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AL LT LV MK RO SI(71) Applicant: **AGFA-GEVAERT N.V.****2640 Mortsel (BE)**(72) Inventor: **Desie, Guido****2640 Mortsel (BE)**(30) Priority: **18.12.1997 EP 97204014**

(54) **A printhead structure for use in a device for direct electrostatic printing comprising symmetrical control electrodes in the printing nip**

(57) A printhead structure (106) for use in a device for direct electrostatic printing using dry toner particles comprising a sheet of insulating material (106c) having two faces, a row of printing apertures (106d) through the insulating material, a printing nip (120), with edges, defined around the row and control electrodes (106a) on at least one of the faces, each of the control electrodes having a first electric conductor (C1) around at least one

of the printing apertures, and two further electric conductors (C2 and C3) extending from the first electric conductor towards the edges of the printing nip, one of the further electric conductors having a length, LC3, larger than 3 mm and one having a length, LC2, of at most 4 mm and the lengths LC2 and LC3 being such that $LC2/LC3 \leq 0.75$.

A device incorporating a printhead such a printhead structure is also disclosed.

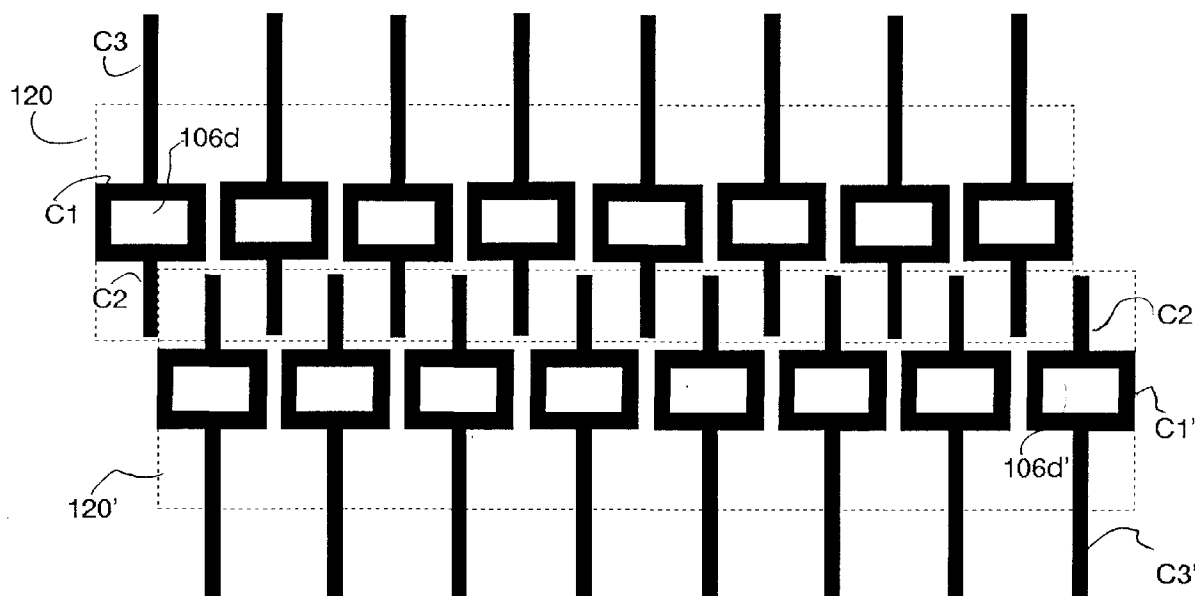


Fig. 4

Description

FIELD OF THE INVENTION

[0001] This invention relates to an apparatus for use in the process of electrostatic printing and more particularly in Direct Electrostatic Printing (DEP). In DEP, electrostatic printing on an image receiving substrate is performed by creating a flow of toner particles from a toner bearing surface to the image receiving substrate and image-wise modulating the flow of toner particles by means of an electronically addressable printhead structure.

BACKGROUND OF THE INVENTION

[0002] In DEP (Direct Electrostatic Printing) the toner or developing material is deposited directly in an image-wise way on a receiving substrate, the latter not bearing any image-wise latent electrostatic image. The substrate can be an intermediate endless flexible belt (e.g. aluminium, polyimide etc.). In that case the image-wise deposited toner must be transferred onto another final substrate. Preferentially the toner is deposited directly on the final receiving substrate, thus offering a possibility to create directly the image on the final receiving substrate, e.g. plain paper, transparency, etc. This deposition step is followed by a final fusing step.

[0003] This makes the method different from classical electrography, in which a latent electrostatic image on a charge retentive surface is developed by a suitable material to make the latent image visible. Further on, either the powder image is fused directly to said charge retentive surface, which then results in a direct electrographic print, or the powder image is subsequently transferred to the final substrate and then fused to that medium. The latter process results in an indirect electrographic print. The final substrate may be a transparent medium, opaque polymeric film, paper, etc.

[0004] DEP is also markedly different from electrophotography in which an additional step and additional member is introduced to create the latent electrostatic image. More specifically, a photoconductor is used and a charging/exposure cycle is necessary.

[0005] A DEP device is disclosed in e.g. **US-A-3 689 935** This document discloses an electrostatic line printer having a multi-layered particle modulator or printhead structure comprising :

- a layer of insulating material, called isolation layer ;
- a shield electrode consisting of a continuous layer of conductive material on one side of the isolation layer ;
- a plurality of control electrodes formed by a segmented layer of conductive material on the other side of the isolation layer ; and
- at least one row of apertures.

[0006] Each control electrode is formed around one aperture and is isolated from each other control electrode.

[0007] Selected electric potentials are applied to each of the control electrodes while a fixed potential is applied to the shield electrode. An overall applied propulsion field between a toner delivery means and a support for a toner receiving substrate projects charged toner particles through a row of apertures of the printhead structure. The intensity of the particle stream is modulated according to the pattern of potentials applied to the control electrodes. The modulated stream of charged particles impinges upon a receiving substrate, interposed in the modulated particle stream. The receiving substrate is transported in a direction orthogonal to the printhead structure, to provide a line-by-line scan printing. The shield electrode may face the toner delivery means and the control electrodes may face the receiving substrate. A DC-field is applied between the printhead structure and a single back electrode on the receiving substrate. This propulsion field is responsible for the attraction of toner to the receiving substrate that is placed between the printhead structure and the back electrode.

[0008] One of the recognised problems with this type of printhead structures is that the printing apertures are easily clogged by toner particles when the DEP device is used over a longer period of time and partially accumulation of charged toner particles to said printhead structure leads to variations in printing density for various printing apertures.

[0009] The problem of variations in printing density have been addressed in several ways in the literature.

[0010] In **US-A-5 307 092** an anti-static coating is applied to the electrodes in the printhead so that any tribo-charge that accumulates during writing can be grounded. As a result the net tribo-charge on the printhead (which is unwanted and is responsible for unpredictable results and clogging) is removed and a better long-time performance results.

[0011] In **US-A-5 596 356** a printhead structure is described comprising printing apertures, control electrodes and shield electrodes in a matrix design with the incorporation of an extra dummy electrode for improved performance.

[0012] In **US-A-5 650 809** a printhead structure is described comprising printing apertures, control electrodes and dummy control electrodes so that constant image quality over the complete printhead width can be obtained.

[0013] However, there remains still a need for less complicated but further improved DEP devices with high printing speed and high long-term stability concerning image density.

OBJECTS AND SUMMARY OF THE INVENTION

[0014] It is an object of the invention to provide a printhead structure for use in direct electrostatic printing with

dry toner particles making it possible to print patches of even density with very low unevenness and almost no banding.

[0015] It is an other object of the invention to provide a DEP device, i.e. a device for direct electrostatic printing that can print at high speed with low clogging of the control electrodes and with high and constant maximum density and with a high degree of density resolution (i.e. for producing an image comprising a high amount of differentiated density levels) and spatial resolution.

[0016] A further object of the invention is to provide a DEP device that can be used with a wide variety of types of toner particles, and that can print at high speed with low clogging of the control electrodes, with high maximum density and with a printing quality that is constant over a long period of time.

[0017] Further objects and advantages of the invention will become clear from the detailed description herein after.

The objects of the invention are realised by providing a printhead structure (106) for use in a device for direct electrostatic printing using dry toner particles comprising a sheet of insulating material (106c) having two faces, a row of printing apertures (106d) through said insulating material, a printing nip, with edges, defined around said row and control electrodes (106a) on at least one of said faces, each of said control electrodes having a first electric conductor (C1) around at least one of said printing apertures,

characterised in that

two further electric conductors (C2 and C3) extending from said first electric conductor towards said edges, are included in each of said control electrodes, a longer one having a length, LC3, larger than 3 mm and a shorter one having a length, LC2, of at most 4 mm and $LC2/LC3 \leq 0.75$.

[0018] The further objects of the invention are realised by providing a device for direct electrostatic printing comprising

- a means for delivering charged toner particles, said means having a toner bearing surface coupled to a means for applying a first electric potential to said surface,
- a means for creating a flow of said charged toner particles away from said surface,
- a means for passing an image receiving substrate in said flow,
- a printhead structure having printing apertures and control electrodes, placed between said toner bearing surface and said image receiving substrate, leaving a gap d between said toner bearing surface and said control electrodes, characterised in that
- said printhead structure comprises a sheet of insulating material having two faces and, printing apertures through said insulating material and control electrodes on at least one of said faces, each of said control electrodes having a first electric conductor

around at least one of said printing apertures, wherein

two further electric conductors extending from said first electric conductor towards said edges, are included in each of said control electrodes, a longer one having a length, LC3, larger than 3 mm and a shorter one having a length, LC2, of at most 4 mm and wherein $LC2/LC3 \leq 0.75$.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Figure 1 illustrates schematically the definition of a printing nip and its dimensions.

[0020] Figure 2 shows a printhead structure according to the prior art.

[0021] Figure 3 shows a printhead structure according to a first embodiment of the present invention.

[0022] Figure 4 shows a printhead structure according to a second embodiment of the present invention.

[0023] Figure 5 shows a DEP device comprising a printhead structure of the first embodiment of the present invention.

[0024] Figure 6 shows a DEP device comprising a printhead structure of a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] It is known in the art of DEP (direct electrostatic printing), as described in the background art section above, that, in a DEP device, in a DC-field, a flow of charge toner particles is created between a means for delivering charged toner particles and an image receiving substrate. A printhead structure, having control electrodes around printing apertures, is interposed in said flow of toner particles for image-wise controlling said flow of toner particles. The application of an AC-field to the surface of a means for delivering toner particles can be used to increase the printing speed by providing a denser flow of toner particles in the vicinity of the printing apertures. This dense flow of toner particles from the surface bearing charged toner particles to a back electrode is a continuous flow, and this dense flow is image-wise modulated by putting a DC-voltage upon the control electrodes present in said printhead structure. Said DC-voltage either has a further propagating field (leading to image density) or a blocking field (leading to no-image density).

[0026] Levelling or reversing the propulsion field rapidly leads to toner adherence upon the printhead structure and to the wall of the printing apertures in the insulating material of the printhead structure, this leads to partially clogging of the printing apertures and thus to image artefacts and poor print quality, e.g., white dots or lines of reduced density in even density patches due to the fact that some printing apertures are partially clogged. In most of the prior art disclosures, the flow of toner particles towards the printhead structure is a con-

tinuous one and the image-wise modulation is done by image-wise blocking the passage of the toner flow through printing apertures. The problems of image density fluctuations is in the prior art mainly addressed by means to relieve the clogging and diminish the number of grey levels to only two, i.e. a binary modulation technique.

[0027] In a printhead structure for use in a device for direct electrostatic printing a "printing nip" can be defined in the vicinity of each row of printing apertures that are associated with control electrodes. A "printing nip" is shown in figure 1, a "printing nip" occupies a surface in the printhead structure (120) defined by the length, ℓ of the row of printing apertures (106d) and by two distances, a and b , extending, from the line through the centre points of the printing apertures in the row of printing apertures, in opposite directions parallel to the movement, in the direction of arrow D, of the image receiving substrate.

[0028] Charged toner particles present under the "printing nip" are influenced by the electric field provided by the control electrodes in the "printing nip". Charged toner particles outside the "printing nip" are not influenced by the electric field in said "printing nip" so that they do not have any tendency to move to or from the neighbourhood of said printing apertures. Depending on the geometry of the printhead structure and the surface of the means for delivering toner particles whereon the toner particles are present and the relative distances between said printhead structure and said surface, the dimensions of the "printing nip" vary. It is possible that the distances a and b are equal (a symmetrical printing nip) or that these distances are different. In a DEP device incorporating a printhead structure according to this invention, it is preferred to adjust the geometry of the printhead structure and of the surface of the means for delivering charged toner particles so that the printing nip around each row of printing apertures present in the printhead structure is symmetrical. The sum of the distances a and b can vary, depending on the factors set out immediately above, from 1 mm to 8 mm or more. Thus in the case where $a = b$, which is a preferred embodiment of this invention, the distance a and b fulfil preferably the equation $0.5 \text{ mm} \leq a = b \leq 4 \text{ mm}$. Therefore, the present invention includes a printhead structure in which the "electrical" surfaces that individual toner particles can see, i.e. the electric fields that influence the toner particles, approaching and leaving the vicinity of the row of printing apertures, is equivalent for all printing apertures.

[0029] Not intending to be bound by any theory, it gives the impression that a cloud of charged toner particles formed between the surface of the toner delivery means and the surface of the printhead structure is largely influenced by the conductors of the control electrodes on the printhead structure. In a DEP device the surface of the means for delivering toner particles is passed under the printing apertures, bringing charged

toner particles in the vicinity the apertures and taking the non-used toner particles away from the printing apertures. The region under the "printing nip" from where the means for delivering toner particles brings charged toner particles to the vicinity of the printing apertures is the "feed-region" and the region under the "printing nip" wherein the non-used toner particles are brought after being passed in the vicinity of the apertures is the "removal-region". It is very difficult, even impossible to print the same density through a printing aperture associated with a control electrode having a conductor (for connecting said control electrode to a voltage source) extending in the "feed-region" and a printing aperture associated with a control electrode having a conductor (for connecting said control electrode to a voltage source) extending in the "removal-region".

[0030] In a prior art printhead structure, according to **US-A-5 650 809** and as shown in figure 2, the printing apertures (P1) and the control electrode (P2) are accompanied by dummy electrodes (P2) that are only present for adjusting the electric fields in the vicinity of the printing apertures. The construction of such a printhead structure is not that straightforward, and especially when two rows of printing apertures are present in the printhead structure, designing a compact geometry of the rows of printing apertures and dummy electrodes is not so simple.

[0031] It can further be seen in figure 2 that said control electrodes do not have a plane of symmetry through the line connecting the centre of the apertures so that it is not guaranteed that the electric fields acting on the charged toner particles in the "feed region" and in the "removal region" are the same.

[0032] Also in **DE-A-197 16 115** it has been recognised that charged toner particles present under the "printing nip" are influenced by the electric field provided by neighbouring control electrodes in the "printing nip", requiring a compensation for cross-talk in order to enhance the printing quality. To diminish, in a printhead structure having multiple rows of printing apertures, the influence of the electric field on the various control electrode strips extending in between and towards the various rows of printing apertures on the toner particles in the "printing nip", it is suggested to print in various printing periods wherein in the first period the printing apertures of the first row are used for printing while the other rows are not used for printing but are kept on closing voltage. This procedure does diminish the influence of the various control electrode strips extending in between and towards the various rows of printing apertures on the toner particles but also diminishes the printing speed, since, e.g., with a printhead structure having four rows of printing apertures only one row at a time is used for printing while otherwise the four rows are simultaneously used for printing. This means that in this case the printing speed with the method of **DE-A-197 16 115** for avoiding the influence of the various electric fields on the toner particles is four times slower.

[0033] In **US-A-5,128,695** a printhead structure having a single row of printing apertures with symmetrical control electrodes is shown, without any reference to a possible advantage of the structure.

[0034] It was found that by changing the appearance of the control electrode paths in the "printing nip", a nearly constant toner flux from the surface of means for applying charged toner particles to said printhead structure could be realised, leading to stable and constant image density even at intermediate grey levels. It was found that when the control electrodes were arranged so that in the printing nip a plane of symmetry existed through the line connecting the centre points of the printing apertures in a row, very even printing densities could be achieved.

[0035] Thus in this invention a printhead structure for use in a device for direct electrostatic printing using dry toner particles is provided comprising a sheet of insulating material having two faces, at least one row of printing apertures through said insulating material, a printing nip, with edges parallel to said row of printing apertures, defined around said row and control electrodes on at least one of said faces, each of said control electrodes having a first electric conductor around at least one of said printing apertures, and two further electric conductors connected to said first one and extending towards said edges of said printing nip, one of said further conductors being longer than 3 mm, with length LC3 and one having a length, LC2, of at most 4 mm and wherein $LC2/LC3 \leq 0.75$. It is preferred that the longer one of the further conductors is coupled to a variable voltage source for selectively preventing the charged toner particles from passing the printing apertures and allowing the charged toner particles to pass the printing in accordance with image data to be printed. In figure 3 a printhead structure according to a first embodiment of the present invention, having a single row of printing apertures is shown. Eight printing apertures (106d) on a single row are shown, each of the printing apertures is surrounded by a first conductor (C1) and two conductors, a shorter one (C2) and a longer one (C3) extending from said first conductor towards the edges of the printing nip (120). Here it is possible to draw a plane of symmetry through the centre points of the printing apertures (within the printing nip). When only one row of printing apertures is present (as in figure 3) it is preferred that said further conductor having a length larger than 3 mm (C3) included in a first control electrode and coupled to a voltage source, and said further conductor having a length larger than 3 mm (C3) included in a control electrode adjacent to said first control electrode and coupled to a voltage source are located on opposite sides of said row of printing apertures.

[0036] Figure 4 shows a printhead structure according to a second embodiment of the present invention, wherein two parallel rows of eight printing apertures are shown. Each of the printing apertures (106d) of the first row is surrounded by a first conductor (C1) and two con-

ductors, a shorter one (C2) and a longer one (C3) extending from said first conductor towards the edges of the printing nip (120) and each of the printing apertures (106d') of the second row is surrounded by a first conductor (C1') and two conductors a short one (C2') and a long one (C3') extending from said first conductor towards the edges of the printing nip (120'). The printing nip (120) surrounding the first row and the printing nip (120') surrounding the second row overlap with each other. But again it is possible to draw a plane of symmetry through the printing apertures in each of the two rows of printing apertures within each printing nip associated with the respective row. Toner particles that are brought near to each row of printing apertures in said printhead structure from the feed-region and away from said row in to the "removal-region" are, independently of their location parallel to the row of printing apertures, subjected to an equal electric field.

[0037] It is preferred that the conductor (C1) of the control electrode around each of the printing apertures is connected to two further conductors, a shorter one (C2) having a length, LC2, of at most 4 mm and a longer one, having a length, LC3, larger than 3 mm (C3) (or groups of conductors) conductor C2 and C3 extending in a direction opposite to each other and towards the edges of the printing nip that are parallel with the row of printing apertures. It was found that with such a printhead structure it was possible to print an equal density through all printing apertures. Even better performance and more degrees of freedom for choosing the relative geometry of and distances between the surface of the means for delivering toner particles and the printhead structure were obtained when said short conductor extended over a length LC2 of 0.25 mm or more but at most over a length of 4 mm from the line through the centre point of the printing apertures on a row and very good printing results with a high degree of freedom for choosing the relative geometry of and distances between the surface of the means for delivering toner particles and the printhead structure were obtained when said short conductor extended over a length LC2 of 0.5 mm or more but at most over a length of 4 mm from the line through the centre point of the printing apertures on a row, even better results were obtained when said short conductor extended over a length LC2 of 0.5 mm or more but at most over a length of 4 mm from the line through the centre point of the printing apertures on a row.

[0038] It is preferred that only one of said two further electric conductors (C2 and C3), included in each of said control electrodes, is coupled to a voltage source arranged for image-wise modulating a flow of toner particles through the row of printing apertures. It is further preferred that the conductor, of said two further conductors, connected to the voltage source is longer than the other conductor. Figure 3 and 4 show schematically a printhead structure with control electrodes according to this invention, but are not intended to show, on scale,

exact dimensions. E.g. the conductors C3, which in the figure is longer than conductor C2 can extend farther away from the edge of printing nips 120 and 120' for being connected to a voltage source, that is not shown in the figures 3 and 4.

[0039] For most systems said sum of distances a and b of the printing nip is around 2 mm, and frequently for very good performance, the geometry is adjusted so that $a + b = 4$ mm, preferably the geometry is adjusted so that $a + b = 8$ mm.

[0040] It is preferred that the two further conductors (C3 and C2) coupled to the conductor C1 of the control electrode around the printing aperture have an extension that is related to the extension of the printing nip. It is preferred that the longer of the further conductors has a length LC3 such that $LC3 \geq (a + b)/2$, preferably so that $LC3 \geq a + b$ and the other one of the shorter one of the two further conductors has a length LC2, such that $0.25 \leq (LC2/(a + b)) \leq 0.5$. Given a symmetrical printing nip, wherein $0.5 \text{ mm} \leq a = b \leq 4 \text{ mm}$ the values for LC2 vary between 0.25 mm and 4 mm both limits included, preferably LC2 is chosen such that it varies between 0.5 mm and 4 mm, both limits included and in a very preferred embodiment LC2 is between 1 mm and 4 mm, both limits included. The values of LC3 vary between 0.5 mm and 4 mm or larger, preferably between 1 mm and 8 mm or larger as long as $LC2/LC3 \leq 0.75$.

The use of control electrodes designed according to this invention, is beneficial in any printhead structure for use in direct electrostatic printing comprising control electrodes and a common shield electrode as well as in a printhead structure where no shield electrode is present. Control electrodes designed as described immediately above can also be incorporated in a printhead with a specific shield electrode. Control electrodes, designed as per this invention, can be used in a printhead structure comprising, an insulating material having a first and a second side, said first side carrying control electrodes associated with printing apertures, said second side carrying a shield electrode, wherein

- i) said printing apertures have a longest dimension A, measured on said side of said insulating material carrying said shield electrode and have a longest dimension D, measured on said side of said insulating material carrying said control electrodes,
- ii) said shield electrode has openings with a dimension B, measured parallel to said longest dimension A, said dimension B being equal to or larger than said dimension A,
- iii) said control electrodes have openings with a dimension E measured parallel to said longest dimension D, said dimension E being equal to or larger than said dimension D,
- iv) in each of said openings at least one printing aperture is present, and
- v) for each of said printing apertures present in each

of said openings, $B/A > 1.10$ or $E/D > 1.10$. Such a printhead structure has been disclosed in **EP-A-812 269**

- 5 **[0041]** A printhead structure, according to this invention, having control electrodes with conductors as described above can be used in any DEP device known in the art, e.g. in devices as described in **EP-A-795 802**, **EP-A-780 740**, **EP-A-740 224**, **EP-A-731 394**, **EP-A-712 055**, **US-A-5 606 402**, **US-A-5 523 777**, **GB-A-2 108 432**, **US-A-4 743 926**. It can also be used in a method for direct electrostatic printing operating without back electrode, as disclosed in **EP-A-823 676**. Also in a method and device for direct electrostatic printing wherein the toner bearing surface is the sleeve of a magnetic brush with a rotating core, as described in **EP-A-827 046**, a printhead structure according to this invention can be useful. The toner cloud in the vicinity of the printing apertures can originate from a surface carrying charged mono-component magnetic developer, from a surface carrying charged non-magnetic mono-component toner brought to said surface from a container for non-magnetic mono-component developer as well as brought to said surface from a magnetic brush containing two-component developer with non-magnetic toner particles and magnetic carrier particles. The toner cloud may also originate directly from a magnetic brush containing two-component developer with non-magnetic toner particles and magnetic carrier particles.
- 30 **[0042]** It is preferred to use a printhead structure according to this invention, with the described geometry of the control electrodes, in a DEP device wherein the flow of toner particles from the means for delivering toner particles and the image receiving member is controlled by a printhead structure that is arranged for image-wise providing an AC-field between said means for delivering toner particles and said control electrode. Such a device has been described in European Application No. 97203268, filed on October 20, 1997. In that application a device for direct electrostatic printing, as shown in figure 5, is disclosed, comprising :

- a means (101) for delivering charged toner particles, said means having a toner bearing surface (103b) coupled to a device (118) for applying a first electric potential to said surface,
- a means for creating a flow (104) of said charged toner particles away from said surface,
- a means (107) for passing an image receiving substrate (108) in said flow,
- a printhead structure (106) having printing apertures and control electrodes (106a), placed between said toner bearing surface and said image receiving substrate, leaving a gap (d) between said toner bearing surface and said control electrodes, characterised in that
- said control electrodes are arranged to be selectively connected, in accordance with image data, to

said device (118) for applying a first electric potential on said toner bearing surface and to a device (119) for generating a second electric potential and each of said control electrodes having a first electric conductor (C1) around at least one of said printing apertures, two further electric conductors (C2 and C3) extending from said first electric conductor towards said edges, are included in each of said control electrodes and one of said further electric conductors having a length larger than 3 mm and one having a length of at most 4 mm.

[0043] In such a device, the toner flow through the printing apertures is basically controlled by image-wise applying an AC-field over the gap between the surface of the means for delivering toner particles and the printhead structure : when an AC-field is present the toner flow passes the printing apertures, when NO AC-field is present the printing aperture is blocked. Two interesting ways of providing such a device, wherein a printhead structure according to this invention is included, are described below :

[0044] A device for direct electrostatic printing including a printhead structure of the present invention can comprise a shield electrode, then, the shield electrode (106b) is preferably kept at ground potential (i.e. 0 V, DC). The device can also be operated without shield electrode. The toner bearing surface is kept at a DC-potential - 100 V, whereon an AC-potential with peak to peak voltage 400 V and a frequency $1/\lambda_1$ is applied. When the printing aperture is intended to stop the toner flow completely (CE_{OFF}), a DC voltage of - 100 V is applied to the control electrode and an AC-potential with peak to peak voltage 400 V and a frequency $1/\lambda_1$ is applied on top of said DC-potential. The AC voltage on the toner bearing surface and on the control electrode are in phase. Thus the AC-field on the control electrode and the AC-field on the tone bearing surface balance each other out and no AC-field exists over the gap between the toner bearing surface and the control electrodes when the printing aperture has to block the toner flow. When the printing aperture is intended to let the toner flow uninfluenced (CE_{ON}), a DC voltage of - 0 V is applied to the control electrode, (i.e. the control electrode is grounded). Thus, an AC-field exists over the gap between the toner bearing surface and the control electrodes when the printing aperture has to let toner particles pass freely.

[0045] Such a device is shown in figure 5. The DEP device shown comprises means for delivering toner particles with a container (101) for developer (102) wherein a magnetic brush (103) having a core (103a) wherein magnets are present and a sleeve (103b) rotatably mounted around the core is present. The developer (102) can be a mono-component developer with magnetic toner particles and then on the surface of the sleeve of the magnetic brush, toner particles are present, i.e. the surface of the sleeve (103b) of the mag-

netic brush is the toner bearing surface. The developer (102) can also be a multi-component developer containing magnetic carrier particles and non-magnetic toner particles and then on the sleeve of the magnetic brush carrier and toner particles are present, but the sleeve is still the toner bearing surface in the sense of this invention. The magnetic brush (103) can have a fixed core (103a) and a sleeve (103b) rotatably mounted around the core equipped with means for rotating the core. In another embodiment, the core (103a) of the magnetic brush is also equipped with means for rotating the core and can thus also be rotated and the sleeve (103b) can be rotated around the core or kept stationary. (The means for rotating the core and/or the sleeve are not shown in the figure). The part of the magnetic brush that rotates, does so in the direction of arrow B. A device (118) for generating a DC-voltage and an AC-voltage is connected to the sleeve of the magnetic brush and applies a DC-voltage (DC1) and an AC-field (AC1) to said sleeve (the toner bearing surface). Between said device for generating DC1 and AC1 and the toner bearing surface, optionally a further means for providing a DC and/or AC-potential (116) to the toner bearing surface may be present. The amount of developer on the toner bearing surface is regulated by a doctor blade (113).

[0046] The device, as shown, further comprises a back electrode (105) connected to a DC voltage source applying a voltage DC4 to the back electrode. An image receiving substrate (108) is passed by means for moving the substrate (107) in the direction of arrow A between the printhead structure (106) and the back electrode by conveying means (107). The difference between voltage DC4 and voltage DC1 applies a DC-propulsion field wherein a flow of toner particles (104) is created from the sleeve of the magnetic brush (the toner bearing surface) to the image receiving substrate on the back electrode. The AC-field (AC1) on the sleeve of the magnetic brush makes the flow (104) of toner particles denser than when no AC-field would be present.

[0047] A printhead structure (106), with an insulating material (106c) carrying control electrodes (106a), wherein the control electrodes are designed according to this invention, is interposed in the flow (104) of toner particles. The control electrodes (106a) can selectively be connected, over switch (115) either to a device (119) for generating a DC-voltage (DC3) and an AC-field (AC3) or to said device (118) for generating a DC-voltage (DC1) and an AC-voltage (AC1). Between said device for applying a DC-voltage (DC3) and an AC-field (AC3) to the control electrode, optionally a further means for providing a DC and/or AC-potential (117) to the control electrode may be present.

[0048] By image-wise modulating the electric potential applied by switch (115) to the control electrodes, the flow of charged toner particles is image-wise modulated in the vicinity of the control electrodes. The voltage applied to the control electrodes can be set to a value totally blocking the passage of the toner particles (i.e.

when switch 115 connects the control electrodes to when DC1 and AC1). Alternatively, the toner flow passes totally unimpeded when $AC3 = 0$ and $DC3 = 0$ (i.e. when the control electrode is grounded). In a preferred embodiment of the invention, the control electrode is grounded for printing full density through the printing aperture it controls and the grey levels are printed by time modulating the switching of a switch (115) between the devices providing DC3 and AC3 and the devices providing DC1 and AC1. In the simplest implementation no device (119) for generating a DC-voltage (DC3) and an AC-field (AC3) is incorporated, and the switch (115) switches the control electrode between the device (118) connected to the toner bearing surface and the ground. It is possible, as described above, to apply a DC-voltage (DC3) having a value different from DC1 and/or an AC-field (AC3) having a value different from the AC-field (AC1) to the control electrode, for partially blocking the printing apertures and at the same time again time modulating the switching of switch 115. By doing so, the number of grey levels that can be printed can be enhanced.

[0049] The control electrodes in said printhead structure and, designed according to this invention are placed at a distance d from the toner bearing surface, a spacer (110) keeps the distance d constant during operation of the device. The control electrode paths extend in both directions perpendicular to the toner bearing member to a length larger than the printing nip in which toner particles can be selected for said printing apertures. In practice said minimal length is at least 1 mm, preferably at least 3 mm.

[0050] The device comprises further means (109) for fixing the toner particles to the image receiving substrate.

[0051] In an other embodiment, a printhead structure according to this invention is included in a device wherein the toner bearing surface is kept at a DC-potential of 0 V (i.e. it is grounded). When the printing aperture is intended to stop the toner flow completely (CE_{OFF}), a DC voltage of 0 V is applied to the control electrode, and again no AC-field exists over the gap between the toner bearing surface and the control electrodes when the printing aperture has to block the toner flow. When the printing aperture is intended to let the toner flow uninfluenced (CE_{ON}), a DC voltage of + 100 V is applied to the control electrode, on top of which an AC-potential with peak to peak voltage 400 V and a frequency $1/\lambda_1$ is applied. Again, an AC-field exists over the gap between the toner bearing surface and the control electrodes when the printing aperture has to let toner particles pass freely. Such a device is shown in figure 6.

[0052] In figure 5, the toner bearing surface is the surface of the sleeve of a magnetic brush, in figure 6 a device according to a further embodiment of the invention is shown, wherein the toner bearing surface is the surface of an applicator carrying toner particles derived from a non-magnetic mono-component developer.

[0053] The device, shown in figure 6 is the same as the one shown in figure 5, except for the toner bearing surface, so only the numericals different from those used in figure 4 will be described. In a container (101) for non magnetic mono component developer a roller (112) is present, having a surface. On this surface toner particles are applied by means of a feeding roller (111) made of porous foamed polymers. A developer mixing blade (114) mixes and transports said non-magnetic mono-component developer towards said feeding roller. A doctor blade (113) regulates the thickness of the charged toner particles upon the surface said roller (112), i.e. on the toner bearing surface.

[0054] In the DEP device shown in figure 6 only a device (118) only generating a DC-potential (DC1) is connected to the sleeve of the toner bearing surface. The control electrodes (106a) can over a switch 115 selectively be connected to a device (119) providing an AC-field (AC3) and a device providing a DC-voltage (DC3) or to the device (118) providing a DC-voltage (DC1) on the toner bearing surface. The DC potential (DC3) and the AC-field (AC3) are image-wise modulated in order to modulate the toner flow through the control electrodes. The voltage applied to the control electrodes can be varied between a value totally blocking the passage of the toner particles when the switch (115) connects the control electrode to the device (118) providing a DC-voltage (DC1), and a value leaving the toner flow pass totally unimpeded when the switch (115) connects the control electrode to the device (119) providing a DC-voltage (DC3) and an AC-field (AC3). Intermediate settings of DC3 and AC3 make it again possible, as described above, to increase the number of grey levels that can be printed.

[0055] Grey levels can then be printed by bringing the control electrode and the toner bearing surface only a fraction of the line time (LT) to the same electric potential, thus blocking the toner flow for only a fraction of the line time (LT). This time modulation is a preferred embodiment of the present invention. It is possible, for increasing the number of grey levels that can be printed, to have a DC-voltage on the control electrodes deviating from the DC-voltage on the toner bearing surface and/or to have an AC-voltage on the control electrodes deviating from the AC-voltage on the toner bearing surface. Thus it is possible to choose the strength of the AC-field over the gap between the toner bearing surface and the control electrodes such that so that, e.g. not D_{max} is formed, but only three quarter of D_{max} , half of D_{max} , a quarter of D_{max} , etc. By combining a time modulation with a modulation of the strength of the AC-field, it is possible to print a higher number of density levels, than when using time-modulation alone or using the modulation of the strength of the AC-field alone.

[0056] The insulating material, used for producing a printhead structure, according to the present invention, can be glass, ceramic, plastic, etc. Preferably said insulating material is a plastic material, and can be a poly-

imide, a polyester (e.g. polyethylene terephthalate, polyethylene naphthalate, etc.), polyolefines, an epoxy resin, an organosilicon resin, rubber, etc.

[0057] The selection of an insulating material for the production of a printhead structure according to the present invention, is governed by the elasticity modulus of the insulating material. Insulating material, useful in the present invention, has an elasticity modulus between 0.1 and 10 GPa, both limits included, preferably between 2 and 8 GPa and most preferably between 4 and 6 GPa. The insulating material has a thickness between 25 and 1000 μm , preferably between 50 and 200 μm .

[0058] The back electrode (105) of a DEP device can also be made to cooperate with the printhead structure according to this invention, said back electrode being constructed from different styli or wires that are galvanically isolated and connected to a voltage source as disclosed in e.g. **US-A-4, 568, 955** and **US-A-4, 733, 256**. The back electrode, co-operating with the printhead structure, can also comprise one or more flexible PCB's (Printed Circuit Board).

[0059] The combination of a high spatial resolution and of the multiple grey level capabilities typical for DEP, opens the way for multilevel half-toning techniques, such as e.g. described in EP-A-634 862 with title "Screening method for a rendering device having restricted density resolution". This enables the DEP device, according to the present invention, to render high quality images.

[0060] The use of a printhead structure according to this invention has the advantage that from a printhead structure with multiple rows, all rows can be used for printing during the printing period, thus making it possible to print faster than with the method described in DE-A-197 16 115. Thus the invention also encompasses a method for direct electrostatic printing comprising the steps of :

- applying a first electric potential a toner bearing surface carrying charged toner particles,
- creating a flow of said charged toner particles away from said surface,
- passing an image receiving substrate (108) in said flow,
- placing a printhead structure (106) having printing apertures (106d) and control electrodes (106a) in at least two rows, between said toner bearing (103b) surface and said image receiving substrate (109), leaving a gap d between said toner bearing surface (103b) and said control electrodes (106a), characterised in that
- said printhead structure is a printhead structure according to any of claims 1 to 5,
- applying a variable voltage in accordance with image data to said control electrodes for selectively opening and closing said apertures for said charged toner particles, and

- all rows of printing aperture are used during the printing period.

EXAMPLES

EXAMPLE 1

The printhead structure.

[0061] A printhead structure (106) was made from a polyimide film of 50 μm thickness (106c), single sided coated with a 5 μm thick copper film. The printhead structure (106) had one row of printing apertures. On the back side of the printhead structure, facing the receiving member substrate, a rectangular shaped control electrode (106a) was arranged around each aperture. Each of said control electrodes had conductive paths in a direction parallel to the printing direction over 10 mm and was connected over 2 M Ω resistors to a HV 507 (trade name) high voltage switching IC, commercially available through Supertex, USA, that was powered from a high voltage power amplifier. The printing apertures were rectangular shaped with dimensions of 200 by 100 μm . The dimension of the central part (C1) of the rectangular shaped copper control electrodes was 320 by 300 μm , the line width of the C2 and C3 segments was 100 μm . The apertures were spaced at a 400 μm pitch. Said printhead structure was fabricated in the following way. First of all the control electrode pattern was etched by conventional copper etching techniques. The apertures were made by a step and repeat focused excimer laser making use of the control electrode patterns as focusing aid. After excimer burning the printhead structure was cleaned by a short isotropic plasma etching cleaning. Finally a thin coating of PLASTIK70, commercially available from Kontakt Chemie, was applied over the control electrode side of said printhead structure.

The toner delivery means

[0062] The toner delivery means was a commercially available toner cartridge comprising non magnetic mono component developer, the COLOR LASER TONER CARTRIDGE MAGENTA (M3760GIA), for the COLOR LASER WRITER (Trade names of Apple Computer, USA). The toner bearing surface is the surface of an aluminium roller (112), whereon tone particles are applied by a feeding roller (111) The toner particles carried a negative charge.

The printing engine

[0063] The printhead structure, mounted in a PVC-frame (116), was bent with frictional contact over the surface of the roller of the toner delivery means. A 50 μm thick polyurethane coating was used as self-regulating spacer means (110).

[0064] A back electrode was present behind the paper whereon the printing proceeded, the distance between the back electrode (105) and the back side of the printhead structure (i.e. control electrodes (106a)) was set to 1000 μm and the paper travelled at 200 cm/min.

[0065] The back electrode was connected to a high voltage power supply, applying a voltage DC4 of + 1000 V to the back electrode. To the toner bearing surface of the toner delivery means a sinusoidally changing AC voltage (AC1) with 400 V peak to peak and a frequency of 3 kHz was applied and a DC-offset (DC1) of -100 V. The DC-propulsion field, i.e. the potential difference between DC4 and DC1, was 1100 V. To the individual control electrodes an (image-wise-selected) voltage was applied selected from 0 V (printing a pixel of maximum density) or the same voltage as applied to the toner delivery means (DC1 and AC1 with the same amplitude and phase as the voltages applied to the toner bearing surface: printing a pixel with minimum density). Grey scale images of a human face and control wedges from maximum to minimum density were printed during several minutes after which the image quality and toner accumulation upon said printhead structure was observed. Said printing example showed extremely good results.

COMPARATIVE EXAMPLE

[0066] The same experiment was done as described in example 1 except that the even control electrodes in said printhead structure were connected to said HV507 control IC's over one side and said control electrodes did not have an extension in the other direction, and the uneven control electrodes in said printhead structure were connected to said HV507 control IC's over the other side and said control electrodes did not have an extension in said first direction. After printing the printing density was not identical for the printing apertures having control electrode paths in the upstream and downstream direction.

EXAMPLE 2.

[0067] The same experiment as described in example 1 was repeated except that a printhead structure having two separate rows of printing apertures was used. Here again no difference in printing density was observed for both rows of printing apertures.

Claims

1. A printhead structure (106) for use in a device for direct electrostatic printing using dry toner particles comprising a sheet of insulating material (106c) having two faces, a row of printing apertures (106d) through said insulating material, a printing nip, with edges parallel to said row, defined around said row and control electrodes (106a) on at least one of said

faces, each of said control electrodes having a first electric conductor (C1) around at least one of said printing apertures, characterised in that

two further electric conductors (C2 and C3) extending from said first electric conductor towards said edges, are included in each of said control electrodes, a longer one having a length, LC3, larger than 3 mm and a shorter one having a length, LC2, of at most 4 mm and $\text{LC2/LC3} \leq 0.75$.

2. A printhead structure according to claim 1, wherein shorter one of said further electric conductors has a length between 0.25 mm and 4 mm both limits included.
3. A printhead structure according to claim 1, wherein shorter one of said further electric conductors has a length between 0.5 mm and 4 mm both limits included.
4. A printhead structure according to any of claims 1 to 3, wherein only one of said two further electric conductors, included in each of said control electrodes, is coupled to a voltage source.
5. A printhead structure according to claim 4, wherein only said longer of said two further conductors is coupled to a voltage source.
6. A printhead structure according to any of claims 1 to 4, wherein
said printing apertures, each having a centre point, are arranged in at least one row wherein all said centre-points are situated on a single line, and said two further electric conductors (C1, C2) are in line with each other and extend from said first electric conductor towards said edges in directions opposite to each other.
7. A printhead structure according to any of claims 1 to 5, having a multiple number of rows of printing apertures, wherein said further conductors (C2, C3) present in a first row of printing apertures do not pass between printing apertures in a further row of printing apertures.
8. A printhead structure according to any of claims 1 to 5, having two rows of printing apertures, a first and a second one, wherein said further conductors (C2, C3) present in said first row do not pass between printing apertures in said second row of printing apertures.
9. A printhead structure according to any of claims 1 to 5, wherein only one row of printing apertures is present and said further conductor having a length larger than 3 mm (C3) included in a first control elec-

trode and coupled to a voltage source and said further conductor having a length larger than 3 mm (C3) included in a control electrode adjacent to said first control electrode and coupled to a voltage source are located on opposite sides of said row of printing apertures. 5

10. A printhead structure according to any of claims 1 to 8, wherein on said second face of said insulating material a common shield electrode is present. 10

11. A printhead structure according to any of claims 1 to 8, wherein only control electrodes associated with printing apertures are present on said insulating material. 15

12. A device for direct electrostatic printing comprising

- a means for delivering charged toner particles, said means having a toner bearing surface (103b) coupled to a means (118) for applying a first electric potential to said surface, 20
- a means (105) for creating a flow of said charged toner particles away from said surface,
- a means (107) for passing an image receiving substrate (108) in said flow, 25
- a printhead structure (106) having printing apertures (106d) and control electrodes (106a), placed between said toner bearing (103b) surface and said image receiving substrate (109), leaving a gap d between said toner bearing surface (103b) and said control electrodes (106a), characterised in that 30
- said printhead structure is a printhead structure according to any of the preceding claims and 35
- said control electrodes are arranged to be selectively connected, in accordance with image data, to said means (118) for applying a first electric potential on said toner bearing surface and to a device (119) for generating a second electric potential. 40

13. A method for direct electrostatic printing comprising the steps of : 45

- applying a first electric potential a toner bearing surface carrying charged toner particles,
- creating a flow of said charged toner particles away from said surface,
- passing an image receiving substrate (108) in said flow, 50
- placing a printhead structure (106) having printing apertures (106d) and control electrodes (106a) in at least two rows, between said toner bearing (103b) surface and said image receiving substrate (109), leaving a gap d between said toner bearing surface (103b) and said control electrodes (106a), characterised in that 55

- said printhead structure is a printhead structure according to any of claims 1 to 10,
- applying a variable voltage in accordance with image data to said control electrodes for selectively opening and closing said apertures for said charged toner particles, and
- all rows of printing aperture are used during line time.

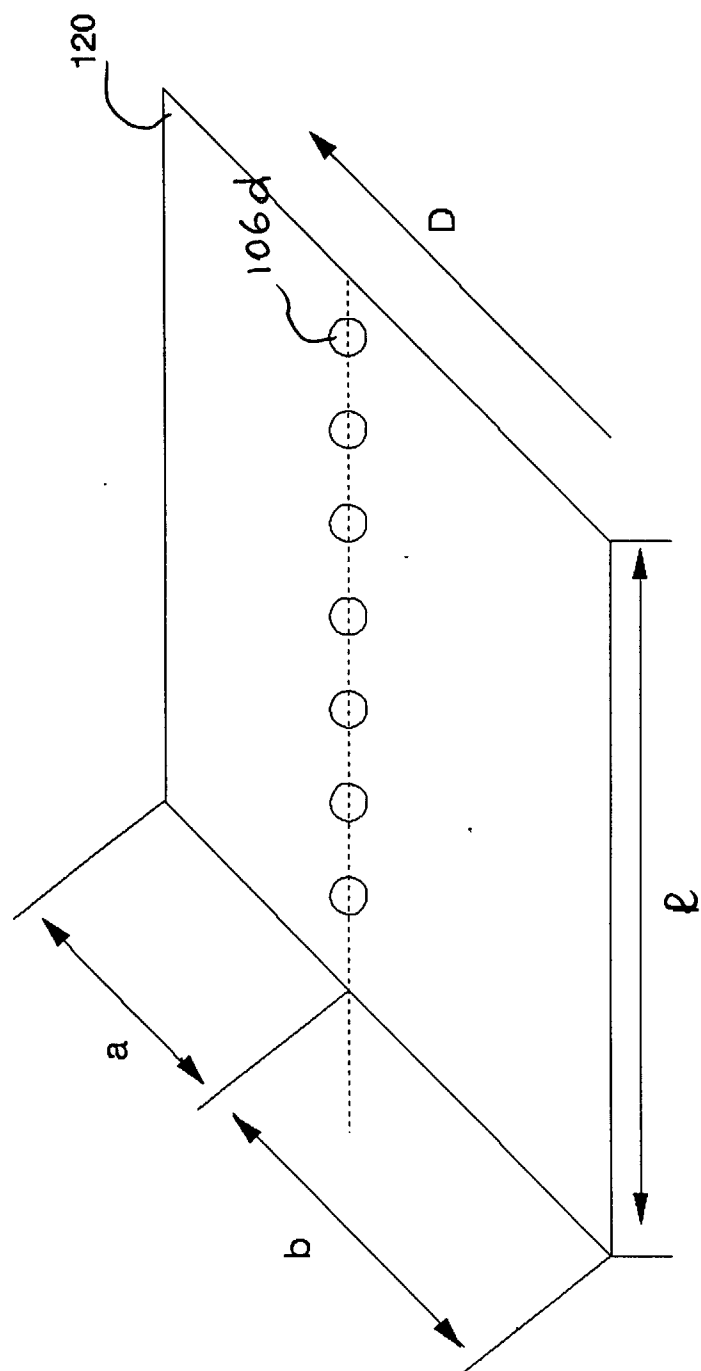
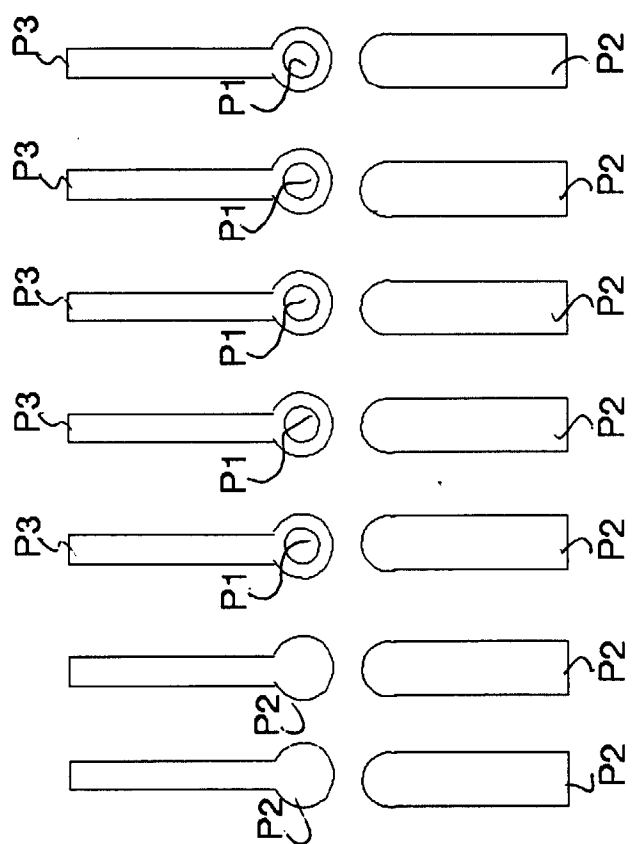


Fig. 1.



PRIOR ART

Fig. 2

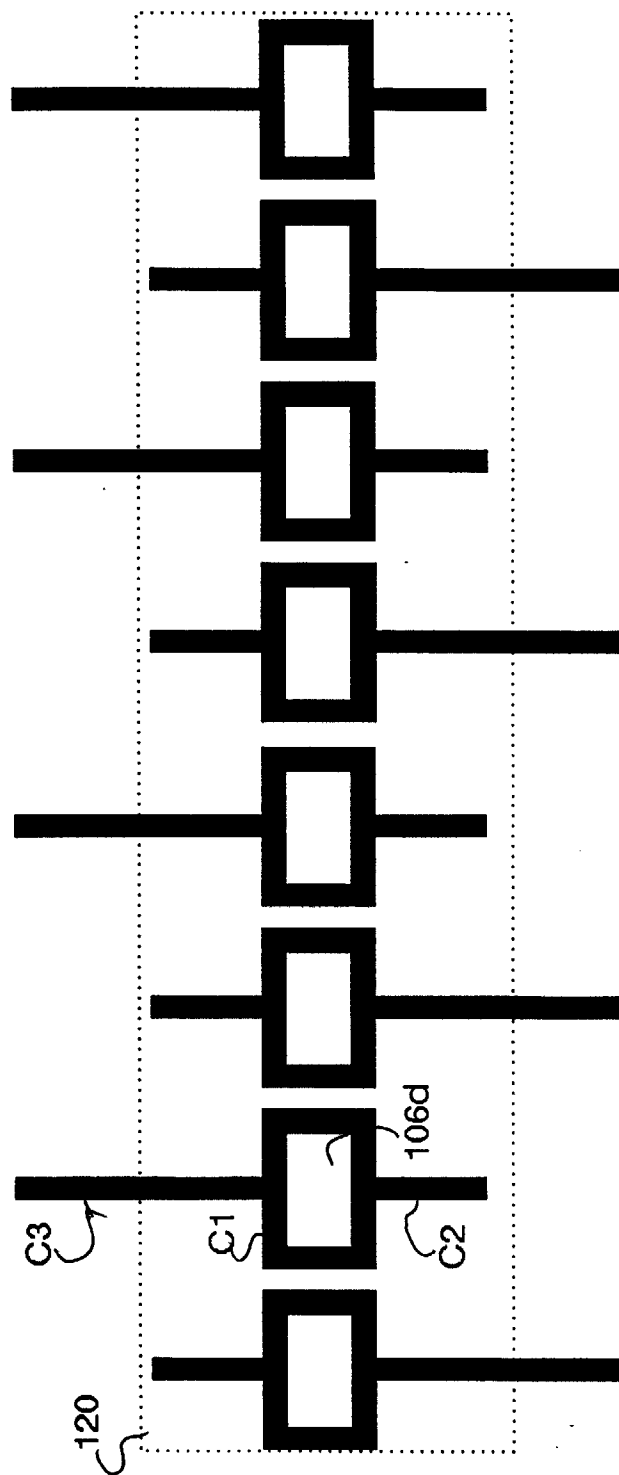


Fig. 3

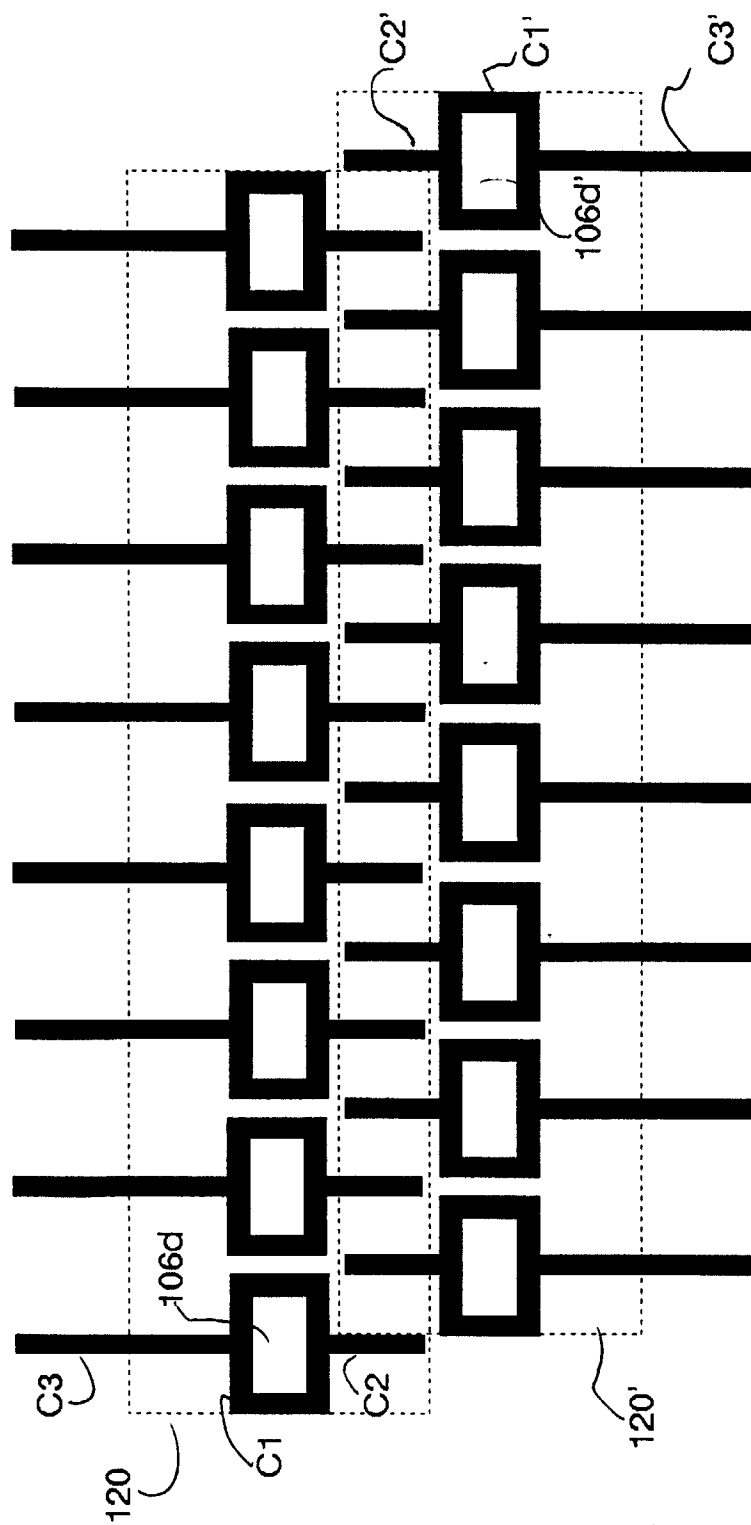


Fig. 4

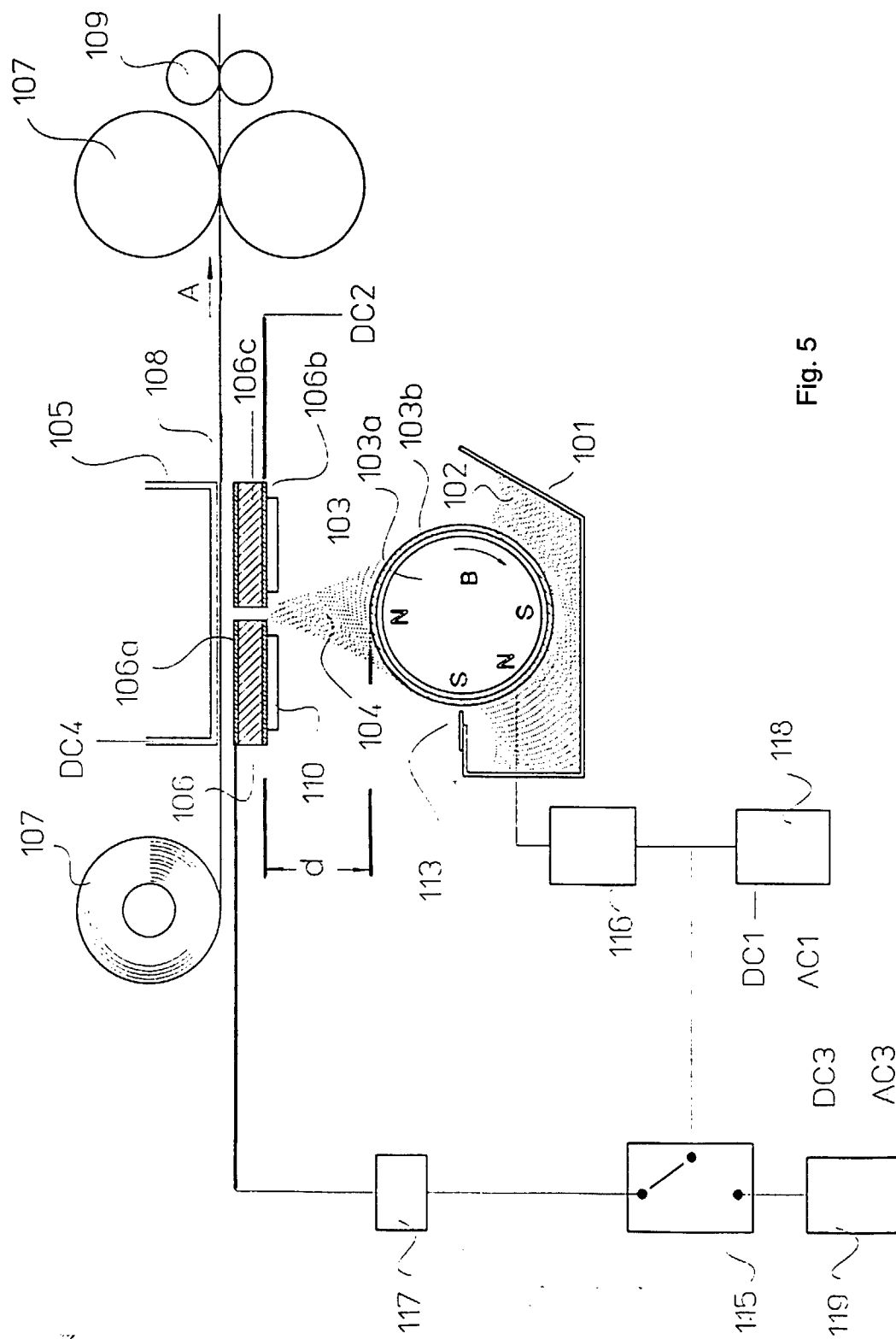


Fig. 5

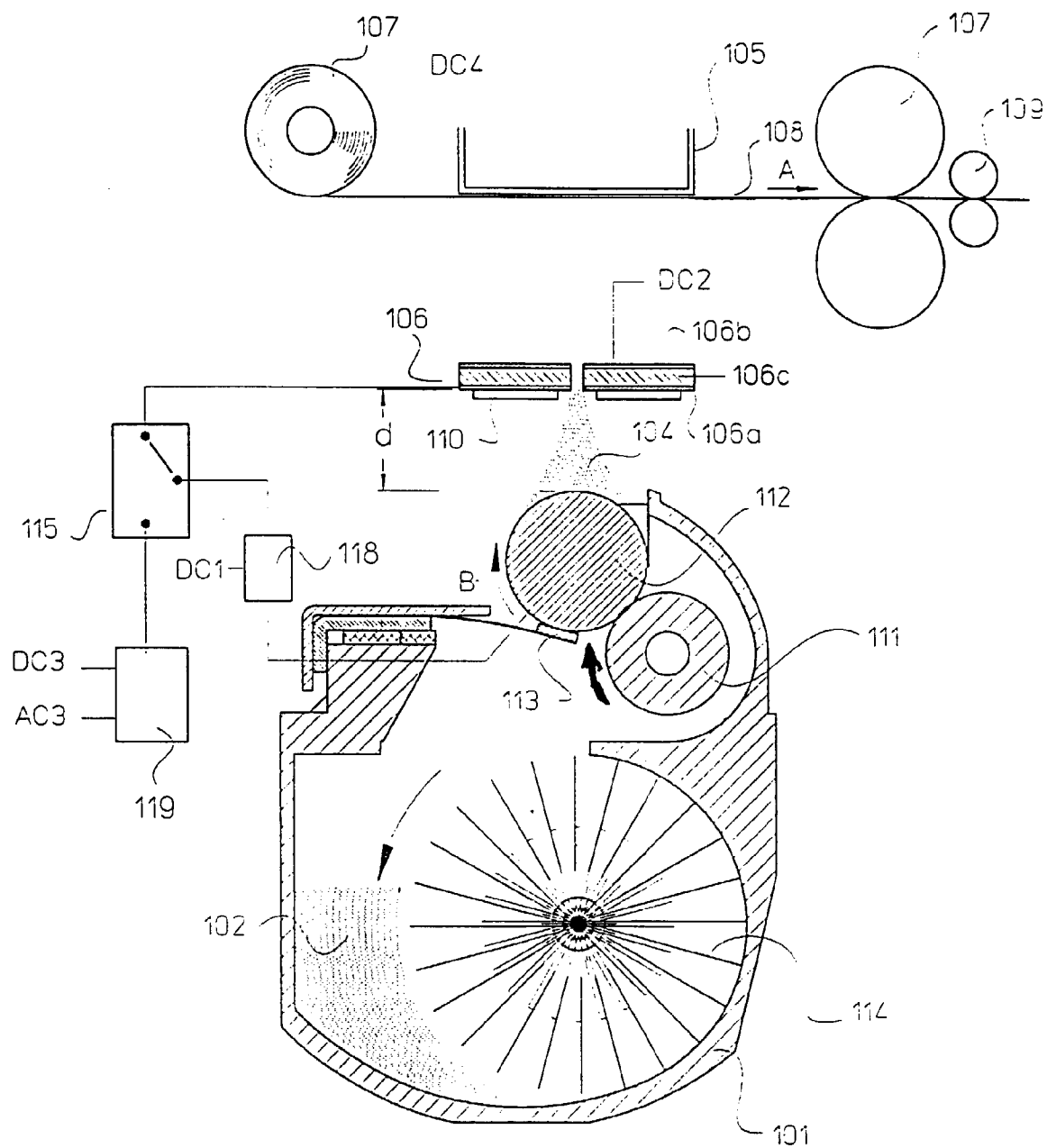


Fig. 6



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 4099

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	DE 197 16 115 A (ARRAY PRINTERS AB) 30 October 1997	1-4,12	B41J2/415
Y	* column 5, line 47 - column 8, line 44; figures *	9,11	
A	---	5	
X	US 5 128 695 A (MAEDA MASATAKA) 7 July 1992	1-3,6,10	
Y	* column 3, line 55 - column 4, line 16; figure 2 * * column 5, line 31 - column 6, line 23 *	9,11	
A	---		
A	US 5 477 250 A (LARSON OVE) 19 December 1995 * column 2, line 27 - column 3, line 25; figures 2-5 *	1,12	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B41J
A	WO 94 26527 A (ARRAY PRINTERS AB) 24 November 1994 * page 8, line 3 - page 12, line 5; figure 3 *	1,12	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 7 April 1999	Examiner De Groot, R
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 20 4099

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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07-04-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19716115 A	30-10-1997	JP 10044491 A	17-02-1998
US 5128695 A	07-07-1992	JP 2850504 B	27-01-1999
		JP 4085053 A	18-03-1992
US 5477250 A	19-12-1995	SE 470421 B	21-02-1994
		DE 4338992 A	26-05-1994
		JP 2790602 B	27-08-1998
		JP 6234233 A	23-08-1994
		SE 9203392 A	21-02-1994
WO 9426527 A	24-11-1994	US 5515084 A	07-05-1996