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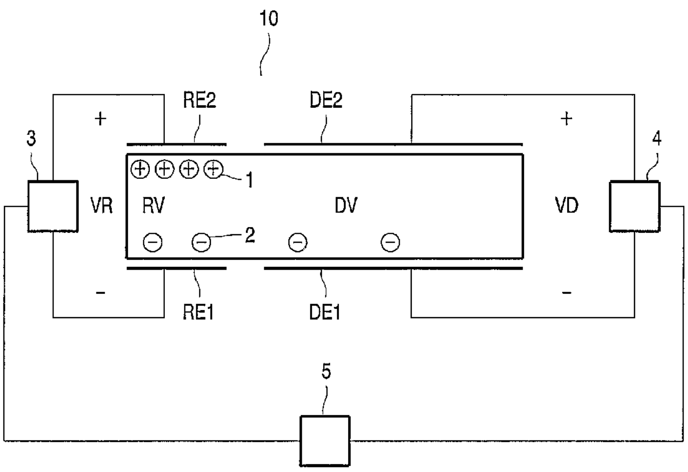
(54) Title: A COLOR ELECTROPHORETIC DISPLAY



(57) Abstract: A driver for an electrophoretic display with display cells (10) comprises first particles (1) and second particles (2) which have different optical properties and which are oppositely charged. A first reset electrode (REl) and a second reset electrode (RE2) are associated with a reservoir volume (RV). A first data electrode (DEl) and a second data electrode (DE2) are associated with a display volume (DV). A reset driver (3) supplies a reset voltage (VR) between the first reset electrode (REl) and the second reset electrode (RE2). A display driver (4) supplies a drive voltage (VD) between the first data electrode (DE1) and the second data electrode (DE2). A controller (5) controls the reset driver (3) and the display driver (4) to obtain the following sequence of states of the display cells (10): (i) a reset state wherein the first particles (1) and the second particles (2) are present in the reservoir volume (RV), (ii) a first fill state wherein the reset voltage (VR) has a first reset polarity to attract the first particles (1) to the first reset electrode (RE I) and the second particles (2) to the second reset electrode (RE2), and wherein the drive voltage (VD) has a first drive polarity and a level to attract the first particles (1) towards part of the display volume (DV) adjacent to the first data electrode (DEI), and to prevent the second particles (2) to move between the reservoir volume (RV) and the display volume (DV), (iii) a reversal state wherein the reset voltage (VR) has a second reset polarity opposite to the first reset polarity to attract the second particles (2) to the first reset electrode (REI) and the first particles (1) to the second reset electrode (RE2), and wherein the drive voltage (DV) has a second drive polarity opposite to the first drive polarity and a level for preventing movement of the first particles (1) and the second particles (2) between the reset volume (RV) and the display volume (DV), and (iv) a second fill state wherein the reset voltage (VR) has the second reset polarity, and wherein the drive voltage (VB) has the second drive polarity and a level to attract the second particles (2) towards the display volume (DV) adjacent to the first data electrode (DE I), and to prevent the first particles (1) to move between the reservoir volume (RV) and the display volume (DV).

WO 2006/016301 A1

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A color electrophoretic display

The invention relates to a driver for an electrophoretic display, the electrophoretic display, a display apparatus comprising the electrophoretic display, and a method of driving the electrophoretic display.

The non-pre-published European patent application in accordance to applicants docket referred to as PHNL031253 which has been filed as European patent application 03103915.9 discloses a color electrophoretic display. In this display, each pixel comprises at least two sub-pixels, and each sub-pixel is provided with a color filter and contains an electrophoretic media comprising two oppositely charged particle types. According to a particular embodiment, each pixel comprises three sub-pixels having a cyan, magenta, and yellow absorbing filter, respectively.

A single sub-pixel comprises two reservoirs, one for each particle species, separated by a visible pixel volume. The reservoirs comprise data electrodes, a reset electrode for negatively charged particles, and a reset electrode for positively charged particles. The data electrodes may be connected via thin film transistors (TFT's) to data drivers in an active matrix, while the reset electrodes may be common electrodes for a plurality of pixels or even for the entire display. A black matrix covers the reservoirs to hide them for the viewer. The pixel further comprises a white reflective background. Barriers forming sub-pixel walls may separate the sub-pixels from each other. Optionally, the brightness of this reflective display could be enhanced by using a front light assembly. In an alternative embodiment, the inventive display is transmissive, instead of white reflectors, the display is fitted with a backlight which comprises, for example, a light guide and a light source.

The sub-pixels are filled with the corresponding electrophoretic solutions, which comprise the correctly colored and charged particles, into individual sub-pixel areas, each of which is surrounded by a pixel wall structure. The perceived color of the pixel is determined by the number of visible particles of each color type which are present in each sub-pixel volume. If no particles are present, the sub-pixel takes the color of its color filter. If all particles are present, the sub-pixel becomes black. Other colors are achieved by providing intermediate numbers of the respective particles.

A first aspect of the invention provides a driver for an electrophoretic display as claimed in claim 1. A second aspect of the invention provides an electrophoretic display as claimed in claim 2. A third aspect of the invention provides a display apparatus comprising the electrophoretic display as claimed in claim 8. A fourth aspect of the invention provides a method of driving the electrophoretic display as claimed in claim 9. Advantageous embodiments are defined in the dependent claims.

The electrophoretic display in accordance with the second aspect of the invention comprises display cells which each comprise first particles and second particles having different optical properties and being oppositely charged. A first reset electrode and a second reset electrode are associated with a reservoir volume. A first data electrode and a second data electrode are associated with a display volume which is adjacent to the reservoir volume. A reset driver supplies a reset voltage between the first reset electrode and the second reset electrode. A display driver supplies a drive voltage between the first data electrode and the second data electrode.

A controller controls the reset driver and the display driver to obtain the following sequence of states of the display cells:

(i) a reset state wherein both the first particles and the second particles are present in the reservoir volume. The voltage on the first data electrode, the second data electrode, the first reset electrode and the second reset electrode are selected such that the particles stay in the reservoir volume. For example, after the particles are attracted into the reservoir volume, identical voltages are supplied to all the electrodes.

(ii) a first fill state wherein the reset voltage has a first polarity, further referred to as the first reset polarity, to attract the first particles to the first reset electrode and the second particles to the second reset electrode. The drive voltage has a first polarity, further referred to as the first drive polarity. The drive voltage has a level with respect to the reset voltage to attract the first particles towards part of the display volume adjacent to the first data electrode, and to prevent the second particles to move between the reservoir volume and the display volume.

(iii) a reversal state wherein the reset voltage has a second reset polarity opposite to the first reset polarity to attract the second particles to the first reset electrode and the first particles to the second reset electrode, and wherein the drive voltage has a second drive polarity opposite to the first drive polarity and a level for preventing movement of the first particles and the second particles between the reset volume and the display volume, and

(iv) a second fill state wherein the reset voltage has the second reset polarity, and wherein the drive voltage has the second drive polarity and a level to attract the second particles towards the display volume adjacent to the first data electrode and to prevent the first particles to move between the reservoir volume and the display volume.

During the fill states, the amount of particles which move from the reservoir volume to the display volume depends on both the voltage difference between the second reset electrode and the second data electrode and the time this voltage difference is present.

The present invention differs from the non-pre-published prior art in that the positive and negative particles are present in a single reservoir volume, in that the data electrodes are associated with the display volume which is adjacent to the reservoir volume and in that a polarity reversal drive is used. This results in a more efficient display because less space is required by the single reservoir volume.

In an embodiment as claimed in claim 4, the group of display cells which is associated with the interconnected first reset electrodes, the second reset electrodes, and the second data electrodes, respectively, only require, per display cell, individual driving of the first data electrode. Thus only a single drive transistor, usually a TFT (Thin Film Transistor), which is coupled to the first data electrode, is required for each display cell. In the non-pre-published European patent application PHNL031253 two drive transistors are required per display cell.

In an embodiment as claimed in claim 5, the reservoir volume and the display volume are arranged in line. Now, the particles can move efficiently in a short path between the reservoir volume and the display volume.

In the embodiments as claimed in claims 6 or 7, the display cells further comprise help electrodes which facilitate the movement of the particles between the reservoir volume and the display volume and/or in the display volume.

In an embodiment as claimed in claim 10, in the reset state, the positive charged particles are attracted towards the second reset electrode and the negative charged particles are attracted towards the first reset electrode. The positive voltage on the first reset electrodes keeps the negative particles in the reservoir volume. There is no electrical field which allows the positive particles to leave the reservoir volume.

During the first fill state, the voltages on the first reset electrode, the second reset electrode and the second data electrode are not changed, only the voltage on the first data electrode is changed. The negative particles near the first reset electrode are attracted towards the display volume near the first data electrode due to the voltage on the first data electrode which is more positive than the voltage on the first reset electrode. The positive particles do not move between the reservoir volume and the display volume because there is no voltage difference between the second reset electrode and the second data electrode.

During the reversal state, the voltage on the second reset electrode and the second data electrode are not changed. The voltage on the first reset electrode and the first data electrode both get the same negative voltage. In the reservoir volume, the positive particles are attracted towards the first reset electrode and the negative particles are attracted towards the second reset electrode and thus swap position. In the display volume, the negative particles move from the first data electrode to the second data electrode. As now no voltage difference exists between the second reset electrode and the second data electrode, and between the first reset electrode and the first data electrode, both the positive and negative particles will not move between the reservoir volume and the display volume.

During the second fill state, the voltages on the first reset electrode, the second reset electrode and the second data electrode are not changed, the voltage on the first data electrode is now made more negative than the voltage on the first reset electrode and the positive particles move from the reservoir volume to the display volume. The negative particles will not move between the reservoir volume and the display volume because the voltage between the second reset electrode and the second data electrode is zero.

It has to be noted that, in all states, the voltages on the first reset electrode, the second reset electrode, and the second data electrode can be identical for all display cells. The amount of particles which move between the reservoir volume and the display volume during the first and the second fill states only depend on the voltage on the first data electrode (and the duration this voltage is present). It thus suffices to control only the first data electrode of each pixel separately, and thus only one TFT per display cell is required.

In an embodiment as claimed in claim 11, in a similar manner, during the first fill period the positive particles are moved between the reservoir volume and the display volume and than, after the polarity reversal, during the second fill period the negative particles are moved between the reservoir volume and the display volume.

In an embodiment as claimed in claim 12, the drive methods as claimed in claim 10 and 11 alternate to obtain a DC-balanced driving.

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

In the drawings:

Fig. 1 shows schematically a cross-section of a display cell, and its driver,

Fig. 2 shows schematically an electrophoretic display comprising multiple display cells,

Figs. 3A- 3E show schematically an embodiment of the voltages on the electrodes of the display cell to obtain the different optical states of the display cell,

Figs. 4A – 4E show schematically another embodiment of the voltages on the electrodes of the display cell to obtain the different optical states of the display cell,

Figs. 5A – 5B show schematically an embodiment of a display cell which comprises help electrodes, and

Fig. 6 shows an embodiment of an electrode configuration on the bottom substrate of the display cell.

Fig. 1 shows schematically a cross-section of a display cell, and its driver. The display cell 10 comprises a reservoir volume RV and a display volume DV. The reservoir volume RV is present between an opposing first reset electrode RE1 and a second reset electrode RE2. The display volume DV is present between an opposing first data electrode DE1 and a second data electrode DE2. A reset driver 3 supplies a reset voltage VR between the first reset electrode RE1 and the second reset electrode RE2. The data driver 4 supplies a data voltage VD between the first data electrode DE1 and the second data electrode DE2. A controller 5 controls the reset driver 3 and the data driver 4 to supply the reset voltage VR and the data voltage VD with the desired voltage levels during the desired periods in time to change the optical state of the display cell 10. The number of particles 1 and 2 present in the reservoir volume RV has either a minor or no influence on the color of the display cell 10. Preferably, the reservoir volume RV is shielded from the viewer. The number of particles 1 and 2 present in the display volume DV determines the perceived color of the display cell 10.

The optical state of the display cell 10 is determined by the distribution of the particles 1 and 2 which are oppositely charged and have different optical properties. For example, the particles 1 may be positively charged and the particles 2 may be negatively charged as shown in Fig. 1. For example, the positively charged particles 1 may absorb red light and the negatively charged particles 2 may absorb green light. If no particles are present in the display cell 10 the light impinging on the display cell 10 may pass the cell or may be reflected by a reflector at the side of the cell opposite to the side where the light impinges. A color filter (not shown) may be present to filter the light, either in the form of a color filter element, or alternatively incorporated into the display cell in the form of a colored liquid or a colored reflector.

If no color filter is present and cyan particles 1 are present in the display volume DV of the cell 10, all, or part of the red light is absorbed and cyan light will be transmitted or reflected. If in addition a yellow filter is present, and the blue light is absorbed by the filter, only green light will be transmitted or reflected. If only the negative magenta particles 2 are present in the display volume DV of the cell 10 and a yellow filter is present, the green light is absorbed by the negative particles and only the red light will be transmitted or reflected. If the yellow filter is used and both particles 1 and 2 are in the display volume DV of the cell 10 both the red and green light is absorbed and no light will be able transmitted or reflected. Many alternatives are possible, for example, the color of the filter and the particles may be selected differently, or the particles may reflect or scatter light which has a specific color.

Embodiments of operation of the display cell 10 will be elucidated with respect to Figs. 3A – 3E and 4A – 4E.

Fig. 2 shows schematically an electrophoretic display 100 comprising multiple display cells 10. Preferably, as shown, the display cells 10 are arranged in a matrix as well known in the art. The processing circuit 101 receives a data signal RVS and supplies a display video signal DVS suitable for the display 100. The received data signal RVS may be an analog or digital signal, the display video signal DVS is a digital signal which is fed to the controller 5 (shown in Figs. 5A – 5B) to control the reset driver 3 and the data driver 4 to obtain an optical state of the display cells 10 for representing the image(s) of the data signal RVS.

Figs. 3A – 3E show schematically an embodiment of the voltages on the electrodes of the display cell to obtain the different optical states of the display cell. The same items as in Fig. 1 have the same references. A black mask BM is added to shield the reset volume RV from the viewer.

Fig. 3A shows the first part of the reset state wherein the voltage on the first reset electrode RE1, the first data electrode DE1, and the second data electrode DE2 are 0V, and the voltage on the second reset electrode RE2 is -10V. The positive particles 1 are attracted towards the second reset electrode RE2 by the negative voltage -10V on the second reset electrode RE2. The negative particles 2 will stay in the display volume DV because no electric field exists which attracts these particles 2 towards the reset volume RV. The voltages applied to the electrodes may deviate from the voltages shown. What counts is that an electric field is generated which attracts the positive particles 1 towards the reset volume RV and which leaves the negative particles 2 in the display volume DV. For example, the voltage on the first reset electrode RE1 may be negative with respect to the first data electrode DE1, or the second data electrode DE2 may be negative with respect to the first data electrode DE1.

Fig. 3B shows the second part of the reset state wherein the voltage on the second reset electrode RE2, the first data electrode DE1, and the second data electrode DE2 are 0V, and the voltage on the first reset electrode RE1 is +10V. The negative particles 2 are attracted towards the first reset electrode RE1 by the positive voltage +10V on the first reset electrode RE1. The positive particles 1 will stay in the reset volume RV because no electric field exists which attracts these particles 1 towards the display volume DV. Again, the voltages applied to the electrodes may deviate from the voltages shown. What counts is that an electric field is generated which attracts the negative particles 2 towards the reset volume RV and which leaves the positive particles 1 in the reset volume RV. For example, the voltage on the second data electrode DE2 may be positive with respect to the first data electrode DE1 but should be less positive than the voltage +10V on the first reset electrode RE1.

Fig. 3C shows the first part of the fill state during which only the negative particles 2 are moved from the reset volume RV to the display volume DV. Now, the voltage on the first data electrode DE1 should be positive with respect to the first reset electrode RE1 to attract the negative particles 2 towards the display volume DV. The voltage on the second reset electrode RE2 and the second data electrode DE2 should be selected such that the positive particles 1 stay in the reset volume RV and the movement of the negative particles 2 towards the display volume DV is possible. In the example shown, the voltage on the first reset electrode RE1 is +10V, the voltage on the first data electrode is +20V, and the voltages on the second reset electrode RE2 and the second data electrode DE2 are 0V.

Fig. 3D shows the top-bottom reversal state during which the position of the positive particles 1 and the negative particles 2 is reversed. Now, the voltages on the electrodes are changed such that in the reset volume RV the positive particles 1 are moved from the second reset electrode RE2 towards the first reset electrode RE1. Thus, the voltage on the first reset electrode RE1 should become negative with respect to the voltage on the second reset electrode RE2. Consequently, the negative particles 2 in the reset volume RV will move from the first reset electrode RE1 towards the second reset electrode RE2. Further, the negative particles 2 are moved in the display volume DV from the first data electrode DE1 towards the second data electrode DE2 because the voltage on the first data electrode DE1 is negative with respect to the voltage on the second data electrode DE2. The voltages on the data electrodes DE1, DE2 have to be selected with respect to the voltages on the reset electrodes RE1, RE2 such that the particles 1, 2 do not move between the reset volume RV and the display volume DV. In the example shown, the first reset voltage RE1 and the first data voltage DE1 both are -10V and the second reset voltage RE2 and the second data voltage DE2 both are 0V.

Fig. 3E shows the second part of the fill state during which only the positive particles 1 are moved from the reset volume RV to the display volume DV. Now, the voltage on the first data electrode DE1 should be negative with respect to the first reset electrode RE1 to attract the positive particles 1 towards the display volume DV. The voltage on the second reset electrode RE2 and the second data electrode DE2 should be selected such that the negative particles 2 do not move between the reset volume RV and the display volume DV, and such that the movement of the positive particles 1 towards the display volume DV is possible. In the example shown, the voltage on the first reset electrode RE1 is -10V, the voltage on the first data electrode is -15V, and the voltages on the second reset electrode RE2 and the second data electrode DE2 are 0V.

Figs. 4A – 4E show schematically another embodiment of the voltages on the electrodes of the display cell to obtain the different optical states of the display cell. In fact, Figs. 4A – 4E are very similar to Figs. 3A – 3E, only the position of the particles 1, 2 is swapped at the starting situation shown in Fig. 4A with respect to the situation shown in Fig. 3A. The same items in Figs. 4A – 4E as in Figs. 3A – 3E have the same function.

Fig. 4A shows the first part of the reset state wherein the voltage on the first reset electrode RE1, the first data electrode DE1, and the second data electrode DE2 are 0V, and the voltage on the second reset electrode RE2 is +10V. The negative particles 2 are attracted towards the second reset electrode RE2 by the positive voltage +10V on the second reset electrode RE2. The positive particles 1 will stay in the display volume DV because no electric field exists which attracts these particles 1 towards the reset volume RV. The voltages applied to the electrodes may deviate from the voltages shown. What counts is that an electric field is generated which attracts the negative particles 2 towards the reset volume RV and which leaves the positive particles 1 in the display volume DV. For example, the voltage on the first reset electrode RE1 may be positive with respect to the first data electrode DE1, or the second data electrode DE2 may be positive with respect to the first data electrode DE1.

Fig. 4B shows the second part of the reset state wherein the voltage on the second reset electrode RE2, the first data electrode DE1, and the second data electrode DE2 are 0V, and the voltage on the first reset electrode RE1 is -10V. The positive particles 1 are attracted towards the first reset electrode RE1 by the negative voltage -10V on the first reset electrode RE1. The negative particles 2 will stay in the reset volume RV because no electric field exists which attracts these particles 2 towards the display volume DV. Again, the voltages applied to the electrodes may deviate from the voltages shown. What counts is that an electric field is generated which attracts the positive particles 1 towards the reset volume RV and which leaves the negative particles 2 in the reset volume RV. For example, the voltage on the second data electrode DE2 may be negative with respect to the first data electrode DE1 but should be less negative than the voltage -10V on the first reset electrode RE1.

Fig. 4C shows the first part of the fill state during which only the positive particles 1 are moved from the reset volume RV to the display volume DV. Now, the voltage on the first data electrode DE1 should be negative with respect to the first reset electrode RE1 to attract the positive particles 1 towards the display volume DV. The voltage on the second reset electrode RE2 and the second data electrode DE2 should be selected such that the negative particles 2 stay in the reset volume RV and the movement of the positive particles 1 towards the display volume DV is possible. In the example shown, the voltage on the first reset electrode RE1 is -10V, the voltage on the first data electrode is -15V, and the voltages on the second reset electrode RE2 and the second data electrode DE2 are 0V.

Fig. 4D shows the top-bottom reversal state during which the position of the positive particles 1 and the negative particles 2 is reversed. Now, the voltages on the electrodes are changed such that in the reset volume RV the negative particles 2 are moved from the second reset electrode RE2 towards the first reset electrode RE1. Thus, the voltage on the first reset electrode RE1 should become positive with respect to the voltage on the second reset electrode RE2. Consequently, the positive particles 1 in the reset volume RV will move from the first reset electrode RE1 towards the second reset electrode RE2. Further, the positive particles 1 are moved in the display volume DV from the first data electrode DE1 towards the second data electrode DE2 because the voltage on the first data electrode DE1 is positive with respect to the voltage on the second data electrode DE2. The voltages on the data electrodes DE1, DE2 have to be selected with respect to the voltages on the reset electrodes RE1, RE2 such that the particles 1, 2 do not move between the reset volume RV and the display volume DV. In the example shown, the first reset voltage RE1 and the first data voltage DE1 both are +10V and the second reset voltage RE2 and the second data voltage DE2 both are 0V.

Fig. 4E shows the second part of the fill state during which only the negative particles 2 are moved from the reset volume RV to the display volume DV. Now, the voltage on the first data electrode DE1 should be positive with respect to the first reset electrode RE1 to attract the negative particles 2 towards the display volume DV. The voltage on the second reset electrode RE2 and the second data electrode DE2 should be selected such that the positive particles 1 do not move between the reset volume RV and the display volume DV, and such that the movement of the negative particles 2 towards the display volume DV is possible. In the example shown, the voltage on the first reset electrode RE1 is +10V, the voltage on the first data electrode is +20V, and the voltages on the second reset electrode RE2 and the second data electrode DE2 are 0V.

In a further embodiment, it is possible to alternate the approaches illustrated in figures 3 and 4 for successive image updates. In this manner, the electrode voltages become substantially DC balanced, whereby artifacts such as image retention will be reduced.

Figs. 5A – 5B show schematically an embodiment of a display cell which comprises help electrodes. Both the display cells shown in Fig. 5A and 5B comprise a color filter CF, either in the form of a color filter element, or alternatively incorporated into the display cell in the form of a colored liquid or a colored reflector, a black mask BM, a first reset electrode RE1, a first data electrode DE1, a second reset electrode RE2, a second data electrode DE2, a help electrode E1, a help electrode E2, and a pixel volume which comprises a reservoir volume RV and a display volume DV and positive and negative particles 1, 2. By way of example, the pixel volume has a rectangular cross-section. The second reset electrode RE2 and the second data electrode DE2 are arranged between the color filter CF and the pixel volume. The black mask BM is arranged between the color filter CF and the second reset electrode RE2 to shield the reservoir volume from the viewer. The viewer sees the display volume DV through the color filter CF. The optical state of the display cell depends on the amount of positive and negative particles 1, 2 in the display volume DV. The first reset electrode RE1 is positioned opposite to the second reset electrode RE2, the reset volume RV is present between the first and the second reset electrodes RE1 and RE2. The first data electrode DE1 is positioned opposite to the second data electrode DE2, the display volume DV is present between the first and the second data electrodes DE1 and DE2. The help electrode E1 is arranged between the first reset electrode RE1 and the first data electrode DE1. The help electrode E2 is arranged such that the first data electrode DE1 is arranged in-between the help electrodes E1 and E2.

By controlling the voltage on the help electrodes E1 and E2, the particles 1, 2 can be moved through the display volume DV, as is shown, by way of example, for the negative particles in Fig. 5A. The movement of the negative particles 2 is obtained by applying a positive voltage between the help electrode E1 and the first reset electrode RE1, and a positive voltage between the help electrode E2 and the help electrode E1. In the example shown in Fig. 5A, the voltage on the first reset electrode RE1 is +10V, the voltage on the help electrode E1 is +12V and the voltage on the help electrode E2 is +20V. Of course, the voltages should be adapted if the positive particles 1 have to be moved through the display volume DV. Particles that are not needed in the display volume DV can be returned to the reservoir volume RV by a suitable voltage on the help electrode E1. It is also possible to prevent particles in the display volume to move back to the reservoir volume.

In the example shown in Fig. 5B, wherein the negative particles 2 are prevented to move back in the reservoir volume RV, the voltage on the help electrode E1 should have both a lower level than the voltage on the first reset electrode RE1, and than the voltage on the first data electrode DE1. Preferably, if the help electrode E2 is present, it has the same voltage level as the first data electrode DE1. In the example shown in Fig. 5B, the voltage on the first reset electrode RE1 is +10V, the voltage on the help electrode E1 is +5V and the voltage on both the first data electrode DE1 and the help electrode E2 is +20V.

Similar effects can be reached if only one of the help electrodes E1 or E2 is present.

Fig. 6 shows an embodiment of an electrode configuration on the bottom substrate of the display cell. The square help electrode E2 is positioned at the center of the display cell 10. The help electrode E2 may have any other shape. The geometrical center of the help electrode need not coincident with the geometric center of the display cell 10. The first data electrode DE1 surrounds the help electrode E2. The help electrode E1 surrounds the first data electrode DE1, and the first reset electrode RE1 surrounds the help electrode E1.

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.

For example, it is possible to make a stack of two or more of the cells 1 shown. For example a complete cell may comprise two cells 1 shown. At least one of the particles in the extra cell should have an optical property different than the optical properties of the particles in the other cell. Alternatively, it is possible to stack one cell which is identical to the cell 1 shown in the Figs. 1, 3A – 3E , 4A – 4E or 5A – 5B with another cell which may contain a single type of particles which single type has an optical property which is different from the optical properties of the two particles types present in the cell 1. This single particle cell may be controlled in a same manner as the known single particle cells with separate electrodes which are shielded from the electrodes of the cell 1. Alternatively, the bottom electrodes of the single particle cell may be combined with the top electrodes of the cell1.

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. A driver for an electrophoretic display with display cells (10) comprising first particles (1) and second particles (2) having different optical properties and being oppositely charged, a first reset electrode (RE1) and a second reset electrode (RE2) being associated with a reservoir volume (RV), a first data electrode (DE1) and a second data electrode (DE2) being associated with a display volume (DV), the driver comprises

a reset driver (3) for supplying a reset voltage (VR) between the first reset electrode (RE1) and the second reset electrode (RE2), a display driver (4) for supplying a drive voltage (VD) between the first data electrode (DE1) and the second data electrode (DE2), and a controller (5) for controlling the reset driver (3) and the display driver (4) to obtain the following sequence of states of the display cells (10):

(i) a reset state wherein the first particles (1) and the second particles (2) are present in the reservoir volume (RV),

(ii) a first fill state wherein the reset voltage (VR) has a first reset polarity to attract the first particles (1) to the first reset electrode (RE1) and the second particles (2) to the second reset electrode (RE2), and wherein the drive voltage (VD) has a first drive polarity and a level to attract the first particles (1) towards part of the display volume (DV) adjacent to the first data electrode (DE1), and to prevent the second particles (2) to move between the reservoir volume (RV) and the display volume (DV),

(iii) a reversal state wherein the reset voltage (VR) has a second reset polarity opposite to the first reset polarity to attract the second particles (2) to the first reset electrode (RE1) and the first particles (1) to the second reset electrode (RE2), and wherein the drive voltage (DV) has a second drive polarity opposite to the first drive polarity and a level for preventing movement of the first particles (1) and the second particles (2) between the reset volume (RV) and the display volume (DV), and

(iv) a second fill state wherein the reset voltage (VR) has the second reset polarity, and wherein the drive voltage (VB) has the second drive polarity and a level to attract the second particles (2) towards the display volume (DV) adjacent to the first data electrode (DE1), and to prevent the first particles (1) to move between the reservoir volume (RV) and the display volume (DV).

2. An electrophoretic display (100) comprising

a display cell (10) comprising first particles (1) and second particles (2) having different optical properties and being oppositely charged, a first reset electrode (RE1) and a second reset electrode (RE2) being associated with a reservoir volume (RV), a first data electrode (DE1) and a second data electrode (DE2) being associated with a display volume (DV), and

the driver as claimed in claim 1.

3. An electrophoretic display as claimed in claim 2, wherein the second data electrodes (DE2), the first reset electrodes (RE1) and the second reset electrodes (RE2) are interconnected in respective groups to form a common second data electrode, a common first reset electrode, and a common second reset electrode, respectively, for at least one group of display cells (10).

4. An electrophoretic display as claimed in claim 3, further comprising electronic switching elements, a single one for each display cell (10) being connected to the first data electrode (DE1) of the associated one of the display cells (10).

5. An electrophoretic display as claimed in claim 2, wherein the first reset electrode (RE1) and the first data electrode (DE1) are arranged in line, the second reset electrode (RE2) and the second data electrode (DE2) are arranged in line, the first data electrode (DE1) is arranged opposite the second data electrode (DE2), and the first reset electrode (RE1) is arranged opposite the second reset electrode (RE2).

6. An electrophoretic display as claimed in claim 2, wherein the display cells (10) comprise a first help electrode (HE1) being arranged between the first reset electrode and the first data electrode (DE1) for facilitating (i) movement of the particles in the display volume (DV), and/or (ii) movement of particles from the display volume (DV) to the reservoir volume (RV).

7. An electrophoretic display as claimed in claim 2, wherein the display cells (10) comprise a second help electrode (HE2) being arranged adjacent the first data electrode (DE1) for facilitating movement of the particles in the display volume (DV), wherein the first

data electrode (DE1) is arranged in-between the first reset electrode and the second help electrode (HE2).

8. A display apparatus comprising

the electrophoretic display (100) as claimed in claim 2, and

processing circuitry (101) to process a received video signal (RVS) into a display video signal (DVS) to be displayed on said display (100).

9. A method of driving an electrophoretic display with display cells (10) comprising first particles (1) and second particles (2) having different optical properties and being oppositely charged, and a first reset electrode (RE1) and a second reset electrode (RE2) being associated with a reservoir volume (RV), a first data electrode (DE1) and a second data electrode (DE2) being associated with a display volume (DV), the method comprising

supplying (3) a reset voltage (VR) between the first reset electrode (RE1) and the second reset electrode (RE2) and supplying (4) a drive voltage (VD) between the first data electrode (DE1) and the second data electrode (DE2) to obtain the following sequence of states of the display cells (10):

(i) a reset state wherein the first particles (1) and the second particles (2) are present in the reservoir volume (RV),

(ii) a first fill state wherein the reset voltage (VR) has a first reset polarity to attract the first particles (1) to the first reset electrode (RE1) and the second particles (2) to the second reset electrode (RE2), and wherein the drive voltage (VD) has a first drive polarity and a level to attract the first particles (1) towards part of the display volume (DV) adjacent to the first data electrode (DE1), and to prevent the second particles (2) to move between the reservoir volume (RV) and the display volume (DV),

(iii) a reversal state wherein the reset voltage (VR) has a second reset polarity opposite to the first reset polarity to attract the second particles (2) to the first reset electrode (RE1) and the first particles (1) to the second reset electrode (RE2), and wherein the drive voltage (VD) has a second drive polarity opposite to the first drive polarity and a level for preventing movement of the first particles (1) and the second particles (2) between the reset volume (RV) and the display volume (DV), and

(iv) a second fill state wherein the reset voltage (VR) has the second reset polarity, and wherein the drive voltage (VD) has the second drive polarity and a level to attract the second particles (2) towards the display volume (DV) adjacent to the first data electrode (DE1), and to prevent the first particles (1) to move between the reservoir volume (RV) and the display volume (DV).

10. A method of driving an electrophoretic display as claimed in claim 9, comprising:

(i) supplying (3, 4), during the reset state, a substantially same first voltage level (0V) to the second reset electrode (RE2), the first data electrode (DE1) and the second data electrode (DE2), and a second voltage level (+10V) being more positive than the first reset electrode (RE2),

(ii) supplying (3, 4), during the first fill state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), the second voltage level (+10V) to the first reset electrode (RE1), a third voltage level (+20V) being more positive than the second voltage level (+10V) to the first data electrode (DE1),

(iii) supplying, during the reversal state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), and a substantially identical fourth voltage level (-10V) being negative to the first reset electrode (RE1) and the first data electrode (DE1),

(iv) supplying, during the second fill state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), the fourth voltage level (-10V) to the first reset electrode, a fifth voltage level (-15V) being more negative than the fourth voltage level (-10V) to the first data electrode (DE1).

11. A method of driving an electrophoretic display as claimed in claim 9, comprising:

(i) supplying (3, 4), during the reset state, a substantially same first voltage level (0V) to the second reset electrode (RE2), the first data electrode (DE1) and the second data electrode (DE2), and a second voltage level (-10V) being more negative to the first reset electrode (RE1),

(ii) supplying (3, 4), during the first fill state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), the second voltage level (-10V) to the first reset electrode (RE1), a third voltage level (-15V) being more negative than the second voltage level (-10V) to the first data electrode (DE1),

(iii) supplying (3, 4), during the reversal state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), and a fourth substantially identical voltage level (+10V) being positive to the first reset electrode (RE1) and the first data electrode (DE1),

(iv) supplying (3, 4), during the second fill state, the first voltage level (0V) to the second reset electrode (RE2) and the second data electrode (DE2), the fourth voltage level (+10V) to the first reset electrode (RE1), a fifth voltage level (+20V) being more positive than the fourth voltage level (+10V) to the first data electrode (DE1).

12. A method of driving an electrophoretic display as claimed in claim 10 and 11, wherein the method of driving the electrophoretic display as claimed in claim 10 alternates with the method of driving the electrophoretic display as claimed in claim 11.

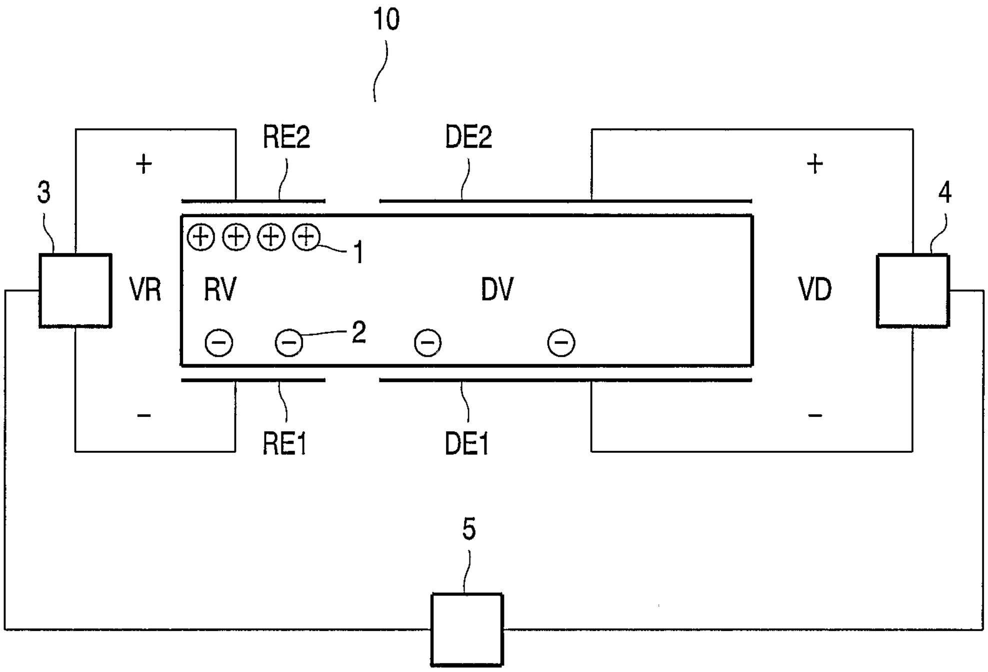

FIG. 1

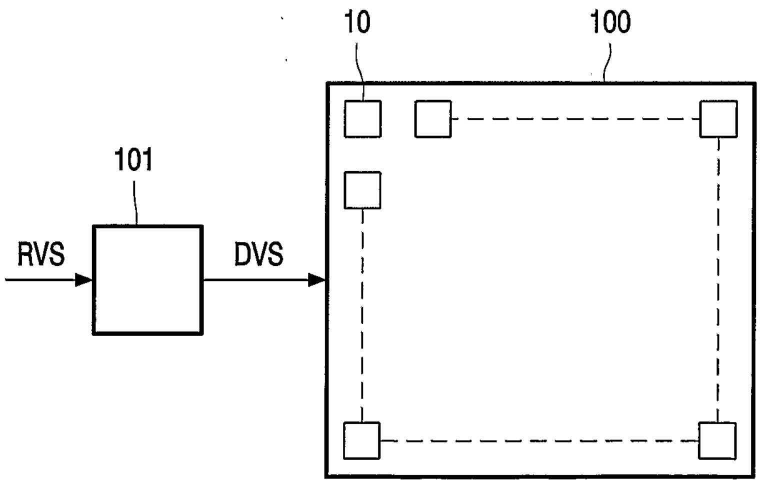

FIG. 2

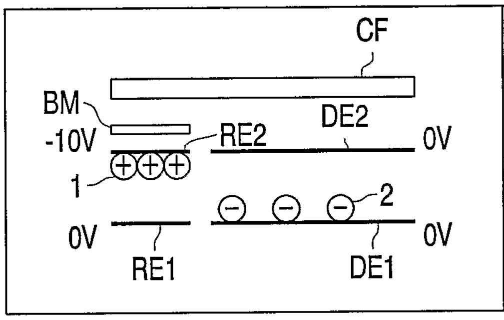

FIG. 3A

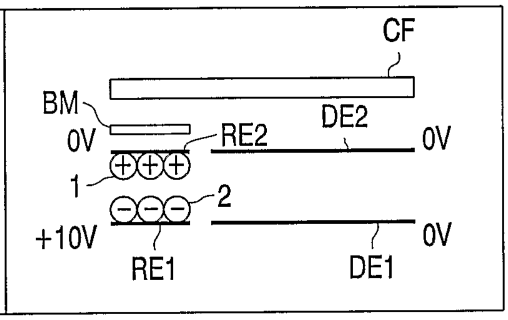

FIG. 3B

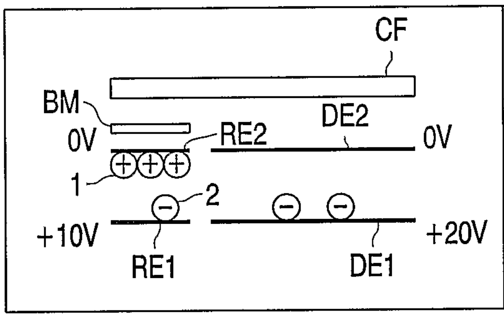

FIG. 3C

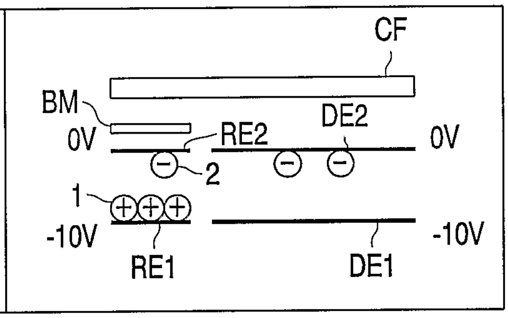

FIG. 3D

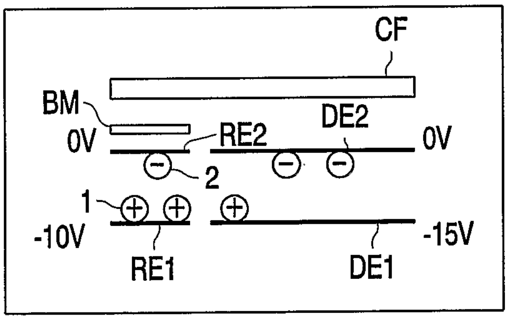

FIG. 3E

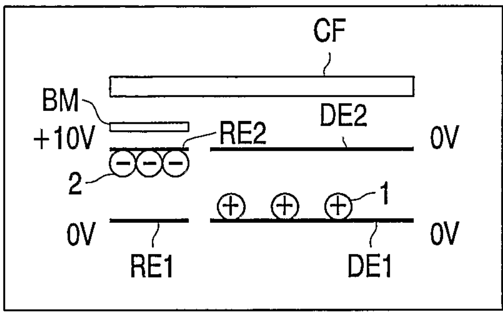

FIG. 4A

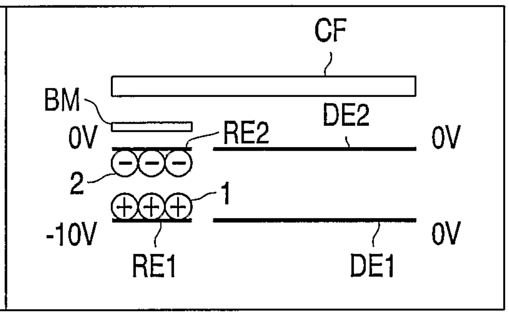

FIG. 4B

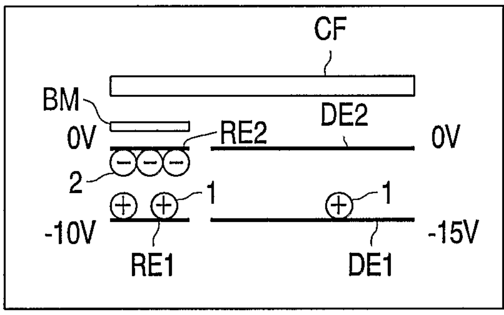

FIG. 4C

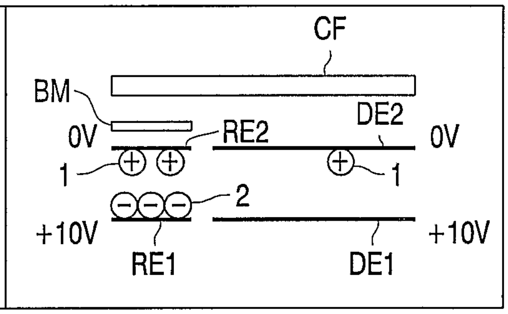

FIG. 4D

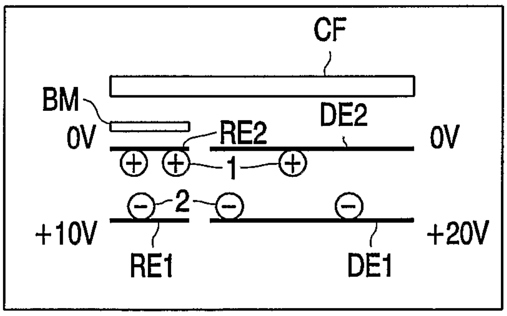

FIG. 4E

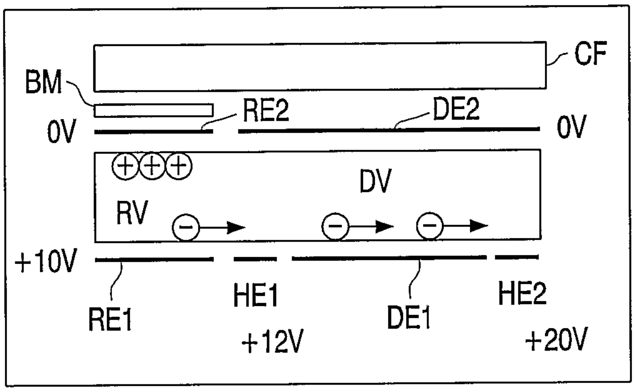

FIG. 5A

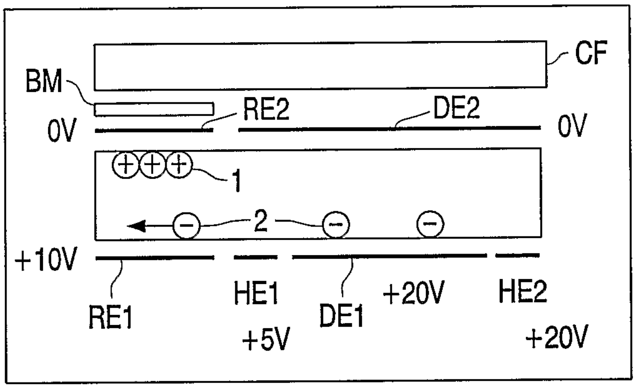

FIG. 5B

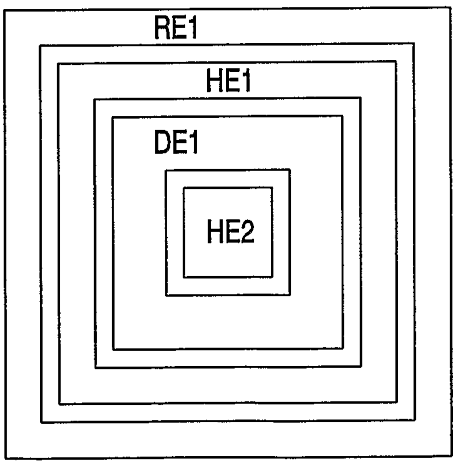

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/052487

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09G3/34 G02F1/167

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09G 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, INSPEC, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2003/231162 A1 (KISHI ETSURO) 18 December 2003 (2003-12-18) abstract paragraphs ‘0061! - ‘0077!; figures 1,2,4,6,7	1-3,5, 9-12 4,8
Y	US 2003/038772 A1 (DE BOER DIRK KORNELIS GERHARDUS ET AL) 27 February 2003 (2003-02-27) abstract paragraph ‘0031!; figure 1	4,8
P,A	WO 2004/088409 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; SCHLANGEN, LUCAS, J., M; JOHNSON,) 14 October 2004 (2004-10-14) abstract page 2 - page 5; figures 1,2	1-3,9-12

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

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 October 2005	28/10/2005

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, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wolff, L

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2005/052487

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	WO 2005/076062 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; DUINE, PETER, A; BROER, DIRK, J;) 18 August 2005 (2005-08-18) abstract page 12, line 17 - page 13, line 5; figure 5	1-3,9-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB2005/052487

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		WO 03019279 A1	06-03-2003
		JP 2005501296 T	13-01-2005
		TW 574528 B	01-02-2004
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WO 2005076062 A	18-08-2005	NONE	