

Jan. 24, 1967

L. J. JAVORIK ET AL
ELECTROSTATIC PRINTING PROCESS FOR USE WITH PRINTING
PLATE HAVING PLURAL LEVELS

3,299,809

Filed Nov. 5, 1964

2 Sheets-Sheet 1

FIG. 1

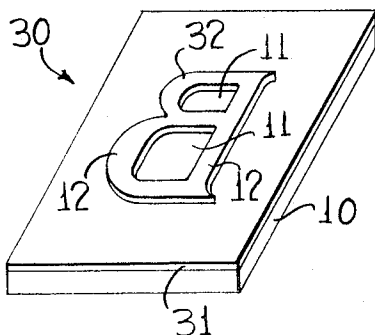


FIG. 5

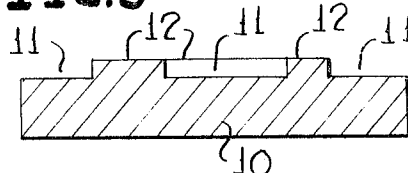


FIG. 6

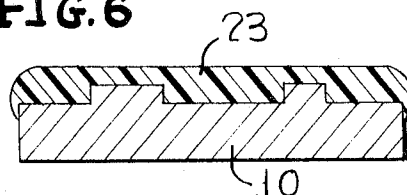


FIG. 2

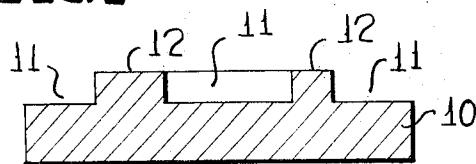


FIG. 7

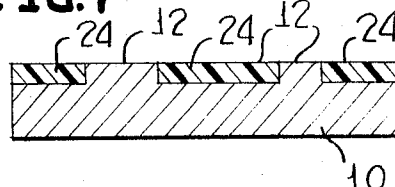


FIG. 3

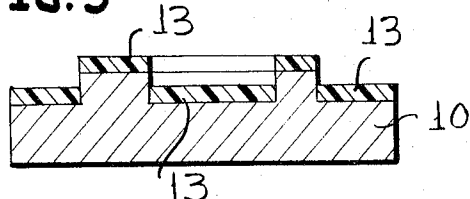


FIG. 8

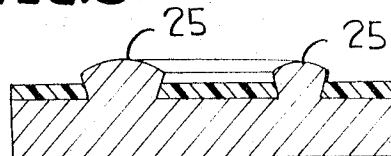


FIG. 4

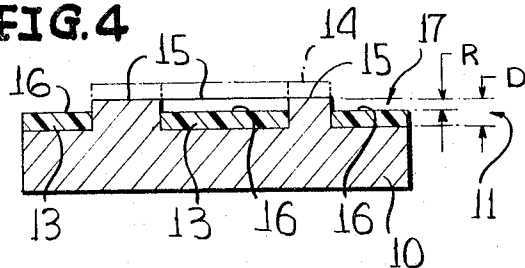
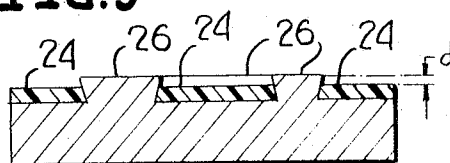


FIG. 9



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FIG. 10

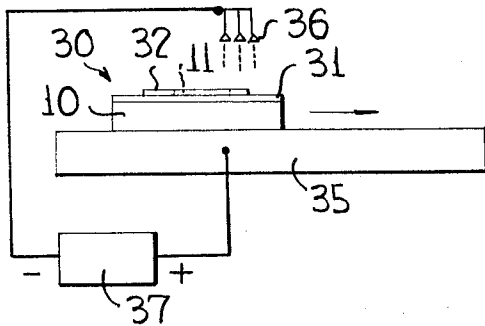


FIG. 11

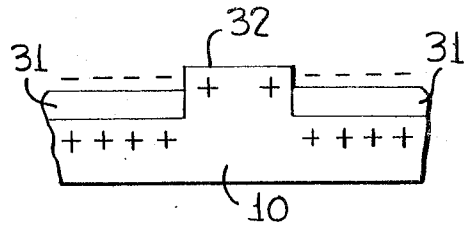


FIG. 12

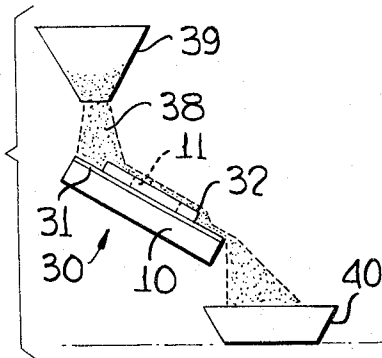


FIG. 13

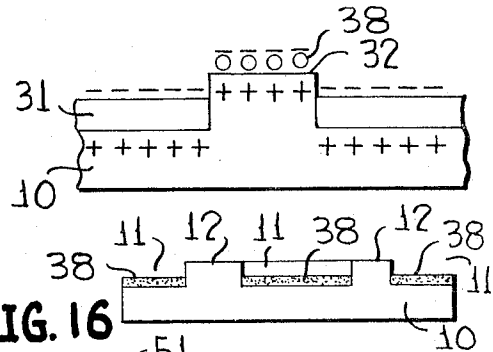


FIG. 14

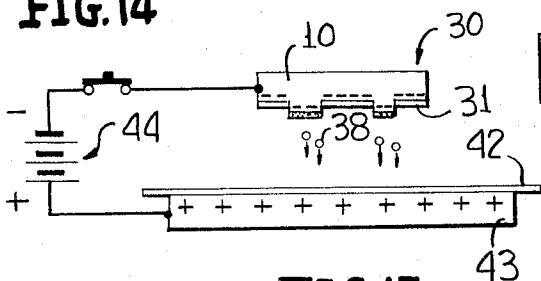


FIG. 15

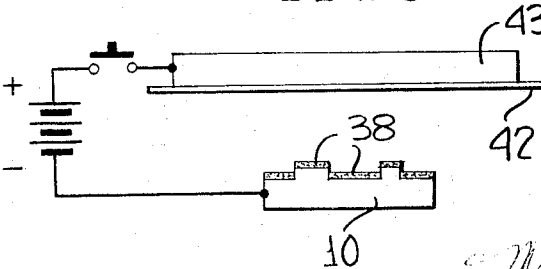


FIG. 16

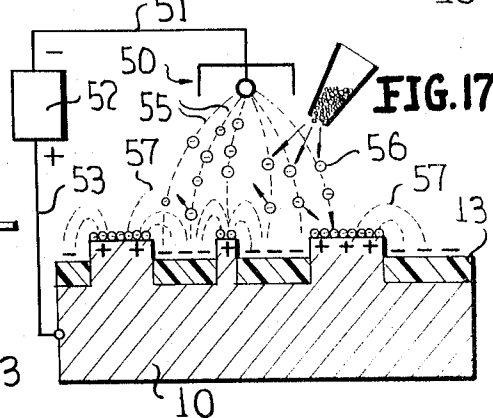
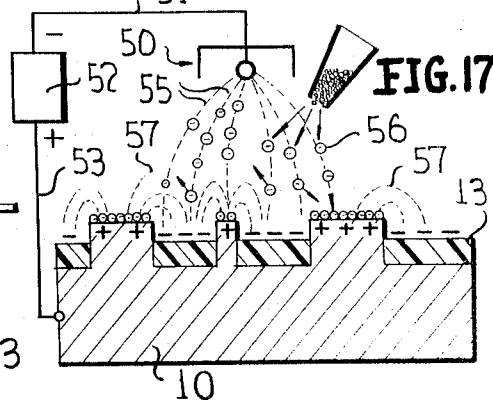


FIG. 17



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ELECTROSTATIC PRINTING PROCESS FOR USE WITH PRINTING PLATE HAVING PLURAL LEVELS

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9 Claims. (Cl. 101-426)

This invention relates to a printing procedure and a printing plate for employment therewith, whereby multiple copies may be printed by an electrostatic operation.

It is known to provide a printing plate having image areas and non-image or background areas, to apply development particles to such a plate whereby they collect on the image areas, and then to effect transfer of the particles to a substrate by employing an electrostatic field. Prior proposals and practices have included the preparation of such a plate of metal, with depressed background areas and elevated image or printing areas, for example by etching; and then filling the depressions or recesses with a non-conductive or dielectric material: the entire plate surface is then exposed to a corona discharge while holding the metal base at a different potential than the corona discharge device. Thereupon, the charges which are delivered upon the dielectric remain in place, while those which encounter the metal areas are dissipated therein and to the conductor thereto. Alternatively, a metal base has received an all-over coating of dielectric and the dielectric has been removed, e.g., by scratching, at the areas which are to form the print image.

It has been found in practice that defects in the dielectric, such as pinholes, scratches, local variations in dielectric by thickness or dielectric constant, and surface contaminations upon the surface thereof, can cause defects in the printing. During printing, usually some of the developer particles remain adherent to the surface of the dielectric and modify its reaction to a later corona charging; and mechanical cleaning of the plate, between printings, does not maintain a satisfactory quality of printing. Each mechanical cleaning increases the probability of scratching the surface.

It has been found that a superior printing effect can be attained by having the image areas provided by base metal, with this surface located closer to the substrate to be printed than the non-image or background areas.

Illustrative practices are shown on the accompanying drawings, in which:

FIGURE 1 is a perspective view of a portion of a composite printing plate;

FIGURE 2 is a section through a metal base being prepared to form a printing plate according to this invention, with raised metal image areas thereon;

FIGURE 3 shows the metal base of FIGURE 2, with a coating of dielectric thereon;

FIGURE 4 shows the base as in FIGURE 3, with the dielectric coating removed from the metal printing areas;

FIGURE 5 is a view like FIGURE 2, of a metal base for practicing another form of the invention;

FIGURE 6 is a view of the base of FIGURE 5, with a thick all-over coating of a dielectric;

FIGURE 7 shows the same, with the surface reduced to the level of the metal surface of the original base;

FIGURE 8 shows the same, with metal deposited upon the exposed metal areas of FIGURE 7;

FIGURE 9 shows the same, with the deposited metal reduced to a smooth surface above the level of the dielectric;

FIGURE 10 is a diagrammatic showing of the charging of a composite printing plate;

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FIGURE 11 is an enlarged section through a portion of a charged printing plate;

FIGURE 12 is a diagrammatic showing of the development of a printing plate;

FIGURE 13 is an enlarged section through a portion of a developed printing plate;

FIGURE 14 is a diagrammatic showing of an operation of printing from a developed plate;

FIGURE 15 is a diagrammatic showing of another printing operation;

FIGURE 16 is a section through another form of printing plate, after printing therefrom.

FIGURE 17 is a diagrammatic showing of simultaneous charging and developing of a composite printing plate.

It will be understood that each figure illustrates a part of the plate being prepared, and that the dimensions have been exaggerated for clearness of disclosure.

The printing plate may be the surface of a roller, or a flat sheet, the latter being illustrated.

In the form of practice according to FIGURES 2 to 4, a base 10, formed of metal or other conductive material, has depressions 11 formed therein, e.g., by etching, routing or other operation, so that elevated metal surface areas 12 exist in the pattern of the image to be printed, while the depressions 11 are to define the background or non-printed areas of the final substrate to be printed. An all-over insulating coating, preferably of uniform thickness, is then applied to the base 10 as a coating 13 which in the depressions 11 is of a lesser thickness than the depth of the depressions. Such a coating 13 may be applied by spraying or brushing an organic enamel composition. A satisfactory composition is one in which the solids are electrically insulating when dried, and which gives a tough adherent coating. Polyesters and acrylic resins have been found suitable, in a volatile organic solvent. When the coating has dried, the portions which overlie the metal image areas, as shown by dotted lines 14 in FIGURE 4, are removed so the metal is exposed.

The resulting printing plate has the metal base 10 with exposed metal image areas 15 where the dielectric portions 14 have been removed, and dielectric coatings in the depressions 11, with the top surfaces 16 of the dielectric coatings at a lower level than the metal areas 15. As is shown in FIGURE 4, the depressions 11 have a depth D, and the difference between the surface of image areas 15 and the top surface 16 of the non-image areas define a recess 17 having a depth R.

The dielectric coating below the surface 16 must be thinner than the depth of the depressions 11 so as to form the recess 17. A dielectric coating as thin or less than one thousandths of an inch can be satisfactory. Depressions 11 should be as deep as possible. A depth of 0.005" produces an appreciable improvement which might be suitable for half tone but further improvements are obtained by increasing the depth to a dimension of $\frac{1}{10}$ of an inch or greater.

In the practice according to FIGURES 5 to 9, the metal base 10 of FIGURE 5 is like that of FIGURE 2, with depressions 11 at background areas, and with the raised metal surfaces 12 providing the pattern or image areas which are to be printed. A thick coating 23 of dielectric material is then applied, preferably to a thickness which is greater than the depth of the cavities; FIG. 6. This may be by a single application of a lacquer as with FIGURE 3, or by successive buildup coatings, or by a fused resin polyester or any suitable dielectric. When hard, the surface of the total plate is then dressed down, as by grinding, to a single level; FIGURE 7. The metal areas are thus bared, while the areas between and around them, i.e., the background areas, are occupied by the dielectric bodies 24. The metal areas 12 are then built up in height, e.g., by electroplating with the

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dielectric bodies 24 providing resists so that no metal is deposited over the background regions, to a greater height 25 which extends well above the surfaces of the background regions. Finally the metal elevations are dressed down to parallelism with the background surfaces, FIGURE 9, to provide the printing image surfaces 26. Thus, the electroplated deposits may extend 20 to 50 mils or more above the background surfaces, and be dressed down to a differential elevation of 15 to 45 mils or to any suitable level between the raised metal and the surfaces of the dielectric.

In the practice of FIGURES 2-4, the metal base 10 must be etched to a depth sufficiently greater than the extending difference of level so that the surface of the dielectric areas 16, FIGURE 4, will be at the desired level below the metal printing areas 15. In the practice of FIGURES 5-9, the etching depth can be less, because the difference in level is provided by increasing the metal thickness above the background levels 24.

The composite printing plate 30 of FIGURE 1 has the conductive or metal base 10 with a layer of dielectric or insulating material 31 thereon at the background or nonprinting portions thereof, such being the residues 16 or 24 of FIGURES 2-9. The image or printing areas 32 are formed of bare conductor as set out for the areas 15 or 26 of FIGURES 2-9.

Printing with such plates can be accomplished as shown in FIGURES 10-14.

In FIGURE 10, the composite plate 30 is being moved over a conductive support 35 in the direction of the arrow, and beneath a source of corona discharge shown as wires 36 extending across the direction of plate movement. The wires 36 may be moved relative to the plate 30, noting that the purpose is to apply charges to the dielectric areas 31. The high voltage source 37 acts to establish a potential difference by which the metal base 10 becomes positive relative to the corona wires 36, and these wires emit electrons and negative ions which move toward the composite plate along paths at right angles to the composite plate. The electrons and negative ions which encountered the exposed metal areas 32 are dissipated and discharged thereat or, in other words, complete the movement of the electric current in circuit back to the source 37. The electrons and negative ions which encounter the insulation areas 31 remain in place thereon, being prevented from continuing in the circuit by the insulating material. The composite plate is thus charged, so that the surfaces of the insulating areas 31 have a resident negative electric charge, i.e., at the background areas from which no printing is to be done, while the body of the metal including the exposed metal areas from which printing is to be done is maintained at a positive potential relative to the charging potential as indicated in FIGURE 11.

The composite plate is then developed by employment of toner particles having a negative charge. This may be done as in FIGURE 12, where the composite plate 30 is positioned at a slope and the toner 38 is delivered from a hopper 39 and allowed to cascade over the plate surface, with the residue being collected in a trough 40. The negatively charged particles are attracted to and held by the metal areas 32, which are maintained at a positive potential that is induced by the negative charge on the surfaces 31, and are repelled from the negatively charged surfaces 31 of insulating material. Several factors acting singly or in conjunction contribute to the force that holds the toner particles to the metal areas depending on the position of the plate in the cycle and the method employed to charge the particles. Among these are image effect, induced electrostatic edge effect, field and corona discharge or other electrostatic field.

It is preferred to employ the toner as smaller particles of non-conductive material in mixture with larger and

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more massive carrier particles of a different material whereby the tribo-electric effect between toner and carrier particles causes the toner particles to become negatively charged and the carrier particles to have a positive charge effect whereby clusters are formed with a positively charged carrier core and electrostatically adherent negatively charged toner particles. When such clusters cascade along the plate surface, toner particles become separated and adhere to the metal areas 32 as in FIGURE 13, while the mass or weight of the carrier particles prevents their remaining electrostatically adherent to the insulation areas 31. Alternatively, the development may be by introducing a cloud of toner particles beneath the corona wires 36, so the particles become negatively charged and are attracted to and deposit upon the metal areas 32, which are maintained at a positive potential with respect to the corona wires 36, but are repelled from the negatively charged insulation areas 31, noting that such corona-charged toner particles are preferably employed after a primary negative corona charging of the areas 31 has been accomplished.

The developed composite plate 30 is then brought opposite a substrate 42 to be printed, as in FIGURE 14. The substrate 42 may be of conductive material such as metal. If the substrate 42 is of dielectric material, e.g., a nonconductor or poor conductor such as paper or a plastic film, it is placed against a back electrode 43. A source 44 is connected to establish an electrostatic field between the base 10 of the composite plate and the surface of the substrate 42, with the substrate positive relative to the base 10. This electrostatic field creates a force on the toner particles 38 which in the case of some of the particles, particularly the particles in the outer layers, exceeds the force attracting the particles to the metal area 32 and, hence, these particles are transferred to the substrate along paths essentially at right angles to the substrate. But it should also be noted, particularly in the case of pressureless contact printing, that toner particles in the outside layers (closest to the substrate) can be transferred to the substrate without any external potential and even against a negative repelling field. This is due to the fact that the imaging forces of the charged particles varies inversely as the second power of the distance, thus higher imaging forces can be obtained toward the substrate than toward the printing drum. Prints made by using a conductive rubber drum and zero transfer voltage have shown the sharpest edges and highest resolution. In practice, with paper, the normal moisture content thereof allows conduction so that the exposed substrate surface, being at the top in FIGURE 14, is at substantially the potential of the back electrode 43.

The toner can then be fixed to the substrate by appropriate means. When the particles include a thermofusible component, this fixation may be by simple heating.

The transfer from composite plate to substrate can be accomplished with the substrate above the plate 10, as shown in FIGURE 15.

In practice, it has been found that good prints can be made from recessed metal plates; where the recessed portions provide the background of the pattern, that is, the areas not to be printed, without the employment of dielectric coverings over the recessed surfaces, when the distance from the bottom of depressions 11 to the substrate is significantly greater than the distance from the raised areas 15 to the substrate. Thus a plate 10, etched as in FIGURES 2 and 5 to a depth of 20 to 50 mils or to any suitable depth for the background areas has been coated with negatively charged toner particles by electrostatic deposition from a cloud of such particles, wherewith a substantially uniform layer of particles 38 is formed on both raised and recessed areas of a plate 10 which is maintained at a positive potential with respect to the repelling electrode or corona wires 36. When a substrate 42 is brought opposite this plate 10 as in FIGURE 15, and a transfer potential drop applied with the metal base

10 negative and the substrate 42 relatively positive, the toner on the raised areas 12 is conveyed to the substrate, while the toner on the recessed portions 11 is not. Thus, as shown in FIGURE 16, after the transfer, the toner remains on the recessed portions 11 while that which was on the raised portions 12 has been expelled. This action occurs because the forces act to move the particles from the plate to a charged substrate surface in such a way as to be very effective when this distance is small and ineffective when the distance is large, such as in the recessed background areas. The magnitude of the force can be stated as:

$$F = C_1 e E_1 / d_1 + C_2 e E_2 / d_2 - C_3 e^2 / d_3^2 + C_4 e^2 / d_4^2$$

Where:

F = Transfer force (grams).

C_1, C_2, C_3 and C_4 are constants.

e = Charge of the toner particle (coulombs).

E_1 / d_1 = Transfer potential gradient between the center of the particle and the transfer electrode or conductive substrate (volts/cm.).

E_2 / d_2 = Potential gradient between the center of the particle and the printing plate, which voltage and gradient are produced by the induced electrostatic field of the charged-up dielectric.

d_3 = Diameter of the particle (cm.).

d_4 = Double of the distance between the center of the particle and the substrate.

It is to be noted that if the particle is in a recessed portion 11 of the printing plate or drum 10, d_4 is so big that $C_4 e^2 / d_4^2$ can be neglected; E_1 / d_1 is so small that it can also be neglected; thus, the equation for this case can be written:

$$F_{\text{Recess}} \approx C_2 e E_2 / d_2 - C_3 e^2 / d_3^2$$

On the other hand, when the particle is on the printing surface, almost touching the substrate, we can presume that $d_3 = d_4$; thus:

$$C_4 e^2 / d_4^2 - C_3 e^2 / d_3^2 \approx 0$$

Furthermore, there is no dielectric in this case and $E_2 / d_2 = 0$; thus:

$$F_{\text{Print}} \approx C_1 e E_1 / d_1$$

Therewith the potential between a toner particle on a raised area and the substrate, as compared with that between a toner particle on a recessed area, is so large that the particle on the raised area is transferred while the particle on the recessed area remains held to the metal plate 10. With reasonable depths of etched recesses and spacing of the substrate from the printing plate, the forces differ by more than an order of magnitude.

This latter practice has been found useful with smooth-surfaced metal substrates, and with smooth paper substrates in which the humidity conduction factor is high so that the transfer potential is essentially that between the adjacent surfaces of substrate and printing plate, noting that therewith the thickness of the substrate can be neglected in computing the voltage gradient.

The practices according to FIGURES 2 to 9 can be employed with rougher-textured substrates, where parts of the substrate surface may be at greater distances from the raised metal areas than other parts are from depressed metal areas. The thin dielectric layers, with repellent electric charges thereon, greatly reduce the amount of toner adherent to the background or non-image areas defined thereby, and clean and sharply defined prints are produced. After each use, there is a residue of toner particles upon such areas, having been held by forces other than merely electrostatic attraction. The composite plates are easy to clean, by a long-haired brush, by airblast, or the like, without requiring a vigorous wiping or scraping action which could cause scratchnig.

A factor for selecting between the practice of FIGURES 2-4, and that of FIGURES 5-9, is that of the width of

lines to be printed. With FIGURES 2-4, the widths of metal areas 12 is determined during the etching; with FIGURES 5-9, the area increases due to the widening of the metal area during electroplating, as shown in the drawings. When very thin lines are required, the practice of FIGURES 2-4 is preferred. For wider lines and areas, the practice of FIGURES 5-9 is preferred, allowance being made for the widening, e.g., by etching the adjacent recesses so that the metal area 12 of FIGURE 5 is narrower than the printing to be done therefrom.

FIGURE 17 shows a corona discharge device 50 which is energized by the negative terminal 51 of a power supply 52 which has a positive terminal 53 connected to the base metal of the printing plate 10. This results in the position of negative charges on the surface of the dielectric coating 13, which negative charges induce positive charges on the metal surface areas 12 immediately adjacent to the dielectric coating 13. The electrostatic field created between the corona discharge device 50 and the printing plate 10, which electric field is indicated by the dotted lines 55, propels toner particles 56 to the metal surfaces of the printing plate 10 even in the absence of the electrostatic charge induced in the metal portions by the negative charge on the dielectric coating 13. This negative charge prevents deposition of toner particles upon the dielectric coating 13 and causes toner particles 56 to be repelled therefrom and be directed instead to the metal surface of the printing plate 10, as is indicated by the dotted lines 57. The corona discharge device 50 thus has two functions; one function is to charge the toner particles 56, and the other function is that of a development electrode for charging the printing plate 10.

The above embodiments have been set out for the employment of toners having negative charges. It will be understood that positively charged toners, with or without negatively charged carrier particles, can be employed by employing a positive charging of the dielectric areas 31, e.g., by reversing the connections from the source 37 to the corona wires 36 and to the base 35. Likewise, the printing plates 10 need not be planar, but can be cylindrical; wherewith the difference in levels between raised and recessed portions is the radial distance between the cylindrical surface including the raised portions and the surface including the recessed portions.

The illustrative embodiments are not restrictive, and the invention may be practiced in other ways within the scope of the appended claimed subject matter.

What is claimed is:

1. The method of electrostatic printing, which comprises preparing a printing plate of conductive material having raised image areas and recessed background or nonprinting areas, holding the plate at one polarity and applying to both the raised image areas and recessed background areas a toner comprising particles charged to the opposite polarity, bringing a substrate to be printed to a position opposite to the raised and recessed areas of the plate, and applying a potential difference between the substrate and the plate which establishes forces upon the toner particles on raised areas of the plate adequate to cause the particles to leave the same, said potential difference being selected to be too low to establish forces upon the toner particles on recessed areas of the plate adequate to cause the latter toner particles to leave the recessed areas.

2. The method of electrostatic printing, which comprises preparing a printing plate of conductive material having raised image areas and recessed background or nonprinting areas, said recessed areas having a dielectric layer thereon, the exposed surfaces of said layers being below the levels of the adjacent raised portions of the plate, holding the plate at one polarity and applying to both the raised image areas and recessed dielectric layer, a toner comprising particles charged to the opposite polarity, bringing a substrate to be printed to a position opposite to the raised and recessed areas of the plate, and apply-

ing a potential difference between the substrate and the plate which establishes forces upon the toner particles on raised areas of the plate adequate to cause the particles to leave the same, said potential difference being selected to be too low to establish forces upon the toner particles on recessed areas of the plate adequate to cause the latter toner particles to leave the recessed areas.

3. The method of claim 2, in which the plate is prepared by forming the recesses, applying the dielectric over both recessed and raised portions to a thickness less than the difference in levels of the raised and recessed areas, and then removing the dielectric from the tops of the raised areas.

4. The method of claim 2, in which the plate is prepared by forming the recesses, applying the dielectric over both recessed and raised portions, then removing the dielectric from the tops of the raised areas, and depositing metal upon the bared raised areas.

5. The method of claim 4, in which the dielectric is applied in a thickness greater than the difference in levels of the recessed and raised portions, the dielectric is then removed to a common level with the raised portions exposed, the metal is then deposited to a level above said common level, and the deposited metal is then dressed to a uniform level.

6. The method of claim 2, in which an electrostatic charge of the same polarity as the charged toner particles is deposited on the surface of the recessed dielectric so as to repel toner particles therefrom in order to reduce the number of toner particles and the number of layers of toner particles so that the imaging forces in the direction of the printing plate in the recessed area greatly exceed the imaging forces in the direction of the substrate.

7. The method of developing a printing plate comprising the steps of providing a printing plate having raised image areas formed of electrically conductive material and recessed non-image areas covered with dielectric material, exposing the printing plate to a corona discharge having a predetermined polarity, and simultaneously introducing toner particles into the zone of the same corona discharge, said corona discharge charging said toner particles and said dielectric material to the same polarity whereby toner particles are repelled by said dielectric material.

8. The method of electrostatic printing which comprises the steps of, preparing a printing plate of conductive material having raised image areas and recessed non-image areas, said non-image areas having a dielectric layer thereon, exposing the printing plate to a corona discharge having a predetermined polarity, developing said printing plate by introducing toner particles into the zone of the same corona discharge for charging said toner particles and said dielectric material to said predetermined polarity whereby toner particles are applied to said image areas and repelled by said dielectric layer on said non-image area; bringing a substrate to be printed to a position opposite to the image areas and non-image areas of the plate; and creating a potential difference between the substrate and the printing plate for applying forces upon the toner particles to cause the toner particles to be transferred from the image areas of said printing plate to the substrate.

9. The method of claim 8 wherein the conductive material of said printing plate is held at a polarity opposite to the predetermined polarity of the corona discharge during exposing of the printing plate thereby; and wherein the exposing of the printing plate and the developing of the toner particles are performed simultaneously.

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