Electrostatic transfer of charged particles to a transfer member is accomplished using a roller electrode composed of an electrically conductive core or base having an electrically relaxable primary layer, a self-leveling secondary layer superimposed thereover, said layers being substantially hermetically sealed by a third overcoat layer. The overcoat layer is composed of a polymeric material having a low water vapor permeability constant such that the lower layers of the roll will be rendered insensitive to abrupt humidity changes and consequent electrical instability.
MOISTURE STABLE BIAS TRANSFER ROLL

BACKGROUND OF THE INVENTION

This invention relates to electrophotography, in particular, to an electrically stable apparatus for transferring toner images from one surface to another. In conventional electrophotographic xerography, a photosensitive plate, which consists of a photosensitive coating placed over a conductive backing, is charged uniformly and the charge plate then exposed to a light image of an original. Under the influence of the light image, the charge on the plate is selectively dissipated to record the original input scene information on the plate in the form of a latent electrostatic image. The latent image is developed, or made visible, by applying oppositely charged toner particles to the plate surface in a manner so that the toner particles are attracted into the imaged areas. The developed images are generally transferred from the photosensitive material, such as paper or the like, and affixed thereto to form a permanent record of the original.

Historically, the transfer of toner images between supporting surfaces is accomplished with the electrostatic transfer of either a corotron or a roller electrode biased to constant potential (constant voltage) levels. In corona induced transfer as, for example, disclosed in U.S. Pat. No. 2,836,725, the final support sheet is placed in direct contact with the toner image while the image is supported on the photosensitive surface. The back of the sheet, that is, the side away from the image, is sprayed with a corona discharge having a polarity opposite to that carried by the toner particle causing the toner to be electrostatically transferred to the sheet. Biased roll transfer has been tried with some limited success as a means of controlling the forces acting on the toner during transfer. This type of transfer is disclosed by Fitch in U.S. Pat. No. 2,807,233 and involves the use of a metal roll coated with a resilient coating having a resistivity of about 10^6 to 10^7 cm. Because of the resistivity of the coating, the amount of bias that can be applied to the roll is limited to relatively low operating values because, at the higher ranges, the air in and about the transfer zone begins to break down, i.e., ionizes causing the image to be degraded during transfer. Shellfio in U.S. Pat. No. 3,520,604, suggests that the resilient coating have a resistivity of between 10^11 to 10^12 ohms cm. Here, in order to give the roll the needed resiliency required in most practical applications, the coating must be relatively thick. A thick coating of high resistivity acts to build up a surface charge on the roll resulting in break down in the transfer region and eventually copy degradation. More recently, improved bias transfer members have been disclosed which overcome many of the electrical and image degradation problems associated with some previous transfer techniques. U.S. Pat. No. 3,702,482 discloses a multiple layer transfer roll member for transferring xerographic images under controlled conditions. The member is capable of electrically cooperating with a conductive support surface to attract charged toner particles from the support surface towards the member or towards a transfer material such as paper positioned there between, the member having a conductive substrate for supporting a biased potential thereon, an intermediate blanket (primary layer) placed in contact with the substrate to the outer periphery of the blanket and a relatively thin outer coating (secondary layer) placed over the blanket having an electrical resistivity to minimize ionization of the atmosphere when the transfer member is placed in electrical cooperation with the image support surface and providing a good toner release property enabling the device to be cleaned of said toner. U.S. Pat. No. 3,781,105 discloses a simulator transfer member employed in conjunction with a variable electrical bias means for regulating automatically the electrical field levels at various points on the transfer member during the transfer operation and providing constant current control.

In the preferred embodiment, the transfer member disclosed in the aforementioned two U.S. patents consists of a roller having a central biasable conductive core further having an intermediate blanket or electrically "relaxable" layer (primary layer) surrounding and in electrical contact with the core, and further having a second blanket or electrically "self-leveling" outer layer (secondary layer) surrounding and in electrical contact with the primary layer. Under operating conditions, it is desirable for optimum transfer to maintain a relatively constant current flow of less than about 30 microamps in the nip area between the transfer roll surface, transfer material, and photosensitive surface from which a developed image is to be transferred. For this condition to exist at given potentials, the resistivity of the primary and secondary layers must lie within critical values and preferably be relatively constant under normal anticipated extremes of operating conditions. Preferably, it has been found that the primary layer should be a resilient elastomeric material having a volume resistivity within the range of 10^10 to less than 10^14 ohm cm, and the secondary layer should also be a resilient material having a volume resistivity within the range of 10^12 to 10^10 ohm cm.

In practice it has been found that elastomer materials used in the transfer member such as polyurethanes which exhibit resistivities within the above ranges are moisture sensitive such that resistivity may vary by as much as a factor of 50 between 10% and 80% R.H. as a function of the amount of moisture absorbed from or lost to the surrounding atmosphere. For example, in the case of polyurethane materials which are employed as the primary layer and which have exceptionally good electrical characteristics, the volume resistivity may change from 10^14 ohm cm at low moisture contents, i.e., less than about 0.1% moisture, to 10^6 ohm cm at higher moisture levels, i.e., about 2.5% moisture. Other polyurethanes suitable for use as the secondary layer exhibit resistivity variations from about 10^10 to 10^12 ohm cm as a function of increasing moisture content. The consequent variations in resistivity will ordinarily give rise to erratic performance of the transfer member from day to day particularly in terms of transfer efficiency unless compensated for by a concomitant change in the voltages sufficient to maintain a constant nip current, as disclosed in U.S. Pat. No. 3,781,105.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a bias transfer roll for use in a xerographic transfer process which is more electrically stable over extremes of relative humidity encountered under operating conditions. Another object is to maximize image quality and transfer efficiency in effecting transfer of toner from a
3,920,325

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photonsensitive surface to a transfer surface. These and other objects of the present invention are accomplished using a bias transfer member comprising a conductive core, an electrically relaxable primary layer laminated thereto, a self-leveling secondary layer superimposed thereover, and a third overcoat layer which substantially hermetically seals said primary and secondary layers. The overcoat layer is composed of a polymeric material with a low water vapor permeability constant such that the transmission of moisture through to said primary and secondary layers is severely retarded. The thickness of the layer should be such that the dielectric breakdown strength of the material is exceeded under operating transfer conditions.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a partial section of the preferred bias transfer roll of the present invention. FIG. 2 is a graph showing a typical relationship between resistivity and moisture content of an elastomeric polyurethane material. FIG. 3 is a graph comparing fluctuations in moisture content of transfer rolls having no overcoat vs. overcoated rolls.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary transfer roller 10 shown in FIG. 1 includes a central conductive core or axle 11, which is preferably a hollow cylindrical tube of conductive aluminum, an electrically "relaxable" primary layer 12, an electrically "self-leveling" secondary layer 13 and an overcoat layer 14 composed of a polymeric material exhibiting a low water vapor permeability constant. Thicknesses of the various layers shown in the drawing are not necessarily to scale but merely illustrative.

Polymeric materials suitable for use as the transfer roll overcoat layer 14 according to the present invention broadly include those materials which exhibit a water vapor permeability less than the water vapor permeability of the materials used in the primary and secondary transfer roll layers, e.g., polyurethane. Since the main purpose of the overcoat material is to prevent or minimize moisture transmission from the external environment to the moisture sensitive primary and secondary layers, and since the maximum thickness of the overcoat is limited for electrical reasons as hereinafter disclosed, polymeric materials exhibiting very low water vapor permeabilities are much preferred. This would encompass polymeric films having a water vapor permeability constant (P) of less than about 1 x 10^-8 at about 30°C., where P is expressed by the relationship: P=(ml at STP) (cm²)/(sec.) (cm Hg). In this equation (ml at STP) refers to ml of H₂O absorbed at Standard Temperature and Pressure, (sec.) refers to a given length of film, (cm) refers to time and (cm Hg) is pressure. Materials satisfying the above criteria include low density polyethylene and other polymers which exhibit a permeability constant less than low density polyethylene including, but not limited to, high density polyethylene, polypropylene, butyl rubber, ethylene/propylene rubber, certain low moisture permeable polymides such as nylons, polyvinylidene chloride, polyvinylidene fluoride, polyfluorochloroethylene, rubber hydrochloride, copolymers and ter-polymers of acrylonitrile with vinyl monomers or with monoolefins and/or diolefins such as styrene/acylonitrile resins, acrylonitrile/butadiene/styrene (ABS resins) or styrene-acrylonitrile/butene resins, and like materials.

The amount of moisture transmitted through a given film material is a function of the thickness of the film, i.e., the thicker the film, the less moisture transmitted. Thus, while relatively thick overcoat films (e.g., greater than about 10 mls) might be desirable, the electrical characteristics of such films during transfer would be undesirable. Most polymeric materials have a volume resistivity in excess of 10¹⁴ ohm cm. A thick layer of a highly resistive material would reduce the field imposed at the transfer nip thereby rendering the transfer roll substantially inoperative during the transfer process unless an extremely high and impractical potential were imposed. Therefore the maximum thickness of an overcoat composed of a polymeric material of high resistivity must be such that the dielectric breakdown strength of the overcoat layer may be exceeded under operating transfer conditions thereby rendering the layer "electrically invisible" to the process. Where the moisture barrier polymeric overcoat layer is of relatively low volume resistivity, i.e., less than about 10¹³ ohm-cm., the maximum thickness of the layer should be below about 5 mls, preferably below 2 mls. Where the resistivity of the polymeric overcoat is high, i.e., greater than about 10¹⁴ ohm-cm., the maximum thickness of the layer should be less than about 1 mls. In most cases, the ideal thickness of a highly resistive overcoat layer for a proper balance of moisture permeability and electrical properties is in the order of about 1/10 of the thickness of the secondary overcoat layer, or within the range of about 0.2 to 0.3 mls or 0.0002-0.0003 inches.

The primary relaxable layer 12 of FIG. 1 comprises a material that functionally takes a selected time period to transmit a charge from the conductive core 11 to the interface between the relaxable layer 12 and the self-leveling layer 13 sufficient to restore said interface to about the bias potential applied to the core. This selected time period is that corresponding to the roller speed and nip region width, i.e., roughly greater than the time any point on the transfer roller is in the nip region, and is chosen to be approximately one quarter of the roller revolution time. Functionally, this means that the duration of the external electric field increases significantly from the pre-nip entrance toward the post-nip exit, while the field within the relaxable layer diminishes. Thus, a relaxable layer is one that has an external voltage profile which is non-symmetrical about the transfer nip.

The primary layer is formed of an elastomeric or resilient material such as polyurethane or silicone rubber having a thickness in the range of about 0.2 to 0.30 inches, preferably about 0.25 inch and having sufficient resiliency to allow the roll to deform when brought in moving contact with a photoconductive surface which may be in the form of a plate, drum or belt. This insures an extended contact region in which toner particles can be transferred between the photoconductive surface and transfer material. Preferably the primary layer has a durometer hardness in the range of 15-25, Shore A. Because the primary layer should be capable of responding rapidly to the biasing potential to electrically impart the charge potential on the core to the outer of the roll surface, it preferably should have a resistivity in the order of 10⁹ to 10¹⁴ ohms cm., with about 2.0 x 10⁹ ohms cm. a particularly desirable target.
The secondary self-levelling layer 13 is a leaky insulator. The layer is selected for substantially higher resistive values, which in the present embodiment means in the order of about $10^{11}$ to $10^{12}$ ohms per centimeter, more preferably in the order of $10^{13}$ to $10^{14}$ ohm cm. In addition, the self-levelling layer includes materials, (or is so related to the relaxable layer), such that charges applied to the outer surface of the self-levelling layer will be generally dissipated within one revolution of the roller. This dissipation of charge is desirable to prevent suppression of the transfer field in the nip.

The secondary layer is also formed of a resilient material preferably having a durometer hardness in the range of about 65–75, Shore D, and a preferred thickness in the range of about 0.0020 to 0.0030 inches, preferably about 0.0025 inch. It has been found that in order to minimize ionization in the atmosphere and in and about the nip contact region, it is preferred that the secondary layer have a target resistivity of about $3.2 \times 10^{14}$ ohms cm. A preferred material for use as the secondary layer is a polyurethane marketed by the duPont Company under the trade name “Adiprene”.

The moisture barrier polymeric overcoat layer may be applied to the elastomeric surface of the transfer roll by any suitable process which will permit the formation of a relatively thin film having a substantially uniform thickness throughout. Suitable techniques include forming a solution of the moisture barrier polymer in a suitable solvent and applying the solution to the surface of the transfer roll by spraying or dipping. Alternatively, thin films of the moisture barrier polymer may be laminated directly to the transfer roll surface using a suitable adhesive or using heat shrinking techniques.

The following example illustrates the fabrication of a transfer roll having a moisture barrier overcoating comprising polyvinylidene chloride.

**EXAMPLE 1**

A xerographic transfer roll as disclosed in U.S. Pat. Nos. 3,702,482 or 3,781,105 was provided. The roll consists of an aluminum core, a primary overcoating layer comprising a polyurethane material (“Upjohn 2137–20”, marketed by the Upjohn Corp.) having a thickness of about 0.25 inch and a room temperature volume resistivity of about $5 \times 10^{6}$ ohms cm at a moisture content of about 1.5% (50% RH), and a secondary overcoating layer comprising a polyurethane material (“Adiprene L–315”, marketed by the duPont Corp.) having a thickness of about 0.0025 inch and a room temperature volume resistivity of about $3 \times 10^{14}$ ohms cm at a moisture content of about 1.0% (50% RH).

A solution of polyvinylidene chloride (PVCl) was prepared by dissolving 10 parts by weight of PVCl in 225 parts by weight of methylisobutyl-ketone. About 0.01 parts of a hydrophobic silicon dioxide (Silanox — Cabot Corporation) was added as a levelling agent for the PVCl. This solution was then loaded into a laboratory spray gun and sprayed uniformly on the peripheral surface of the secondary overcoat layer of the above transfer roll. Spraying was continued until sufficient solution had been applied to yield, after drying, a PVCl film having a uniform thickness of less than about 0.3 mil. The resistivity of PVCl is such that the thickness of the PVCl overcoat should not exceed about 0.3 mils so that the dielectric breakdown strength of the layer may be exceeded during the transfer operation i.e., when about 2500 volts is applied.

The transfer roll was thoroughly dried to yield a three layer structure wherein the elastomeric layers are hermetically sealed by a PVCl overcoat having a substantially uniform thickness of about 0.2 mil.

The stability of the transfer rolls of the present invention towards moisture transmission and consequent electrical stability is demonstrated by FIG. 3. A coated roll as prepared in Example 1 was evaluated vs. a roll with no moisture barrier coating over a period of 28 days at various humidity values 80 from % RH to 10% RH. As shown in FIG. 3, the fluctuations in moisture content (both gain and loss of moisture) were severe with the uncoated roll but relatively stable with the coated sealed roll. The resistivity of the uncoated roll fluctuates by large order of magnitude over the moisture range encountered during the test. Variations in resistivity for the uncoated roll are shown to fluctuate from $9 \times 10^{10}$ to $3 \times 10^{10}$ ohm-cm under low and high humidity conditions, while the sealed roll variation is only $1 \times 10^{10}$ to $9 \times 10^{9}$ ohm-cm.

In practice it has been found that the efficiency of transfer of toner to the transfer substrate (paper) is maximized at nip currents within the range of about 15 to 20 micro amps. Improved stabilization of the resistivities of the primary and secondary overcoat layers of the transfer roll according to the present invention thus allows for reasonable maintenance of this nip current under operating conditions without the need to resort to sophisticated means for altering the voltage applied to the transfer roll to compensate for large fluctuations in roll resistivity due to changes in humidity conditions.

The transfer roll encompassed by the present invention may be used in conjunction with any suitable electrophotographic apparatus as a means for transferring toner particles bearing an electrostatic charge from the surface of photoconductive insulating layer to a transfer surface such as paper. Transfer is accomplished as in the prior art by feeding a sheet of transfer material into the nip region formed by the surface of the transfer roll and surface of a photoconductive insulating material bearing a developed image, and imposing a potential on the transfer roll sufficient to cause the transfer of the toner material from the surface of the photoconductive insulating material to the adjacent surface of the transfer material. In practice, any source of electrical power connected to the central conductive core of the transfer roll and capable of placing the transfer roll member at potential sufficient to attract toner images from the photoconductive insulating surface towards the roll may be employed. A more complete discussion of the principles and configurations involved in bias roll transfer may be found in U.S. Pat. Nos. 2,951,443, 3,620,616, 3,633,543, or 3,781,105.

What I claim is:

1. A transfer member for electrically cooperating with a conductive support surface to electrically attract charge particles from the support surface towards the member including:
   a. a conductive support;
   b. a primary elastomeric intermediate layer overlying said conductive support, said primary layer having a relatively constant volume resistivity within the range of about $10^{7}$ to less than $10^{9}$ ohms cm;
   c. a secondary elastomeric intermediate layer overlying said primary layer, said secondary layer having a relatively constant volume resistivity within the range of about $10^{11}$ to $10^{14}$ ohms cm; and
d. a polymeric overcoating layer overlying and hermetically sealing said layers, said overcoating layer having a substantially uniform thickness of less than about 5 mils and a moisture permeability content of less than about $1 \times 10^{-8}$ at 30°C.

2. The transfer member of claim 1 wherein said polymeric overcoating layer has a volume resistivity of greater than about $10^{14}$ ohm-cm. and a thickness of less than about 1 mil.

3. The transfer member of claim 2 wherein said primary layer has a volume resistivity within the range of about $10^9$ to $10^{14}$ ohms-cm. and said secondary layer has a volume resistivity within the range of about $10^{13}$ to $10^{15}$ ohms-cm.

4. The transfer member of claim 3 wherein said primary layer has a volume resistivity of about $2 \times 10^9$ ohms-cm. and said secondary layer has a volume resistivity of about $3.2 \times 10^{14}$ ohms-cm.

5. The transfer member of claim 3 wherein the primary layer has a thickness of about 0.25 inch, the secondary layer has a thickness of about 0.0025 inch, and the polymeric overcoating layer has a thickness of about 0.0025 inch.

6. The transfer member of claim 3 wherein the polymeric overcoating layer is selected from the group consisting of high or low density polyethylene, polypropylene, butyl rubber, ethylene/propylene rubber, polyamides, polyvinylidene chloride, polyvinylidene fluoride, polytetrafluoroethylene, rubber hydrochloride, and copolymers of acrylonitrile with vinyl monomers, monoolefins or diolefins.

7. The transfer member of claim 6 wherein the polymeric overcoating layer comprises polyvinylidene chloride.

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