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(54) Method and apparatus for ink transfer printing.

(57) An ink transfer printing device in which ink transfer is controlled by a viscosity change in ink includes an ink reservoir (2) for retaining ink held under pressure. The ink reservoir (2) is associated with an ink transfer surface (4) which has a plurality of perforations (6). Under ambient conditions, the viscosity of the ink prevents flow of the ink through the perforations (6). The ink transfer printing device also includes a viscosity control unit (8, 20, 25, 26, 32, 38, 42, 46) for inducing a change in the viscosity of the ink near certain perforations thereby enabling a controlled amount of the ink near each of these certain perforations (6) to flow through these certain perforations to an outer surface of the ink transfer surface (4). Techniques for controlling the ink dot size using concentric regions (72, 74, 76, 78, 80, 82) about each of the perforations (6) are disclosed. The ink which has flowed onto the outer surface can then be transferred to an intermediate surface (54) or a printing media (10). A method for viscosity-driven ink transfer printing is also disclosed. The present invention enables a printer, a copier, or the like to provide low cost, high speed, high resolution printed images.

The present invention relates to the field of ink transfer printing and, more particularly, to ink transfer printing which is driven by a viscosity change in ink.

Over the years, many attempts have been made to develop a printing technique with a simple mechanical structure. The hope being that such a printing technique would lead to reliable, low cost products. For one reason or another, known printing techniques have not been able to fully satisfy these goals.

Known thermal printing techniques have certain drawbacks. Direct thermal printing, for example, requires special heat sensitive paper. Thermal transfer printing inefficiently uses ink ribbons, which leads to higher cost for ribbon usage, especially for color printing. Another disadvantage of thermal printers is that their printing speed is too slow for large volume printing.

Ink jet printing has many advantages, but continues to have some reliability concerns. A major disadvantage of ink jets, namely bubble-type ink jet devices, is that deposits form in the nozzles when the organic compounds in the ink break down at high temperatures (e.g., 350°C). The high temperatures are needed to produce the bubbles which cause a drop to be ejected. As a result, the bubble-type ink jets tend to have a clogging or crusting problem at the nozzles. Another disadvantage of ink jets is that the ink used must have a low viscosity (e.g., typically <10 centipoise) which severely limits the type and variety of inks which may be used. The printing speed of ink jets is also too slow for large volume printing.

Additional background information on known printing techniques may be found in "Computer Graphics - Technology and Applications," Vol. II - "Output Hardcopy Devices," by Robert C. Durbeck and Sol Sherr, San Diego 1988.

In Hori, U.S. Patent 4,608,577, an ink jet type thermal printing machine is described. The printing machine includes a film or belt having a plurality of holes which correspond to the conventional ink jet nozzle. The holes in the film or belt are filled with ink. The ink in the holes is then heated (vaporized) until bubble pressure causes the ink to be jetted out onto paper.

In Bupara, U.S. Patent 4,675,694, a printer is described. The printer includes a perforated printing plate, individual heaters, and an ink container. The ink utilized is a phase-change or hot-melt ink which is a solid at room temperature. The printer operates on the principle that when a portion of the solid ink contained in the holes of the printing plate is heated, it undergoes a volume expansion (due to its change from a solid state to a liquid state) which causes ink to protrude out of the holes which have been heated. After the ink has been expanded in certain holes, a printing medium is brought into contact with the liquified ink for transfer thereto. The printing medium must be brought into contact with the liquified ink before the ink is allowed to cool. Alternatively, the printing medium may be placed in contact with the printing plate prior to the volume expansion.

In Cielo et al., U.S. Patent 4,275,290, a thermally activated liquid ink printer is described. The printer includes an ink reservoir having a plurality of orifices. The driving force of the printer is the application of localized heat to ink in an orifice which causes at least partial vaporization of the ink and/or reduction in the surface tension. As a result, ink flows out of the orifices being heated. Preferably, the heating produces bubbles which cause ink drops to be ejected. Alternatively, the heating acts only to reduce surface tension which causes ink to flow through the orifices being heated. This alternative operation uses a hydrostatic pressure which is less than the surface tension of unheated ink at the ink surface.

In Cielo et al., U. S. Patent 4,164,745, a method is described for varying the amount of ink deposited on a sheet of paper moving past an orifice based on the viscosity of the ink. For example, the width of a line being printed can be controlled. The method described is unable to completely control the flow of ink. That is, the flow of ink is continuous. It is only the amount of ink flowing which is variable. In this regard, Cielo et al. ('745) provides a bypass to prevent the continuous flow of ink from flowing out of an orifice across a gap onto paper, but only while the viscosity is above a predetermined value. The ink which does flow out from an orifice must cross a gap before it reaches the paper.

As will become more apparent below, the present invention provides a novel and nonobvious technique for printing which has the potential for a wide range of applicability. The present invention overcomes many of the disadvantages of known printing techniques because it has not only a simple and reliable design, but also the ability to use a wide variety of inks to achieve high resolution printing. The technology associated with the present invention is applicable to printers, digital copiers, video printers, facsimile machines, etc. Color and gray scale printing or copying are also available with this technology.

Furthermore, the known prior art failed to appreciate the advantages and benefits of viscosity driven printing. The present invention can easily and accurately control printing by altering the viscosity of the ink. Such control is superior to that provided by bubble, phase-change or surface tension driven printing. Cielo et al. ('745) assumes that the ink always flows through the orifices, and attempts to control the amount of ink deposited on paper using ink viscosity. Bupara operates on volume expansion solid ink as its phase changes from solid to liquid. The Bupara technique is very cumbersome and time consuming in that it requires a large number of procedures to transfer ink to paper. Cielo et al. ('290) operates either in a vaporization mode in which ink is

ejected out of orifices across a gap to paper or in a surface tension and pressure mode in which ink under pressure flows out of orifices when heat is applied to the orifices. The vaporization mode of Cielo et al. is similar to a bubble-type ink jet and, therefore, very dissimilar to the present invention. The surface tension and pressure mode of Cielo et al. has questionable operability. Namely, it is unclear how ink transfer will take place because the paper never contacts the orifice plate. Furthermore, it would be very difficult, if not impossible, to construct a practical printer which relies on surface tension to control the printing process.

Although it is known that surface tension and viscosity vary with temperature, the magnitude of change between surface tension and viscosity is drastically different. Table 1 (below) shows that the viscosity change of fluids resembling ink is quite drastic over an 80°C temperature change in comparison to the slight change in surface tension. The well known fluids of glycerol and ethylene glycol are used to model characteristics of inks which would be useful in the present invention.

TABLE 1

	VISCOSITY (cps)		SURFACE TENSION (dyne/cm)	
Temperature (Celsius)	20	100	20	100
Glycerol	1410	16	63.3	~60
Ethylene Glycol	~19	2.3	48.43	41.31

As shown in Table 1, the magnitude of change in viscosity far exceeds the change in surface tension. This large magnitude of viscosity change provides a high level of control which is necessary to manufacture a reliable, low cost product. In contrast, a device relying on surface tension would be difficult to control because the magnitude of change in surface tension over a reasonable temperature change is not significant from a design or engineering standpoint.

In sum, the known prior art fails to appreciate the benefits and advantages of a printer which is driven by a viscosity change in ink.

In the present invention, an ink transfer printing device includes an ink reservoir for retaining ink held under pressure. The ink reservoir is associated with an ink transfer surface which has a plurality of perforations. The operating principle of the present invention is to drive the ink transfer process by changing the viscosity of the ink near certain of the perforation. The viscosity of the ink near each of the perforations can be changed using a number of techniques, including thermal, magnetic and electric techniques.

Under ambient conditions, the viscosity of the ink prevents flow of the ink through the perforations of the ink transfer surface. However, a change in viscosity of the ink near certain of the perforations causes a controlled amount of the ink near each of these certain perforations to flow through these certain perforations and onto the ink transfer surface. That is, the ink flows only after the viscosity of the ink is changed.

The ink which has flowed onto the ink transfer surface forms ink dots on the ink transfer surface above these certain perforations. The ink dots can then be transferred to a printing media, thereby printing an image. The ink dots may be transferred by contacting the printing media with the ink transfer surface. Alternatively, it may be preferable to initially transfer the ink dots to an intermediate surface and, thereafter, transfer the ink dots from the intermediate surface to the printing media.

Moreover, if the spread of the ink dots on the ink transfer surface is controlled, then improved printing results. By providing the ink transfer printing device with at least one concentric region on the ink transfer surface about each of the perforations, the spread of the ink can be accurately controlled. The concentric regions form flow barriers which impede the spread of the ink at each orifice. The improved dot size control provided by the present invention enables the printing device to improve print quality.

The present invention offers a number of benefits, including the following. The printing technique of the present invention is capable of high speed and high resolution printing. In addition, the printing technique can perform gray scale toning, continuous toning and full color printing when printing an image. The printing technique of the present invention can also achieve excellent print quality on a variety of printing media using a wide range of inks. Moreover, the printing technique can be engineered to print a character, a line, or a page

at a time.

The present invention will be readily understood by the following description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

FIG. 1 is a three-dimensional diagram of a perforated ink transfer device which includes an ink reservoir and a perforated sheet according to the present invention;

FIG. 2 is a three-dimensional diagram illustrating a small printhead in comparison to a page to be printed;

FIG. 3 is a three-dimensional diagram illustrating a line printhead in comparison to a page to be printed;

FIG. 4 is a cross-sectional diagram of a perforated ink transfer device in a non-printing state;

FIG. 5A is a cross-sectional diagram of a perforated ink transfer device in a printing state;

FIG. 5B is a detailed cross-sectional diagram of an orifice of the ink transfer device illustrated in FIG. 5A;

FIGS. 6A-6D are schematic diagrams illustrating various techniques for supplying thermal energy to selective orifices;

FIG. 7 is a top view diagram illustrating a matrix of wires connected to resistors which are coupled to each of the orifices;

FIGS. 8A and 8B are cross-sectional diagrams illustrating embodiments for applying an electrical field to selective orifices;

FIG. 9 is a cross-sectional diagram illustrating an embodiment for applying a magnetic field to selective orifices;

FIG. 10A is a top view diagram illustrating an ink channel formed under a perforated sheet;

FIG. 10B is a side view diagram illustrating the ink channel shown in FIG. 10A;

FIG. 11 is a top view diagram illustrating an ink channel formed under a circular printhead;

FIG. 12 is a three-dimensional diagram illustrating an ink transfer system which includes an ink transfer area and a post treatment area;

FIGS. 13A-13E are three-dimensional diagrams illustrating structural implementations for a color ink transfer device;

FIG. 14 is a three-dimensional diagram illustrating an ink transfer system which uses an intermediate transfer surface;

FIG. 15 is a cross-sectional diagram illustrating a rectangular ink reservoir which includes a pressurized chamber and a piston to pressurize the ink;

FIG. 16A is a three-dimensional diagram illustrating a cylindrical-shaped ink reservoir which includes an inner cylinder, a pressurized chamber and a piston to pressurize the ink;

FIG. 16B is a cross-sectional diagram of the cylindrical-shaped ink reservoir illustrated in FIG. 16A;

FIG. 17 is a detailed top view diagram of the ink transfer device illustrated in FIG. 1 showing concentric rings disposed about each orifice; and

FIG. 18 is a detailed cross-sectional diagram of an orifice of the ink transfer device having etched rings.

FIG. 1 illustrates a perforated ink transfer device 1 which includes an ink reservoir 2 and an ink transfer surface 4 (contact surface). The ink reservoir 2 retains ink which is used for printing. The ink transfer surface 4 has a plurality of orifices 6. Each orifice 6 of the ink transfer surface 4 corresponds to an ink dot which may be printed on a printing media.

Before explaining the detailed operation of the ink transfer device 1, it is useful to discuss the physical features of the ink reservoir 2 and the ink transfer surface 4. Generally speaking, the size, shape and construction of both the ink reservoir 2 and the ink transfer surface 4 are very flexible.

More particularly, in FIG. 1, the ink transfer surface 4 is a flat perforated sheet. However, various other perforated surfaces may be used (see e.g., FIGS. 11, 13A-13E). Hence, the size and shape of the ink transfer surface 4 is not critical. For example, the ink transfer surface 4 may be cylindrically shaped with a circumference which is less than, equal to, or greater than, the length of a page.

It may be preferable to size the ink transfer surface 4 so that it slightly exceeds the size of a page of paper (i.e., page size ink transfer surface). A page size ink transfer surface 4 would increase printing speed by transferring ink a page at a time. Printing a page at a time is typically faster than printing a character or line at a time because the printing media need only contact the ink transfer surface 4 once every page. On the other hand, as illustrated in FIG. 2, the ink transfer device 1 may form a printhead 8 in which the length and width of the ink transfer surface 4 may be relatively small compared to the size of a page. In such case, the printhead 8 must contact a printing media 10 several times for each page to be printed (see dashed lines in FIG. 2). The printhead 8 can also have a variety of sizes and shapes. For example, as illustrated in FIG. 3, the printhead could be a line printhead 12 which would print a line at a time.

Thus, the physical features of the ink transfer device 1 are not critical. Hence, the size, shape and configuration of the ink transfer device 1 (ink reservoir 2 and ink transfer surface 4) can be designed for specific applications.

The present invention is able to achieve a wide range of resolutions, namely, from a low resolution of 10 dpi (dots per inch) to a very high resolution in excess of 1000 dpi. Each dot corresponds to an orifice 6 in the ink transfer surface 4. Consequently, an ink transfer device having 600 dpi will have 36,000 orifices per square inch.

Although the shape of the orifices 6 shown in FIG. 1 is circular, the shape of the orifices 6 is not critical. For example, the orifices 6 could be oval or square. The size of the orifices 6 in the ink transfer surface 4 ranges from 10 μm to 200 μm depending on the printing resolution desired. The thickness of the orifices 6 ranges from 10 to 500 μm , depending on the resolution and applications desired. The orifices 6 are formed by micromachining processes, such as laser ablation, wet etching or plasma etching, which are generally known in the semiconductor processing art.

The ink transfer surface 4 (e.g., perforated sheet) can be made from a wide variety of materials. More particularly, the perforated sheet 4 can be formed from a stainless steel mesh screen, electroformed of nickel, or made from processed polyimide (e.g., KAPTON or UPILEX from E.I. DuPont Company and Ube Company of Japan, respectively).

The operation of the ink transfer device 1 is explained in detail below.

In FIG. 4, a cross-sectional view of an ink transfer device 1 in a non-printing state is illustrated. The ink reservoir 2 contains ink 14. The viscosity of the ink 14 at room temperature is preferably greater than 20 centipoise (cps). A wide variety of inks including inexpensive commercial ones are able to (or can be easily made to) satisfy the viscosity requirement of the present invention. A pressure inlet 16 to the ink reservoir 2 places a positive pressure on the ink 14. The amount of pressure on the ink 14 is dependent on the viscosity of the ink 14 and the geometry of the orifices 6. For example, in experiments using glycerol with 50 μm orifice diameter and 125 μm thickness, the inventors successfully used an applied pressure on the order of 8-20 Torrs. Preferably, the applied pressure is constant so that the volume of ink within each ink drop is constant.

The viscosity of the ink 14 at room temperature is normally high so that the ink transfer device 1 is normally in the non-printing state. That is, due to the high viscosity of the ink 14 within the ink reservoir 2, the pressurized ink 14 will not flow through the orifices 6 of the ink transfer surface 4. In a technical sense, over several years some flow within the orifices 6 may be observed, but the flow would not be noticeable to the eye.

Accordingly, in the non-printing state, ink does not flow or protrude out of the orifices 6 of the ink transfer surface 4 even though a positive pressure is applied via the pressure inlet 16. That is, for a particular ink 14 being utilized, the applied pressure is not so great as to cause the ink to flow through the orifices 6 while at room temperature. Thus, regardless of whether the printing media 10 is brought into contact with the ink transfer surface 4, no ink can be transferred to the printing media 10 while the ink transfer device 1 is in the non-printing state.

On the other hand, the ink transfer device 1 can be switched to a printing state wherein ink can be selectively transferred to the printing media 10. The device 1 switches from a non-printing state to a printing state on an orifice-by-orifice basis by locally changing the viscosity of the ink associated with each orifice 6.

When the normally high viscosity of the ink 14 is reduced, the ink 14 having the lowered viscosity flows through the orifices 6 onto the ink transfer surface 4 to form an ink dot. Although the ink 14 with the reduced viscosity may flow onto the ink transfer surface 4 by capillary action, the ink 14 within the ink reservoir 2 should be pressurized with a small positive pressure via the pressure inlet 16. The pressure applied to the ink reservoir 2 is set such that it is sufficient to push the ink with the reduced viscosity through the orifices 6, but not so high as to cause the non-reduced viscosity ink to flow through the orifices 6. The ink transfer process is explained in more detail with reference to FIG. 5A,

FIG. 5A is a cross-sectional diagram of an ink transfer device 1 in a printing state. FIGS. 4 and 5A are basically the same structurally except that the device in FIG. 5A includes divergent orifice walls as well as thermal barriers 17 which are discussed in more detail below. Although the orifice walls shown in FIG. 5A are divergent, the orifice wall could also be convergent or straight as shown in FIG. 4. The orifices 6 could also be divergent.

In FIG. 5A, three orifices 6 of the ink transfer surface 4 are illustrated. However, as shown in FIG. 5A, ink has flowed to the ink transfer surface 4 only through the middle orifice 6. The ink which has flowed onto the ink transfer surface 4 via the middle orifice 6 is transferred to the printing media 10 by bringing the printing media 10 into contact with the ink transfer surface 4 of the ink transfer device 1. The ink transfer surface 4 is then devoid of any ink (although some microscopic residue will exist) and may be reused immediately.

In FIG. 5A, only the viscosity of the ink 14 near the middle orifice 6 has been reduced. As a result, the ink 14 near the middle orifice 6 was able to flow through the middle orifice 6 onto the ink transfer surface 4 primarily due to the pressure applied via the pressure inlet 16. On the other hand, the viscosity of the ink 14 near the left and right orifices 6 has not been reduced and, therefore, remains high enough to prevent the applied pressure from pushing the ink through the left and right orifices 6. Thus, as shown in FIG. 5A, the ink 14 near the left and right orifices 6 has not flowed to the ink transfer surface 4.

FIG. 5B is a detailed view of an orifice 6 of the ink transfer device 1 shown in FIG. 5A. FIG. 5B is provided to explain what is meant by lowering the viscosity of the ink which is near (or in close proximity to) a particular orifice. In FIG. 5B, an orifice 6 is shown partially filled with ink and directly coupled to the ink reservoir 2 below the orifice 6. The dot-dash line (a) provided in FIG. 5B indicates the portion of the ink 14 in which the viscosity is reduced, that is, the ink which may be deemed near the orifice 6. However, in practice, other portions of the ink which are further from the orifice 6 will also undergo a viscosity change but to a lesser extent. Nevertheless, the idea is to reduce the viscosity of the ink beginning with the ink closest to the orifice 6 so that a predetermined amount of ink will flow through the orifice 6 to the outer surface of the ink reservoir 2 to produce an ink dot having a particular size. Depending on the technique used, orifice size, viscosity of ink at ambient conditions, pressure, size of ink dot desired, etc., the actual operating parameters can easily be determined experimentally.

It is important that the viscosity of the ink 14 be reduced only near the orifices 6 from which ink 14 is to flow. By selectively reducing the viscosity of the ink 14 near the orifices 6 from which an ink dot or pixel is desired, an image can be printed. That is, each orifice 6 represents an ink dot on the printed image. If the viscosity of the ink 14 near a particular orifice has been reduced, an ink dot will be produced on the printed image at a location corresponding to the particular orifice. On the other hand, if the viscosity of the ink 14 near the particular orifice has not been reduced, no ink dot will be produced on the printed image at the location corresponding to the particular orifice.

The ink, which has flowed to the ink transfer surface 4, remains on the ink transfer surface 4 until transferred to the printing media 10. That is, the reduced viscosity ink which has flowed to the ink transfer surface will not retreat back into the orifices from which it came, regardless of whether the viscosity of the ink returns to its normal viscosity level.

Consequently, the ink transfer process performed by the present invention is viscosity driven. Specifically, the viscosity of the ink is utilized as a switch. Normally, at ambient conditions, the viscosity of the ink is sufficiently high with respect to the applied pressure to prevent flow of the ink (i.e., switched off). On the other hand, at operating conditions, an ink dot is produced on a printed image (i.e., switched on) when the viscosity of ink near the orifice corresponding to the dot is lowered.

The viscosity of ink has the following functional relationships:

$$\text{VISCOSITY} \equiv f[T, E, H, \text{pH}, hv],$$

where T is temperature, E is electric field, and H is magnetic field. Hence, the viscosity of the ink near certain orifices 6 can be lowered a number of different ways, including increasing temperature, applying an electric or magnetic field, lowering pH, and increasing hv. Temperature and hv are closely related in that increasing light intensity is one method of increasing temperature. Although it is critical that the viscosity of the ink be lowered, the method or technique used to lower the viscosity is not critical.

Regardless of the technique utilized, for reliable viscosity control, it may be preferable that the localized viscosity reduction be at least 50%. At room temperature (ambient conditions), the ink can be a solid ink or any viscous ink whose viscosity is greater than 10 cps. Preferably, the viscosity of the ink is greater than 100 cps. However, at operating conditions, the ink becomes a low viscosity liquid. Typically, the viscosity of the ink at operating conditions ranges from 1-100 cps. However, higher viscosities may be used if a corresponding higher pressure is applied.

Ambient conditions are defined as conditions in which the ink transfer device 1 is in a non-printing state. For example, at ambient conditions, no external exciting energy (thermal, electrical or magnetic) is applied to the device 1. As a result, all the ink within the ink transfer device 1 would be at room temperature or some actively controlled temperature. Operating conditions, on the other hand, are defined as conditions in which the ink transfer device 1 is in a printing state. For example, at operating conditions, external energy (thermal, electrical or magnetic) is applied to the device 1. The ink may or may not be at room temperature depending on the type of energy applied.

The ink composition is selected based on the method used to change the viscosity of the ink. For example, in an embodiment which uses a magnetic field to induce the change in viscosity, the ink contains magnetic toner like materials. Likewise, in an embodiment which uses an electric field to induce the change in viscosity, the ink is an electrorheological fluid such as described in "Design of Devices Using Electrorheological Fluids," SAE Technical Paper Series, #881134, by T. Ducios of Lord Corporation (1988).

In an embodiment which thermally induces a reduction in viscosity, the ink may be composed of: colorant 2-10% (by weight); carriers(s) 93-60%; additives 5-30%. The colorant can be either dye or pigments. The carrier or vehicle materials can be waxes, monomers, oligomers or polymers. The waxy materials, for example, include natural waxes such as carnauba wax and synthetic waxes such as stearic acid derivatives. The monomeric, oligomeric and polymeric carrier materials include acrylic, vinyl derivatives, ester type of monomers and copolymers. The carrier materials also include glucose derivatives and rosin derivatives. The vehicle or carrier

can also be a mixture of a solvent such as water and a viscous liquid such as glycol series (ethylene glycol, diethylene glycol, propylene glycol, butanediol, glycerol, etc.) and polyethylene glycol series. The ink vehicle or carrier can also include commercial lithographic, screen printing, gravure ink. The additives include, for example, various types of surfactant and viscosity reducers, hardening and toughening agents, optical property (transparency) and solubility improver of dyes. Additives may not be a critical requirement. Nevertheless, the purpose of the additives is to modify the viscosity and surface tension of the ink so as to improve print quality and system reliability.

One way to control the viscosity of the ink 14 is with temperature. At room temperature, the ink 14 preferably has a viscosity of at least 20 cps. However, as the temperature of ink 14 increases, the viscosity of the ink 14 decreases. Table 1 shows the magnitude of viscosity change over 80°C temperature change for several fluids representative of inks. Namely, the viscosity of glycerol was reduced by about 95%, and the viscosity of ethylene glycol was reduced about 70%.

Thus, the application of localized heat will act to induce the flow of ink 14 from the ink reservoir 2 to the ink transfer surface 4 via the orifices 6. More particularly, the application of heat to certain orifices causes the ink near these orifices to be heated. The heating of the ink lowers the viscosity of the ink. When the viscosity of the ink falls below a critical level, the applied pressure causes the heated ink to flow through the corresponding orifices to the ink transfer surface 4.

FIGS. 6A-6D illustrate various structures which may be used to locally heat the ink 14 near certain of the orifices 6 to thereby lower its viscosity.

In FIG. 6A, a thermal printhead 8 is shown having a heating element 18. The heating element 18 is placed near (preferably over) each of the orifices 6 from which an ink dot is desired. When so placed, the heating element 18 acts to heat the ink near the orifice 6 over which the printhead 8 is placed by providing a heat flux to the ink contained in the orifice 6. The heated ink then flows to the surface of the ink transfer surface 4 (perforated sheet) where it remains until transferred to the printing media 10. Therefore, a printed image can be produced by moving the thermal printhead 8 over each of the orifices 6 from which an ink dot is desired.

One significant advantage of the present invention is that the printhead 8 may heat each of the orifices 6 for an entire page before transferring any of the ink produced thereby to the printing media 10. This is because once the ink has flowed onto the ink transfer surface 4 via a particular orifice 6, the ink which has so flowed need not remain heated. That is, the ink may cool once it reaches the ink transfer surface 4 because it will not drain back into the orifice 6 from which it came. Thus, the ink will remain on the ink transfer surface 4 until it is transferred to the printing media 10. This advantage occurs regardless of the method used to induce the viscosity reduction (e.g., T, E, H, pH, hv). As a result, the size of the printhead 8 can vary from very small such that only the ink near a single orifice would be heated at a time (see FIG. 6A) to very large such that all of the orifices could be heated at the same time. A reasonable compromise of speed and cost would lead to a printhead 8 somewhere in between the two extremes, perhaps a line printhead such as illustrated in FIG. 3.

In FIG. 6B, heaters 20 (resistors) and thermal conductors 22 are used to provide the thermal energy necessary to selectively lower the viscosity of the ink 14 near certain orifices 6. Although the heaters 20 are shown as being attached to the under side of the ink transfer surface 4 at each orifice 6, the heaters 20 may be positioned in any manner provided each is closely associated with an orifice 6. For example, the heaters 20 may be recessed within the perforated sheet 4 itself.

Preferably, each heater 20 has a thermal conductor 22 coupled thereto to facilitate the transfer of heat from the heater 20 to the ink 14 in the corresponding orifice. It is preferable to symmetrically heat the ink near an orifice 6 to obtain uniform heating. For example, the heater 20 could have either a ring shape or four small heaters could be equally spaced around each orifice.

FIG. 7 illustrates a layer of an ink transfer surface 4 having coaxial resistors 20' at each orifice 6 connected together in matrix fashion by wires 24. FIG. 7 also illustrates a control unit/energy source 25 for controlling the supply of electrical energy to the resistors 20'.

The ink transfer surface 4 is made from a wide variety of materials such as ceramics, glass, plastic, etc. The wires 24 enable each coaxial resistor 20' to be individually addressed so that electrical energy can be supplied to those coaxial resistors 20' which correspond to orifices 6 from which an ink dot is desired. The heaters 20 and 20' as well as the wires 24 can be formed by thick film or thick film processes which are well known techniques.

The back side of the ink transfer surface 4 (perforated sheet) may include a thin-film structure consisting, for example, of a glass substrate, a resistor layer, metallic electrical conductors, and a passivation layer. The thin-film structure is similar to that of a ThinkJet® printhead which is well known in the art and described in detail in Volume 36, No. 5 of *Hewlett-Packard Journal*, particularly the article entitled "Development of the Thin-Film Structure for the ThinkJet Printhead" beginning on page 27 of that journal. However, since ink bubble

generation is not required, the thin-film structure for the present invention is more simplified. Unlike an ink jet device which positions the resistor layer on the substrate and below the orifices, the present invention positions the resistor layer so that the heat produced thereby is very close to the orifices 6. For example, in FIG. 6B, the heaters 20 are coaxial with the orifices and affixed to the inner surface of the ink transfer surface 4. Alternatively, the heaters 20 could be placed either in the orifices themselves or on the outer surface of the ink transfer surface 4. This embodiment can sufficiently lower the viscosity of the ink in the orifices in about 100 microseconds. Further, the thermal conductors 22 may be utilized to assist in heating the ink within the orifices.

The electrical energy supplied to the heaters is dependent on a number of parameters, e.g., the composition of the ink, resistance, voltage, pulse width, and period. These parameters can be readily determined for specific designs. Even so, it is believed that a thermal embodiment (FIG. 6B) which uses a glycerol based ink could be successfully operated using heaters with a resistance between 5 and 200 ohms, and applied pulses with a voltage between 0.5 and 50 volts and a pulse width between 5 μ sec and 4 msec.

FIGS. 6C and 6D illustrate that the thermal energy may be supplied to the ink near the orifices 6 using light (hv). The light can, for example, be provided by a laser beam, an infrared lamp, a flash lamp, an ultraviolet lamp, or an incandescent lamp. In FIG. 6C, a laser 26 produces a laser beam which is reflected from a mirror 30 to a given orifice 6 of the ink transfer surface 4. This type of set-up can easily and rapidly address each of the orifices 6 of the ink transfer surface 4 so that the ink may be locally heated by the laser beam. In FIG. 6D, an infrared light (IR) source 32 and a reflective housing 34 are used to focus infrared light to the orifices 6 of the ink transfer surface 4. Other types of light sources may be utilized to heat the ink in the orifices.

Alternative ways to control the viscosity of the ink 14 involve applying an electric field (E), applying a magnetic field (M) field, or lowering pH. Since lowering pH is closely related to applying an electric field (i.e., the application of an electric field operates to lower pH), this way will not be separately discussed.

FIGS. 8A and 8B illustrate embodiments of the present invention in which an electric field is produced to induce the reduction in viscosity. In FIG. 8A, electrodes 38-1, 38-2 are provided on the under side of the ink transfer surface 4. The electrodes 38-1, 38-2 are connected by conductors 40 to an AC generator 42. The AC generator 42 operates, under the control of a control unit (not shown), to induce an electric field E in the orifice 6 of the ink transfer surface 4 to thereby reduce the viscosity of the ink 14 near the orifice 6. In FIG. 8B, the electrodes 38-1, 38-2 are orientated differently. In particular, the electrode 38-1 is an upper electrode and electrode 38-2 is a lower electrode 40. In addition, thermal barriers 17 (described below) are provided in this embodiment. Many other electrode configurations can be used to produce the necessary electric field. For example, a roller or platen which provides the printing media 10 to the ink transfer device 1 could even be used as an upper electrode.

FIG. 9 illustrates an embodiment of the present invention which provides a magnetic field (H) to selective orifices to induce a reduction in viscosity. This embodiment is structurally similar to FIG. 8A except that coils 46-1, 46-2 are used instead of electrodes 38-1, 38-2. The coils 46-1, 46-2 can be fabricated using techniques which are used in producing magnetic recording thin film heads. When the coils 46-1, 46-2 are activated by the AC generator 42, a magnetic field H is produced in the orifice 6. The magnetic field H causes a reduction in the viscosity of the ink near the orifice 6. Many other configurations are possible so long as a magnetic field is produced near the orifice.

An optional feature of the present invention is to thermally isolate the ink 14 at each of the perforations. Thermal isolation improves the performance of the ink transfer device by decreasing heat loss to surrounding ink and guarding against cross-talk between the orifices 6.

The ink transfer device 1 illustrated in FIG. 5A includes thermal barriers 17 which serve to provide thermal isolation between nearby orifices 6. More particularly, the barriers 17 function to decrease heat loss to the surrounding ink within the ink reservoir 2 and to guard against cross-talk between neighboring orifices. The barrier 17 shown in FIG. 5A is coaxial with the middle orifice 6 so as to thermally isolate the ink 14 near the middle orifice 6 from the ink near other orifices. The barrier 17 extends from the inner surface of the ink transfer surface 4 downward about 50 μ m into the ink reservoir 2. The barriers 17 can be made using a number of conventional techniques, such as etching, deposition, or a photo-imagable dry film resist (e.g., RISTON or VACREL, which are trade names for polymer materials of the E.I. DuPont Company of Wilmington, Del.). The depth and configuration of the barriers 17 discussed above are not critical.

The structural design of ink channels within an ink reservoir can also provide thermal isolation between orifices. Namely, by isolating portions of the ink in ink channels which feed ink to certain orifices, some thermal isolation of the ink occurs. FIGS. 10A, 10B and 11 illustrate examples of ink channels 48 which may be used to provide thermal isolation between orifices 6. In such cases, the ink reservoir 2 is a main supply for the ink and the ink channels 48 receive ink from the main supply.

In FIG. 10A, the ink channels 48 supply ink 14 to orifices 6. As a result, the ink associated with a particular

orifice is thermally isolated from other orifices 6. FIG. 10B illustrates a side view of the ink channel 48 shown in FIG. 10A. The ink 14 within the ink reservoir 2 is supplied to an orifice 6 via the channel 48. Within the ink channel 48, ink initially flows up from the reservoir 2 and then over to an orifice 6. Hence, the ink 14 is supplied to the orifice 6 in a direction which is perpendicular to the direction in which ink 14 flows out of the orifice 6 during a printing state.

FIG. 11 illustrates a top view of a circular printhead 4, 8 in which the orifices 6 are arranged in a circular pattern. The ink channel 48, shown in FIG. 11, supplies ink 14 to all of the orifices 6 of the printhead 4, 8. Again, like FIGS. 10A and 10B, the ink 14 is applied to the orifices 6 in a direction which is perpendicular to the direction in which ink 14 flows out of the orifice 6 during a printing state. The construction of the ink chamber 48 shown in FIG. 11 is further advantageous in that the pressure of the ink 14 at each orifice 6 is the same. On the other hand, using the construction of the ink chamber 48 shown in FIGS. 10A and 10B the pressure of the ink 14 at the orifices 6 is not as evenly distributed because a plurality of channels 48 are used and the ink path to each orifice 6 is not always the same length. Further, although the channels 48 reduce cross-talk, they also require a greater pressure than embodiments shown in FIGS. 4 and 5 which lack such channels.

Another optional feature of the present invention is a post treatment area where the ink which has transferred to the printing media 10 would be rapidly fixed. FIG. 12 illustrates an ink transfer system which includes an ink transfer area and a post treatment area. The ink transfer area contains the ink transfer device 1 which has been described in detail above. The printing media 10 is supplied to the ink transfer area where the ink transfer device 1 acts to transfer ink to the printing media 10. At this point, the printing media 10 contains a printed image but the ink may be wet or tacky. Moreover, the image may not be durable and is often embossed. Hence, fixing or curing the images on the printing media 10 may be necessary. Next, the printing media 10 having the ink is delivered to the post treatment area where a thermal ink fixing unit 50 is provided. The thermal ink fixing unit 50 uses heat to fix and/or fuse the ink to the printing media 10. A wide range of thermal ink fixing units 50 may be employed. For example, the heat of the thermal ink fixing unit 50 could be provided by a laser beam, a light source, a heated roller or platen, or an oven. An additional advantage of using the heated roller or platen is that by slightly pressurizing the rollers the images may be flattened out.

A further optional feature of the present invention is use of colored ink. More particularly, the present invention can be easily adapted to color printing. Since the present invention can use such a wide variety of inks, all that is really needed is to change the color of the ink within the ink reservoir. For example, on a basic level, the ink transfer device 1 can print in any color ink which is placed in the ink reservoir 2. However, to obtain full color printing, inks corresponding to the three primary colors of cyan, magenta and yellow as well as black must be simultaneously provided. Hence, full color printing can be provided by pre-aligning four ink transfer devices 1 relative to one another, each device having a different color ink. The construction of such a device would be relatively simple compared to existing color printers. Further, the numerous advantages of the present invention would remain, namely high resolution, inexpensive production and simple construction.

FIGS. 13A-13E illustrate several structural implementations for a color ink transfer device 52. However, it is important to note that the color ink transfer device 52 can have many different sizes and shapes. FIG. 13A illustrates a page-width linear array embodiment in which the device 52 can print the width of the printing media 10 in each of four colors. The pagewidth linear array includes a cyan chamber 1a, a magenta chamber 1b, a yellow chamber 1c and a black chamber 1d. Each chamber 1a-1d supplies colored ink to a distinct group of orifices 6 which correspond to the particular chamber. That is, the cyan chamber 1a supplies cyan colored ink to the orifices 6a, the magenta chamber 1b supplies magenta colored ink to the orifices 6b, the yellow chamber 1c supplies yellow colored ink to the orifices 6c, and the black chamber 1d supplies black ink to the orifices 6d. Thus, by combining the ink from the various chambers, full color printing is achieved.

FIG. 13B illustrates a full-page array embodiment in which ink chambers 1e-1h enable the color ink transfer device 52 to print one page at a time in each of the three primary colors as well as black. In this embodiment, each of the ink chambers 1e-1h is slightly larger than a page to be printed. FIG. 13C illustrates a cubic array in which each side surface is an ink transfer device 1 with an ink chamber 1i-1l having a different colored ink. FIG. 13D illustrates a curved cubic array having colored ink chambers 1m-1p. FIG. 13E illustrates a cylinder array having colored ink chambers 1q-1t. The size and shape of the ink chambers 1a-1t is flexible, but dependent on the configuration of the color ink transfer device 52 desired.

Another optional feature of the present invention is the use of an intermediate transfer surface. FIG. 14 illustrates an ink transfer device 1 which uses an intermediate transfer surface 54 to assist in transferring the ink from the surface of the ink reservoir 2 to the printing media 10. As discussed above, an advantage of the present invention is that a wide variety of printing media 10 may be used, including plain paper and transparencies. However, since the present invention is able to operate with a wide variety of printing media, the paper quality and absorptivity could vary significantly. As a result, it may be desirable to first transfer the ink on the outer surface of the ink reservoir 2 to the intermediate transfer surface 54.

For example, FIG. 14 shows a cylindrical-shape ink reservoir 2 contacting a cylindrical-shape intermediate transfer surface 54. The intermediate transfer surface 54 will have a known quality and absorptivity such that the ink will cleanly transfer to the intermediate transfer surface 54. That is, virtually none of the ink will remain on the outer surface of the ink reservoir 2. As an example, the outer surface of the intermediate transfer surface 54 can be made of a polymer material such as mylar or rubber. Further, the size of the intermediate transfer surface 54 need not be similar to that of the ink reservoir 2.

Once the ink is on the intermediate transfer surface 54, the ink can be transferred to the printing media 10 by contacting the printing media 10 with the intermediate transfer surface 54 using any of a number of techniques. FIG. 14 shows the ink being transferred to the printing media 10 using a roller 56 which presses the printing media 10 against the intermediate transfer surface 54. After the ink is transferred to the printing media 10, the intermediate transfer surface 54 is cleaned off to remove any residue ink which did not transfer. A rubber doctor blade (not shown) may be used to perform the cleaning off process.

Still another optional feature of the present invention is perhaps a preferred way to pressurize the ink reservoir 2. According to this feature, the ink reservoir 2 is itself pressurized without any need for a pressure inlet 16 (see FIG. 4). FIGs. 15, 16A and 16B illustrate implementations of this feature. The ink reservoir 2 further includes a piston 58, a pressurized inner chamber 60 and an ink chamber 61, but no longer includes a pressure inlet 16. The piston 58 is fitted with an o-ring 62 so that the ink chamber 61 is isolated from the pressurized inner chamber 60. The pressure applied by the pressurized inner chamber 60 causes the piston 58 to move toward the ink transfer surface 4 as the ink flows out from the orifices 6 during printing.

FIG. 15 illustrates this feature in a rectangular ink reservoir, while FIGs. 16A and 16B illustrate this feature with respect to a cylindrical-shaped ink reservoir. With respect to the cylindrical-shaped ink reservoir, an inner cylinder 64 is also needed. In this case, the piston 58 and o-ring 62 contact the inner cylinder 64 as shown in FIG. 16B. The inner cylinder 64 is also shorter than the cylindrical-shaped ink reservoir 2. As ink flows from the orifices 6 during printing, the piston 58 will move so as to expand the pressurized chamber 60 and reduce the volume of the ink chamber 61. This piston movement pushes ink out of the ink chamber 61 and towards the orifices 6 via channels 66 (see FIG. 16B). Hence, the ink is pressurized using the pressurized chamber 60. Although the pressure applied to the ink will decrease as the quantity of ink within the ink chamber 61 decreases, the device can be constructed so that the pressure variation is within an acceptable range of operation.

Yet another optional feature of the present invention is to control of the size of the ink dots produced. Image quality can be improved not only by increasing resolution, but also by using halftone techniques. The information content of a halftone image goes beyond resolution and includes different dot sizes and maybe even different shapes of the ink dots. As an example, a 150 dot per inch (dpi) image with 16 dot sizes will have a quality comparable to a 600 dpi image having a single dot size. Hence, to produce high quality printed images using an ink transfer printing device 1, it is desirable to consistently control not only the volume of ink which flows from an orifice 6 onto the ink transfer surface 4, but also the spread of the ink which has flowed onto the ink transfer surface 4. By controlling the spread of the ink dots, images produced using continuous toning and multi-color printing will have excellent print quality.

The volume of ink which flows through an orifice 6 can be regulated by controlling the quantity and duration of applied viscosity-reducing energy. Basically, the more energy applied, the greater the volume of ink which flows. The viscosity-reducing energy is typically supplied by thermal, electrical or magnetic means. For example, in a thermally activated system, a light source or resistive heater element heats the ink near a particular orifice 6. To increase the volume of ink which flows through the particular orifice 6 and onto the ink transfer device 1, the pulse width, voltage and/or period may be increased. The result is an ink dot with a greater volume of ink.

When the volume of the ink dot is increased, the spread of the ink on the ink transfer surface 4 becomes more of a consideration. If the volume of ink within the ink dot is small, then the spread of the ink dot is not a major concern. However, as the volume of the ink dot is increased, the spread of the ink becomes more of a concern. The spread of the ink dot is particularly important when printing various sizes of dots to obtain continuous toning or when mixing various colors of ink for multicolor printing.

Furthermore, when printing in multiple colors, it is advantageous to control both the spread and volume of the ink at each orifice. Colored inks can be mixed in numerous ways when both the volume and spread are controlled. For example, if one had a color ink transfer printing device and wanted to print a magenta pixel with a red center, the following steps might occur. First, a large volume of magenta ink would be placed on the ink transfer surface via an orifice. The spread of the magenta ink would also be controlled to insure that the ink was uniformly spread a relatively large predetermined radius out from the orifice. The magenta ink dot would then be transferred to an intermediate surface or a printing media. Next, a small volume of yellow ink would be placed on the ink transfer surface. The spread of the yellow ink on the ink transfer surface would

be controlled to insure that it spread only a relatively small predetermined radius out from the orifice. The small yellow dot would then be transferred to the intermediate surface or printing media at the center of the larger magenta dot. The yellow ink dot would then mix with the magenta ink so as to produce a red center in the magenta dot. Thereafter, the ink would be fixed to the printing media.

Thus, by controlling the spread of ink at each orifice 6 (so called "ink dot spread"), better and more visually appealing print quality can be obtained. Namely, continuous gray scale toning can be achieved by controlling the ink dot spread. In addition, in a color ink transfer printing device, various colored inks can be uniquely mixed by controlling both the volume and the ink dot spread for each color of ink.

Two embodiments for controlling ink dot spread are described below. A first embodiment provides rings of alternating wet and non-wet surfaces on an ink transfer surface 4. A second embodiment provides etched grooves in an ink transfer surface 4.

According to the first embodiment, alternating rings of wet and non-wet surfaces are provided around each orifice 6 of the ink transfer surface 4. FIG. 17 illustrates a top view of an ink transfer surface 4 according to a first embodiment. The ink transfer surface 4 shown in FIG. 17 contains nine orifices 6. The orifices 6 are 50 μm in diameter and spaced apart from each other by 100 μm center to center. Around each orifice 6 are three wet rings 72 and two non-wet rings 74. Each of the rings has a width of 5 μm . The number, size and shape of the rings shown in FIG. 17 are illustrative and not limitations on the invention. For example, the shape of the rings 72, 74 could be oval or square.

The wet and non-wet rings 72, 74 form flow barriers which impede the ink dot spread. Namely, at each transition from a wet ring 72 to a non-wet ring 74, the ink dot seeking to spread out from an orifice will encounter a flow barrier. The barrier results from the transition from a low surface tension region to a high surface tension region. The barrier impedes the ink dot spread until the volume of ink builds up to overcome the barrier.

One way to make the wet and non-wet rings 72, 74 is to coat the portion of the ink transfer surface 4 corresponding to certain rings with wetting or non-wetting materials. For example, the wet and non-wet rings can be made by applying a chemical coating to certain portions of the ink transfer surface 4. With respect to aqueous ink, examples of wetting chemicals are silicon dioxide and aluminum oxide. Examples of non-wetting chemicals are fluorocarbon compounds such as fluorolipathic polymeric esters (e.g., FC-430 by 3M Company).

If the top surface of the outer ink transfer surface 4 is normally a non-wet surface such as fluorocarbon (e.g., TEFLON) for aqueous inks or polyimide (e.g., KAPTON produced by E.I. DuPont Company), a coating of a wetting chemical such as silicon dioxide may be deposited using a plasma enhanced chemical vapor deposition process to form wet rings 72. In particular, the wetting agent is deposited on concentric regions of the top surface about each of the orifices 6. The concentric regions of the wetting agent so deposited form the wet rings 72. Although the concentric regions have a common center, the concentric regions of the wetting agent which are deposited do not contact one another. That is, the concentric wet regions formed by the wetting agent are separated by concentric non-wet regions. Since the top surface is non-wet, no surface treatment is required to form the non-wet rings 74. Hence, the non-wet rings 74 are identified when the wet rings 72 are formed.

Another way to make the wet rings 72 is to modify concentric regions of the ink transfer surface 4. These surface modifications can be performed using conventional methods. One conventional method exposes the concentric regions of the ink transfer surface 4 to a gas plasma. For example, assuming the ink transfer surface 4 is a non-wet surface such as KAPTON, with the exception of the concentric regions of the ink transfer surface 4, the entire surface of the ink transfer surface 4 is shielded with a mask. The ink transfer surface 4 is then exposed to a gas plasma which changes the unmasked portion of the surface to wet rings 74. Examples of the gases which may be used are oxygen plasma, CH_4/O_2 plasma or ion implantation.

According to the second embodiment, concentric regions are etched into the ink transfer surface 4. FIG. 18 illustrates a detailed cross-sectional view of an ink transfer surface 4 according to the second embodiment.

In FIG. 18, the concentric regions are etched rings 76, 78. The etched rings 76, 78 have a width of 1 μm and a depth less than 0.2 μm . The number, depth and width of the etched rings 76, 78 shown in FIG. 18 are illustrative and not limitations of the invention. The etched rings 76, 78 control the ink dot spread. Although the ink transfer surface 4 should be non-wet, the etched rings 76, 78 may be either wet or non-wet. The etched rings 76, 78 can be formed on the ink transfer surface 4 using conventional methods, such as reactive ion etching, ion beam milling or excimer laser ablation.

This embodiment restricts the ink dot spread using the non-wet surface of the ink transfer surface. Once the etched rings 76, 78 are formed, non-wet rings 80, 82 are identified. Due to the surface tension of the non-wet rings 80, 82, the ink flowing from an orifice 6 will not want to flow across non-wet rings 80, 82. However, as additional ink flows through the orifice 6, the volume of the ink dot such that the surface tension of the non-wet ring 80 is exceeded. Once the surface tension is exceeded, the ink will spread out to just before the next non-wet ring 82.

The etched rings 76, 78 provide an increased flow barrier to the spread of the ink dot. In particular, for the ink dot to spread out over the non-wet ring 82, the volume build up of ink must exceed the surface tension of the non-wet ring 82. At this non-wet ring 82, the surface tension seen by the ink dot is greater than the surface tension seen when the ink dot sought to spread out over the non-wet ring 80. Namely, the provision of the etched ring 76 just before the non-wet ring 82 enlarges the barrier which the ink dot must overcome to spread out to the next ring. Hence, a greater volume of ink build up will be required to overcome the barrier.

The etched rings 76, 78 may be etched using conventional methods. For example, the ink transfer surface 4 may be polyimide (e.g., KAPTON) which is non-wet with respect to aqueous ink. A mask pattern corresponding to the regions which are not to be etched is placed on the ink transfer surface 4. The etched rings 76, 78 are then etched in the ink transfer surface 4 by excimer laser ablation.

It may be advantageous to clean the ink transfer surface 4 after each use. In particular, after ink dots on the ink transfer surface 4 have been transferred to the intermediate surface or printing media, some residue may remain. The residue ink may be cleaned off using a doctor blade made of rubber or cloth. A doctor blade made of felt material or other cloth like material might be preferred in an embodiment which uses etched rings.

It may also be advantageous to combine the features of the first and second embodiments. For example, an ink transfer surface might use wet rings, non-wet rings and etched rings.

The many features and advantages of the present invention are apparent from the detailed description and thus it is intended by the appended claims to cover all such features and advantages of the invention. Further, since numerous modification and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation as illustrated and described. Hence, all suitable modifications and equivalents may be resorted to as falling within the scope of the invention.

Claims

1. An ink transfer printing device (1) wherein ink is transferred from an ink reservoir (2) to a printing medium (10) via a perforated surface (4), said perforated surface (4) having a plurality of orifices (6), said printing device (1) being characterized by controlling ink transfer by changing the viscosity of the ink near certain of said orifices (6) thereby enabling a controlled amount of the ink near said certain of said orifices (6) to flow onto said perforated surface (4) via said certain of said orifices (6).
2. An ink transfer printing device as recited in claim 1, further characterized in that the viscosity of the ink at ambient conditions is at least 10 cps.
3. An ink transfer printing device as recited in claim 1, further characterized in that the ink consists essentially of (by weight) 2-10% colorant, 93-60% carriers(s), and 5-30% additives.
4. An ink transfer printing device as recited in claims 1, 2 or 3, further characterized in that said perforated surface (4) includes at least one concentric region (72, 74, 76, 78, 80, 82) about each of said orifices (6) to control the spread of the ink.
5. An ink transfer printing device as recited in claim 4, wherein said concentric region forms a flow barrier at the junction of a wet surface (72) and a non-wet surface (74).
6. An ink transfer printing device as recited in claim 4, wherein said concentric region forms a flow barrier at the junction of an etched pattern (76, 78) and a non-wet surface (80, 82).
7. An ink transfer printing device as recited in claim 1, 2 or 3, wherein the ink reservoir (2) is characterized by comprising an ink chamber (61) for containing the ink, a pressurized chamber (60) for pressurizing the ink within said ink chamber (61), and a movable piston (58) for separating said pressurized chamber (60) from said ink chamber (61).
8. An ink transfer printing device as recited in claim 1, 2 or 3, further characterized in that said perforated surface (4) has a circular shape, and said ink reservoir (2) comprises a common channel (48) and a plurality of ink channels, each of said ink channels supplying ink (14) to at least one of said orifices (6), said ink channels extend radially outward from said common channel (48) which supplies the ink from said ink reservoir (2) to said ink channels.
9. An ink transfer printing device as recited in claim 1, 2 or 3, further characterized in that said printing me-

dium (10) contacts an outer surface of said perforated surface (4) to transfer the ink which has flowed onto said outer surface to said printing media.

- 5 10. An ink transfer printing device as recited in claim 1, 2 or 3, further characterized in that said ink reservoir (2) comprises first through fourth chambers (6a, 6b, 6c, 6d) each retaining a different color ink, each of said orifices (6) being associated with one of said first through fourth chambers.
- 10 11. An ink transfer printing device as recited in claim 10, further characterized in that each of said chambers (6a, 6b, 6c, 6d) has a portion of said perforated surface (4) dedicated thereto, and that a common section of said printing medium (10) contacts a plurality of the dedicated portions of said perforated surface (4), thereby producing various colors.
- 15 12. An ink transfer method for transferring ink from an ink reservoir (2) to a printing medium (10), the ink reservoir (2) being associated with a contact (4) surface having a plurality of perforations (6), said method characterized by the steps of:
 - (a) applying a positive pressure to the ink;
 - (b) using the viscosity of the ink at ambient conditions to retain the ink within the reservoir;
 - (c) inducing a change in the viscosity of the ink near certain of the perforations thereby enabling a controlled amount of the ink near each of said certain of the perforations (6) to flow onto the contact surface (4) via said certain of the perforations (6); and
 - 20 (d) transferring the ink, which has flowed onto the contact surface (4), to the printing medium (10).
- 25 13. A method as recited in claim 12, wherein step (d) comprises the steps of:
 - (d1) transferring the ink on the contact surface (4) to an intermediate transfer surface (54); and
 - (d2) transferring the ink from the intermediate transfer surface (54) to the printing medium (10).
- 30 14. A method as recited in claim 12, wherein said inducing step (c) is characterized by one of the following:
 - (i) locally heating the ink near said certain of the perforations (6) to reduce the viscosity of the ink near said certain of the perforations (6);
 - (ii) applying an electric field near each of said certain of the perforations (6) to change the viscosity of the ink near said certain of the perforations (6); and
 - (iii) applying a magnetic field near each of said certain of the perforations (6) to change the viscosity of the ink near said certain of the perforations (6).

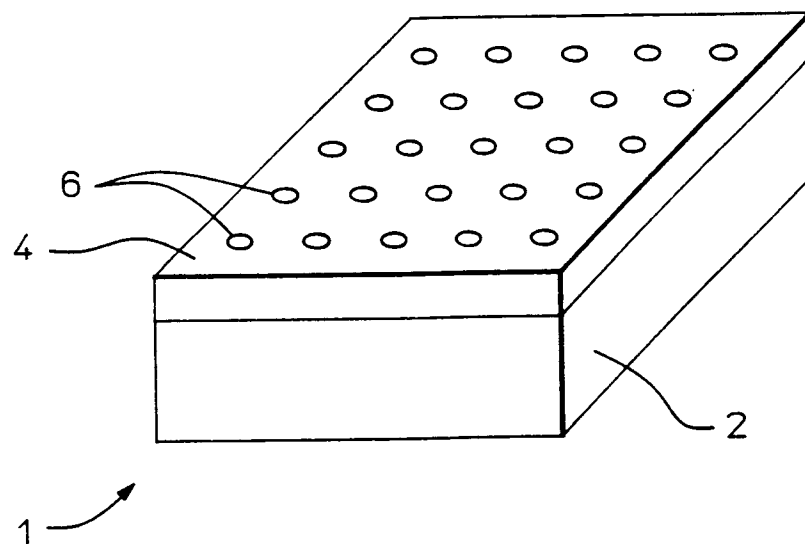


FIG 1

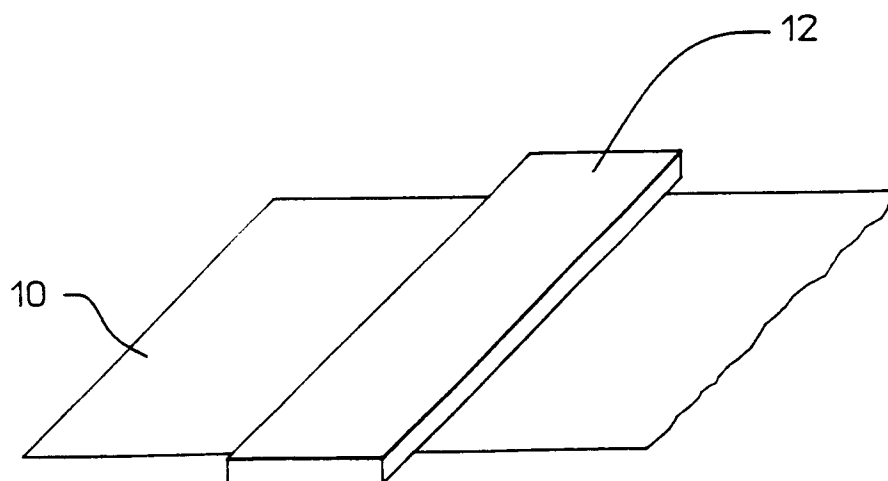


FIG 3

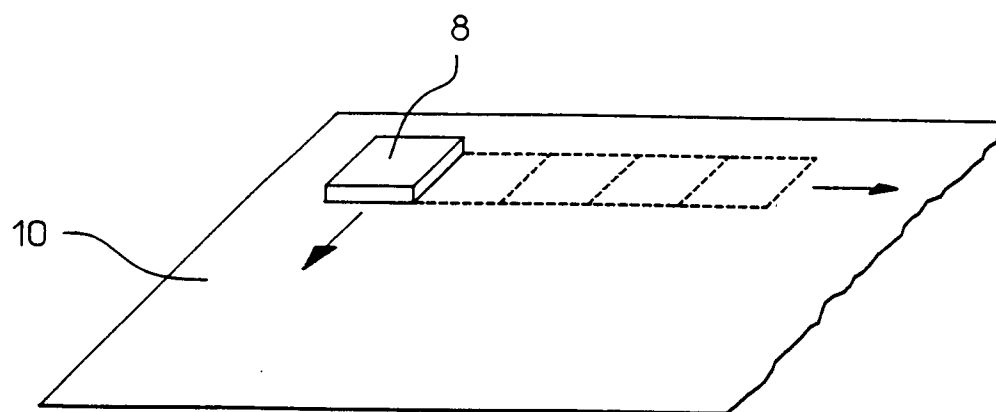


FIG 2

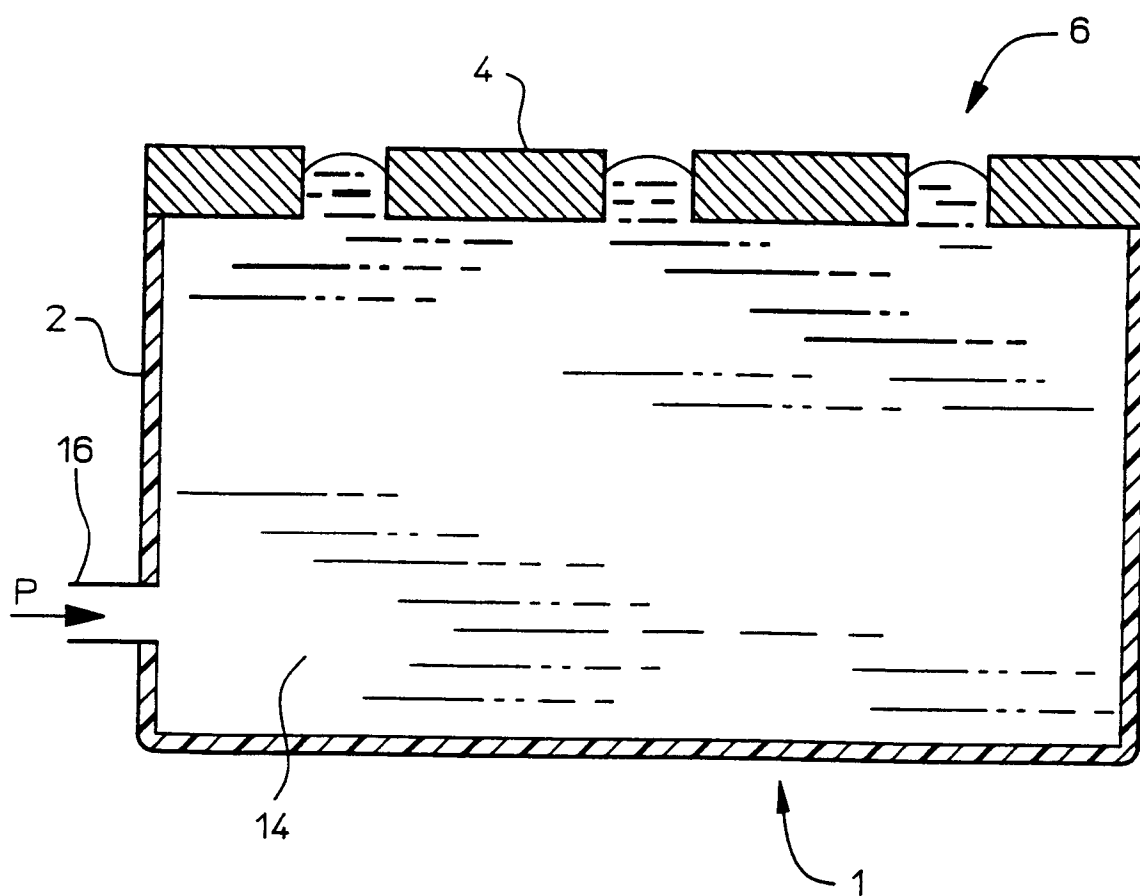


FIG 4

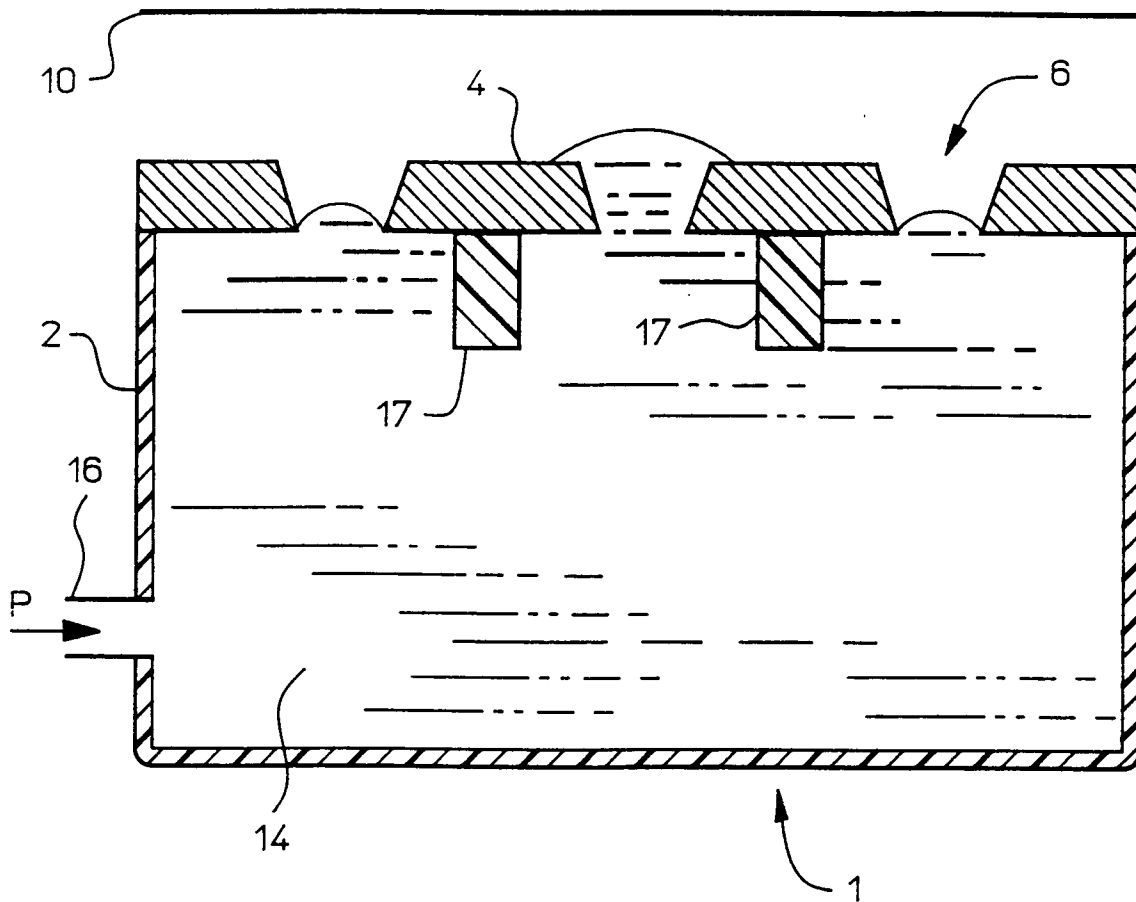


FIG 5A

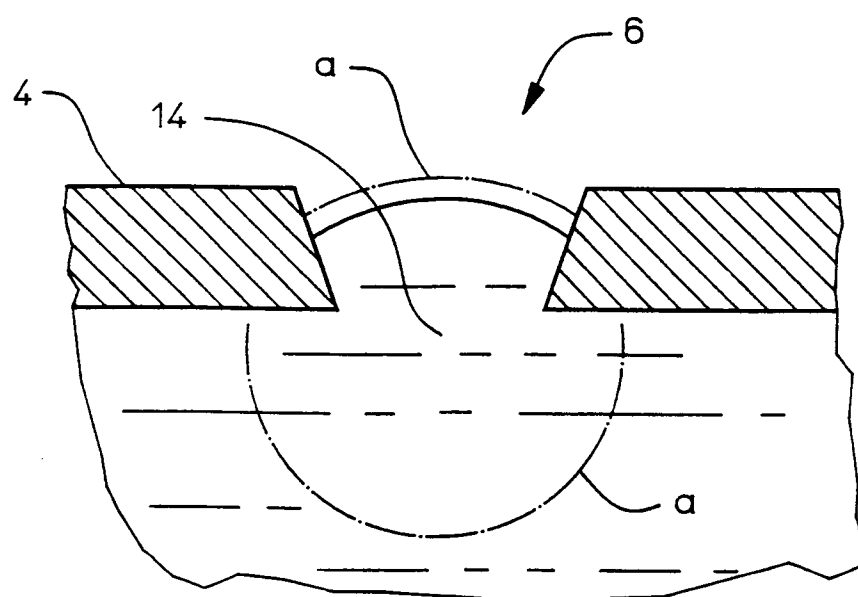


FIG 5B

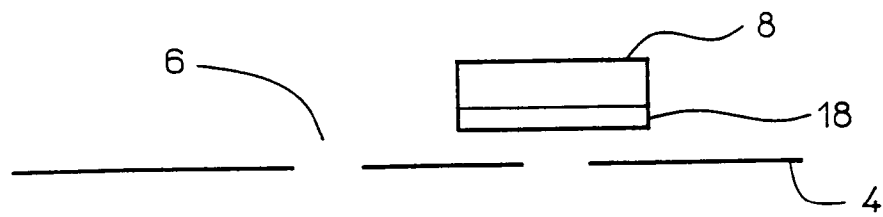


FIG 6A

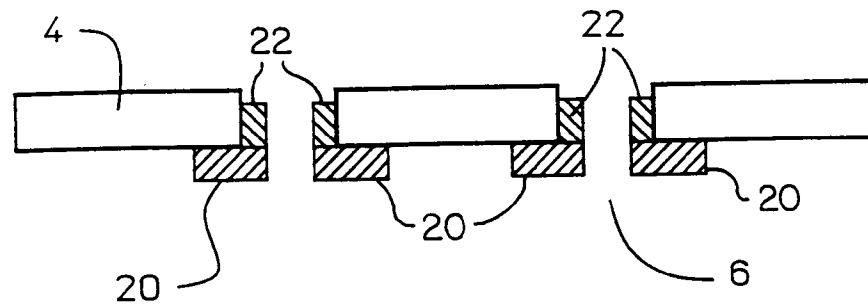


FIG 6B

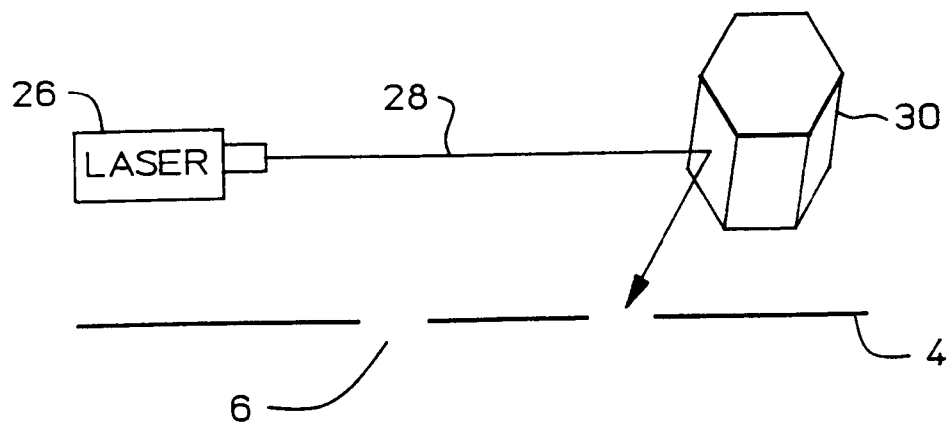


FIG 6C

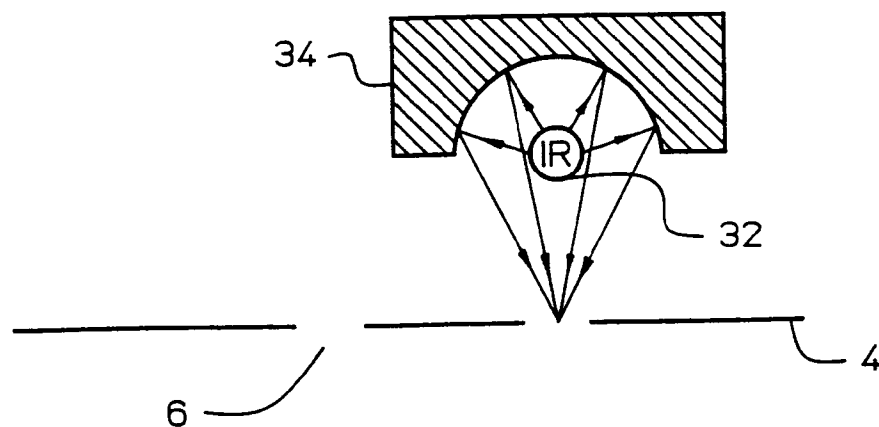


FIG 6D

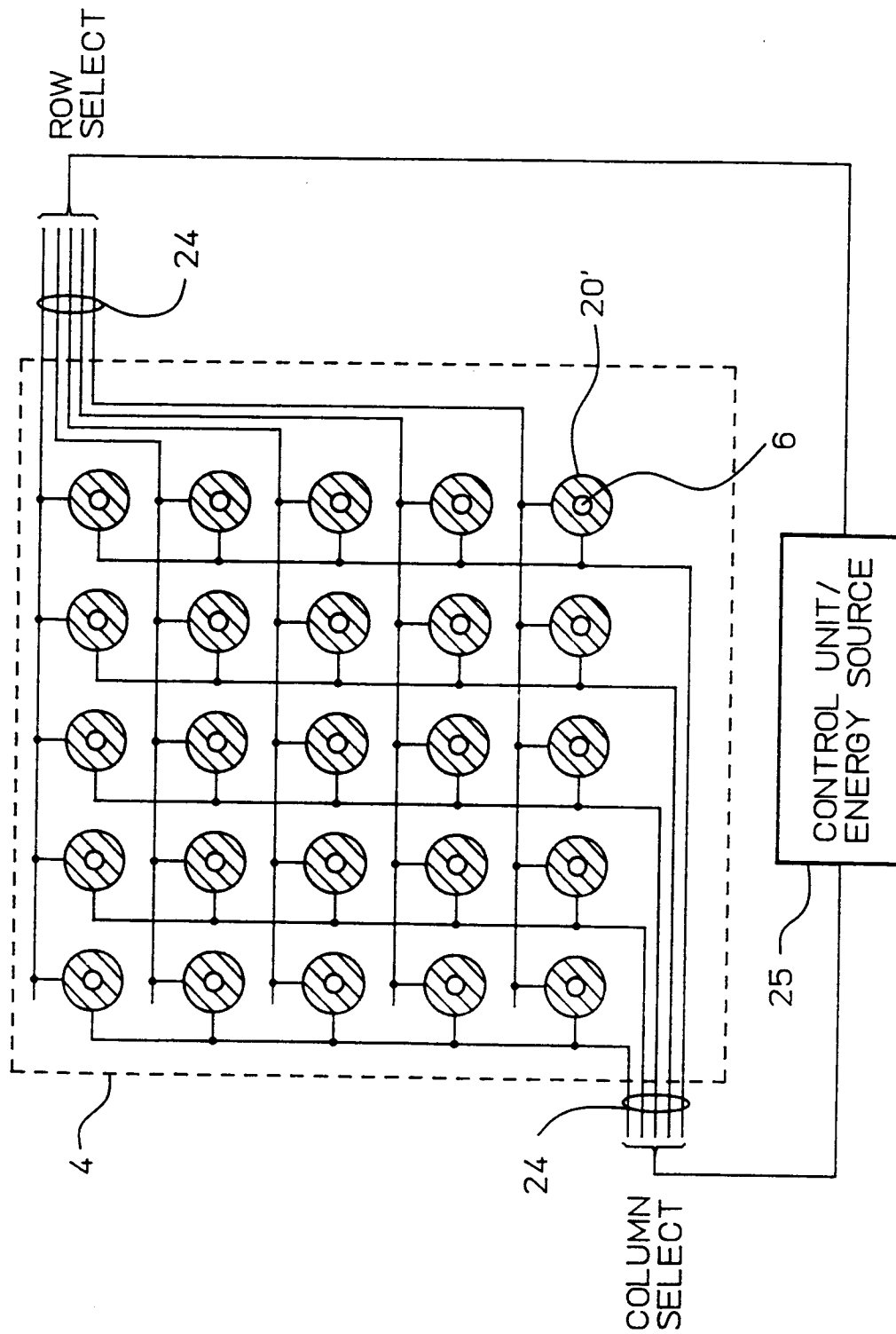


FIG 7

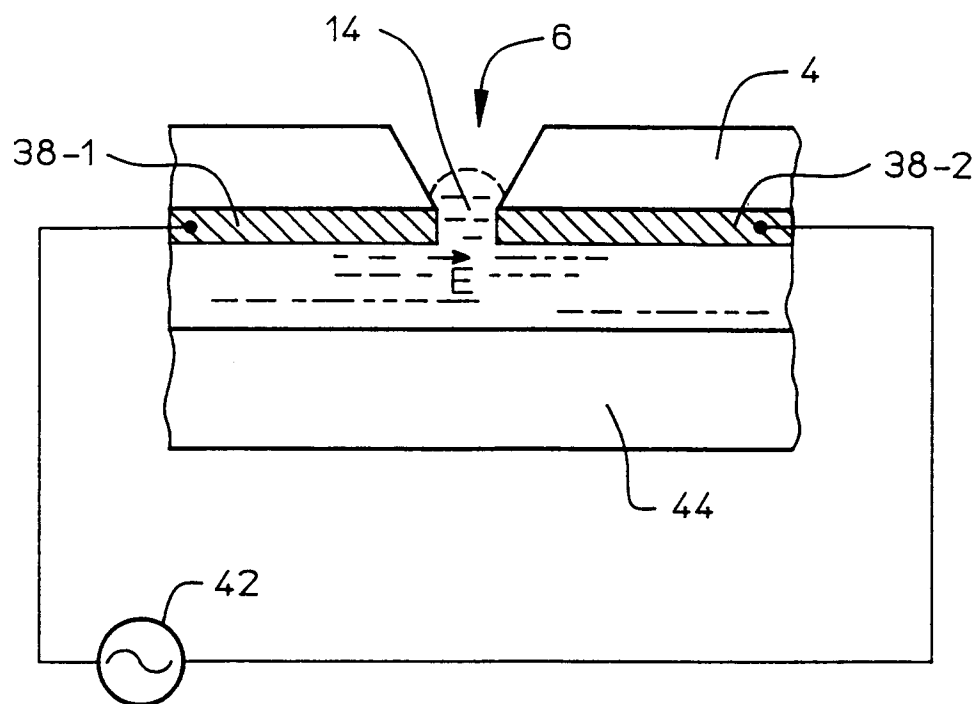


FIG 8A

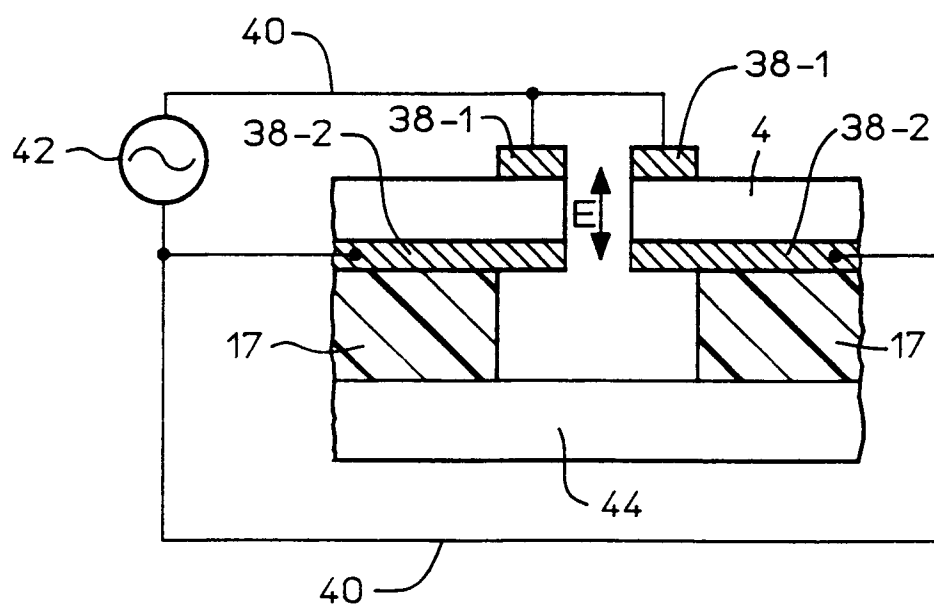


FIG 8B

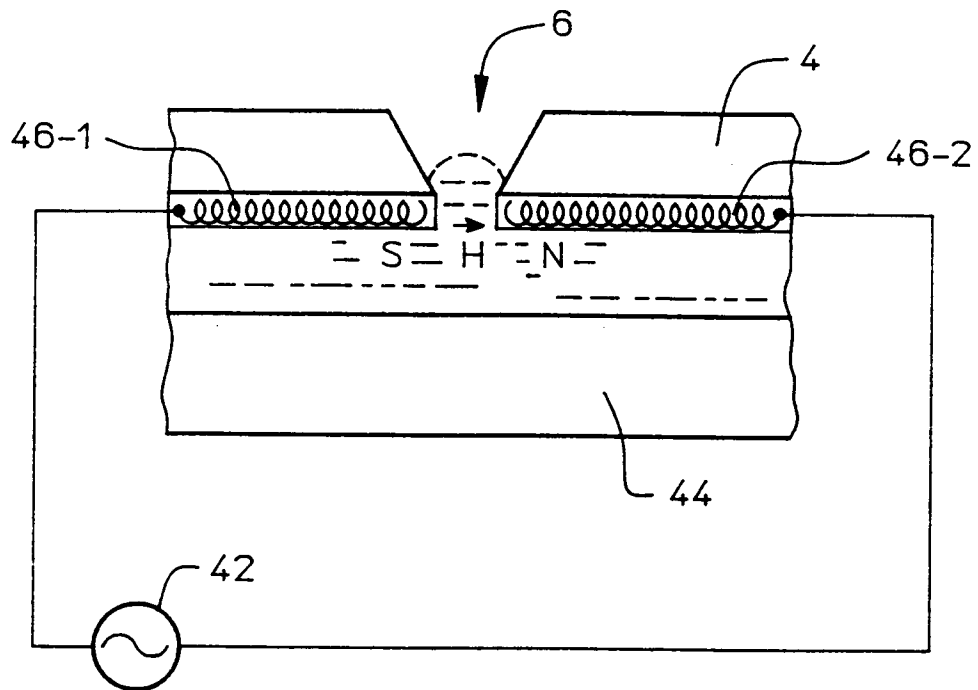


FIG 9

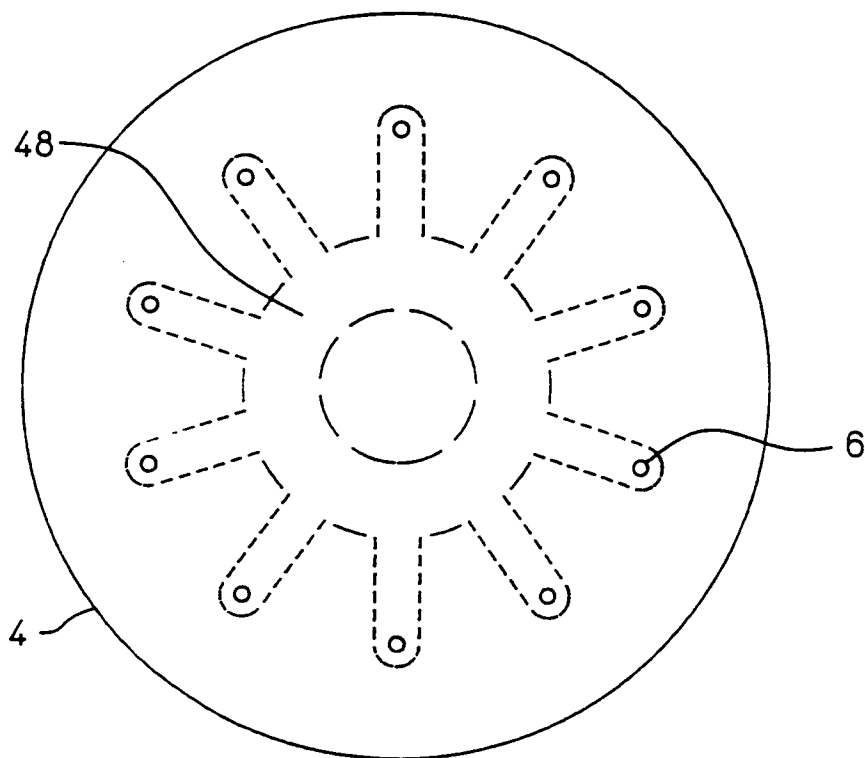


FIG 11

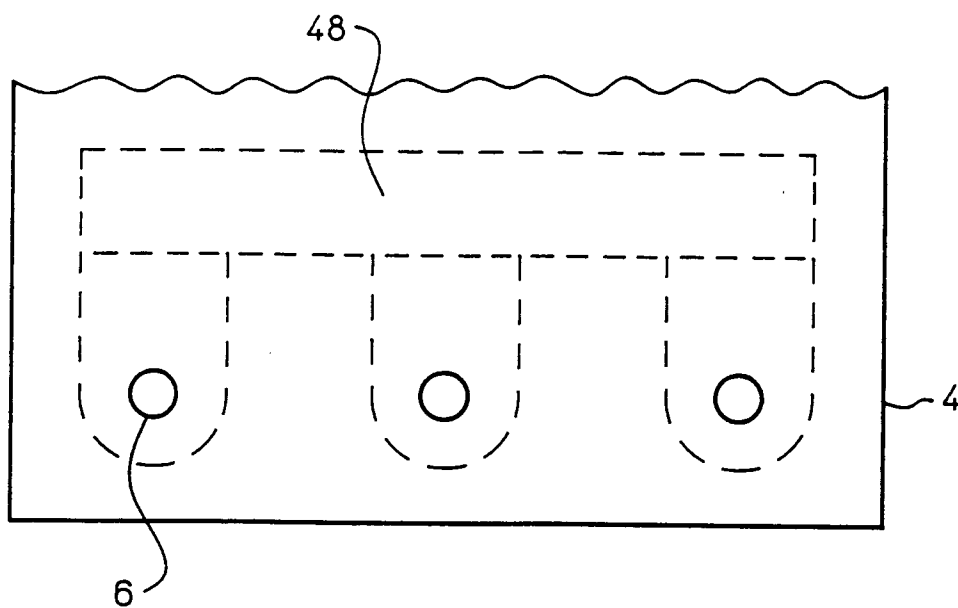


FIG 10A

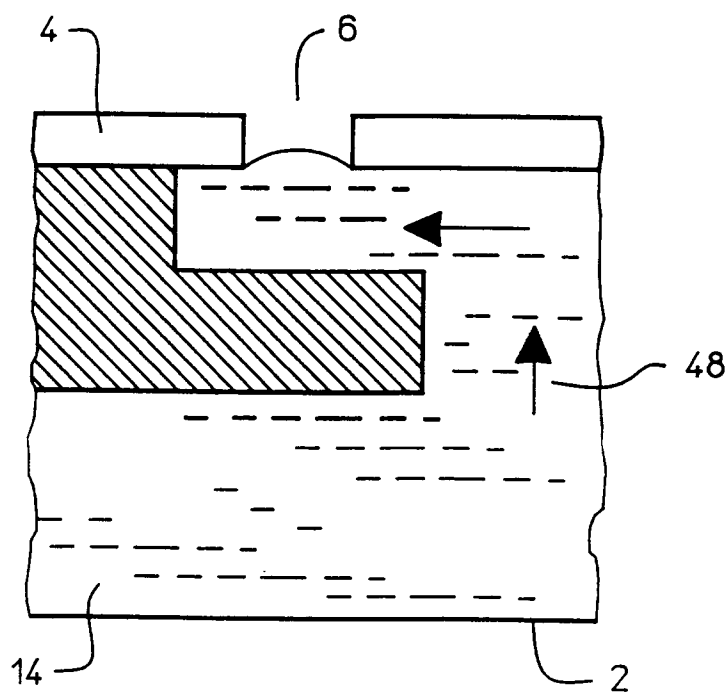


FIG 10B

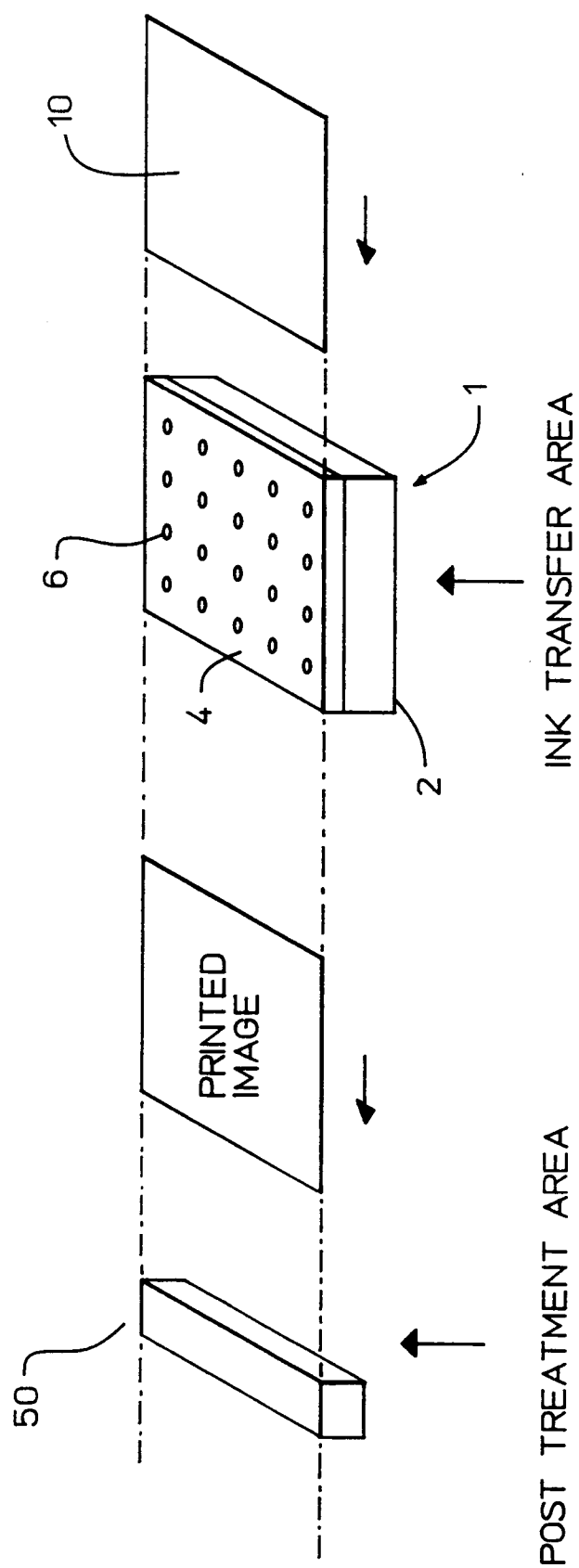


FIG 12

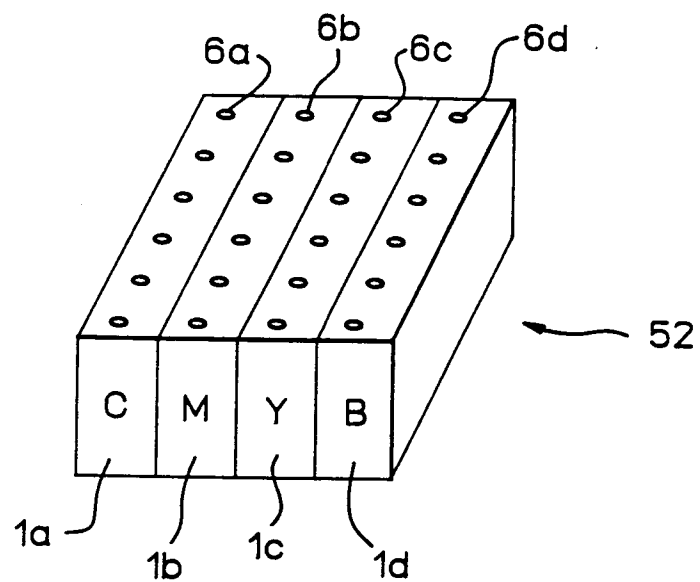


FIG 13A

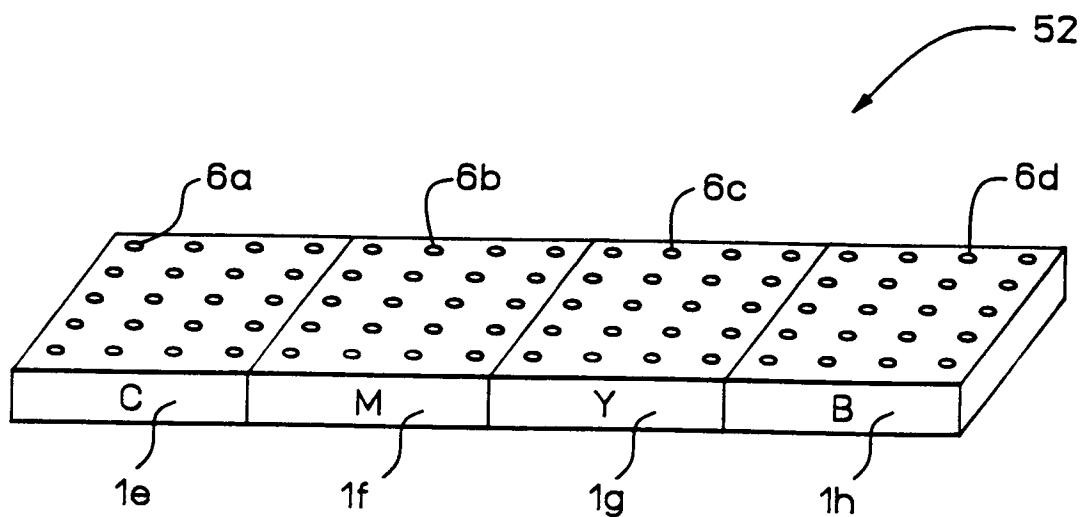


FIG 13B

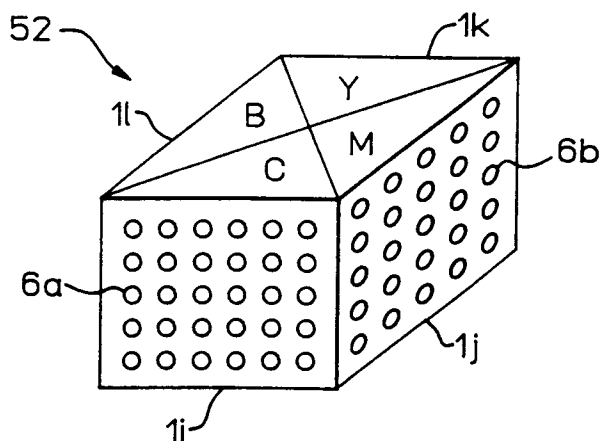


FIG 13C

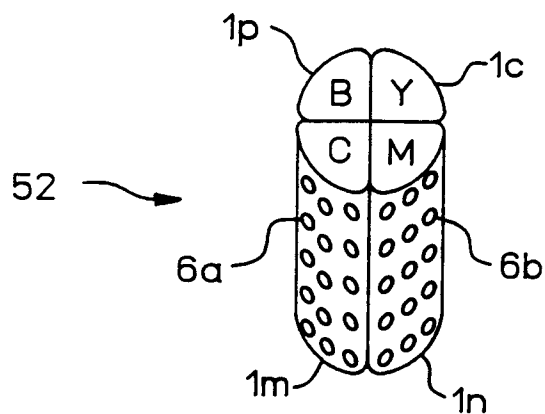


FIG 13D

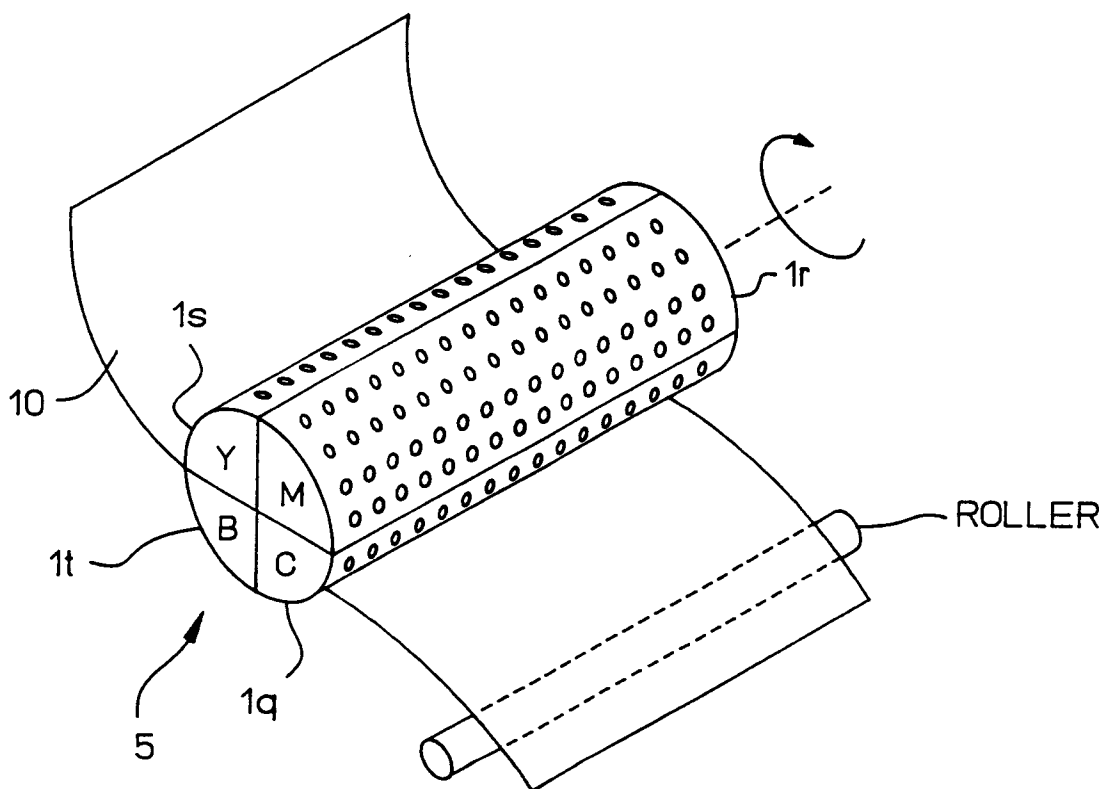


FIG 13E

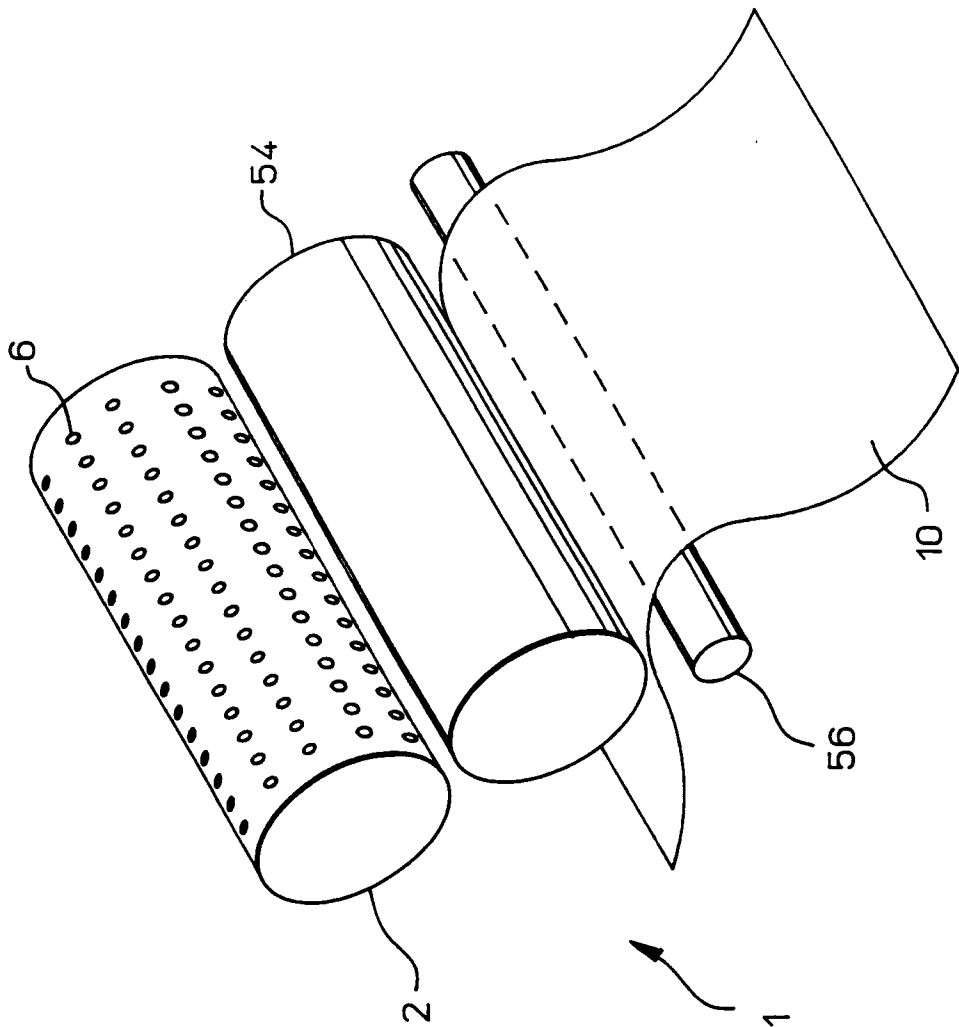


FIG 14

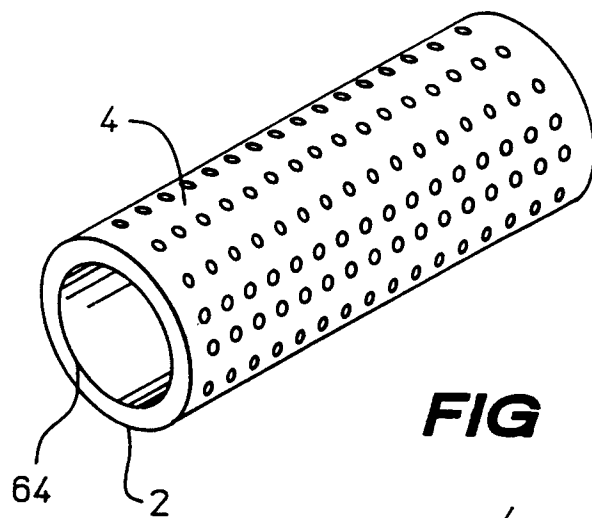


FIG 16A

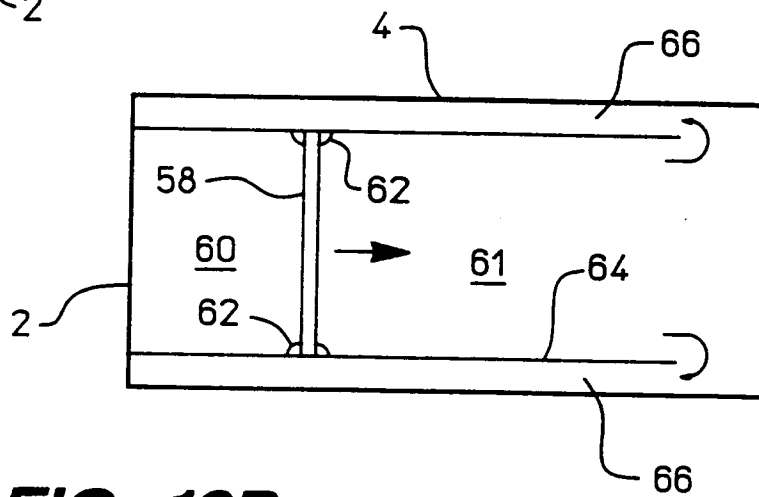


FIG 16B

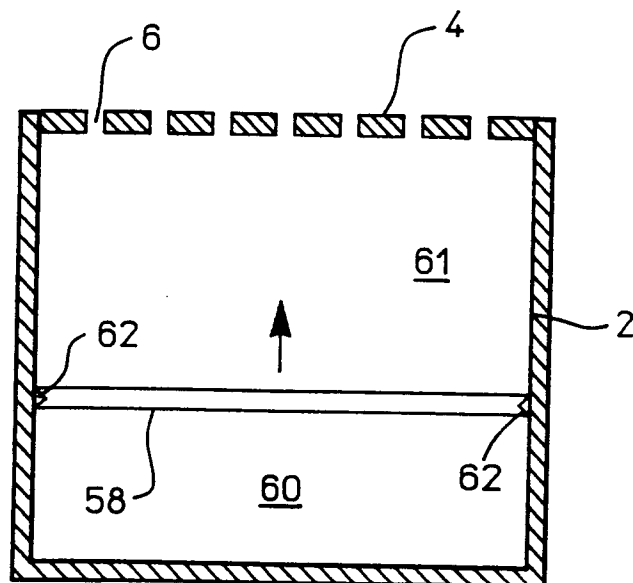


FIG 15

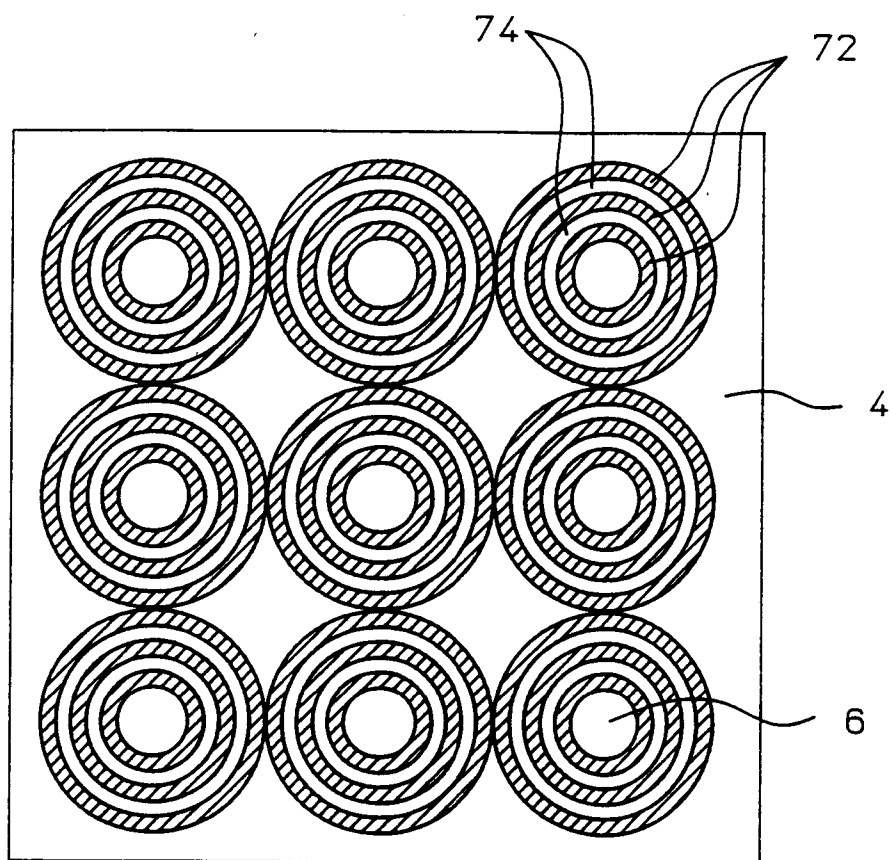


FIG 17

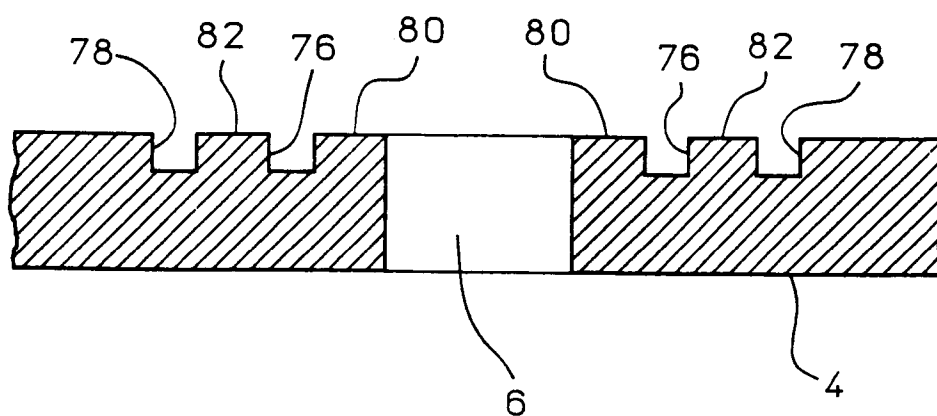


FIG 18