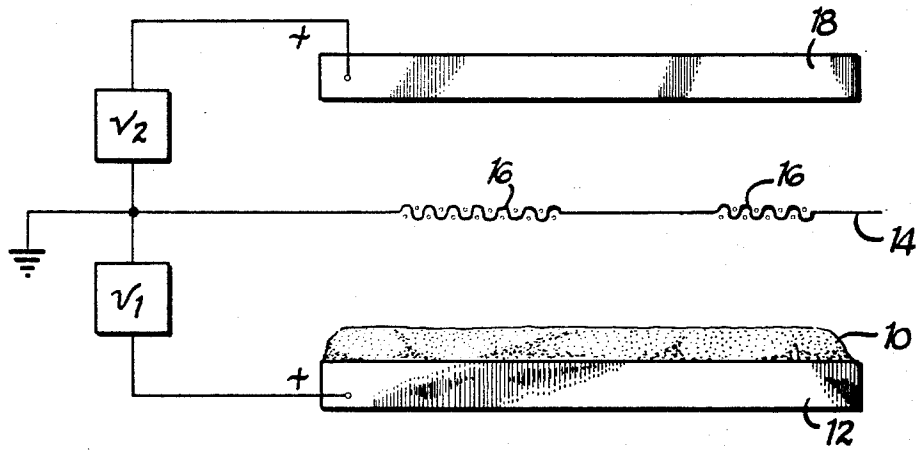
Jan. 7, 1969 W. E. JOHNSON 3,420,168

ELECTRICAL PRINTING PROCESS USING AN OPPOSING FIELD

Filed Sept. 22, 1965



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United States Patent Office 3,420,168 Patented Jan. 7, 1969

3,420,168

ELECTRICAL PRINTING PROCESS USING AN OPPOSING FIELD

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Filed Sept. 22, 1965, Ser. No. 489,350
U.S. Cl. 101—129 4 Claims
Int. Cl. B411 1/12

ABSTRACT OF THE DISCLOSURE

Electrical printing processes of the type in which powder particles in a supply bed are electrically charged and impelled from the bed through the apertures of an electrically conductive stencil to an article's surface. Improved image resolution is achieved by establishing an electric field between the article's surface and stencil which opposes or retards the movement of charged particles toward the article's surface, this field being most effective on particles which deviate from straight line paths toward the article's surface.

In my copending application Ser. No. 393,817, filed Aug. 31, 1964, now abandoned, and assigned to the assignee of the present application, there are disclosed certain exemplary processes for electrically applying an image-shaped layer of printing powder particles to an article surface. The subject matter of Ser. No. 393,817 has been carried forward in a continuation-in-part application Ser. No. 575,868, filed Aug. 29, 1966. In general, in these processes a supply bed of printing powder particles is supported upon an electrically conductive plate. A stencil screen having an image-defining aperture is supported in spaced relationship above the powder bed and an article to be decorated is brought into spaced registry above the aperture in the screen. A relatively high strength electric field is applied between the conductive plate and the stencil screen to electrically charge and impel powder particles from the supply upwardly through the screen apertures toward the article surface. To focus and assist in guiding the particles to areas of the article surface in vertical registry with the aperture of the stencil, a second relatively low strength electric field is applied during the transfer operation between the article surface and the stencil screen. The second field is oriented to assist the particles in moving toward the article surface, the article surface being maintained at an electric potential of opposite polarity from the charge on the particles being transferred.

In the processes described in my copending application Ser. No. 393,817, the second field, between the stencil and article surface, functions primarily to exert a focusing or guiding action on the particles during their transit between the screen and article surface. This guiding or focusing action is applied to minimize scattering or deflection of the particles being transferred to areas on the article surface outside of the desired area to which the image was to be applied. Scattering of the particles is due to several effects on the particles during their transfer, these effects being primarily aerodynamic effects occasioned by the simultaneous movement of a large number of particles through a relatively confined air space, mechanical collisions between the particles, and electrical effects due to distortion of the electric field by the spaced wires of the wire mesh stencil screen.

While the processes described in my copending application Ser. No. 393,817 resulted in improvements in image resolution, or reduction of scattering, over previously employed processes, scattering was found to still be present in some degree.

It is a primary object of the present invention to provide an electrical printing process for electrically transferring powder particles from a supply bed through a stencil screen to an article surface in which a high degree of resolution of image is achieved.

It is another object of the present invention to provide an electrical printing process in which particles veering to paths tending to carry the particles outside of the desired image area are repelled from the article surface.

The foregoing, and other objects and features of the invention will become apparent by reference to the following specification and to the drawings.

In the drawing:

The single figure is a schematic diagram of one form of apparatus embodying the present invention.

In the drawing, a loosely packed bed **10** of printing powder particles capable of being electrically charged is supported upon an electrically conductive plate **12** which, in turn, is supported in a suitable manner, not shown. A wire mesh stencil screen **14** having image-defining apertures such as **16** is supported, by suitable means, not shown, at a fixed distance spaced above the surface of bed **10**. An article schematically indicated at **18** is in turn supported in spaced relationship above screen **14** with the surface of the article to which an image is to be applied located in registry with the image apertures **16** of screen **14**. Voltage sourves V1 and V2 are electrically connected to support plate **12**, screen **14**, and article **18** as shown in the drawings.

The electrical connections are such that the polarity of support plate **12** and the article **18** is the same. In the drawing, article **18** and plate **12** are indicated as being of positive electric polarity, however, the sign of the polarity is unimportant as long as like polarities are applied to the support plate and article surface.

Apart from the like polarity relationship between the support plate **12** and article surface **18**, the characteristics of the powder and structure of screen **14** may be substantially the same as those described in my above-mentioned copending application Ser. No. 393,817. The powder particles of bed **10** may take the form of a fine glass frit having a particle size range which is relatively small as compared with the dimensions of the mesh openings of screen **14**. Screen **14** is formed of a wire mesh which is coated to fill the mesh openings. The coating is removed, by a photographic process, from areas of the screen to form the image aperatures **16**, this process being taught in United States Letters Patent 3,100,150, for example. Further details as to the resistivity of the powder, etc. may be had by reference to my above application Ser. No. 393,817.

In previously employed arrangements similar to that shown in the drawings, the usual practice was to connect support plate **12** to one potential source and to electrically charge the surface of the article **18** to a potential of the opposite polarity. In this manner, an electric field was established extending from the surface of support plate **12** through powder bed **10** to the article surface. The potential applied to support plate **10** was chosen to be sufficiently high to be operable to electrically charge the powder particles in bed **10** and to impel the particles from the bed upwardly to the article surface. The repulsion force exerted between support plate **10** and the particles, which were charged to the like polarity, was assisted by the attractive force of the article surface, charged to the opposite polarity from that of the particles.

Assuming support plate **12**, screen **14**, and the surface of article **18** to be flat surfaces supported in spaced parallel relationship with each other, the lines of force of the electric field created as described above would be parallel to each other and perpendicular to the respective surfaces, especially over the area of image apertures **16**

which are located inwardly from the edges of the plate **12** and article surface **18** so that curved edge effects upon the lines of force are not present. With this arrangement, the particles in theory should travel along straight lines and the image apertures **16** of the stencil should thus, in theory, result in the application of an image-shaped layer of powder to the surface of article **18** having sharply defined edges. However, as discussed in my copending application Ser. No. 393,817, the above described process, in actual practice, often resulted in images lacking the desired degree of sharpness or resolution, caused by particles which deviate from paths perpendicular to the article surface and thus strike the article surface at regions outside the desired image area.

This effect is referred to as scattering and may be caused in several different ways. One cause of scattering is that of turbulent air currents generated by the simultaneous transfer of a large number of particles through a relatively small air space. The powder transfer operation is performed in relatively short time intervals, the electric field being applied for a time interval of from 100 to 200 milliseconds. The spacing between the surface of powder bed **10** and screen **14** may be of the order of ⅛ of an inch while the spacing between the screen and article surface may be of the order of $\frac{1}{10}$ of an inch. With this confined spacing and the simultaneous transfer of thousands of particles through the confined space, air currents are generated which tend to carry particles toward the outer edges of the image, thus resulting in lack of resolution.

Other particles are deflected from a true vertical path by collisions with other particles or by the slight curvature of the electric field produced by the spacing between the wires of stencil **14**.

The present invention is especially directed toward increasing the sharpness or resolution of the image by minimizing the effect of scattering. To this end, the article surface is electrically charged to a polarity which is the same as the polarity of the charged particles being transferred. In this manner, an electric field is set up between screen **14** and the surface of article **18** which acts to oppose movement of the charged particles toward the article surface. Particles which are deflected from straight line movement toward the article surface are more susceptible to the repulsion action of this field because their velocity component toward the article surface is reduced proportionately with the deflection of the particle from the true straight line path.

The characteristics of the individual particles being transferred vary considerably. In typical transfer operations, the particle size may vary between 2 and 50 microns and because of this variation, substantial differences in mass exist between the individual particles. The total electric charge can likewise differ substantially between individual particles, and because the magnitude of the charge on an individual particle is determinative of the acceleration or repelling force exerted upon it by support plate **12**, a wide range of particle velocities exist which is further expanded by interparticle collisions while the particles are in transit between the bed and article surface.

Because of the opposing action of the electric field between the surface of article **18** and screen **14**, the lower field—that is the electric field between support plate **12** and screen **14**—must impel particles upwardly through apertures **16** of screen **14** with a force great enough so that the particle has sufficient momentum in a direction toward article surface **18** to overcome the repelling force exerted by the upper field—that is the field between article **18** and screen **14**.

The strength of the upper field is thus selected to repel from the article surface those particles whose momentums toward the article surface fall below a minimum amount.

By so rejecting the lower energy particles, an increase in resolution is observed. In terms of specific examples,

the following are some conditions under which the present invention has been practiced.

In one example, a supply of powder particles of a size range between 10 and 50 microns was arranged in a bed approximately ¼ of an inch in thickness upon a support plate **12**. The stencil screen **14** was supported $\frac{1}{16}$ of an inch above the surface of the powder bed, the screen being of a #200 mesh stainless steel. The surface of article **18** was spaced at a distance of 8 mils above stencil **14**. Voltage source **V1**, during the transfer operation, applied a potential difference of 3 kilovolts across the $\frac{1}{16}$ of an inch gap between the surface of bed **10** and screen **14**, thus applying an electric field of approximately 48 vols per mil during the transfer operation. In order to accomplish this, voltage source **V1** should have an output of approximately 7 kilovolts under no-load conditions.

Voltage source **V2** was operated to apply a 90 volt potential difference across the 8 mil gap between screen **14** and the surface of article **18** thereby creating an electric field of approximately 11 volts per mil. Voltage source **V1** and **V2** were arranged so that the article **18** and the powder in supply bed **10** were charged to the same electric polarity.

With the foregoing arrangement, the two voltage sources were simultaneously energized to apply the respective electric fields in a pulse of 150 milliseconds time duration. Under these conditions, an image of very satisfactory resolution was applied to the article surface, the weight of powder applied being approximately 160 milligrams, this being representative of the thickness of the image layer so applied.

In a comparative test, the gap between stencil screen **14** and the article surface was increased to 16 mils. With the same lower field as in the previous example, a 320 volt potential difference was applied by source **V2** to establish an upper field of 20 volts per mil with article **18** being of the opposite polarity from the charged particles. With a field pulse of 85 milliseconds, approximately 190 milligrams of powder were deposited.

Under the same conditions, with the 16 mil upper field gap, voltage source **V2** was set up to apply 180 volts or approximately 11 volts per mil with article **18** being of the same polarity as the charged particles. In this setup, an 85 millisecond pulse resulted in an image of approximately 110 milligrams weight, but with an image resolution much better than that of the comparative test where the upper field assisted movement of the particles.

Further investigation indicated that the present invention is most effective when the lower field strength is between 40 and 60 volts per mil and the upper field strength opposing motion of the particles is between 5 and 20 volts per mil. At lower field strengths much above 60 volts per mil, variations in the polarity or field strength of the upper field have but little observable effect. At lower field strengths much below 40 volts per mil, it is difficult to transfer particles, even with an assisting upper field.

The improved resolution achieved by the opposing upper field method is gained only at the cost of a somewhat lessened particle transfer efficiency inherently due to the fact that the upper field rejects or repeals at least a portion of particles which would otherwise reach the article surface. However, the results indicate that by so repelling the lower energy and off-course particles, a substantial improvement in image resolution is achieved, and the decrease in transfer efficiency is readily overcome merely by applying the field for an additional period of time measured in milliseconds.

While certain examples of the invention have been described above, it will be apparent to those skilled in the art that the conditions described above can be modified. Therefore, the foregoing description is to be considered exemplary rather than limiting, and the true scope of the invention is that defined in the following claims.

I claim:

1. The method of applying an image shaped layer of printing powder particles capable of being electrically charged to an article surface comprising the steps of interposing an electrically conductive stencil screen having an image-defining aperture therethrough between a supply bed of said particles and an article surface with said screen in spaced relationship to the surface of said bed and said article surface, electrically charging particles in said supply bed and establishing a first electric field between said bed and said stencil screen operable to electrically impel the charged particles from said bed through the image aperture of said screen to said article surface, and establishing a second electric field between said article surface and said screen oriented to oppose movement of said charged particles toward said article surface.

2. The method of applying an image shaped layer of printing powder particles capable of being electrically charged to an article surface comprising the steps of interposing an electrically conductive stencil screen having an image-defining aperture therethrough between a supply bed of said particles and an article surface with said screen in spaced relationship to the surface of said bed and said article surface, applying an electric field having a field strength of between 40 and 60 volts per mil between said bed and said stencil screen to electrically impel charged particles from said bed through the image aperture of said screen to said article surface, and simultaneously applying a second electric field between said article surface and said screen oriented to oppose movement of said charged particles toward said article surface and having a field strength of between 5 and 20 volts per mil.

3. The method of applying an image shaped layer of printing powder particles capable of being electrically charged to an article surface comprising the steps of supporting a bed of said particles upon an electrically conductive support interposing an electrically conductive stencil screen having an image-defining aperture therethrough between said bed and an article surface with said screen in spaced relationship to the surface of said bed and said article surface, electrically connecting an electric potential source to said support and said screen to establish a first electric field between said support and said stencil screen operable to electrically charge

particles in said bed to a first polarity and to impel the charged particles from said bed through the image aperture of said screen to said article surface, and establishing a second electric field between said article surface and said screen oriented to oppose movement of said charged particles toward said article surface and having a field strength sufficient to repel from said surface at least a portion of the charged particles impelled through said screen by said first field.

4. The method of applying an image shaped layer of prinitng powder particles capable of being electrically charged to an article surface comprising the steps of supporting a bed of said particles upon an electrically conductive support, interposing an electrically conductive stencil screen having an image-defining aperture therethrough between said bed of said particles and an article surface with said screen in spaced relationship to the surface of said bed and said article surface, electrically connecting said support and said article surface to electrical potential sources operable when energized to charge said support and surface to electric potentials of like polarity, and simultaneously energizing said sources while maintaining said screen at a potential operable to establish electric fields of opposite orientation on opposite sides of said screen with potential difference between said screen and said support high enough to electrically charge particles in said bed and to impel at least some of the charged particles through the image aperture of the screen to the article surface against the opposition of the field between the screen and article surface.

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U.S. Cl. X.R.

101—114; 117—17.5