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(54) Title: PRINTING AN ARRAY OF CHANNELS ON A SUBSTRATE

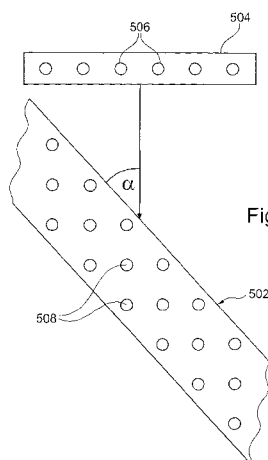


Fig. 5

(57) Abstract: A method of printing an array of channels on a substrate using a print head, wherein relative movement between the print head and the substrate is at an oblique angle relative to the longitudinal axis of the channels.



PRINTING AN ARRAY OF CHANNELS ON A SUBSTRATE

Field of Invention

This invention relates to a method of printing an array of channels on a substrate. Certain embodiments also relate to a printing apparatus, a controller, and a computer program for performing the method of the present invention. Certain of the embodiments relate to devices formed using the method of the present invention while more particular embodiments relate to printing of devices, particularly opto-electronic devices such as displays and sensor arrays. Each channel of the array may correspond to a pixel or sub-pixel of such a device. Alternatively, each channel of the array may correspond to a plurality of discrete pixels or sub-pixels of such a device. This may be achieved by printing a plurality of discrete pixels or sub-pixels in each channel or otherwise fully filling each channel with fluid and providing a plurality of addressing means per channel such that different portions of each channel can be separately addressed to form the pixels or sub-pixels. Alternatively still, embodiments of the invention can be utilized to form column arrays, as opposed to pixel arrays, which are both formed from, and emit as, continuous vertical columns. Such arrangements can be used as lighting panels.

Background of Invention

An array of pixels on a substrate can be defined in terms of vertical columns of pixels and horizontal rows of pixels. The columns of pixels can be defined on a substrate by way of

channels into which ink is printed to form the pixels. The channels may extend down the entire vertical length of the array area such that each individual channel comprises a plurality of pixel or sub-pixel areas disposed at intervals down the vertical length of the array area. Alternatively, each channel may comprise a plurality of discrete wells defining individual pixel or sub-pixel areas on the substrate.

These two alternative arrangements are illustrated in Figures 1 and 2. It should be noted that in reality, these arrays would usually have many more pixels/sub-pixels than illustrated.

Figure 1 shows a substrate 102 comprising a pixel array area 104. The pixel array area 104 comprises a plurality of channels 106 defining columns in the array area 104. In this arrangement, the channels 106 extend down the entire vertical length of the array area 104 such that each individual channel comprises a plurality of pixel or sub-pixel areas 108 disposed at intervals down the vertical length of the pixel array area 104. This may be achieved by printing a plurality of discrete pixels or sub-pixels in each channel or otherwise fully filling each channel with fluid during printing and providing a plurality of addressing means per channel such that different portions of each channel can be separately addressed to form the pixels or sub-pixels. For example, addressing electrodes in a device may be patterned such that different portions of each channel can be separately addressed. Alternatively still, a pure column array, as oppose to pixel array, can be formed by fully filling the channels and individually addressing the

channels such that each channel emits as a continuous vertical column.

Figure 2 shows a substrate 202 comprising a pixel array area 204. The pixel array area 204 comprises a plurality of channels 206 defining columns in the array area 204. In this arrangement, each column comprises a plurality of discrete channels 206 defining individual pixel or sub-pixel areas on the substrate 202.

For a full colour array, each pixel 208 generally comprises red, green, and blue sub-pixels and the array is divided into red, green and blue columns of sub-pixels. Such a full colour array may be provided utilizing a substrate of the type illustrated in Figures 1 or 2.

For example, in a full colour array utilizing a substrate of the type illustrated in Figure 1, the 1st column comprises a plurality of red sub-pixels, the 2nd column comprises a plurality of green sub-pixels and the 3rd column comprises a plurality of blue sub-pixels. This pattern is then repeated across the width of the array. A full colour pixel comprises red, green and blue sub-pixels from three adjacent columns. Each sub-pixel is generally elongate in shape such that the pixel formed by three adjacent sub-pixels is approximately square-shaped. The pixel aspect ratio is usually around 3:1, but isn't confined to this ratio and does vary according to different pixel array configurations. In fact, most often the pixel aspect ratio is a little greater than 3:1.

A full colour array utilizing a substrate of the type illustrated in Figure 2 is very similar. Again, the 1st column comprises a plurality of red sub-pixels, the 2nd column comprises a plurality of green sub-pixels and the 3rd column comprises a plurality of blue sub-pixels. This pattern is then repeated across the width of the array. The difference between this arrangement and the arrangement illustrated in Figure 1 is that each sub-pixel is formed in its own discrete channel/well. A full colour pixel comprises red, green and blue sub-pixels from three adjacent columns. Each channel/well, and thus each sub-pixel, is generally elongate in shape with an approximately 3:1 aspect ratio such that the pixel formed by three adjacent sub-pixels is approximately square-shaped. Again, as mentioned in relation to Figure 1, the pixel aspect ratio is not confined to an approximately 3:1 aspect ratio and can vary according to different pixel array configurations.

Alternatively still, a monochrome, two colour, or even three colour lighting panel can be formed using a substrate of the type illustrated in Figure 1 by fully filling the channels and individually addressing the channels such that each channel emits as a continuous vertical column rather than as individual pixels or sub-pixels.

Conventionally, channel arrays are printed by moving a print head over a substrate in a vertical direction down columns on the substrate as illustrated in Figure 3. The print head 302 may comprise a plurality of printing nozzles 304 disposed in a line and spaced such that each nozzle 304 is aligned with a column 306 on the substrate. Accordingly, each column 306 is

printed by drops 308 from a single printing nozzle 304. It is to be noted that the print head is not required to have a nozzle spacing which matches the column spacing on the substrate. A single print head can actually be used to print a variety of different column spacings by rotating the print head to change the effective spacing of the nozzles in a direction normal to the relative motion between the print head and the substrate.

This can cause problems in that any variation in the printing nozzles can lead to a variation in the quantity of ink printed into each column. This can lead to vertically oriented striations across the array of channels due to variations in the quantity of ink in the channels.

A second problem with the vertically oriented printing method is that of channel filling. The printing nozzles are generally aligned so that each nozzle is disposed over a central position of each column. As such, ink deposited into the channels may remain substantially in a central region of the channel and may not spread sufficiently to completely fill the channel from edge to edge in a width wise direction. Even if the ink does spread to the edges of the channel, there may be variations in the amount of ink distributed in the channel.

Another possible method for printing an array of channels is illustrated in Figure 4. In this arrangement, a print head 402 is moved in a horizontal direction across channels 404 on a substrate. Such sideways printing allows many nozzles to print each channel 404 such that the effect of variations between nozzles is averaged out. However, when printing with a print

head 402 narrower than the column is long, multiple passes are required to print the array. Since the printing process involves printing stripes (or swathes) of ink (corresponding to the print head width) there is an inbuilt asymmetry in the drying environment at a swathe join 406. Such a problem can result in horizontally disposed striations due to non-uniformities in the film formed as the ink dries.

Certain aspects of the present invention are directed at solving the aforementioned problems in order to achieve the advantageous properties of both horizontal and vertical printing while avoiding the problems associated with each of these methods.

Summary of the Invention

According to the first aspect of the present invention, there is provided a method of printing an array of channels on a substrate using a print head, wherein relative movement between the print head and the substrate is at an oblique angle relative to the longitudinal axis of the channels.

According to a second aspect of the present invention, there is provided a printing apparatus comprising a print head and a substrate receiving stage, wherein the print head and the substrate receiving stage are configured to move relative to each other such that the print head passes over the substrate receiving stage, and the substrate receiving stage is configured to mount a substrate at an oblique angle to the relative movement of the print head and the substrate receiving stage.

According to the third aspect of the present invention, there is provided a controller for a printing apparatus according to the second aspect of the present invention. The controller of the third aspect is configured to control printing of a plurality of nozzles in a print head in order to perform the method of the first aspect of the present invention.

According to a fourth aspect of the present invention, a computer program is provided for use in the controller of the third aspect of the present invention.

Finally, in accordance with a fifth aspect of the present invention there is provided a device formed using to the method of the first aspect of the present invention. The device may be an emissive display, a sensing array, or a lighting panel.

Brief Summary of the Drawings

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 shows a substrate comprising a pixel array area with a plurality of channels which extend down the entire vertical length of the array area;

Figure 2 shows a substrate comprising a pixel array area in which each column comprises a plurality of discrete channels or wells;

Figure 3 illustrates a conventional vertical printing method;

Figure 4 illustrates a sideways multi-pass printing method;

Figure 5 illustrates the basic principles of oblique printing in accordance with an embodiment of the present invention;

Figure 6 illustrates a printing arrangement in accordance with an embodiment of the present invention;

Figure 7 illustrates a device printed in accordance with an embodiment of the present invention; and

Figure 8 illustrates a cross-section of a column of an organic light emissive display device in accordance with an embodiment of the present invention.

Detailed Description of Embodiments

Figure 5 illustrates the basic principles of oblique printing. The method involves printing an array of channels on a substrate, wherein relative movement between a print head and the substrate is at an oblique angle α relative to the longitudinal axis of the channels. In the arrangement illustrated in Figure 5, only a single channel 502 is shown for clarity. A print head 504 comprising a line of printing nozzles 506 is shown as moving at an oblique angle α relative to the channel 502 to print droplets 508 in the channel 502. However, the relative movement could of course be achieved by moving the substrate relative to the print head.

By angling a substrate such that a channel on the substrate is disposed at an oblique angle relative to movement of the print head, one or more nozzles can print into the channel at any one time, but as the print head moves down the channel, the nozzles printing drops into the channel change.

In this way, each nozzle may print several drops into a channel, but the method still allows several nozzles to be used to print each channel. This is in contrast to conventional vertical printing when usually only one nozzle is placed over each channel, or sideways printing where the channel width does not allow many drops to be printed across it (and often only one).

Oblique printing therefore allows the averaging of variations between drops from different nozzles by using several nozzles to print each channel (a feature shared with sideways printing). In addition, because the number of drops printed in each channel by each nozzle is increased in comparison with sideways printing, it may also be possible to change the number of drops from a given nozzle to adjust the total volume produced by that nozzle and thus reduce the effect of variations between nozzles.

For relatively small angles, whole channels can be printed in a single pass, removing the problem of swathe joins which can occur with multi-pass sideways printing. Oblique printing also gives the ability to place drops at channel edges (a feature shared with sideways printing with multiple drops per nozzle) which is usually not possible with conventional vertical

printing (where a single nozzle passes down a channel centreline).

In these ways, oblique printing brings together key advantages of both conventional vertical printing and sideways printing.

The oblique angle α may lie in the range $1^\circ < \alpha < 30^\circ$, $1^\circ < \alpha < 20^\circ$, or $1^\circ < \alpha < 10^\circ$ according to certain embodiments. However, the preferred angle to be used will vary depend on the substrate and print head configuration. If the angle of printing is high, then the number of drops per nozzle which is printed into each channel is reduced. If the angle is low then many drops from a single nozzle are printed into a channel.

It is to be noted that in accordance with the present invention, the printing angle is defined in terms of the direction of motion of the print head relative to the channels of the substrate. Angling the print head for vertical printing is known. However, angling the print head and then moving the print head in a vertical direction results in the same problem as standard vertical printing in that each channel is printed by only a single nozzle.

Figure 6 illustrates a printing arrangement in accordance with an embodiment of the present invention.

A substrate 602 is positioned at an oblique angle relative to a print head 604 comprising a row of printing nozzles 606. The substrate 602 may be of the type illustrated in Figure 1 or Figure 2 as described in the background section. In Figure 6, a

substrate of the type illustrated in Figure 1 is shown. The substrate 602 comprises a pixel array area 608 with a plurality of channels 610 defining columns in the array area 608. The channels 610 may be defined by banks forming troughs/wells on the substrate 602 for receiving and confining ink printed into the channels 610 from the print head 604. A peripheral dummy printing area 612 is disposed around the pixel array area 608 (the peripheral dummy printing area will be discussed in more detail later).

The substrate 602 is set at a desired oblique angle using a substrate receiving stage 614 which is configured to mount the substrate 602 at an oblique angle relative to the direction of movement of the print head 604. The substrate receiving stage 614 is also configured to hold the substrate 602 at the desired angle. This may be achieved in a variety of different ways. For example, the substrate receiving stage 614 may comprise one or more clamps 616 for receiving and holding the substrate 602 at the desired oblique angle relative to the movement of the print head 604. Alternatively, a recess may be provided in the substrate receiving stage 614 for receiving and holding the substrate 602 at the desired angle. Another possibility would be to provide a vacuum chuck to hold the substrate at the desired angle on the substrate receiving stage. The vacuum chuck could be provided on its own or in combination with an aligning mechanism such as one or more clamps or a recess. Other possibilities may also be envisaged for aligning and holding the substrate at the desired oblique angle relative to the movement of the print head 604.

The substrate receiving stage 614 may be provided with a clamping/holding mechanism 614 (for example, one of the possible arrangements described above) which can be set to a variety of different angles such that a particular angle can be selected and set for a particular printing run. For example, different angles may be utilized for different substrate types and/or substrate sizes and/or print head arrangements.

The print head 604 illustrated in Figure 6 comprises a single row of printing nozzles 606. However, print heads which can be used in embodiments of the present invention may have a variety of different designs. For example, a plurality of lines of printing nozzles may be provided. Furthermore, it is possible to use more than one print head to print a substrate in accordance with certain embodiments of the invention.

In accordance with certain arrangements, the array is printed in a single pass with a single print head being utilised for printing each array.

Preferably, more than one droplet is printed in each pixel or sub-pixel area. For certain displays, it is preferred to print in range of 2 to 50, more preferably 5 to 40, and most preferably 10 to 30 drops per pixel or sub-pixel. It is often better to use smaller drops as this allows for further control of volume and spreading within the channel so as to produce a better film. Preferably, asymmetric pixels are utilised in methods of the present invention. It is envisaged that the bigger the aspect ratio of pixels then the more benefit will be provided by the oblique printing method.

Figure 6 also illustrates a controller 618 for controlling the relative movement of the print head 604 and substrate 602 and for controlling when drops are ejected from each of the nozzles 606. In accordance with embodiments of the present invention, printing is controlled by the controller to ensure that each nozzle fires in the correct place. This requires a slightly more complex control algorithm than for vertical or horizontal printing. The control algorithm can be defined in terms of a function of a number of parameters including printing angle, nozzle position, channel size and position, print speed, drop size, and nozzle frequency. A computer program can be provided to implement the algorithm in the controller.

Figure 7 illustrates a device 702 printed in accordance with an embodiment of the present invention. The device 702 comprises an array of pixels 704 in a pixel array area 706 printed in accordance with the oblique printing method described herein. As droplets printed into the pixels generally coalesce, it may be difficult to discern that an oblique printing method has been used to form the device 702 by analysing the pixels 704 themselves. However, conventionally, ink is printed in a peripheral area around the pixel array area 706 to avoid edge effects in the pixel array area 706. Such printing results in so called dummy drops 708 around the peripheral region in a dummy printing area 710. Such printing is visible in a final device and an analysis of the pattern of these dummy droplets can be utilised to identify how the device was printed. Accordingly, devices printed in accordance with embodiments of the present invention can be identified by the pattern of dummy

droplets around the periphery of a device. In particular, lines of dummy droplets disposed at an oblique angle relative to the columns of pixels in the device will show that the device was manufactured using an oblique printing method in accordance with the present invention.

Devices produced in accordance with an oblique printing method are advantageous as they can be made without any substantial variations in the pixel/column array. The oblique printing method is particularly advantageous for depositing semiconductive organic material in pixels/columns of an organic opto-electronic device such as an organic light-emissive device (OLED). Such devices require the organic films to be uniform to nanometer tolerance and the oblique printing method is useful in achieving such uniformity.

Figure 8 illustrates a cross-section of a column of an organic light-emissive device in accordance with an embodiment of the present invention. The device comprises a substrate 802 on which an anode electrode layer 804 is disposed. Bank material is deposited to form banks 806 which define channel regions for receiving and containing ink printed from a print head. In this instance the ink comprises an organic light-emissive material dissolved in a solvent. The ink is printed in the channel region and the solvent dries to form an organic light-emissive layer 808. A cathode layer 810 is then deposited over the organic light-emissive layer 808 to form a light emissive diode structure. An array of such diodes is provided in an organic light-emissive display. As the brightness of each diode is highly dependent on the thickness and uniformity of the organic

light-emissive layer, the oblique printing method is advantageous for printing the organic light-emissive layer 808. Furthermore, such devices may comprise other organic layers such as one or more conductive organic charge injection layers and/or one or more semiconductive charge transport layers between the organic light-emissive layer 808 and one or both of the electrodes. As the brightness of each diode can be highly dependent on the thickness and uniformity of these additional layers, the oblique printing method is also advantageous for printing these layers.

While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the scope and invention as defined by the appended claims.

CLAIMS:

1. A method of printing an array of channels on a substrate using a print head, wherein relative movement between the print head and the substrate is at an oblique angle relative to the longitudinal axis of the channels.
2. A method according to claim 1, wherein the oblique angle α lies in the range $1^\circ < \alpha < 30^\circ$, $1^\circ < \alpha < 20^\circ$, or $1^\circ < \alpha < 10^\circ$.
3. A method according to claim 1 or 2, wherein the print head comprises a plurality of nozzles, wherein at least one of the plurality of nozzles prints a plurality of drops into one of the plurality of channels and then prints a plurality of drops into an adjacent channel, and wherein each column is printed by more than one nozzle in a single printing pass down the channels.
4. A method according to any preceding claim, wherein all the plurality of channels are printed in a single pass of the print head.
5. A method according to any preceding claim, wherein the substrate comprises a pixel array area with the plurality of channels defining columns in the pixel array area, the channels extending down the length of the columns in the pixel area array, each individual channel comprising a plurality of pixel or sub-pixel areas disposed at intervals down the length of the columns in the pixel area array, the method comprising printing into the channels in the pixel or sub-pixel areas.

6. A method according to any one of claims 1 to 4, wherein the substrate comprises a pixel array area with the plurality of channels defining columns in the pixel array area, each column comprising a plurality of discrete channels defining individual pixel or sub-pixel areas on the substrate, the method comprising printing into the discrete channels in the pixel or sub-pixel areas.

7. A printing apparatus comprising a print head and a substrate receiving stage, wherein the print head and the substrate receiving stage are configured to move relative to each other such that the print head passes over the substrate receiving stage, and the substrate receiving stage is configured to mount a substrate at an oblique angle to the relative movement of the print head and substrate receiving stage.

8. A printing apparatus according to claim 7, wherein the substrate receiving stage is configured to mount the substrate at an oblique angle α which lies in the range $1^\circ < \alpha < 30^\circ$, $1^\circ < \alpha < 20^\circ$, or $1^\circ < \alpha < 10^\circ$.

9. A printing apparatus according to claim 7 or 8, wherein the substrate receiving stage comprises one or more clamps or a recess for receiving the substrate and holding the substrate at the oblique angle.

10. A printing apparatus according to claim 9, wherein the one or more clamps or the recess is adjustable to provide a plurality of possible oblique angles.

11. A printing apparatus according to any one of claims 7 to 10, wherein the print head comprises a plurality of nozzles

12. A printing apparatus according to claim 11, further comprising a controller configured to control the print head whereby at least one of the plurality of nozzles prints a plurality of drops into one of a plurality of channels in a substrate mounted on the substrate receiving stage and then prints a plurality of drops into an adjacent channel whereby each channel is printed by more than one nozzle in a single printing pass down the channels.

13. A printing apparatus according to any one of claims 7 to 12, wherein the print head and the substrate receiving stage are configured to print the substrate in a single pass of the print head.

14. A controller configured to perform the method of any one of claims 1 to 6 when inserted in the printing apparatus of any one of claims 7 to 13.

15. A computer program configured to perform the method of any one of claims 1 to 6 when loaded into the controller of claim 14 and inserted in the printing apparatus of any one of claims 7 to 13.

16. A device formed using to the method of any one of claims 1 to 6.

17. A device according to claim 16, wherein the device is an opto-electronic device.

18. A device according to claim 17, wherein the device is an organic opto-electronic device.

19. A device according to claim 17 or 18, wherein the device is an emissive display, a sensing array, or a lighting panel.

20. A device according to claim 19, wherein the device is an organic light-emissive display.

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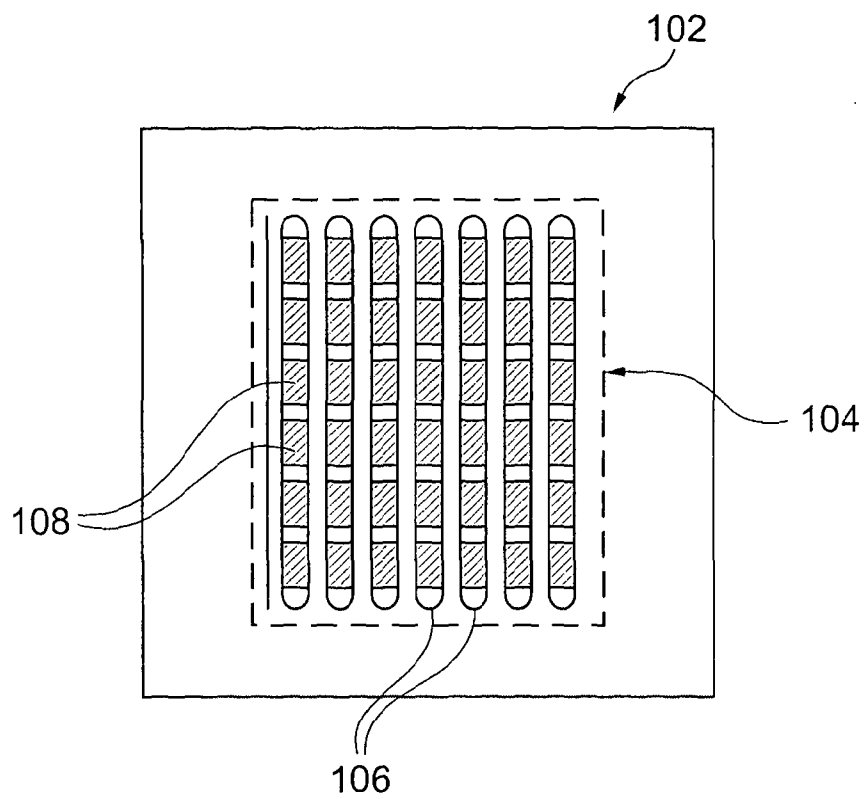


Fig. 1

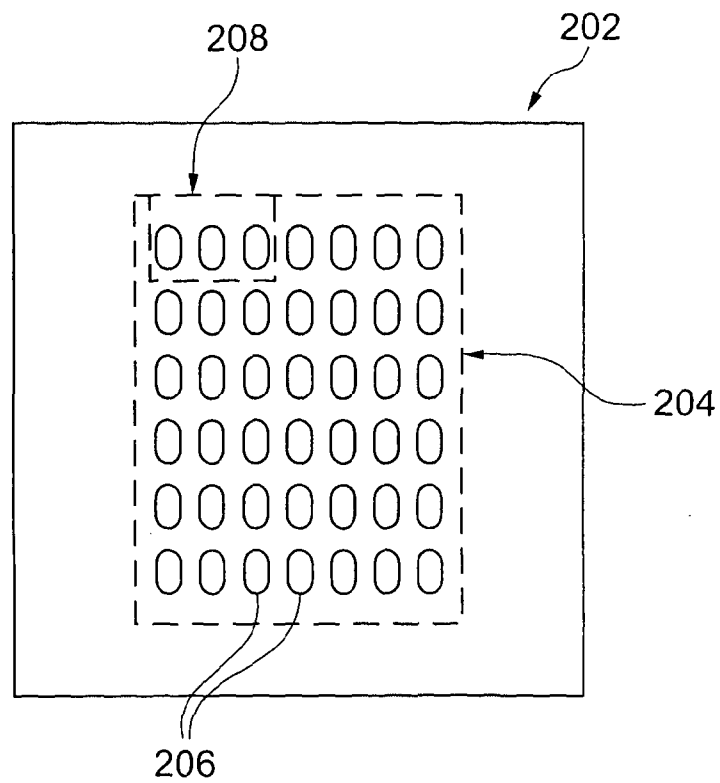


Fig. 2

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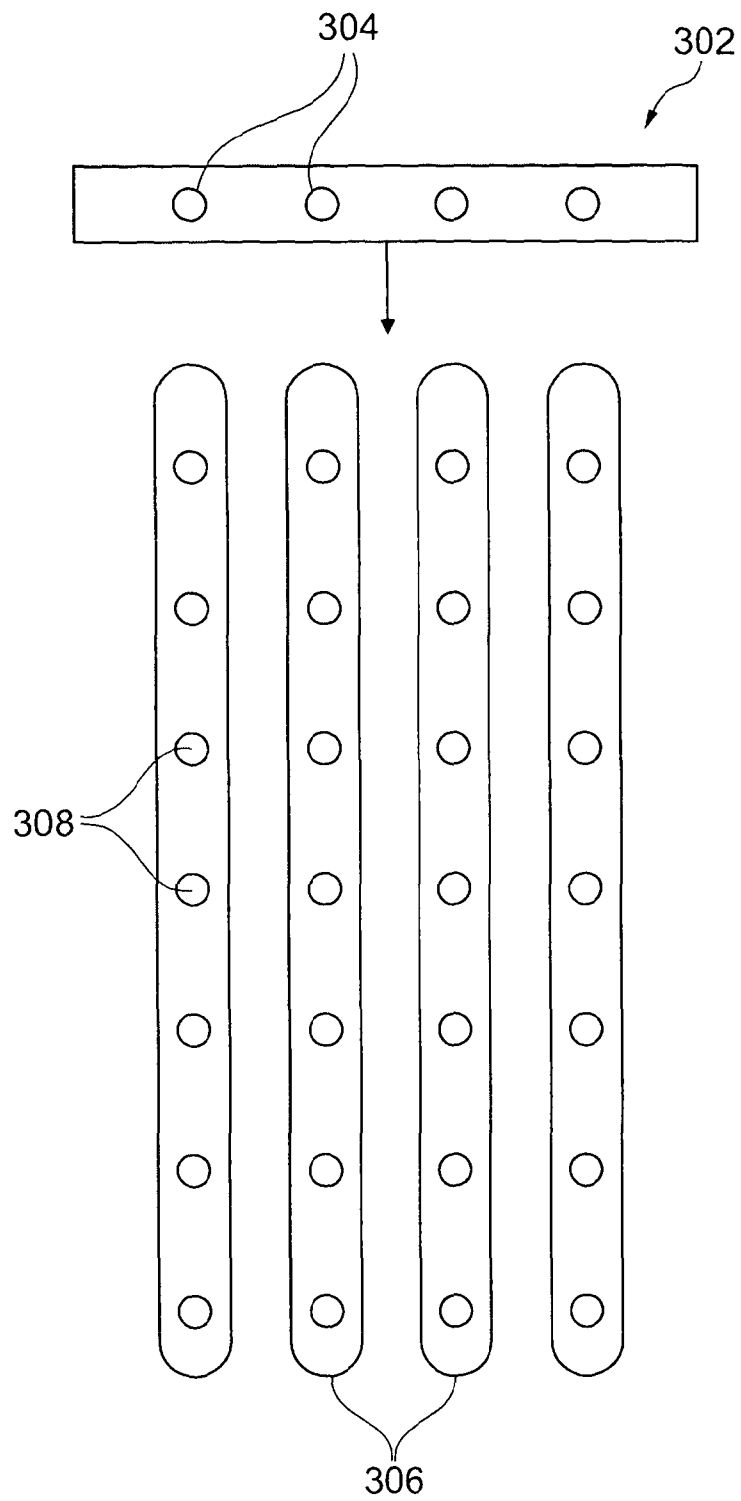


Fig. 3

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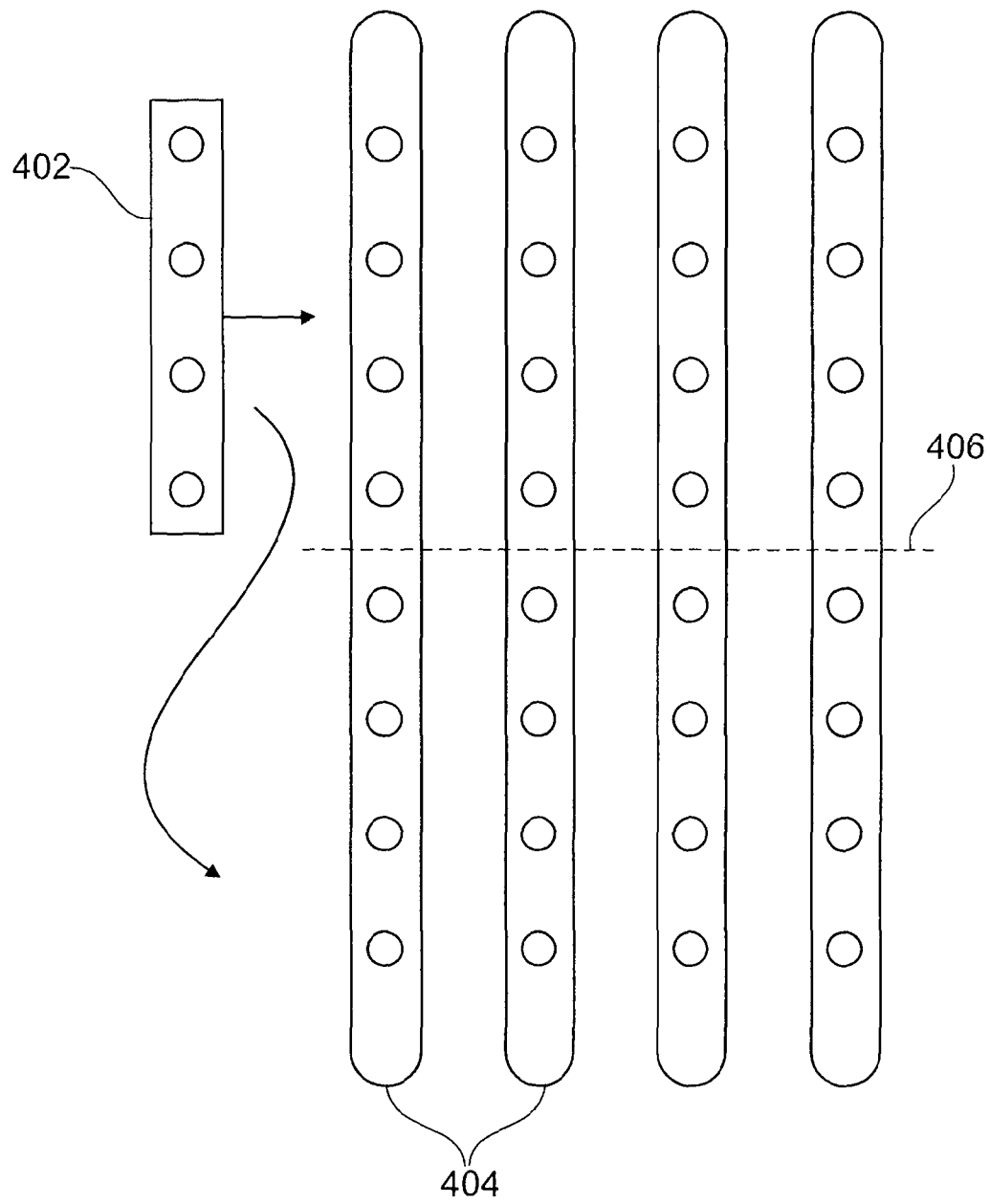


Fig. 4

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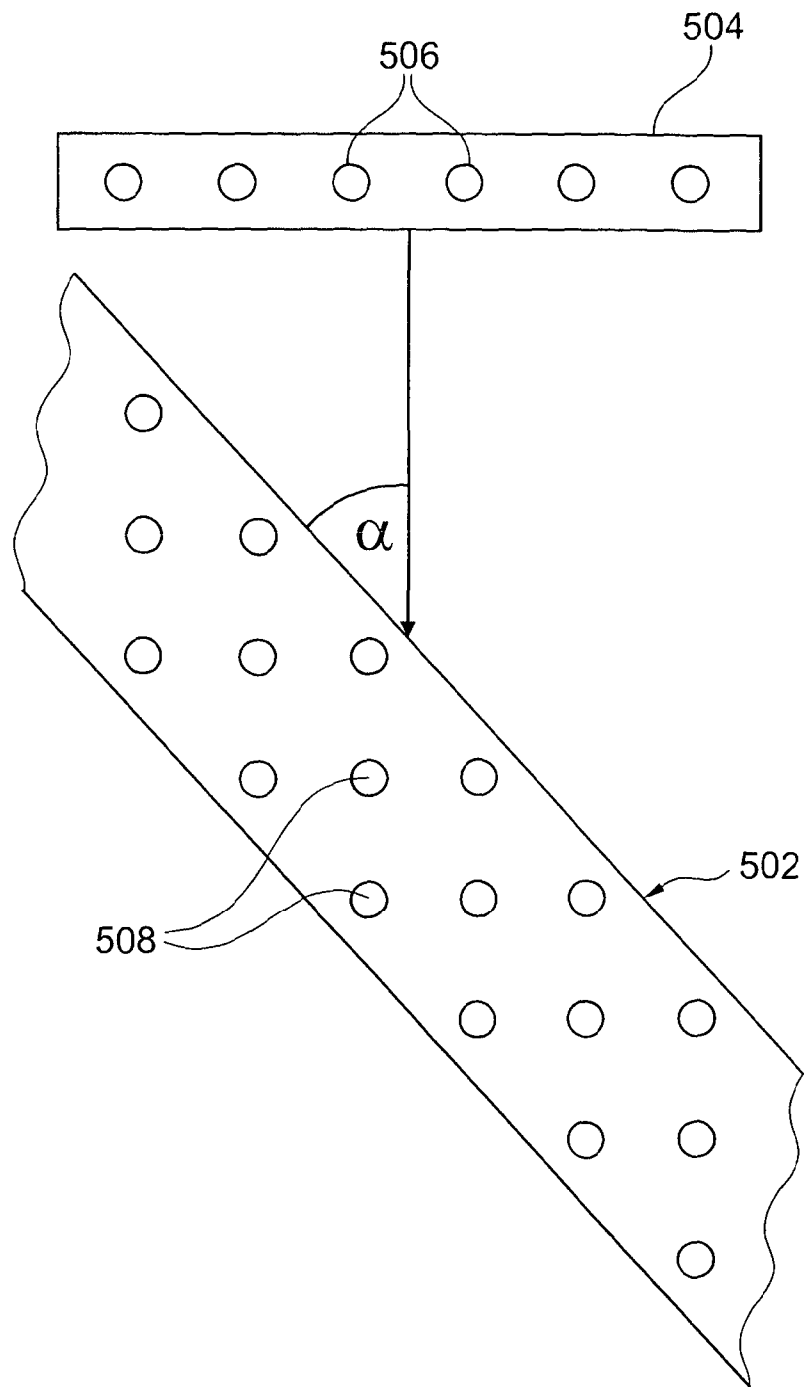


Fig. 5

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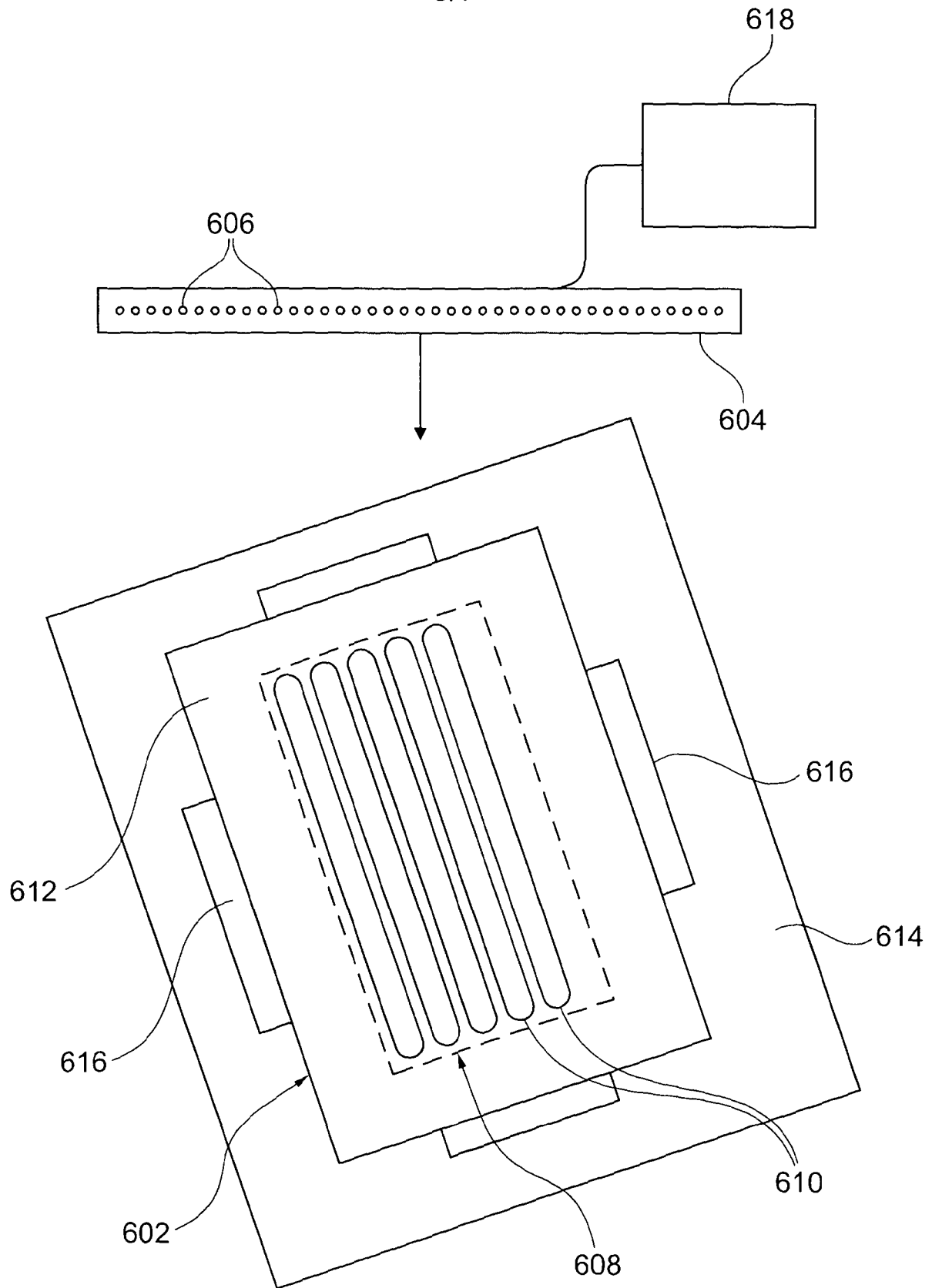


Fig. 6

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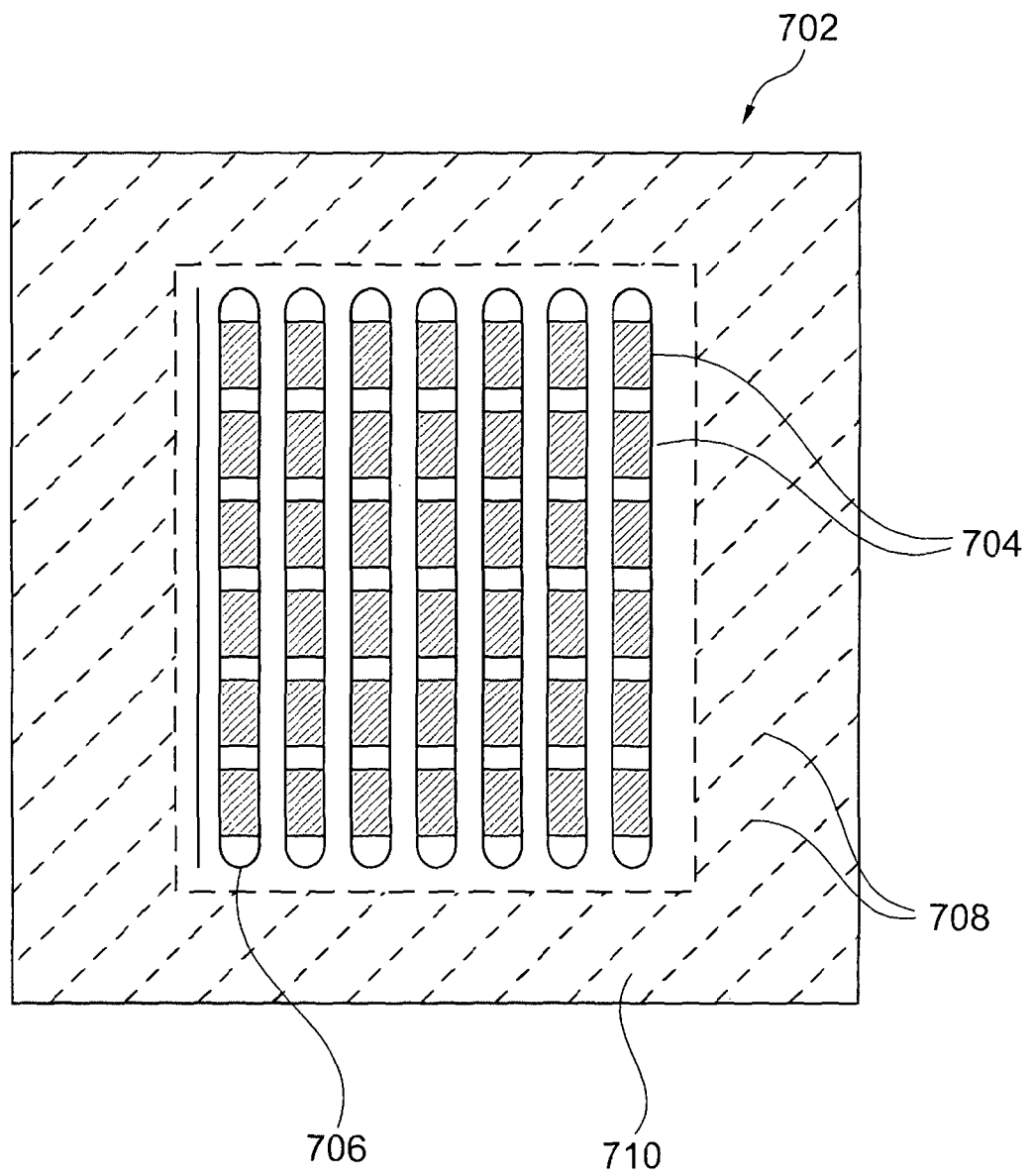


Fig. 7

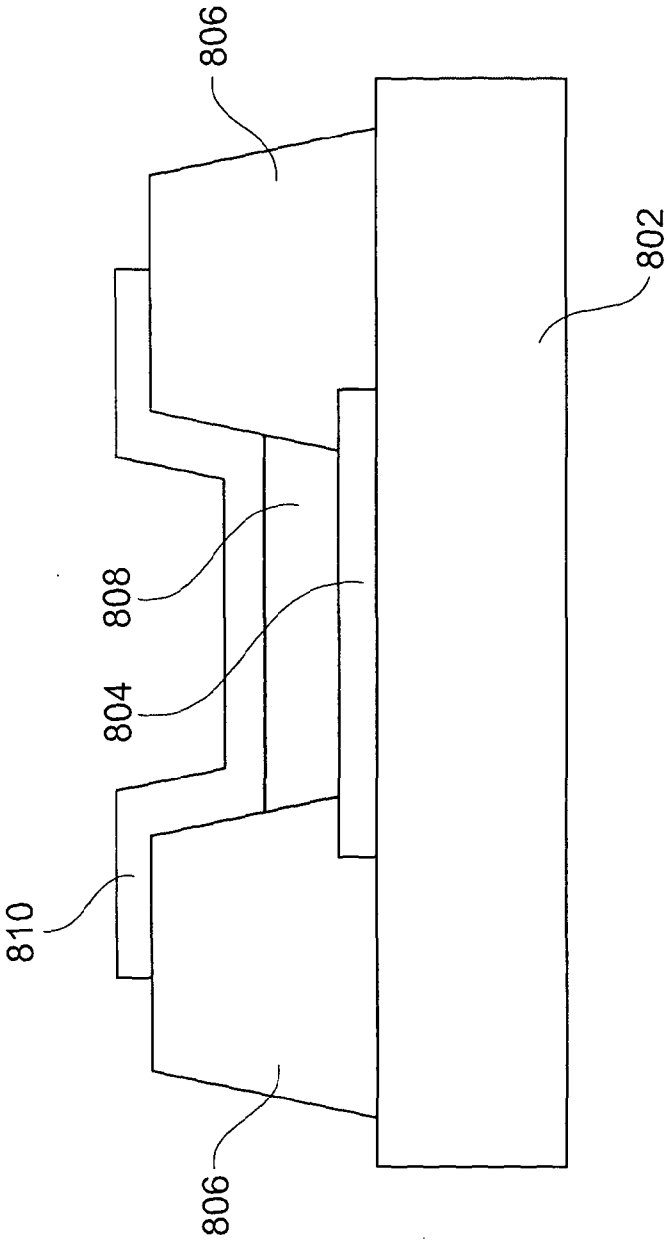


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/000214

A. CLASSIFICATION OF SUBJECT MATTER

INV. B41J2/21 B41J25/00 H01L51/00
ADD.

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)

B41J H01L H05K 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 2006/246215 A1 (JUNG JIN-SOO [KR] ET AL) 2 November 2006 (2006-11-02) figures 3,4,5,6A,8 paragraphs [0003], [0040] - [0046], [0050], [0055], [0056], [0065] - [0069] -----	1-20
X	US 2007/218220 A1 (DRURY PAUL R [GB] ET AL) 20 September 2007 (2007-09-20) figures 3,5,7 paragraphs [0003] - [0005], [0046], [0049], [0053], [0080], [0112] -----	1-6,16, 17,19
X	EP 1 426 190 A1 (FUJI PHOTO FILM CO LTD [JP]) 9 June 2004 (2004-06-09) paragraphs [0053] - [0055], [0113], [0115]; figures 1,2,8,17 ----- -/-	1,4,16, 17,19



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

2 August 2011

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09/08/2011

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/000214

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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