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Osman

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[54] **ELECTRODE FOR SHEET MATERIAL SURFACE TREATMENT APPARATUS**

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[52] **U.S. Cl.** **250/531,** 204/165

[51] **Int. Cl.** **B01k 1/00**

[58] **Field of Search** 250/531, 542, 546; 204/165

[56] **References Cited**

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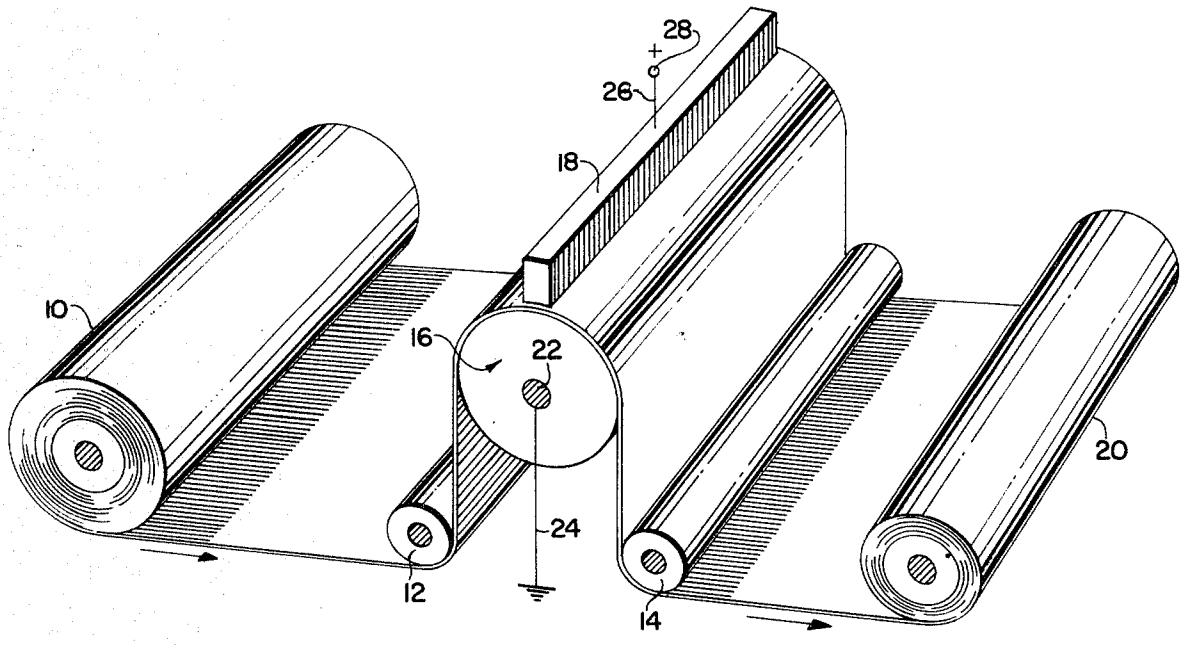
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[57] **ABSTRACT**

An improved electrode for use in apparatus for the treatment of the surface of a thin sheet of material includes an electrically conductive cylindrical core, a thin layer of dielectric material covering the cylindrical surface of the core, and an outer layer or sheath of electrically conductive material insulated from the core and completely surrounding the dielectric material. The electrode cooperates with one or more stationary electrodes in corona treatment apparatus to reduce the possibility of electrode arcing and to establish an electric field in the electrode gap with greater efficiency than the prior art.

4 Claims, 5 Drawing Figures



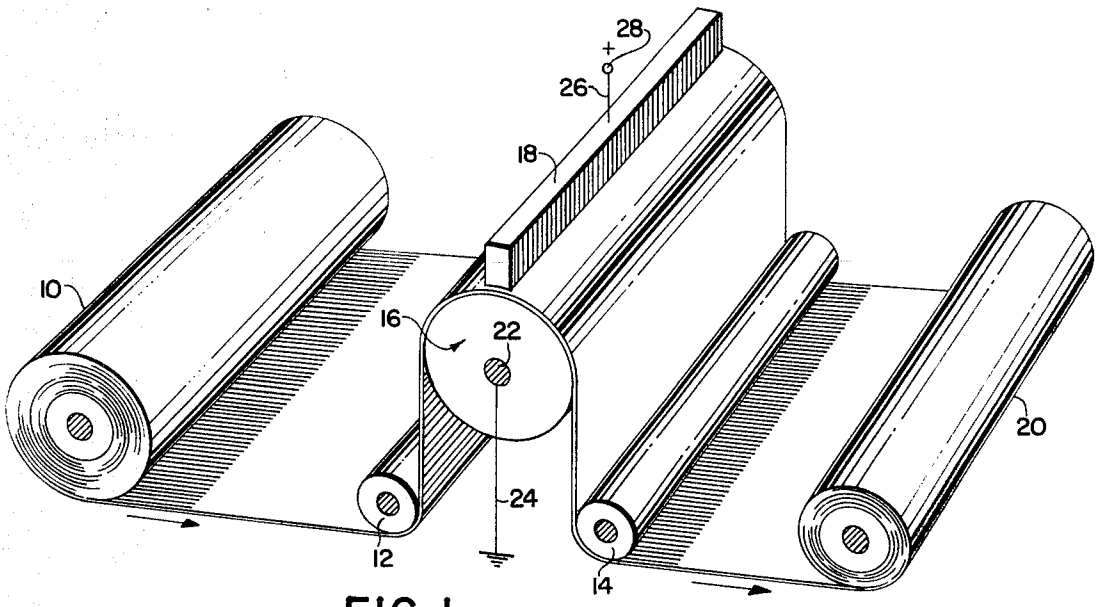


FIG. 1

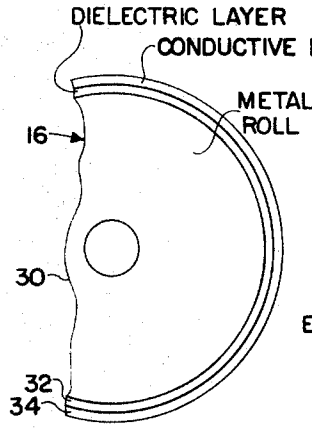
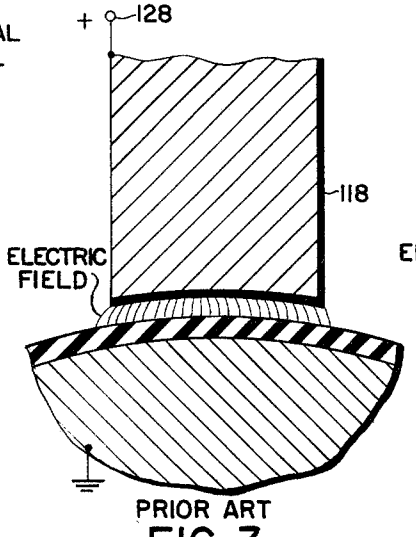


FIG. 2



PRIOR ART

FIG. 3

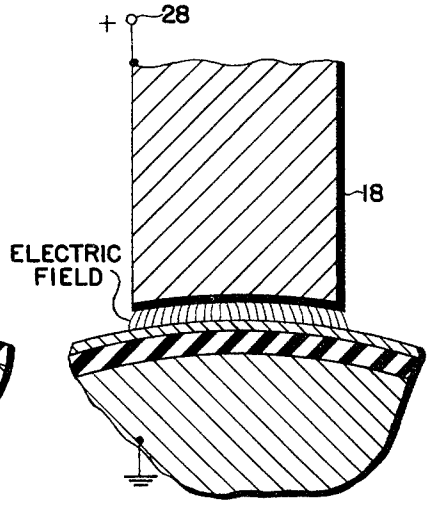


FIG. 4

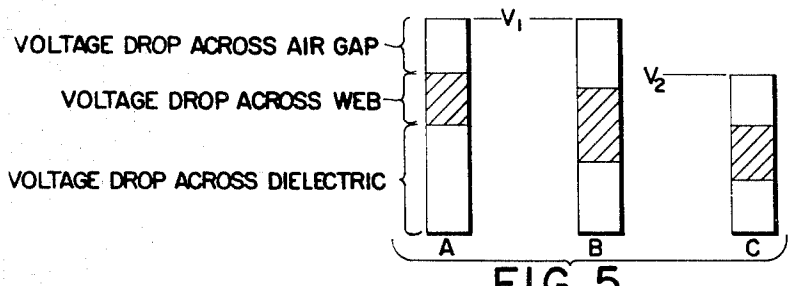


FIG. 5

ELECTRODE FOR SHEET MATERIAL SURFACE TREATMENT APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to apparatus for the surface treatment of sheet material and more particularly to an improved drum electrode for such apparatus to improve system efficiency and at the same time reduce maintenance costs and material damage during processing.

Sheet structures formed of various polymers, such as polyethylene, polypropylene and polyethylene terephthalate, for example, have received widespread acceptance for numerous diversified applications in which there is a need to apply a printing ink, adhesive or other material to the surface of such sheets. Due to the chemically inert character of most polymeric sheet surfaces, however, it has been found that such surfaces are generally unreceptive to printing inks, adhesives and other materials with obviously disadvantageous results. Efforts to overcome these disadvantages have been generally directed to techniques for providing surface treatment of the plastic sheet by exposure to chemical oxidizing agents, by surface impingement of a gas flame, or by passing the plastic web between a pair of electrodes at which a high voltage corona discharge is established.

In comparison with other prior art approaches, the electrostatic method of surface treating a plastic sheet has proven to be highly desirable. In the electrostatic process, a high voltage potential is applied across a pair of spaced electrodes one of which is typically tied to a source of reference potential or ground. When the potential gradient across the gap between the electrodes exceeds a particular value, the air or gas surrounding the ungrounded electrode becomes ionized such that a corona discharge is established thereabout. The corona discharge acts upon the surface of the web or plastic sheet so as to increase the receptivity thereof to printing inks, adhesives and the like.

Generally, in treating plastic films by exposure to a corona discharge, the film is passed between a pair of electrodes one of which is in the form of a rotatable metallic drum which carries the film past a stationary electrode. The roller itself is grounded and cooperates with the stationary electrode to provide the corona discharge necessary for effectuating the desired treatment. It has been found that the use of the above-described apparatus has often resulted in the establishment of undesired arcing between the electrodes at locations where minute holes or defects in the film exist of where dust or other foreign particles are collected on the surface of the sheet. Such arcing causes obvious damage to the plastic web by creating burn holes, for example, and in addition, often produces pitting of the drum electrode itself. Also, as the drum becomes more pitted, the plastic sheet may be damaged by the rough drum surface, which requires that the apparatus be disassembled and the roller electrode replaced or refinished at regular intervals.

A recent attempt to overcome the above deficiencies has been to coat the roller drum electrode with a thin layer of a suitable dielectric. By this approach, the dielectric coating of the roller itself cooperates with the dielectric property of the plastic web to effectively suppress the tendency of the apparatus to arc or otherwise break down during operation. As with the prior approaches, however, the dielectric coated electrode has also exhibited certain drawbacks such as the fact that it is often difficult to apply an even, low porosity coating of the dielectric material about the cylindrical peripheral surface of the electrode. In addition, such electrodes are difficult to maintain clean especially since extreme care must be taken not to scratch, mar or otherwise damage the somewhat fragile dielectric layer. Furthermore, it has been found that in order to practically establish a sufficiently high field in the electrode gap to produce an effective corona treatment of the plastic sheet the potential applied across the gap must be quite high requiring the use of heavy duty wiring and insulation and produces arcing and concomitant web and apparatus damage.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a roller electrode for surface treatment apparatus which is easy to clean and requires minimal maintenance.

The present invention has another object in the construction of a roller electrode for sheet material treatment apparatus in which the electrode is coated first with a layer of dielectric material and then with a durable, conductive outer layer.

A further object of this invention is to reduce the applied electrical potential required to establish a corona discharge between electrodes of a thin film surface treatment apparatus.

The present invention is summarized in that an electrode for use with apparatus for exposing the surface of a thin sheet of material to an electrical charge includes a cylindrical, electrically conductive drum, and a cylindrical conductive member disposed thereabout in spaced, electrically insulated relationship therewith.

A number of advantages are provided over the prior art in accordance with this invention. For example, the applied potential necessary to establish a corona discharge for the surface treatment of a film or sheet material is reduced; the roller drum electrode is more durable, less porous and is easier to clean and maintain; and the tendency of apparatus employing the electrode of the present invention to produce spurious arcing is minimized.

Other objects and advantages of the present invention will become apparent from the following description of the preferred embodiment when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of apparatus for the corona surface treatment of a thin sheet of material embodying the improved roller electrode according to the present invention;

FIG. 2 is an enlarged elevational view of a peripheral portion of the roller electrode of FIG. 1;

FIG. 3 is a diagrammatic representation of the electric field configuration established across the electrode gap of prior art corona treatment apparatus;

FIG. 4 is a diagrammatic representation similar to FIG. 3 and illustrative of the electric field configuration established by the roller electrode of the present invention; and

FIG. 5 is a set of bar graphs representing the potential gradient profile of various electrode gaps and illustrat-

ing the improved efficiency of the roller electrode according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is preferably embodied in corona treatment apparatus shown diagrammatically in FIG. 1 and including a suitable source of sheet material shown for purposes of illustration as supply roll **10.** It can be appreciated, of course, that the thin sheet of material, a plastic for example, may be fed directly from conventional extrusion processing apparatus directly to the corona treatment apparatus to be described below.

The plastic film from supply roll **10** is fed through an electrode treatment gap by means of a pair of freely rotatable guide rollers **12** and **14** which are located below a roller drum electrode generally indicated at **16** and adapted to maintain a first electric potential. A stationary electrode **18** is mounted in spaced relationship with roller electrode **16** in superposition therewith, with the spacing between the two electrodes sufficient to accommodate the plastic sheet or web under treatment, said stationary electrode being adapted to maintain a second electric potential. It is further noted that while only a single stationary electrode **18** is illustrated, any electrode or electrode bank configuration desired may be utilized, with the single electrode shown herein for purposes of simplicity only. Each of the guide rollers **12** and **14** may be appropriately biased by any conventional apparatus (not shown) so as to maintain the plastic film in smooth contact with the electrode drum **16** and are disposed with the common tangent between each guide roller and the drum electrode **16** being upwardly divergent such that the film sheet is drawn about at least one-half of the surface of the drum electrode. Roller drum **16** may be positively driven by means not shown to advance the film sheet in frictional engagement with it through the electrode gap whereupon the treated sheet may be taken up by a storage roll **20** or fed directly to subsequent processing stations, as desired. Roller drum **16** is preferably at ground potential by having its supporting shaft **22** electrically connected by a suitable brush (not shown) and a ground conductor **24** to ground, and electrode **18** is preferably connected to receive a high voltage operating potential via line **26** from a suitable high voltage source represented by terminal **28.** It should be understood that any particular type of high voltage source may be used to apply continuous, pulsating or the like forms of electrical energy for developing the corona discharge in the electrode gap.

Referring to FIG. **2,** the roller drum electrode **16** is formed of a cylindrical hub **30** which may be hollow or solid and is constructed of a suitable conductive material, such as stainless steel, and upon which is applied a layer of dielectric material **32** about the cylindrical, peripheral surface thereof. A metallic conductive layer **34** which may also be stainless steel completely surrounds the dielectric material **32** to form a smooth outer surface for the electrode **16** and is electrically insulated from hub **30** by dielectric **32.** The thicknesses of the dielectric and conductive layers **32** and **34,** respectively, may vary depending, for example, upon the particular characteristics of the sheet to be processed and the supply voltage being used, with the dielectric and outer conductive layers taking the form of relatively thin laminae about the peripheral, cylindrical surface of the hub or core member **30.**

As an example of apparatus including the improved roller drum electrode according to the present invention, a web of polyethylene material of any desired width is advanced between electrodes **16** and **18** at a rate of between **20** feet and **150** feet per minute. The diameter of the electrode **16** is approximately 6 inches and the width of electrode **18** is approximately three-eighths inch with the spacing between the outer surface of conductive layer **34** of electrode **16** and the bottom face of electrode **18** selected at approximately 0.05 inch. The dielectric coating **32** on electrode **16** is preferably a layer of chlorosulfonated polyethylene having a thickness of about 100 to 200 mils, and similarly, the outer metallic member **34** is a layer preferably of stainless steel having a thickness of about one-fourth to one-half inch. The potential applied across the electrodes **16** and **18** is somewhere in the range of approximately 3,000 volts to 4,000 volts and has a frequency of between 400 and 4,000 cycles per second, as desired.

When the surface treatment apparatus is operated within the general parameters noted above, a number of materially important advantages are provided as a result of the drum electrode configuration of the present invention. For example, by utilizing a prior art grounded conductive roller electrode, even with a dielectric coating thereon, a pin hole through either the plastic web or the dielectric coating provides an almost direct short circuit path between the high voltage electrode **18** and ground. Consequently, a high probability of arcing will arise at that point. On the contrary, in the roller electrode configuration illustrated in FIG. **2,** the conductive outer layer **34** is electrically insulated from ground by dielectric layer **32** such that its potential is "floating" even when hub **30** is connected to ground. As a result, a pin hole in the plastic web does not present an apparent short circuit to the electrode pair, but rather the charge accumulated on the outer surface of the conductive layer **34** under high voltage electrode **18** rapidly approaches the oppositely poled charge of the electrode **18.** By reason of the conductive nature of outer layer **34,** the charge built up on its outer surface under the area of electrode **18** causes a like oppositely poled charge to be distributed about the entire inner surface thereof. This charge is thereafter dissipated through the entire dielectric layer to the grounded core **30** with little, if any, tendency for the system to produce arcing in the electrode gap. Thus, in the event that a section of the plastic web having a pin hole is passed through the electrode gap, the positive charge of the high voltage electrode **18** will produce the rapid accumulation of an identical negative charge directly under the electrode area on the outer surface of conductive layer **34** which, by reason of the electrical conductivity of layer **34,** will result in the even distribution of a like positive charge over the entire inner surface thereof. This has a material effect in improving the efficiency of the treatment apparatus, i.e., in reducing the amount of high voltage energy required to establish the corona discharge, as will be described below.

In FIG. **3,** which is a diagrammatic representation of prior art corona treatment apparatus having a dielectric coated roller electrode, structure similar to that of the present invention is identified by similar reference numerals to which the number 100 has been added and will not be described in detail for the sake of brevity.

As shown in FIG. 3, the spacing between the positive electrode **118** and the electrically grounded electrode core **130** is equal to the gap spacing plus the thickness of the dielectric layer **132.** In comparison, the effective spacing shown diagrammatically in FIG. **4** for apparatus using a roller electrode according to the present invention is only that of the air gap between the high voltage electrode **18** and the conductive outer layer **34.** The reduced gap spacing eliminates the undesirable field spread which exists at the corners of the high voltage electrodes of prior art apparatus and serves to concentrate the electric field directly between the high voltage electrode and the area of the roller electrode immediately thereunder.

Furthermore, the laminar construction of the roller electrode of the present invention reduces the supply potential necessary to establish the requisite corona discharge in the electrode gap as compared with conventional prior art electrodes. This can be appreciated from the following analysis, for which purposes the electrode gap can be characterized as including three capacitors connected in series; namely, the air gap capacitor, the web capacitor, and the dielectric capacitor. Since the air gap capacitor and the web capacitor act identically, only the air gap capacitor will be treated in the following equations, it being understood that the web capacitance may be included by obvious extensions thereof.

Since the capacitance of a pair of plates separated by a dielectric follows the equation:

$$C = k\epsilon_0 A/d \qquad \text{(eq. I)}$$

(where k and ϵ_0 are constants, A is the area of the capacitor, and d is the distance between the plates), an increase in the area, A, of either the air gap capacitor or the dielectric capacitor will proportionally increase the capacitance exhibited thereby. As can be appreciated from a comparison of the diagrammatic views of FIGS. **3** and **4,** the effective area of the air gap capacitor is approximately the same for both the prior art dielectric coated roller electrode (FIG. **3**) and the electrode of the present invention (FIGS. **2** and **4**). In accordance with equation I, the air gap capacitance will thus be the same for both the prior art electrode and that of the present invention.

In the case of the dielectric capacitor, however, its effective area will be increased from that immediately underneath the high voltage electrode **118** to the area of the entire cylindrical surface of the central hub or core **30.** This substantial increase is due to the fact that the conductive outer layer **34** distributes the charge accumulated under electrode **18** over the entire inner surface of the conductive layer, as noted above. Consequently, the capacitance of the dielectric capacitor of the present invention will be materially greater than that of the exemplary prior art electrode of FIG. **3.**

As can be readily derived, the voltage drop across the air gap capacitor of the series network of the electrode gap is:

$$V_{air} = [C_d/(C_a + C_d)]\, V_{supply} \qquad \text{(eq. II)}$$

(where C_d is the lumped capacitance of the dielectric and C_a is the lumped capacitance of the air gap). Since the capacitance of the dielectric capacitor of the electrode of the present invention is considerably larger than that of the prior art device, the voltage drop in the air gap (V_{air}) will be correspondingly increased in accordance with equation II.

The above comparison is visually represented by graphs A and B of FIG. **5.** It is therein shown that for the same value of supply voltage, V_1, both the air gap and web voltage drops will increase proportionally in going from the prior art electrode (graph A) to that of the present invention (graph B), while the potential drop experienced across the dielectric layer **32** will be reduced accordingly. Since the voltage drop across the air gap, the web and the dielectric in graph B will be proportionally reduced to that of graph C as the source potential is dropped from V_1 to the lesser value of V_2, the supply voltage necessary to provide the same voltage drop in the air gap and across the web as provided by prior art apparatus (compare graphs A and C) is considerably less when a roller electrode constructed in accordance with the present invention is used. As a result, substantial reductions in insulation, wiring, high voltage breakdown damage and undesired arcing may be achieved without sacrificing the electric field strength in the electrode gap necessary to establish the desired corona discharge.

Thus, it can be appreciated that by constructing a roller drum electrode by first applying a dielectric layer to the drum core and thereafter applying a conductive outer layer surrounding the dielectric, an effective and durable electrode is provided for the surface treatment of sheet material. Since the dielectric layer is not exposed but is surrounded by the conductive outer layer, the electrode is considerably more durable than prior art devices, is less porous, and can be more easily cleaned. Furthermore, since the electrode enables system operation at a reduced voltage level, considerable cost and maintenance savings will be provided by the present invention over an extended useful lifetime.

Since certain changes may be made in the above product without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for exposing the surface of a thin sheet of dielectric material to an electrical charge which comprises at least two electrodes adapted to be maintained at first and second electric potentials and spaced to accommodate the passage of said thin sheet of material therebetween, one of said electrodes comprising:

an electrically-conductive cylinder adapted to be maintained at said first electric potential; and

a cylindrical conductive member coaxially disposed about said cylinder and associated therewith in spaced, electrically insulated relationship such that said con-ductive member and said cylinder exhibit capacitive coupling.

2. The invention of claim **1** wherein said cylinder is a hollow drum.

3. The invention of claim **2** wherein said cylindrical conductive member is spaced from said conductive cylinder by a continuous uniform layer of dielectric material in direct contact with both said conductive cylinder and said cylindrical conductive member.

4. The invention of claim **3** wherein said electrode comprising said conductive cylinder is capable of being rotated thereby providing transport means for said thin sheet of material in frictional engagement therewith.

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