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(54) **Color laser printer apparatus**

(57) A method and apparatus for an electrophotographic color printer (200, 300, 400, 500). The method of developing a color image onto a photoconductor (212, 214, 312, 314, 316, 412, 414, 416, 512, 514) includes providing at least two photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514) and at least three developing stations (231, 232, 233, 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535) such that the number of developing (231, 232, 233, 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535) stations is greater than the number of photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514). The method also includes discharging the photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514) so as to produce at least two patterns on at least one photoconductor and at least one pattern on at least one photoconductor, then developing each pattern with a respective toner and combining the patterns to form a multi-color finished image.

The invention further includes an apparatus (500) for performing four-color laser printing, including dot-on-dot printing, using five developing stations (535, 532, 533, 534, 535) and only two photoconductors (512, 514). The apparatus (500) includes at least two photoconductors (512, 514), and at least three developing stations (531, 532, 533, 534, 535), such that at least one photoconductor has at least two developing stations associated therewith. The invention also includes an apparatus (400) which produces color images of increased quality by using six toners, including light and dark tints of two colors, and no more than three photoconductors (412, 414, 416).

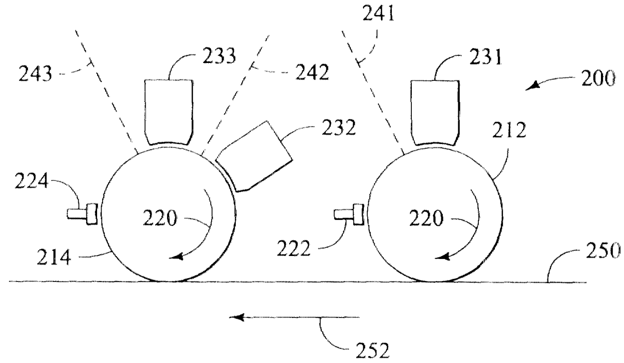

FIG.5

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Description

Field of the Invention

[0001] This invention pertains to color laser printing devices, and in particular to methods and apparatus for achieving multi-color, high quality printing and copying with a system having a simplified design.

Background

[0002] Color printing by an electrophotographic printer is achieved by scanning a digitized image onto a photoconductor. Typically, the scanning is performed with laser diodes which pulse a beam of laser energy onto the photoconductor. Light emitting diodes (LEDs) can be used in place of the laser diodes. The photoconductor typically comprises a drum or a belt coated with a photoconductive material to make up a photoconductive surface. Toner (particles used to print the image onto a medium such as a sheet of paper) is selectively applied to the photoconductor, and then is transferred to the medium, resulting in the finished copy. The photoconductive surface is capable of retaining localized electrical charges. Each localized area capable of receiving a charge corresponds to a pixel. Together, the vertical and horizontal matrix of pixels result in the final image which is to be printed on the medium. Each pixel is initially charged to a base electrical potential, and then is either exposed or not exposed by the laser, as dictated by the digital data used to pulse the laser. The digital data corresponds to a digitized version of the image to be finally printed on the medium. Exposing a pixel corresponds to electrically altering (typically discharging) the localized area from the base electrical potential to a different electrical potential. One electrical potential will attract toner, and the other electrical potential will not. In this manner, toner is selectively transferred to the photoconductor.

[0003] In most electrophotographic printing processes, the exposed (electrically discharged) pixels on the photoconductive surface attract toner onto the photoconductive surface. This process is known as discharge area development (DAD). However, in some electrophotographic printing processes the toner is attracted to the un-discharged (i.e., charged) area on the photoconductive surface. This latter type of electrophotographic printing is known as charge-area-development (CAD). For purposes of discussion, it will be assumed that DAD is used, although the present invention is not limited to DAD.

[0004] Once the photoconductive surface has had the desired toner transferred to it, the toner is then transferred to a finished product medium. This transfer can either be direct, or it can be indirect using an intermediate transfer device. The finished product medium typically comprises a sheet of paper, normally white, but can also comprise a transparency or a colored sheet of paper. After the toner is transferred to the finished product medium, it is processed to fix the toner to the medium. This last step is normally accomplished by thermally heating the toner to fuse it to the medium, or applying pressure to the toner on the medium.

[0005] There are a variety of known methods for selectively attracting toner to a photoconductor. Generally, each toner has a known electrical potential affinity. Selected areas of the photoconductor are exposed from a base potential to the potential for the selected toner, and then the photoconductor is exposed to the toner so that the toner is attracted to the selectively exposed areas of the photoconductor. This latter step is known as developing the photoconductor. In some processes, after the photoconductor is developed by a first toner, the photoconductor is then recharged to the base potential and subsequently exposed and developed by a second toner. In other processes, the photoconductor is not recharged to the base potential after being exposed and developed by a selected toner. In yet another process, the photoconductor is exposed and developed by a plurality of toners, then recharged, and then exposed and developed by another toner. In certain processes, individual photoconductors are individually developed with a dedicated color, and then the toner is transferred from the various photoconductors to a finished product medium, or to a transfer medium which then transfers the toner to the finished product medium. The process of exposing and developing the photoconductor is known in electrophotographic printing as the "charge-expose-develop" process.

[0006] The selection of the particular charge-expose-develop process to be used depends on a number of variables, such as the type of toner used and the ultimate quality of the image desired. The quality of the final image on the medium is typically associated with complexity and cost of the printer, such that higher quality electrophotographic printers which produce high quality images are more complex, and concomitantly more expensive.

[0007] Image data for an electrophotographic printer, including color laser printers (which will also be known herein as a "laser printer"), is digital data which is stored in computer memory. The data is stored in the form of a matrix or "raster" which identifies the location and color of each pixel which comprises the overall image. The raster image data can be obtained by scanning an original analog document and digitizing the image into raster data, or by reading an already digitized image file. The former method is more common to photocopiers, while the latter method is more common to printing computer files using a printer. Accordingly, the technology to which the invention described below is directed is applicable to either photocopiers or printers.

[0008] Recent technology has removed the distinction between printers and photocopiers, such that a single printing apparatus can be used either as a copier or as a printer for computer files. These apparatus have been known as multifunction printers ("MFPs)", a term indicating the ability of the apparatus to act as a photocopier, a printer, or a facsimile machine. In any event, the image to be printed onto tangible media is stored in computer memory as a digital image file. The digital image data is then used to pulse the beam of a laser in the manner described above so that the image can be reproduced by the electrophotographic printing apparatus. Accordingly, the expression "printer" should not be considered as limited to a device for printing a file from a computer, but should also include a photocopier capable of printing a digitized image of an original document. "Original documents" include not only already digitized documents such as text and image files, but photographs and other images, including hybrid text-image documents, which are scanned and digitized into raster data.

[0009] The raster image data file is essentially organized into a two-dimensional matrix. The image is digitized into a number of lines. Each line comprises a number of discrete dots or pixels across the line. Each pixel is assigned a binary value relating information pertaining to its color and potentially other attributes, such as color density. The combination of lines of pixels makes up the resultant image. The digital image is stored in computer readable memory as a raster image. That is, the image is cataloged by line, and each line is cataloged by each pixel in the line. A computer processor reads the raster image data line by line, and actuates the laser to selectively expose a pixel based on the presence or absence of coloration, and the degree of coloration for the pixel. Typical pixel densities for images are in the range of 300 to 1200 pixels per inch, in each direction.

[0010] The method of transferring the digital raster data to the photoconductor via a laser, lasers, or LEDs, is known as the image scanning process, or the scanning process. The scanning process is performed by a scanning portion or scanning section of the electrophotographic printer. The process of attracting toner to the photoconductor is known as the developing process. The developing process is accomplished by the developer section of the printer. Image quality is dependent on both of these processes. Image quality is thus dependent on both the scanning section of the printer, which transfers the raster data image to the photoconductor, as well as the developer section of the printer, which manages the transfer of the toner to the photoconductor.

[0011] The image quality of a given printer is also dependent, to some degree, on whether the printer has what is known as "dot-on-dot" printing capability in addition to basic color printing capability, known as "dot-next-to-dot." To illustrate, it should be pointed out that the four color planes typically printed, and which are generally considered as necessary to generate a relatively complete palate of colors, are yellow, magenta, cyan and black. That is, a typical color printer is generally provided with toners in each of these four colors. These colors are generally known as the "primary colors". With only these four colors, in addition to the color of the finished product media, a fairly broad gamut of colors is available for printing.

[0012] As an example, to print a pure cyan image, every pixel in a given region of a photoconductor would be developed with cyan toner. However, a different shade of cyan may be obtained by developing only half of the pixels in the given region with cyan toner, and leaving half of the pixels undeveloped. If the developed cyan pixels are evenly dispersed within the undeveloped pixels, the resulting image, if printed on a white sheet of paper, will be a lighter shade of cyan. This results from the whiteness of the paper sheet being visible as a result of the undeveloped pixels between the developed cyan pixels.

[0013] Because of the relative smallness of the pixels, human sight does not usually detect the color of each individual pixel. Instead, the eye is "tricked" into seeing a blend of the different colors of each individual pixel. For example, in the case illustrated above, since half the pixels of the image would be white, while the other half would be cyan, the resulting color seen by the human eye would be about halfway between pure white and pure cyan. However, if only one-quarter of the pixels were white, and three-quarters cyan, the resulting color would be slightly lighter than pure cyan, but not as light as the above case in which only half the pixels were cyan. Thus, by varying the number of developed pixels which are dispersed in undeveloped pixels, the tint of the resulting image can be varied.

[0014] The technique of interspersing developed pixels with undeveloped pixels can also be used to create secondary colors using the four primary colors. In other words, rather than simply interspersing a given color with the underlying color of the finished medium, such as white paper, two or more colors may be interspersed with each other in the manner discussed above to create varying hues of color. For example, pixels developed with cyan toner can be interspersed with pixels developed with yellow toner to create the impression of a green image. Also, by varying the proportions of the yellow and cyan pixels, varying hues of green can be created. Furthermore, by interspersing undeveloped pixels with the yellow and cyan pixels, lighter tints of green can be created. Likewise, darker shades can be created by interspersing black pixels with the yellow and cyan. By gradually increasing the density of black pixels among the other color pixels, a shading can be obtained. This method is commonly known as "dithering".

[0015] Although a given printer may not be provided with a green toner, the technique of interspersing cyan and yellow pixels with each other can "trick" the human eye into believing that it actually sees a green image. This technique, as discussed above, of creating differing tints and hues by printing adjacent pixels of an image with different toners is sometimes referred to as "dot-next-to-dot" printing because pixels of different colors are printed next to each other.

[0016] Although the gamut of colors made available by using the dot-next-to-dot printing technique is fairly broad, the color gamut is not unlimited. For example, to obtain a certain very light shade of cyan on a white sheet of paper may require a very high portion of the pixels of the image to be left undeveloped in order to have the proper amount of white dispersed with the cyan. This portion of undeveloped white pixels may so high as to render the quality of the image unacceptable. That is, the portion of cyan pixels may be so low that the human eye would be able to detect the individual cyan pixels as dots against the surrounding white background.

[0017] Another printing technique which is somewhat different than dot-next-to-dot printing is that known as "dot-on-dot" printing. Dot-on-dot printing involves applying a toner of one color on top of a toner of a second color to produce a third color. For example, a yellow toner could be applied on top of a cyan toner to produce a greenish color on the printed image. Dot-on-dot printing is generally considered to produce a higher quality image than dot-next-to-dot printing. For example, suppose a green image is to be printed using only the four standard toner colors of yellow, magenta, cyan, and black. A dot-next-to-dot printer cannot print an actual green image, but must print yellow pixels next to cyan pixels so as to approximate a green image. Conversely, a printer configured to provide dot-on-dot printing is capable of actually printing a green image. This is accomplished by applying yellow on top of cyan, for example. This results in an image made up of green pixels as opposed to an image that is made up of cyan pixels interspersed with yellow pixels. Thus, in order to have dot-on-dot capability, a printer must generally be capable of applying one toner on top of another toner.

[0018] A schematic side-elevation diagram of a prior-art developing section of a typical four-color in-line laser printer is shown in Fig. 1. As can be seen, the printer developing section 10 comprises a first, second, third, and fourth photoconductor drum 12, 14, 16, 18. The photoconductors shown in Fig. 1 are configured in the form of rotatable cylindrical drums, although they can be configured in another form such as, for example, continuous belts. The photoconductors 12, 14, 16, 18 are supported in fixed relation to one another as shown in Fig. 1, and are configured to rotate in the direction indicated by the arrows labeled 20. Each photoconductor 12, 14, 16, 18 has an associated charger unit 22, 24, 26, 28 which charges each respective photoconductor 12, 14, 16, 18 as it rotates.

[0019] In addition, as indicated by Fig. 1, each photoconductor 12, 14, 16, 18 has an associated developer station 32, 34, 36, 38, fixed proximate thereto as shown. Each developer station 32, 34, 36, 38 is configured to apply a toner (not shown) to the respective photoconductor 12, 14, 16, 18. For example, a first developer station 32 is shown to be configured to apply a given toner to a first photoconductor 12. A further study of Fig. 1 will reveal that each photoconductor 12, 14, 16, 18 has an associated selectively pulsed beam of energy, such as for example, a laser, 42, 44, 46, 48 projected upon it. For example, a first beam of energy 42 is projected onto the first photoconductor 12. Similarly, second, third, and fourth beams of energy 44, 46, 48 are projected onto the second, third, and fourth photoconductors 14, 16, 18, respectively.

[0020] As also revealed by Fig. 1, the photoconductors 12, 14, 16, 18 are configured so as to move in close proximity to a moving surface which is indicated by the numeral 50. The surface 50 is configured to move relative to the photoconductors 12, 14, 16, 18 in a direction indicated by the arrow labeled 52 as the photoconductors rotate in the direction labeled 20. The surface 50 can be in the form of a continuous rotating belt such as, for example, an intermediate transfer belt. Alternatively, the surface 50 can be in the form of a finished product media such as, for example, a sheet of paper. A study of Fig. 1 will reveal that when the surface 50 moves in direction 52 relative to the photoconductors 12, 14, 16, 18, the photoconductors will appear to be rolling on the moving surface 50.

[0021] Still referring to Fig. 1, in operation, the moving surface 50 moves in direction 52 and the surfaces 12, 14, 16, 18 rotate in direction 20. A charger unit 22, 24, 26 and 28 charges each respective photoconductor 12, 14, 16, 18 as the photoconductor rotates. Also, as each photoconductor 12, 14, 16, 18 rotate, the respective beam of energy 42, 44, 46, 48, scans the photoconductor. In doing so, each beam of energy forms a predetermined pattern (not shown) on the respective photoconductor 12, 14, 16, 18 by selectively discharging portions of the photoconductor. As the pattern on each photoconductor 12, 14, 16, 18 passes the respective developer station 32, 34, 36, 38, a toner is applied to the photoconductor from the respective developer station so as to develop the pattern. That is, a given toner is applied to the respective photoconductor 12, 14, 16, 18 such that the toner is attracted to the discharged portions of the respective photoconductor forming a pattern of toner thereon.

[0022] Referring now to Fig. 2, a graphical representation is shown of the relative electrical potentials associated with the process of developing a photoconductor 12, 14, 16, 18 of Fig. 1 with a single toner. Numeral 60 indicates a horizontal line segment which represents an initial level of zero electrical potential of a given photoconductor 12, 14, 16, 18. The arrow labeled 61 indicates the direction of increasing electrical potential. The line segments labeled 62 indicate the relative level of electrical potential applied to a given photoconductor 12, 14, 16, 18 by the respective cleaner/charger unit 22, 24, 26, 28. The line segment labeled 64 indicates the level of electrical potential of a pixel on a photoconductor 12, 14, 16, 18 after the pixel has been discharged by a respective selectively pulsed beam of energy 42, 44, 46, 48. The line segment labeled 66 indicates the level of electrical potential of the pixel after a toner has been applied to the pixel. The difference between the levels indicated by 64 and 66 is the level of electrical potential associated with the toner which has been applied. It should be noted that the level of electrical potential 66 of the pixel after development is typically selected to be less than the electrical potential 62 of the non-discharged pixels of the photoconductor. This difference in electrical potentials decreases the likelihood that toner from the developed pixel will migrate to undeveloped areas of the photoconductor.

[0023] Now referring to Fig. 1, after the toner is applied to a given photoconductor 12, 14, 16, 18, the photoconductor continues to rotate so that the pattern of toner on the photoconductor contacts the moving surface 50, whereupon the pattern of toner is transferred from the photoconductor to the moving surface 50. In this manner, each pattern of toner is sequentially transferred from the respective photoconductor 12, 14, 16, 18 to the moving surface 50. That is, a first pattern of toner is transferred from the first photoconductor 12 to the moving surface 50. Then, as the first pattern moves on the surface 50 and reaches the second photoconductor 14, a second pattern of toner is transferred from the second photoconductor 14 to the surface 50 and added to the first pattern. This sequence is repeated likewise for the third photoconductor 16 and the fourth photoconductor 18, until a full, finished pattern, which is made up of the toners from all four photoconductors, is formed on the surface 50.

[0024] In this manner, the four toners can be combined in either dot-on-dot, or dot-next-to-dot techniques to form the finished image. For example, toner from the second developing station 34 can be applied on top of toner from the first developing station 32. Likewise, a toner from a third developing station 36 can be applied over toners from either the first developing station 32 or the second developing station 34. Also, any of the toners can be applied beside any other toner. Thus, the in-line type of printer discussed above is generally capable of dot-on-dot, as well as dot-next-to-dot, printing techniques, resulting in a relatively high image quality and large color gamut.

[0025] Although the in-line type of color printer described above is known to perform well, it has at least one major drawback. One such drawback of the in-line color printer design is that a separate photoconductor is required, along with the associated drive mechanism and charger, for each color of toner. This tends to make the in-line color printer relatively complex and large, even when configured with just the standard four colors of yellow, black, magenta, and cyan.

[0026] In response to the relative complexity and large size of the in-line color printer design as described above, at least one alternative color laser printer design has been proposed. A schematic side-elevation diagram of one such prior art alternative design is shown in Fig. 3. As is apparent from a study of Fig. 3, this alternative design utilizes only one photoconductor drum 112, and one charger 122. As can be seen in Fig. 3, the photoconductor 112 is configured as a rotatable cylindrical drum as in the in-line design. Other configurations of the photoconductor can be utilized. For example, just as in the in-line design, the photoconductor 112 could be configured as a single, continuous belt. As further indicated in Fig. 3, the photoconductor is configured to rotate in a direction indicated by the arrow labeled 120.

[0027] Although only one photoconductor 112 is utilized for the apparatus shown in Fig. 3, four developing stations 132, 134, 136, 138 are each configured to apply an associated toner to the photoconductor, as shown in Fig. 3. Likewise, four selectively pulsed beams of energy, such as for example, lasers, 142, 144, 146, 148 are projected onto the photoconductor 112. As can be seen from Fig. 3, each beam of energy 142, 144, 146, 148 is associated with a respective developer station 132, 134, 136, 138. For example, a first beam of energy 142 is associated with a first developer station 132, and a second beam of energy 144 is associated with a second developer station 134. Likewise, a third and a fourth beam of energy 146, 148 are associated with a third and a fourth developer station 136, 138, respectively.

[0028] As further revealed by Fig. 3, the photoconductor 112 is configured so as to move in close proximity to a moving surface 150. The surface 150 is configured to move relative to the photoconductor 112 in a direction indicated by the arrow labeled 152 as the photoconductor rotates in the direction 120. The surface 150 can be in the form of a continuous rotating belt such as, for example, an intermediate transfer belt. Alternatively, the surface 150 can be in the form of a finished product media such as, for example, a sheet of paper. A study of Fig. 3 will reveal that when the surface 150 moves in direction 152 relative to the photoconductor 112, the photoconductor 112 will appear to have the effect of rolling on the surface 50.

[0029] Now still referring to Fig. 3, in operation, the surface 150 moves in direction 152 and the photoconductor 112 rotates in direction 120. The charger unit 122 charges the photoconductor 112. As the photoconductor 112 continues to rotate, a first selectively pulsed beam of energy 142 scans the photoconductor 112 to discharge portions thereof and to form a first pattern thereon. The first pattern then moves on to a first developer station 132 where a first toner is applied to the first pattern. As the photoconductor 112 continues to rotate in direction 120, the first pattern moves to a second selectively pulsed beam of energy 144. The second beam of energy 144 scans the photoconductor 112 to further discharge portions of thereof and to form a second pattern thereon in predetermined relation to the first pattern. As the photoconductor 112 continues to rotate, a second developer station 134 applies a second toner to the second pattern. This sequence is likewise repeated for a third beam of energy 146 and developer station 136, and for a fourth beam of energy 148 and developer station 138, respectively.

[0030] Turning now to Fig. 4, a graphical representation is shown of the relative electrical potentials associated with developing the photoconductor 112 with four different toners. Numeral 170 indicates a horizontal line segment which represents an initial level of zero electrical potential of the photoconductor 112. The arrow labeled 171 indicates the direction of increasing electrical potential. The line segments labeled 172 indicate the relative level of electrical potential of the photoconductor 112 after being charged by the cleaner/charger unit 122. Line segment 174 indicates the level of electrical potential of a first pixel on the photoconductor 112 after the pixel is discharged by the first beam of energy 142. Line segment 176 indicates the level of electrical potential of the first pixel after it has been developed with toner from the first developer station 132. Likewise, line segments 178, 182, 186 indicate the level of electrical potential of a second, a third, and a fourth pixel, respectively, after they have been discharged by the second, third, and fourth beams of energy 144, 146, 148, respectively. Similarly, line segments 180, 184, and 188 indicate the level of electrical potential of the second, third, and fourth pixels after being developed with toner from the second, third, and fourth developing sections 134, 136, 138, respectively. The difference in levels between the line 176 and line 174 represents the relative level of electrical potential of the toner applied by the first developer station 132. Likewise, the differences in levels between the line 180 and the line 178, and between the line 184 and the line 182, and the line 188 and the line 186 represent the relative electrical potentials of the toners from the second, third, and fourth developing stations 134, 136, 138, respectively. As is evident by Fig. 4, once the photoconductor has been developed with one toner, there is no possibility to apply a second toner on top of the first toner (i.e., to perform dot-on-dot printing), and so the apparatus of Fig. 3 is limited to dot-next-to-dot printing.

[0031] Turning now back to Fig. 3, after toner from all of the developer stations 132, 134, 136, 138 has been applied to the photoconductor 112, the photoconductor continues to rotate so that the four-color pattern comes into close proximity to the moving surface 150, at which point the four-color pattern is transferred from the photoconductor 112 onto the moving surface 150, forming a finished four-color image thereon. It should be apparent from a study of Fig. 3 that the single-photoconductor design has several advantages over the in-line design depicted in Fig. 1. For example, having only a single photoconductor, as opposed to the four separate photoconductors of the in-line design, requires only one photoconductor drive mechanism and only one charger unit. Also, a single-photoconductor developer section can be made to be considerably smaller than that of an in-line design.

[0032] It should be noted however, that the printer depicted in Fig. 3 is generally not configured to be capable of dot-on-dot printing technique. That is, because all the toners are applied to a common photoconductor in a single pass, the toners can generally only be placed beside each other in a dot-next-to-dot printing technique. Thus, while the printer shown in Fig. 3 has the attributes of being smaller and less complex, it has the disadvantage of lacking the capability to print the high quality images that can be obtained with dot-on-dot printing. In contrast, the in-line printer shown in Fig. 1 has the attributes of being capable of printing dot-on-dot as well as dot-next-to-dot. However, the in-line printer of Fig. 1 has the disadvantage of being relatively complex and large.

[0033] What is needed then, is an electrophotographic color printing apparatus which incorporates the attributes of both the in-line design and the single-drum design. That is, what is needed is an electrophotographic color printer which is both less complex and smaller than a prior art in-line color printer, and which also has the capability to print dot-next-to-dot and dot-on-dot.

Summary of the Invention

[0034] The invention includes an electrophotographic color imaging system having a plurality of photoconductors and a plurality of developing stations which are configured to apply toner to the photoconductors. The number of developing stations is greater than the number of photoconductors which results in at least two developing stations applying toner to a common photoconductor. Furthermore, when two toners are applied to a common photoconductor, the two colors can be yellow and black, or cyan and light cyan, or magenta and light magenta.

[0035] The invention further includes developer section for use in an electrophotographic color printer having a first photoconductor configured to have selected portions discharged to form a first and a second predetermined pattern. A first developing station is configured to apply a first toner to the first pattern and a second developing station is configured to apply a second toner to the second pattern. Furthermore, the invention includes a second photoconductor configured to have selected portions discharged to form a third predetermined pattern, and a third developing station configured to apply a third toner to the second photoconductor to develop the third pattern.

[0036] Another aspect of the present invention is a method of developing a color image onto a photoconductor which includes providing a plurality of photoconductors and a plurality of developing stations, each of which is configured to apply a given toner to a given pattern on a given photoconductor. In the method, a first toner is developed onto a first photoconductor, and then a second toner is developed onto the first photoconductor. The first and second toner are then transferred to a medium. Thereafter, a third toner is developed onto a second photoconductor, and the third toner is then transferred to the medium. In one variation, a first toner is developed onto a first photoconductor and transferred to the medium, and thereafter a second and third toner are developed onto a second photoconductor, and the second and third toners are then transferred to the medium. In general, in the method the number of developing stations is greater than the number of photoconductors.

Brief Description of the Drawings

[0037]

Fig. 1 is a side elevation schematic of a developing section of a prior art electrophotographic in-line color laser printer.

Fig. 2 is a graphical representation of the relative electrical potentials associated with the photoconductor development process in a prior art electrophotographic in-line color laser printer.

Fig. 3 is a side elevation schematic of a developing section of a prior art electrophotographic single-drum color laser printer.

Fig. 4 is a graphical representation of the relative electrical potentials associated with the photoconductor development process in a prior art electrophotographic single-drum color laser printer.

Fig. 5 is a side elevation schematic of a developing section of a electrophotographic in-line color laser printer in accordance with one embodiment of the present invention.

Fig. 6 is a side elevation schematic of a developing section of a electrophotographic in-line color laser printer in accordance with a second embodiment of the present invention.

Fig. 7 is a side elevation schematic of a developing section of a electrophotographic in-line color laser printer in accordance with a third embodiment of the present invention.

Fig. 8 is a side elevation schematic of a developing section of a electrophotographic in-line color laser printer in accordance with a fourth embodiment of the present invention.

Detailed Description of Preferred Embodiments of the Invention

[0038] While the present invention has particular application to electrophotographic color laser printers, it is understood that the invention has equal applicability in any electrophotographic imaging apparatus which is designed to reproduce digital raster data, including digital photocopiers and facsimile machines. Therefore, when we use the expression "printer", we mean to include any apparatus which is configured to print a color image from digital raster data using lasers and photoconductive material. Further, when we mention applying a color to a photoconductor using a toner, we mean to include applying black as a color.

The Apparatus

[0039] The invention comprises at least two rotating photoconductors and at least three developing stations, with the number of developing stations being greater than the number of photoconductors. At least four colors, can be printed onto a finished product medium using a color laser printer in accordance with one embodiment of the present invention which has only three photoconductors. An apparatus in accordance with a second embodiment of the present invention makes possible a printer that, with only three photoconductors, can print six different toners, including four colors and two additional color shades, which results in a wider color gamut than a typical prior art device. A color laser printer in accordance with a third embodiment of the present invention allows the printing of at least four colors with only two photoconductors. In addition, a full practical range of dot-on-dot and dot-next-to-dot color combinations are available with all three embodiments.

[0040] Turning to Fig. 5, a side elevation schematic diagram depicting a developing section of a printer 200 in accordance with one embodiment of the present invention is shown. The apparatus 200 comprises a plurality of continuous rotatable photoconductors 212, 214. It should be understood that when we say photoconductor, we mean any surface having a photoconductive material supported thereon. As shown in Fig. 5, the photoconductors 212, 214 are configured in the form of cylindrical drums. However, it should be understood that photoconductors utilized in accordance with the present invention are not to be limited to any particular form, and can be configured in other forms such as, for example, a continuous rotatable belt.

[0041] A study of Fig. 5 will reveal that the apparatus 200 further comprises a plurality of developing stations 231, 232, 233. Each developing station 231, 232, 233 is configured to apply toner to predetermined portions of a given photoconductor 212, 214. It should be evident from Fig. 5 that the number of developing stations 231, 232, 233 is greater than the number of photoconductors 212, 214. Thus, at least two toners are applied to one of the photoconductors 212, 214. That is, a first toner applied by a first developer station 233, and a second toner applied by a second developing station 232, are applied to a common photoconductor 214.

[0042] As further shown in Fig. 5, a first surface 250 is shown to pass in close proximity to the photoconductors 212, 214. The surface 250 can be in the form of an intermediate photoconductive transfer surface, from which the toner is subsequently transferred to a final medium, such as paper. Alternatively, the first surface 250 can be in the form of a finished product medium such as, for example, a piece of paper, or a transparency. The arrows labeled 220 indicate the direction in which the photoconductors 212, 214 are configured to rotate. Likewise, the arrow labeled 252 indicates the direction in which the first surface 250 moves. It is understood that the relative positions of the photoconductors in relation to one another can be reversed. That is, the photoconductor labeled 212 can be located on the left of the photoconductor labeled 214 rather than on the right as shown in Fig. 5. Each photoconductor 212, 214 has a respective cleaner/charger 222, 224 located in operable orientation thereto. The cleaner/chargers 224, 222 apply a base electrostatic potential to the photoconductors 214 and 212, respectively, which can then be discharged to a lower electrical potential by the pulsed laser beams 243, 242 and 241. The discharged areas on the photoconductors attract toner from the developer stations 233, 232 and 231 as described in the background section above. The cleaners/chargers 224 and 222 also remove any remaining toner from the photoconductors 214, 212 which is not transferred to the first surface 250. Although a charger/cleaner can be added between developer station 233 and 232, this is less preferable since it will require the photoconductor to be larger in diameter, and will add complexity to the apparatus 200.

[0043] Also shown in Fig. 5 are three selectively pulsed beams of energy 241, 242, 243. These beams are generated in response to the digital data of the image to be printed which resides in computer memory. A separate beam is generated for each color to be developed onto a photoconductor. The beam labeled 241 is configured to be projected on the photoconductor labeled 212, while the beams labeled 242 and 243 are configured to be projected on the photoconductor labeled 214. Each beam of energy 241, 242, 243 is configured to expose a predetermined pattern on the respective photoconductor 212, 214 on which it is projected. Likewise, the developer stations 231, 232, 233 are configured to apply toner to the patterns exposed by the respective beams 241, 242, 243. That is, a developing station 231 is configured to apply a first toner to first predetermined portions of a given region of photoconductor 212, and developing stations 232 and 233 are configured to apply a second and third toner, respectively, to second and third respective predetermined portions of a given region of photoconductor 214.

[0044] The photoconductors 212, 214 are further configured to transfer the toner applied by the respective developer stations 231, 232, 233 to the first surface 250 as the surface moves past each photoconductor. As should be evident from Fig. 5, each photoconductor 212, 214 is configured to successively transfer at least one toner, which is in a predetermined pattern, to the first surface 250. Furthermore, at least one photoconductor 214 is configured to transfer at least two toners substantially simultaneously in two predetermined patterns to the first surface 250. By predetermined pattern, we are referring to any pattern formed on the photoconductor which is to make up at least a portion of the finished image produced by the printer. By successively transfer, we mean that one toner is transferred from one photoconductor 112 to the first surface 250 at a given point in time, and then another toner is transferred from another photoconductor 214 to the first surface 250 at a later point in time. When we say surface, we mean to include any surface, such as for example, a finished product medium or an intermediate transfer belt.

[0045] It should be noted that any given developing station 231, 232, 233 can be configured to apply one of any number of different colors of toner, as preference dictates. However, it should be further noted that such configuration of the developing stations can be chosen so as to be advantageous in accordance with one of a given number of circumstances. For example, in one circumstance, a primary concern can be the contamination of a pattern with a subsequently applied toner. To illustrate, suppose a first and second toner are to be applied by first and second developing stations 233, 232, respectively, to respective first and second patterns located on a given portion of a common photoconductor 214. Also, suppose that the first toner is applied to the first pattern before the second toner is applied to the second pattern due to the rotation 220 of the photoconductor 214.

[0046] Suppose further that in some anomalous instances, the first pattern is not fully developed with the first toner. In other words, in some anomalous instances, some portions of the first pattern remain exposed, or undeveloped, after application of the first toner thereto. In this case, the second toner which is subsequently applied to the second pattern can tend to "migrate" to the exposed, underdeveloped areas of the first pattern. The result will be that the first pattern will contain objectionable traces of the second toner in the finished image. To reduce the effects of such an occurrence, the toners which are to be applied to a common photoconductor 214 can be chosen such that the darker color toner is applied before the lighter color toner. Such a choice of toner application will reduce effects of toner migration because the contamination of a darker image with lighter toner will be less noticeable than the contamination of a lighter image with a darker toner.

[0047] In another circumstance, it can be possible to develop alternative techniques to prevent, or minimize the effects of, toner migration. In such a circumstance, a secondary consideration in choosing the configuration the developing stations 231, 232, 233 can be that of hopper contamination. To illustrate hopper contamination, suppose that a first and second toners are to be applied to a common photoconductor 214, as above, by a first and second respective developing stations 233, 232, respectively. Each developing station 232, 233 can comprise a respective hopper (not shown) for storing a given amount of respective toner.

[0048] Suppose further that the first toner is applied to a given portion of the common photoconductor 214 before the second toner is applied thereto. In this case, the first toner, once it is applied to the common photoconductor 214, will move toward the second developing station 232 due to the rotation 220 of the common photoconductor 214. As the first toner moves past the second developing station 232, minute traces of the first toner can be lodged within the second developing station 232, whereupon the minute traces of the first toner can mix with, and contaminate, the second toner which resides in the hopper of the second developing station 232. The result of this will be that the portions of the finished image containing the second toner will also contain objectionable traces of the first toner.

[0049] To reduce the effects of such hopper contamination, the toners which are to be applied to a common photoconductor can be chosen such that the lighter color toner is applied before the darker color toner. This will minimize the effects of hopper contamination, because contamination of a dark toner with minute traces of light toner will be less noticeable than contamination of a light toner with minute traces of dark toner.

[0050] Yet a further consideration in configuring the developing stations with regard to color of toner, is to consider which toners are least likely to be combined in a dot-on-dot printing technique. This is a relevant consideration because one given toner which is applied to a common photoconductor 212, 214 cannot be applied in a dot-on-dot technique with regard to another given toner applied to the common photoconductor. Thus, it can be advantageous to configure developing stations 231, 232, 233 such that the toners chosen to be applied to a common photoconductor 212, 214 are those toners which are least likely to be combined in a dot-on-dot printing technique.

[0051] For example, if two toners are chosen to be applied to a common photoconductor 212, 214, then an advantageous choice can be the colors of black and yellow since a dot-on-dot combination of black and yellow would be relatively minimal compared to other possible dot-on-dot color combinations. Furthermore, if toner migration is a concern, then black can be chosen to be applied before yellow to minimize the effects of toner migration on the common photoconductor 212, 214. Conversely, if hopper contamination is a primary concern, then yellow can be chosen to be applied before black to minimize the effects of hopper contamination in this instance.

[0052] Turning now to Fig. 6, 7, and 8, devices 300, 400, and 500, are each in accordance with second, third, and fourth embodiments, respectively, of the present invention shown in respective side schematic views. As shown in Fig. 6, 7, the each of the devices 300, 400 comprise first, second, and third continuous rotatable photoconductors 312, 314, 316, 412, 414, 416. As shown in Fig. 8, the device 500 comprises first and second continuous rotatable photoconductors 512, 514. Each photoconductor 312, 314, 316, 412, 414, 416, 512, 514 has an associated cleaner/charger 322, 324, 326, 422, 424, 426, 522, 524 located in operable orientation thereto. Each cleaner/charger serves to clean excess toner from the associated photoconductor 312, 314, 316, 412, 414, 416, 512, 514 and also serves to apply a base electrostatic potential to each respective photoconductor.

[0053] Further study of Fig. 6 and 7 will reveal that a second and third surface 350, 450 respectively is shown to pass in close proximity to each of the photoconductors 312, 314, 316, 412, 414, 416 of the respective devices 300, 400. Likewise, as shown in Fig. 8, a fourth surface is shown to pass in close proximity to each of the photoconductors 512, 514. The surfaces 350, 450, 550 can be in the form of a finished product medium such as, for example, a sheet of paper, or a transparency. Alternatively, the surfaces 350, 450, 550 can be in the form of an intermediate photoconductive transfer surface from which toner is transferred to a finished product medium.

[0054] The arrows 320, 420, 520 indicate the direction in which the photoconductors 312, 314, 316, 412, 414, 416, 512, 514 are configured to rotate. Likewise, the arrows 352, 452, 552 indicate the direction in which the respective surfaces 350, 450, 550 move. It is understood that the respective relative positions of the photoconductors in relation to one another can be reversed. Likewise, it should be understood that the directions of movement 320, 352, 420, 452, 520, 552 of the photoconductors 312, 314, 316, 412, 414, 416, 512, 514 and the surfaces 350, 450, 550 can be reversed as well.

[0055] Still referring to Fig. 6, 7, and 8, it can be seen that each device 300, 400, 500 further comprises a plurality of developing stations which are located in operable orientation relative to a respective photoconductor. More specifically, the device 300 shown in Fig. 6 comprises first, second, third, and fourth developing stations 331, 332, 333, 334 which are configured to apply first, second, third, and fourth toners to respective photoconductors. The device 400 shown in Fig. 7 comprises first, second, third, fourth, fifth and sixth developing stations 431, 432, 433, 434, 435, 436 which are configured to apply first, second, third, fourth, fifth, and sixth toners to respective photoconductors. Likewise, the device 500 shown in Fig. 8 comprises first, second, third, fourth, and fifth developing stations 531, 532, 533, 534, 535 which are configured to apply first, second, third, fourth, and fifth toners to respective photoconductors. Each developing station 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535 is configured to apply a given toner to predetermined portions of its associated photoconductor 312, 314, 316, 412, 414, 416, 512, 514.

[0056] As can be seen in Fig. 6, 7, and 8, each photoconductor 312, 314, 316, 412, 414, 416, 512, 514 is configured to have at least one selectively pulsed beam of energy 341, 342, 343, 344, 441, 442, 443, 444, 445, 446, 541, 542, 543, 544, 545, such as, for example, a laser, projected upon it. The beams are generated in response to digital data of the image to be printed which resides in computer memory. A separate beam is generated for each color to be developed onto a photoconductor. The beams 341, 342, 343, 344, 441, 442, 443, 444, 445, 446, 541, 542, 543, 544, 545 serve to selectively discharge predetermined portions of each respective photoconductor 312, 314, 316, 412, 414, 416, 512, 514 to a lower electrical potential so as to form a respective predetermined pattern thereon.

[0057] The discharged portions of the photoconductors 312, 314, 316, 412, 414, 416, 512, 514, which form the predetermined patterns, attract toner from the respective developing stations 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535 as described in the background section above. That is, each developing station applies a given toner to a respective predetermined pattern formed on a respective photoconductor. Each pattern of toner is then transferred from each photoconductor 312, 314, 316, 412, 414, 416, 512, 514 to the respective surface 350, 450, 550 to form an image thereon as described in the background section above. The cleaner/chargers 322, 324, 326, 422, 424, 426, 522, 524 also remove remaining toner from the photoconductors 312, 314, 316, 412, 414, 416, 512, 514 which is not transferred to the respective surface 350, 450, 550. Although additional cleaner/chargers can be added to each device 300, 400, 500, this is less preferable since it would require the respective photoconductor to be larger and would ad complexity to the respective device.

[0058] Referring now to Fig. 6, it should be evident that the device 300 in accordance with the embodiment shown has three photoconductors 312, 314, 316 and four developing stations 331, 332, 333, 334. It should also be evident that two of the photoconductors 312, 314 each have a single respective developing station 331, 332 located in operable orientation thereto. Also, one of the photoconductors 316 has set of two developing stations 333, 334 located in operable location thereto. Thus, it should be evident that the device 300 can print an image made up of four different toners. Furthermore, it should be evident that each of the four toners can be combined with any number of the other toners in either a dot-on-dot or dot-next-to-dot techniques with the exception that the toners applied by the set of two developing stations 333, 334 cannot be applied in a dot-on-dot technique with respect to one another.

[0059] As describe above in another embodiment of the present invention, here too the colors of the four toners to be applied by the four developing stations 331, 332, 333, 334 can be chosen advantageously. The typical four colors of black, yellow, magenta, and cyan can be chosen as the colors of the four toners. Because the effect of printing yellow and black together in a dot-on-dot technique is minimal, it can be advantageous to chose black and yellow as the colors of the two toners to be applied by the set of two developing stations 333, 334. Thus, if the set of two developing stations 333, 334 are configured to apply a first and a second toner, respectively, then the first and second toners can be one each of the colors yellow and black. That is, the first toner can be yellow and the second black, or the first toner can be black and the second yellow.

[0060] Likewise, if the remaining developing stations 331 and 332 are configured to apply a third and a fourth toner, respectively, then the third and fourth toners can be one each of the colors cyan and magenta. That is, the third toner can be cyan and the fourth toner magenta, or the third toner can be magenta and the fourth cyan. Thus, it should be clear that the device 300 can print any practical combination of the four colors of black, yellow, cyan, and magenta in either dot-on-dot or dot-next-to-dot while having only three photoconductors.

[0061] Now referring to Fig. 7, it should be evident that the device 400 in accordance with the embodiment shown has three photoconductors 412, 414, 416 and six developing stations 431, 432, 433, 434, 435, 436. It should also be evident that all three of the photoconductors 412, 414, 416 each have a respective set of two developing stations 431, 432, 433, 434, 435, 436, each of which is located in operable orientation to a respective developing station. Thus, it should be evident that the device 400 can print an image made up of six different toners. Furthermore, it should be evident that each of the six toners can be combined with any number of the other toners in either a dot-on-dot or dot-next-to-dot techniques with the exception that the toners applied by a given set of developing stations cannot be applied in a dot-on-dot technique with respect to one another. That is, any given toner cannot be combined in a dot-on-dot technique with another toner when the two are applied by the same set of developing stations.

[0062] As discussed earlier with regard to another embodiment, the colors of the toners can be chosen advantageously. For example, the typical four colors of black, yellow, magenta, and cyan can be chosen as the colors of four of the six toners. The remaining two colors can be chosen to be light cyan and light magenta. As describe above, because the effect of printing yellow and black together in a dot-on-dot technique is minimal, it can be advantageous to choose black and yellow as the colors of the two toners of one of the sets of two developing stations 431, 432. Similarly, the effect of printing a given color with a lighter shade of the given color in a dot-on-dot technique will have minimal effect. Thus, light cyan and cyan can be chosen as colors of the two toners of one of the sets of two developing stations 433, 434. Likewise, magenta and light magenta can be chosen as colors of the two toners of the remaining set of two developing stations 435, 436.

[0063] Thus, if one set of developing stations 431, 432 is configured to apply a first and a second toner, respectively, then the first and second toners can be one each of the colors yellow and black. That is, the first toner can be yellow and the second black, or the first toner can be black and the second yellow. Likewise, if another set of developing stations 433, 434 is configured to apply a third and a fifth toner, respectively, then the third and fifth toners can be one each of the colors light cyan and cyan. That is, the third toner can be light cyan and the fifth toner cyan, or the third toner can be cyan and the fifth light cyan. Similarly, if the remaining set of developing stations 435, 436 is configured to apply a fourth and a sixth toner, respectively, then the fourth and sixth toners can be one each of the colors light magenta and magenta. That is, the fourth toner can be light magenta and the sixth toner magenta, or the fourth toner can be magenta and the sixth light magenta. It should be noted that by adding the colors of light cyan and light magenta to the typical four colors, the color gamut of the device 400 can be increased substantially relative to a comparable device having only the four colors of black, yellow, magenta, and cyan. Thus, it should be clear that the device 400 can print any practical combination of the six colors of black, yellow, light cyan, cyan, light magenta, and magenta in either dot-on-dot or dot-next-to-dot while having only three photoconductors.

[0064] Turning now to Fig. 8, it should be evident that the device 500 in accordance with the embodiment shown has two photoconductors 512, 514, and five developing stations 431, 532, 533, 534, 535. It should also be evident that one of the photoconductors 512 has a set of two developing stations 531, 532, each of which is located in operable orientation to the photoconductor 512. Likewise, the other photoconductor 514 has a set of three developing stations 533, 534, 535, each of which is located in operable orientation to the photoconductor 514. Thus, it should be evident that the device 500 can print an image made up of five different toners. Furthermore, it should be evident that each of the five toners can be combined with any number of the other toners in either a dot-on-dot or dot-next-to-dot techniques with the exception that the toners applied by a given set of developing stations cannot be applied in a dot-on-dot technique with respect to one another. That is, any toner which is applied by a given developer station cannot be combined in a dot-on-dot technique with any other toner which is applied by a developer station of the same set.

[0065] As above, the colors of the five toners can be chosen advantageously. For example, the typical four colors of black, yellow, magenta, and cyan can be chosen as the colors of four of the five toners. The color of the remaining fifth toner can be chosen to be either cyan or magenta. As described above, because the effect of printing yellow and black together in a dot-on-dot technique is minimal, it can be advantageous to choose black and yellow as the colors of two toners of two respective developing stations 533, 535 of one set. Cyan and magenta can be chosen as the colors of two of the toners of the respective developing stations 531, 532 of the other set. This results in two sets of toners, each set associated with a respective common photoconductor, with one set having at least the colors of black and yellow, and another set having at the colors of cyan and magenta.

[0066] It should be evident that, in this embodiment as described thus far, cyan and magenta cannot be printed in a dot-on-dot technique with regard to one another since cyan and magenta are applied to a common photoconductor by a set of developing stations 531, 532. However, it can be desirable to print cyan and magenta in a dot-on-dot technique. Therefore, it can be advantageous to choose the color of the fifth toner to be either cyan or magenta and place this fifth toner along with the yellow and black toners to make up the set of three developing stations 533, 534, 535.

[0067] Thus, if the set of two developing stations 532, 532 is configured to apply a first and a second toner, respectively, then the first and second toners can be one each of the colors cyan and magenta. That is, the first toner can be magenta and the second cyan, or the first toner can be cyan and the second magenta. Likewise, if the set of three developing stations 533, 534, 535 is configured to apply a third, fourth, and fifth toner, respectively, then the third and fifth toners can be one each of the colors black and yellow. That is, the third toner can be black and the fifth toner yellow, or the third toner can be yellow and the fifth black. The fourth toner can be one of the colors cyan and magenta. That is, the fourth toner can be cyan or it can be magenta. It should be noted that, as discussed earlier, toners which are applied to a common photoconductor can be advantageously applied in order of light to dark or dark to light depending on whether the primary concern is hopper contamination or toner migration, respectively. Thus, to minimize either of the problems of hopper contamination or toner migration, cyan or magenta toner can be applied intermediate the application of black and yellow toner because black is darker than both cyan and magenta and because yellow is lighter than both cyan and magenta. It should be evident that, as configured thus far, the device 500 can print any practical combination of the four colors of black, yellow, cyan, and magenta in either dot-on-dot or dot-next-to-dot while having only two photoconductors.

The Method

[0068] Another aspect of the present invention is a method of developing a color image onto a photoconductor. The first step of the method includes providing at least two rotatable continuous photoconductors, each of which can be configured to be charged to a given electrical potential, and further configured to have at least one discrete predetermined pattern formed thereon by selectively discharging portions thereof. The continuous surface can be a rotatable drum, although other forms could be used. The method also includes providing at least three developing stations, each of which is configured to apply a given toner to a given pattern on a given photoconductor. Furthermore, each toner is configured to have a given electrical potential. A first electrical bias is applied to a portion of each photoconductor to create an electrically charged region thereon. This can be achieved by using a base charging station for charging the photoconductor. A first pattern is formed on a given region of the first photoconductor by discharging predetermined portions thereof. Typically, this discharging is performed with a selectively pulsed beam of energy, such as a laser, and corresponds to exposing pixels to be printed by the respective toner. The predetermined portions of the first photoconductor are then developed by applying a first toner to the first pattern. Likewise, a second pattern is formed on a given region of the second photoconductor by discharging predetermined portions thereof, and a second toner is applied to the second pattern. Similarly, a third pattern is formed on a given region of the second photoconductor by discharging predetermined portions thereof. The selected portions of the third photoconductor which make up the third pattern are then developed by applying a third toner to the third pattern. The second and third toners can be differing tints of substantially the same color. The toners are thereafter transferred to a secondary surface, such as an intermediate transfer belt or a sheet of media on which the final image is to be rendered, such as a sheet of paper.

[0069] The method can further include charging a third photoconductor and forming a fourth pattern on a given region of the third photoconductor by discharging predetermined portions thereof. A fifth pattern is then formed on a given region of the second photoconductor by discharging predetermined portions thereof, followed by an application of a fifth toner to the fifth pattern. Finally, a sixth pattern is formed on the given region of the third surface by discharging predetermined portions thereof, and applying a sixth toner to the sixth pattern. The fifth and sixth toners are thereafter transferred to the secondary surface in the manner described above.

[0070] Yet another aspect of the present invention is a further method of developing a color image onto a photoconductor. This method includes the steps of providing at least two continuous rotatable photoconductors, each of which can be configured to be charged to a given electrical potential, and further configured to have at least one discrete predetermined pattern formed thereon by selectively discharging portions thereof A further step is to provide at least five developing stations, each of which can be configured to apply a given toner to a given pattern on a given photoconductor, and wherein each toner is configured to have a given electrical potential. Additional steps include charging a first and second photoconductor, and forming a first pattern on a given region of the first photoconductor by discharging predetermined portions thereof. Then, a first toner is applied to the first pattern, and a second pattern is formed on a given region of the first photoconductor by discharging predetermined portions thereof. A second toner is then applied to the second pattern. Further steps can include forming third, fourth, and fifth patterns on the second photoconductor by discharging predetermined portions thereof, and thereafter applying a third, fourth, and fifth toner to the respective third, fourth, and fifth patterns.

[0071] It should be apparent from the forgoing discussion that a color printing apparatus in accordance with any of the several embodiments of the present invention will be capable of producing high quality images with a full range of practical dot-on-dot capability, while being both less complex and smaller than the prior art four-color in-line printers. This is due to the use, in accordance with the invention, of a developer section which comprises a number of developing stations and a number of photoconductors, and in which the number of developing stations is greater than the number of photoconductors. This allows sets of toners, which would ordinarily not be printed in a dot-on-dot technique, to be assigned to a common photoconductor, thus eliminating unnecessary photoconductors from the printer.

[0072] While the above invention has been described in language more or less specific as to structural and methodical features, it is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

Claims

1. An electrophotographic color printer (200, 300, 400, 500), comprising:

    a plurality of continuous rotatable photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514); and,
    a plurality of developing stations (231, 232, 233, 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535), and wherein each developing station is configured to apply a toner to predetermined portions of a given photoconductor, and wherein the number of developing stations is greater than the number of photoconductors.

2. The printer of claim 1, and wherein:

    each of the photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514) is configured to successively transfer at least one of the toners in a predetermined pattern to a first surface (250); and
    at least one of the photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514) is configured to transfer at least two of the toners substantially simultaneously in two respective predetermined patterns to the first surface (250).

3. The printer of claim 1, and wherein a first toner and a second toner are applied to a common photocon-

ductor (214).

4. The printer of claim 3, and wherein the first toner is substantially yellow in color and the second toner is substantially black in color.

5. The printer of claim 3, and wherein the first toner is substantially light cyan in color and the second toner is substantially cyan in color.

6. The printer of claim 3, and wherein the first toner is substantially light magenta in color and the second toner is substantially magenta in color.

7. A method of producing a color image in a developer section of a color printer, comprising:

providing at least two continuous rotatable photoconductors (212, 214, 312, 314, 316, 412, 414, 416, 512, 514), each of which is configured to be charged to a given electrical potential, and further configured to have at least one discrete predetermined pattern formed thereon by selectively discharging portions thereof;
providing at least three developing stations (231, 232, 233, 331, 332, 333, 334, 431, 432, 433, 434, 435, 436, 531, 532, 533, 534, 535), each of which is configured to apply a given toner to a given pattern on a given photoconductor (212, 214, 312, 314, 316, 412, 414, 416, 512, 514), and wherein each toner is configured to have a given electrical potential, and wherein the number of developing stations is greater than the number of photoconductors;
charging a first one of the photoconductors (214, 316, 412, 512) with a base electrical potential;
forming a first pattern on a given region of the first photoconductor (214, 316, 412, 512) by discharging predetermined portions thereof from the base electrical potential;
developing the first pattern with a first toner;
forming a second pattern on the given region of the first photoconductor (214, 316, 412, 512) by discharging predetermined portions thereof from the base electrical potential;
developing the second pattern with a second toner;
charging a second photoconductor (212, 314, 414, 514) to a second base electrical potential;
forming a third pattern on a given region of the second photoconductor (212, 314, 414, 514) by discharging predetermined portions thereof from the base electrical potential; and,
developing the third pattern with a third toner.

8. The method of claim 7, and further comprising:

providing at least three continuous rotatable photoconductors (312, 314, 316);
providing at least four developing stations (331, 332, 333, 334);
charging a third one of the photoconductors (312) to a third base electrical potential;
forming a fourth pattern on a given region of the third photoconductor (312) by discharging predetermined portions thereof from the third base electrical potential; and,
developing the fourth pattern with a fourth toner.

9. The method of claim 7, and further comprising:

providing at least three continuous rotatable photoconductors (412, 414, 416);
providing at least six developing stations (431, 432, 433, 434, 435, 436);
forming a fourth pattern on the given region of the second photoconductor (414) by discharging predetermined portions thereof from their respective base electrical potentials;
charging a third photoconductor (416) to a third base electrical potential;
forming a fifth pattern on a given region of the third photoconductor (416) by discharging predetermined portions thereof from its base electrical potential;
developing the fifth pattern with a fifth toner;
forming a sixth pattern on the given region of the third photoconductor (416) by discharging predetermined portions thereof from its base electrical potential; and,
developing the sixth pattern with a sixth toner.

10. The method of claim 7, and further comprising:

forming a fourth pattern on the given region of the second photoconductor (514) by discharging predetermined portions thereof from its base electrical potential;
developing the fourth pattern with a fourth toner;
forming a fifth pattern on the given region of the second photoconductor (514) by discharging predetermined portions thereof from its base electrical potential; and
developing the fifth pattern with a fifth toner.

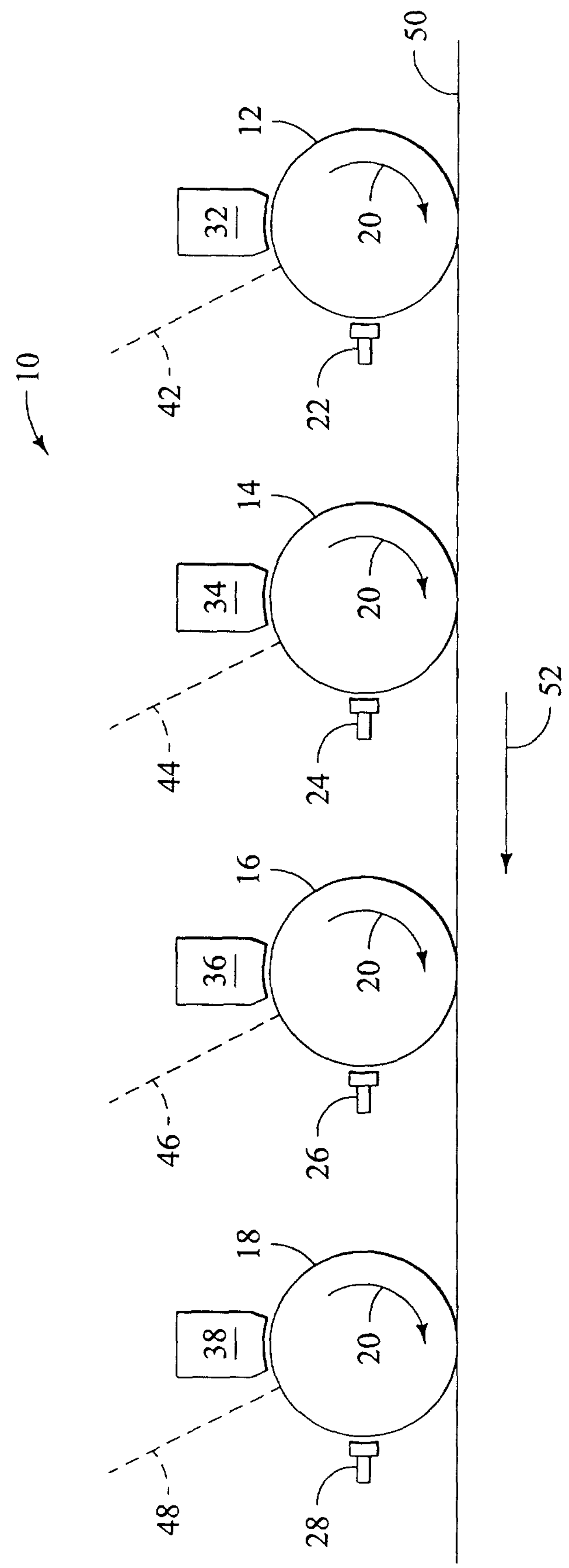


FIG.1
PRIOR ART

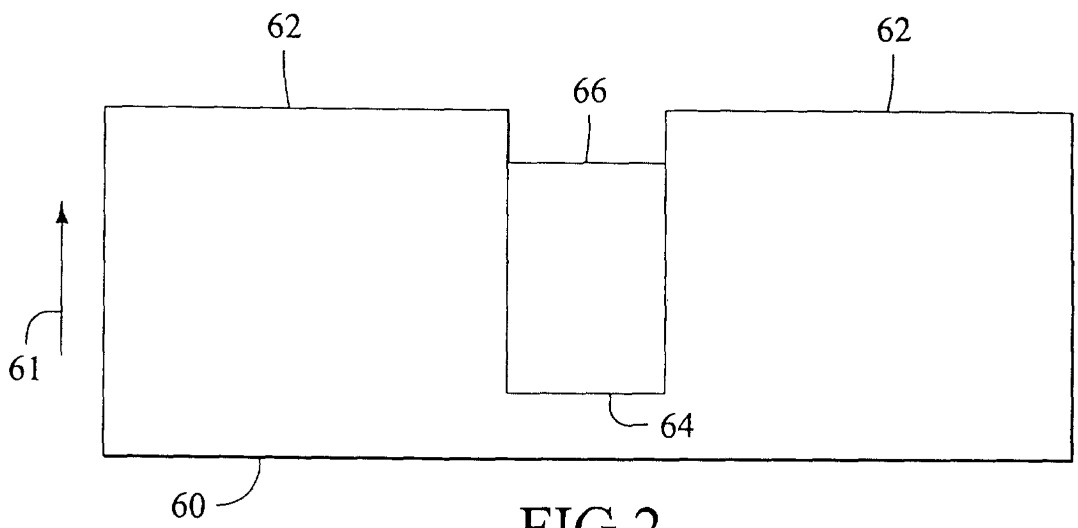


FIG.2
PRIOR ART

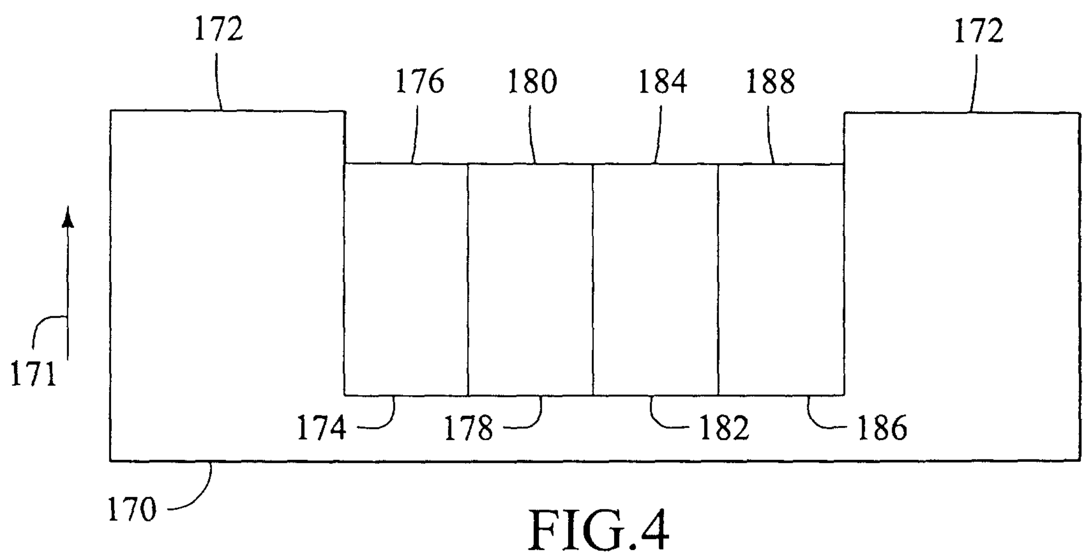


FIG.4
PRIOR ART

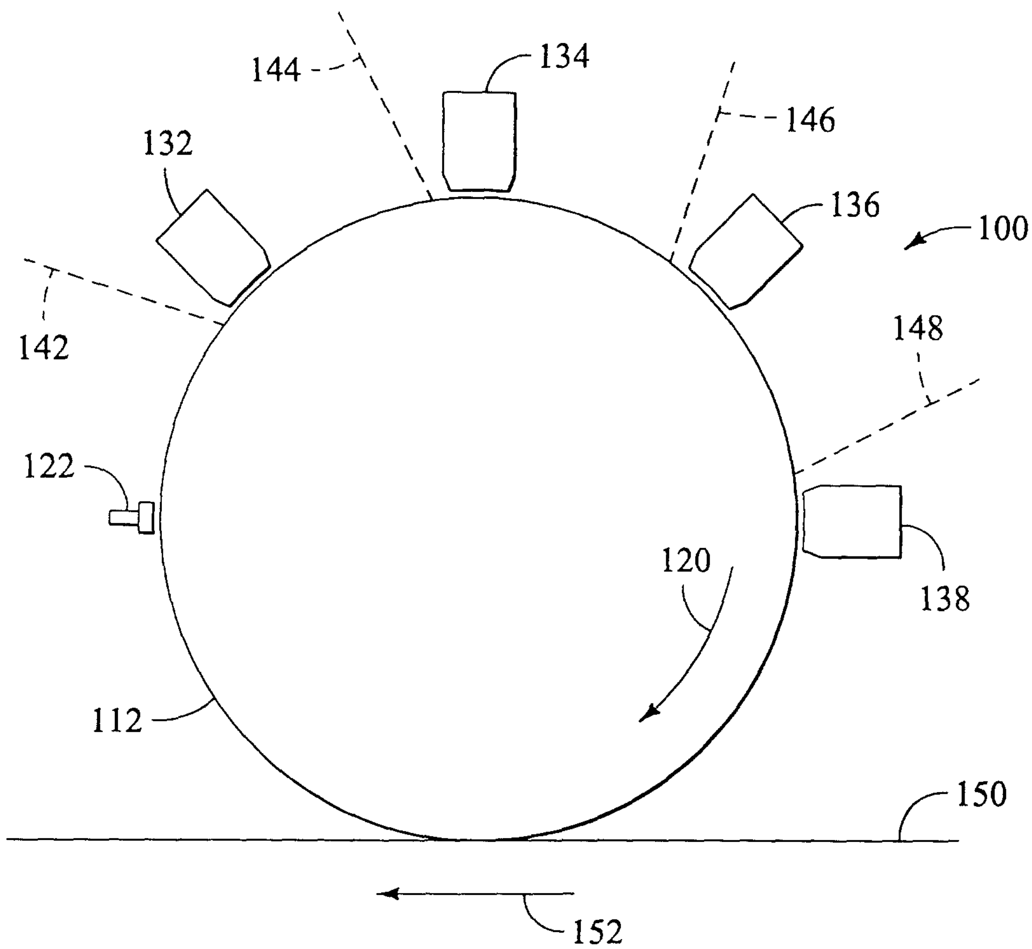
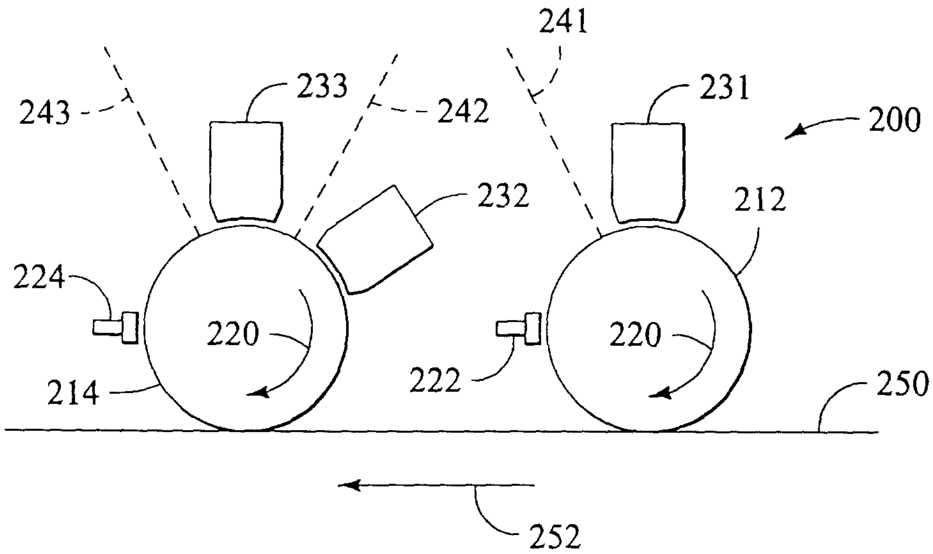


FIG.3
PRIOR ART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231
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242
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224
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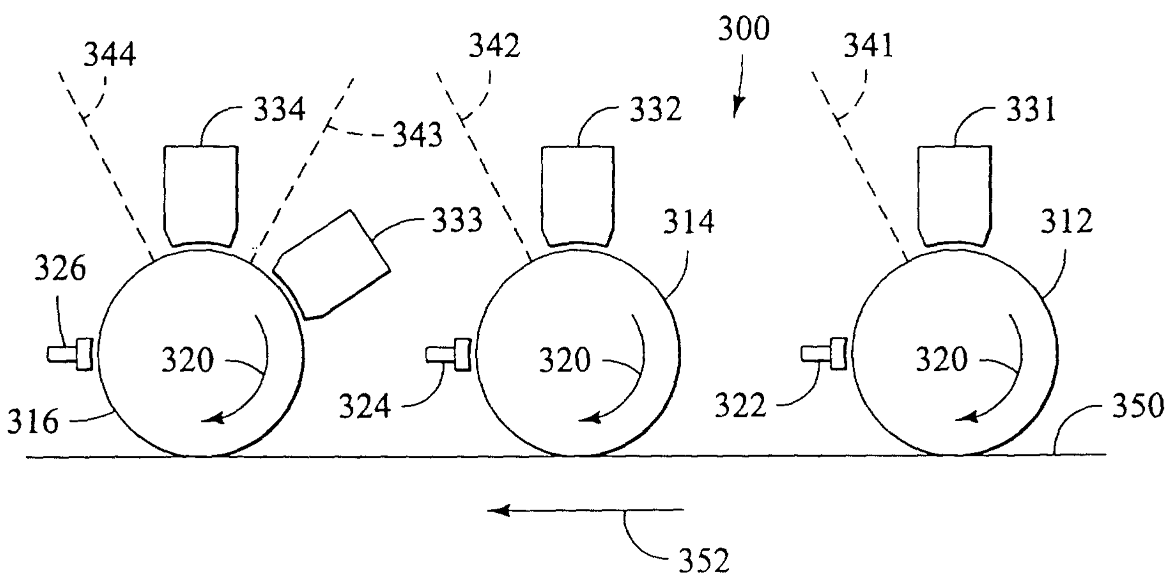
220
222
214
250
252

FIG.5


344
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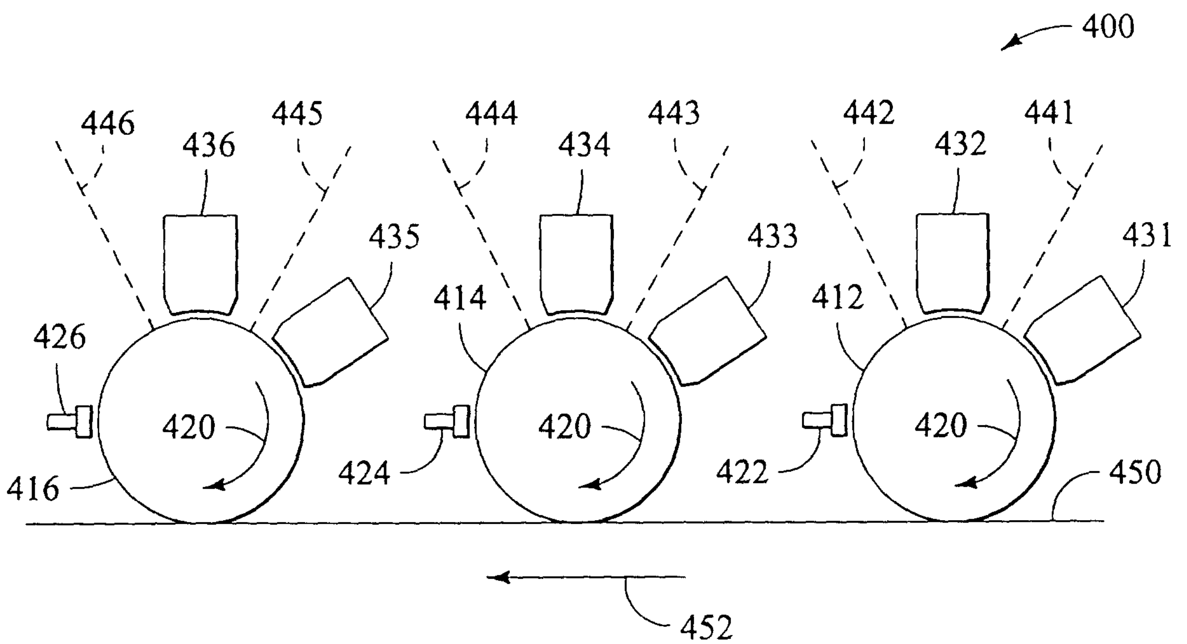
350
352

FIG.6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450
452

FIG.7

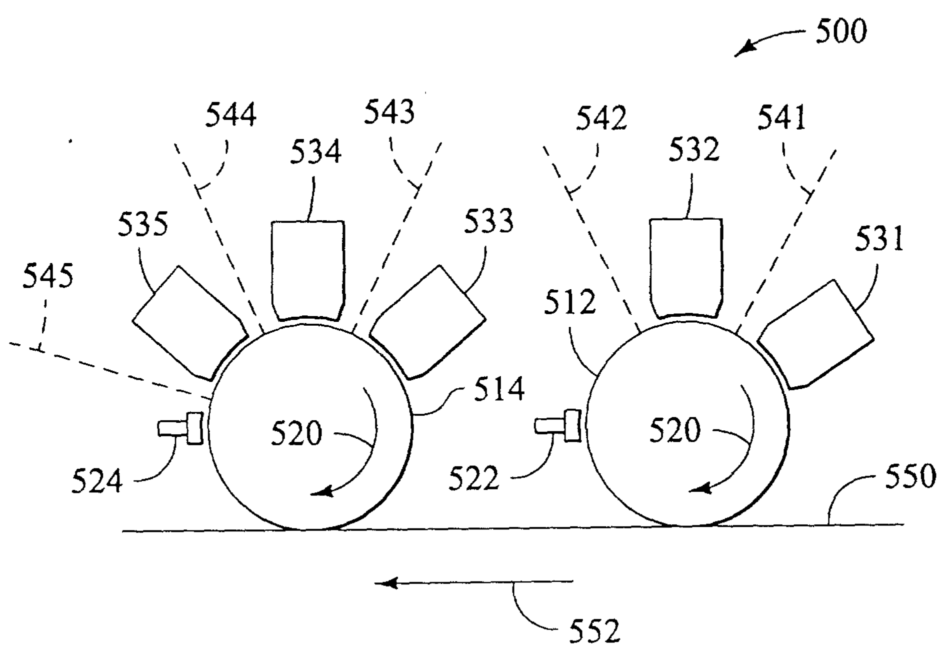
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FIG.8