Description

The invention relates to an electrophotographic printing system and, more particularly, to an electrostatically operative toner transfer system for an electrophotographic printing system.

Printers provide a means for outputting a permanent record in human readable form. Most printers may be characterized as utilizing either an impact printing technique or a non-impact printing technique. In impact printing techniques, an image is formed by striking an inked ribbon placed near the surface of a sheet of paper. Impact printing techniques may be further categorized as utilizing either formed-character printing or dot-matrix printing. In formed-character printing, the element which strikes the ribbon to produce the image consists of a raised mirror image of the desired character. In dot-matrix printing, the character is formed as a series of closely spaced dots which are produced by striking a provided wire or wires against the ribbon. By selectively striking the provided wires, any character representable by a matrix of dots can be produced. Non-impact printing is often preferred over impact printing in view of its tendency to provide higher printing speeds as well as its better suitability for printing graphics and half-tone images. Non-impact printing is also relatively noise free. One form of non-impact printing is generally classified as ink jet printing. In this technique, ink is forced, most commonly under pressure, through a tiny nozzle to form a droplet. The droplet is electrostatically charged and is attracted to an oppositely charged platen located behind the sheet of paper. Using electrically controlled deflection plates similar to those in a CRT, the trajectory of the droplet can be controlled to hit a desired spot on the paper. Unused drops are deflected away from the paper into a reservoir for recycling the ink. Due to the small size of the droplet and the precise trajectory control, ink jet printing quality can approach that of formed-character impact printing.

Another non-impact printing technique is generally referred to as electrophotographic printing. In this technique, a controller, for example, a microprocessor associated with a computer system, turns a small laser or other light source on and off at a very rapid rate which readily exceeds millions of times per second. Reflection means, for example, a multifaceted polygonal mirror, reflects the light stream off a facet thereof and sweeps the light stream across a negatively charged print drum. The reflected light discharges portions of the surface of the negatively charged print drum, thereby producing a latent image on the drum. As the print drum rotates, it is dusted with negatively charged toner in the form of small particles. The toner particles stick only to the discharged areas. When negatively charged paper contacts the drum, the toner particles are attracted to the discharged image areas, thereby forming the desired image. The image is then fused to the paper by a combination of heat and pressure. As the finished page is produced, the drum is cleared of its electrical charge, cleaned and recharged for a next cycle.

Various techniques have been utilized to supply toner to a photosensitive surface, for example, the surface of a print drum, where a latent image has been formed. In cascade type developing devices, a developer material which is comprised of carrier material and toner particles is cascaded onto the photosensitive surface from a position above the surface, thereby developing a latent image previously formed on the photoreceptor surface into a visible toner powder image. The use of cascade type developing devices is often undesirable due to the size, slow process speed and somewhat reduced print quality of such devices, particularly when the reproduction of half-tones and solid areas is desired.

Many other techniques utilize magnetic attraction to supply toner to the photosensitive surface of a print drum. For example, U.S. Patent No. 3,985,436 to Tanaka et al. discloses an electrophotographic copying system in which stationary bar magnets attract developing material consisting of magnetizable carrier material such as iron particles and electroscopic toner particles onto the surface of a cylinder to form magnetic brush bristles. As the cylinder rotates, the brush bristles rub lightly against the latent image formed on the surface of the rotating drum to develop the latent image into a visible toner powder image.

While electrophotographic printing techniques which utilize magnetic developers produce high quality images at relatively fast processing speeds, there remain several drawbacks to such systems. In particular, the brushing action on a print drum produced by a developer roller carrying a developer which includes both toner and carrier tends to wear itself out as well as wear out the print drum. Numerous solutions to this problem have been proposed. For example, U.S. Patent No. 4,538,896 to Tajima et al. describes a electrophotographic copying system where a hopper supplies a one component magnetic toner to a magnetic roller. In turn, the magnetic roller transfers the toner to a photosensitive drum.

Other solutions avoid the use of magnetic developers entirely. For example, U.S. Patent No. 4,100,884 to Mochizuki et al. discloses an apparatus for developing an electrostatic image on a photosensitive member in which a one component nonmagnetic toner is supplied to a developer roller. As the surface of the developer roller is formed of an elastic rubber having good adherence and retention qualities for fine powders, the toner is readily attached to the surface of the developer roller as a toner layer. In the event that the deposited toner is not level, a levelling member is included to provide a uniform thickness for the toner layer. The apparatus disclosed by Mochizuki et al. further includes a triboelectric charging member which charges the retained toner to a given polarity. As the electrostatic attraction is greater than the toner retaining capability of the developer roller, the charged toner will then be deposited on the image bear-

ing member.

It is an object of this invention to provide an electrophotographic printing system which includes an electrostatically operative toner transfer system.

It is another object of this invention to provide an electrostatically operative toner transfer system which utilizes relative differences in electrical charges to promote the transfer of toner through the toner transfer system.

It is yet another object of this invention to provide an electrophotographic printing system in which electrostatic attraction is utilized to orientate the toner, thus electrostatically simulating a magnetic brush-like configuration.

US-A-4835565 discloses an image developing apparatus which employs transfer rollers of differing potentials. US-A-3152012 discloses an image developing apparatus employing the triboelectric effect to transfer toner.

According to the present invention, there is provided an apparatus for developing an image on a photoconductive surface, the apparatus comprising:

a first roller constructed of a first material and mounted on a first conductive shaft, the first roller positioned adjacent to the photoconductive surface;

a second roller mounted on a second conductive shaft, the first and second rollers positioned such that the surfaces thereof frictionally engage each other;

means for depositing toner on the surface of the second roller;

a first voltage source electrically connected to the second conductive shaft, the first voltage source placing a negative biasing voltage on the second roller such that the toner carried thereby retains a negative charge;

the frictional engagement between the first and second rollers electrostatically attracting the negatively charged toner deposited on and carried by the second roller to the surface of the first roller;

a second voltage source electrically connected to the first conductive shaft, the second voltage source placing a negative biasing voltage on the first roller which exceeds the negative biasing voltage placed on the second roller, the second voltage source adhering the electrostatically attracted toner to the surface of the first roller in a layer; and

means for transferring the negatively charged toner electrostatically adhered to the surface of the first roller to the photoconductive surface; characterised by:

the second roller being constructed of a resilient porous material which temporarily retains the toner deposited thereon, and being higher in the triboelectric series than the first material.

Means may be provided which electrostatically adhere a variable layer of the negatively charged toner to the surface of the first roller.

The toner depositing means may be a third roller having a plurality of radially extending apertures formed on the surface thereon, constructed of a third material higher in the triboelectric series than the second material and positioned such that the second and third rollers frictionally engage each other. Toner is supplied to the surface of the third roller where it fills the apertures therein. The toner is then carried by the third roller until electrostatically attracted to the surface of the second roller by the frictional engagement of the second snd third rollers where the toner is deposited thereon and temporarily retained therein.

The invention may be better understood and its numerous objects, features and advantages become apparent to those skilled in the art by referencing the accompanying drawings in which:

FIG. 1 is a perspective view of a computer system which includes an electrophotographic printer constructed in accordance with the teachings of the present invention;

FIG. 2 is a cross-sectional schematic view of the electrophotographic printer illustrated in FIG. 1;

FIG. 3a is an enlarged cross-sectional view of the feed and donor rollers illustrated in FIG 2;

FIG. 3b is an enlarged cross-sectional view of an alternative embodiment of the feed and donor rollers of FIG. 3a;

FIG. 4 is a first enlarged cross-sectional view of the donor and developer rollers illustrated in FIG. 2; and

FIG. 5 is a second enlarged cross-sectional view of the donor and developer rollers illustrated in FIG. 2.

Referring now to FIG. 1, a computer system 10 which includes a computer 12 provided with both data processing and storage means and electrically connected to a plurality of peripheral devices may now be seen. Typically, the peripheral devices will include a keyboard 14 for inputting data and commands from an operator and a monitor 16 for displaying information. Also connected to the computer 12 is an electrophotographic printer 18 for providing a permanent record of data in human readable form and which is constructed in accordance with the teachings of the present invention. The electrophotographic printer 18 is electrically connected

to the computer 12 by a cable 20 which is attached to ports (not shown) provided on the electrophotographic printer 18 and the computer 12, respectively.

During a printing operation, blank sheets of paper are drawn inside the electrophotographic printer 18 from paper supply means 22 such as a paper tray by feed means (not shown). The sheets of paper travel along guide means (not shown) within the electrophotographic printer 18 where, as to be more fully described below, an image is formed thereon. The imprinted sheet is then deposited in an output tray 24 where it may be removed. An access panel 26 provides internal access to the main body of the electrophotographic printer 18. As may be clearly seen in FIG. 1, the main body of the electrophotographic printer 18 includes an opening 28 for receiving an electrophotographic printer cartridge 30 which is utilized to form the aforementioned images on sheets of paper travelling along the guide means. The electrophotographic printer cartridge 30 may be easily removed from the electrophotographic printer 18 for repair, replacement or replenishment of toner and, after servicing, may be readily reinstalled therein. As illustrated herein, the electrophotographic printer cartridge 30 is installed from one side of the electrophotographic printer 18. It is equally contemplated, however, that the electrophotographic printer 18 may be configured such that the electrophotographic printer cartridge 30 may be installed via an access panel provided along the top side of the printer. Furthermore, while the electrophotographic printer cartridge 30 is disclosed as part of a printer used to output data from a computer system in a permanent form, it is fully contemplated that the concepts of the present invention may be readily utilized in an electrophotographic copier to produce copies of an image already in permanent form.

Referring next to FIG. 2, a cross-sectional schematic view of the electrophotographic printer cartridge 30 inserted within the electrophotographic printer 18 may now be seen. As schematically illustrated, the electrophotographic printer cartridge 30 includes a housing 32, preferably formed of a hard plastic material, within which the components of the electrophotographic printer cartridge are housed. Within the cartridge housing 32 and adjacent its left end, a photosensitive drum 34 is positioned. Proceeding rightwardly from the photosensitive drum 34, a rotatable developer roller 36, a rotatable donor roller 38, a feed roller 40 and a toner reservoir 42 are all provided within the cartridge housing 32. The toner reservoir 42 may be integrally formed with the cartridge housing 32 or, in one embodiment, may be provided as a separate cartridge which is removably secured to the cartridge housing 32. Furthermore, in still other alternate embodiments of the invention, the toner reservoir 42 may be provided as a sealed compartment which requires disposal after the toner stored therein has been depleted or may be provided as an accessible compartment which may be refilled with additional toner. For example, the toner reservoir 42 illustrated in FIG. 2 includes a removable lid 43, thereby enabling the toner reservoir 42 to be refilled. Alternately, the lid 43 may be fixedly attached to the toner reservoir 42 but be further provided with a removable cap or other means for accessing the interior of the toner reservoir 42. The photosensitive drum 34 is comprised of a photoconductive layer 44 provided on a conductive drum base 46. Preferably, the photoconductive layer 44 should be a organic photoconductive material. The conductive drum base 46 is mounted on a rotatable shaft 48 such that photosensitive drum 34 is rotatable in a direction "a". To rotate the photosensitive drum 34, a controller 50 would cause drive means (not shown) to rotate the shaft 48. During operation of the electrophotographic printer cartridge 30, the photoconductive drum 34 is rotationally driven in the direction "a" such that the surface of the photoconductive layer 44 passes a corona discharger 52 where the surface of the photoconductive layer 44 is uniformly charged with a predetermined polarity suitable for the charging characteristics of the photoconductive layer 44 of the photosensitive drum 34. For example, it is contemplated herein that the corona charger should change the voltage potential at the surface of the photosensitive drum 34 to a voltage in the range of about -700 to -800 volts.

As the photosensitive drum 34 continues to rotate, light generated by light means 54 strikes the photoconductive layer 44. In the embodiment disclosed herein, light means 54 includes a laser light source controlled by the controller 50. Depending on the particular image to be produced, the controller 50 instructs the laser light source to turn on and off rapidly in a pattern related to the desired image. The resultant rays of light are reflected by a series of reflecting mirrors also included as part of light means 54 and directed through an exposure slot 56 formed in the housing 32 where the rays strike the photoconductive layer 44. Wherever the light rays strike, the photoconductive layer 44 is discharged, i.e. reduced to a significantly lower voltage potential having the same polarity. Typically, the light rays would reduce the voltage potential at the surface of the photosensitive drum 34 to a voltage in the range of about -50 volts to about -100 volts. By discharging designated areas, image areas are formed on the photoconductive layer 44. Those areas which are not discharged by the light means 54 form background areas on the photoconductive layer 44. Thusly, photoconductive layer 44 corresponds to the white areas on the paper.

Next, the rotating photosensitive drum 34 contacts the developer roller 36 which is rotating in a direction "b" which is the direction opposite to the direction which the photosensitive drum 34 is rotates. As to be more fully described below, a layer of negatively charged toner particles electrostatically adhered to the side surface of the developer roller 36 are electrostatically attracted to the discharged image areas of the photoconductive layer 44. As the discharged image areas on the photoconductive layer 44 are more electrostatically attractive to the toner particles than the surface of the developer roller 36, the

toner particles will be transferred to the discharged image areas. The photosensitive drum 34 is then rotated to a position above a transfer charger 58. The transfer corotron 58 emits positive ions onto the backside of the leftwardly moving paper stock 60 passing in close proximity to the photosensitive drum 34, thereby providing sufficient electrostatic attraction such that the toner particles will transfer to the paper stock 60, thereby creating darkened image areas on the paper stock 60. The moving paper stock 60 will then pass over a conventional thermal fusing device (not shown) which thermally fuses the transferred toner particles onto the paper stock 60 and exit from the electrophotographic printer 18.

Mounted within a toner collection housing 61 included as part of the cartridge housing 32 is a scraper blade 62. As the photosensitive drum 34 continues to rotate, the scraper blade 62 strips away any excess toner particles not deposited on the paper stock 60. The toner particles removed by the scraper blade 62 are dropped off the scraper blade 62 onto a rotating auger 63 which transports the toner to the front or rear end of the cartridge 32 where the toner is deposited into a small collection bottle (not shown). Finally, the photosensitive drum 34 rotates past an array 64 of erasure LEDs which remove any residual negative charge on the photoconductive layer 44 before the photoconductive layer 44 is re-charged with a negative charge by the corona discharger 52.

Having described the operation of the photosensitive drum 34, the transfer of toner particles from the toner reservoir 42 to the photosensitive drum 34 shall now be described in detail. In the embodiment of the invention disclosed herein, the toner reservoir 42 may be a dual well reservoir having first and second wells 66 and 68, each filled with toner particles, as illustrated in FIG. 2, or may be a single well reservoir instead. Each well 66, 68 includes an axially extending lifter 70 mounted on a shaft 72. Mounted to the end of each axially extending lifter 70 are flexible blade means 74. When the shafts 72 are rotated by drive means (not shown), the lifters 70 rotates, thereby rotating the flexible blade means 74 through the toner particles stored in each well 66, 68 of the toner reservoir 42. As the lifters 70 rotate, therefore, the flexible blade means 74 forces particles of toner out of the toner reservoir 42 through an aperture 76.

Referring now to FIG. 3a, the path of the toner particles exiting the toner reservoir 42 shall now be described in greater detail. Positioned in close proximity to the aperture 76 is the feed roller 40. The feed roller 40 is mounted on a shaft 80 driven by drive means (not shown). As the shaft 80 rotates the feed roller 40 in the direction "b", radially extending grooves 40a formed along the surface of the feed roller 40 are filled with toner particles. In the embodiment disclosed herein, the feed roller 40 is provided with first and second generally V-shaped grooves formed therein. It is fully contemplated, however, that additional grooves may be formed in the feed roller 40 to increase the rate at which the feed roller 40 supplies toner to the donor roller 38. In one aspect of the invention, it is contemplated that the feed roller 40 may should be constructed of a material having a higher or more positive position in the triboelectric series than the material from which the donor roller 38 is constructed. By doing so, the feed roller 40 will donate electrons to the donor roller 38, thereby charging it negatively. For example, it is contemplated that the feed roller 40 may be constructed from a polyamide material.

As the feed roller 40 continues to rotate, the toner particles which have been forced into the aperture 76 and which have filled the groove 40a are transported to the donor roller 38. The remaining particles of toner are forced by the sidewalls which define the aperture 76 to remain in the toner reservoir 42. In the embodiment of the invention illustrated in FIG. 3a, the surfaces of the feed roller 40 and the donor roller 38 are spaced apart. In this embodiment, as the feed roller 40 rotates, the toner particles stored in the generally V-shaped groove 40a are dumped onto the donor roller 38. In an alternate embodiment of the invention illustrated in FIG. 3b, the surfaces of the feed roller 40 and the donor roller 38 frictionally engage each other. As the surfaces of the feed roller 40 and the donor roller 38 frictionally engage with each other, the triboelectric charge generated thereby will negatively charge toner particles being carried in the grooves 40a of the feed roller 40 and deposited onto the surface of the donor roller 38.

The donor roller 38 is rotatable mounted on an electrically conductive shaft 82 driven by drive means (not shown). The donor roller 38 is formed of a resilient porous material which meets the triboelectric series requirements previously discussed. For example, the donor roller 38 may be formed from a polyurethane foam. As the donor roller 38 is porous, the particles of toner deposited on the surface of the donor roller 38 are temporarily retained on the surface of the donor roller 38. Preferably, the resilient porous material should be selected to have a porosity in the range of 20-30 pores per inch. In one embodiment of the invention, the electrically conductive shaft 82 of the donor roller 38 may be connected to a first biasing means 84 such as a DC voltage source. For example, it is contemplated that a negative bias up to -500 volts may be applied to the donor roller 38. By applying a negative bias to the donor roller 38, the toner particles carried thereby retain its negative charge.

Referring now to FIG. 4, the temporarily retained toner particles are then carried in direction "b" by the rotating donor roller 38 until transferred to the developer roller 36 in a manner to be more fully described below. To encourage the transfer of toner particles from the donor roller 38 to the developer roller 36, it is preferred that the donor roller 38 be constructed of a material having a higher or more positive position in the triboelectric series than the material from which the developer roller 36 is constructed. Preferably, the developer roller 36 should have a relative hardness of 50-70 durometers and a spe-

cific resistivity in the range of 10^4 to 10^8 ohm-cm. For example, it is contemplated that the developer roller may be constructed from neoprene or urethane. In one embodiment, the developer roller 36 may be configured to include a base section capable of conducting electricity and a sleeve formed from a semi-conductive material.

A blade 86 is mounted to the cartridge housing 32 and orientated such that the tip of the blade is positioned between the donor roller 38 and the developer roller 36. Preferably, the blade 86 should be formed of a relatively stiff material such as cellulose acetate or its equivalent. As the donor roller 38 rotates, the blade 86 compresses the resiliently porous donor roller 38, thereby forcing negatively charged toner particles temporarily retained therein to the surface of the donor roller 38. As the surfaces of the developer roller 36 and the donor roller 38 frictionally engage each other, the relative positions of the donor roller 38 and the developer roller 36 on the triboelectric ladder will cause the developer roller 36 to develop a negative charge with respect to the donor roller 38. As a result, the low negatively charged toner particles on the surface of the donor roller 38 will be electrostatically attracted to the surface of the high negatively biased developer roller 36.

Returning momentarily to FIG. 2, it is further contemplated that, in one embodiment of the invention, the developer roller 36 is rotatably mounted on an electrically conductive shaft 89. A second biasing means 91 is electrically connected to the conductive shaft 89. The second biasing means 91 is selected such that it will be able to apply a negative bias to the developer roller 36 which is more negative than the negative bias applied to the donor roller 38. By applying a greater negative charge to the developer roller, the electrostatic attraction of the negatively charged toner particles to the developer roller 36 is strengthened. Furthermore, the negative charge prevents degradation of the electrostatic attraction of the toner particles to the developer roller 36 which could result from the presence of increasing levels of humidity. Generally, increases in humidity causes the triboelectric ladder to effectively shrink. As a result, materials on the lower end of the triboelectric ladder acquire less of a negative charge relative to materials placed higher on the ladder. Thus, the effect of an increase in humidity would be to weaken the electrostatic attraction of the negatively charged toner particles to the developer roller 36. By placing a greater negative charge on the developer roller 36 than the negative charge placed on the donor roller 38, the greater negative charge can compensate for losses in electrostatic attraction which could potentially result from increases in humidity.

Referring again to FIG. 4, an additional aspect of this embodiment of the invention shall now be described in detail. Here, it is preferred that the developer roller 36 is spaced slightly apart from the photosensitive drum 34. In this embodiment, the second biasing means 91 is an AC source used to apply an AC voltage and frequency on the developer roller 36. For example, it is contemplated that the second biasing means 91 may apply up to 2000 volts AC and up to a frequency of 2,500 Hz on the developer roller 36. By applying the AC voltage to the developer roller 36, the toner particles adhering to the surface of the developer roller 36 are orientated in a series of axially extending bristles 88 which closely resemble the pulsating, brush configuration which is more typically produced by a magnetic brush developer system in which a carrier is utilized to adhere toner particles to a magnetically charged developer roller. Furthermore, the configuration of the bristles 88 on the developer roller 36 may be readily controlled by the second biasing means 91. Specifically, the height of the bristles 88 may be modified by changing the amplitude of the applied AC voltage and the separation or rate of pulsation between successive bristles 88 may be modified by changing the frequency of the applied AC voltage. Modification of the toner adhering to the developer roller 36 is possible because not all toner particles carried by the donor roller 38 receive a defined polarity during the transfer process. Those not receiving a defined polarity typically remain adhered to the donor roller 38 for at least one additional rotation. Thus, by increasing the voltage, the number of toner particles receiving a defined polarity, and thereby the number of toner particles transferring to the developer roller 36 increases.

In yet another aspect of the invention illustrated in FIG. 5, second biasing means 91 places a DC voltage on the developer roller 36. Under the influence of a DC voltage, a uniform layer of toner particles would adhere to the surface of the developer roller 36. In either aspect of the invention, as the developer roller 36 rotates, the toner particles adhered to the surface thereto, would pass in close proximity to an electrostatic metering blade 90. Preferably, the electrostatic metering blade 90 should be constructed of a conductive material and be mounted to the insulative cartridge housing 32. If found necessary, a reinforcing negative voltage in the range of 0 to -500 volts may be applied to the electrostatic metering blade 90, to more effectively excise excess toner particles adhering to the surface of the developer roller 36 such that the layer of toner particles 92, either uniform or brush-like, which remain adhered to the developer roller 36 may reduced to approximately the thickness of 1-2 toner particles (about 15-30 micrometers). Excised toner particles would be reabsorbed by the donor roller 38 for retransfer to the developer roller 36. The toner particles 92 which remain adhered to the developer roller 36 would then be deposited onto the photosensitive drum 34 in accordance with the methods previously described. Toner particles not deposited onto the photosensitive drum 34 would be returned to the developer roller 36. More specifically, a flexible seal 96 mounted to the cartridge housing 32 and positioned between the photosensitive drum 34 and the developer roller 36 is provided to contain any toner dropped by the developer roller 36.

It has been discovered that by reducing the separation between bristles 88 of toner particles, the speed at

which the development process can operate is increased. It has been further discovered that by producing a brush-like configuration of the toner electrostatically adhering to the developer roller 36, a high quality image is developed on the photosensitive drum 34. In traditional development processes, while the majority of the toner particles are deposited on the low negative charge image areas formed on the photoconductive layer 44, a few of the toner particles end up deposited on the high negative charge background areas. As the negatively charged toner particles adhering to the developer roller 36 in the brush-like configuration pass in close proximity to the photosensitive drum 34, toner particles adhering to the high negative charge background areas would view the bristles 88 as a positive charge. The bristles 88 would electrostatically attract or "scavenge" the toner particles adhering to the background, thereby remove stray toner particles improperly deposited on the background areas. Then, when the bristles 88 pass in close proximity to the low negative charge image areas, the scavenged toner particles would be redeposited onto the image areas, thus improving the contrast between the image and background areas.

Thus, there has been described and illustrated herein an electrostatically operative toner transfer system for use in an electrophotographic printer in which the exploitation of relative differences in electrical charges on the system components and triboelectric charges resulting between the system components are utilized to produce an electrophotographic printer which transfers toner by electrostatic attraction, thereby eliminating wear the photoconductive drum produced by the use of carriers to magnetically transfer toner and which is less susceptible to humidity. Furthermore, by the application of an AC bias to the developer roller, the electrostatically attracted toner particles may be orientated in a magnetic brush-like configuration which permits increased operating speeds and improved image quality. However, those skilled in the art will recognize that many modifications and variations besides those specifically mentioned may be made in the techniques described herein without departing substantially from the concept of the present invention as defined in the appended claims.

Claims

1. An apparatus for developing an image on a photoconductive surface (34,44), the apparatus comprising:

   a first roller (36) constructed of a first material and mounted on a first conductive shaft (89), the first roller positioned adjacent to the photoconductive surface (34,44);

   a second roller (38) mounted on a second conductive shaft (82), the first and second rollers positioned such that the surfaces thereof frictionally engage each other;

   means (40) for depositing toner on the surface of the second roller;

   a first voltage (84) source electrically connected to the second conductive shaft, the first voltage source placing a negative biasing voltage on the second roller such that the toner carried thereby retains a negative charge;

   the frictional engagement between the first and second rollers electrostatically attracting the negatively charged toner deposited on and carried by the second roller to the surface of the first roller;

   a second voltage source (91) electrically connected to the first conductive shaft, the second voltage source placing a negative biasing voltage on the first roller which exceeds the negative biasing voltage placed on the second roller, the second voltage source adhering the electrostatically attracted toner to the surface of the first roller in a layer; and

   means for transferring the negatively charged toner electrostatically adhered to the surface of the first roller to the photoconductive surface; characterised by:

   the second roller (38) being constructed of a resilient porous material which temporarily retains the toner deposited thereon, and being higher in the triboelectric series than the first material.

2. An apparatus according to Claim 1, further comprising blade means (86) for compressing the second roller (38) to extract negatively charged toner temporarily retained thereby, the negatively charged toner being electrostatically attracted to the first roller (36) upon extraction.

3. An apparatus according to Claim 1, wherein the second voltage source (91) further comprises a DC voltage source electrically connected to the first conductive shaft (89), the DC voltage source electrostatically adhering a uniform layer of the negatively charged toner to the surface of the first roller (36).

4. An apparatus according to Claim 1, further comprising electrostatic metering means (90) for reducing the thickness of the layer of negatively charged toner electrostatically adhered to the surface of the first roller (36).

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which the development process can operate is increased. It has been further discovered that by producing a brush-like configuration of the toner electrostatically adhering to the developer roller 36, a high quality image is developed on the photosensitive drum 34. In traditional development processes, while the majority of the toner particles are deposited on the low negative charge image areas formed on the photoconductive layer 44, a few of the toner particles end up deposited on the high negative charge background areas. As the negatively charged toner particles adhering to the developer roller 36 in the brush-like configuration pass in close proximity to the photosensitive drum 34, toner particles adhering to the high negative charge background areas would view the bristles 88 as a positive charge. The bristles 88 would electrostatically attract or "scavenge" the toner particles adhering to the background, thereby remove stray toner particles improperly deposited on the background areas. Then, when the bristles 88 pass in close proximity to the low negative charge image areas, the scavenged toner particles would be redeposited onto the image areas, thus improving the contrast between the image and background areas.

Thus, there has been described and illustrated herein an electrostatically operative toner transfer system for use in an electrophotographic printer in which the exploitation of relative differences in electrical charges on the system components and triboelectric charges resulting between the system components are utilized to produce an electrophotographic printer which transfers toner by electrostatic attraction, thereby eliminating wear the photoconductive drum produced by the use of carriers to magnetically transfer toner and which is less susceptible to humidity. Furthermore, by the application of an AC bias to the developer roller, the electrostatically attracted toner particles may be orientated in a magnetic brush-like configuration which permits increased operating speeds and improved image quality. However, those skilled in the art will recognize that many modifications and variations besides those specifically mentioned may be made in the techniques described herein without departing substantially from the concept of the present invention as defined in the appended claims.

Claims

1. An apparatus for developing an image on a photoconductive surface (34,44), the apparatus comprising:

   a first roller (36) constructed of a first material and mounted on a first conductive shaft (89), the first roller positioned adjacent to the photoconductive surface (34,44);

   a second roller (38) mounted on a second conductive shaft (82), the first and second rollers positioned such that the surfaces thereof frictionally engage each other;

   means (40) for depositing toner on the surface of the second roller;

   a first voltage (84) source electrically connected to the second conductive shaft, the first voltage source placing a negative biasing voltage on the second roller such that the toner carried thereby retains a negative charge;

   the frictional engagement between the first and second rollers electrostatically attracting the negatively charged toner deposited on and carried by the second roller to the surface of the first roller;

   a second voltage source (91) electrically connected to the first conductive shaft, the second voltage source placing a negative biasing voltage on the first roller which exceeds the negative biasing voltage placed on the second roller, the second voltage source adhering the electrostatically attracted toner to the surface of the first roller in a layer; and

   means for transferring the negatively charged toner electrostatically adhered to the surface of the first roller to the photoconductive surface; characterised by:

   the second roller (38) being constructed of a resilient porous material which temporarily retains the toner deposited thereon, and being higher in the triboelectric series than the first material.

2. An apparatus according to Claim 1, further comprising blade means (86) for compressing the second roller (38) to extract negatively charged toner temporarily retained thereby, the negatively charged toner being electrostatically attracted to the first roller (36) upon extraction.

3. An apparatus according to Claim 1, wherein the second voltage source (91) further comprises a DC voltage source electrically connected to the first conductive shaft (89), the DC voltage source electrostatically adhering a uniform layer of the negatively charged toner to the surface of the first roller (36).

4. An apparatus according to Claim 1, further comprising electrostatic metering means (90) for reducing the thickness of the layer of negatively charged toner electrostatically adhered to the surface of the first roller (36).

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5. An apparatus according to Claim 1, wherein the first and second voltage sources (84,91) further comprise first and second DC voltage sources (84,91) electrically connected to the second and first conductive shafts (82,89), respectively, the second DC voltage source electrostatically adhering a uniform layer of the negatively charged toner to the surface of the first roller (36).

6. An apparatus according to Claim 5, wherein a negative charge in the range of about -50 volts to about -500 volts is placed on the second roller (38) by the first DC voltage source (84) and a negative charge of approximately -1000 volts is placed on the first roller (36) by the second DC voltage source (91).

7. An apparatus according to claim 1, wherein the second voltage source (91) includes means (91) for electrostatically adhering a variable layer of negatively charged toner to the surface of the first roller (36).

8. An apparatus according to Claim 7, wherein the means (91) for electrostatically adhering a variable layer of negatively charged toner to the surface of the first roller (36) further comprises an AC voltage source (91) electrically connected to the first roller.

9. An apparatus according to Claim 8, wherein the variable layer of negatively charged toner is provided in a magnetic brush-like configuration and the apparatus further comprises means for adjusting the frequency and amplitude of the brush-like toner configuration.

10. An apparatus according to Claim 9, wherein the first voltage source (84) is a DC voltage source (84).

11. An apparatus according to Claim 10, wherein a negative charge in the range of about -50 volts to about -500 volts is placed on the second roller (38) by the DC voltage source (84) and a charge of approximately 2000 volts is placed on the first roller (36) by the AC voltage source (91).

12. An apparatus according to Claim 11, further comprising means for modifying the frequency of the charge placed on the first roller (36) by the AC voltage source (91).

13. An apparatus according to Claim 12, wherein a charge of approximately 2000 volts at a frequency up to 2500 Hz is placed on the first roller (36) by the AC voltage source (91).

14. An apparatus according to Claim 13, further comprising electrostatic metering means (90) for reducing the thickness of the layer of negatively charged toner electrostatically adhered to the surface of the second roller (38) and means for biasing the electrostatic metering means in the range of 0 to -500 volts.

15. An apparatus according to claim 1, wherein the toner depositing means (40) includes:

a third roller (40) constructed of a third material higher in the triboelectric series than the second material, the second and third rollers (38,40) positioned such that the surfaces thereof frictionally engage each other, the third roller having a plurality of radially extending apertures (40a) formed on the surface thereon; the apparatus further comprising:

means (68,70,72,74) for supplying toner to the surface of the third roller, the toner filling the apertures and being carried by the third roller until electrostatically attracted to the surface of the second roller by the frictional engagement of the second and third rollers.

16. An apparatus according to Claim 15, wherein the radially extending apertures (40a) are generally V-shaped.

Patentansprüche

1. Gerät zum Entwickeln einer Abbildung auf einer photoleitenden Oberfläche (34,44), wobei das Gerät aufweist:

eine erste Walze (36), die aus einem ersten Material aufgebaut und an einer ersten, leitenden Welle (89) befestigt ist, wobei die erste Walze benachbart der photoleitenden Oberfläche (34,44) positioniert ist;

eine zweite Walze (38), die an einer zweiten, leitenden Welle (82) befestigt ist, wobei die erste und die zweite Walze derart positioniert sind, daß die Oberflächen davon reibungsmäßig miteinander eingreifen;

eine Einrichtung (40) zum Entwickeln von Toner auf der Oberfläche der zweiten Walze;

eine erste Spannungsquelle (84), die elektrisch mit der zweiten, leitenden Welle verbunden ist, wobei die erste Spannungsquelle eine negative, vorspannende Spannung auf der zweiten Walze derart plaziert, daß der Toner, der dadurch getragen wird, eine negative Ladung beibehält;

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wobei der reibungsmäßige Eingriff zwischen der ersten und der zweiten Walze elektrostatisch den negativ geladenen Toner, der auf der zweiten Walze niedergeschlagen und durch diese getragen wird, auf die Oberfläche der ersten Walze anzieht;

eine zweite Spannungsquelle (91), die elektrisch mit der ersten leitenden Welle verbunden ist, wobei die zweite Spannungsquelle eine negative Vorspannung auf der ersten Walze plaziert, die die negative Vorspannung übersteigt, die auf der zweiten Walze plaziert ist, wobei die zweite Spannungsquelle den elektrostatisch angezogenen Toner an der Oberfläche der ersten Walze in einer Schicht anhaftet; und

eine Einrichtung zur Übertragung des negativ aufgeladenen Toners, der elektrostatisch an der Oberfläche der ersten Walze an der photoleitenden Oberfläche anhaftet; gekennzeichnet durch:

die zweite Walze (38) ist aus einem elastisch porösen Material, das temporär den Toner, der darauf niedergeschlagen ist, zurückhält, und das in den triboelektrischen Reihen höher als das erste Material liegt, aufgebaut .

2. Gerät nach Anspruch 1, das weiterhin eine Messereinrichtung (86) zum Komprimieren der zweiten Walze (38) so, um negativ geladenen Toner herauszuziehen, der temporär dadurch zurückgehalten wird, wobei der negativ geladene Toner elektrostatisch auf die erste Walze (36) unter der Extraktion angezogen wird, umfaßt.

3. Gerät nach Anspruch 1, wobei die zweite Spannungsquelle (91) weiterhin eine DC-Spannungsquelle aufweist, die elektrisch mit der ersten leitenden Welle (89) verbunden ist, wobei die DC-Spannungsquelle elektrostatisch eine gleichförmige Schicht des negativ geladenen Toners an der Oberfläche der ersten Walze (36) anhaftet.

4. Gerät nach Anspruch 1, das weiterhin eine elektrostatische Dosiereinrichtung (90) zum Reduzieren der Dicke der Schicht des negativ geladenen Toners, der elektrostatisch an der Oberfläche der ersten Walze (36) anhaftet, aufweist.

5. Gerät nach Anspruch 1, wobei die erste und die zweite Spannungsquelle (84,91) weiterhin erste und zweite DC-Spannungsquellen (84,91) aufweisen, die elektrisch mit der ersten und der zweiten leitfähigen Welle (82,89) jeweils verbunden sind, wobei die zweite DC-Spannungsquelle elektrostatisch eine gleichförmige Schicht des negativ geladenen Toners an der Oberfläche der ersten Walze (36) anhaftet.

6. Gerät nach Anspruch 5, wobei eine negative Spannung in dem Bereich von ungefähr -50 Volt bis ungefähr -500 Volt auf der zweiten Walze (38) durch die erste DC-Spannungsquelle (84) plaziert wird und eine negative Ladung von ungefähr -1000 Volt auf der ersten Walze (36) durch die zweite DC-Spannungsquelle (91) plaziert wird.

7. Gerät nach Anspruch 1, wobei die zweite Spannungsquelle (91) eine Einrichtung (91) zum elektrostatischen Anhaften einer variablen Schicht negativ geladenen Toners an der ersten Walze (36) umfaßt.

8. Gerät nach Anspruch 7, wobei die Einrichtung (91) zum elektrostatischen Anhaften einer variablen Schicht eines negativ geladenen Toners an der Oberfläche der ersten Walze (36) weiterhin eine AC-Spannungsquelle (91) aufweist, die elektrisch mit der ersten Walze verbunden ist.

9. Gerät nach Anspruch 8, wobei die variable Schicht eines negativ geladenen Toners in einer magnetischen, bürstenähnlichen Konfiguration gebildet wird und das Gerät weiterhin eine Einrichtung zum Einstellen der Frequenz und der Amplitude der bürstenähnlichen Tonerkonfiguration aufweist.

10. Gerät nach Anspruch 9, wobei die erste Spannungsquelle (84) eine DC-Spannungsquelle (84) ist.

11. Gerät nach Anspruch 10, wobei eine negative Ladung in dem Bereich von ungefähr -50 Volt bis ungefähr -500 Volt auf der zweiten Walze (38) durch die DC-Spannungsquelle (84) plaziert ist und eine Ladung von ungefähr 2000 Volt auf der ersten Walze (36) durch eine AC-Spannungsquelle (91) plaziert ist.

12. Gerät nach Anspruch 11, das weiterhin Einrichtungen zum Modifizieren der Frequenz der Ladung, die auf der ersten Walze (36) durch die AC-Spannungsquelle (91) plaziert ist, aufweist.

13. Gerät nach Anspruch 12, wobei eine Ladung von ungefähr 2000 Volt bei einer Frequenz bis zu 2500 Hz auf der ersten Walze (36) durch die AC-Spannungsquelle (91) plaziert ist.

14. Gerät nach Anspruch 13, das weiterhin eine elektrostatische Dosiereinrichtung (90) zum Reduzieren der Dicke der Schicht des negativ geladenen Toners, der elektrostatisch an der Oberfläche der zweiten Walze (38) anhaftet, und eine Einrichtung zum Vorspannen der elektrostatischen Dosiereinrichtung in dem Bereich von 0 bis -500 Volt aufweist.

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15. Gerät nach Anspruch 1, wobei die Tonerniederschlagseinrichtung (40) umfaßt:

eine dritte Walze (40), die aus einem dritten Material höher in den triboelektrischen Reihen als das zweite Material aufgebaut ist, wobei die zweite und die dritte Walze (38,40) derart positioniert sind, daß die Oberflächen davon reibungsmäßig ineinander eingreifen, wobei die dritte Walze eine Vielzahl sich radial erstreckender Öffnungen (40a) besitzt, die auf der Oberfläche davon gebildet sind; wobei das Gerät weiterhin aufweist:

Einrichtungen (68,70,72,74) zum Zuführen von Toner auf die Oberfläche der dritten Walze, wobei der Toner die Öffnungen füllt und durch die dritte Walze getragen wird, bis er elektrostatisch auf die Oberfläche der zweiten Walze durch den reibungsmäßigen Eingriff der zweiten und der dritten Walze angezogen wird.

16. Gerät nach Anspruch 15, wobei die sich radial erstreckenden Öffnungen (40a) allgemein V-förmig sind.

Revendications

1. Appareil pour développer une image sur une surface photoconductrice (34,44), l'appareil comprenant:

un premier rouleau (36) réalisé en une première matière et monté sur un premier arbre conducteur (89), le premier rouleau étant disposé au voisinage immédiat de la surface photoconductrice (34,44);

un second rouleau (38) monté sur un second arbre conducteur (82), les premier et second rouleaux étant disposés de façon que leurs surfaces viennent frotter l'une contre l'autre;

un moyen (40) pour déposer du toner sur la surface du second rouleau;

une première source (84) de tension connectée au second arbre conducteur, la première source de tension appliquant au second rouleau une tension de polarisation négative de façon que le toner porté par celui-ci conserve une charge négative;

le frottement entre les premier et second rouleaux attirant par voie électrostatique, vers la surface du premier rouleau, le toner à charge négative déposé sur et porté par le second rouleau;

une seconde source (91) de tension reliée électriquement au premier arbre conducteur, la seconde source de tension appliquant au premier rouleau une tension de polarisation négative qui est supérieure à la tension de polarisation négative appliquée au second rouleau, la seconde source de tension faisant adhérer en couche, sur la surface du premier rouleau, le toner attiré par voie électrostatique; et

un moyen pour transférer sur la surface photoconductrice le toner à charge négative amené par voie électrostatique à adhérer sur la surface du premier rouleau; caractérisé en ce que:

le second rouleau (38) est en matière élastique poreuse retenant temporairement le toner déposé sur celui-ci et occupe dans la série triboélectrique un rang supérieur à celui de la première matière.

2. Appareil selon la revendication 1, comportant en outre un moyen formant lame (86) pour comprimer le second rouleau (38) afin d'extraire le toner à charge négative temporairement retenu par celui-ci, le toner à charge négative étant attiré par voie électrostatique vers le premier rouleau (36) au moment où il est extrait.

3. Appareil selon la revendication 1, dans lequel la seconde source (91) de tension comporte en outre une source de tension continue reliée électriquement au premier arbre conducteur (89), la source de tension continue faisant adhérer par voie électrostatique, sur la surface du premier rouleau (36), une couche uniforme de toner à charge négative.

4. Appareil selon la revendication 1, comportant en outre un moyen de mesure électrostatique (90) pour réduire l'épaisseur de la couche de toner à charge négative adhérant par voie électrostatique à la surface du premier rouleau (36).

5. Appareil selon la revendication 1, dans lequel les première et seconde sources (84,91) de tension comprennent en outre une première et une seconde sources (84,91) de tension continue respectivement reliées électriquement aux second et premier arbres conducteurs (82,89), la seconde source de tension continue faisant adhérer par voie électrostatique, sur la surface du premier rouleau (36), une couche uniforme du toner à charge négative.

6. Appareil selon la revendication 5, dans lequel une charge négative comprise entre environ -50 volts et environ -500 volts est appliquée au second rouleau (38) par la première source (84) de tension continue et une charge négative d'environ -1000 volts est

appliquée au premier rouleau (36) par la seconde source (91) de tension continue.

7. Appareil selon la revendication 1, dans lequel la seconde source (91) de tension comprend un moyen (91) pour faire adhérer par voie électrostatique, sur la surface du premier rouleau (36), une couche variable de toner à charge négative.

8. Appareil selon la revendication 7, dans lequel le moyen (91) pour faire adhérer par voie électrostatique sur la surface du premier rouleau (36) une couche variable de toner à charge négative comprend une source (91) de tension alternative reliée électriquement au premier rouleau.

9. Appareil selon la revendication 8, dans lequel la couche variable de toner à charge négative est réalisée selon une configuration analogue à un pinceau magnétique et l'appareil comporte en outre un moyen pour régler la fréquence et l'amplitude de la configuration de toner analogue à un pinceau.

10. Appareil selon la revendication 9, dans lequel la première source (84) de tension est une source (84) de tension continue.

11. Appareil selon la revendication 10, dans lequel une charge négative comprise entre environ -50 volts et environ -500 volts est appliquée au second rouleau (38) par la source (84) de tension continue et une charge d'environ 2000 volts est appliquée au premier rouleau (36) par la source (91) de tension alternative.

12. Appareil selon la revendication 11, comportant en outre un moyen pour modifier la fréquence de la charge appliquée au premier rouleau (36) par la source (91) de tension alternative.

13. Appareil selon la revendication 12, dans lequel une charge d'environ 2000 volts à une fréquence maximale de 2500 Hz est appliquée au premier rouleau (36) par la source (91) de tension alternative.

14. Appareil selon la revendication 13, comportant en outre un moyen de mesure électrostatique (90) pour réduire l'épaisseur de la couche de toner à charge négative amené par voie électrostatique à adhérer à la surface du second rouleau (38) et un moyen pour polariser le moyen de mesure électrostatique entre 0 et -500 volts.

15. Appareil selon la revendication 1, dans lequel le moyen (40) de dépôt de toner comporte:

un troisième rouleau (40) qui est en une troisième matière occupant dans la série triboélectrique un rang supérieur à celui de la seconde matière, les second et troisième rouleaux (38,40) étant disposés de telle façon que les surfaces de ceux-ci viennent frotter l'une contre l'autre, le troisième rouleau ayant plusieurs orifices (40a) s'étendant radialement et formés sur la surface de celui-ci; l'appareil comportant en outre:

un moyen (68,70,72,74) pour appliquer du toner sur la surface du troisième rouleau, le toner remplissant les orifices et étant porté par le troisième rouleau jusqu'à ce qu'il soit attiré sur la surface du second rouleau par le frottement des second et troisième rouleaux l'un contre l'autre.

16. Appareil selon la revendication 15, dans lequel les orifices (40a) s'étendant radialement ont globalement une forme en V.