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(54) **A method of printing in a device for direct electrostatic printing comprising a printhead structure with deflection electrodes and a means for electrically controlling said deflection electrodes.**

Druckverfahren und Steuerung für Druckkopf mit Ablenkelektroden zum direkten elektrostatischen Drucken

Méthode d'impression et contrôle pour une tête d'impression avec électrodes de déviation pour l'impression électrostatique directe

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EP-A- 0 945 275
WO-A-97/35725
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Description

FIELD OF THE INVENTION

[0001] This invention relates to a recording method and an apparatus for use in the process of Direct Electrostatic Printing (DEP), in which an image is created upon a receiving substrate 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) toner particles are deposited directly in an image-wise way on a receiving substrate, the latter not bearing any image-wise latent electrostatic image.

[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, or from electrophotography in which an additional step and additional member is introduced to create the latent electrostatic image (photoconductor and charging/exposure cycle).

[0004] 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.

[0005] Each control electrode is formed around one aperture and is isolated from each other control electrode.

[0006] 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 perpendicular 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.

[0007] One of the recognised problems with this type of printhead structures is that the printing apertures focus the toner flux on the receiver leading to lower density spaces in the printing direction between neighbouring printing apertures, and drastically reducing the maximum density that can be obtained with such printhead structures.

[0008] Several possible solutions for this problem of lower density lines in the print direction have been described.

[0009] In **US-A-4 860 036** e.g. a printhead structure with at least 3 rows of printing apertures is disclosed in order to diminish the white zone between neighbouring printing apertures.

[0010] In **US-A-5 666 148** and **US-A-5 714 992** said problem is tackled by the implementation of a printhead structure that comprises control electrodes with more than one aperture per control electrode.

[0011] In **US-A-5 659 344** a DEP device is disclosed having a printhead structure that comprises an insulating material with apertures and control electrodes, and extra apertures in between two of said neighbouring control electrodes.

[0012] In **EP-A-780 740** a printhead structure, for a DEP device is disclosed that comprises an insulating material and a slit as printing aperture with many control electrodes reaching to the end of said slit aperture. In such a printhead structure lower density banding in the print direction is impossible. However, the construction of said slit-printhead structure is not that easy.

[0013] In **US-A-5 625 392** an edge electrode is described so that instead of individual apertures or a larger slit as described in **EP-A-780 740** an even larger free zone between the toner applicator and the receiver exists, resulting in even density printing without lower density banding. Moreover, it is much easier to manufacture such a DEP device comprising an edge electrode.

[0014] In **DE-A-195 34 705** a DEP device is described in which the problem of lower density banding is tackled by the introduction of two different printhead structures and two toner application devices. This is of course an easy but costly solution to said banding problem.

[0015] Further interesting concepts for diminishing said problem of lower density banding have been proposed. In **US-A-5 170 185** a DEP device is disclosed that comprises a printhead structure, an ultrasonic vibration means, an image information generating means and a toner deflecting means. Said toner deflecting means is a set of deflection electrodes (isolated from said control electrodes) positioned in between said image receptive member and said printhead structure. Between said two sets of deflection electrodes a varying electrical field is applied resulting to deformation of said toner flux towards said image receptive member. In this disclosure said varying electrical field can be a pulsed voltage, a stepwise voltage as well as a saw-tooth voltage. The printhead structure is rather complex since it comprises (if it is formed in a PCB-layout) three different conductor layers that have to be isolated from each other. If a simple printhead structure is used with only two planes with electrodes, a further set of deflection electrodes is placed between the printhead structure and the substrate to be printed.
[0016] The same idea has also been proposed in **US-A-5 606 402**, where a DEP device is disclosed which comprises a layer of control electrodes in a control grid, a toner flying stabilisation grid and a set of deflection electrodes that can position a dot on the final receiver on one of different possible positions.
[0017] In **WO-97 35 725** a DEP device and a method of printing have been described comprising at least a set of deflection electrodes and a controller for said deflection electrodes so that through one printing aperture three dots can be printed, in a straight, a left and a right position. In such a case the number of control electrodes is lower than the addressability of the device, i.e. there are less control electrodes than dots printed. This implementation can enhance the resolution of the printhead structure or diminish the complexity by reducing the number of control IC's that are essential for providing the image variation, but by using said deflection electrodes on a time-based scale to print three different dots on the receiving material in consecutive order, the maximum attainable printing speed is diminished by a factor of at least 3.
[0018] In **DE-A-197 39 988** and its US equivalent **US-A-5,774,159** a DEP device and a method of printing have been described comprising at least a set of deflection electrodes and a controller for said deflection electrodes. On the control electrodes a changing voltage is applied with a period equal to the line time. Thus during line time the toner flow trough a printing aperture is continuously moved from one side to another so that a circular dot is printed as an ellipse. By doing so white banding in the print direction is avoided. As shown in that disclosure (figure 10) the white banding is avoided in the higher density, but is not totally avoided in the lower densities.
[0019] The prior art disclosures concentrate on the construction of the printhead structure, the deflection electrodes and the voltage applied to the deflection electrodes.

OBJECTS AND SUMMARY OF THE INVENTION

[0020] It is an object of the invention is to provide a DEP device, i.e. a device for direct electrostatic printing that can print at high speed with low clogging of the printing apertures and with high and constant maximum density with almost no white banding parallel to the printing direction.
[0021] Further objects and advantages of the invention will become clear from the detailed description herein after.
[0022] The object of the invention is realised by providing a device for direct electrostatic printing with an addressability, AD, in dots per cm, comprising

- a means for delivering charged toner particles, said means having a surface bearing charged toner particles (112) coupled to a means for applying a first electric potential (DC1) to said surface,
- a means for coupling an image receiving substrate (108) to a second electric potential (DC4) different from said first, said difference (|DC4-DC1|) creating an electric field between said surface and said substrate, wherein a flow of said charged toner particles (104) towards said substrate is created,
- a means (115)for moving said substrate in a printing direction (arrow A) so as to have a line time, LT,
- a printhead structure (106), placed between said toner bearing surface (112) and said image receiving substrate (108), leaving a gap, d, between said toner bearing surface and said printhead structure and leaving a gap, d_B, between said printhead structure and said image receiving substrate, said printhead structure having

  a sheet of insulating material (106c) with a first and a second face, a number of printing elements (116), forming at least one row on said substrate, each of said printing elements including at least one printing aperture (107) through said insulating substrate,
  and at least two sets of deflection electrodes (106b1, 106b2), arranged in said printhead structure so as to have, near two adjacent printing elements, at least two deflection electrodes,

- a voltage source, DC3, coupled to said printing elements for image-wise applying electric potentials (V3) to said printing elements for selectively opening and closing said printing apertures in accordance with image data and
- a voltage source, coupled to each of said at least two sets two sets of deflection electrodes, for applying a varying

voltage to said deflection electrodes,
characterised in that
said gap, d_B, between said printhead structure and said image receiving substrate, relates to said difference between DC4 and DC1 so that $R1 = (|DC4-DC1|/d_B) \leq 1.5$ V/µm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Figure 1 shows schematically a first possible embodiment of printhead structure useful in a DEP device of this invention.

[0024] Figure 2 shows schematically a second possible embodiment of a printhead structure useful in a DEP device of this invention.

[0025] Figure 3 shows schematically a third possible embodiment of a printhead structure useful in a DEP device according to the present invention.

[0026] Figure 4 shows a DEP device comprising a printhead structure according to the first possible embodiment of a printhead structure useful in a method for Direct Electrostatic Printing and in a DEP device according to of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0027] Line time (LT): the time for printing one pixel dot. When an aperture is kept open during the total line time, maximum density is achieved in that one pixel dot. When, e.g., a pixel with a dimension of 250 µm in the print direction A is printed in a printer running at 200 cm/mm, the line time, LT, is 8 ms.

[0028] Write time (WRT): a fraction of LT. By changing WRT grey scale printing is effected. When e.g., LT is divided in 128 parts, and WRT varies between 0/128 LT to 128/128 LT.

[0029] Wait time (WAT) : LT - WRT = WAT.

[0030] Addressability : the number of dots printed per unit of length (2.54 dots per inch (dpi) equal 1 dot per cm) that are addressed. Thus a DEP device having a number of control electrodes equal to the addressability have one control electrode for each dot to be addressed. One dot can be written via one printing aperture controlled by one control electrode or by more than one printing aperture when these printing apertures are controlled by one control electrode. The latter system has been described in detail in e.g. EP-A-754 557.

[0031] Printing element : In this document, one or more printing apertures together with the part of a single control electrode near to that printing aperture(s) for controlling the electric fields and the passage of charged toner particles through that aperture(s) is designated by the wording "printing element". E.g., referring to figure 2a of this text, printing aperture 107 and conductor C1 of control electrode 106a together form a printing element 116. Thus conductors C2 and C3, although being part of the control electrode, are, not included when the wording "printing element" is used.

[0032] Adjacent printing elements : for this document adjacent printing elements are printing elements that are adjacent in a row of printing elements. These can, but must not, be printing elements arranged in the printhead structure to print adjacent dots on the image receiving member.

[0033] It is known in the art of DEP (direct electrostatic printing), as described in the background art section above, that printing is performed by jetting dry toner particles through an aperture in a printhead structure to an image receptive member, leading to image density which is highest in the centre of said aperture and diminishes to the edge of the apertures. This is advantageous for printing high resolution lines, but when printing patches of even density, this phenomenon leads easily to lower density stripes (further on called "white stripes") parallel to the printing direction resulting in areas of even density. This banding phenomenon is easily perceptible for the human eye and is judged as bad image quality.

[0034] In direct electrostatic printing charged toner particles are moved in a continuous flow in an electric field from a surface bearing toner particles to a substrate and a printhead structure with printing apertures associated with control electrode is positioned in that flow. By image-wise applying different voltages to the control electrodes around the printing apertures, the amount of toner particles that pass through a printing aperture and/or the time wherein toner particles can pass through a specific apertures is image-wise modulated.

[0035] It has been disclosed in e.g. **US-A-5 170 185, US-A-5 606 402, WO-97 35 725** and in **US-A-5,774,159** to provide deflection electrodes with a varying voltage to smear the dot over a larger area than would be printed without the use of deflection electrodes and deflection voltages. Especially in US-A-5,774,159 a DEP printing system giving good printing quality, both in terms of resolution and absence of lower density banding, is disclosed, material) associated with printing apertures and by providing further electrodes in the vicinity of the printing apertures in the same plane. Preferably so by placing at least two sets of deflection electrodes on the printhead structure in such a way that between two adjacent printing apertures at least two deflection electrodes are present, one of each set. These deflection electrode can be coupled to a voltage source for applying a varying voltage to the deflection electrodes. The voltage source coupled to said deflection electrodes can be equipped for providing a stepwise varying voltage to the deflection electrodes. I.e. the voltage applied to the deflection electrodes varies in discrete steps. By doing so de DEP device of this invention can be used for printing multiple dots through one printing, since the step wise varying voltage applied to the deflection electrode deflects the toner to discrete places on the imaging substrate. The voltage source can, e.g., be designed to apply a voltage varying in three steps to the deflection electrodes, in a first step the left deflection electrode is given an attracting voltage so that the toner particles are, during printing, deviated to the left side of the centre of the printing element, then no deflection voltage is used and the toner particles are attracted at the centre of the printing elements and then the right deflection electrode is given an attracting voltage so that the toner particles are, during printing, deviated to the right side of the centre of the printing element. Ways and means for applying a voltage varying in discrete steps to deflection electrodes has been described in e.g. US-A-5 847 733 or it equivalent WO-A-97 35725. In this case the number of control electrodes in the printhead can be diminished to 1/3 of the addressability of the printing device, since for printing 3 dots, only one printing element (one control electrode) is necessary or the addressability increased with a factor three for a given number of printing elements per cm. The printing speed is however diminished by a factor 3.

[0036] The voltage source coupled to said deflection electrodes can also be equipped for providing a continuously varying voltage to the deflection electrodes. The continuously varying voltages provided by the voltage source coupled to the deflection electrodes vary on a time scale the toner flux passing an aperture is, during the line time moved from left to right so that an elliptic dot would be formed through a circular-shaped aperture, said long side of said elliptic dot being positioned essentially perpendicular to said printing direction. It is possible to couple these deflection electrodes, as e.g. in US-A-5,774,159, to a voltage source for providing a varying voltage with a frequency, f, so that f x LT is exactly 1.00. Thus during the line time, LT, when the varying voltage is applied to the deflection electrodes, the flow of toner particles through the printing aperture moves from one side to the other side of said printing aperture in a direction perpendicular to the printing direction. Thus helps to avoid the occurrence of white stripes in the print direction.

[0037] In the prior art teachings, no attention was given to the DEP device as a whole, as long as the deflection electrodes were coupled to an appropriate voltage source any beneficial effect could be achieved.

[0038] It was now found that the effects above could be indeed be realised following the teachings of the prior art, but that it was very important that in a DEP device using a printhead structure with at least two deflection electrodes between adjacent printing elements, the distance between the surface of image receiving substrate and the printhead structure, the electric potential difference between the toner bearing surface and the surface of image receiving substrate and the peak to peak voltage applied to the deflection electrodes had to be adjusted so as to have a specified relation between those values.

[0039] It was found that, in a device for direct electrostatic printing (a DEP device) using a printhead structure with printing elements and at least two deflection electrode between the printing elements and having a voltage source coupled to the deflection electrodes, providing a varying voltage to the deflection electrodes, the propulsion field, PF, between the toner bearing surface and the imaging substrate (this is the absolute value of the difference in voltage between DC4 and DC1) (in V) must relate to the distance, d_B, between the printhead structure and the image receiving substrate must relate to the distance, d_B, between the printhead structure and the image receiving substrate in a ratio, R1, so that

$R1 = (PF/d_B) \leq 1.5$ V/μm, preferably so that $R1 = (PF/d_B)/d_B \leq 1.0$ V/μm. The differences are taken in their absolute value, since the sign of the difference is chosen depending on the sign of the charge (positive of negative) of the toner particles, thus PF = (|DC4-DC1|).

[0040] It was further found that not only the ratio R1 had importance for good printing, but that also the peak to peak voltage, Vp, of the varying voltage (AC5, AC6) applied to the deflection electrodes has to relate to the ratio R1. It was found that when $V_p/R_1 > 250$ μm good printing results could be achieved, whereas when $V_p/R_1 > 400$ μm very good printing results could be achieved.

[0041] This proved to be true when the varying voltage varied in discrete steps, as well as when the varying voltage applied to the deflection electrodes varied continuously with a frequency, f, chosen in relation to the line time so that f x LT = 1.00. The invention includes thus a device for direct electrostatic printing with an addressability, AD, in dots per cm, comprising

- a means for delivering charged toner particles, said means having a surface bearing charged toner particles (112) coupled to a means for applying a first electric potential (DC1) to said surface,
- a back electrode (105) for coupling an image receiving substrate (108) to a second electric potential (DC4) different from said first, said difference (|DC4-DC1|) creating an electric field between said surface and said substrate, wherein a flow of said charged toner particles (104) towards said substrate is created,
- a means (115)for moving said substrate in a printing direction (arrow A) so as to have a line time, LT, said line time

being the time for printing a dot at full density,

- a printhead structure (106), placed between said toner bearing surface (112) and said image receiving substrate (108), leaving a gap, d, between said toner bearing surface and said printhead structure and leaving a gap, d_B, between said printhead structure and said backelectrode,

  said printhead structure having

  a sheet of insulating material (106c) with a first and a second face, a number of printing elements (116), forming at least one row on said sheet of insulating material, each of said printing elements including at least one printing aperture (107) through said sheet of insulating material,

  at least two sets of deflection electrodes (106b1, 106b2), arranged in said printhead structure so as to have, near two adjacent printing elements, at least one deflection electrode

- a voltage source, DC3, coupled to said printing elements for image-wise applying electric potentials (V3) to said printing elements for selectively opening and closing said printing apertures in accordance with image data
- a voltage source coupled to each of said at least two sets of deflection electrodes for applying a varying voltage (AC5, AC6) to said deflection electrodes

characterised in that

said gap, d_B, between said printhead structure and said back electrode, relates to said difference between DC4 and DC1 so that $R1 = (|DC4-DC1|/d_B) \leq 1.5$ V/µm and that said voltage source coupled to said deflection electrode is equipped for providing a varying voltage to said deflection electrodes with a peak-to-peak voltage, Vp, so that $V_p/R1 > 250$ µm.

[0042] In figure 1, a first possible embodiment of a printhead structure is shown having two rows of printing apertures (107), each of the printing apertures being surrounded by a control electrode that is connected to a voltage source (DC3). Between the printing apertures, in the same plane as the control electrodes, two sets of deflection electrodes (106b1 and 106b2) connected to voltage source V1 and V2 respectively) are present.

[0043] In fig. 2a, 2b and 2c the first and second face of a first embodiment of a printhead structure according to this invention is shown. The printhead structure comprises an insulating material and conductors in only two planes. Figure 2a shows the control electrodes (106a) on the first face of the insulating material, rectangular printing apertures (107) with three conductors, C1 around the apertures, C2 coupled to a voltage source (DC3) that in accordance with image-data changes the electric field in the printing aperture and a conductor C3, the conductor C1 and the printing aperture 107 associated with each of them, form printing element (116). A printhead structure with such a configuration of the control electrodes has been described in European Application 97204014, filed on December 18, 1997. Figure 2b shows the second face of the insulating material (106c) with a shield electrode is shown in a form so as to be useful as deflection electrode (further on such shield electrode will be termed 'deflection electrode').It shows two sets of deflection electrodes, each of said sets formed as a comb. The first set, as shown, looks like first comb (106b1), the teeth of which extend to the row of printing elements (116) and the second set as a second comb (106b2), the teeth of which extend also to the row of printing elements. Thus the teeth of the comb are basically parallel with the printing direction. The teeth of the first comb alternate with the teeth of the second comb, and on one side of each printing element (a side basically perpendicular to the printing direction extending to conductor C2) a tooth of the first comb is present and on the other side a tooth of the second comb. Thus between two adjacent printing elements, two deflection electrodes, one of each set, are present. At the edges of the row(s) or printing elements, only one deflection electrode is present, within the rows, two deflection electrodes, one of each set, are present between two adjacent printing apertures. The centre of each printing aperture, which coincides in this embodiment with the centre of the printing element, is located in the middle between the tooth of the first comb and the tooth of the second comb surrounding it. The first comb is coupled,to a voltage source (AC5) for providing a varying voltage on said first set of deflection electrodes (i.e. said first comb) and the second comb to a voltage source (AC5) for providing a varying voltage on said second set of deflection electrodes (i.e. said second comb). In figure 2c, a cross-section through the printing apertures and the electrodes is shown. On one face of the insulating material control electrodes (106a) are present around each of the printing apertures (107)on the other face deflection electrodes are present between two printing apertures two deflection electrodes are present, one (106b1)of the first set and one (106b2) of the second set. In fact along the cross-section an alternating unit consisting of an aperture (107), deflection electrode one (106b1) and deflection electrode two (106b2) is present.

[0044] Although it is preferred that the teeth of the first comb alternate with the teeth of the second comb, this is not necessary so, a printhead structure wherein these teeth do not alternate regularly is within the scope of this invention as long as between two printing apertures at least two deflection electrodes from different sets are present.

[0045] In Fig. 3a, 3b and 3c a printhead structure according to a second implementation of the first embodiment of the present invention, is shown. Basically the printhead structure is construed as the one shown in figures 2a, 2b and

2c, except that now two parallel rows of staggered printing elements are present each of them coupled to a voltage source (DC3) that in accordance with image-data changes the electric field in the printing aperture on the first side of the insulating material as shown in figure 3a. As shown in figure 3b two sets of deflection electrodes (106b1, 106b2) are formed on the second side of the insulating material (106c) in the form of two combs the teeth of which are not rectilinear. Again, the centre of each printing element is located in the middle between the tooth of the first comb and the tooth of the second comb surrounding it. In figure 3c a cross-section through the printing apertures and the electrodes on one row is shown. On one face of the insulating material control electrodes (106a) are present around each of the printing apertures (107)on the other face deflection electrodes are present between two printing apertures two deflection electrodes are present, one (106b1)of the first set and one (106b2) of the second set. In fact along the cross-section an alternating unit consisting of an aperture (107), deflection electrode one (106b1) and deflection electrode two (106b2) is present.

[0046] In fig. 4 a DEP device incorporating a printhead structure according to this invention is shown.

[0047] The DEP device shown comprises means for delivering toner particles with a container (101) for non magnetic mono component developer, a roller (112) having a surface on which toner particles are applied by means of a feeding roller (111) made of porous foamed polymers, a developer mixing blade (114) mixing and transporting said non-magnetic mono-component developer towards said feeding roller, a doctor blade (113) regulating the thickness of the charged toner particles upon the surface of said roller (112), i.e. on the toner bearing surface. Said roller (112) bearing said charged toner particles rotates in a direction depicted by arrow B. A device for applying a DC voltage is connected to the sleeve of said roller (112) and applies voltage DC1 to said sleeve and a device for applying an AC-field is connected to the sleeve of said roller and applies AC-field AC1 to said sleeve (the toner bearing surface).

[0048] The device, as shown, further comprises a back electrode (105) connected to a DC voltage source applying a voltage DC4 to the electrode. An image receiving substrate (108) is passed by means for moving (115) the substrate in the direction of arrow A between a printhead structure according to this invention and the back electrode by conveying means (115). The difference between DC4 and DC1 applies a DC propulsion field wherein a flow of toner particles (104) is created from the sleeve of the roller bearing charged toner particles to the image receiving substrate on the back electrode. The AC-field - AC1 - on the sleeve of the toner roller (112) makes the flow (104)of toner particles denser than when no AC-field would be present.

[0049] A printhead structure (106) is placed in said flow (104) of toner particles, said printhead structure having an insulating material (106c) carrying control electrodes (106a) and deflection electrodes (106b1 and 106b2). A DC-source (DC3) is connected to the control electrodes and the voltage applied by this DC-source is image-wise modulated in order to modulate the toner flow image wise in the vicinity of the control electrodes. The voltage applied by the DC source DC3 can be varied between a value totally blocking the passage of the toner particles, and a value leaving the toner flow pass totally unimpeded. The control electrodes in said printhead structure are placed at a distance, d, in μm from the toner bearing surface, a spacer (110) keeps the distance d constant during operation of the device. The printhead structure (106) is placed at a distance, d_B, form the image receiving member.

[0050] The sets of control electrodes (106b1 and 106b2) are connected to voltage sources for providing a varying voltage (AC5 and AC6) on said sets of deflection electrodes. The varying voltages have the same frequency, f, such that f x LT = 1.00.

[0051] The device comprises further means (109) for fixing the toner particles to the image receiving substrate.

[0052] The distance d_B is in devices operating with a back electrode calculated from the surface of the printhead structure to the surface of the image receiving member.

[0053] The back electrode (105) of a DEP device can also be made to co-operate 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).

EXAMPLES

[0054] After printing, the printing quality, especially with respect to the lower density was visually evaluated on a scale from 1 to 10, wherein 1 is bad, 5 is acceptable and 10 is very good.

[0055] In all printing examples the line time LT was set to 8 ms and when two sets of deflection electrodes were present each of said sets was coupled to a voltage source delivering a varying voltage both voltages (AC5 and AC6) having the same frequency and being out of phase by 180 ° so that the peak voltage applied to the deflection electrodes, V_p, equals AC5 + AC6.

PRINTING EXAMPLE 1 (PE1)

The printhead structure.

[0056] A printhead structure (106) was made from a polyimide film of 50 μm thickness (106c), double sided coated with a 5 μm thick copper film. The printhead structure (106) had one row of printing apertures. On the front side of the printhead structure, facing the toner bearing roller, 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 MΩ 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 pm, the line width of the extending segments was 100 μm. The apertures were spaced at a 500 μm pitch. On the back side of the printhead structure, facing the image receiving member, a double set of deflection electrodes (106b1 and 106b2) was arranged in between each set of neighbouring apertures. Said deflection electrodes had a line width of 70 μm and were isolated from each other by a free zone of 70 μm. The centre of said free zone was located in the middle between two neighbouring printing apertures so that both sets of deflection electrodes were available in a symmetrical order with respect to the printing apertures. Said printhead structure was fabricated in the following way. First of all the control electrode pattern and deflection 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 and deflection electrode side of said printhead structure.

The toner delivery means

[0057] 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

[0058] The printhead structure, mounted in a PVC-frame, was bent with frictional contact over the surface of the roller of the toner delivery means. A 50 μm (this is distance d) thick polyurethane coating was used as self-regulating spacer means (110).

[0059] 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 (d_B) was set to 500 μm and the paper travelled at 300 cm/min.

[0060] 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 -50 V. The DC-propulsion field, i.e. the potential difference between DC4 and DC1, was 1050 V. To the individual control electrodes an (image-wise-selected) voltage was applied selected from 0 V (printing a pixel of maximum density) or -280 V (printing a pixel of minimum density). To the first set of deflection electrodes a sinusoidally changing AC voltage (AC5) with 250 V peak to peak and a frequency of 500 Hz was applied, to the second set of deflection electrodes a sinusoidally changing AC voltage (AC6) with 250 V peak to peak and a frequency 500 Hz. Said frequency was adjusted so that it was synchronised with said first AC-voltage applied to said first set of deflection electrodes but 180° out of phase: i.e. the voltage applied to said first set of deflection electrodes gained a maximum value (.e.g. +250 V) at the moment that the voltage applied tot said second set of deflection electrodes gained a minimum value (e.g. -250V) was applied. Thus the maximum peak voltage difference between on the sets of deflection electrodes was 500 V, this is V_p.

[0061] 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 was observed in terms of lower density stripes in the printing direction in regions of higher image density.

[0062] The results of the evaluation of the printing quality are given in table 1. In table 1 the distance of the back electrode towards said printhead structure (d_B) is expressed in μm, the voltage applied to said back electrode (DC4) in V, the amplitude of the sinusoidally varying voltage signal, AC5 and AC6, applied between said two sets of deflection electrodes (AC5 and AC6) in peak to peak voltage, V_p, since both signals are shifted over 180 ° out of phase, equalling (AC5 + AC6), the ratio , R1 = $|DC4-DC1|/d_B$ (since DC 1 is small compared to DC4, only the value of DC4 is used in determining the ratio R1 and V_p/R1 are expressed in the same units as the individual members. The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLE 2 (PE2)

[0063] The same experiment was done as described in example 1 except that d_B was set to 1000 μm and DC4 at 1500 V.

PRINTING EXAMPLE 3 (PE3)

[0064] The same experiment was done as described in example 2 except that DC4 at 1000 V.

PRINTING EXAMPLES 4-7 (PE4-PE7)

[0065] The same experiment was done as described in example 3 except that the amplitude of the synchronised AC5 and AC6 applied was set to 50, 100, 150 and 200 V (peak to peak value), respectively. Thus the maximum peak voltage difference (V_p) between the two sets of deflection electrodes was 100, 200, 300 and 400 V The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLE 8 (PE8)

[0066] An experiment was done wherein d_B was set at 1000 μm, DC4 at 500 V, the amplitude of the synchronised the amplitude of the synchronised AC5 and AC6 applied was set to 150 V (peak to peak value), respectively. Thus the maximum peak voltage difference (V_p) between the two sets of deflection electrodes was 300 V. The results of the evaluation of the printing quality are given in table 1

TABLE 1

#	dB (μm)	DC4 (V)	AC5	AC6	f^+ Hz	$R1^{++}$	V_p/R1 \$	QC£
PE1	500	1000	250	250	125, s	2.0	500	2
PE2	1000	1500	250	250	125, s	1.5	333	5
PE3	1000	1000	250	250	125, s	1.0	500	7
PE4	1000	1000	50	50	125, s	1.0	100	2
PE5	1000	1000	100	100	125, s	1.0	200	3
PE6	1000	1000	150	150	125 ,s	1.0	300	5
PE7	1000	1000	200	200	125, s	1.0	400	6
PE8	1000	500	150	150	125, s	0.5	600	8

+ frequency and form of the varying voltage :
s : sinusoidal, b : block, sts : saw-tooth symmetrical, sta : saw-tooth asymmetrical
++ R1 = DC4/d_B, since the value of DC1 was in all experiments small compared to the value of DC4, the difference |DC4-DC1| was taken to be equal to DC4.
\$ V_p/R1 equals (AC5+AC6)/(DC4/d_B)
£ QC : printing quality 10 is very good, 1 is bad, 5 is; acceptable.
◊ : deflection electrodes facing the toner bearing substrate and contacting it; in the other examples the deflection electrodes faced the substrate to be printed.

[0067] It must be clear for those skilled in the art that the incorporation of a non-complicated deflection design in a printhead structure for the DEP-technique can solve the problem of lower density stripes in the print direction.

[0068] It is, e.g., also possible to use a stochastic method in the generation of halftone values (as described in EP-A-851 316 in combination with a not-coupled deflection voltage source. It is also possible to incorporate the deflection electrodes in different layers (multilayer structure) and enhancing the deflection voltage in ratio proportional to the isolation power. It is also possible to combine the concept of deflection electrodes with other concepts for elimination of lower density stripes as multiple printhead structures, multiple apertures per control electrode, multipass printing, sliding contact between the toner particle source and the printhead structure, etc..

Claims

1. A device for direct electrostatic printing with an addressability, AD, in dots per cm, comprising

- a means for delivering charged toner particles, said means having a surface bearing charged toner particles (112) coupled to a means for applying a first electric potential (DC1) to said surface,
- a back electrode (105) for coupling an image receiving substrate (108) to a second electric potential (DC4) different from said first, said difference (|DC4-DC1|) creating an electric field between said surface and said substrate, wherein a flow of said charged toner particles (104) towards said substrate is created,
- a means (115)for moving said substrate in a printing direction (arrow A) so as to have a line time, LT, said line time being the time for printing a dot at full density,
- a printhead structure (106), placed between said toner bearing surface (112) and said image receiving substrate (108), leaving a gap, d, between said toner bearing surface and said printhead structure and leaving a gap, d_B, between said printhead structure and said back electrode,
  said printhead structure having

  a sheet of insulating material (106c) with a first and a second face, a number of printing elements (116), forming at least one row on said sheet of insulating material, each of said printing elements including at least one printing aperture (107) through said sheet of insulating material,
  at least two sets of deflection electrodes (106b1, 106b2), arranged in said printhead structure so as to have, near two adjacent printing elements, at least one deflection electrode

- a voltage source, DC3, coupled to said printing elements for image-wise applying electric potentials (V3) to said printing elements for selectively opening and closing said printing apertures in accordance with image data
- a voltage source coupled to each of said at least two sets of deflection electrodes for applying a varying voltage (AC5, AC6) to said deflection electrodes

characterised in that

said gap, d_B, between said printhead structure and said back electrode, relates to said difference between DC4 and DC1 so that $R1 = (|DC4-DC1|/d_B) \leq 1.5$ V/µm and that said voltage source coupled to said deflection electrode is equipped for providing a varying voltage to said deflection electrodes with a peak-to-peak voltage, V_p, so that $V_p/R1 > 250$ µm.

2. A device according to claim 1, wherein said voltage source coupled to said deflection electrodes is equipped for providing a varying voltage to said deflection electrodes with a peak-to-peak voltage, V_p, so that $V_P/R1 > 400$ µm.

3. A device according to claim 1 or 2, wherein said gap, d_B, between said printhead structure and said back electrode, relates to said difference between DC4 and DC1 so that

$$R1 = (|DC4-DC1|/d_B) \leq 1.0 \text{ V/µm}.$$

4. A device according to any of claims 1 to 3, wherein said varying voltage varies in discrete steps.

5. A device according to any of claims 1 to 4, wherein said varying voltage varies continuously and has a frequency, f, related to said line time LT so that f x LT = 1.00.

Patentansprüche

1. Einrichtung für den elektrostatischen Direktdruck mit Adressierbarkeit AD in Punkten pro cm, die folgendes umfaßt:

- ein Mittel zum Zuliefern von geladenen Tonerteilchen, wobei das Mittel eine geladene Tonerteilchen (112) tragende Oberfläche aufweist, die an ein Mittel zum Anlegen eines ersten elektrischen Potentials (DC1) an die Oberfläche angekoppelt ist,
- eine Rückelektrode (105) zum Ankoppeln eines bildaufnehmenden Substrats (108) an ein von dem ersten unterschiedliches zweites elektrisches Potential (DC4), wobei die Differenz (|DC4-DC1|) zwischen der Ober-

fläche und dem Substrat ein elektrisches Feld erzeugt, wobei ein Fluß der geladenen Tonerteilchen (104) zu dem Substrat erzeugt wird,

- ein Mittel (115) zum Bewegen des Substrats in einer Druckrichtung (Pfeil A), um eine Zeilenzeit LT zu haben, wobei die Zeilenzeit die Zeit zum Drucken eines Punkts mit voller Dichte ist,
- eine Druckkopfkonstruktion (106), die zwischen der tonertragenden Oberfläche (112) und dem bildaufnehmenden Substrat (108) plaziert ist, wobei zwischen der tonertragenden Oberfläche und der Druckkopfkonstruktion ein Spalt d bleibt und zwischen der Druckkopfkonstruktion und der Rückelektrode ein Spalt d_B bleibt, wobei die Druckkopfkonstruktion folgendes aufweist:

  eine Folie aus isolierendem Material (106c) mit einer ersten und einer zweiten Seite, einer Anzahl von Druckelementen (116), die mindestens eine Reihe auf der Folie aus Isoliermaterial bilden, wobei jedes der Druckelemente mindestens eine Drucköffnung (106) durch die Folie aus isolierendem Material enthält, mindestens zwei Sätze von Ablenkelektroden (106b1, 106b2), die in der Druckkopfkonstruktion so angeordnet sind, daß in der Nähe von zwei benachbarten Druckelementen mindestens eine Ablenkelektrode vorliegt

- eine Spannungsquelle DC3, die an die Druckelemente angekoppelt ist, zum bildmäßigen Anlegen von elektrischen Potentialen (V3) an die Druckelemente zum gezielten Öffnen und Schließen der Drucköffnungen gemäß Bilddaten
- eine an jede der mindestens zwei Sätze von Ablenkelektroden angekoppelte Spannungsquelle zum Anlegen einer veränderlichen Spannung (AC5, AC6) an die Ablenkelektroden,

dadurch gekennzeichnet, daß

der Spalt d_B zwischen der Druckkopfkonstruktion und der Rückelektrode zu der Differenz zwischen DC4 und DC1 in Beziehung steht, so daß $R1 = (|DC4-DC1|/d_B) \leq 1{,}5\ V/\mu m$ ist und daß die an die Ablenkelektrode angekoppelte Spannungsquelle so ausgestattet ist, daß sie eine veränderliche Spannung an die Ablenkelektroden mit einer Spitze-Spitze-Spannung V_p liefert, so daß $V_p/R1 > 250\ /\mu m$.

2. Einrichtung nach Anspruch 1, wobei die an die Ablenkelektroden angekoppelte Spannungsquelle dafür ausgerüstet ist, eine sich verändernde Spannung an die Ablenkelektroden mit einer Spitze-Spitze-Spannung V_p zu liefern, so daß $V_p/R1 > 400\ \mu m$

3. Einrichtung nach Anspruch 1 oder 2, wobei der Abstand d_B zwischen der Druckkopfkonstruktion und der Rükkelektrode zu der Differenz zwischen DC4 und DC1 in Beziehung steht, so daß $R1 = (|DC4-DC1|/dB) \leq 1{,}0\ V/\mu m$.

4. Einrichtung nach einem der Ansprüche 1 bis 3, wobei die sich verändernde Spannung in diskreten Schritten variiert.

5. Einrichtung nach einem der Ansprüche 1 bis 4, wobei die sich verändernde Spannung kontinuierlich variiert und eine Frequenz f aufweist, die zu der Zeilenzeit LT in Beziehung steht, so daß f x LT = 1,00.

Revendications

1. Dispositif d'impression électrostatique directe ayant une adressabilité, AD, en points par cm, comprenant

- un moyen pour distribuer des particules de toner chargées, ledit moyen ayant une surface porteuse de particules de toner chargées (112) couplée à un moyen pour appliquer un premier potentiel électrique (DC1) à ladite surface,
- une électrode arrière (105) pour coupler un substrat récepteur d'image (108) à un deuxième potentiel électrique (DC4) différent dudit premier, ladite différence (|DC4-DC1|) créant un champ électrique entre ladite surface et ledit substrat, dans lequel un flux desdites particules de toner chargées (104) est créé vers ledit substrat,
- un moyen (115) pour déplacer ledit substrat dans un sens d'impression (flèche A) de manière à avoir un temps de ligne, LT, ledit temps de ligne étant le temps nécessaire pour imprimer un point à la pleine densité,
- une structure de tête d'impression (106), placée entre ladite surface porteuse de toner (112) et ledit substrat récepteur d'image (108), laissant un écart, d, entre ladite surface porteuse de toner et ladite structure de tête d'impression et laissant un écart, d_B, entre ladite structure de tête d'impression et ladite électrode arrière, ladite structure de tête d'impression ayant

une feuille de matière isolante (106c) avec une première et une deuxième face, un certain nombre d'éléments d'impression (116) formant au moins une rangée sur ladite feuille de matière isolante, chacun desdits éléments d'impression comportant au moins une ouverture d'impression (107) à travers ladite feuille de matière isolante,
au moins deux ensembles d'électrodes de déviation (106b1, 106b2), disposés dans ladite structure de tête d'impression de manière à avoir, près de deux éléments d'impression adjacents, au moins une électrode de déviation,

- une source de tension, DC3, couplée auxdits éléments d'impression pour appliquer selon l'image des potentiels électriques (V3) auxdits éléments d'impression pour ouvrir et fermer sélectivement lesdites ouvertures d'impression conformément à des données d'image
- une source de tension, couplée à chacun desdits au moins deux ensembles d'électrodes de déviation, pour appliquer une tension variable (AC5, AC6) auxdites électrodes de déviation,

caractérisé en ce que

ledit écart, d_B, entre ladite structure de tête d'impression et ladite électrode arrière, se rapporte à ladite différence entre DC4 et DC1 de telle sorte que $R1 = (|DC4\text{-}DC1|/d_B) \leq 1{,}5\ V/\mu m$ et que ladite source de tension couplée à ladite électrode de déviation est équipée pour fournir une tension variable auxdites électrodes de déviation avec une tension crête à crête, V_p de telle sorte que $V_p/R_1 > 250\ \mu m$.

2. Dispositif selon la revendication 1, dans lequel ladite source de tension couplée auxdites électrodes de déviation est équipée pour fournir une tension variable auxdites électrodes de déviation avec une tension crête à crête, V_p, de telle sorte que $V_p/R1 > 400\ \mu m$.

3. Dispositif selon la revendication 1 ou 2, dans lequel ledit écart, d_B, entre ladite structure de tête d'impression et ladite électrode arrière, se rapporte à ladite différence entre DC4 et DC1 de telle sorte que

$$R1 = (|DC4\text{-}DC1|/d_B) \leq 1{,}0\ V/\mu m.$$

4. Dispositif selon l'une quelconque des revendications 1 à 3, dans lequel ladite tension variable varie par pas discrets.

5. Dispositif selon l'une quelconque des revendications 1 à 4, dans lequel ladite tension variable varie continuellement et a une fréquence, f, se rapportant audit temps de ligne LT de telle sorte que f x LT = 1,00.

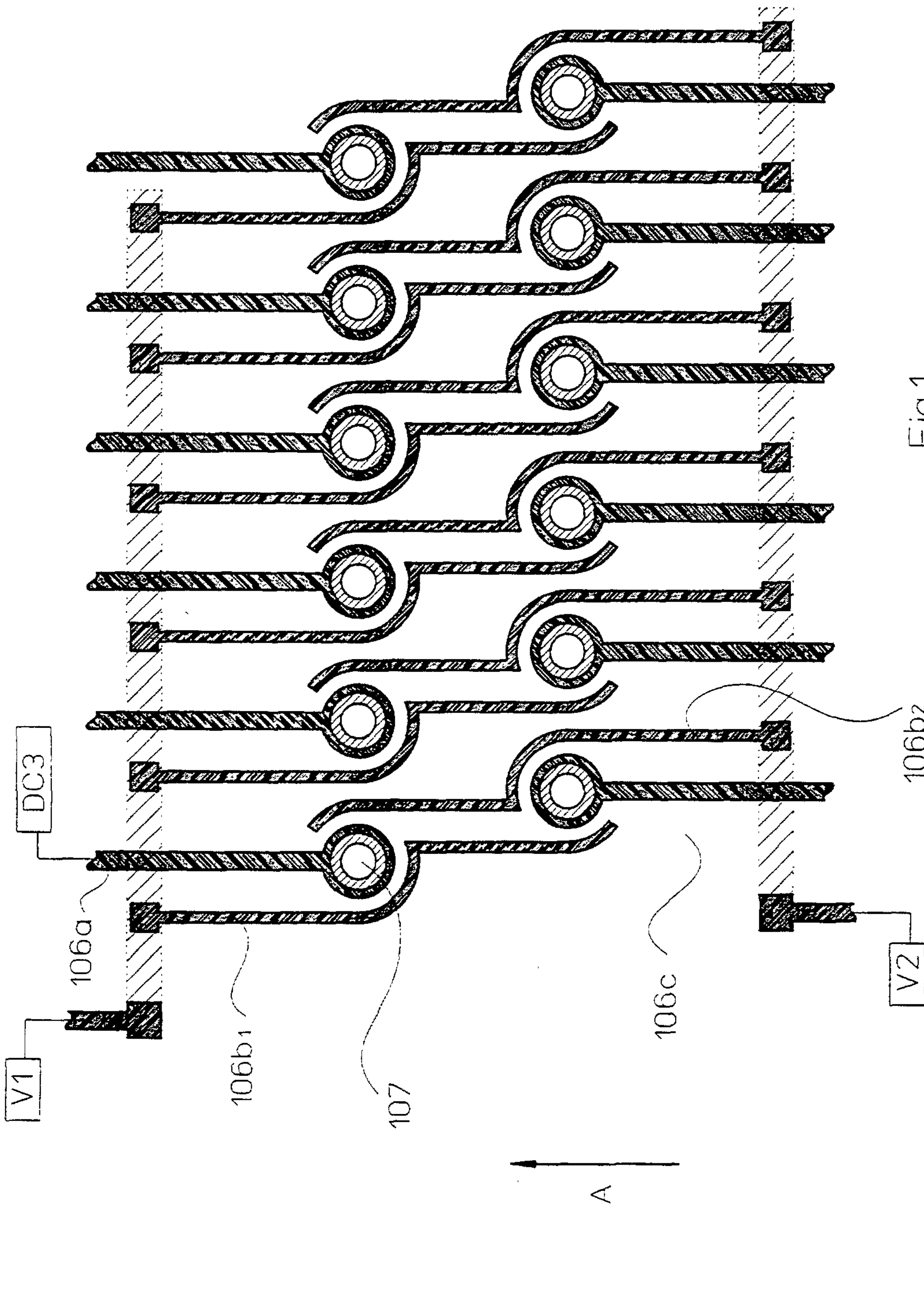

Fig.1

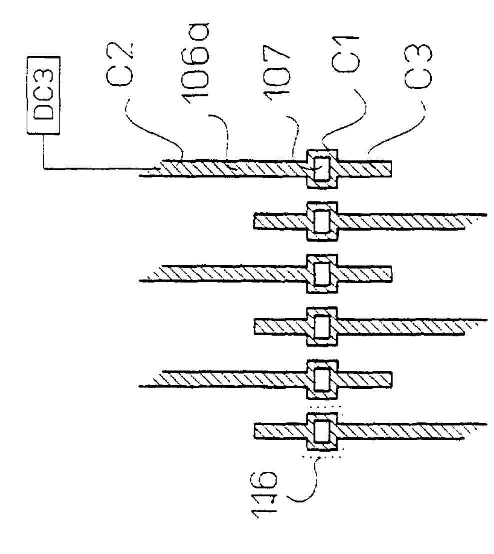

Fig.2a

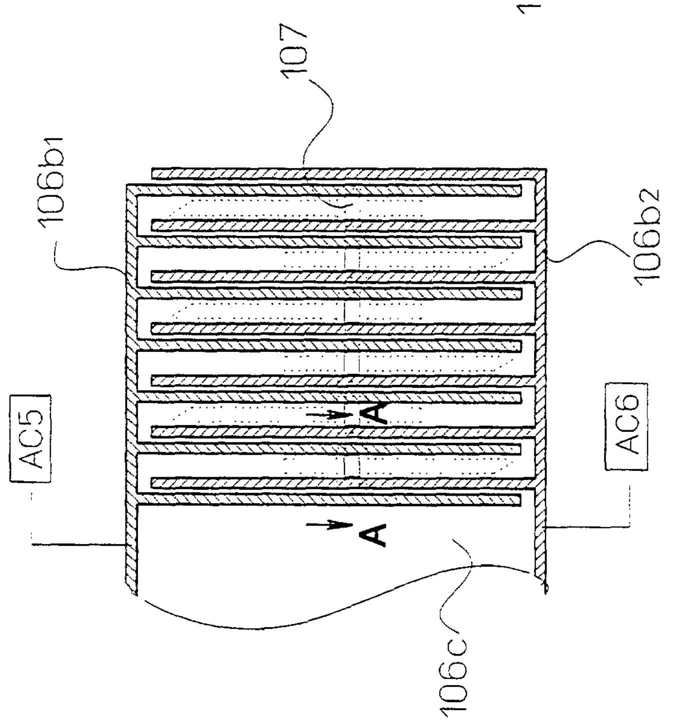

Fig.2b

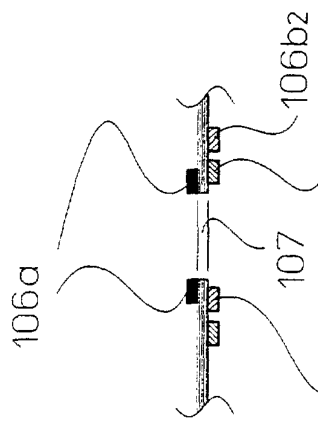

Fig.2c

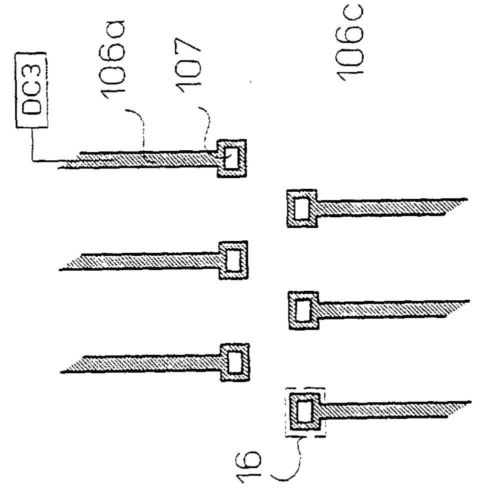

Fig.3a

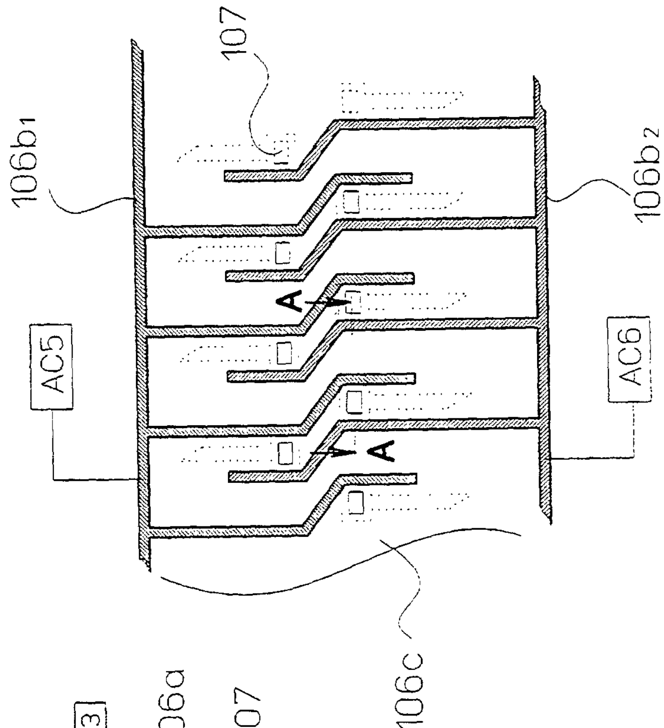

Fig 3b

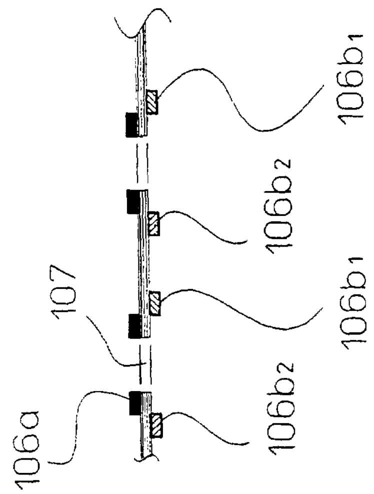

Fig.3c

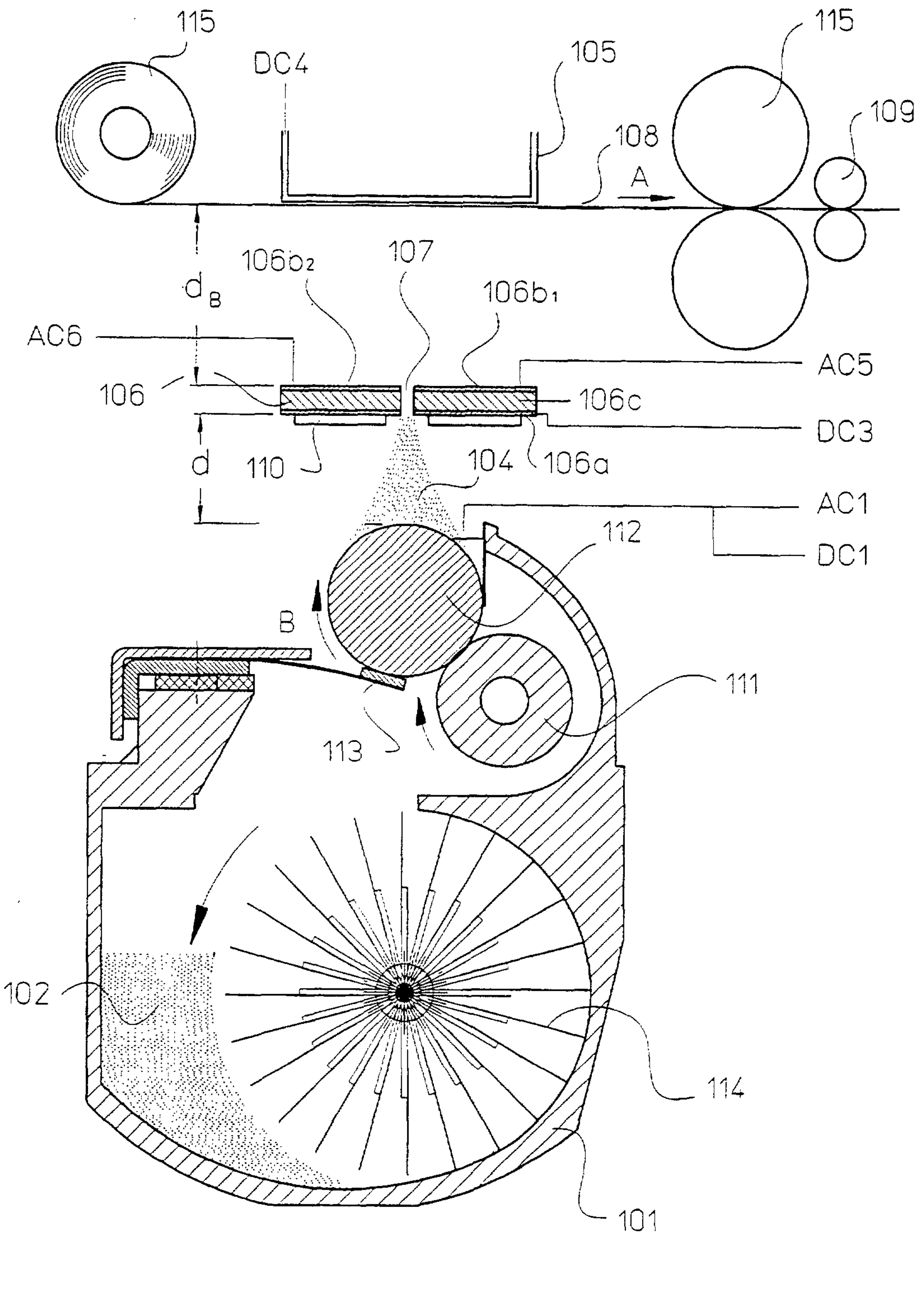
115
DC4
105
115
109
108
A
d_B
106b2
107
106b1
AC6
AC5
106
106c
DC3
d
110
104
106a
AC1
112
DC1
B
111
113
102
114
101

Fig. 4