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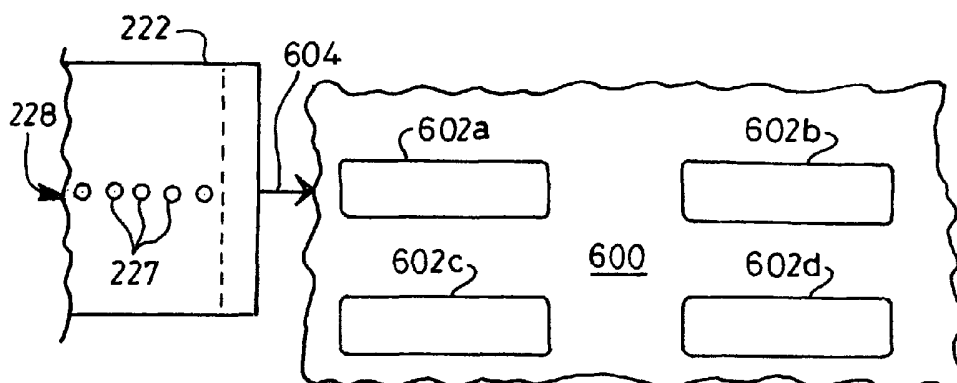
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(54) Title: DEPOSITION APPARATUS AND METHODS



(57) Abstract: This invention relates to the deposition of material for electronic devices, particularly or molecular electronic devices such as organic light emitting diodes, by an ink jet-type process. A method of depositing material for an electronic device onto a substrate in a pattern comprising a plurality of pixels is described. The method employs a printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in a solvent onto said substrate, a first direction being defined substantially parallel to said substantially linearly arranged orifices. The method comprises moving one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that the majority of said orifices pass over a single said pixel in turn; ejecting droplets of material from orifices of said majority of orifices as the orifices pass over the said pixel; and repeating said moving and ejecting to build up said pattern.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DEPOSITION APPARATUS AND METHODS

This invention relates to the deposition of material for electronic devices, particularly molecular electronic devices such as organic light emitting diodes, by an ink jet-type process.

Organic light emitting diodes (OLEDs) comprise a particularly advantageous form of electro-optic display. They are bright, colourful, fast-switching, provide a wide viewing angle and are easy and cheap to fabricate on a variety of substrates. Organic LEDs may be fabricated using either polymers or small molecules in a range of colours (or in multi-coloured displays), depending upon the materials used. Examples of polymer-based organic LEDs are described in WO 90/13148, WO 95/06400 and WO 99/48160; examples of so called small molecule based devices are described in US 4,539,507.

A basic structure 100 of a typical organic LED is shown in Figure 1a. A glass or plastic substrate 102 supports a transparent anode layer 104 comprising, for example, indium tin oxide (ITO) on which is deposited a hole transport layer 106, an electroluminescent layer 108, and a cathode 110. The electroluminescent layer 108 may comprise, for example, a PPV (poly(p-phenylenevinylene)) and the hole transport layer 106, which helps match the hole energy levels of the anode layer 104 and electroluminescent layer 108, may comprise, for example, PEDOT:PSS (polystyrene-sulphonate-doped polyethylene-dioxythiophene). Cathode layer 110 typically comprises a low work function metal such as calcium and may include an additional layer immediately adjacent electroluminescent layer 108, such as a layer of aluminium, for improved electron energy level matching. Contact wires 114 and 116 to the anode the cathode respectively provide a connection to a power source 118. The same basic structure may also be employed for small molecule devices.

In the example shown in Figure 1a light 120 is emitted through transparent anode 104 and substrate 102 and such devices are referred to as "bottom emitters". Devices which

emit through the cathode may also be constructed, for example by keeping the thickness of cathode layer 110 less than around 50-100 nm so that the cathode is substantially transparent.

Organic LEDs may be deposited on a substrate in a matrix of pixels to form a single or multi-colour pixellated display. A multicoloured display may be constructed using groups of red, green, and blue emitting pixels. In such displays the individual elements are generally addressed by activating row (or column) lines to select the pixels, and rows (or columns) of pixels are written to, to create a display. So-called active matrix displays have a memory element, typically a storage capacitor and a transistor, associated with each pixel whilst passive matrix displays have no such memory element and instead are repetitively scanned, somewhat similarly to a TV picture, to give the impression of a steady image.

Figure 1b shows a cross section through a passive matrix OLED display 150 in which like elements to those of Figure 1a are indicated by like reference numerals. In the passive matrix display 150 the electroluminescent layer 108 comprises a plurality of pixels 152 and the cathode layer 110 comprises a plurality of mutually electrically insulated conductive lines 154, running into the page in Figure 1b, each with an associated contact 156. Likewise the ITO anode layer 104 also comprises a plurality of anode lines 158, of which only one is shown in Figure 1b, running at right angles to the cathode lines. Contacts (not shown in Figure 1b) are also provided for each anode line. An electroluminescent pixel 152 at the intersection of a cathode line and anode line may be addressed by applying a voltage between the relevant anode and cathode lines.

It is known to deposit material for organic light emitting diodes (OLEDs) using ink jet printing techniques. This is described in, for example, T.R. Hebner, C.C. Wu, D. Marcy, M.H. Lu and J.C. Sturm, "Ink-jet Printing of doped Polymers for Organic Light Emitting Devices", *Applied Physics Letters*, Vol. 72, No. 5, pp.519- 521, 1998; Y. Yang, "Review of Recent Progress on Polymer Electroluminescent Devices," *SPIE Photonics West: Optoelectronics '98*, Conf. 3279, San Jose, Jan., 1998; EP O 880 303; and "Ink-Jet Printing of Polymer Light-Emitting Devices", Paul C. Duineveld, Margreet M. de Kok, Michael Buechel, Aad H. Sempel, Kees A.H. Mutsaers, Peter van de

Weijer, Ivo G.J. Camps, Ton J.M. van den Biggelaar, Jan-Eric J.M. Rubingh and Eliav I. Haskal, Organic Light-Emitting Materials and Devices V, Zakya H. Kafafi, Editor, Proceedings of SPIE Vol. 4464 (2002). Ink jet techniques can be used to deposit materials for both small molecule and polymer LEDs, although these applications present their own particular problems, which are different to the problems encountered in conventional ink jet printing of images on paper or plastic, as will be explained more fully below.

Use of an ink jet printer to deposit red, green and blue colour filters for an electroluminescent display is described in EP 1,219,980A. A similar technique is described in US 2002/0105688. Figures 2a and 2b, which are taken from EP '980, show ink jet printing apparatus which may be employed for this type of application. Figure 2a shows an ink jet printer 200 comprising a base 209 supporting first and second linear positioners 206, 208 for moving a substrate 212 and ink jet print head 222 relative to one another along two orthogonal axis Y and X. Positioner 206 comprises a pair of rails 254 mounting a slider 256 provided with a turntable 251 supporting a table or bed 249 on which the substrate 212 is supported. The substrate 212 is aligned on table or bed 249 by means of stops 250 against which two edges of the substrate abut. Turntable 251 allows the table and substrate 249, 212 to be rotated relative to the print head 222.

Positioner 208 comprises a pair of rails 252 mounting a slider 253 which carries rotary positioners 244, 246, 247 which allow a print head unit 226 carrying the print head to be rotated independently about three orthogonal axes. A further linear positioner 248 is also mounted on slider 253 to allow the print head unit and print head to be translated in the Z-direction, that is towards and away from substrate 212.

Ink jet printer system 200 is controlled by a computer terminal 202 via an umbilical 204. Terminal 202 may comprise a general purpose computer with interface hardware for interfacing to the above-described linear and rotary positioners, running operating system, user interface and other ink jet printer drive and control software, in a conventional manner. Thus terminal 202 typically includes a data input device such as a network interface or floppy disk drive for receiving data defining a pattern to be

printed, and printer control software to control the printer hardware to print a pattern in accordance with stored or input data. Other conventional functions such as test functions, head cleaning functions and the like are generally also provided by software running on terminal 202.

Figure 2b shows print head 222 in more detail. The print head has a plurality of nozzles 227, typically orifices in a nozzle plate for ejecting droplets of fluid from the print head onto the substrate. A fluid supply for printing (not shown in Figure 2b) may either be provided by a reservoir within the print head or print head unit or fluid may be supplied from an external source. In the illustrated example the print head 222 has a single row 228 of nozzles 227, but in other examples of print heads more than one row of nozzles may be provided with nozzles offset in one or two dimensions. The diameter of the orifices of nozzles 227 is typically between 10 μ m and 100 μ m, and drop sizes are similar. The space or pitch between adjacent nozzle orifices is typically between 50 μ m and 100 μ m.

Figure 3a shows a conventional printing strategy in which print head 222 prints successive swathes 302, 304 in the Y-direction, stepping in the X-direction between each swathe. The technique illustrated in Figure 3b may be employed to produce a finer dot pitch. The print head is positioned at an angle Φ to the X-direction to reduce the dot pitch by a factor of $\cos \Phi$. Figure 3c shows two examples 306 and 308 of the distribution of drop volume ejected from nozzles 227 across the width of print head 222. Generally the size or volume distribution of drops is non-uniform, increasing or falling off at nozzles at the edge of the print head (that is, near an end of a row of nozzles), and further non-uniformity arise from small variations in nozzle heights. Figure 3c shows variations in drop volume, but in general similar variations are also observed in drop velocity. This problem is sometimes addressed in conventional ink jet printing by overlapping the swathes 302, 304.

When depositing materials for molecular electronic devices such as OLEDs, there is a need for both high resolution, generally than better than that required for the best high resolution graphics, and accurate control of the volume of material deposited, which

translates to accurate control of “ink” drop volume. Preferably drop volume should be consistent, and preferably controllable to a few percent.

The pattern of material to be deposited is made up of pixels formed by depositing the electroluminescent material into a well as described in EP 0 880 303. The wells are usually formed by photolithography of a photoresist as described in EP 0 862 156 to which reference may be made. In the case of OLEDs these pixels and wells have regular shapes and a regular pattern, but in other cases potentially having irregular shapes. One known strategy for more accurately controlling the volume of material deposited is to cover a pixel or fill a well using a plurality of drops rather than a single drop, and this strategy is described in EP ‘980, in which the print head makes multiple passes in the Y-direction (referring to Figure 3a), depositing one drop onto a pixel on each pass. However this has the disadvantage that there is a relatively long period between successive drops landing on a single pixel, which can result in the “coffee ring” problem illustrated in Figure 4 (discussed below). Furthermore because a zig-zag scanning strategy is adopted for the X-direction the intervals between successive drops landing is non-uniform, depending upon the position of a pixel in the X-direction.

To deposit a molecular electronic material a volatile solvent such as is employed with 1-2% dissolved solvent material. This results in a relatively thin film in comparison with the initial “ink” volume. The drying time is dependent upon the solvent mix and the atmosphere above the substrate, but typically varies between a few seconds and some minutes. It is strongly preferable all the drops comprising material which are eventually to make up a pixel are deposited before drying begins. Solvents which may be used include alkylated benzenes, in particular toluene or xylene. Other solvents for inkjet printing are described in WO 00/59267, WO 01/16251 and WO 02/18513.

Figure 4 illustrates a problem which arises if one drop begins to dry before another is deposited. As the solvent begins to evaporate from drop 400 solvent flows in a direction indicated by arrows 402 because the edge 404 of the drop tends to remain pinned to substrate 406. This results, after a period, in drop shape 410 and the dissolved material tends to be deposited in a ring rather than uniformly. The Applicant's

publication WO 02/69119 describes this effect in more detail, and a method of overcoming it by selection of a solvent blend.

With the technique described in EP '980 a slow drying solvent must be employed to prevent drying between successive swathes, but a greater flexibility in solvent choice is preferable and for some applications relatively quick drying solvents such as toluene and xylene, for example with drop drying times of the order of one second, are useful. The technique of EP '980 is known for averaging out drop landing errors (thus reducing "banding") as much as for averaging out drop volume variations.

For graphics applications it is drop placement rather than drop volume which is significant and volume variations of 5 to 10% are acceptable. However when constructing molecular electronic devices it is drop volume which is important since this will determine the eventual film thickness which, for an OLED, impacts upon brightness and hence drive current and device lifetime. Thus it is desirable to achieve a volume variation of better than 2%, preferably better than 1%, across an entire OLED display.

There are a number of other factors which are also important to consider when depositing materials for molecular electronic devices. Generally it is desirable to print or deposit material as fast as possible without compromising quality and repeatability. There are two main limits on deposition speed, one hydraulic and one related to the print head electronics and a mechanism of operation.

Figure 5 illustrates development of a problem known as "tail hooking". In Figure 5 a drop 500 is exiting from an orifice or nozzle 502 of a nozzle plate 504. The drop will eventually break off along dashed line 506 leaving a small amount of dissolved material to drain back into the nozzle orifice before another drop is ejected from the orifice. If sufficient time is not allowed for this process material tends to build up on one side of a nozzle, and this material tends to capture or hook an exiting drop causing the drop to travel at an angle to the desired path. The "dehooking" time depends upon the fluid properties of the solution comprising the drop and upon dewetting properties of the nozzle plate. For example, for organic polymers for OLEDs dissolved at 1 to 3%

dewetting is relatively slow limiting drop eject frequencies from a single nozzle to a few hundred hertz. This compares with a typical maximum "electronic" frequency of a print head of between 5KHz and 10KHz. However whereas graphics printing is generally evenly spread across a page, printing for molecular electronic devices tends to be in patterns of pixels with spaces in between. Data for these spaces, for example comprising all zeros, may therefore be clocked into the print head as fast as "electronically" possible.

In the light of the above difficulties there is a need for ink jet-type printing techniques which provide print volume uniformity without overly comprising print speed. It is also desirable to provide techniques which allow the use of a range of solvent and solvent blends.

According to the present invention there is therefore provided a method of depositing material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the method employing a printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in a solvent onto said substrate, a first direction being defined substantially parallel to said substantially linear arrangement of orifices, the method comprising moving one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that the majority of said orifices pass over a single said pixel in turn; ejecting droplets of material from orifices of said majority of orifices as the orifices pass over the said pixel; and repeating said moving and ejecting to build up said pattern.

By closely aligning the first and second directions most of the print head orifices or nozzles pass over each pixel or well in turn, and preferably substantially all of the orifices pass over a single pixel so that substantially all of the orifices are potentially available for deposition onto the pixel. Each of a plurality of nozzles can then fire one drop into the well in rapid succession, thus providing an averaged out volume, giving more accurate deposition volume repeatability, and depositing the desired quantity of material relatively quickly so that, for example, the final drop of a set may be deposited before the first has started to dry. The print head may be exactly aligned to the direction

of motion, so that the first and second directions coincide, but advantageously the print head is slightly offset to its axis of motion. In this way the nozzles depositing into a particular well or pixel are able to deposit in a range of positions across the well or pixel, assisting an even dispersion of the deposited material over the pixel (or well) area. However the directions should preferably be sufficiently aligned for all the drops making up a pixel to land within the pixel envelope. Dispersing the drops slightly over the area of a pixel assists in the formation of an even film before drying begins and pinning occurs.

One or other or both of the print head and substrate may be moved and, preferably, the relatively motion of the print head and substrate is aligned to an axis of pixel repetition (not corresponding to an X or Y axis of the printer), whether or not the print head nozzles are aligned exactly to the axis of motion.

If drop volume averaging using a plurality of nozzles is insufficient for a desired uniformity of total deposited volume per pixel, a subset of the nozzles may be employed for deposition. Thus an initial, relatively crude measurement of drop volumes from each nozzle may be made and used to remove the outliers, that is nozzles with drop volumes very different from the average. Thus the deposition may use a subset of the nozzles with drop volumes matched to within a tolerance threshold. This would increase the print time (in proportion to the number of "missing" nozzles) but, by contrast with a conventional technique the speed reduction is small. (When printing in swathes, omitting to use the middle nozzle of a print head row paths the swathe width and doubles the printer time). Thus embodiments of a method according to the invention are also relatively little affected by blocked and/or faulty nozzles.

The method may also include driving the print head at a variable rate to eject the droplets. Thus, for example, where the print head is clocked the clock rate may be increased between pixels when sending data for non-ejection of droplets, say strings of zeros. Alternatively a "drop eject on demand" type of print head may be employed, such as the XJ126, XJ128 or XJ500 print heads from Xaar of Cambridge, UK, which provide such a feature (sometimes termed "cycle trigger"). In this latter case data need only be sent to the print head when a nozzle or jet is to fire to eject a droplet, so that no

data (or string of zeros) need be sent when the nozzle is not to eject droplets. This helps overcome electrical limitations in the print head drive and, in embodiments, allows an average print frequency, per nozzle, which is similar to that achieved by conventional printers operating in swathe mode. Thus overall deposition time may be little different to that achieved by swathe mode printers.

In another aspect the invention provides a printer controller for controlling a printer to deposit material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in solvent onto said substrate, a first direction being defined substantially parallel to said substantially linear arrangement of orifices, the printer controller being configured to control said printer to move one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that the majority of said orifices pass over a single said pixel; and eject droplets of material from orifices of said majority of orifices as the orifices pass over the said pixel.

The invention also provides a printer controller for controlling a printer to deposit material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in a solvent onto said substrate, a first direction being defined substantially parallel to said substantially linearly arranged orifices, the controller comprising data memory operable to store deposition data; an instruction memory storing processor implementable instructions; and a processor coupled to the data memory and to the instruction memory and operable to process said deposition data in accordance with the instructions, the instructions comprising instructions for controlling the printer to move one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that a plurality of said orifices passes over a single said pixel; and eject droplets of material from orifices of the plurality of said orifices as the orifices pass over the said pixel, in accordance with said deposition data.

Preferably 3 or more, more preferably 5 or 10 or more of the orifices pass over a single pixel and selected ones or each of these orifices may be used for deposition onto the pixel.

The above-described method and printer controllers may be implemented using processor control codes such as conventional program code or code for setting up or controlling an ASIC (Application Specific Integrated Circuit) or FPGA (Field Programmable Gate Array). This processor control code may be provided on a carrier medium such as a hard or floppy disk, CD- or DVD-ROM, programmed memory such as read only memory (Firmware), or on a data carrier such as an optical or electrical signal carrier. As the skilled person will appreciate such code may be distributed between a plurality of couple components in communication with one another, for example across a network.

These and other aspects of the invention can now be further described, by way of example only, with reference to the accompanying figures in which:

Figures 1a and 1b show, respectively, cross sections through organic light emitting diode and a passive matrix OLED display;

Figures 2a and 2b show, respectively, an ink jet printer and an ink jet printer head;

Figures 3a to 3c show, respectively, conventional swathe printing, skewed printing for reduced dot pitch, and typical ink jet drop volume variations across a print head;

Figure 4 shows drop drying with edge pinning;

Figure 5 shows a cross-section through a nozzle plate illustrating development of tail hooking;

Figure 6 shows a top view of a print head and substrate illustrating a printing strategy according to an embodiment of the present invention;

Figure 7 shows a timing diagram for driving nozzles of the print head of Figure 6;

Figures 8a and 8b show, respectively, a printing process with a skewed head direction, and a schematic diagram of a result of this deposition process;

Figures 9a to 9c show examples of pixel patterns and print head motion directions; and

Figure 10 shows a general purpose computer system configured for implementing a printer controller for controlling a printer in accordance with an embodiment of an aspect of the present invention.

Referring now to Figure 6, this shows a top view of a print head and substrate, illustrating a printing strategy according to an embodiment of the present invention.

A substrate 600 has a plurality of positions or regions 602 at which it is desired to deposit molecular electronic material such as polymer material for a polymer OLED. The positions of regions 602, which hereafter will be termed pixels or wells, are defined by data in a deposition data file locally stored in a controller for the printer. Typically pixels 602 coincide with wells formed within substrate 600. Where such wells are present the print head may be aligned with the substrate by means of, for example fiducial markers on the substrate identifiable by sensors on the print head, or by means of the mechanical stops 250 mentioned with reference to Figure 2a above.

In Figure 6, as above, the print head is denoted by reference numeral 222 and the print head nozzles by reference numeral 227. In the illustrated print head a single row 228 of nozzles is present but print heads with a plurality of parallel rows of nozzles may be also be employed although in such cases it becomes more difficult to align rows of nozzles with pixels. Since, broadly speaking, the row pitch needs to be substantially the same as the pixel pitch for reasons which will become apparent when the operation of the technique is described. Substrate 600 typically comprises a substantially non-absorbent material such as, for OLED displays, glass, clear plastics such as polyethylene or PET or other materials such as polyvinylidene fluoride or polyimide. In an OLED display pixels 602 are typically around 50 μ m wide (in a direction

perpendicular to nozzle row 228) and 40-50 μ m long in a colour display or approximately three times in a monochrome display. The pixel spacing is typically 10-20 μ m. By contrast the print head 222 is typically around 1cm wide (in a direction perpendicular to nozzle row 228) and a few centimetres long (along the length of nozzle row 228). It will therefore be appreciated that Figure 6 is not to scale.

In operation print head 222 is in the direction indicated by arrow 604, preferably along an axis of pixel repetition. Nozzle row 228 may be aligned with direction 604 or offset at a slight angle to this direction. As the print head 222 moves over pixel 602a each of nozzles 227 move over the pixel in turn and each of several nozzles is thus able to fire one drop of dissolved material for deposition on to the pixel (or into the well) in turn in rapid succession, thus providing an averaged out volume of dissolved material very quickly whilst ensuring that the last drop is deposited before the first start to dry. The use of more than one nozzle to deposit onto a pixel (or into a well) averages the variations in the volumes of drops provided by different nozzles and also addresses the electrical and hydraulic limitations on nozzle firing rate described above.

Typically 5 and 10 nozzles are used for deposition into a pixel, but fewer (for example 2 or 3 nozzles) or more (for example 20, 50 or 100) nozzles may be employed. Thus, for example, nozzles A, B, C, D and E in Figure 6 may be employed for successive drop deposition into pixel 602a and nozzles further along row 228 may be used for deposition into pixel 602b. However to ease timing constraints it is generally preferred to interleave the nozzles used for deposition into different pixels so that, for example nozzles 1, 21, 41, 61 and 81 all fire into pixel 602a, nozzles 2, 22, 42, 62 and 82 fire into pixel 602b and so on. It will be appreciated that, in practice, the length of nozzle row 228 will span a plurality of pixels and thus deposition may occur into a plurality of pixels simultaneously (that is, into all the pixels spanned by row 228).

Figure 7 shows an exemplary set of waveforms for driving print head nozzles A to E for a mode of operation in which nozzles A to E all fire into pixel 602a. Binary values 702 show data input to each of nozzles A to E according to a constant frequency clocking scheme. It can be seen that each nozzle receives a binary "1" indicating that the nozzle is to eject a drop of dissolved material, followed by a string of "0"s during which is

quiescent. The corresponding driving waveforms 704 (voltage against time) are shown in the lower portion of Figure 7. With a scheme in which nozzles firing into different pixels are interleaved similar waveforms are provided but with different relative timings for drop ejection signals (binary "1"s). It can be appreciated that the string of "0"s may be clocked into the print head at substantially the maximum rate at which the print head can accept data for a nozzle and thus the clock frequency for the print head may be varied so that the frequency is increased between pixels or between firings. Alternatively, as can be appreciated from waveforms 704, a drop-on-demand type of firing scheme can be employed in which a pulse is only provided to a nozzle when a drop is to be ejected. This latter scheme avoids having to send strings of "0"s and thus potentially allows an increase in throughput of actual firing data. It will be appreciated that these potential improvements arise from the character of the pattern being printed (separated pixels or regions) which is different from conventional graphics printing.

An ink jet printing machine such as that described above with reference to Figure 2 may be employed for the deposition, mounting the substrate so that the pixel axis is coincident with an X or Y axis of the machine.

Figure 8a shows a variant of the method described with reference to Figure 6 in which the row 228 of nozzles 227 of the print head 222 is offset at an angle to the direction 604 in which the print head moves. Figure 8b shows a result of this process. As with Figure 6, Figures 8a and 8b are not to scale.

It is helpful in achieving a uniform deposition of material into a pixel to deposit drops of dissolved material across the width of a pixel. This can be achieved by angling the row of nozzles in a direction 800 at a slight angle to the direction 604 of motion of the print head so that as nozzles 227 successively pass over a pixel drops are deposited at different positions across the width of the pixel. Figure 8a indicates a simplified diagram of this process, and the result of the successive firing of nozzles 227 is illustrated in Figure 8b in which droplets 802 (not to scale) vary in position from one side of the pixel to the other side of the pixel as the length of the pixel is traversed.

In practice to allow the use of substantially all of the nozzles of a print head direction 800 is chosen such that substantially all the nozzles in a row 228 lie within the width of a single pixel (otherwise nozzles at one and/or the other end of a row would lie in the space between pixels. For example, with a $50\mu\text{m}$ pixel width and $30\mu\text{m}$ drop width, direction 800 may be chosen such that there is a lateral difference in position of approximately $20\mu\text{m}$ between the first and last pixel of a row 228 so that the drops span the width of a pixel. It will be appreciated that the angle between directions 604 and 800 will be very small (it is exaggerated in Figure 8a, for clarity) and the nozzle row will be almost straight on to the head motion 604 and hence to the pixel axis to which direction 604 is aligned. Where nozzles firing into each pixel are not interleaved, for example according to the simplified representation of Figure 6, greater angles are possible, but again these are not preferable because a significant fraction of the nozzles would lie over non-deposition areas. Thus directions 604 and 800 are preferably substantially aligned, that is either exactly aligned or at only a very small angle, for example so that substantially all the nozzles fall within the width of a pixel envelope, that is within the lateral boundary of a pixel.

Figures 9a to 9c show some examples of pixel patterns and head motion directions. Figure 9a shows a pixel pattern suitable for an OLED or other electroluminescent display, in which print head 222 may be scanned along the X direction to deposit materials for successive pixels and then stepped in the Y direction in readiness for scanning the next row of pixels. Figure 9b shows a pixel pattern for a molecular electronics device such as a device incorporating polymer FETs (Field Effect Transistors). Again, in a similar way to Figure 9a, the pixel pattern may be built up by scanning rows in the X-direction, stepping in the Y direction in a raster pattern. Figure 9c shows a hexagonal arrangement of pixels, for example for a display, in which the direction 604 in which the print head is moved may be 1 (or more) of directions W, X and Y.

Figure 10 shows a general purpose computer system configured for implementing a printer controller to control a printer to operate according to the above-described methods.

Referring to Figure 10, the computer system 100 includes a data and control bus 1002 to which are connected a processor 1012, working memory 1014, data memory 1016, programme memory 1018, and a key board and pointing device 1008 and a display 1010 for providing a user interface. Also coupled to bus 1002 are a network interface device 1006 for interfacing to a local area network for exchange of data such as deposition data files, print head drive circuitry 1020, print head X Y motion control circuitry 1022 and ancillary control circuitry 1024. Data in program memory 918 and/or data memory 916 may be written to and/or read from portable storage media, illustratively shown by floppy disk 1004.

The print head drive circuitry 1020 provides an electrical drive to the print head via a serial or parallel bus within umbilical 204 of Figure 2a to control to drop ejection from the print head. The X-Y motion control circuitry 1022 also connects to umbilical 204 to provide X-Y drive control signals, for example to stepper motors and, optionally, to receive feedback, for example from shaft encoders. Ancillary control circuitry 1024 provides ancillary control functions, for example position detection/calibration and Z-direction head motion control. Circuitry 1020, 1022 and 1024 may comprise cards within the general purpose computer system or separate hardware. Permanent program memory 1018 includes head-substrate motion control code for controlling the motion of the print head relative to the substrate, print head driver code for driving the print head to eject droplets of solved material for deposition, optional head skew adjust code for adjusting an angle of the print head to a direction of motion of the print head, deposition data management code, for example for loading, saving and/or modifying deposition data, operator interface code for providing a user interface for an operator, and operating system code. Processor 1012 loads and implements this code to provide the corresponding functions. Data memory 1016 stores deposition data files, preferably in non-volatile memory, specifying a pixel pattern and volumes of material to deposit, for example at a map of desired deposited volume by location. The code in program 1018 interprets this map to control the printer to deposit dissolved material according to the map. Working memory 1014 is used by processor 1012 for temporary calculations for this purpose.

No doubt many other effective alternatives will occur to the skilled person and it will be understood the invention is not limited to the described embodiments and encompasses modifications apparent to those skilled in the art lying within the spirit and scope of the claims appended hereto.

CLAIMS:

1. A method of depositing material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the method employing a printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in a solvent onto said substrate, a first direction being defined substantially parallel to said substantially linear arrangement of orifices, the method comprising:
 - moving one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that the majority of said orifices pass over a single said pixel in turn;
 - ejecting droplets of material from orifices of said majority of orifices as the orifices pass over the said pixel; and
 - repeating said moving and ejecting to build up said pattern
2. A method as claimed in claim 1 wherein substantially all said orifices pass over said single pixel.
3. A method as claimed in claim 1 or 2 wherein said second direction substantially coincides with said first direction.
4. A method as claimed in claims 1, 2, or 3 wherein said pixels of said pattern define at least one pixel repetition axis and wherein said second direction substantially coincides with said pixel repetition axis.
5. A method as claimed in claim 4 wherein said moving comprises repeatedly scanning in said second direction to build up said pattern.
6. A method as claimed in any preceding claim further comprising driving said print head at a variable rate to eject said droplets.
7. A method as claimed in any preceding claims wherein said pixels comprise regions of active organic electronic devices.

8. A method as claimed in claim 7 wherein said active organic electronic devices comprise organic light emitting diodes.

9. Processor control code to control a printer to implement the method of any preceding claim.

10. A carrier carrying the processor control code of claim 9.

11. A printer controller for controlling a printer to deposit material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in solvent onto said substrate, a first direction being defined substantially parallel to said substantially linear arrangement of orifices, the printer controller being configured to control said printer to:

move one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that the majority of said orifices pass over a single said pixel; and

eject droplets of material from orifices of said majority of orifices as the orifices pass over the said pixel.

12. A printer controller for controlling a printer to deposit material for an electronic device onto a substrate in a pattern comprising a plurality of pixels, the printer having a print head with a plurality of substantially linearly arranged orifices for ejecting droplets of said material dissolved in a solvent onto said substrate, a first direction being defined substantially parallel to said substantially linearly arranged orifices, the controller comprising:

data memory operable to store deposition data;

an instruction memory storing processor implementable instructions; and a processor coupled to the data memory and to the instruction memory and operable to process said deposition data in accordance with the instructions, the instructions comprising instructions for controlling the printer to:

move one of said print head and said substrate relative to the other in a second direction sufficiently close to said first direction that a plurality of said orifices passes over a single said pixel; and

eject droplets of material from orifices of the plurality of said orifices as the orifices pass over the said pixel, in accordance with said deposition data.

13. A printer controller as claimed in claim 11 or 12 wherein substantially all said orifices pass over said single pixel.
14. A printer controller as claimed in claim 11, 12 or 12 wherein said second direction substantially coincides with said first direction.
15. A printer controller as claimed in any one of claims 11 to 14, wherein said pixels of said pattern define at least one pixel repetition axis and wherein said second direction substantially coincides with said pixel repetition axis.
16. A printer controller as claimed in claim 11 further configured to drive said print head at a variable rate to eject said droplets.
17. A printer controller as claimed in claim 12 wherein said instructions comprise instructions for driving said print head at a variable rate to eject said droplets.
18. A printer controller as claimed in any one of claims 11 to 17 wherein said pixels comprise regions of active organic electronic devices.
19. A printer controller as claimed in claim 18 wherein said active organic electronic devices comprise organic light emitting diodes.
20. A data carrier carrying the processor implementable instructions of claim 12.

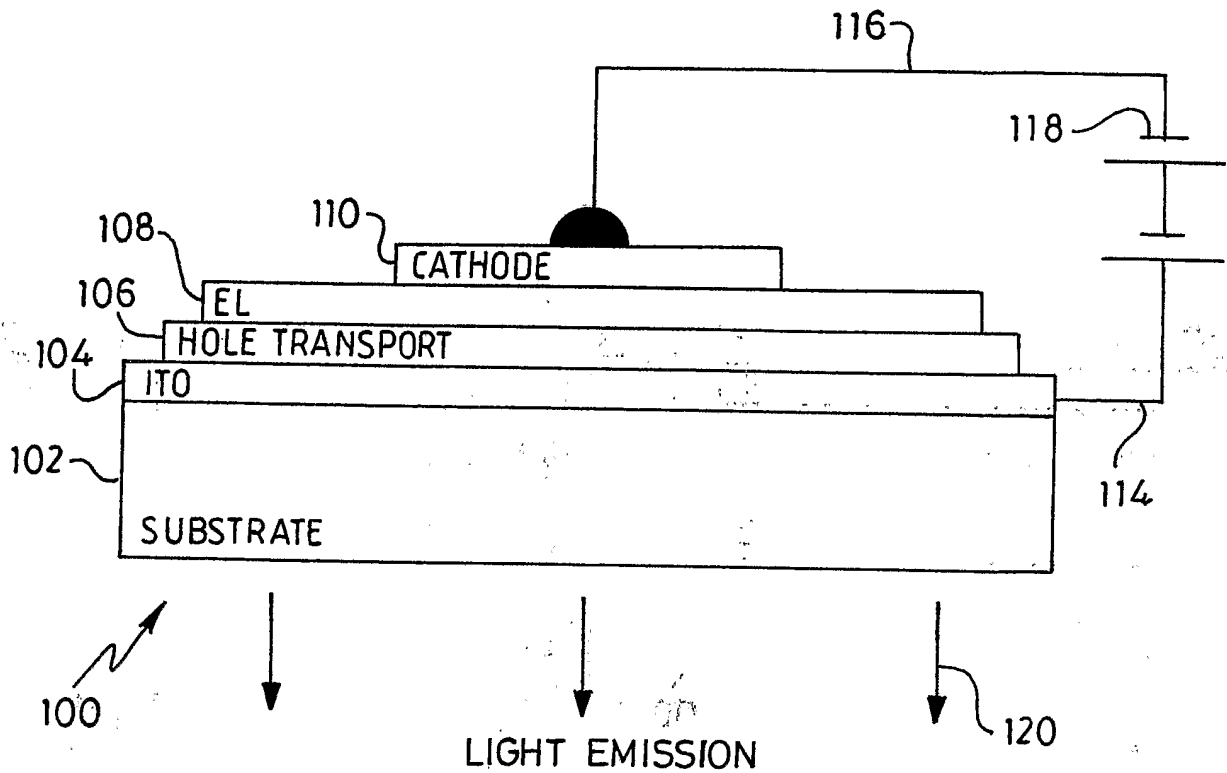


Fig. 1a
(PRIOR ART)

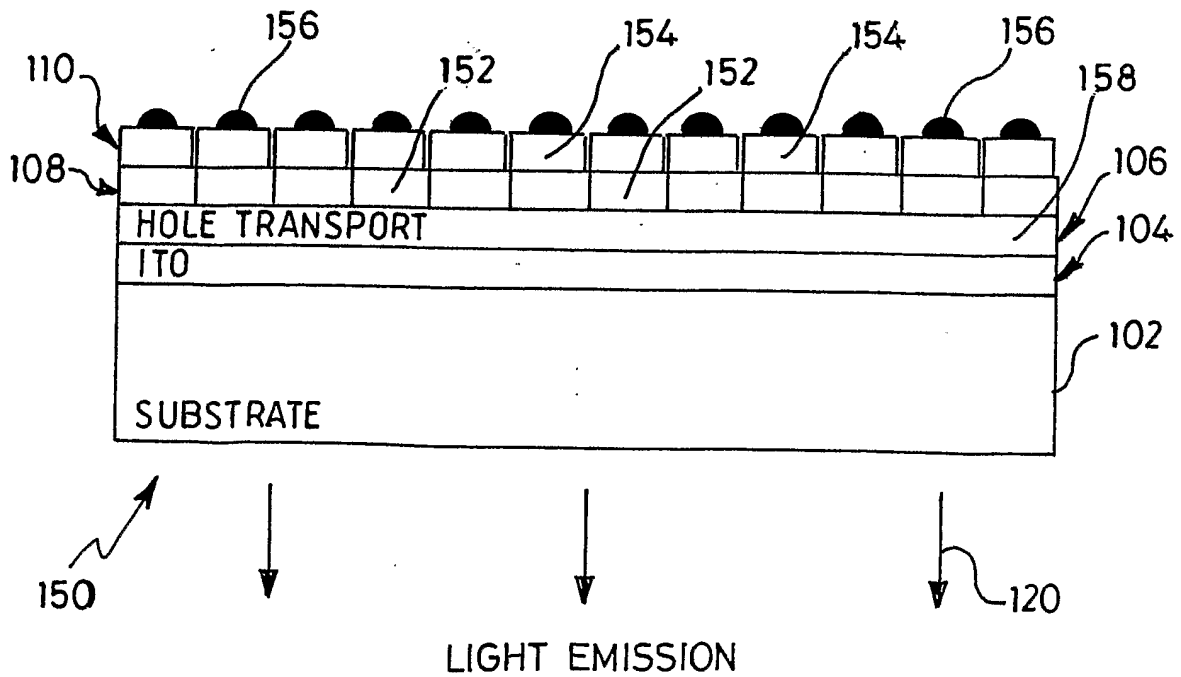


Fig. 1b
(PRIOR ART)

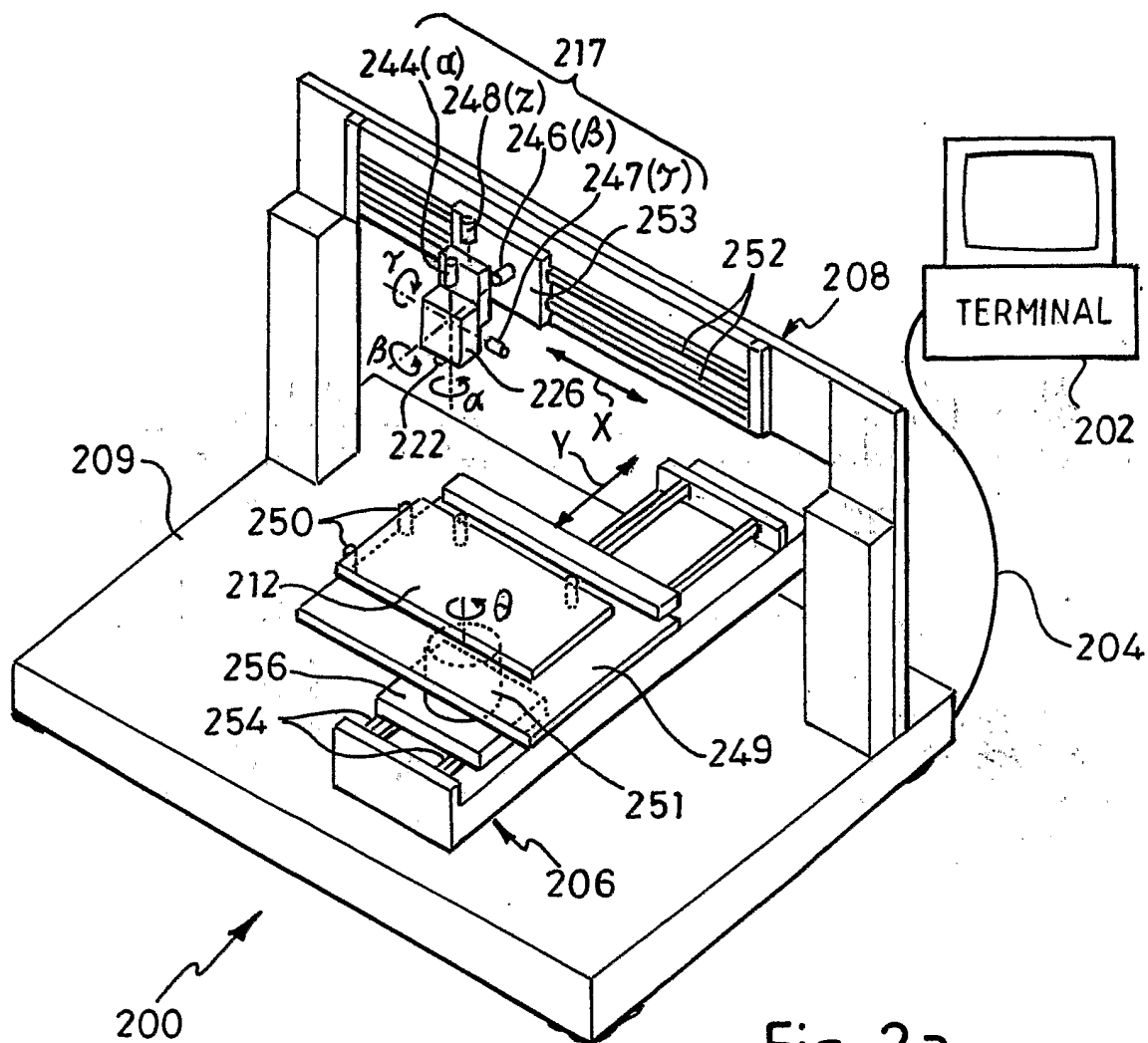


Fig. 2a

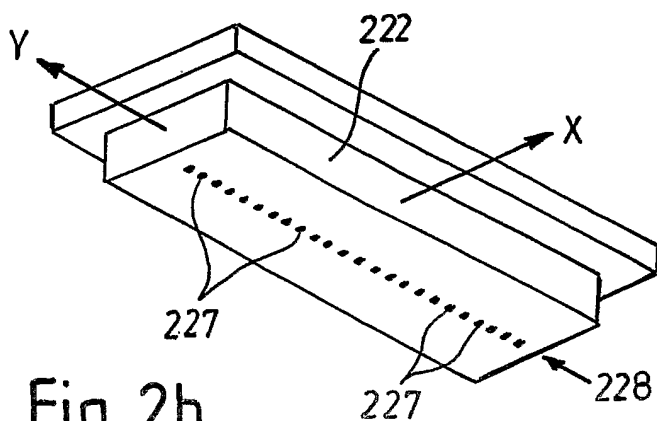


Fig. 2b

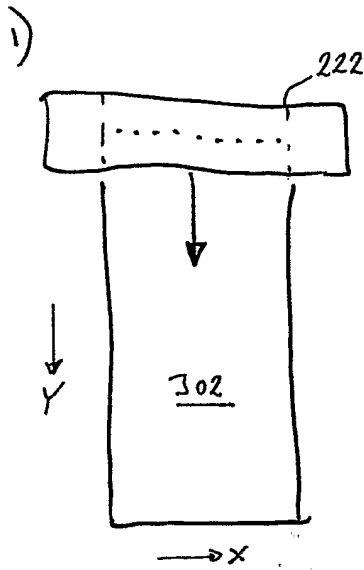


FIGURE 3A

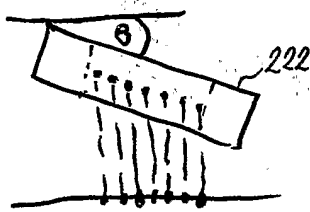
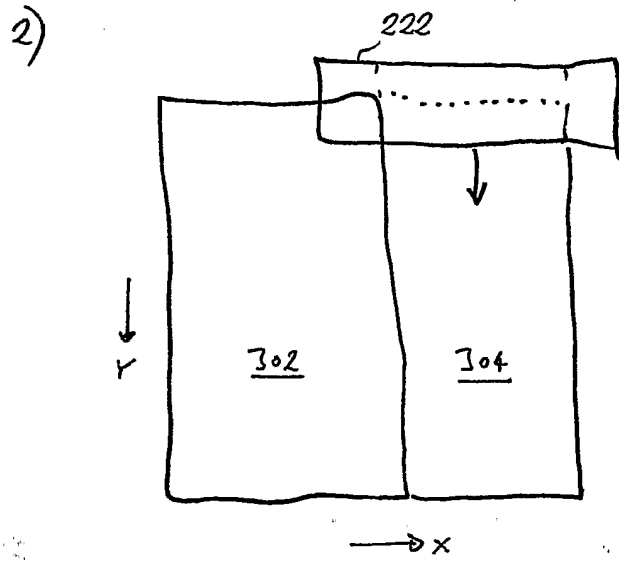


FIGURE 3B

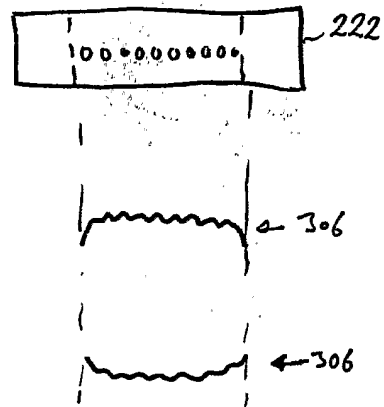


FIGURE 3C

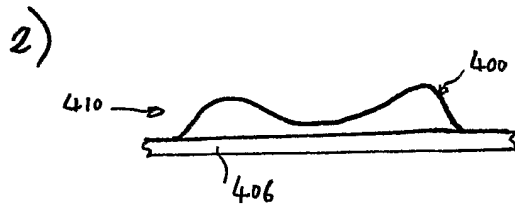
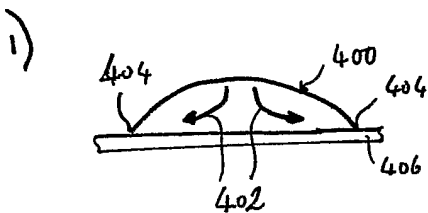


FIGURE 4

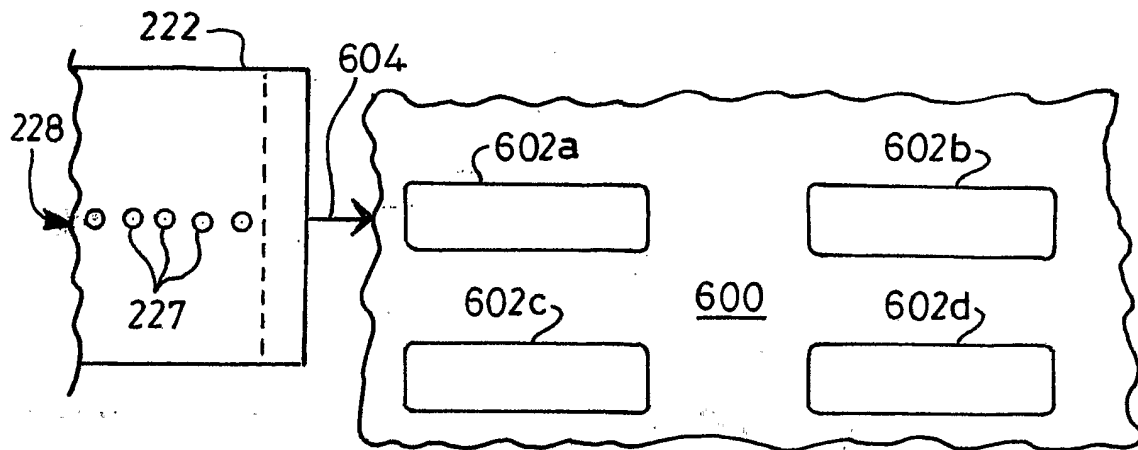


Fig. 6

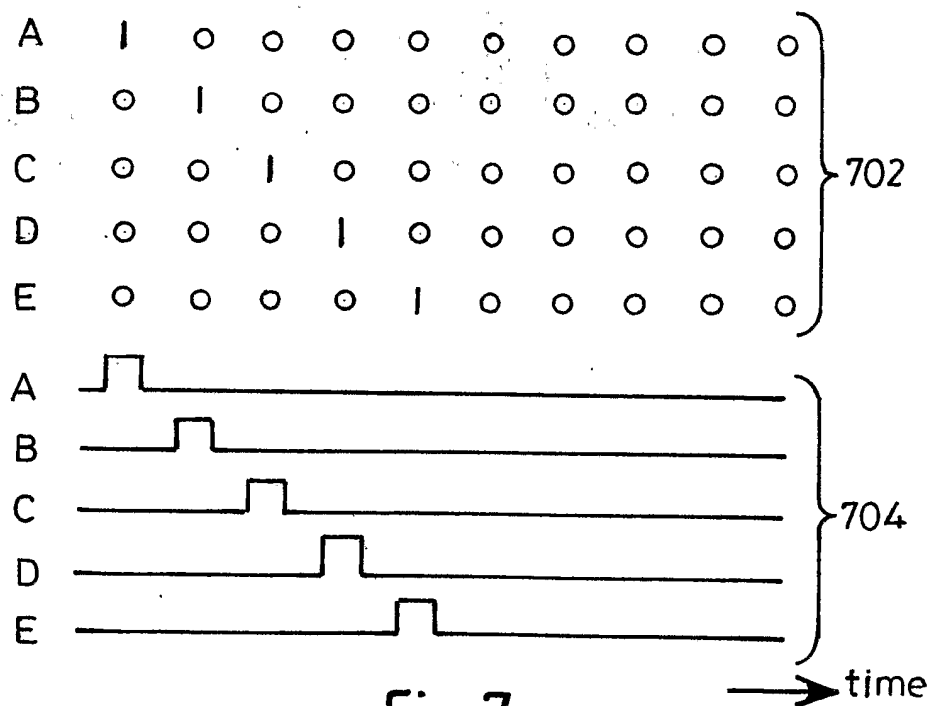


Fig. 7

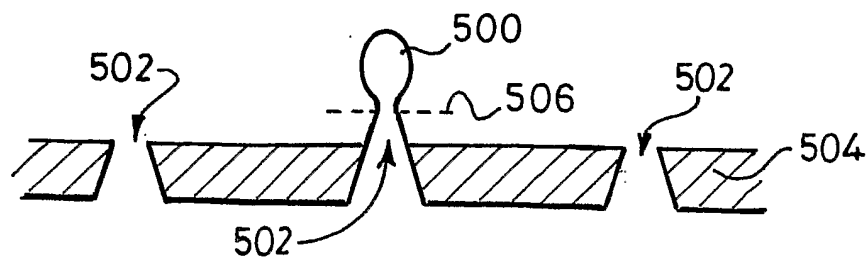


Fig. 5

