hydrophobic surface upon switching said electrode layers from a powered to an unpowered state.

5. Electrowetting element according to claim 4, wherein said hydrophobic surface comprises a organosilane layer for matching said chemical properties of said non-polar liquid with said chemical properties of said hydrophobic surface.

6. Electrowetting element according to claim 5, wherein said non-polar liquid comprises a hydrocarbon compound, and said organosilane layer comprises an organosilane based on said hydrocarbon compound.

7. Electrowetting element according to any of the previous claims, wherein said hydrophobic surface comprises a substance selected from a group comprising an alkylsilane, octadecyltrichlorosilane, methyltrimethoxysilane, nonafluorohexyltrimethoxysilane, vinyltriethoxysilane, paraffin wax, ethyl-trimethoxysilane, propyltrimethoxysilane, poly(chlorotrifluoroethylene), poly(propylene), poly(propylene oxide), polyethylene, trifluoropropyl-trimethoxysilane, 3-(2-aminoethyl)-aminopropyltrimethoxysilane, poly(styrene), p-tolyltrimethoxysilane, cyanoethyltrimethoxysilane, aminopropyltriethoxysilane.

8. Electrowetting element according to any of the previous claims, wherein said non-polar liquid is selected from a group comprising mineral oils, animal and vegetable oils, esters, high-boiling hydrocarbons, higher fatty acids, higher alcohols and polyolefins, in particular alkanes such as decane, vaseline, spindle oil, castor oil, olive oil, liquid paraffin and polybutene.

9. Electrowetting element according to any of the previous claims, wherein said porosity of said hydrophobic surface is below 10%.

10. Method of manufacturing an electrowetting element comprising a first electrode layer having a hydrophobic surface and a second electrode layer opposite said hydrophobic surface, a containment space formed between said first and said second electrode layer, pixel walls mounted on said hydrophobic surface for forming at least one pixel element in said containment space between said pixel walls, wherein said containment space and said at least one pixel element formed therein comprise at least one polar liquid having a first conductivity and at least one non-polar liquid having a second conductivity, said polar and said non-polar liquid being immiscible with each other, and wherein said electrowetting element further

comprises powering means for controllably powering said first and second electrode layers for rearranging said polar liquid relative to said non-polar liquid for switching said at least one pixel element between an optically transmissive and optically non-transmissive state, characterized in that said method comprises a step of selecting a substance for forming said hydrophobic surface such that said hydrophobic surface having a surface tension such that said hydrophobic surface is oleophilic, and that a porosity of said hydrophobic surface is such as to prevent penetration of said polar liquid into said hydrophobic surface.

11. Method according to claim 10, wherein said substance is selected having chemical properties such that

an interfacial tension between said non-polar liquid and hydrophobic surface is approximately equal to the difference between an interfacial tension between said polar liquid and hydrophobic surface and an interfacial tension between said polar liquid and said non-polar liquid for minimizing a contact angle of an interface between said non-polar liquid and said polar liquid relative to said hydrophobic surface; or

an interfacial tension between said non-polar liquid and said hydrophobic surface is at least one order of a magnitude smaller than at least one of an interfacial tension between said non-polar liquid and said polar liquid and an interfacial tension between said polar liquid and said hydrophobic surface.

12. Method according to any of the claims 10-11, wherein said substance is selected such that said hydrophobic surface has a surface tension between 0.020 N/m and 0.035 N/m.

13. Method according to any of the claims 10-12, wherein said substance is selected such that said chemical properties of said hydrophobic surface match with chemical properties of said non-polar liquid for enabling said non-polar liquid to spread across said hydrophobic surface upon switching said electrode layers from a powered to an unpowered state.

14. Method according to any of the claims 13, wherein said substance comprises an organosilane compound.

15. Method according to any of the claims 10-14, wherein said organosilane compound comprises a substance selected from a group comprising an alkylsilane, octadecyltrichlorosilane, methyltrimethoxysilane, nonafluorohexyltrimethoxysilane, vinyltriethoxysilane, paraffin wax, ethyltrimethoxy-

silane, propyltrimethoxysilane, poly(chlorotrifluoroethylene), poly(propylene), poly(propylene oxide), polyethylene, trifluoropropyl-trimethoxysilane, 3-(2-aminoethyl)-aminopropyltrimethoxysilane, poly(styrene), p-tolyltrimethoxysilane, cyanoethyltrimethoxysilane, aminopropyltriethoxysilane.

16. Method according to any of the claims 15 or 16, wherein said non-polar liquid comprises a hydrocarbon compound, and said organosilane compound comprises an organosilane based on said hydrocarbon compound.

17. Method according to any of the claims 10-16, wherein substance is selected such that said porosity of said hydrophobic surface is below 10%.

1/3

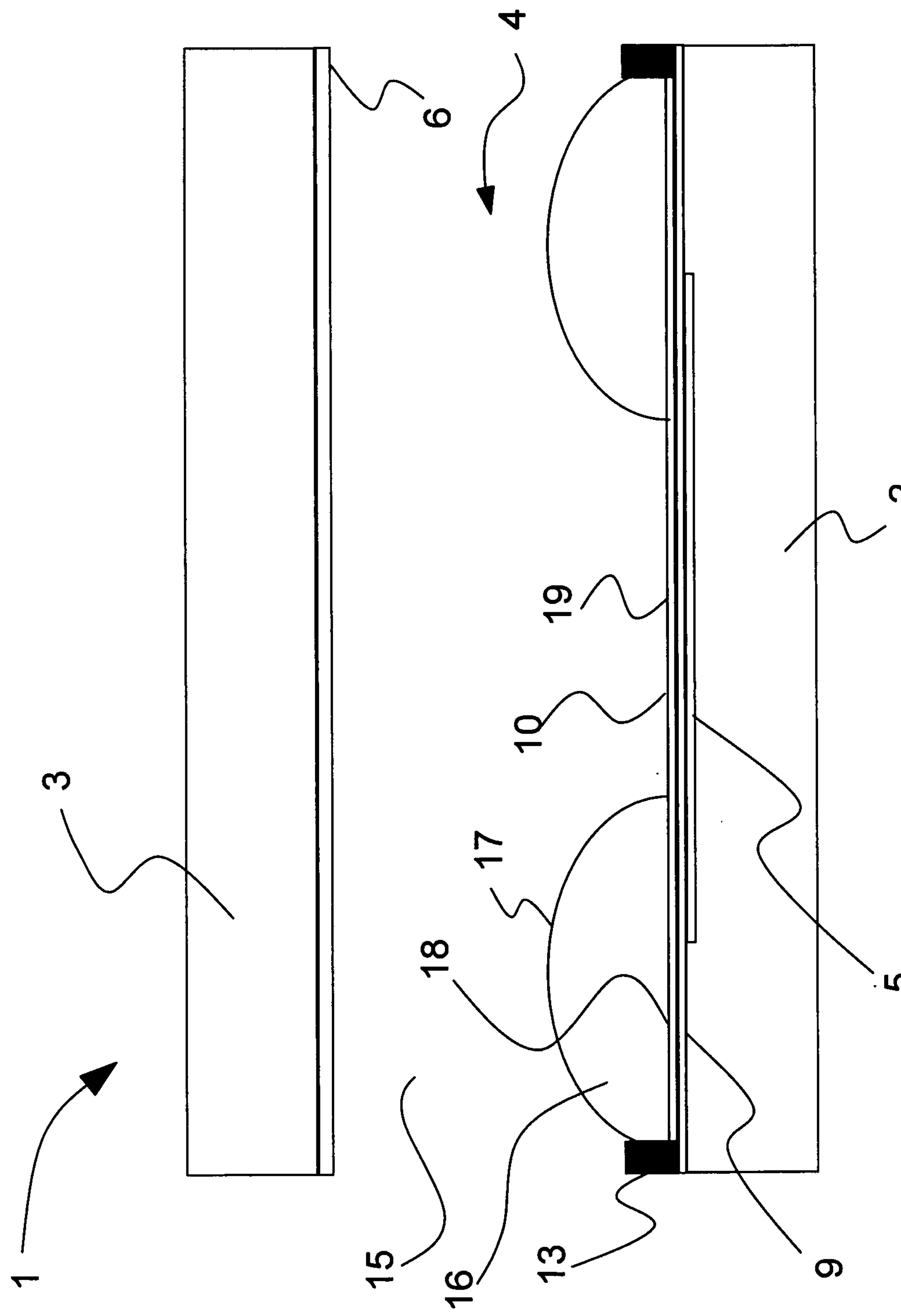

Fig. 1

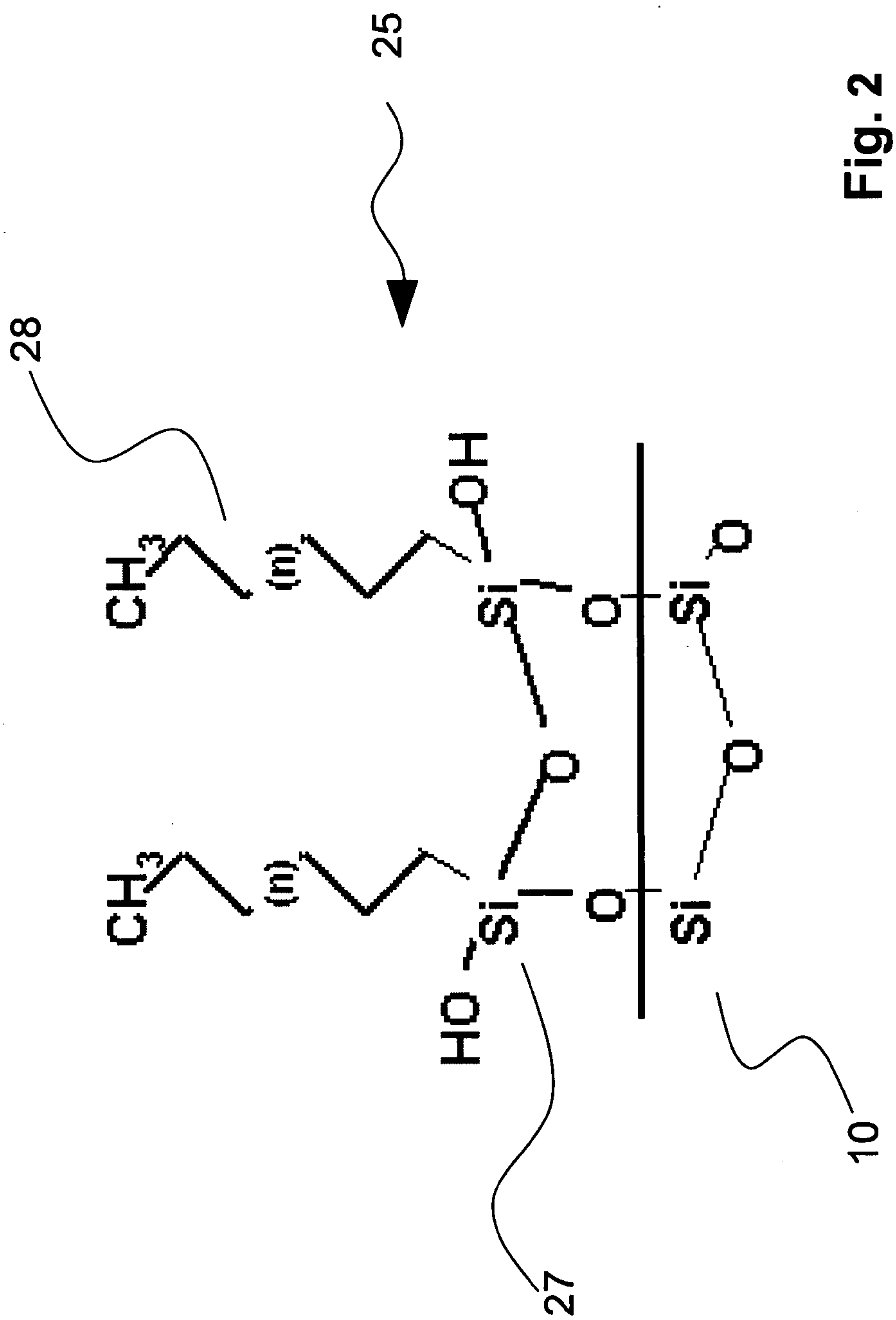

Fig. 2

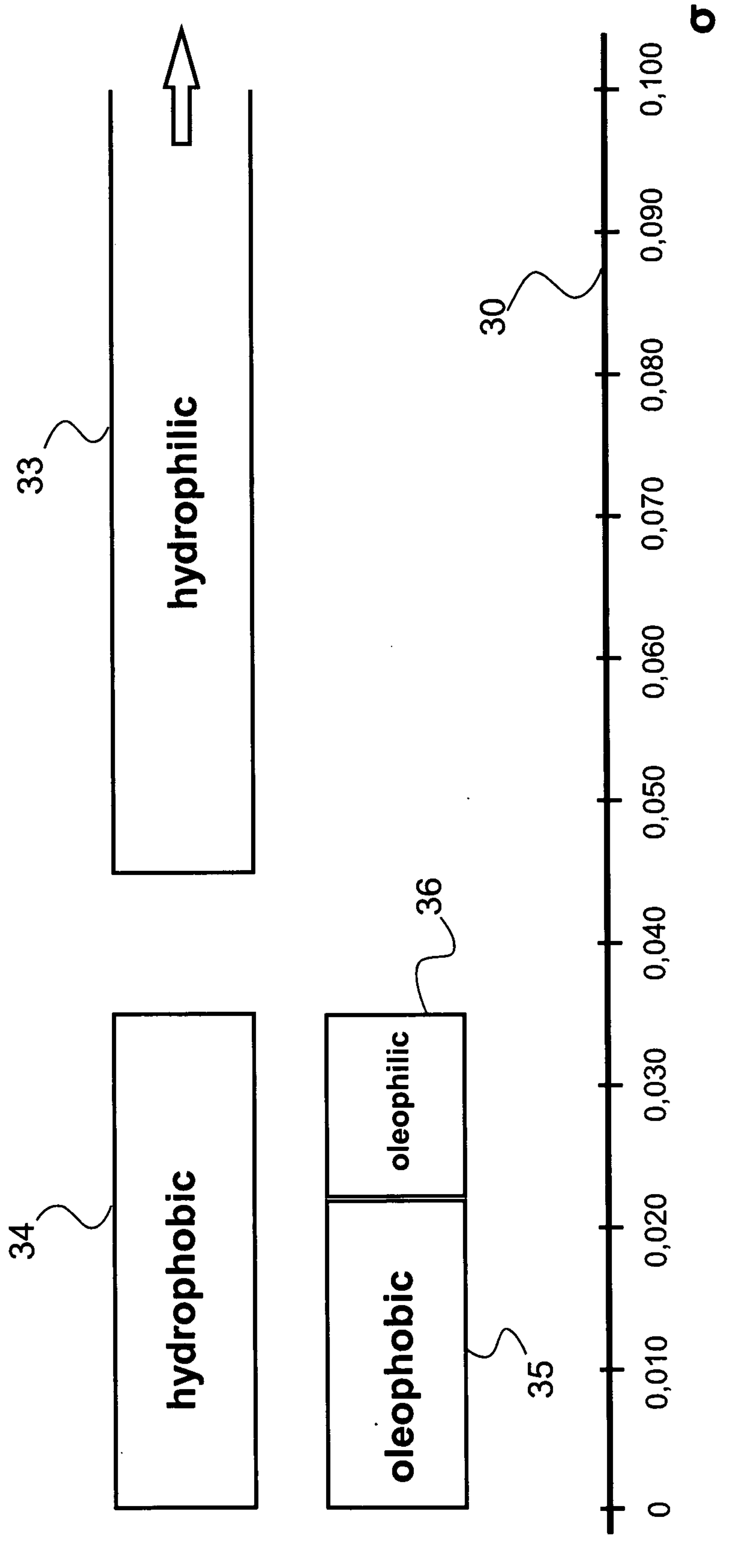
hydrophilic
33
hydrophobic
34
oleophobic
35
oleophilic
36
30
0
0,010
0,020
0,030
0,040
0,050
0,060
0,070
0,080
0,090
0,100
σ

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2008/000258

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B26/02

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)
G02B

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	EP 1 542 056 A (LG ELECTRONICS INC [KR]) 15 June 2005 (2005-06-15) paragraph [0029] - paragraph [0036]; figure 2 paragraph [0037] - paragraph [0045]; figures 3-5	1,4,8, 10,13
X	WO 2005/038764 A (E INK CORP [US]; JACOBSON JOSEPH M [US]; WHITESIDES THOMAS H [US]; MCC) 28 April 2005 (2005-04-28) paragraph [0033] - paragraph [0036]; figures 1,2 paragraph [0010] paragraph [0038] - paragraph [0040]; figure 4	1,4,8, 10,13

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

"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
15 January 2009	26/01/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	A. Jacobs

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2005/098524 A (KONINKL PHILIPS ELECTRONICS NV [NL]; HAYES ROBERT A [NL]; JOULAUD MICK) 20 October 2005 (2005-10-20) page 1 - page 3; claim 4; figures 1,2	1,4,8, 10,13
A	HAYES R A ET AL: "Video-speed electronic paper based on electrowetting" NATURE, NATURE PUBLISHING GROUP, LONDON, UK, vol. 425, no. 6956, 25 September 2003 (2003-09-25), pages 383-385, XP002286158 ISSN: 0028-0836 pages 383,384; figures 1,3	2,4,9, 11,13,17
A	US 6 369 954 B1 (BERGE BRUNO [FR] ET AL) 9 April 2002 (2002-04-09) column 6, line 49 - line 58; figure 1	6,16
A	US 2001/017985 A1 (TSUBOI TAKAYUKI [JP] ET AL) 30 August 2001 (2001-08-30) paragraph [0051]	2,11
A	WO 2007/088453 A (VARIOPTIC [FR]; MAILLARD MATHIEU [FR]; LIOGIER D ARDHUY GAETAN [FR]; L) 9 August 2007 (2007-08-09) page 6, line 33 - page 7, line 2 page 9, line 16 - line 30 page 11, line 14 - line 20 page 12, line 23 - line 26	3,8,12
A	FEENSTRA B J ET AL: "Electrowetting-Based Displays: Bringing Microfluidics Alive On-Screen" MICRO ELECTRO MECHANICAL SYSTEMS, 2006. MEMS 2006 ISTANBUL. 19TH IEEE INTERNATIONAL CONFERENCE ON ISTANBUL, TURKEY 22-26 JAN. 2006, PISCATAWAY, NJ, USA,IEEE, 22 January 2006 (2006-01-22), pages 48-53, XP010914522 ISBN: 978-0-7803-9475-9 page 48	2,11
A	US 2006/067663 A1 (KITA KAZUNORI [JP]) 30 March 2006 (2006-03-30) table 3	3,7,12, 15
A	WO 2006/017129 A (UNIV CINCINNATI [US]; STECKL ANDREW J [US]; HEIKENFELD JASON C [US]) 16 February 2006 (2006-02-16) page 9	3,9,12, 17
A	WO 2007/097709 A (AGENCY SCIENCE TECH & RES [SG]; DHARMATILLEKE SAMAN [SG]; RODRIGUEZ FE) 30 August 2007 (2007-08-30) paragraphs [0035], [0040]	5,7,8, 14,15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2008/000258

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1542056	A	15-06-2005	CN	1627467	A	15-06-2005
			JP	2005173605	A	30-06-2005
			KR	20050056774	A	16-06-2005
			US	2005128370	A1	16-06-2005
WO 2005038764	A	28-04-2005	AT	405916	T	15-09-2008
			CN	1864191	A	15-11-2006
			CN	101256278	A	03-09-2008
			EP	1671304	A1	21-06-2006
			EP	1967888	A2	10-09-2008
			JP	2007508584	T	05-04-2007
WO 2005098524	A	20-10-2005	CN	1942820	A	04-04-2007
			JP	2007531917	T	08-11-2007
			KR	20070044393	A	27-04-2007
			US	2008225374	A1	18-09-2008
US 6369954	B1	09-04-2002	AT	214164	T	15-03-2002
			CA	2306249	A1	15-04-1999
			DE	69804119	D1	11-04-2002
			DE	69804119	T2	28-11-2002
			EP	1019758	A1	19-07-2000
			ES	2171041	T3	16-08-2002
			FR	2769375	A1	09-04-1999
			WO	9918456	A1	15-04-1999
			JP	4154858	B2	24-09-2008
			JP	2001519539	T	23-10-2001
			US	RE39874	E1	09-10-2007
US 2001017985	A1	30-08-2001	NONE			
WO 2007088453	A	09-08-2007	EP	1991890	A1	19-11-2008
			KR	20080091790	A	14-10-2008
US 2006067663	A1	30-03-2006	JP	2006098987	A	13-04-2006
WO 2006017129	A	16-02-2006	CA	2572952	A1	16-02-2006
			EP	1774391	A2	18-04-2007
			US	2008297880	A1	04-12-2008
WO 2007097709	A	30-08-2007	NONE			