United States Patent

Robinson

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[54] **METHOD AND APPARATUS ELECTROSTATICALLY CLASSIFYING TONER PARTICLES**

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[52] **U.S. Cl.** **209/129,** 117/17.5, 118/610, 209/4

[51] **Int. Cl.** **B03c 7/00**

[58] **Field of Search** 209/127–131, 3, 209/4; 117/17.5; 118/637; 101/114

[56] **References Cited**

UNITED STATES PATENTS

2,428,224	9/1947	Johnson et al.	209/127 X
476,991	6/1892	Edison	209/128
1,551,397	8/1925	Johnson	209/129
1,355,477	10/1920	Howell	209/129
2,63,416	5/1953	Walkup et al.	209/127 X

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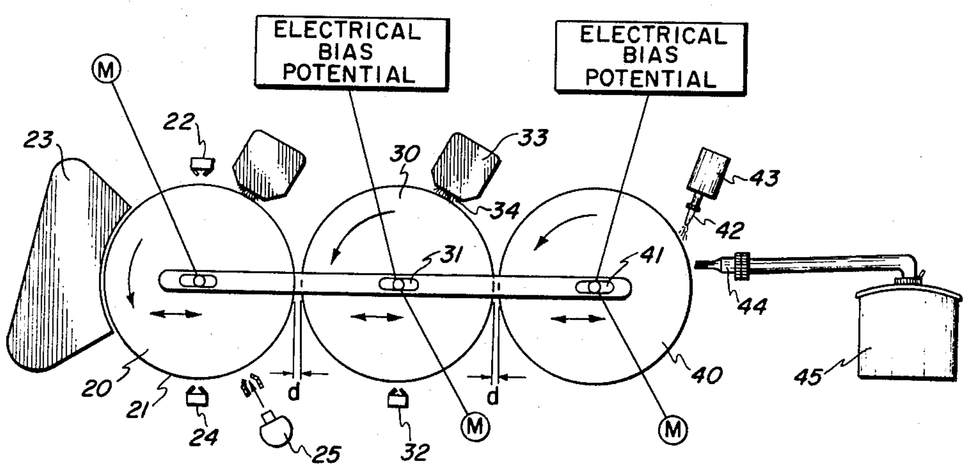
[57] **ABSTRACT**

Method and apparatus to electrostatically classify electroscopic toner particles according to size. Particles to be classified are supported on a photocondctive surface and electrically charged to one polarity. An electrically conductive surface spaced a predetermined distance from the charged particles is electrically biased by a potential of opposite polarity to collect toner particles which are attracted to the surface in response to the magnitude of the biasing voltage and the between-surface spacing.

13 Claims, 6 Drawing Figures



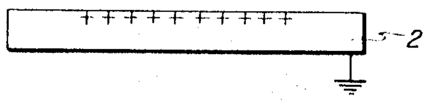


FIG. 1a

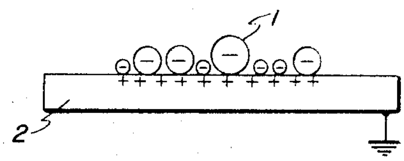


FIG. 1b

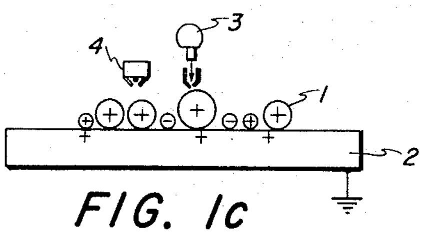


FIG. 1c

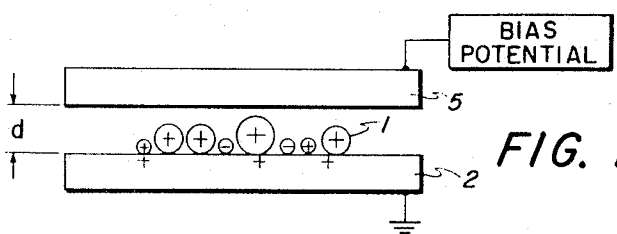


FIG. 1d

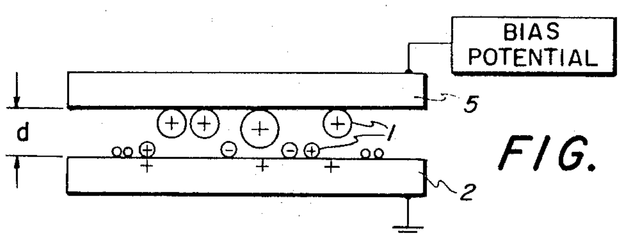


FIG. 1e

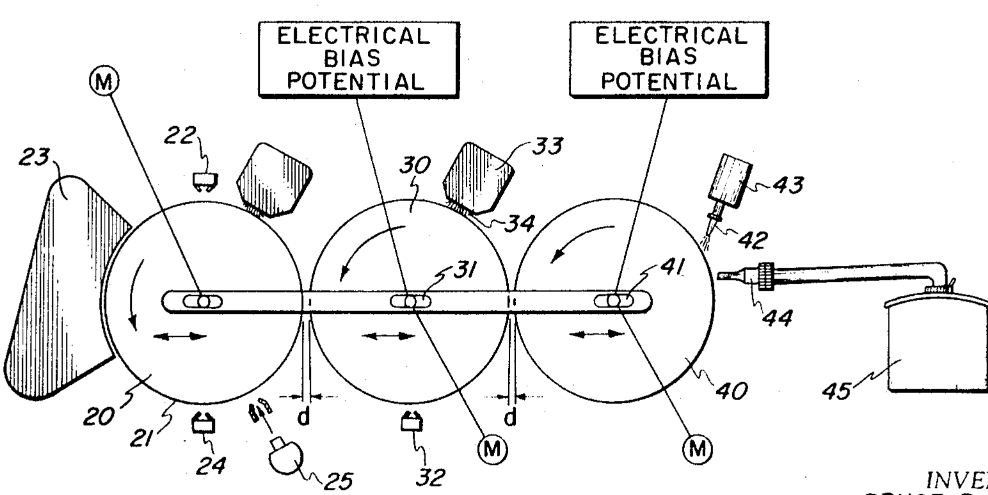


FIG. 2

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METHOD AND APPARATUS ELECTROSTATICALLY CLASSIFYING TONER PARTICLES

BACKGROUND OF THE INVENTION

This invention relates to the electroscopic developing materials, and, in particular, to an improved method and apparatus for classifying electroscopic particles.

More specifically, the invention relates to a classification method and apparatus whereby a very narrow size distribution of electroscopic particles may be obtained by electrostatically attracting the particles to an attraction member spaced therefrom a predetermined distance. Both the particles to be classified and the attraction member are charged to predetermined voltage levels of opposite polarities.

Electroscopic materials, materials capable of retaining an electrical charge on or in their surface, are extensively utilized in the field of graphic communication and especially in the science of xerography. As is well known in the xerographic art, electroscopic developer material comprising toner powder and carrier material is used to develop a latent electrostatic image on a photoreceptive surface. This image may subsequently be transferred from the photoconductive surface to a support material such as paper and permanently fixed thereto to form a reproduction of the original document.

Various methods are utilized in the art to bring the electroscopic toner particles into contact with the latent electrostatic image and an example is disclosed in Walkup, U.S. Pat. No. 2,618,551, wherein the toner particles are carried to a photoconductive surface by a carrier material. The carrier material and toner particles are selected to have a predetermined triboelectric relationship whereby the toner is triboelectrically bonded to the carrier. The developer material, comprising the toner and carrier, is brought into contact with a latent electrostatic image and the magnitude of the electrostatic force of the latent image will overcome this triboelectric bond to physically remove the toner from the carrier and electrostatically bond it to the image. This type of latent electrostatic image development is known as cascade development. The carrier particles in cascade development are much larger than the toner and carry a plurality of toner particles to the photoconductive surface. In addition to the cascade method of development, other well-known development methods use a fur brush, magnetic particles simulating a brush, direct application of toner to the image by means of a donor belt or simple dusting and the like.

Many different types of toner particles are utilized in the development of latent electrostatic images. One example of the range of sizes and compositions of toner particles is disclosed in Carlson U.S. Pat. No. Re. 25,136, wherein an average size toner is indicated to be less than 20 microns, preferably 5 to 10 microns. However, toner particles of a size less than 5 microns or more than 20 microns are utilized for certain latent image development. In some commercially available toners the size of the individual toner particles can range from less than 5 microns to as great as 50 microns. However, as higher speed and more efficient xerographic devices are developed, it is necessary to use toner particles of a more uniform size. For example, a more uniform size distribution will result in a more efficient transfer of toner particles from the photoconductive surface to the support member thereby making cleaning of the residual toner image left on the photoconductor drum after transfer less difficult. Generally, image transfer is effected by an electrostatic field applied to the support material by a corona discharge device or biased conductive roller device operatively contacting the material on the side opposite the toner particles. However, if the toner particles comprising the developed image are of non-uniform sizes, an incomplete transfer of the toner will occur since the smaller particles will not be uniformly transferred under a particular electrostatic field condition. Therefore, it becomes difficult to adjust and select the electrostatic bias to be applied to the support material to insure the complete image transfer if the toner particles are of a diverse range of sizes. It has been

found to be nearly impossible to effect a complete transfer of non-uniform sized toner to the support material. However, if toner is uniformly sized, transfer of the toner is significantly more efficient as well as minimizing or eliminating the aforementioned difficulty in removing a residual toner powder image from the photoreceptor surface.

A further advantage in utilizing a uniform sized toner is better image development characteristics. For example, when an image is developed by a process using a two component developer, the triboelectric bond between a toner and carrier is different for a toner of one size as compared to toner of another size in relationship to the same size carrier as is well known. This variation in the triboelectric bond results in a non-uniform range of attraction forces existing between the carrier and toner, comprising developer, which prohibits control of image development. Beneficial results accrue from the use of uniform sized toner in every known development technique.

Numerous other advantages of using toner of substantially uniform size distribution should be apparent in nearly every step of the xerographic process. However, in order to attain a more uniform size toner it is necessary that an efficient and effective size classification method and apparatus be utilized in selecting the proper toner. In the past, centrifugal force devices have been relied on to classify toner particles, but these results have produced a relatively broad size distribution. Further, centrifugal classifiers tend to be relatively large and expensive. The classification process and device of this invention, however, has been found to inexpensively and accurately achieve the desired result of a more narrow distribution of sizes of the toner particles resulting in the separation of toner particles of a substantially uniform size.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to efficiently classify electroscopic particles according to size by an improved electrostatic method and apparatus.

A further object of this invention is to classify toner particles used in the art of xerography within a narrow range of size distribution by selectively attracting charged particles of a predetermined size to an electrically biased member.

There and other objects are attained in accordance with the present invention wherein there is provided a method and apparatus which is based on phenomena that the larger size of uniformly charged particles can be more readily attracted by a conductive electrode member biased by an electrical potential of opposite polarity than smaller particles. By selecting the magnitude of the charge and bias and the distance between the charged particles and conductive member, toner particles of a certain minimum size and greater may be attracted to the conductive member while smaller particles are not attracted. Thereby, it is possible to separate particles to desired size classifications by varying the aforementioned various parameters according to desired classifications and obtain very narrow size distribution.

DESCRIPTION OF THE DRAWINGS

Further objects of this invention, together with additional features contributing thereto and advantage accruing therefrom, will be apparent from the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIGS. **1***a* through *e* illustrate a diagrammatic analysis of the particle classification of this invention.

FIG. **2** is a schematic view of one form of device for classifying particles according to this invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring in particular to each of the FIGS. **1***a* through **1***e* there is illustrated the principles and theory upon which the method and apparatus of this invention are based. As discussed previously, the method of this invention utilizes an electrostatic attraction of two oppositely charged elements to achieve classification. For convenience of description, the polarities of the electrostatic charges and bias potential illustrated in FIGS. 1*c* through 1*e* and described below are only intended to be examples, and it is within the scope of the present invention to use opposite polarities than as disclosed. To analyze this process in detail, reference is made in particular to FIG. 1*a* wherein a plate 2 is illustrated having a uniform positive charge applied thereto. The plate is shown having at least the surface being of a photoconductive insulating material as used in the xerographic process, (e.g., see Eichler et al. U.S. Pat. No. 2,945,434) but the plate could be of other materials capable of retaining a charge. The positive charge may be deposited on the surface by any well-known process such as electrostatic charging by a corona discharge device, induction charging device, or the like.

In FIG. 1*b* the next step is illustrated wherein the toner particles to be classified are placed in contact with the uniformly charged photoconductive plate and are electrostatically bonded thereto in a substantially uniform layer. The toner particles 1 may be brought into contact with the plate 2 by well-known development methods such as the aforementioned cascade development. As shown in FIG. 1*b* the charged toner particles 1 of different sizes adhere to the oppositely charged plate 2.

Referring now in particular to FIG. 1*c*, there is illustrated the next step of the process. The developed plate is exposed to light from a suitable source 3 and a new positive electrostatic charge is applied to the toner particles 1 on the plate by conventional means 4 of the type previously described. The toner particles on the photoconductive surface are exposed to light to dissipate much of the positive charge existing on the photoconductive plate through the conductive backing as shown in FIG. 1*c*, but the charge is not removed in the interface areas between the particles and surface, since illumination to those areas is blocked by the position of the toner. By subsequently applying a positive charge of a sufficient magnitude upon the toner particles their polarity is reversed as further illustrated in FIG. 1*c*. These two steps of applying a positive charge on the particles and exposing the plate to light may be performed simultaneously as well as sequentially.

Referring to FIG. 1*d*, there is illustrated a conductive plate or electrode 5 located a distance *d* from the photoconductive plate 2 supporting the positive charged toner particles 1. The conductive plate is biased by an electrical potential to a polarity opposite from the positively charged toner to establish an electrostatic field of attraction between the particles 1 and the conductive surface 5. The magnitude of the charge on the toner or the bias potential for a given distance *d* controls the size distribution of the particles attracted to the conductive plate 5. Such a result occurs because the electrostatic attraction force is a function of the unit area of the toner particles. By properly choosing the polarity and magnitude of the electrical bias, particles of a predetermined size or greater can be selectively attracted to the conductive surface. It is also possible to vary the size distribution of the particle attracted to the conductive plate by varying the distance *d* between the toner and conductive plate 5 and maintaining a constant bias potential on the conductive plate. FIG. 1*e* illustrates what occurs after transfer to the second plate 5 wherein the larger positively charged toner particles are attracted to the conductive plate 5 and the smaller positively charged particles remain on the photoconductive surface 2.

In summarizing the process of the invention illustrated in FIGS. 1*a* through 1*e*, a photoconductive plate 2 is uniformly charged and the toner 1 to be classified is placed in contact with the charged surface. The photoconductive plate and particles are exposed to light 3 and the particles electrostatically charged to reverse their polarity. The conductive plate 5, located a predetermined distance *d* from the particles, is electrically biased to a predetermined magnitude of a polarity opposite to the charge on the toner particles, whereby the particles of a predetermined size distribution are attracted to the conductive surface. This predetermined size distribution depends on force of the electric field which is a function of the variables of the conductive surface biasing potential magnitude and the initial charge on the particles as well as inversely to the distance *d*. It is also possible to further classify the particles collected on the conductive plate by placing a second conductive surface adjacent the first conductive surface. This second surface is connected to a different bias of like polarity and thereby attracts particles of a second larger predetermined size from the first conductive surface. A plurality of such surfaces could be utilized whereupon it would be possible to collect on each surface the desired size classification.

For an example of the process of this invention, the photoconductive plate 2 was positively charged to 600 volts. The plate was then developed by a uniform layer of toner particles to be classified on the charged plate. The plate 2 was then exposed and the particles 1 charged positively by a corotron applying a 2/ma/inch current at 3 inches/second. An aluminum plate 5 was supported 7 mils from the charged particles and a negative bias of approximately 1,000 volts was applied to the metal. Approximately 95 to 98 percent of the particles transferred to the aluminum plate were 10 microns or greater. To further classify the particles of 10 microns or greater collected by the first plate 5, a second plate biased by approximately 1,000 volts was positioned 7 mils from first plate 5 resulting in a still larger range of particles being transferred to the second plate whereupon particles in the range of 10 to 20 microns remained on the first conductive plate 5. A larger range of particles was transferred to the second conductive plate, because the level of charge on the particles changed in the first transfer from the photoconductive plate 2 to the plate 5. However, depending on the charge on the collected particles on the first conductive plate 5 and the desired range of particle sizes subsequently to be left thereon, the magnitude of the bias on the second conductive plate may be selected to be a different value than the bias applied to the plate 5. From these results it can be seen that the process produces very effective classification of toner particles according to size. As is apparent from the foregoing, different magnitudes of voltage and distance may be employed according to desired classification.

Referring now in particular to FIG. 2, an embodiment of the device for classifying the particles according to the invention is illustrated. A drum 20 is rotatably mounted on suitable bearings (not shown) and is driven by a motor M in a counterclockwise direction. The drum includes a standard xerographic surface 21 comprising a conventional photoconductive insulating material. Mounted adjacent to the top of the drum is a charging device 22 for depositing a uniform electrostatic charge on the photoconductive surface. Charging device 22 may be any means capable of uniformly charging an insulating surface, as for example, a conventional corotron. Adjacent the left side of the drum is a conventional development device 23 such as the aforementioned cascade system for bringing particles to be classified in contact with the photoconductive surface. Other developing means, such as a brush, magnetic, or a simple dusting device, may be utilized for development.

Located next in the path of drum surface movement is a charging device 24 for placing a charge on the developed photoconductive surface and an exposure device 25 for dissipating much of the surface charge on the photoconductive surface of the drum. A conductive drum 30 is rotatably mounted adjacent the drum 20 with the surface of the conductive drum located a predetermined distance *d* from the photoconductive surface. The exact predetermined distance is selected according to desired size classification of the particles. Drum 30 is slidably supported from a bracket 31 to allow adjustment of the distance between the surfaces. The drum 30 may be made of any electrically conductive material such as aluminum and is connected to an electrical bias potential of opposite polarity from the charged particles. The conductive drum also has an adjacently mounted charging device 32 which may be a corotron as shown or the like, to charge the toner particles attracted to the conductive drum. By charging the collected particles to a predetermined level, a transfer of a different size range of particles may be accomplished from the first conductive drum to a second conductive drum to allow a more narrow classification of size to be discussed later. The first conductive drum includes a collection means **33** for collecting the attracted particles and a brush **34** to clean the surface.

The second conductive drum **40**, preferably metal, is similar to the first conductor drum and is rotatably mounted in a suitable bearing. An electrical bias potential having the same polarity as that on the conductive drum **30** is applied to this second drum. By selecting a suitable magnitude for both the bias on the second drum and the charge placed on the attracted particles of the first conductor drum, another range of particle size will be attracted from drum **30** to the second drum **40** to further classify the toner. It is understood, however, that the distance between the two conductor drums is a variable which also must be considered. Accordingly, the second conductive drum includes distance adjustment means (not shown) such as an adjustable bracket. Therefore, according to this invention it is clear that a plurality of such conductive drums could be mounted in tandem to achieve a very precise classification of toner.

Collection means **41**, adjacent the second drum, illustrates an example of how the transferred particles are collected. A nozzle **42**, connected to a pressurized air source **43** to direct an air jet onto the surface of the drum **40**, loosens the collected particles on the drum surface and an exhaust means **44** removes the loosened toner. Exhaust means **44** is coupled to a particle container **45** for collecting the toner. Other collection means could be utilized in the device of this invention and if a plurality of conductive drums were employed in the device, each drum would include such a collection means.

In operation, the photoconductive surface **20** is charged by the charging device **22** with, for example, a positive electrostatic charge. The charged surface is rotated past the development means **23** where particles to be classified come in contact with and cling to the photoconductive surface. The developed area then moves past the second charging means **24** and exposure means **25** whereby a positive charge is placed on the particles, and much of the charge on the photoconductive surface is dissipated because of the light exposure of the photoconductive surface. The surface of the photoconductor drum bearing the charged particles then rotates to a position adjacent the surface of the negatively biased conductive drum **30**. By electrostatic attraction, particles larger than a precalculated size transfer to the conductive drum **30**, while the particles smaller than this size remain on the photoconductive surface. The particles transferred to the conductive drum **30** rotate past the charging device **32** and are again positively charged. These transferred particles are rotated to a position in operative contact with the second conductive drum, which is also negatively biased. The second drum removes another predetermined range of sizes from the first conductive drum. The predetermined size of the toner particles attracted to the second drum is greater than the particles attracted to the first conductive drum selectively excluding a portion of the particles which will remain on the first surface. In operation, a plurality of these conductive surfaces would provide a very close distribution of the size of the toner. Collection means for each drum operates to remove the collected and sorted toner particles.

It has been found that when the conductive drum **30** is negatively biased in the range of 250–1,000 volts classification is effected for many conventional toners. If more than one conductive drum is utilized, then each drum is negatively biased in the range of 250–1,000 volts. The range of separation of the charged particles and the surface of the first conductive drum **30** for the above bias has been found to be preferably 5 to 20 mils. Each additional conductive drum is separated from the adjoining one a similar order of distance. The device can employ voltage polarities and magnitudes and spacing ranges other than those indicated here depending on the range of sizes of the particles to be classified as well as the size distribution desired.

Modifications of the aforedescribed method and apparatus are within the scope of this invention. For example, the polarity of charges and bias disclosed in the method and apparatus of this invention could be opposite than described, as long as the polarity of the charge on the particles is opposite to the bias on the collecting member. Also, the conductive attraction member could be of an insulating material having an electrostatically charged surface. It is further within the scope of this invention to classify any electroscopic particles as well as the toner particles used in the xerographic process. Moreover, the form of the drums used in the description of the embodiment of FIG. **2** could be modified to use various alternatives, as for example, a web or plate means.

While this invention has been described with reference to the structure and process disclosed herein, it is not intended to be confined to the details set forth or the specific environment set forth. Therefore, this application is intended to cover such modifications or changes as may come within the purposes of the invention or the scope of the following claims.

What is claimed is:

1. A method for classifying electroscopic particles according to size comprising the steps of

placing an electrostatic charge of a first polarity upon a photoconductive insulating surface,

dusting said surface with electroscopic particles to be classified charged to a second polarity opposite the first by charging means so that the particles cling to said surface,

exposing said surface to light to dissipate the charge thereon,

placing a second predetermined charge of said first polarity upon said particles on said surface,

and applying a predetermined bias potential of the second polarity upon a conductive surface located a predetermined distance from said photoconductive surface to attract particles of a predetermined size to said conductive surface for classification.

2. The method of claim **1** further comprising the step of collecting the particles attracted to said conductive surface.

3. The method of claim **1** wherein said step of exposing and said step of placing said second charge are performed simultaneously.

4. The method of claim **1** further comprising the step of

placing a second bias potential of a different magnitude than said predetermined bias potential upon a second conductive surface located a predetermined distance from said first conductive surface whereas particles of a second or more range of sizes of particles are attracted to said second or more conductive surfaces from said first conductive surface for a further classification of said particles.

5. The method of claim **1** further comprising the step of

varying the magnitude of one of said second charge or said bias potential to selectively vary the range of sizes of said particles attracted to said conductive surface.

6. The method of claim **1** further comprising the step of

varying the distance between said photoconductive surface and said conductive surface to alter the range of sizes of said particles attracted to said conductive surface.

7. A method of classifying according to size electroscopic toner particles composed of the same material comprising

charging the particles to provide charged particles of a first charge polarity,

forming a particle layer by electrically attracting charged particles of the first polarity to a support member electrically biased to a first potential,

depositing electrostatic charge of a second polarity opposite the first polarity onto the particle layer, and

separating larger particles from the particle layer by steps including spacing an electrically conductive separation member a predetermined distance from the particle layer and coupling an electrical bias of a second potential of a different magnitude than said first potential to the separation member whereby the magnitude of the electrostatic charge on the particles, the difference between the first and second bias potentials and the spacing between the support and separation members establish the size particle separated from the particle layer.

8. The method of claim 7 wherein the surface of the support member on which the particle layer is formed is electrically conductive.

9. The method of claim 7 wherein the surface of the support member on which the particle layer is formed includes a photoconductive insulating material and further including the step of exposing particle layer to light simultaneously with the depositing of electrostatic charge on the particle layer.

10. The method of claim 7 wherein the surface of the support member on which the particle layer is formed includes a photoconductive insulating material and further including the step of exposing the particle layer to light subsequent to depositing electrostatic charge on the particle layer.

11. The method of claim 7 further including classifying the particles separated from the particle layer to the separation member by steps including

moving the separated particles on the separation member from the vicinity of the support member,

spacing a third electrically conductive member a predetermined distance from the separated particles on the separation member, and

coupling an electrical bias of a third potential to the third member whereby the magnitude of the charge on the separate particles, the difference between the second and third potentials and the spacing between the separation and third members establish the size particle attracted to the third member for further classification of the particles.

12. The method of claim 11 further including depositing electrostatic charge onto the separated particles on the separation member prior to spacing the third member adjacent the separated particles.

13. Apparatus for classifying according to size electroscopic toner particles composed of the same material comprising

a xerographic plate surface including a photoconductive surface said plate being coupled to an electrical bias of a first potential,

first charging means for depositing electrostatic charge of a first polarity on a surface of said support member,

development means for forming a particle layer of charged toner particles of a second polarity opposite the first on the charged surface of said support member,

second charging mean for depositing electrostatic charge of the second polarity on said particle layer formed on the support member,

exposure means for exposing said charged particle layer to light and an electrically conductive separation member coupled to an electrical bias of a second potential and adapted to be spaced a predetermined distance from a charged and exposed particle layer whereby the magnitude of the charge of second polarity, the difference between the first and second potentials and the spacing between the support and separation members establish the size particle separated from the particle layer on the support member.

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