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HIROOMI SAWADA ET AL
ELECTROSTATIC PRINTING APPARATUS WITH INKING
MEANS BETWEEN ELECTRODES
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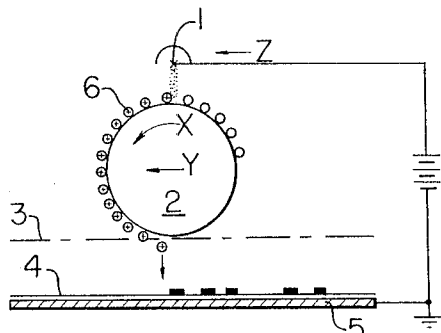


Fig. 1

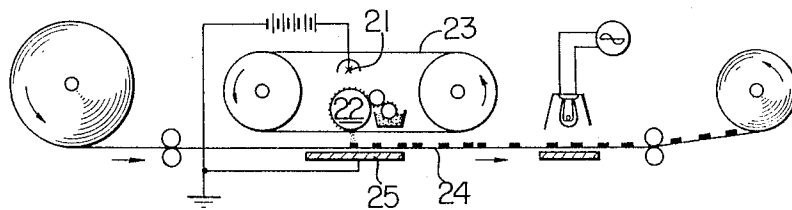


Fig. 2

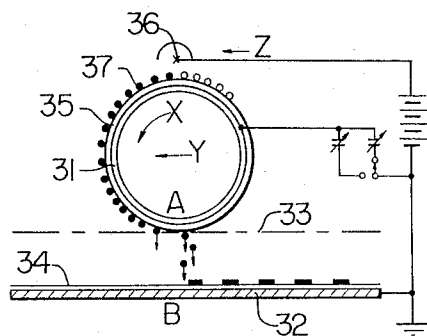


Fig. 3

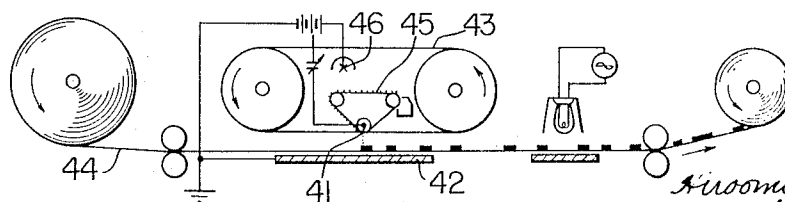


Fig. 4

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**ELECTROSTATIC PRINTING APPARATUS WITH
INKING MEANS BETWEEN ELECTRODES**

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This invention relates to a method of printing by means of electrostatic force and an apparatus therefor. More particularly, the invention relates to a method of printing which comprises positioning below a stencil the material to be imprinted, bringing electrically charged powdered ink close to the stencil, having a particle size such that it can pass through the open areas of the stencil and by utilizing the electrostatic force which acts between the electrically charged powdered ink and the material to be imprinted, causing the adherence of the former to the latter via the stencil in accordance with the pattern of said stencil; and to a suitable apparatus to be used in such a method.

Numerous methods of imparting print to material to be imprinted are known, screen printing being one of them. However, in accordance with the conventional printing methods, inclusive of the usual screen printing methods, there was always required a certain amount of printing pressure. Hence, when the surface unevenness of the material to be impressed was pronounced, it was impossible to impart precise print to such a material.

An object of this invention is to provide a printing method and apparatus, which do not have the hereinbefore noted shortcoming.

Other objects of this invention will in part be obvious and will in part appear hereinafter.

These objects of the invention can be achieved by an operation and apparatus based on the following theory.

When powdered ink is temporarily adhered to the surface of a carrying member, say, a roller, which has the function of carrying powdered ink and conveying it, an electric charge is imparted thereto by means of corona discharge, following which the roller is rotated to bring the electrically charged powdered ink on the roller surface close to the material to be imprinted. The powdered ink separates from the roller by means of the electrostatic force which acts between the powdered ink and the material to be imprinted, when the electrostatic force becomes greater than the adhering force of the powdered ink to the roller and become transferred to the material to be imprinted. Now, by interposing a stencil between the roller and the material to be imprinted, part of the powdered ink which has left the roller pass through the open areas of the stencil while the passage of others are blocked, with the consequence that a print is obtained on the material to be imprinted which is a configuration of the pattern of the open areas of stencil. Further, by affording mechanically a start to the transfer of the powdered ink, its transferability is enhanced. The transferability is increased also by the provision behind the rear side of the material to be imprinted, of a grounded electrode plate or an electrode plate charged with a polarity opposite to that of the corona discharge electrode. However, when the material to be imprinted is one which, per se, possesses a great electric capacity, the transferability is excellent even though such an electrode is not provided.

As the powdered ink, preferred is the use of a pigmented resin powder such as the developer used in electrophotographic process. After these have been adhered

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to the material to be imprinted, they can be readily fixed thereto by means of heat or a solvent. Further, it is also possible to use a powdered carrier, such as a clay calcium carbonate, alumina, to which dyes have been adhered temporarily, and after transferring this from the carrying member to the material to be imprinted, to fix this alone to the material, while eliminating the carrier.

As the carrying member, a means so set up by use of a material whose surface is such that it can temporarily adhere and carry the powdered ink, e.g., such as felt, flannel, velvet, astrakhan, mohair, shaggy, pile, brush, nonwoven fabric, woolen knit goods, buckskin, sponge and synthetic rubber foam, will do. As an example, there can be used a roller whose surface is wrapped with these materials or an endless felt made of these materials.

While preferably the screen stencil is made of material being relatively well insulated, such as silk and the polyamide and polyester fibers, metal screens can also be used. The preparation of the printing stencil can be done by the various methods that are usually practiced in screen printing. When a high precision print is not required, i.e., when the invention method is to be employed for, say, a simple stamping, the stencil may be simply a stencil of paper. The stencil and the material to be imprinted can be disposed in spaced relationship to each other, for example, with a clearance of from 1 mm. to 1 cm. This is an important feature of this invention, and it is for this reason that the printing can be accomplished accurately, though no printing pressure at all is applied to the material to be imprinted. In this respect, the present invention can be regarded as having transcended the conventional concept of printing. It is, of course, permissible to dispose the stencil and the material to be imprinted in intimate contact with each other. When it is intended to imprint an exact reproduction of the pattern of the stencil, the stencil and the material to be imprinted must be placed in parallel to each other, but when it is desired to distort the pattern, the material to be imprinted can be disposed obliquely with respect to the stencil or in a distorted position. In any event, however, it is preferred that the two are maintained in a substantially parallel relationship to each other.

The accompanying drawings FIGS. 1, 2, 3 and 4 are schematic views illustrating embodiments of the apparatus and method of the present invention. The invention will be fully described below with reference to these drawings.

In FIG. 1, a roller 2, which, while rotating in the direction of arrow X, is adapted to roll in the direction of arrow Y, is employed. Carrying roller 2 is equipped with a suitably designed feed means (not shown) by which the roller surface is fed constantly with a fresh supply of powdered ink 6 from a conventional powdered ink feeding means (not shown). Corona discharge electrode 1 also is so designed that it is movable in the direction of arrow Z synchronously with the travel of carrying roller 2 in a horizontal direction (direction of arrow Y). These are, of course, adapted to roll, turn back and move in the opposite direction as well. Material to be imprinted 4 is placed below stencil 3 in parallel thereto, and below the material to be imprinted 4 is placed an electrode plate 5. Now when this apparatus is placed in operation, powdered ink 6 carried by carrying roller 2 receives a charge by means of a discharge from corona discharge electrode 1 in the vicinity of a point where it has approached nearest to the electrode and then approaches the material to be imprinted 4 with the rotation of carrying roller 2. When the charged powdered ink 6 contacts stencil 3—or due to the electrostatic force which acts between the powdered ink and the material to be imprinted 4, minute as it is—it leaves carrying roller 2, passes through the open areas

of the stencil 3, and adheres to the material to be imprinted 4 to accomplish the printing. Hence, in accordance with the embodiment shown in FIG. 1, printing is accomplished on the material to be imprinted progressively as the carrying roller is rotated.

The apparatus can be designed so that the stencil is forcibly charged by means of such as, for example, a battery, electric capacitor, or other suitable means so that a constant potential is maintained at all times. By designing the apparatus in this manner, a control can be had over the amount adhered of the powdered ink. The material for the stencil and screen should be chosen from those having high conductivity such as the metals when an electric potential is to be applied, but otherwise those of relatively high resistivity such as silk, nylon and polyesters are preferred.

The deposited powdered ink is then fixed to the imprinted material by means of heat or solvent vapor.

While the embodiment described with reference to FIG. 1 is the so-called sheet-by-sheet printing method, the invention method can also be applied to the continuous, high speed printing method. FIG. 2 shows one example of such an embodiment. Stencil 23 is made up in an endless belt fashion, and the carrying roller 22 and corona discharge electrode 21 are disposed in such a fashion as to be encompassed by stencil 23. Material to be imprinted 24 is moved continuously in the arrow direction slidably over electrode plate 25. Stencil 23 is rotated in the arrow direction, its speed being synchronized with that of the travel of the material to be imprinted 24. Carrying roller 22 also is rotated, the powdered ink successively fed thereto as it rotates by a conventional powdered ink feeding means 22a and being charged by means of a discharge in the neighborhood of corona discharge electrode 21. The powdered ink then is conveyed to the surface of stencil 23 from which it is transferred to the material to be imprinted 24, thus carrying out the printing operation continuously. The imprinted material then, after proceeding through the fixing step, is either wound up or cut.

When the printing operation is carried out in accordance with the methods of FIGS. 1 and 2, the opportunity for the powdered ink to leave the carrying roller is afforded by its contact with the stencil. Thus, even after the powdered ink has passed through the stencil, it is subjected to the influence of its scattering angle. Hence, when the clearance between the stencil and the material to be imprinted is great, there is a tendency for the print to become indistinct. This type of trouble can be prevented by doing as follows. Namely, the stencil and the material to be imprinted are interposed between two electrodes that face each other. The powdered ink carrying member which is connected to a drive means by which it is driven is so disposed between the stencil and the electrode on the stencil side as to be capable of continuously circulating therebetween. Then, after setting up an electrostatic field between the two electrodes, the carrying member, which is caused to circulate, is temporarily adhered with the powdered ink, followed by charging the powdered ink with a corona discharge. The powdered ink which has a charge is then conducted along with the carrying member to above the stencil where the powdered ink is moved towards the material to be imprinted under the influence of the electrostatic field between the two electrodes and is adhered to the material to be imprinted through the intermediary of the stencil. This embodiment of the present invention will be described with reference to FIG. 3.

In FIG. 3, 31 is the electrode on the stencil side while 32 is the electrode on the material-to-be-imprinted side, the electrostatic field being set up at that part between A and B. Stencil 33 and the material to be imprinted 34 is interposed in parallel fashion between the two electrodes 31 and 32. Since electrode 31 on the stencil side is formed by providing a conductive layer on the roller, by wrapping carrying member 35 about the electrode 31,

as the roller is rotated the former circulates between the latter and stencil 33. Corona discharge electrode 36 is disposed close to the carrying member. Corona discharge electrode 36 and electrodes 31 and 32 are suitably connected to a direct current source, the grounding thereof being required. In FIG. 3, as the roller which carries carrying member 35 and electrodes 31 on the stencil side is rolled in the direction of arrow X or in the reverse direction, it is rolled over the stencil in the direction of arrow Y or the reverse direction. Hence, corona discharge electrode 36 is also designed to travel in the direction of arrow Z or in reverse synchronously with the foregoing movement of the roller. It is of course also permissible to dispose a plurality of the corona discharge electrodes in line.

When this apparatus is started up, first powdered ink 37 is fed from a feed means (not shown), then by being conveyed by means of the rotation of the roller receives a charge in the vicinity a point where the roller has come close to corona discharge electrode 36, and thereafter conveyed onto stencil 33. When the roller comes into contact with stencil 33 or immediately theretofore, powdered ink 37 starts to leave carrying member 35, pass through the open areas of the stencil 33 and become transferred to the material to be imprinted. Although the powdered ink is subjected to such other external forces as its contact with the stencil and other forces besides merely the electrostatic force, the external forces are practically all eliminated by the influence of the electrostatic field between A and B, with the consequence that the powdered ink passes through stencil 33 perpendicularly and becomes adhered to the material to be imprinted 34. Thus, the printing is accomplished accurately in conformance with the pattern of the stencil.

While the electrode on the stencil side in FIG. 3 is provided by wrapping a conductive layer about the roller, needless to say, when the roller itself is a conductor, it can be used as the electrode. However, when the roller itself is impressed with a voltage as in this case, there is the inconvenience that it must be completely insulated from the other means which are connected thereto. Hence, even in those cases where the roller itself is a conductor, it is more convenient to wrap an insulator about it and then provide the conductive layer about this insulating material. This conductive layer (the electrode on the stencil side) usually consists of a metallic foil, though it also may be formed by means of a paste of such as carbon, copper, silver, etc. In those cases where the carrying member is made up in endless belt fashion, the stencil side electrode can be made up into a plate, roller or other optional forms. Alternatively, by providing the whole of the backside of the carrying belt with a conductive layer, this may be made to serve as the stencil side electrode.

The electrode on the material-to-be-imprinted side is conveniently made up in plate fashion, whereupon the material to be imprinted is placed. However, when the material to be imprinted has a sufficiently great electric capacity or when it is a conductor and is grounded, since the material to be imprinted itself functions as the opposite electrode of that on the stencil side, it can be made to serve as the electrode without the need for especially providing a back plate. As the opposite electrode of that on the stencil side, the earth or that having an electric capacity sufficiently equivalent thereto can be chosen. That is to say, the electrode on the material-to-be-imprinted side does not necessarily have to be one which has been provided artificially. In general, however, it is preferred to provide an electrode plate whereby the material to be imprinted is grounded as well as to make it possible to charge the material to be imprinted suitably by utilizing conduction or electrostatic induction.

The intensity and direction of the electrostatic field to be formed between the two electrodes must be determined to conform with the magnitude and polarity of the charge

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imparted to the powdered ink. The electrostatic field contributes to the property of the powdered ink to proceed in a straight line as well as in regulating its transferability. For example, if the stencil side electrode is charged with same polarity as that of the powdered ink and the direction of the electrostatic force acting between the two electrodes faces towards the electrode on the material-to-be-imprinted side, the transferability of the powdered ink becomes markedly good. On the other hand, if the polarity of the stencil side electrode is opposite to that of the powdered ink and the direction of the electrostatic force between the two electrodes faces towards the stencil side electrode, the transfer of the powdered ink is greatly inhibited, if not completely prevented. Consequently, if the applied voltage is regulated between the electrodes, the desired transferability can be obtained and the tone of the print becomes controllable.

As the printing according to this invention is accomplished electrostatically, the time required for the actual transfer of the ink is very short, if the mechanical functions are considered separately. Thus, according to the invention method, it becomes possible to carry out ultra high speed continuous printing operations. Continuous printing can be practiced, for example, by means of an apparatus such as shown in FIG. 4.

In FIG. 4, a stencil 43 is made up in an endless belt fashion, and provided such as to be encompassed thereby are endless belt-fashion carrying member 45 and corona discharge electrode 46. Carrying member 45 is supported by three rollers, one of the rollers 41 being impressed with a D.C. voltage, thus functioning as the electrode on the stencil side. Beneath stencil 43 and vis-a-vis the stencil side electrode is provided the material-to-be-imprinted side electrode 42. The material to be imprinted 44, being delivered continuously from a hoop, is conveyed in the arrow direction slidably over the material-to-be-imprinted side electrode. The speed at which the material is conveyed is preferably a speed in synchronism with the rotating speed of the stencil.

The powdered ink is fed to carrying member 45 by powdered ink feeding means 45a and is discharged by means of the discharge from corona discharge electrode 46 and then conveyed to between stencil 43 and the stencil side electrode 41. The powdered ink is here, under the influence of the electrostatic field produced by the two electrodes 41 and 42, transferred by means of the electrostatic force to the side of the material to be imprinted to accomplish the printing. After completion of the printing, the imprinted material 44, after passing through a fixing means, is either wound up or cut.

As fully described hereinabove, the present invention concerns a screen printing method which utilizes electrostatic forces. The point in which the invention method differs from the conventional screen printing method is in that it can make an impression without contact or application of pressure. The fact that printing can be done without application of pressure, i.e., that an accurate impression can be made with the powdered ink advancing in a straight line though there is some distance separating the stencil from the material to be imprinted, means that precision printing can be done even though the material to be imprinted in one whose surface unevenness is unusually great. Further, the fact that printing can be done without application of pressure means that those material which are easily susceptible to deformation by means of stress can also be imprinted. Thus, in accordance with this invention, those materials which were hitherto regarded as impossible of being imprinted, such as sponge, fabric, nonwoven fabric, paste, vegetable, fruit, slate, foamed concrete, etc., can also be imprinted. For example, letters smaller than 10 points can be printed with accuracy and beauty on such as 40-count broadcloth, corrugated nylon pile having piles 1 mm. long, embossed fabrics, etc., even though the material to be imprinted

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is separated by a distance greater than 5 mm. Further, although it is impossible by the usual methods to print letters of less than 2-3 cm. on the surface of, say, light weight foamed concrete known by the trade name of Siporex because of the unusual unevenness of its surface, in accordance with the invention method, since the ink adheres accurately along the uneven portions, the printing of letters of the order of 1.2-1.5 mm. becomes possible. When the surface of the material to be imprinted is smooth and flat, needless to say, still finer printing can be accomplished. For example, in the case of such as glass, ceramics, metal, plastics and coated paper, the printing accurately of letters less than 0.8 mm. is also possible. Particularly, in the case where the mode employed is that in which the powdered ink is transferred in a electrostatic field, this straight-line advancing property of the ink is enhanced, with the consequence that the precision of printing is further enhanced. Hence, it becomes possible to accomplish the multicolored printing of photographs, which compares favorably with those obtained conventionally.

What is claimed is:

1. An electrostatic printing method which comprises positioning a material to be imprinted on one side of an uncharged stencil, placing an electrode plate adjacent the side of the said material to be imprinted remote from said stencil, bringing into contact with the stencil a powdered ink carrying member capable of moving past said stencil, providing another electrode on the opposite side of the ink carrying member from the stencil and which is electrically insulated from the said carrying member in the neighborhood of the point where the said carrying member comes into contact with the stencil in a position such that the electrode is opposed to the electrode plate beneath the material to be imprinted with the stencil and the material to be imprinted between the electrode and electrode plate, establishing a potential difference between the electrode and the electrode plate, supplying a powdered ink to the said carrying member, electrically charging the powdered ink on the said carrying member by applying a corona discharge thereto, bringing the said charged powdered ink onto the stencil by moving the said carrying member, and passing the said powdered ink through openings of the stencil by means of an electrostatic force which acts between said powdered ink and said material to be imprinted, whereby the said ink is adhered to the said material in accordance with the pattern of the stencil.

2. An electrostatic printing apparatus comprising a rolling powdered ink carrying member, powdered ink feeding means associated therewith for feeding powdered ink to said carrying member, a corona discharge electrode adjacent said carrying member for charging said powdered ink carried by said carrying member, an uncharged fixed stencil over which said carrying member rolls, an electrode disposed on the opposite side of said carrying member from the said stencil and being electrically insulated from said carrying member, an electrode plate disposed on the other side of said stencil from said carrying member, said electrode plate being adapted to have the material to be imprinted placed thereon, and means coupled to said apparatus for establishing a potential difference between said electrode plate and the ink on said carrying member.

3. An electrostatic printing apparatus comprising a rotating powdered ink carrying member, powdered ink feeding means associated therewith for feeding powdered ink to said carrying member, a corona discharge electrode adjacent said carrying member for charging the powdered ink carried by said carrying member, an uncharged stencil traveling in endless fashion adjacent to said rotating carrying member, an electrode disposed on the opposite side of said carrying member from said stencil and being electrically insulated from said carry-

ing member, an electrode plate on the other side of said stencil from said carrying member, means for carrying the material to be imprinted slidingly over said electrode plate, and means coupled to said apparatus for establishing a potential difference between said electrode 5 plate and the ink on said carrying member .

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