(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 October 2011 (27.10.2011)

PCT

(10) International Publication Number
WO 2011/131689 A1

(51) **International Patent Classification**:
G02F 1/167 (2006.01) *G02F 1/1343* (2006.01)

(21) **International Application Number**:
PCT/EP2011/056266

(22) **International Filing Date**:
19 April 2011 (19.04.2011)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
10160579.8 21 April 2010 (21.04.2010) EP

(71) **Applicants** *(for all designated States except US)*: **IREX TECHNOLOGIES B.V.** [NL/NL]; High Tech Campus 9, NL-5656 AE Eindhoven (NL). **IRX IP B.V.** [NL/NL]; Science Park Eindhoven 5047, NL-5692 EB Son (NL).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **HENZEN, Alexander Victor** [NL/NL]; De Uitgang 13, NL-5531 NM Bladel (NL). **GROENEWOLD, Jan** [NL/NL]; Grote Peel 6, NL-1112 KG Diemen (NL).

(74) **Agent**: **DELTAPATENTS B.V.**; Fellenoord 370, NL-5611 ZL Eindhoven (NL).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

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

(54) **Title**: ELECTROPHORETIC DISPLAYS

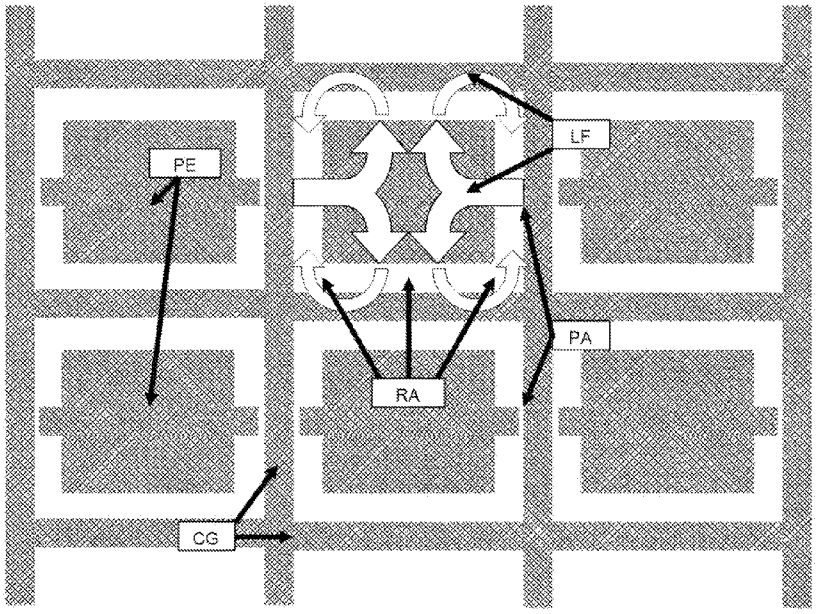


Fig. 2

(57) **Abstract**: Electrophoretic displays use motion of particles through a fluid to generate images. This invention describes the use of concerted motion of particles together with the solvent to generate optical switching.

WO 2011/131689 A1

Electrophoretic displays

Field of the invention

The invention relates to an electrophoretic display.

Background of the invention

Electrophoretic displays have been the basis of electronic paper for several years now. On the way to improve the switching behaviour and create full color capability, it was suggested to use in-plane switching electrophoretic displays. However, rules for aperture and pixel size dictate that in-plane switching requires particles to travel relatively long distances. Since electrophoresis also requires particles to travel through viscous media, switching can take relatively long.

Summary of the invention

It is an object of the invention to create fast switching in-plane electrophoretic displays.

A first aspect of the invention provides an electro-osmotic display as claimed in claim 1. Advantageous embodiments are defined by the dependent claims.

To improve the relatively long switching, it is possible to use a slightly different principle, named electro-osmosis, where the particles don't travel through the stationary media, but rather travel together with the media. This creates liquid flow on a microscopic scale, that can transport absorbing particles onto and off a pixel electrode quickly and over relatively large distances. The layout of the electrode will then determine the accuracy and repeatability of the switching behaviour.

Electrophoretic particles show limited travel speeds through the suspending medium. In order to create fast switching in-plane electrophoretic displays, particles will need to move onto and off pixel areas fast, so preferably within tens of milliseconds. Since a typical pixel size is between 100 and 200 micrometer, particles must travel at a minimum speed of 10 micrometer per millisecond, or 10 millimeter per second. This is exceedingly high for electrophoretic motion. Typical electrophoretic displays move particles over a 30 micrometer distance in ~ 100 ms, translating to 0.3 mm per second. Electro-osmosis, however, can easily reach those speeds using liquid flowing together with the particles, unhindered by particle drag, and only overcoming the friction of the cell walls.

Electro-osmotic flow is not (or at least not intentionally) a naturally occurring phenomenon in electrophoretic displays. Current technology relies on transporting particles from one side of the display to the other (e.g. front to back), which will only work if the suspending liquid is stationary. Because of this, electrophoretic displays are what they are: Material parameters were optimized to advance electrophoretic motion, using relatively large particles in low viscosity liquids.

Transferring this optimization to in-plane electrophoretic systems is not easy, and will be limited by on one end the limited speed of electrophoretic particle motion, and on the other hand the impossibility of creating macroscopic flow. The main reason for this is incompressibility of liquids: it is impossible to create flow in opposite directions onto a pixel. Therefore if a system is created inducing flow, intending to move particles onto a pixel from opposite directions, a horizontal vortex will be created with a very small diameter (approximately the cell gap), limiting flow to the outer edges of the pixel only. No flow will occur in the pixel centre (see Fig. 1).

This problem must be overcome by tuning the pixel layout in such a way that vertical vortices are created, which are much larger (e.g. comparable to the pixel diameter) and allow liquid to freely flow onto and off the pixels. The layout of pixels can for example consist of a narrow "pumping area", which combines a small electrode distance with high field, and which exerts a high force upon the particles and therefore induces strong electro-osmotic flow, and a wider "escape area" next to it, which allows the liquid to leave the pixel again in the opposite direction. Other geometries are possible and may work just as well, as long as the "pumping" feature and "escape" feature are combined in each pixel.

In an electro-osmotic display in accordance with the first aspect of the invention the fluid itself carries a net charge and coloured particles suspended in the liquid also carry a charge, and both fluid and particles can be electrically controlled.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

Brief description of the drawings

In the drawings:

Fig. 1 shows a side view and a top view of a pixel in which the liquid flow is limited to the outer edges,

Fig. 2 shows a top view of pixels in which a fast liquid flow can be induced,

It should be noted that items which have the same reference numbers in different Figures, have the same structural features and the same functions, or are the same signals. Where the function and/or structure of such an item has been explained, there is no necessity for repeated explanation thereof in the detailed description.

Detailed description

Fig. 1 shows a side view SV and a top view TV of a pixel in which the liquid flow is limited to the outer edges. The electrode is referred to as El. HV indicates a horizontal vortex and the reference NF means "no flow" of liquid.

Fig. 2 shows a top view of pixels in which a fast liquid flow can be induced. The common grid or storage electrode is indicated by CG and the pixel electrode or field electrode by PE. The pumping area is referred to as PA, the release area as RA and the liquid flow is indicated by the arrows LF.

The electrode pattern is formed by applying a "common grid" or "common lines" (often referred to as "storage electrode") CG, with pixel electrodes (also called "field electrodes") PE placed in the "common grid" apertures or between the lines CG (see fig. 1). Each pixel consists of an area that constitutes the "pump area" PA, which is an area where a small gap between the "common grid" CG creates a high electric field.

This field exerts a force on the electro-osmotic fluid, inducing fast liquid flow. The liquid is then allowed to leave the pixel electrode again along the other edges of the display, where the pumping force is significantly smaller. To reach this mode of operation, the parameters of the electro-osmotic suspension need to conform to a certain set of parameters (not all these parameters are essential, some parameters are not critical at all):

- (apparent) Particle size
    - o Not critical but typically 10 nm – 500 nm, more typically 20 nm – 100 nm.
    - o Particles must form a stable suspension, this is easier to achieve with smaller particles.
    - o Particles should not adhere permanently to the electrode. This can be achieved by 'internal charging' of the particles, or by a sufficiently thick stabilizing layer. In any case the separation between the charge on the particle and the electrode should be provided with a steric barrier in order to avoid particle binding by image charging.

- Particle average charge and net charge while switching:

o Particle charge not critical. (typical 0.01e to 10e but governed by the build-up of surface charge).

o The surface electrode binds a percentage of the counter-ions (through mirror charges, covalently or otherwise.) 10k/um3 10e13e-/g 0.1C/m3 – 100C/m3 more typical 1-10C/m3.

o In case of a particle charge <<1e sufficient charge exchange between the particles should occur because otherwise part of the particles will remain uncharged on the relevant timescale of the device.

- Particle concentration

o Concentration should be low enough to store all particles on the "common" electrode at the maximum hold voltage. This creates a dependency on cell gap as well. The maximum number of particles per mm2 of electrode area.

o 30g/l for 10 um gap, the numbers are dependent on the gap.

- Cell gap

o Extinction times gap should be >95.

- Suspending liquid (dielectric, viscosity)

o Any low viscosity, low dielectric constant is suitable. Preferred is er< 4, more preferred < 3.

- Relation between pumping area and release area

o Relation adheres to formula: Wp/Lp > Wr,i/Lr,i wherein:

Wp is the total pump area width

Lp is the total pump area length

Wr,i is the sum of all release area contributions

Lr,i is the sum of all release area lengths.

- Pixel geometry

o The pixel area should be covered with two electrodes: a field electrode and a storage electrode.

o The field electrode must be transparent, to provide maximum aperture.

o The storage-electrode should be opaque. The storage electrode should preferably not exceed 20% of the total device area.

- Driving voltage and waveform

o The driving voltage is not critical, but should overcome electrostatic repulsion of the particles. Typically, 5V – 30V is used.

- Counter-ions

o The counter-ion species should be selected in a way to facilitate surface charge adsorption. Small diameter, inorganic species are preferred. High tendency to adsorb to ITO-surface is also preferred.

- Galvanic contact

o If there are excess counter ions which are not immobilized on the electrodes, it is desirable to make galvanic contact such that electron transfer can be achieved. This way screening by the counter ions can be minimized.

This invention can be applied in all displays using light modulation.

Embodiment 1: very high reflectance monochrome display. A display cell is created using a technology largely the same as LCD. The pixels are formed using the geometry described here. The cell is filled with a suspension according to the parameters mentioned here. A diffuse reflector is placed behind the display. The resulting display is connected to drive electronics as is known from e.g. electrophoretic displays. The resulting monochrome display can now display images with reflectance comparable to normal printed paper.

Embodiment 2: Multilayer color display. Starting from Embodiment 1, the display can be filled with colored particles. If these particles can be chosen to be primary colors, like Cyan, Magenta, Yellow, three of these displays can be stacked and yield a full color CMY display. Reflectance and saturation are better than can be achieved with present technologies.

Embodiment 3: Transflective display. The same system as in Embodiment 1 or 2 can be provided with a backlight behind the display. The transmitted light from the backlight will be modulated by the display stack. Because of the much higher transmittance,

the display requires much lower backlight power while achieving the same or better luminance.

The invention is directed to an electro-osmotic display where the fluid itself carries a net charge and coloured particles suspended in the liquid also carry a charge, and both fluid and particles can be electrically controlled to both move in a pixel to change an optical state of the pixel.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. An electro-osmotic display where the fluid itself carries a net charge and coloured particles suspended in the liquid also carry a charge, and both fluid and particles can be electrically controlled.

2. An electro-osmotic display as claimed in claim 1 where the coloured particles are smaller than 500 nm.

3. An electro-osmotic display as claimed in claim 1 where the coloured particles are smaller than 100 nm.

4. An electro-osmotic display as claimed in claim 2 or 3 having a pixel layout with vortices in the plane of the pixel and which vortices have dimensions in the order of a pixel diameter and which allow liquid to flow onto and off the pixels.

5. An electro-osmotic display as claimed in claim 2 or 3 wherein the layout of pixels comprises a narrow pumping area, which combines a small electrode distance with a high field, and which exerts a high force upon the particles and fluid, and therefore induces strong electroosmotic flow onto the pixel, and a wider escape area next to it, which allows the liquid to leave the pixel again in a different direction.

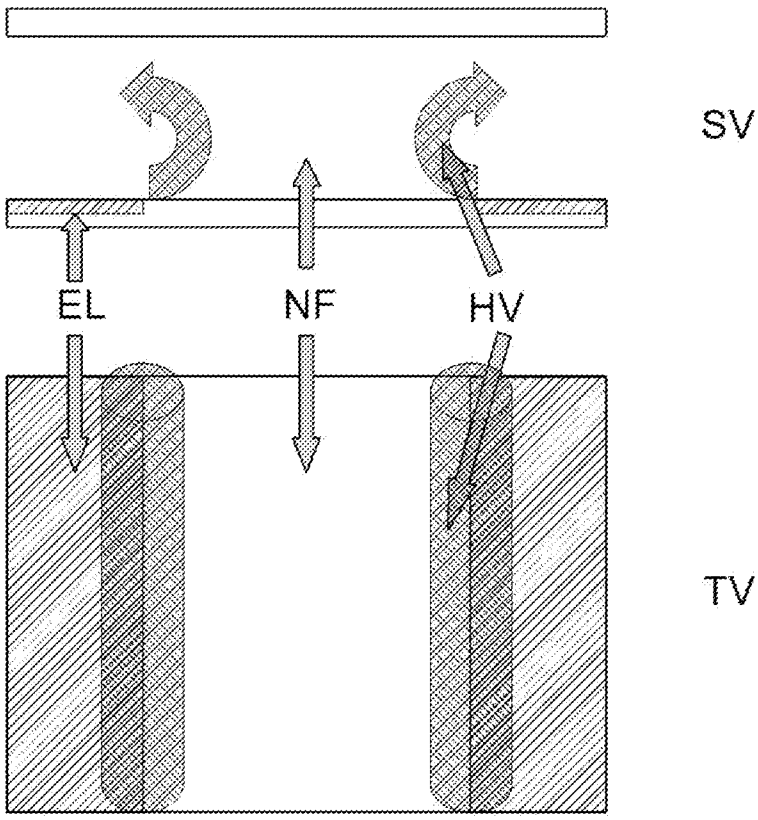


Fig. 1

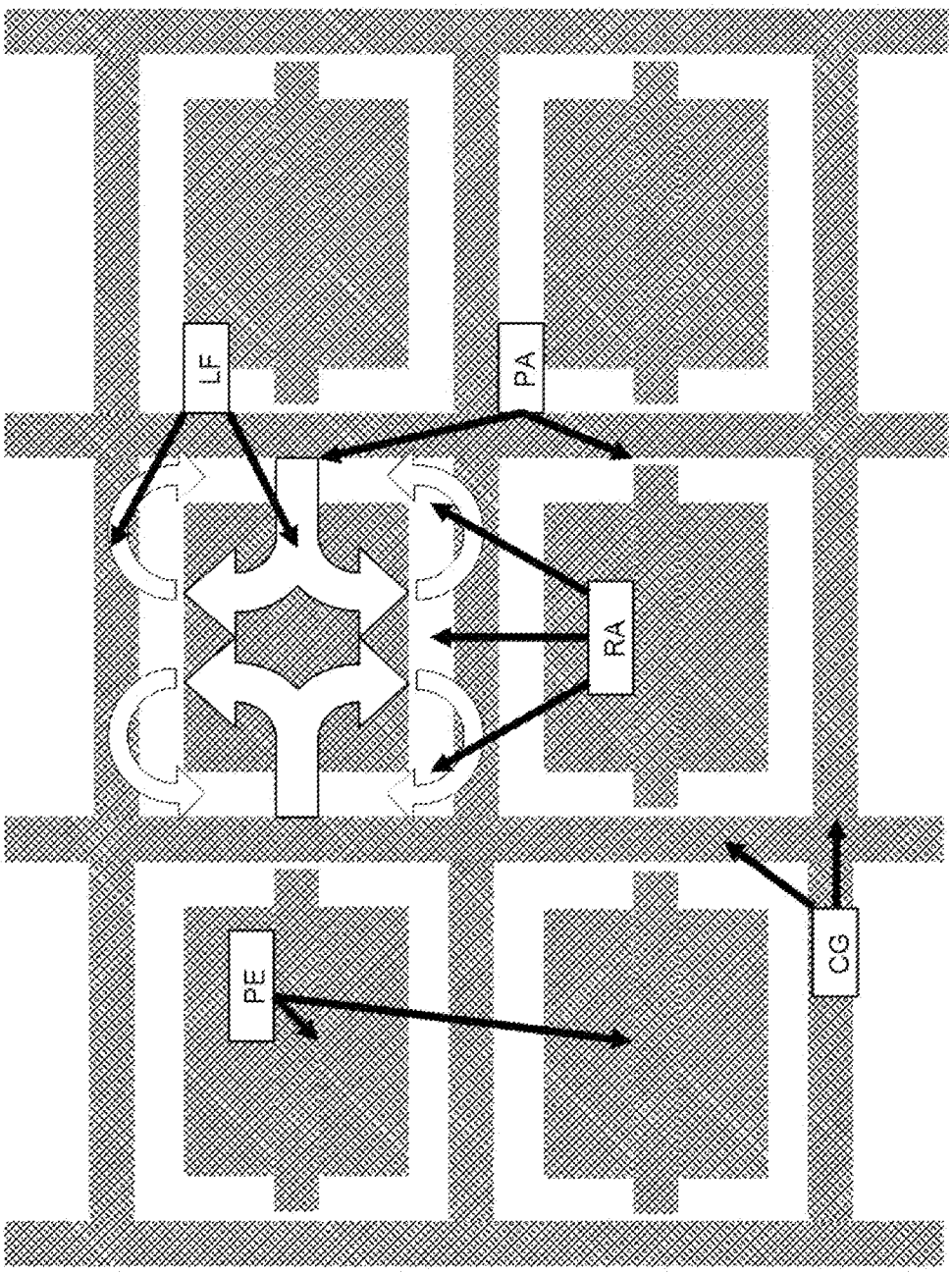


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/056266

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02F1/167
ADD. G02F1/1343

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/027762 A1 (COMISKEY BARRETT [CN] ET AL) 29 January 2009 (2009-01-29)	1-3
Y	abstract paragraphs [0066], [0067], [0121], [0122]	4,5

Y	WO 2010/015979 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; MUELLER MANFRED [NL]; STROEMER JA) 11 February 2010 (2010-02-11) abstract figure 13b page 11	4,5

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

☒ See patent family annex.

* Special categories of cited documents :

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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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
6 July 2011	15/07/2011

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	Sittler, Gilles

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2011/056266

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009027762 A1	29-01-2009	US 2010207073 A1	19-08-2010
WO 2010015979 A1	11-02-2010	EP 2321695 A1	18-05-2011