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(71) Applicant: **AGFA-GEVAERT N.V.**
2640 Mortsel (BE)

(72) Inventor: **Guido, Desie**
Septestraat 27 2640 Mortsel (BE)

(54) A device for direct electrostatic printing wherein the layer of charged toner particles on a toner bearing surface is homogenised

(57) A device for Direct electrostatic Printing incorporating a conductive element, E, (102) coupled to an AC-voltage, AC2, upstream of the development zone (107), forming an AC-field between the toner bearing surface (101) and that conductive element, E, (102) for shuffling the toner particles (106) upstream the development so that at the development zone a homogenous layer or stack of layers of charged toner particles is present on the toner bearing surface.

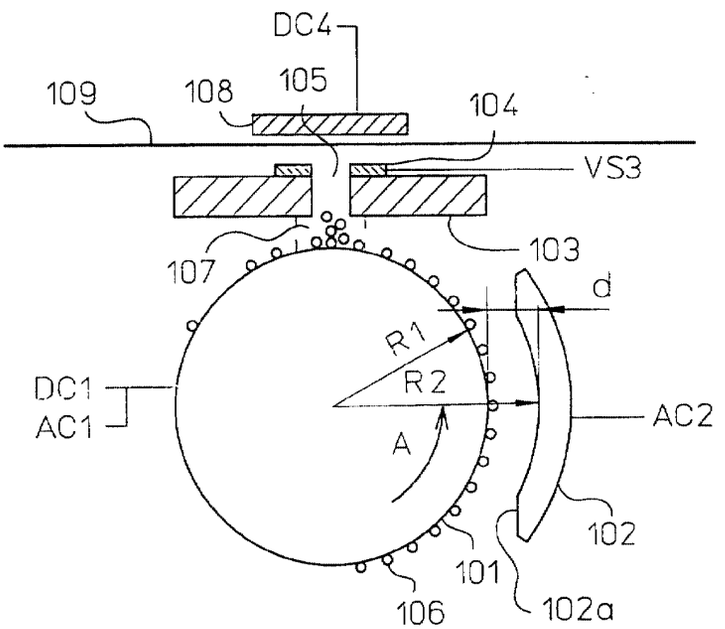

Fig. 3

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Description

FIELD OF THE INVENTION

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

BACKGROUND OF THE INVENTION

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

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

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

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

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

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

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

[0008] In this printing technique banding (visible as density fluctuations in parts of the printed image intended to show even density) and/or white stripes (absence of density) in the print direction can be a problem and measures to avoid these are still highly desired.

OBJECTS AND SUMMARY OF THE INVENTION

[0009] 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, high maximum density, a high degree of density resolution (i.e. for producing an image comprising a high amount of differentiated density levels) and high spatial resolution without banding and/or white stripes in the print direction.

[0010] Further objects and advantages of the invention will become clear from the detailed description herein after.

[0011] The objects of the invention are realised by providing a device for direct electrostatic printing comprising :

- a toner bearing surface (101) carrying charged toner particles (106) and moving in a direction of arrow A and bringing said charged toner in a development zone (107) near a printhead structure (103), that has a row of printing apertures (105) and control electrodes (104) associated therewith,
- a voltage source for creating a DC-voltage field between said surface and an image receiving substrate (109), placed opposite to said printhead structure, said control electrodes being coupled to a voltage source, VS3, for selectively opening and closing said printing apertures,

characterised in that
said device comprises a conductive element, E, (102) placed near said toner bearing surface (101), upstream said development zone, and coupled to an AC-voltage source, AC2, creating a AC-field between said toner bearing surface and said element, E, for homogenising said cloud of charged toner particles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 shows schematically a "development zone" in a DEP-device.

[0013] Fig 2. shows schematically a first embodiment of a DEP-device, according to this invention, including a conductive element upstream the "development zone".

[0014] Fig 3 shows schematically a second embodiment of a DEP-device, according to this invention, including a conductive element upstream the "development zone".

[0015] Fig 4 shows a schematic exploded view of a third embodiment of a DEP-device, according to this invention, including a conductive element upstream the "development zone".

DETAILED DESCRIPTION OF THE INVENTION

[0016] It was now found that when in the development zone on the toner bearing surface a very homogenous layer or stack of layers of toner particles was present that printing without banding (or with at most very faint banding) was possible. The "development zone" is the volume between the printhead structure (103) and the toner bearing surface (101), under the row(s) of printing apertures. In Fig. 1, a non-limitative example of a development zone is given. It is the zone (volume) (107) between the printhead structure (103) - kept at a distance B, from the toner bearing surface - and the toner bearing surface (101), determined by the surface of said printhead structure (103) facing said toner bearing surface, the perpendicular planes dropping from the edges of the array of printing apertures (105) to said toner bearing surface and said toner bearing surface itself (101), within the volume determined by said perpendicular planes. The array of printing apertures (105) has an extension in the printing direction, C and an extension perpendicular to the printing direction, defining the printing width, PW, of the device. The plane A,A',A" in figure 1, shows the plane in which the cross-sections of figure 2 and 3 are made.

[0017] It was now found that it was possible, by placing a conductive element, E, (102) coupled to a AC-voltage, AC2, upstream of the development zone, forming an AC-field between the toner bearing surface and that conductive element, E, (102), to provide a very homogenous layer or stack of layers of toner particles on the toner bearing surface in the "development zone". Is seems that, due to the action of that AC-field, the charged toner particles oscillate between the toner bearing surface and that conductive element, E and are thus by that kind shuffling homogenised so that at the development zone a homogenous layer or stack of layers of charged toner particles is present on the toner bearing surface. This means that under each of the printing apertures an equal amount of toner particles is present and that, when all apertures are opened to print a patch of even density in an image, only very faint banding or no banding at all is observed in the image.

[0018] The conductive element (102) used in a DEP device according to this invention can be made of any conductive material. It may be made of metal, e.g., stainless steel, copper, nickel, etc., it may be made of metal alloys, it may be a non-conductive material whereon a conductive layer is present, e.g., it may be a plastic sheets carrying a conductive layer, which conductive layer can be made, e.g., of metal, metal alloys, metal oxides and conductive organic polymers. The conductive element (102) used in a DEP device according to this invention can be made as a single sheet of conductive material so that it forms one electrode extending over de printing width of the device and that the toner particles are made to oscillate between the toner bearing surface and the conductive member in a direction essentially perpendicular to the toner bearing surface. The conductive element may also be construed as ,e. g., two sets of electrodes isolated from each other extending over the printing width and the AC-voltage source is then coupled to each of the sets in turn. The sets of electrodes on the conductive member (102) are preferably construed as combs with the teeth of one comb being interposed between, but isolated from the teeth of the second comb. This means that an AC-field is present over the gap between the toner bearing surface and conductive member parallel to the printing direction, this means in a direction essentially parallel with the toner bearing surface. By doing so the toner particles are not only made to oscillate in the gap between the toner bearing surface and the conductive member in a direction essentially perpendicular to the toner bearing surface but also in a direction essentially parallel to the toner bearing surface, thus enhancing the shuffling of the particles. This means that in the development zone a very homogenous layer or stack of layers of toner particles is present on the toner bearing surface.

[0019] In figure 2 a DEP-device incorporating a conductive member for homogenising the layer or stack of layers of toner particles on the toner bearing surface is shown. It comprises a charged toner bearing surface (101), carrying charged toner particles (106) and coupled to a DC-voltage source, DC1 (which may be earth potential). The toner bearing surface is further equipped to be moved in the direction of arrow A. Opposite to the toner bearing surface (101), a back electrode (108) is placed, this back electrode is coupled to a DC-voltage source, DC4. The DC-voltage applied to the back elec-

trode is different from the one applied to the toner bearing surface and so a DC-propulsion filed is created wherein the charged toner particles can move, as a flow of toner particles, from the toner bearing surface to the back electrode. Between said toner bearing surface and said back electrode a printhead structure (103) is interposed, having an array of printing apertures (105) that are associated with control electrodes (104) coupled to a DC-voltage source, VS3, that is image-wise varied for selectively opening and closing said printing apertures. An image receiving member (109) is passed between the printhead structure and the back electrode. The toner particles (106) on said surface (101) are, due to the movement of the toner bearing surface, passed under a conductive element, E, (102), placed at a distance, d, from the toner bearing surface and coupled to an AC-voltage source AC2 so that an AC-field exist between said element, E, and the toner bearing surface (101). The toner particles (106) are kind of shuffled and seemingly more evenly distributed. After passing that element, E, (102) the toner particles that have been redistributed settle again on the toner bearing surface and are transported in the development zone (107),from where the toner particles are moved to back electrode (and thus to the image receiving member) through the printing apertures that are opened and closed in accordance with image data. The conductive element (102) extends at least over the printing width, PW, defined by the extension of the array of printing apertures perpendicular to the print direction.

[0020] The DEP-device as shown in figure 2 operates without the presence of an AC-field in the "development zone", making the charged toner particles oscillate between the toner bearing surface and the printhead structure. DEP-devices operating with an AC-field in the "development zone" have been disclosed, e.g., in US-A-4 491 855. It was showed now during experimentation, surprisingly, that banding was not avoided by having an AC-field in the "development zone", making the charged toner particles oscillate between the toner bearing surface and the printhead structure as in US-A-4 491 855, but that banding could be avoided by having the AC-field upstream of the "development zone". It even showed that by adding, in a DEP-device having an AC-field in the "development zone", a conductive element, E, as per this invention, upstream "the development zone" for creating an AC-field between the toner bearing surface and that conductive element, E, the banding could be avoided and the printing speed enhanced.

[0021] In figure 2, the conductive element, E, (102) is showed as being flat, while the toner bearing surface is curved. Although this embodiment does greatly diminish the banding, it was found that the influence of the AC-field created between said conductive member and the toner bearing surface was enhanced when the conductive member followed the shape of the toner bearing surface. Such a DEP device, which is a preferred embodiment of this invention, is shown in figure 3, for a curved toner bearing surface. It comprises a charged toner bearing surface (101), having a curvature defined by radius R1, carrying charged toner particles (106) and coupled to a DC-voltage source, DC1 (which may be earth potential) and to an AC-voltage source, AC1, for creating an AC-field in the development zone. The toner bearing surface is further equipped to be moved in the direction of arrow A. Opposite to the toner bearing surface (101), a back electrode (108) is placed, this back electrode is coupled to a DC-voltage source, DC4. The DC-voltage applied to the back electrode is different from the one applied to the toner bearing surface and so a DC-propulsion field is created wherein the charged toner particles can move, as a flow of toner particles, from the toner bearing surface to the back electrode. Between said toner bearing surface and said back electrode a printhead structure (103) is interposed, having an array of printing apertures (105) that are associated with control electrodes (104) coupled to a voltage source, VS3, that is image-wise varied for selectively opening and closing said printing apertures. The voltage source VS3 can be a DC-voltage source or it can be an AC-voltage source as disclosed in, e.g., EP-A-911 706, or it can be arranged for applying a DC-biased, AC-voltage to the control electrodes. An image receiving member (109) is passed between the printhead structure and the back electrode. The toner particles (106) on said surface (101) are, due to the movement of the toner bearing surface in the direction of arrow A, passed under a conductive element, E, (102) that is coupled to an AC-voltage source AC2 so that an AC-field exist between said element, E, and the toner bearing surface (101). The element, E, (102) is a bow of a circle, that is concentric with the circle defining the curvature of the toner bearing surface. The radius, R2, the circle defining the bow of the conductive element (102) is larger than radius RI defining the curvature of the toner bearing surface, i.e. R2 - R1 define the gap, d, between the conductive element and the toner bearing surface. After passing that element, E, (102) the toner particles settle again on the toner bearing surface and are transported in the development zone (107),from where the toner particles are moved to back electrode (and thus to the image receiving member) through the printing apertures that are opened and closed in accordance with image data. Preferably the curved conductive element is constructed so as not to have points that might influence the uniformity of the AC-field, therefore in figure 3 the ends of the conductive element (102a) are flattened.

[0022] In figure 4 a schematic exploded view of a very preferred embodiment of the invention is shown. A toner bearing surface (101) coupled to a DC-voltage source, DC1 and to an AC-voltage source (AC1) for creating an AC-field in the development zone. The toner bearing surface is further equipped to be moved in the direction of arrow A. Near that surface a conductive element (102), following the curvature of the toner bearing surface is shown. In this embodiment the conductive ele-

ment (102) is not a continuous conductive layer, but comprises two sets (102b) of electrodes constructed as combs with the teeth of one comb being interposed between, but isolated from the teeth of the second comb and extending at least over the printing width, PW. In operation the AC-voltage source, AC2, is consecutively coupled to each of the sets of the conductive element. By doing so, the AC-field between the conductive element and the toner bearing surface also changes in a direction parallel to the printing direction (or to the toner bearing surface), so that the toner particles do not only oscillate from the toner bearing surface to the conductive element, but oscillate also parallel to the toner bearing surface. This brings about a very thorough shuffling of the toner particles in two dimensions, thus homogenising that layer almost completely.

[0023] The AC-voltage source coupled to the conductive element, E, is preferably arranged to provide an AC-voltage with peak to peak voltage between 100 and 1500 and a frequency between 1 kHz and 7 kHz, with the gap, d, between said conductive element and said toner bearing surface having a value between 50 and 150 μm., more preferably said AC-voltage has a peak to peak value between 500 and 1000 V, and a frequency between 2 and 4 kHz. When the conductive element, 102, is not a continuous conductive layer, but comprise at least two sets of electrodes (102b), it is preferred that the consecutive coupling of the AC-voltage to the separate sets, proceeds with a speed so that during one line time, the field AC2 switches at least 1 time between the one set and the other of the electrodes (102b), for very good shuffling of the toner particles it is preferred that the field AC2 switches at least 5 times between the even and the uneven electrodes (102b). If the distance between said conductive element, E, and said toner bearing surface, 101, is kept low, i.e. between 50 and 100 μm, and an AC-voltage is applied to said toner bearing surface, having an AC-peak to peak value that is high enough for said charged toner particles to be propelled between said toner bearing surface and said conductive element over and over again, then it is sufficient to apply only DC-potentials to said two sets of electrodes present upon said conductive element, 102. In this case a DC-potential of +300 V can be applied to one of the sets of electrodes, while a DC-potential of -300 V is applied to the other set of electrodes. Said two DC-potentials are switched between said two sets of electrodes at a frequency of about 1 to 7 kHz. Alternatively, an AC voltage with peak to peak value of 600 V can be applied over said two sets of consecutive electrodes, resulting again in a shuffling motion of said charged toner particles being propelled from said charged toner bearing member to said electrode structure.

[0024] A conductive element as described in this invention can be added to any DEP device known in the art. It can, e.g., with the same beneficial effect be added in a DEP device wherein the toner bearing surface bringing charged toner particles to the development zone is the surface of the exit roller of a cassette with non-magnetic mono-component developer. It can also be added to in a DEP device wherein the charged toner particles are brought to the surface of a Charged Toner Conveyor (the toner bearing surface) by a magnetic brush with multi-component developer having toner and carrier particles (as disclosed in, e.g., EP-A-740 224) or by the exit roller of a cassette with non-magnetic mono-component developer (as disclosed in, e.g., European Application 99203242 filed on October 4, 1999). The Charged Toner Conveyor (CTC) can be in the form of a belt or in the form of a cylinder.

[0025] Also in DEP devices, as disclosed in, e.g., EP-A-911 706 and in European Application 99203305, filed on October 8, 1999, wherein the control electrodes are coupled to an AC-voltage source to a open and close the printing apertures they control, a conductive element as per this invention can be beneficially included.

[0026] It must be clear for those skilled in the art that slight modifications to this basic concept of using an additional conductive element and toner cloud generation for homogenising said layer of charged toner particles upon said charged toner bearing member, fall within the scope of the present invention. It is e.g. possible to use a segmented conductive element with only DC-potentials applied to both sets of segmented parts. Charged toner particles propelled to said segmented conductive elements only see varying DC-potentials and are therefore also performing a shuffling action, while only two fixed DC-potentials are applied to said segments of said conductive element. Also surface coatings applied to said conductive element, improving the charging characteristics of said charged toner particles, fall within the scope of the present invention. Typical surface coatings which are well known to those skilled in the art of carrier design, can be applied to the surface of said conductive element, so that not only a shuffling action is imposed upon said charged toner particles, but also additional charging and/or charge limitation is regulated by means of additional frictional contacts between said charged toner particles and said electrode member.

Parts list

[0027]

101 Toner bearing surface
102 Conductive element
103 Printhead structure
104 Control electrode
105 Printing aperture
106 Charged toner particles
107 Development zone
108 Back electrode
109 Image receiving substrate

Claims

1. A device for direct electrostatic printing comprising

   - a toner bearing surface (101) carrying charged toner particles (106) and moving in a direction of arrow A and bringing said charged toner in a development zone (107) near a printhead structure (103), that has a row of printing apertures (105) and control electrodes (104) associated therewith,
   - a voltage source for creating a DC-voltage field between said surface and an image receiving substrate (109), placed opposite to said printhead structure, said control electrodes being coupled to a voltage source, VS3, for selectively opening and closing said printing apertures,

   characterised in that
   said device comprises a conductive element, E, (102) placed near said toner bearing surface (101), upstream said development zone, and coupled to an AC-voltage source, AC2, creating a AC-field between said toner bearing surface and said element, E, for homogenising said cloud of charged toner particles.

2. A device for direct electrostatic printing according to claim 1, wherein said toner bearing surface is coupled to a further a AC-voltage source, AC1, creating a AC-field between said toner bearing surface and said printhead structure.

3. A device for direct electrostatic printing according to claim 1 or 2, wherein said toner bearing surface is an outer surface of a roller with a curvature defined by radius, R1 and said element E, has a curvature, defined by R2, following said curvature, defined by R1.

4. A device for direct electrostatic printing according to claim 1, wherein said element E extends over said printing width and is equipped with at least two sets of electrodes constructed as combs with the teeth of one comb being interposed between, but isolated from the teeth of the second comb and extending at least over the printing width, PW..

5. A device for direct electrostatic printing according to any of the preceding claims wherein said AC-field, coupled to said conductive element, E, has a peak to peak value between 100 and 1500 V, both limits included.

6. A device for direct electrostatic printing according to any of the preceding claims wherein said AC-field, coupled to said conductive element, E, has a frequency between 1 kHz and 7 kHz, both limits included.

7. A device for direct electrostatic printing according to claim 4, wherein said conductive element, E, is placed at a distance between 50 and 100 μm of said toner bearing surface and said two sets of electrodes are each only coupled to a DC-voltage switched from one set to another.

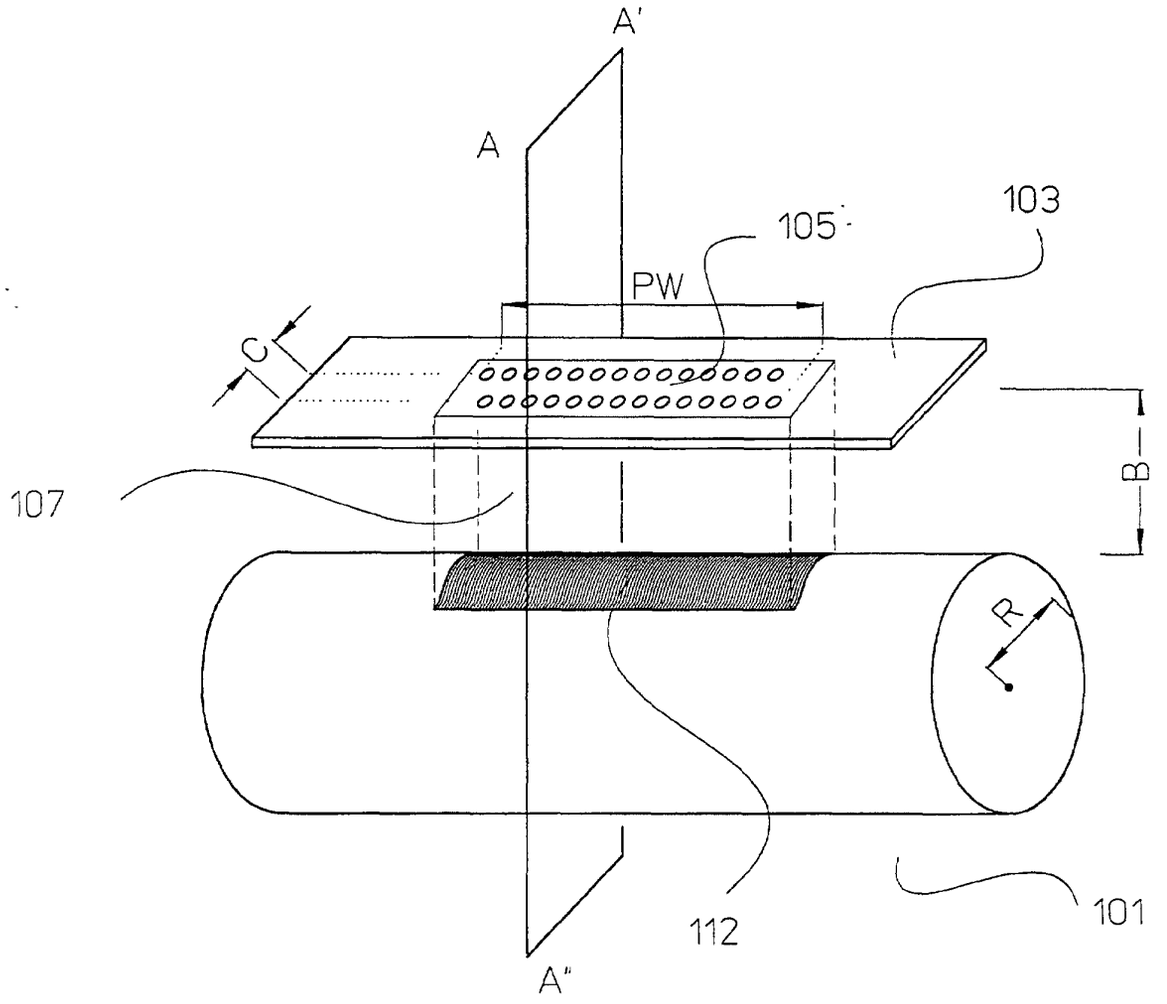

Fig. 1

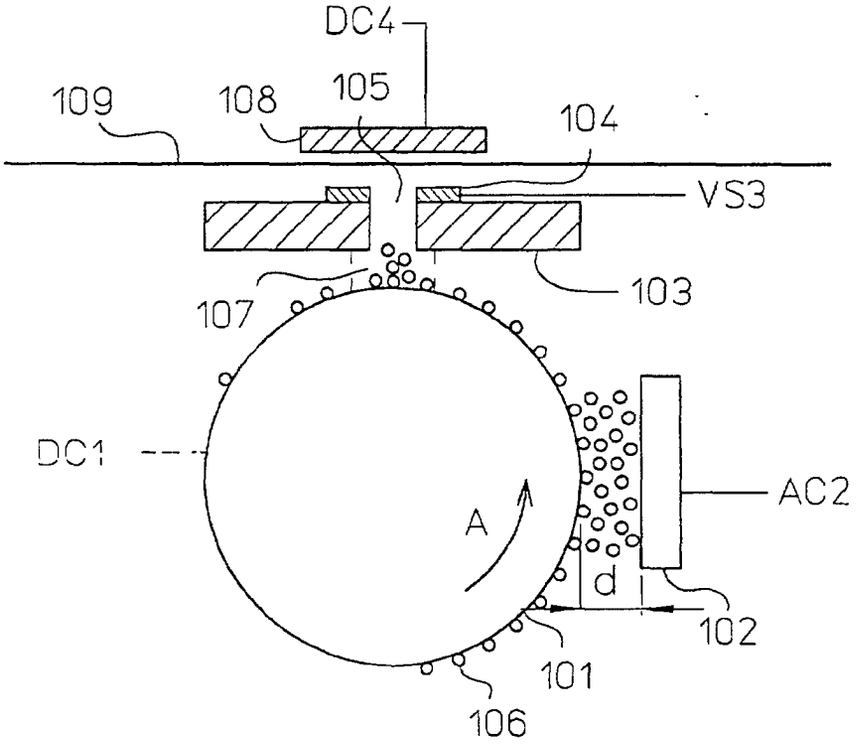

Fig. 2

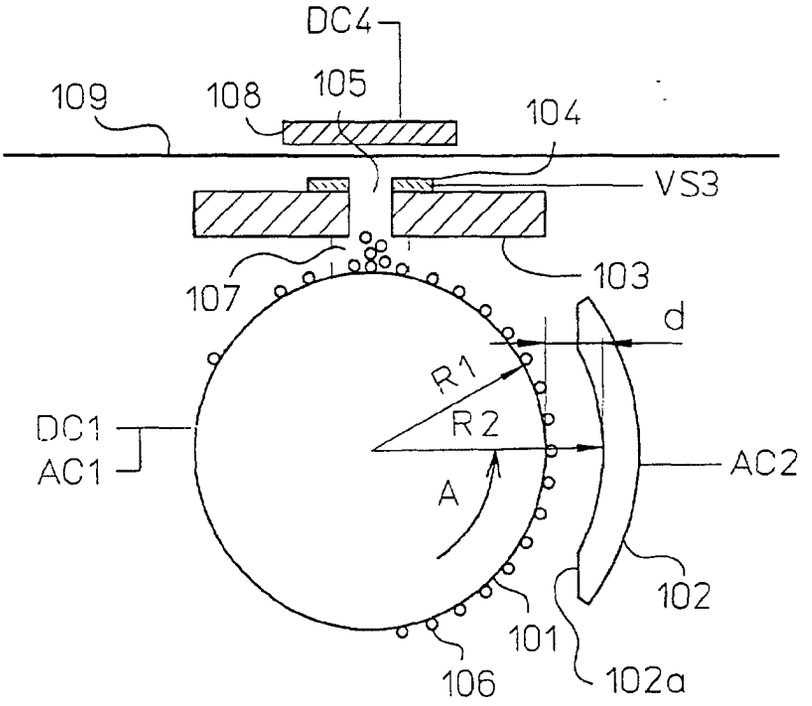
DC4
109
108
105
104
VS3
107
103
d
R1
R2
DC1
AC1
AC2
A
102
101
106
102a

Fig. 3

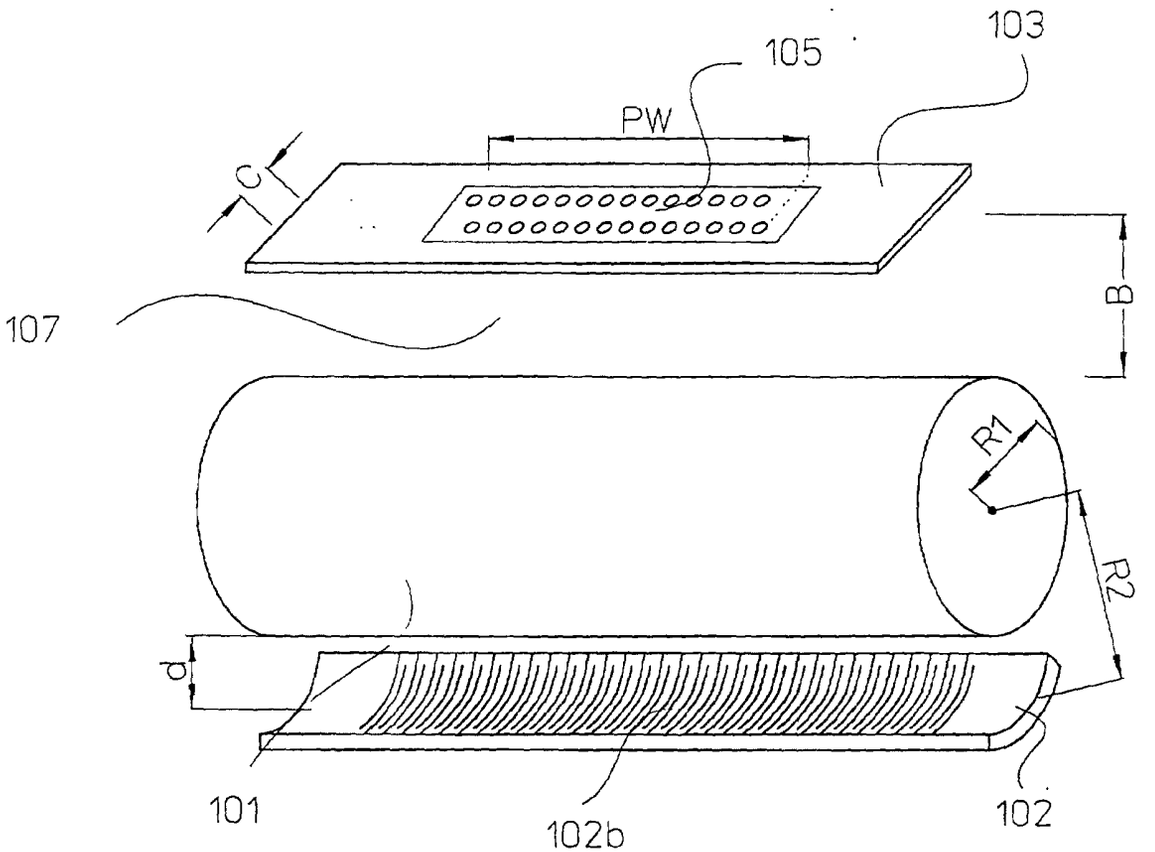

Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 20 0631

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.7)
A	US 5 541 716 A (SCHMIDLIN FRED W) 30 July 1996 (1996-07-30) * column 10, line 53 - column 11, line 9; figure 1 *	1,3	G03G15/34
A	US 4 743 926 A (SCHMIDLIN FRED W ET AL) 10 May 1988 (1988-05-10) * column 6, line 31 - column 7, line 12; figure 1 *	1,5,6	
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 334 (P-515), 13 November 1986 (1986-11-13) -& JP 61 138268 A (OLYMPUS OPTICAL CO LTD), 25 June 1986 (1986-06-25) * abstract *	1,3	
D,A	EP 0 911 706 A (AGFA GEVAERT NV) 28 April 1999 (1999-04-28) * column 11, line 3 - line 51; figure 4 *	1,2	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G03G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 June 2000	Cigoj, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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29-06-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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