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

(57) A device for direct electrostatic printing with an addressability AD in dots per cm, incorporating a printhead structure comprising a sheet of insulating material (106c) having 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 includes at least one printing aperture (107) through said insulating substrate. The printhead structure further comprises at least two sets of deflection electrodes and a voltage source coupled to the deflection electrodes for applying to each set of deflection electrodes a varying voltage with a frequency, f, correlated to the line time of the printing LT, so that $f \times LT > 1.00$. Preferably the sets of deflection electrodes arranged so as to have at least two deflection electrodes from different sets near two adjacent printing elements.

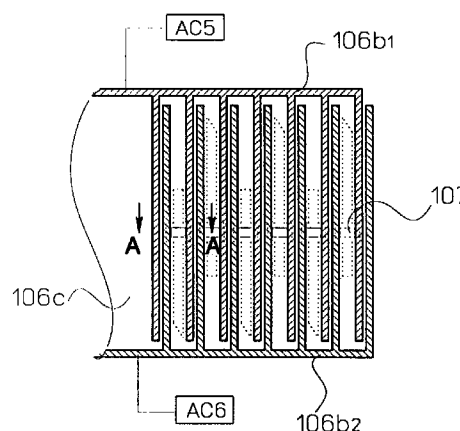


Fig.1b

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Description

FIELD OF THE INVENTION

5 [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.

10 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.

15 [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:

- 20
- 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
 - 25 - at least one row of apertures.

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

30 [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

35 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.

45 [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.

50 [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.

55 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.

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 step-wise 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.

[0014] 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.

In WO-A-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.

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 through 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. All these prior art implementations do, at least partially, cope with the problem of lower density banding but mostly at the cost of machine complexity or printing speed. Thus there is still a need for further improved DEP devices making it possible to print at elevated speed with no or very low lower density banding in areas of maximum density and comprising a printhead structure that can easily be manufactured.

OBJECTS AND SUMMARY OF THE INVENTION

[0015] It is an 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 printing apertures and with high and constant maximum density with almost no white stripes parallel to the printing direction even in low density areas.

It is another object of the invention to provide a method for direct electrostatic printing with dry toner particles making it possible to print patches of even density with very low unevenness and almost no white striping parallel to the printing direction even in low density areas.

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

[0016] The first 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, dB, 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),

- 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 of deflection electrodes applying a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 1.00$, to said deflection electrodes.

The second object of the invention is realised by providing a method for direct electrostatic printing with an addressability AD in dots per cm, on an image receiving substrate comprising the steps of

- applying a potential difference ($|DC4-DC1|$) between a surface carrying charged toner particles and said image receiving substrate for creating a flow of said charged toner particles from said surface to said substrate,
- placing, in said flow of charged toner particles, a printhead structure having

an insulating substrate (106c) with a first and a second face and
a number of printing elements (116) per cm being equal to said addressability, AD, forming at least one row of printing elements 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),

- moving said substrate with respect to said printhead structure in printing direction A, so as to have a line time of LT,
- sending a print signal to a voltage source DC3 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
- coupling said deflection electrodes to a voltage source applying, to said deflection electrodes, a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 1.00$.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Figure 1a shows schematically the first face of a 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.

Figure 1b shows schematically the second face of a 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.

Figure 1c shows a cross section through a row of printing apertures in a printhead structure according said first possible embodiment of this invention.

Figure 2a shows schematically the first face of a second 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.

Figure 2b shows schematically the second face of a second 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.

Figure 2c shows a cross section through a row of printing apertures in a printhead structure according said first possible embodiment of this invention.

Figure 3 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

[0018]

Line time (LT): the time for printing one pixel dot. Then 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/min, the line time, LT, is 8 ms.

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.

Wait time (WAT): $LT - WRT = WAT$.

Addressability: the number of dots printed per unit of length (25.4 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.

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) is designated by the wording "printing element". E.g., referring to figure 1a of this text, printing aperture 107 and conductor C1 of control electrode 106a together form a printing element 116.

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.

[0019] 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.

[0020] 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.

[0021] 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 on or near the printhead structure deflection electrodes connected to a voltage source for applying during printing time a varying voltage to the deflection electrodes. Due to the influence of the varying voltage, a printed dot is "smeared" 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. In that disclosure, a printhead structure is provided on an insulating material with printing apertures through said insulating material and control electrodes in one plane (e.g. on one face of the insulating material) associated with printing apertures and by providing further electrodes in the vicinity of the printing apertures in the same plane. These further electrodes (deflection electrodes) are, in US-A-5,774,159, equipped to be coupled to a voltage source for providing a varying voltage with a frequency, f , so that $f \times LT$ 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. The teachings of this disclosure do make it possible to avoid the occurrence of white stripes in the higher density regions, but as shown in figure 10 of that disclosure, in the lower density areas the white stripes are not avoided.

[0022] It was now found that when, in a DEP device incorporating a printhead structure with deflection electrodes, the voltage source coupled to the deflection electrodes provided a varying voltage with a frequency, f , so that $f \times LT > 1.00$ to the deflection electrodes, the occurrence of white stripes in lower densities could also be diminished and even avoided. Preferably the voltage source coupled to the deflection electrodes provides these electrodes with a varying voltage with a frequency, f , so that $f \times LT \geq 2.00$. Even more preferably the frequency is chosen so that $f \times LT \geq 4.00$.

[0023] Preferably the frequency, f , of said varying voltage is equal to or larger than 125 Hz.

[0024] A printhead structure for use in a DEP device according to this invention has preferably a number of printing elements per cm that is equal to the addressability, AD of the printer.

[0025] A printhead structure for use in a DEP device according to this invention incorporates preferably at least two sets of deflection electrodes, more preferably it incorporates exactly two sets of deflection electrodes. The at least two, or exactly two, sets of deflection electrodes are preferably arranged so as to have, near two adjacent printing elements, at least two deflection electrodes from different sets. More preferably, in a printhead structure of this invention, two sets of deflection electrodes are arranged so as to have two deflection electrodes from different sets extending to or passing between two adjacent printing elements.

[0026] A printhead structure according to be used in a DEP device of the present invention can be implemented by providing on an insulating material, with a first and a second face, control electrodes on said first face associated with printing apertures and by providing further deflection electrodes in the vicinity of the printing elements on the same first face.

[0027] In a preferred embodiment, a printhead structure according to the present invention, comprises a sheet of insulating material having a first and a second face and printing apertures through said insulating material and control electrodes associated with said printing apertures on said first face, and at least two sets of deflection electrodes on said second face of said insulating material near to said printing apertures, so that said printhead structure contains two planes with electrodes.

[0028] When a printhead structure according to this invention is implemented with the control electrodes on a first face of the insulating material and two sets of deflection electrodes on the other side, the printhead structure can comprise two sets of deflection electrodes arranged in such a way that the deflection electrodes are symmetrically positioned (i.e. the centre of each printing element is located in the middle of the deflection electrodes belonging to each set) with respect to the printing apertures.

[0029] When a printhead structure according to this invention is implemented with the control electrodes on a first face of the insulating material and at least two sets of deflection electrodes on the other side, it is advantageous to provide deflection electrodes with a thickness between 5 and 200 μm , even more advantageous to provide deflection electrodes with a thickness between 10 and 100 μm , both limits included. By doing so it is possible to incorporate the printhead structure in a DEP device in such a way that the deflection electrodes are in contact with the toner bearing surface and thus keep the distance between said surface and the printhead structure constant. In this case it is possible to dispense with additional spacing means for keeping the distance between the toner bearing surface and the printhead structure constant.

[0030] In fig. 1a, 1b and 1c 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 1a 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 1b 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 can be 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 1c, 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.

[0031] 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.

[0032] In Fig. 2a, 2b and 2c 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 1a, 1b and 1c, 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 2a. As shown in figure 2b 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 2c 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.

[0033] 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 polyimide, a polyester (e.g. polyethylene terephthalate, polyethylene naphthalate, etc.), polyolefines, an epoxy resin, an organosilicon resin,

rubber, etc.

[0034] 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 .

[0035] The voltage source coupled to the deflection electrodes provides varying voltages varying on a time scale and thus 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. Thus when using a DEP device according to this invention in a DEP, only one pixel formed by one control electrode (controlling one or more printing apertures), but by using a varying voltage on the deflection electrodes, the pixel is kind of "smeared" in a direction essentially perpendicular to the printing direction, so that lower density banding in the print direction is avoided.

[0036] The voltage source for providing the varying voltage, that is coupled to the deflection electrodes may be equipped to provide a varying voltage with different shapes. Various shapes of varying voltage signals can be used in the present invention: e.g. pulsed signals, stepwise signals, saw-tooth signals, sinusoidal signals, etc., as long as the signal has a frequency, f , fulfilling one of the conditions above.

[0037] Although it may be useful, for diminishing the occurrence of white stripes to chose f so that a product $f \times \text{LT}$ that is not an integer value, it is preferred that the varying voltage is preferably synchronous with the line time, i.e. the application of the varying voltage to the sets of deflection electrodes starts when the printing starts, i.e. at the beginning of the line time, and ends when the printing ends, i.e. at the end of the line time. Thus the product $f \times \text{LT}$ is preferably chosen so that it is an integer value.. However, when the product is chosen so as not to be an integer, said product of $f \times \text{LT}$ should not be too close to an integer value because otherwise moiré effect at a low (i.e. visible) frequency can occur. Using a product of, e.g. $f \times \text{LT} = 1.25$ gives an acceptable result, whereas using a product of $f \times \text{LT} = 1.05$ for the same printhead structure, does give lower image quality than using a product that is exactly an integer.

[0038] When exactly two sets of deflection electrodes are present, each set of deflection electrodes is coupled to a voltage source that applies a varying voltage to said set of deflection electrodes, i.e. set one is coupled to a voltage source providing a varying voltage, AC5 and the second set to a voltage source providing a varying voltage, AC6. It is preferred that the frequencies and the peak-to-peak voltage of AC5 and AC6 are equal. It is further preferred that the voltage signals, AC5 and AC6 are 180 ° out of phase so that the peak-to-peak voltage is in this case the sum of the peak-to-peak voltages of both signals, then the effect on the avoidance of lower density banding in the print direction is maximised. In this case the sum of the peak-to-peak voltages of AC5 and AC6 (i.e. AC5 + AC6) is equal to or larger than 300 V.

[0039] The combination of a printhead structure, having at least two sets of deflection electrodes and the coupling of those deflection electrodes 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-S 606 402, US-A-S 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.

[0040] The invention thus includes 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 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 ($|\text{DC4}-\text{DC1}|$) 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)

- 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 of deflection electrodes for applying a varying voltage (AC5, AC6) with a frequency, f , so that $f \times LT > 1.00$, to said deflection electrodes.

[0041] Preferably two sets of deflection electrodes are arranged in said printhead structure so as to have two deflection electrodes from different sets extending or passing between two adjacent printing elements.

[0042] Said means for coupling an image receiving substrate (108) to a second electric potential (DC4) can be a back electrode placed directly behind the image receiving substrate. In this case, the substrate can be in contact with the back electrode or so close to the back electrode that both the back electrode and the image receiving substrate assume essentially the same electric potential. Said means for coupling an image receiving substrate (108) to a second electric potential (DC4) can also be a conductive layer present, on the image receiving substrate, that is coupled to a voltage source. Such DEP devices and methods have been described in e.g. EP-A-823 676 or European Application 98201302 filed on April 22 1998.

[0043] In fig. 3 a DEP device incorporating a printhead structure according to this invention is shown.

[0044] 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).

[0045] 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.

[0046] 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 (V3) 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 , from the image receiving member.

[0047] The device comprises further means (109) for fixing the toner particles to the image receiving substrate.

[0048] The distance d_B is calculated from the surface of the printhead structure to the surface of the imaging member.

[0049] 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 eg. 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)

[0050] In a DEP device, according to this invention, incorporating a printhead structure with deflection electrodes, it is preferred that the distance d_B in pin relates to 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) in a ratio, R1, so that $R1 = (PF/d_B) \leq 1.5 \text{ V}/\mu\text{m}$, preferably so that $R1 = (PF/d_B)/d_B \leq 1.0 \text{ V}/\mu\text{m}$. The difference are taken in their absolute value, since the sign of the difference is chosen depending on the sign of the charge (positive or negative) of the toner particles, thus $PF = (|DC4-DC1|)$.

It was found that the printing quality in a DEP device, according to this invention and incorporating a printhead structure with deflection electrodes, was improved when said ratio R1 related to the peak voltage (V_p) applied to the sets deflection electrodes by the voltage source coupled to said set. For good printing quality the peak-to-peak voltage of voltage AC5 and AC6 relates to the ratio $R1 = PF/d_B$ as $V_p/R1 > 250 \mu\text{m}$, preferably $V_p/R1 > 400 \mu\text{m}$, wherein $V_p = AC5 + AC6$.

[0051] The present invention incorporates also a method for Direct Electrostatic Printing using a DEP device incorporating a printhead structure according to this invention. It thus includes a method for direct electrostatic printing with an addressability AD in dots per cm, on an image receiving substrate comprising the steps of :

- applying a potential difference (|DC4-DC1|) between a surface carrying charged toner particles and said image receiving substrate for creating a flow of said charged toner particles from said surface to said substrate,
- placing, in said flow of charged toner particles, a printhead structure having

an insulating substrate (106c) with a first and a second face and a number of printing elements (116), forming at least one row of printing elements 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),

- moving said substrate with respect to said printhead structure in printing direction A, so as to have a line time of LT,
- sending a print signal to DC-voltage source DC3 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
- coupling said deflection electrodes to a voltage source for applying, to said deflection electrodes, a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 1.00$.

[0052] Preferably said frequency, f, is chosen so that $f \times LT \geq 2.00$ and more preferably so that $f \times LT \geq 4.00$.

[0053] A printhead structure for use in a DEP device according to this invention has preferably a number of printing elements per cm that is equal to the addressability, AD of the printer.

[0054] A printhead structure used in the method according to this invention incorporates preferably at least two sets of deflection electrodes, more preferably it incorporates two sets of deflection electrodes. The at least two, or exactly two, sets of deflection electrode are preferably arranged so as to have, near two adjacent printing elements, at least two deflection electrodes from different sets. More preferably, in a printhead structure of this invention, two sets of deflection electrodes are arranged so as to have two deflection electrodes from different sets extending or passing between two adjacent printing elements.

[0055] When the method of this invention is used for grey scale printing is, it is possible to determine - for each line to be printed - the printing element necessitating the shortest write time of all printing elements in that line and to adapt the frequency, f, of the voltage coupled to the deflection electrodes to that shortest write time, WRT_{short} , so has to have $f \times WRT_{short} = 1.00$. This leads, e.g., with a line time, LT, of 8 ms for a shortest write time, WRT_{short} , of 1/10 LT to a frequency of 1250 Hz. This can be done with the proviso that the frequency is not higher than 4000 Hz.

[0056] For grey scale printing, the time of application of the potentials by voltage source DC3 may be image-wise modulated while applying a constant potential (i.e. time modulation of the image signal or pulse-width-modulation), or the potential itself may be image-wise modulation at a constant line-time (amplitude modulation) or the amplitude modulation can be combined with a time modulation, the latter combination allowing for the printing of a large number of grey levels. When using time modulation (either alone or in combination with amplitude modulation) the write time (WRT) for low density areas is smaller than the total line time (LT). The line time (LT) is divided into several smaller time units (called sub-lines (SL)). The grey scale printing proceeds by having DC-source DC3 to provide a voltage V_{30} (voltage allowing maximum density to be printed) at the control electrode 106a during a certain number of said smaller time units (i.e. during the write time (WRT)) and having DC-source DC3 to provide a voltage V_{3n} (blocking voltage giving minimum density) during $LT - WRT = WAT$ (wait time). The above implies that maximum density is printed when $WRT = LT$ and minimum density when $WRT = 0$. The printing of intermediate densities proceeds at values of WRT between these two extremes.

[0057] When, for writing lower densities, the write time is smaller than the line time it is possible to position the write time at different positions within the line time. It is, e.g., possible to start the write time for the printing elements with $WRT < LT$ together with the write time for the printing elements with $WRT = LT$, thus positioning the shorter write times in the beginning of the line time, or the smaller line times can be positioned exactly in the centre of the line time. E.g. with a line time of 10 ms and a write time of 2 ms, the printing aperture is kept closed (a closing potential is applied to the printing element) during the first 4 ms of the line time, then the printing aperture is opened (an opening potential is applied to the printing element) for 2 ms and is closed for the remaining 4 ms of the line time. This latter positioning has been described in US-A-5,774,159, where the deflection electrodes are coupled to a varying voltage with a frequency, f, so that the product of the frequency with the line time (LT) is exactly one or $f \times LT = 1.00$.

[0058] It was now found that the occurrence of white stripes in the low density areas could be diminished and even avoided, when for grey scale printing using time modulation (alone or in combination with amplitude modulation), the method of this invention was combined with the method disclosed in EP-A-851 316 and the equivalent US serial Number 08/995,778, that is incorporated herein by reference.

[0059] In that disclosure means and ways to place the write time of pixel dots with $WRT < LT$, within the total line time are described.

[0060] In one embodiment the combination of the method of this invention with the method of EP-A-851 316 is performed by not positioning the write time, when it is smaller than the line time, for every pixel and line at a fixed position

within the total line time, but by have it randomly positioned within the line time.

[0061] It proved even more beneficial to have the write time divided in several parts and have these parts divided over the total line time. Thus when an optical density necessitating a write time of, e.g., 0.2 of the line time has to be printed, the white banding was strongly diminished, in a method of this invention, when instead of printing the total write time in consequence the write time was divided in, e.g., 5 portions of 0.04 times the line time and these 5 portions were printed randomly within the line time.

[0062] Thus, in very preferred embodiment of this invention, in the method of this invention the step of sending a print signal for image-wise applying electric potentials to said printing elements can be performed by sending a print signal within a line time, to said printing elements, said print signal comprising elements necessitating a write time shorter than said line time, and by positioning said write time, shorter than said line time, randomly over said line time.

[0063] Thus it is highly preferred, in the method of this invention, that before the step of sending an image signal for image-wise applying electric potentials to said printing elements, said write time, shorter than said line time is divided in portions and said print signal is adapted to send said portion in a random way during said line time.

[0064] The combination of a high spatial resolution and of the multiple grey level capabilities typical for DEP, opens the way for multilevel halftoning 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.

EXAMPLES

[0065] 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.

[0066] 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.

[0067] 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 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 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

[0068] 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

[0069] 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).

[0070] 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 1000 μm and the paper travelled at 300 cm/min.

[0071] 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 to 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 .

[0072] 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.

[0073] The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLES 2-5 (PE2-PE5)

[0074] The same experiment was done as described in example 1 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

[0075] deflection electrodes was 100, 200, 300 and 400 V. The results of the evaluation of the printing quality are given in table 1.

COMPARATIVE PRINTING EXAMPLE 6 (PE6)

[0076] The same experiment was done as described in example 1 except that the amplitude of the synchronised AC5 and AC6 applied to both sets of deflection electrodes was set to 0 V (peak to peak value): i.e. no deflection mechanism was active. The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLES 7-12 (PE7-PE12)

[0077] The same experiment was done as described in example 1 except that the amplitude of the synchronised AC-voltage applied to both sets of deflection electrodes was modified, the distance of said printhead structure towards the back electrode was modified, and the voltage applied to said back electrode was modified, as tabulated in table 1, respectively. 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 13 (PE13)

[0078] The same experiment was done as described in example 1 except that the printhead structure had 2 rows of printing apertures and two sets of deflection electrodes as depicted in figure 2. The pitch between two neighbouring printing apertures in a single row was 500 μm , leading to an overall resolution of about 100 dpi. Said two rows of printing apertures were separated over 1300 μm and the corresponding deflection electrodes were curved in this intermediate zone so that in the neighbourhood of the printing apertures the local arrangement of the deflection electrodes versus

the control electrodes and apertures was identical to the situation of the printhead structure in the previous examples.

[0079] The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLES 14-17 (PE14-PE17)

[0080] The same experiment was done as described in example 11 except that the frequency and shape of the synchronised AC-voltage applied to both sets of deflection electrodes was changed to 1, 2 and 3 kHz (block-signal), respectively.

[0081] The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLES 18-20 (PE18-PE20)

[0082] The same experiment was done as described in example 11 except that the frequency and shape of the synchronised AC-voltage applied to both sets of deflection electrodes was changed to 115, 125 and 135 Hz (block-signal), respectively. The resultant line thickness was larger than the one obtained with the 500 Hz mode, but in areas of equal density a repetitive banding in the printing direction at much lower frequency was obtained. This low frequency banding could only be eliminated by "coupling" the deflection frequency to the image-frequency (which was 125 Hz in this case) so that a variation in deflection voltage was always in phase with a variation in the image signal.

[0083] The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLES 21-23 (PE21-PE23)

[0084] The same experiment was done as described in example 11 except that the frequency and shape of the coupled and synchronised AC-voltages applied to both sets of deflection electrodes were changed to 125 Hz (sinusoidal signal, symmetric saw-tooth signal with no deflection at the start of the line-time, and asymmetric saw-tooth signal with maximum deflection at the start of the line-time), respectively. The resultant line thickness was comparable to the experiment with a coupled and synchronised pulsed voltage applied to the sets of deflection electrodes.

[0085] The results of the evaluation of the printing quality are given in table 1.

PRINTING EXAMPLE 24 (PE24)

[0086] The same experiment was done as described in example 1 except that the orientation of the printhead structure in the printing concept was changed: i.e. the deflection electrodes were located at the side of the toner roller and the control electrodes were located at the side of the image receptive member. Even in this case were the toner application roller was in sliding contact over the isolation toner layer with the deflection electrodes, a time-varying voltage applied to said sets of deflection electrodes caused a deformation of the toner flux leading to broader line widths if compared with grounded deflection electrodes.

[0087] 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	1000	1000	250	250	500, s	1.0	500	7
PE2	1000	1000	50	50	500, s	1.0	100	2
PE3	1000	1000	100	100	500, s	1.0	200	3
PE4	1000	1000	150	150	500, s	1.0	300	5
PE5	1000	1000	200	200	500, s	1.0	400	6
PE6	1000	1000	0	0	0	0.0	0	1
PE7	500	1000	250	250	500, s	2.0	250	2
PE8	500	500	250	250	500, s	1.0	500	5
PE9	1000	500	150	150	500, s	0.5	600	8
PE10	1000	1000	250	250	500, s	1.0	500	7
PE11	1000	1500	250	250	500, s	1.5	333	5
PE12	2000	2000	250	250	500, s	1.0	500	9
PE13	1000	1000	250	250	500, s	1.0	500	10
PE14	1000	1000	250	250	1000, s	1.0	500	9
PE15	1000	1000	250	250	2000, s	1.0	500	8
PE16	1000	1000	250	250	3000, s	1.0	500	6
PE17	1000	1000	0	0	0	0.0	0	1
PE18	1000	1500	250	250	115, b	1.5	333	5
PE19	1000	1500	250	250	125, b	1.5	333	6
PE20	1000	1500	250	250	135, b	1.5	333	6
PE21	1000	1500	250	250	125, s	1.5	333	7
PE22	1000	1500	250	250	125, sts	1.5	333	8
PE23	1000	1500	250	250	125, sta	1.5	333	8
PE24 [◊]	1000	1000	250	250	500, s	1.0	500	6

+ frequency and form of the varying voltage : s : sinusoidal, b : block, sts : saw-tooth symmetrical, sta : saw-tooth asymmetrical

++ R1 = $\text{DC4}/d_B$, 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.

[0088] 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.

[0089] 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 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, for having an electric potential difference ($|DC4-DC1|$) creating an electric field, PF, 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),

- 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 of deflection electrodes for applying a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 1.00$, to said deflection electrodes.

2. A device according to claim 1, wherein in said printhead structure two sets of deflection electrodes are present and are arranged in said printhead structure so as to have at least two deflection electrodes from different sets between two adjacent printing elements.

3. A device according to claim 1 or 2, wherein in said printhead structure control electrodes are present on said first face of said insulating material and said sets of deflection electrodes are present on said second side of said insulating material.

4. A device according to claim 3, wherein said deflection electrodes have a thickness between 1 and 200 μm .

5. A device according to claim 3, wherein said deflection electrodes have a thickness between 5 and 200 μm .

6. A device according to any of claims 1 to 5, wherein said voltage source coupled to said deflection electrodes applies a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 2.00$.

7. A device according to any of the preceding claims, wherein said voltage source coupled to said deflection electrodes is equipped for providing a varying voltage with a peak-to-peak voltage value equal to or higher than 300 V.

8. A device according to any of the preceding claims, wherein said distance d_B and said electric potential difference ($|DC4-DC1|$) relate to each other in a ratio R1 such that $(|DC4-DC1|)/d_B \leq 1.5 \text{ V}/\mu\text{m}$.

9. A device according to any of the preceding claims, wherein said deflection electrodes are coupled to a voltage source equipped for providing a varying voltage to said deflection electrodes with a peak-to-peak voltage, V_p , so that $V_p/R1 > 250 \mu\text{m}$.

10. A method for direct electrostatic printing with an addressability AD in dots per cm, on an image receiving substrate comprising the steps of :

- applying an electric potential difference ($|DC4-DC1|$) between a surface carrying charged toner particles and said image receiving substrate for creating a flow of said charged toner particles from said surface to said substrate,
- placing, in said flow of charged toner particles, a printhead structure having

an insulating substrate (106c) with a first and a second face and
a number of printing elements (116), forming at least one row of printing elements 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),

- moving said substrate with respect to said printhead structure in printing direction A, so as to have a line time of LT,
- sending a print signal to a voltage source DC3 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
- coupling said deflection electrodes to a voltage source for applying, to said deflection electrodes, a varying voltage (AC5, AC6) with a frequency, f, so that $f \times LT > 1.00$.

11. A method according to claim 10, wherein said frequency, f, is chosen so that $f \times LT \geq 2.00$.

12. A method according to claim 10 or 11, wherein, before sending a print signal, for each line to be printed a printing element necessitating a shortest write time, WRT_{short} , of all printing elements in that line is determined and said frequency, f, is chosen so has to have $1.00/WRT_{short} \leq f \leq 4000$ Hz.

13. A method according to any of claims 10 to 12, wherein the step of sending a print signal for image-wise applying electric potentials to said printing elements is performed by sending a print signal, within a line time, said print signal comprising pixel dots necessitating a write time shorter than said line time, and by positioning said write time, shorter than said line time, randomly over said line time.

14. A method according to claim 13, wherein, before sending said print signal, said write time, shorter than said line time is divided in portions and said print signal is adapted to send said portion in a random way during said line time.

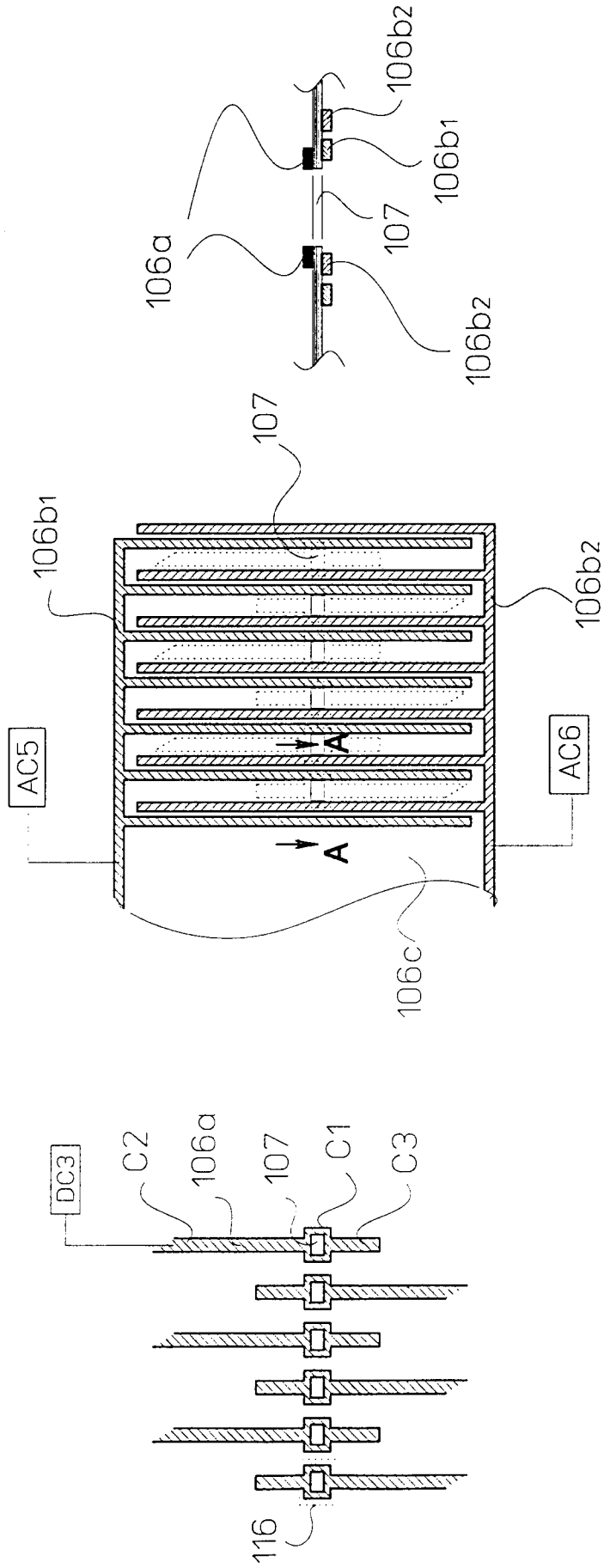


Fig.1a

Fig.1b

Fig.1c

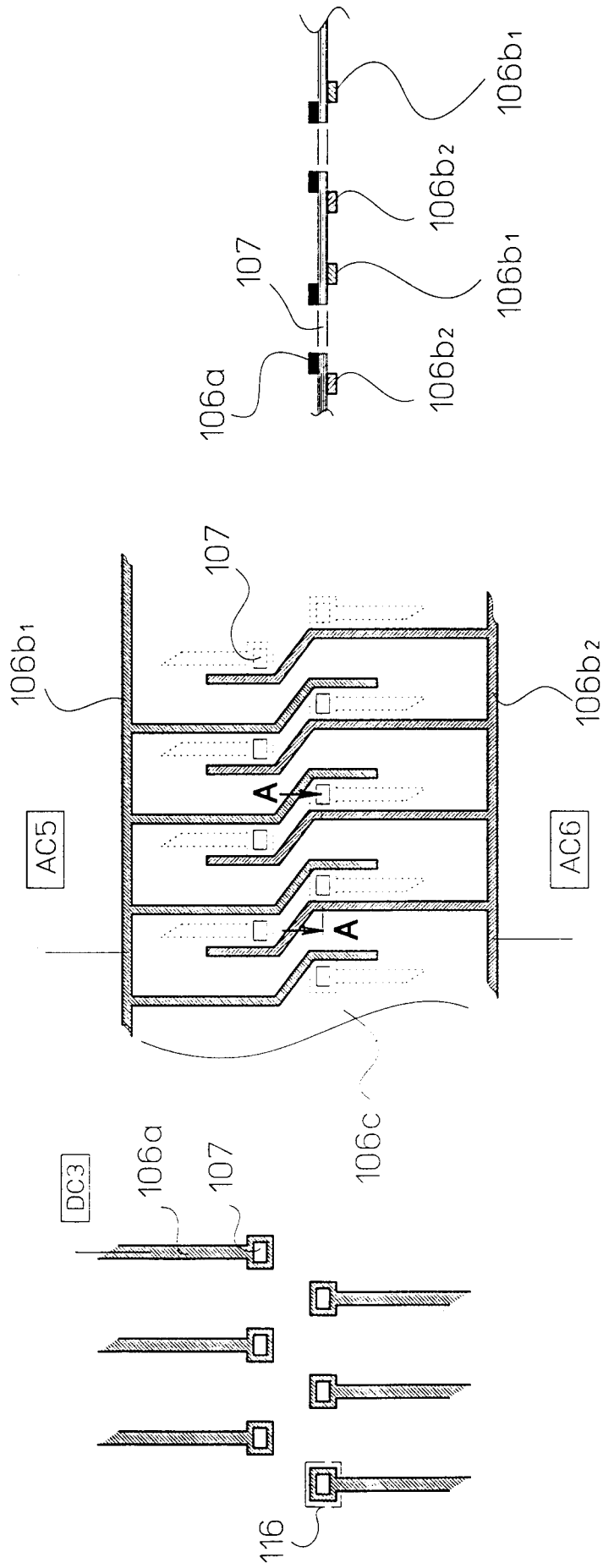


Fig.2a

Fig.2b

Fig.2c

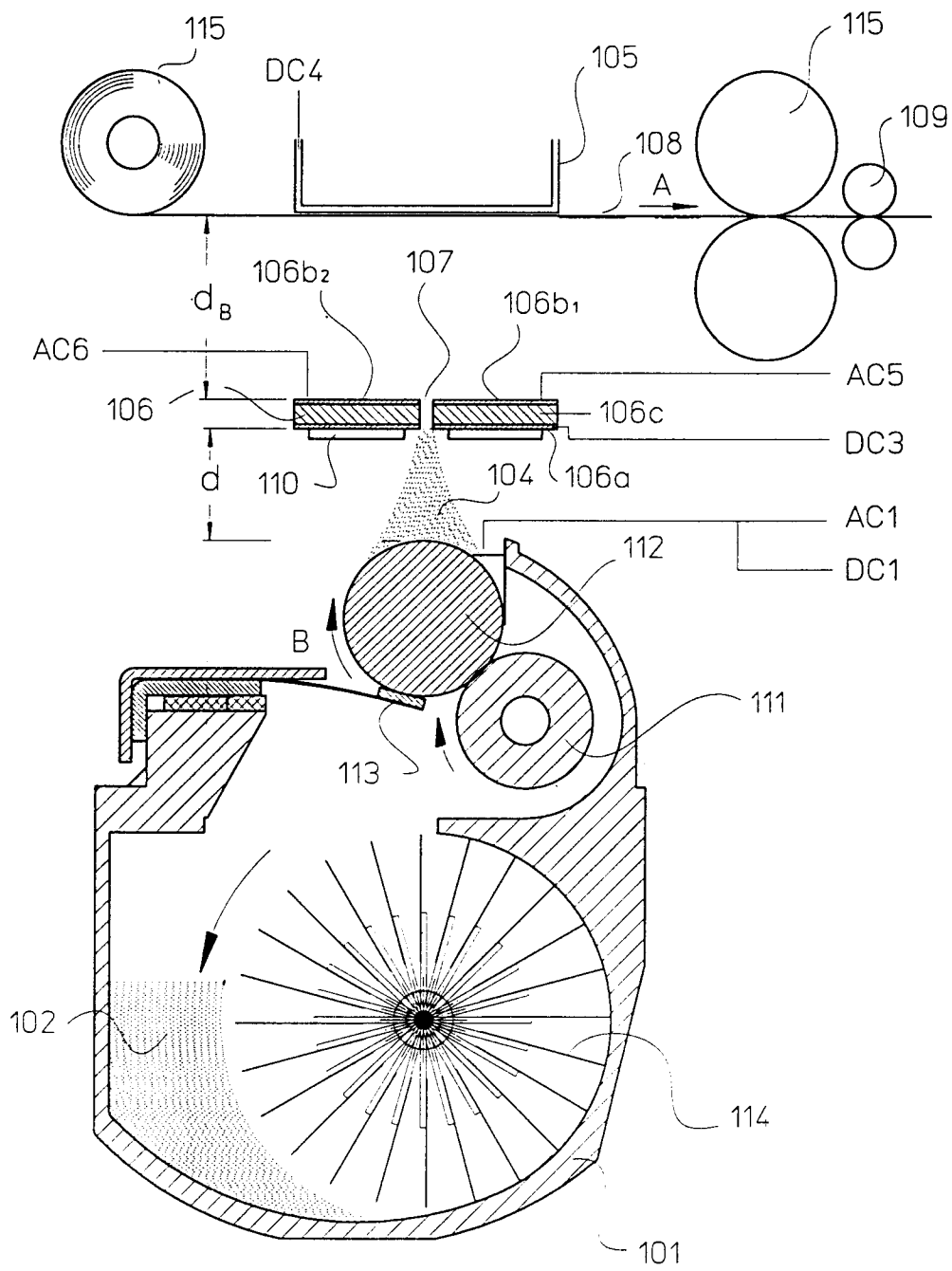


Fig. 3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 20 0480

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,A	DE 197 39 988 A (ARRAY PRINTERS AB) 19 March 1998 (1998-03-19) * column 7, line 50 - column 12, line 16; figures 4-10 *	1,2,10	B41J2/415
D,A	EP 0 463 743 A (MITA INDUSTRIAL CO LTD) 2 January 1992 (1992-01-02) * column 24, line 11 - column 26, line 29; figures 10-13 *	1,10	
D,A	WO 97 35725 A (ARRAY PRINTERS AB) 2 October 1997 (1997-10-02) * column 16, line 55 - column 18, line 25; figures 3,8 *	1,10	
D,A	EP 0 660 201 A (SHARP KK) 28 June 1995 (1995-06-28) * page 19, line 8 - page 20, line 49; figure 35 *	1,10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B41J
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		23 August 1999	De Groot, R
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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