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# DEVELOPER MIXTURE FOR ELECTROSTATIC PRINTING

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## ABSTRACT OF THE DISCLOSURE

In an electrostatic printing process employing a developer mixture comprised of electrically conductive carrier particles and electrostatically attractable toner particles, the speed of printing is increased by incorporating in the developer mixture finely divided particles having a particle size of between about .007 and about 0.09 micron.

## BACKGROUND OF INVENTION

### (1) Field of the invention

The present invention relates to electrostatic printing and more particularly to an electrostatic printing process employing an improved developer mixture.

### (2) The prior art

In an application for an electrostatic printing system, U.S. Ser. No. 386,182, filed July 30, 1964, and now abandoned, for John B. Kennedy, Jr., which is assigned to a common assignee, there is described a method for electrostatic screen printing wherein a developer mixture of large electrically conductive carrier particles having relatively small toner particles adhered thereto by triboelectric forces is brought into contact with an electrically charged base electrode whereby the conductive carrier particles are charged therefrom so that a repulsion effect is established with sufficient strength to cause the developer mixture to be repelled from the base electrode. A screen or stencil which has apertures arranged in a pattern is presened in the path of the developer mixture, the size of the apertures being selected so that the carrier particles are larger than the apertures while the toner is smaller than the apertures. The apertures in the screen mechanically stop the impelled carrier particles while the momentum of the toner causes these particles to detach from the carrier particles and pass through the screen and continue onward to impinge upon the surface of the article to be printed, located above the screen, and spaced therefrom, the areas of impingement of the toner particles on the substrate corresponding to the pattern on the screen. The image body thus formed is then fixed by the application of heat or vapor or the like fusion means which will cause the toner particles to be retained on the surface of the article.

When the article surface is of a conductive material, it is charged oppositely to the toner particles for controlling the paths thereof from the screen to the sub strate. When the article surface is of a non-conductive nature, a backing or back electrode bearing a predetermined potential is placed at the rear of the article and on a side opposite to the side of the article facing the screen and base electrode.

The above-described electrostatic printing process has the advantage that neither pressure nor contact between the printing element and the subject material being printed is required.

In preparing developer mixes for use in accordance with this electrostatic printing process, considerable consideration is given to the triboelectric forces developed upon the mixing of the carrier and toner particles. Thus, the attracive force between toner and carrier, which is proportional to the electrostatic charge generated between them, must be sufficient to withstand the separatory forces during the mixing and conveying of the developer particles to the electrode of the apparatus, but cannot be too strong to withstand the separatory force generated when the toner laden carrier strikes the screen during the printing operation. If the attractive force is too low, dusting or the formation of clouds of fine toner particles is caused which results in soiling the prints and an objectionable atmosphere in the neighborhood of the electrostatic printing apparatus. If the attractive force is too high, there will result a reduction in the printing rate.



## SUMMARY OF THE INVENTION

The present invention provides developer mixtures for use in electrostatic printing in which the electrostatic forces developed between the carrier and toner particles may be controlled within acceptable limits by incorporating in the developer mixture a small but effective amount of finely divided particles having a particle size between about 0.007 and about 0.09 micron.

The developer mixture of the present invention generally improves the quality of copies obtained by electrostatic printing processes as compared with heretofore known mixtures. For a given time, the developer particles prepared in accordance with the present invention deliver toner to the screen at a higher rate, and printing at any given density is generally accomplished in less time than with prior art developer particles.

## PREFERRED EMBODIMENTS

The developer mixture of the present invention is comprised of (1) electrically conductive carrier particles, (2) non-conductive toner particles having a particle size smaller than the particle size of the carrier particles; and (3) finely divided particles having a particle size in the range of about 0.007 to about 0.09 micron and preferably in the range of about 0.01 to about 0.05 micron.

The carrier particles used in the present invention are composed of any electrically conductive material separated in the triboelectric series from the material of the toner. The carrier and toner are held together by the electrostatic forces produced upon contact between them by the triboelectric effect. Conductive materials suitable for use as carrier particles in the developer mixtures of the present invention include iron, nickel, aluminum, cobalt and their alloys.

Carrier particle sizes of 25 to 250 microns are satisfactory for producing good, clear, dense prints. It will be apparent to those skilled in the art that the lower limit of particle size is determined by the apertures contained in the screen utilized in the electrostatic printing apparatus.

The carrier particles preferably have a spheroidal shape and are present in the developer mixture in an amount sufficient to respond to the electric field and to carry sufficient amounts of toner through such field to the screen. It has been found that the amount of toner mixed with the carrier particles can vary from about 0.5 to about 6.0% by weight of the carrier particles. Generally speaking, toner concentrations in the order of about 2% by weight prove to be satisfactory.

The words "toner" and "toner particles" are employed herein to designate particles smaller than the apertures of the screen, capable of adhesion to the carrier particles by a force less than that developed upon impact of the carrier particles against the screen and capable of forming a pattern effect upon the substrate. In usual practice, the toner particles are of a different color than the substrate surface which is being printed. The toner may be negatively or positively charged. Toner particles may be charged triboelectrically by mixing them with carrier particles. The polarity of charge the toner particles acquire

is dependent upon the properties of both the toner and carrier material. Preferably, toners are used which, when mixed with nickel, cobalt or iron carrier paticles, exhibit a negative charge. Negatively charged toner particles are preferably of non-conductive materials. Commercially available types are manufactured by the Xerox Corporation and sold under the trademark Xerox Copier Toner. These non-conductive toner particles, such as Xerox 914 Copier Toner, are comprised of pigmented resin particles having a particle size of from about 1 to about 30 microns, and preferably have an average particle size of about 17 microns, and consist of a finely divided uniform mixture of pigment in a non-tacky polystyrene resin. The polystyrene resin is present in the toner composition in a predominating amount, i.e., at least about 50% of the entire composition, optionally blended or mixed with a polybutyl methacrylate, such as polymerized n-butyl methacrylate. The pigment is present in the toner in a sufficient quantity to cause it to be highly colored whereby it will form a clearly visible image on the substrate on which it is electrostatically deposited. Thus, for example, in the case where lettering and the like is desired on corrugated paperboard, the pigment can be a black pigment, such as carbon black or other minutely divided pigment. Other commercially available toners are available from Interchemical Printing Inks, such as toner designated XRL 8749.B which is a carbon pigmented polystyrene resin having an average particle size of 1.4 micron.

The size of the particles incorporated in the developer mixtures used in the practice of the present invention may range from about 0.007 to about 0.09 micron in diameter, and preferably in the range of 0.01 to about 0.05 micron in diameter. Particles in this size range are available commercially. One example of commercially available particles useful in the practice of the present invention is Cab-O-Sil, manufactured by the Godfrey L. Cabot Company, Cambridge, Mass., and is composed of between 99.0 to 99.7% $SiO_2$, 0.2 to 2.0% free moisture, and about 0.004% $Fe_2O_3$. It has a particle size range of from 0.015 to 0.020 micron mean diameter.

Developer mixtures containing the $SiO_2$ are prepared in accordance with the present invention by thoroughly mixing the $SiO_2$ with the carrier and toner particles at a concentration in the range of 0.01 to 0.15 percent by weight based on the weight of the carrier particles. It is an essential and critical feature in the use of $SiO_2$ particles that the amount of $SiO_2$ incorporated in the developer mixture not exceed the upper limit of this range. As will hereinafter be illustrated, if the concentration of $SiO_2$ in the developer mixture exceeds 0.15 percent by weight of the carrier particles, the mass transfer rate of the toner, i.e., the amount of toner transferred to the substrate to be printed in a given period of time is reduced to levels below that normally obtained in the absence of the $SiO_2$. The speed of printing is directly proportional to the mass transfer rate.

Carbon black is another particle type having a particle size range which may be used in the practice of the present invention and which is available commercially. A specific example of commercially available carbon black particles useful in the practice of the present invention is Superba Special, manufactured by Columbian Carbon Company which has a particle size of 0.014 micron diameter.

In preparing developer mixtures with the carbon particles, it is a critical and essential feature that the concentration of carbon particles mixed with the carrier and toner particles be in the range of about 0.002 to 0.015 percent by weight based on the weight of the carrier particles. As will hereinafter be illustrated, if the concentration of the carbon particles in the developer mixture exceeds 0.015 percent by weight of the carrier particles, the mass transfer rate of the toner is reduced to levels substantially below those normally encountered in the absence of the carbon particles.

To illustrate the manner in which the invention may be carried out, the following examples are given. It is to be understood, however, that the examples are for the purpose of illustration, and the invention is not to be regarded as limited to any of the specific materials or conditions recited therein.

## Example I

Nickel carrier particles having a diameter range of 87 to 103 microns were mixed with Xerox 914 Copier Toner and Cab-O-Sil to prepare a developer mixture for use in an electrostatic printing apparatus for printing on a series of tared aluminum substrates through a screen woven from 1 mil diameter 304 stainless steel wire having 270 apertures per linear inch and 54% open area, the apertures having a diameter of about 2.7 mils (67 microns) at a print voltage of 13 kilovolts. In each case, the developer mixture constituted about 3% by weight of toner based on the weight of the carrier particles. The amount of Cab-O-Sil incorporated in the developer mixture was varied from 0.002 to 0.10 percent based on the weight of the carrier particles. The tared substrates were weighed after an exposure to the printing process for 0.1 second.

The weight of deposited toner particles in mg./in.$^2$ using developer mixtures containing varying amounts of Cab-O-Sil is recorded in Table I below.

In order to demonstrate the increased toner deposition rates obtained with the developer mixtures of the present invention, the deposition of toner using developer mixtures in which Cab-O-Sil was not added or was added in amounts greater than 0.15% was run as a comparison. The deposition of the toner using these control mixtures (designated by the symbol C) is also included in Table I.

TABLE I

| | Percent Cab-O-Sil | Toner deposition, mg./in.$^2$ |
|---|---|---|
| Run number: | | |
| $C_1$ | 0 | 3.30 |
| 1 | 0.01 | 3.45 |
| 2 | 0.02 | 3.70 |
| 3 | 0.04 | 3.92 |
| 4 | 0.05 | 4.95 |
| 5 | 0.10 | 3.80 |
| $C_2$ | 0.25 | 1.80 |

As can be seen from the data in Table I, the deposition of toner was considerably greater using developer mixtures of the present invention having Cab-O-Sil incorporated therein when compared with developer particles in which Cab-O-Sil is absent or incorporated in the developer mixture in an amount in excess of 0.15%.

## Example II

Nickel carrier particles mixed with XRL 8749.B Toner and varying amounts of carbon black having a particle size of 0.014 micron were used to deliver the toner particles on a tared aluminum surface through a woven stainless steel screen following the procedure of Example I over a range of carbon black concentrations. The deposition of toner over the carbon black additive range employed is recorded in Table II below. For purposes of comparison, the deposition of toner using developer mixtures to which carbon black was not added or was added in amounts greater than 0.015% is also included in Table II.

TABLE II

| | Percent carbon black | Toner deposition, mg./in.$^2$ |
|---|---|---|
| Run number: | | |
| $C_3$ | 0 | 3.05 |
| 6 | 0.005 | 4.15 |
| 7 | 0.01 | 4.80 |
| $C_4$ | 0.02 | 1.00 |
| $C_5$ | 0.03 | 0.85 |

From an examination of the data in Table II, it is immediately apparent that within a carbon black additive

range of 0.005 to 0.01%, the deposition of toner is substantially greater than when amounts of carbon black outside this range are used.

By way of further contrast, the incorporation of finely divided particles of zinc oxide having a particle size of 0.1 micron diameter, and titanium dioxide having a particle size of 0.3 micron diameter in a concentration range of 0.01 to 0.1% by weight based on the weight of the carrier particles in nickel carrier developer mixtures of the type used in Example II produced no noticeable improvement in the deposition rate of the toner on the printed substrate.

What is claimed is:

1. A developer mixture for developing electrostatic images, said mixture being comprised of a mixture of (1) electrically conductive carrier particles having a particle size of about 25 to about 250 microns, (2) electrostatically-attractable non-conductive toner particles having a particle size of about 1 to about 30 microns, said toner particles being of a smaller size than the carrier particles used in the mixture and electrostatically charged through triboelectric action by contact with the carrier particles to adhere electrostatically to the surface of said carrier particles and (3) finely divided carbon particles having a particle size in the range of about 0.007 to about 0.09 micron, said carbon particles being present in the mixture in an amount ranging from 0.002 to 0.015 percent by weight based on the weight of the carrier.

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