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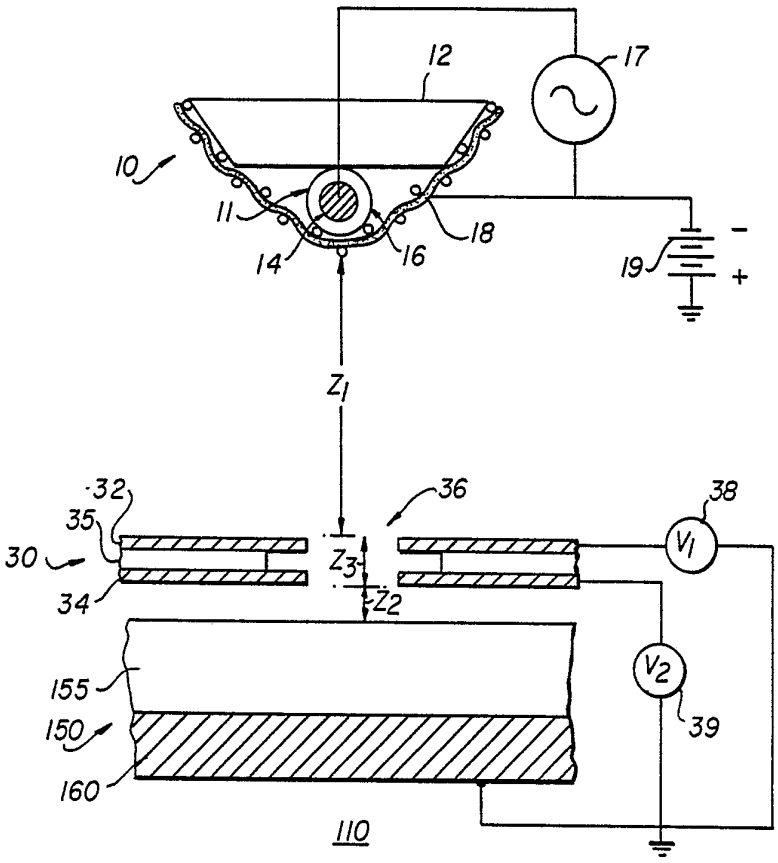
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(54) Title: ELECTROSTATIC IMAGING BY MODULATION OF ION FLOW

(57) Abstract

Method and apparatus for ion projection electrographic imaging using a self-limiting discharge ion source (10). A pool of ions is generated by a high voltage time-varying potential (17) between two electrodes (14 and 18) separated by a solid dielectric (16); ions are extracted by means of an electrical field between one of the electrodes and a further electrode member (160). An apertured ion-modulating plate (20) is interposed between the ion source (10) and an image receptor surface (150) in order to modulate the cross-section of ion flow, thereby forming a desired electrographic image. This device enjoys the advantages of high print uniformity, simplicity of construction, and reliable, durable operation.



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"Electrostatic Imaging by Modulation of Ion Flow."

BACKGROUND OF THE INVENTION

The present invention relates to electrographic imaging devices, and more particularly to electrographic printing devices using ion projection technology.

Ions can be generated to form electrostatic images in a wide variety of ways. Common techniques include the use of air gap breakdown, corona discharges and spark discharges.

A successful ion projection printing technique is disclosed in U.S. Patent Nos. 4,155,093, 4,160,257, and 4,409,604, all are commonly assigned with the present application. These prior art patents disclose various ion generating devices which incorporate a pair of electrodes separated by a solid dielectric member. A high voltage time-varying potential between the two electrodes causes the formation of a pool of ions in an air region adjacent one of the electrodes (the "control" electrode) and the solid dielectric member. Ions may be extracted from this pool to form electrostatic images on a remote, dielectric surface, typically by means of a DC extraction potential interposed between one of the electrodes and a backing electrode for the imaging surface. In the apparatus of U.S. Patent No. 4,155,093, the control electrode has an edge surface which forms a junction with the solid dielectric member, partially or completely defining the air region. In the apparatus of U.S. Patent No. 4,160,257, the '093 apparatus is modified by including an additional, "screen" electrode which is separated from the control electrode by a dielectric spacer layer; i.e. is incorporated in an integral structure. The screen electrode is apentured to modulate the flow of ions from the control electrode, providing an electrostatic

lensing action. The apparatus of U.S. Patent No. 4,409,604 produces ions using an elongate conductor having a dielectric sheath, such as a glass-coated wire, with a transversely oriented conductor contacting or closely spaced from the sheathed conductor. The transverse conductor serves as the control electrode with ions produced at the crossover region with the sheathed conductor. This patent also discloses the possibility of incorporating a screen electrode as part of an integral structure, similar to that of U.S. Patent No. 4,160,257.

The above imaging devices all employ a self-limiting discharge ion production principle wherein the time-varying potential causes the charging of a surface portion of the solid dielectric member, leading to an atmospheric discharge upon achieving an "inception potential". This characteristic provides a number of operating advantages. These include reliable output currents, which are typically higher than those obtained from prior art devices such as corona ion sources. Such devices also enjoy an extended service life. There are, however, certain operating disadvantages associated with such structures. The unitary construction of these devices complicates their manufacture and testing. Furthermore, the close spacing of the various components increases the tendency towards fouling with dust, chemical byproducts of ion generation, and other contaminants.

One particular design of electrographic imaging apparatus commonly employed in the art uses a corona ion source in combination with means for creating an accelerating field to extract ions from the corona to a remote, dielectric imaging surface. Typically this is done by imposing a direct current potential difference between the corona electrode and a backing electrode for

the imaging surface. In order to create a preselected, well-defined image, the ion flow is modulated using an apertured mask which is interposed between the corona ion source and the image receptor surface. Representative patents include U.S. Patent Nos. 3,689,935; 3,742,516; 3,961,574; 3,962,969; 3,980,474; 3,986,189; 4,016,813; 4,022,528; and 4,338,614. Such apparatus may be used to form a visible image either by subsequently toning a latent electrostatic image formed by the above method, or by using such a device to control the flow of an ink mist or other visible medium. In their reliance on corona discharges as the source of ions, such systems are subject to the limitations of corona apparatus, including limited ion currents -- typically a maximum discharge current on the order of 10 microamperes per centimeter. Such limited currents in turn impose printing speed limitations. In addition, coronas can cause significant maintenance problems. Corona wires are small and fragile and easily broken. Because of their high separating potentials they collect dirt and dust and must be frequently cleaned or replaced.

Accordingly, it is a primary object of the invention to provide an improved electrographic printing head. A related object is to utilize ion projection imaging technology in the design of such a device.

One criterion of concern is the magnitude of available ion output currents. A related object is the achievement of high operating speeds.

Another object of the invention is to facilitate manufacture and testing of such devices.

A further object of the invention is the design of a printing head which enjoys prolonged, relatively maintenance-free operation. It is desirable that such a device be easily cleanable, to remove built up contaminants, or be self-cleaning.

Still another aspect of the invention is the achievement of uniform, reliable output currents over various imaging elements in a matrix-defined printing head. It is furthermore desirable that such a device permit multiplexing of the control electronics.

SUMMARY OF THE INVENTION

The invention provides an ion projection printing head for electrographic imaging, incorporating a self-limiting discharge ion source, with a discrete ion modulating screen member. Ions are generated using two electrodes, a "bias electrode" and a "driver electrode", separated by a solid dielectric member. A high voltage time-varying potential between these electrodes induces self-limiting electrical discharges, creating a pool of positive and negative ions in an air region adjacent the control electrode and the solid dielectric member. Ions are extracted from this region using an extraction potential between the bias electrode and a counterelectrode, advantageously a backing electrode for a dielectric imaging surface to which the ions are attracted. The transverse cross-section of the projected ion stream is modulated using an apertured plate or screen interposed between the ion source and the receptor surface, thereby defining the electrostatic image.

In the preferred embodiment, the ion generating device comprises an elongate drive electrode having a dielectric sheath, and a proximate bias electrode. The bias electrode may take a number of suitable forms, including a conductive mesh or grid; an elongated conductive structure which partially encloses the sheathed driver electrode, and other structures. The sheathed driver electrode may take the form of a glass-coated wire, a conductive strip encapsulated with a dielectric material, glass-tubing with a conductive inner lining, and other combinations having the requisite physical characteristics. Suitable ion generating devices of these types are disclosed in commonly assigned U.S. Patent No. 4,379,969, and U.S. Application Serial No. 381,600, filed

May 24, 1982. It is desirable to employ an ion generator which has a relatively high transconductance, which is a quantitative measurement of ion output efficiency.

Another aspect of the invention relates to a preferred design of the ion-modulating plate, which consists of two apertured electrodes mounted onto opposite faces of a dielectric support. These layers are perforated by one or more screen apertures to permit passage of ions. Advantageously, the dielectric layer is recessed from the aperture edges to reduce wall charging effects.

A further aspect of the invention relates to the electrical actuating parameters. The drive voltage, between the bias and driver electrodes, advantageously comprises a high voltage R.F. alternating potential. The extraction potential preferably comprises a D.C. bias, while the screen electrode or electrodes receive a user-variable potential to control the ion-gating characteristics of the screen member. In the preferred embodiment involving a pair of apertured screen electrodes, the electrode nearer the ion source receives an extraction potential V_1, with a second extraction potential V_2 applied to the electrode nearer the imaging surface. Advantageously, these screen potentials take the form of pulsed voltages, which may be supplied by pulse generators in combination with D.C. bias potentials to the respective screen electrodes.

This arrangement is observed to provide approximately parabolic output current characteristics when mapping against given values of V_1 over varied V_2. The second screen electrode provides an ion-accelerating field for a range of values of V_2, with a maximum ion current in the

center of this range. The maximum attainable ion current in turn varies with V_1. Advantageously, the device provides peak ion current densities on the order of 200 microamperes per square centimeter.

In a preferred embodiment of the invention, the electrical actuation parameters are designed to provide "on" and "off" states for individual screen apertures. The "on" or "print" state corresponds to a given nominal ion output current for the screen aperture. When incorporating this device in an electrographic printing system, the print current may be empirically determined by the user in view of various parameters of the printing system. In the preferred, multiplexed dot matrix arrangement, switching between on and off states may be accomplished by switching either or both of V_1 and V_2.

In a preferred application of the invention, an electrostatic imaging device according to the invention is incorporated in a printing system of the type described in U.S. Patent No. 4,365,549. The device forms a latent electrostatic image on the dielectric surface of a rotatable imaging cylinder. The image is developed as a visible toner image, which may then be transferred and simultaneously fused to a receptor sheet using high pressure. The imaging devices of the invention, characterized by high ion current densities, provide high quality developed images at extremely high imaging speeds in apparatus of this type.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and additional aspects of the invention are illustrated in the following detailed description of the preferred embodiments, which is to be taken in conjunction with the drawings in which:

FIGURE 1 is a sectional schematic view of a simple form of electrostatic imaging device embodying the invention, as used for charging a dielectric surface;

FIGURE 2 is a sectional schematic view of an alternative form of imaging device incorporating a dual electrode ion-modulating screen;

FIGURE 3 plots ion output current as a function of control bias potential for the ion source device of Figure 1, for various spacings from an ion receptor surface;

FIGURE 4 plots ion output current from the apertured plate of Figure 2, for various actuating potentials V_1 and V_2 to the screen electrodes;

FIGURE 5 is a plan view of a dot matrix ion-modulating screen of the type shown in Figure 2;

FIGURE 6 is a partially sectioned schematic end view of electrographic printing apparatus incorporating an electrostatic imaging device in accordance with the invention;

FIGURE 7 is a sectional schematic view of an alternative ion source assembly for use in the imaging devices of the invention;

FIGURE 8A is a sectional schematic view of a further alternative ion source assembly;

FIGURE 8B is a plan view of the ion source assembly of Figure 8A; and

FIGURE 9 is a sectional schematic view of yet another ion generator assembly to be incorporated in the imaging devices of the invention.

DETAILED DESCRIPTION

Reference should now be had to Figures 1-9 for a detailed description of electrostatic imaging devices in accordance with preferred embodiments of the invention. Figure 1 depicts in a sectional schematic view a basic form of electrostatic printing head 100 as employed to form latent electrostatic images on a dielectric surface 155. Printing head 100 includes as its principal elements a self-limiting discharge ion generator 10 and an ion-modulating screen 20. In the embodiment of Figure 1, the ion generator 10 is one of the types disclosed in U.S. Patent No. 4,379,969, and includes a corona electrode 11 mounted on a dielectric support 12, covered with a conductive mesh electrode 18. The corona electrode 11 consists of an elongate conductor 14 (seen here in an end view) covered with a dielectric jacket or sheath 16; the conductor 14 functions as the "driver electrode". Ion generator 10 is electrically actuated to form a pool of positive and negative ions in an air region adjacent the mesh electrode 18 by means of a time-varying potential 17 imposed between the elongate conductor 14 and mesh electrode 18. Ions of a given polarity (in the illustrated embodiment, negative ions) are attracted from this air region to the dielectric imaging surface 155 by means of a D.C. extraction potential 19 imposed between the mesh electrode (or more generally, "bias electrode") and a counterelectrode 160 backing the dielectric surface 155.

An ion-modulating screen member 20 is interposed between the ion generator 10 and the ion receptor structure 150 to modulate the cross-section of ion flow. In the basic embodiment of Figure 1, the screen 20 consists of a conductive layer 26 and a dielectric support 24 and includes a screen aperture 27 through these layers.

The ion generator 10 is operated continuously using a continuous wave alternating potential 17 between electrodes 14 and 18 to induce ion-producing electrical discharges. A circular electrostatic ion image is formed on dielectric receptor surface 155 when a negative pulse potential supplied by pulse generator 22 is applied between screen electrode 26 and counterelectrode 160. In the absence of a negative pulse, negative ions drawn from the ion source are not projected through the aperture 27 onto the dielectric surface 155.

Figure 2 is a schematic sectional view of a further embodiment of electrostatic imaging device 110 incorporating a two-electrode ion-modulating plate 30. The ion-modulating plate 30 consists of planar electrodes 32 and 34 separated by dielectric layer 35, all of these layers containing a print aperture 36. The electrical actuation scheme of Figure 1 is modified in the apparatus of Figure 2 by applying dual screen potentials V1 and V2 respectively to the electrodes 32 and 34 of the ion-modulating plate. It is a principal advantage of the embodiment of Figure 2 that the ion transmission characteristics of the screen 30 may be modified by appropriate control of either or both of the electrode potentials V1 and V2. This characteristic allows multiplexing of a multielectrode aperture plate of the type shown in Figure 2, as further explained below.

The ion output currents of these self-limiting discharge ion generators (such as the generator 10 of Figs. 1 and 2) is observed to approximately follow the linear relation $I = gV_o + a$, where V_o is the potential of the bias electrode, g is defined as the transconductance, and a is an offset due to the greater mobility of negative ions as compared with positive ions.

-a/g gives the "offset voltage", or bias required to provide a zero current condition. The transconductance g is a measure of the current output efficiency of these devices, and will vary according to the ion generator design; choice of materials and dimensions for the dielectric 16; magnitude and frequency of the drive potential 17; and gap widths Z_1, Z_2, and Z_3 between the ion generator 10, screens 32 and 34, and surface 155. A primary advantage of these electrostatic imaging devices is their characteristically high ion output currents, due to the use of a self-limiting discharge ion source.

In general, transconductance will increase linearly with the magnitude of drive voltage 17, and when using continuous waveform drive potentials will increase with the frequency of this voltage. The magnitude of this potential is limited by the dielectric strength of the dielectric 16, while an excessive high drive frequency will cause undesirably high temperatures in the discharge region.

The ion output current densities are also observed to vary roughly in proportion to the bias electrode potential V_o. V_o should be maintained below a value which would cause arcing to the screen 30; this is dependent on the separation of electrodes 18, 160.

Transconductance g is also observed to vary hyperbolically (i.e. as 1/Z) with increasing separation from the ion receptor surface (such as dielectric surface 155). Figure 3 gives a family of i-V plots -- i.e. output current per centimeter length of generator 10, plotted against the bias V_o. These are measured for the ion generator 10 of Figure 1 for different values of

Z, where Z is the distance from a current-measuring probe. Inasmuch as the sensitivity of g to distance Z varies as $1/Z^2$, it is important to provide a sufficent gap between ion generator 10 and surface 155 to keep these tolerances within reasonable limits. Additionally, it is beneficial to provide a separation Z_1 between ion generator 10 and screen 30 to facilitate cleaning of these structures, for example using high pressure air flow through this region. The separation Z_3 between screens 32 and 34 (in Figure 2), and Z_2 from screen 34 to imaging surface 155, is desirably kept at a minimum to reduce spreading of the ion stream projected from the screen aperture. An illustrative ratio of $Z_1:Z_3$ is on the order of 10:1.

For a further discussion of the ion output characteristics of the preferred ion generators, see U.S. Patent No. 4,379,969, and U.S. Application S.N. 381,600, filed May 24, 1982. Advantangeously, the ion generator provides an ion current density of at least 50 microamperes per cm^2, most advantageously greater than 200 microamperes per cm^2.

The ion output characteristics of these imaging devices may be analyzed not only as respects the parameters of the ion generator 10, but also in the transfer characteristic of the ion-modulating screen. In the two-screen embodiment of Figure 2, the output current I' may be controlled by variation of either or both of the screen electrode potentials V_1 and V_2.

Figure 4 plots the ion output current density I' for a given plate aperture 36 as a function of the screen potentials V_1 and V_2. The ion output current is plotted as a family of isopotential curves, wherein each curve is mapped for a given potential V_1 over a range of values of V_2. It may be seen that for a given value of V_1, the output current I' is a parabolic

function of V_2 reaching a maximum at the midpoint of the range. The maximum output current is observed to increase with greater absolute values of V_1. The imaging devices of the preferred embodiment are advantageously characterized by a peak output current density for the screen 30 greater than 200 microamperes per cm^2.

The above ion transfer characteristics are attributable to the effect of the respective electrode potentials on the local electrostatic fields in the screen aperture regions. These local fields are a combination of the propulsion field E_p provided by the extraction potential V_o, and the superimposed fields due to the screen potentials V_1 and V_2. The superimposed fields can be directed to oppose and overcome the propulsion field E_p within the screen. The field within each screen aperture is the vector sum of the propulsion field E_p and the fringing field from the screen electrode. In order to totally block ion flow, the fringing field from the screen electrode must be of sufficient magnitude to create a net zero or negative field in the center of the aperture (considering E_p as positive). In the double screen embodiment of Figure 2, a positive net propulsion field must exist within both successive screen apertures (as well as in the regions downstream of these apertures) in order to achieve a "print" condition.

This apparatus may be used to provide an aperture modulation effect -- i.e. an apparent aperture diameter which may vary in accordance with the screen potentials V_1 and V_2. Thus, under conditions in which ion passage is partially but not completely retarded, a diminished diameter of the electrostatic image will result. It is possible as well to enhance the propulsion

field E_p with the superimposed screen electrode field, thereby increasing the effective aperture diameter beyond the physical size of the aperture. This property may be exploited to provide a tonal-range capability using halftone effects.

Although the apparatus of Figure 2 may be operated with continuous variation of either of the potentials V1 and V2, it has been found advantageous to provide these potentials in a switching mode. A nominal "on" or "print" value of output current density is determined for the aperture 36, i.e. a value sufficient to provide a suitable charge density of the electrostatic images on dielectric 155, for an electrostatic image of a predetermined diameter. This value is generally a function of imaging speed, the physical properties of dielectric surface 155, toning thresholds, and other parameters. An approximately zero output current corresponds to the "no print" state; effectively this should be less than 3 percent of the "print" value. V_1 may be set to a preselected value according to various criteria discussed below, and V_2 may be switched between appropriate values according to the given screen transmission characteristics such as those plotted in Figure 4. Alternatively, V_1 may be switched between a value providing the requisite "print" current, and a negligible value. With reference to the printing system 200 shown in Figure 6, discussed in detail below, one may wish to provide electrode 34 with a slightly positive bias where employing a low toning threshold developing system 220.

Figure 5 shows in a plan view a dot matrix aperture plate 40 of the general type shown in section in Figure 2.

Aperture plate 40 consists of a dielectric sheet 41 having on one face a series of parallel electrodes 42 and on the opposite face a crossing series of electrodes 44. Screen apertures 46 are located at the crossover regions of pairs of electrodes 42 and 44. The apparatus of Figure 5 is well suited to a dot matrix multiplexing scheme such as that employing the electrical actuation apparatus of Figure 2.

The electrostatic imaging devices of the invention are well suited to incorporation in high speed electrographic printing systems, such as that disclosed in U.S. Patent No. 4,365,549. These devices enjoy extremely high output current densities, thereby providing commensurately high imaging rates due to the relation $dQ = I' dt$, where dQ is the electrostatic charge created on a unit area of the dielectric surface 155 during the interval dt.

Figure 6 shows somewhat schematically an electrostatic printer 200 incorporating an ion projection printing head in accordance with the invention. A cylinder 230 is mounted for rotation about an axis 238 and has an electrically conductive core 237 coated in a dielectric layer 235. Cylinder 230 receives an electrostatic image from a printing head 210 of the type described herein, driven by an electronic control system 215 and connected by mechanical connectors 217. As the cylinder rotates in the direction shown, an electrostatic image is formed by the cartridge 210 on the outer surface of the dielectric layer 235 and comes into contact with toner supplied from a hopper 223 by a feeder mechanism 225. The resulting toned image is carried by the cylinder 230 towards a nip formed with a pressure roller 240 having a compliant outer layer 245 positioned in the path of a

receptor such as paper 270. The receptor sheet 270 enters between a pair of feed rollers 280, is driven by the cylinder 230 and roller 240, and leaves between a pair of output rollers 282. The pressure in the nip is sufficient to cause the toner to transfer to the receptor 270, and with sufficient pressure, the toner will be fused to the receptor. In order to enhance this action, while restricting the pressure needed, the axes of rotation of the cylinder 230 and roller 240 are skewed relative to one another.

After passing the nip between the cylinder 230 and the roller 240, any toner remaining on the surface of the dielectric layer 235 is removed by a scraper blade assembly 250, and any residual electrostatic charge remaining on the surface is neutralized by a discharge head 260 positioned between the scraper assembly 250 and the printing head 210, to prepare the cylinder for reimaging.

The invention is further illustrated in the following nonlimiting examples.

EXAMPLE 1

An electrostatic imaging device of the type illustrated in Figure 1 was constructed as follows. The ion generator 10 included an insulating substrate 12 fabricated of glass epoxy G10 laminate. The corona electrode 11 consisted of a 7 mil diameter tungsten wire 14 coated with a 2 mil thick glass coating 16, providing an outer diameter of .011 inch. After laying the coated wire on the substrate, a fine woven electrode screen 18 was stretched over the wire and bonded with a thermoset adhesive to the sides of the substrate. The screen consisted of a plain woven 1 mil tungsten wire,

having a mesh count of 100 and an open area of approximately 90 percent. The coated wire electrode was not bonded to the substrate, and was constrained only by the overlying screen.

The apertured plate 20 consisted of a copper-clad glass epoxy insulating sheet having a circular etched aperture 27 with a nominal diameter of 6 mils. The copper-clad surface 26 of apertured plate 20 was located .060 inch from the ion source 10.

The excitation source 17 consisted of a 200 kilohertz, 2000 volt peak-to-peak continuous wave alternating potential. A bias potential of 2000 volts D.C. was imposed between the woven screen electrode 18 and an aluminum plate counterelectrode, which was treated in accordance with the method of U.S. Patent No. 4,413,049 to provide a dielectric imaging surface 155. The dielectric imaging surface 155 was separated from the insulating face 24 of the apertured plate by 10 mils.

The ion source 10 was operated continuously and a circular electrostatic ion image formed on the dielectric surface 155 when a negative pulse potential was supplied by a pulse generator 22 between the copper cladding 26 and the aluminum substrate 160. The electrode 26 was normally maintained at a bias of 50 volts, and a negative pulse of 300 volts having a duration of 60 microseconds was employed.

The above apparatus was observed to provide electrostatic images which could be developed to yield densely toned, well defined images.

EXAMPLE 2

The electrostatic imaging apparatus of Example 1 was modified as follows to provide a double-screen system of the type illustrated in Figure 2. The ion-modulating screen 30 was comprised of a 6 mil thick Kapton layer 35 having 1 mil stainless steel foil laminated to each face. The foil was photoetched to provide a row of 6 mil diameter screen apertures 36, and the Kapton was then etched from the screen apertures to provide clearance regions several aperture diameters in width.

In lieu of the anodized aluminum dielectric imaging member 150, a probe micrometer spindle was employed to measure the output current from ion-modulating plate 30. The probe was connected to an electrometer to measure a portion of the screen current, which could be used to calculate current output per aperture.

The screen electrodes 32, 34 were subjected to a series of pulsed potentials V1, V2, and the output current I' measured using the probe micrometer spindle. The results are tabulated in Table 1.

EXAMPLE 3

The electrostatic imaging apparatus of Example 2 was incorporated in a high-speed electrographic printing system of the type illustrated in Figure 6, using a dot-matrix printing head 70 of the type shown in Figure 5. High velocity air was blown into the gap between the ion generator 10 and screen 30 in order to remove chemical byproducts of the atmospheric electrical discharges and to assist in rapidly removing the ions from their region of generation. The electrode 32 was biased at a level of -200 volts, while electrode 34 was biased at 50 volts.

The dielectric cylinder 230 and pressure roller 240 were fabricated and mounted as described in Example 1 of U.S. Patent No. 4,365,439. Single component toning apparatus, digital imaging electronics, scraper blades, and charge-neutralizing assembly were employed as described in this prior art example. Under these conditions it was found that a 120 volt latent electrostatic image was produced on the dielectric cylinder in the form of discrete dots, when the electrode 32 received a -200 volt pulse simultaneously with application of a -300 volt pulse to electrode 34. Absent either or both of these pulses, no printing was observed.

TABLE 1

V_1 (volts)	V_2 (volts)	I' (per aperture, nanoamperes)
0	300	0
0	400	0
0	500	0
0	700	0
200	50	12
200	130	16
200	200	10
200	250	2
300	100	38
300	200	42
300	300	29
300	400	0
400	100	42
400	200	48
400	350	42
400	450	2
600	100	45
600	300	56
600	500	48
600	650	5

The printer provided high quality dot matrix images when operated at paper throughput speeds of six inches per second.

EXAMPLE 4

The electrostatic imaging apparatus of Example 2 was modified as follows to incorporate an alternative ion-generating assembly. With reference to Figure 7, the corona electrode 53 was fabricated by screening and firing a thick film conductive electrode on a ceramic substrate 51. The electrode 52 had a line width of 8 mils, and was encapsulated with a 1.5 thick layer 54 of glass. This glass layer was formed by silk-screening a glass frit over the electrode and sintering the glass at a high temperature to create a continuous glass coating. The wire mesh screen electrode 56 was stretched over corona electrode and bonded to the insulating substrate as in Example 1.

This apparatus was found capable of generating ions over a larger area than that provided from a single glass coated wire. The ion generator 50 was observed to supply large quantities of ions because of its extensive area.

EXAMPLE 5

The apparatus of Example 2 was modified to incorporate yet another form of ion generator. As seen in the sectional schematic view of Figure 8A, the glass coated wire was replaced with a glass capillary .08 inch in diameter having a wall thickness of about 2 mils. The glass capillary 61 was provided with a conductive inner coating of Aquadag E polymer (Aquadag is a registered trademark of Acheson Colloids Co., Port Huron, Michigan, for water-based graphite pigmented conductive coatings).

The corona electrode 63 was housed in a glass epoxy insulating container 64. As seen in the plan view of Figure 8B, the control electrode 66 consisted of a helical grid of 1 mil tungsten wire, in a pitch of 112 wraps per inch.

This electrostatic imaging assembly provided comparable performance to the assembly of Example 2.

EXAMPLE 6

The electrostatic imaging apparatus of Example 2 was modified by substituting the alternative ion generator illustrated in Figure 9. The ion generator 70 consisted of a glass epoxy plate 76 to which was bonded a 7 mil diameter tungsten wire coated with a 2 mil thick glass layer. Two 11 mil diameter tungsten wires 75 were bonded to the substrate, closely fitted on either side of the glass-coated wire 72. It was found with this apparatus that high quality developed images could be obtained at pulse repetition rates as short as 30 microseconds.

Although the apparatus of the preferred embodiment incorporates particular types of ion generating assemblies and ion-modulating screens, the invention is not limited to these particular subassembly embodiments. While various aspects of the invention have been set forth by the drawings and the specification, it is to be understood that the foregoing detailed description is for illustration only and that various changes in parts, as well as the substituion of equivalent constituents for those shown and described, may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

WE CLAIM:

1. Electrostatic imaging apparatus, comprising:

an ion generator comprised of two electrodes ("bias" and "driver" electrodes) separated by a solid dielectric member, with a time-varying potential between said electrodes to create ion-producing electrical discharges in an air region adjacent the bias electrode and solid dielectric member;

an extraction potential between the bias electrode and a counterelectrode to attract ions from said air region toward said counterelectrode;

a perforated member interposed between the ion generator and the counterelectrode, including at least one screen electrode, with a screen potential applied to said screen electrode; and

means for controlling the screen potential to control the passage of ions through apertures in said perforated member.

2. Apparatus as defined in claim 1, wherein the perforated member comprises a dielectric support having first and second electrodes on opposite faces, including apertures through said first and second screen electrodes and said dielectric support, and further comprising first and second screen potentials respectively applied to first and second screen electrodes.

3. Apparatus as defined in claim 2, for dot matrix electrostatic imaging, wherein the perforated member includes an array of first screen electrodes and a crossing array of second screen electrodes, with apertures located at crossover areas of the first and second screen electrodes.

4. Apparatus as defined in claim 1, further comprising means for forcing air flow under elevated pressure between said ion generator and said perforated member.

5. Electrostatic imaging apparatus, comprising:

an ion generator comprised of two electrodes ("bias" and "driver" electrodes) separated by a solid dielectric member, with a time-varying potential between said electrodes to create ion-producing electrical discharges in an air region adjacent the bias electrode and solid dielectric member;

a direct current extraction potential between the bias electrode and a counterelectrode to attract ions of a given polarity from said air region toward said counterelectrode; and

an ion-modulating screen member intermediate the ion generator and the counterelectrode, having a plurality of apertures, and including means for selectively creating electrostatic fields in and around said apertures to control the passage of ions therethrough.

6. Apparatus as defined in claim 5 wherein the ion-modulating screen member includes at least one screen electrode adjacent said apertures, and the means for selectively creating electrostatic fields comprises a pulsed potential applied to said screen electrode.

7. Improved electrostatic imaging apparatus of the type including a device for forming electrostatic images on a dielectric imaging member, means for developing said electrostatic images to form visible toner images, and means for transferring said toner images to an image receptor sheet, wherein the improvement comprises an improved device for forming electrostatic images, comprising:

an ion generator comprised of two electrodes ("bias" and "driver" electrodes) separated by a solid dielectric member, with a time-varying potential between said electrodes to create ion-producing electrical discharges in an air region adjacent the bias electrode and solid dielectric member;

a direct current extraction potential between the bias electrode and a counterelectrode to attract ions of a given polarity from said air region toward said counterelectrode; and

an ion-modulating screen member intermediate the ion generator and the counterelectrode, having a plurality of apertures, and including means for selectively creating electrostatic fields in and around said apertures to control the passage of ions therethrough.

8. Apparatus as defined in claim 7 wherein the ion-modulating screen member comprises a dielectric support having first and second electrodes on opposite faces, including an aperture through said first and second electrodes and said dielectric support, and further comprising first and second screen potentials respectively applied to the first and second screen electrodes.

9. Apparatus as defined in claim 7, wherein the dielectric imaging member comprises a cylinder with a dielectric surface layer and a conductive substrate, and the means for transferring the toner image comprises a transfer roller in rolling contact with the dielectric cylinder and forming a nip therewith under high pressure.

10. Apparatus as defined in claim 7 further comprising means for forcing air flow under elevated pressure between said ion generator and said ion-modulating screen member.

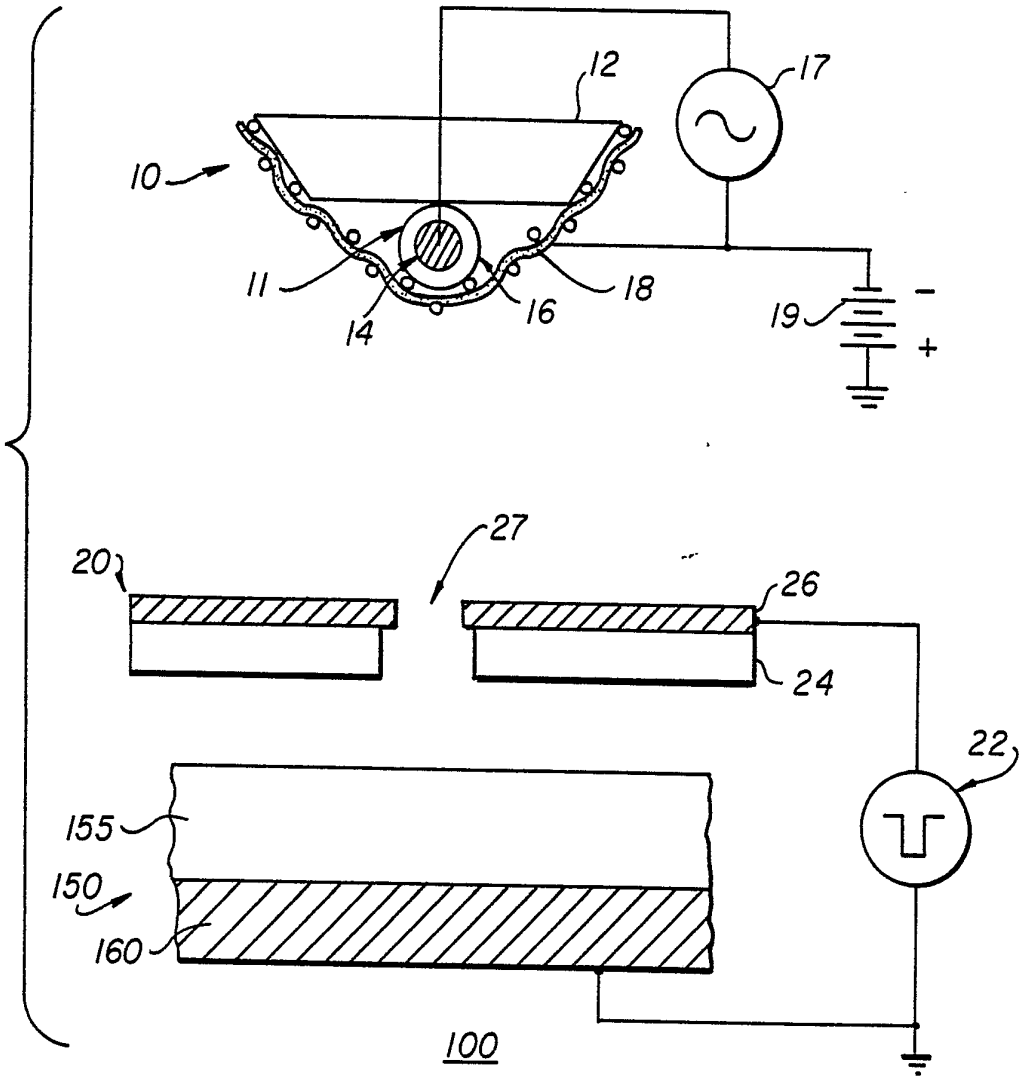


FIG. 1

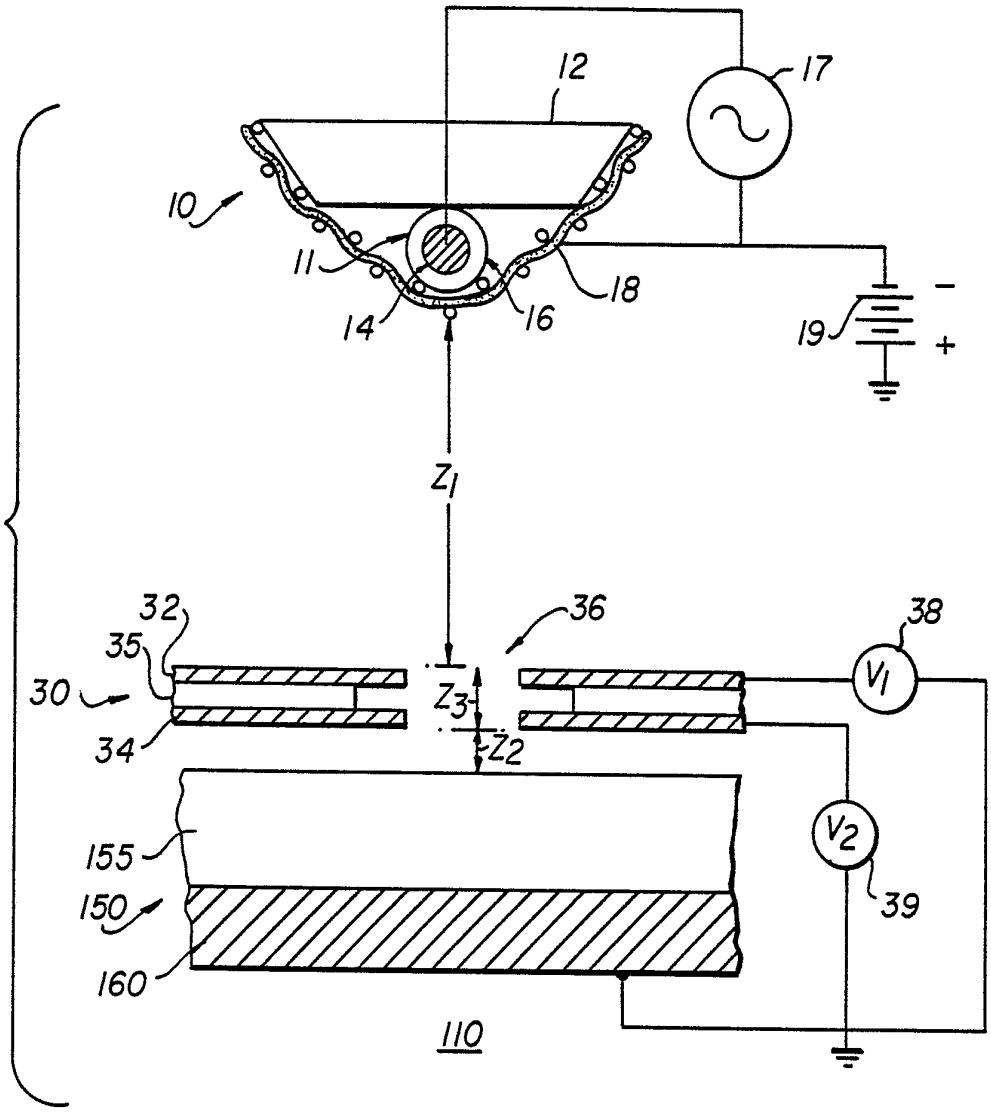
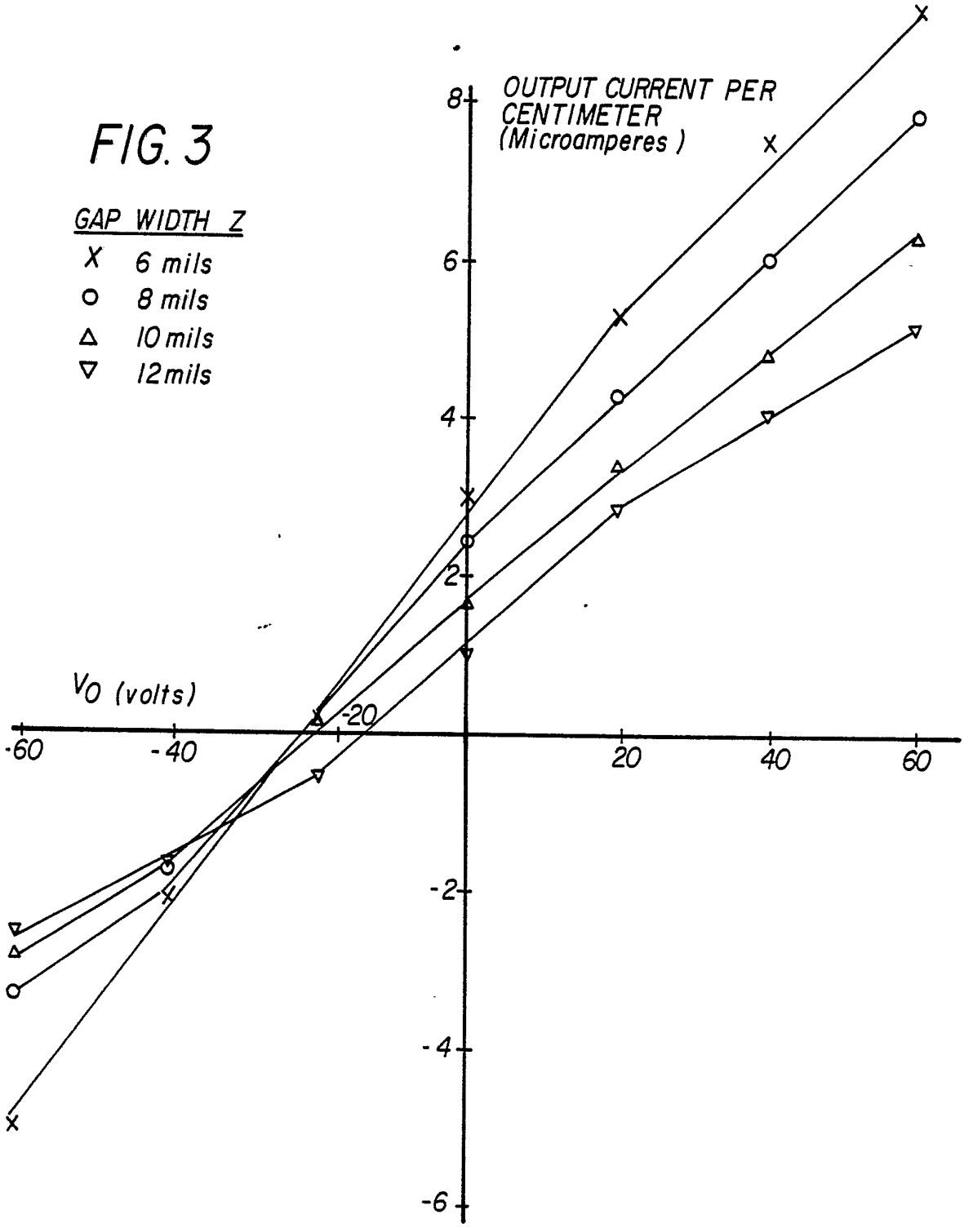

12
17
10
11
18
14
16
19
−
+
Z_1
32
36
38
35
30
Z_3
V_1
34
Z_2
155
V_2
39
150
160
110

FIG. 2

FIG. 3


GAP WIDTH Z
X 6 mils
O 8 mils
Δ 10 mils
▽ 12 mils
OUTPUT CURRENT PER CENTIMETER (Microamperes)
8
6
4
2
-2
-4
-6
Vo (volts)
-60
-40
-20
20
40
60

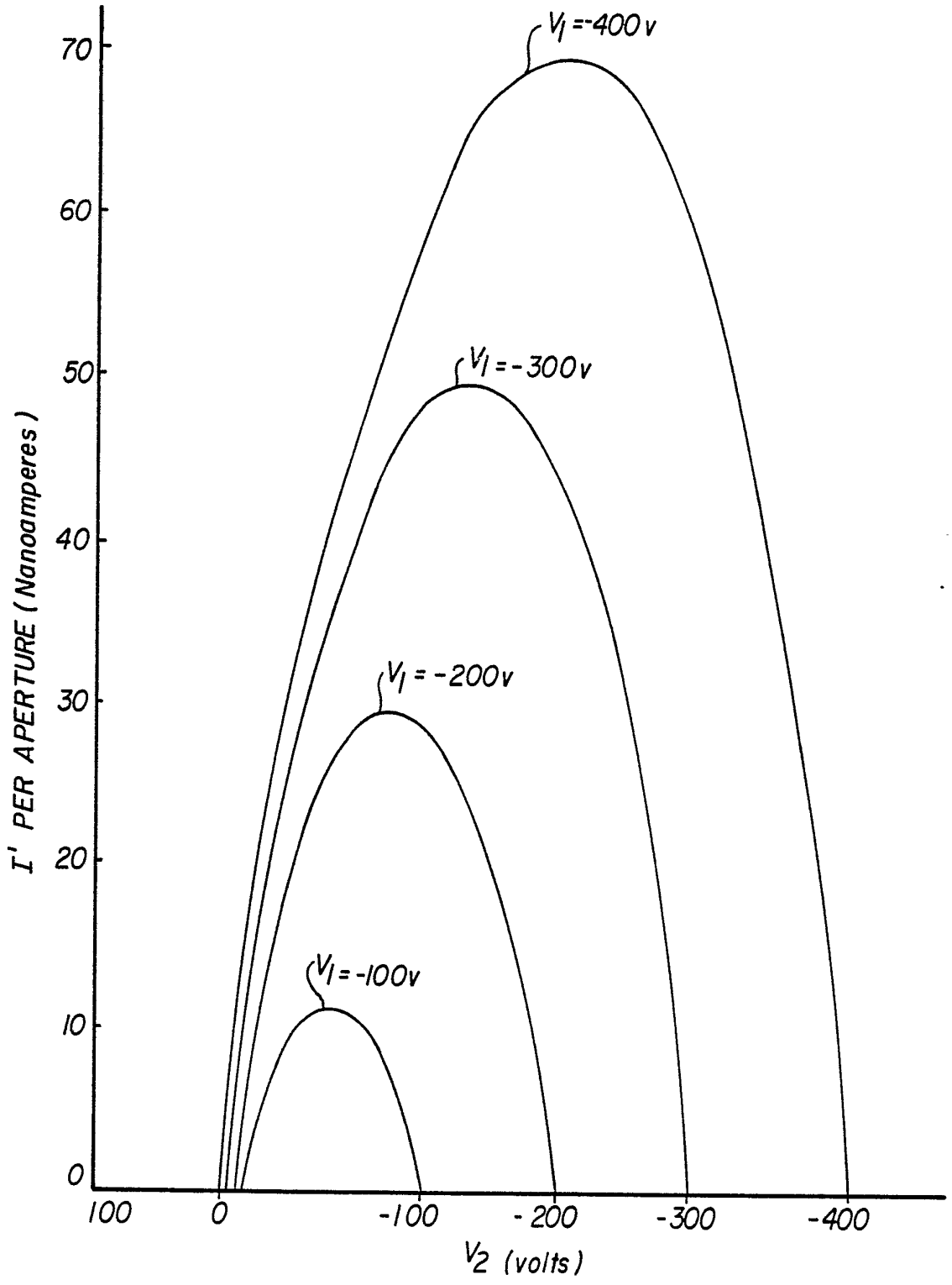

V_1 = -400 v
V_1 = -300 v
V_1 = -200 v
V_1 = -100 v
70
60
50
40
30
20
10
0
I' PER APERTURE (Nanoamperes)
100
0
-100
-200
-300
-400
V_2 (volts)

FIG. 4

FIG. 5

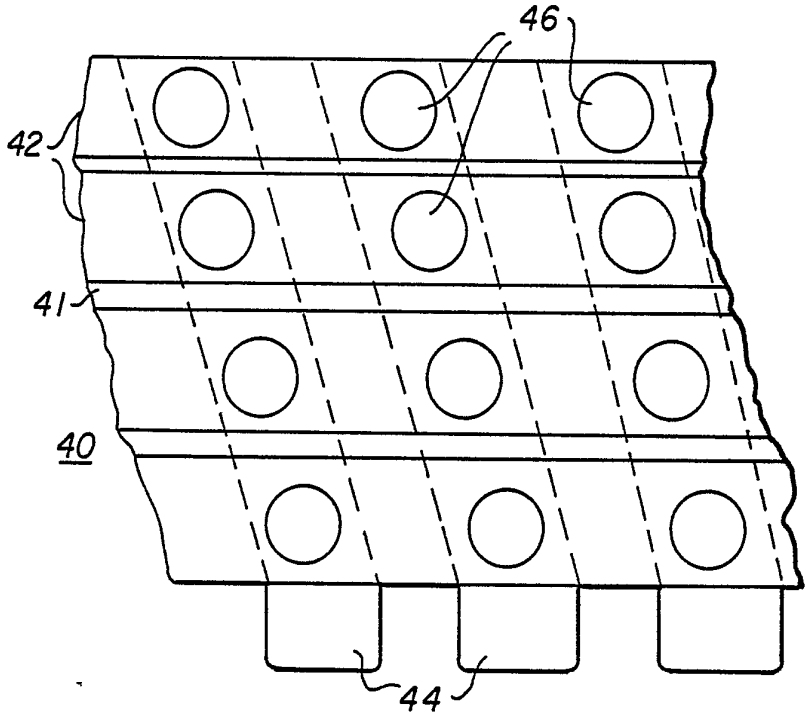


FIG. 7

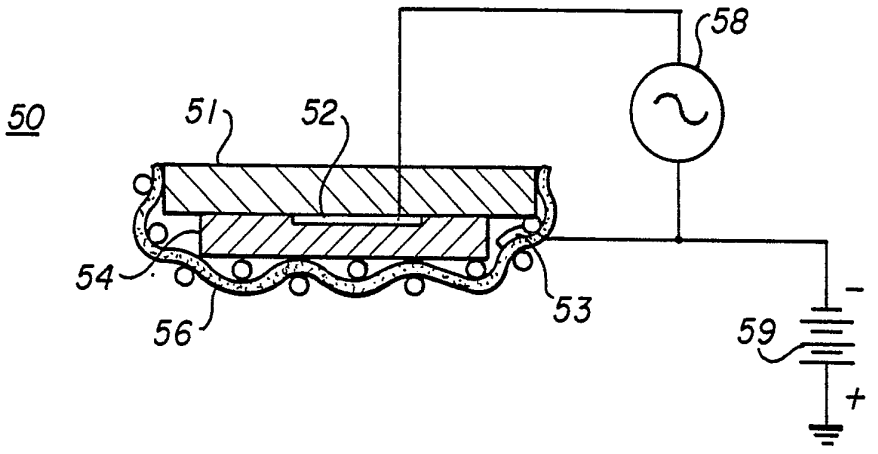


FIG. 6

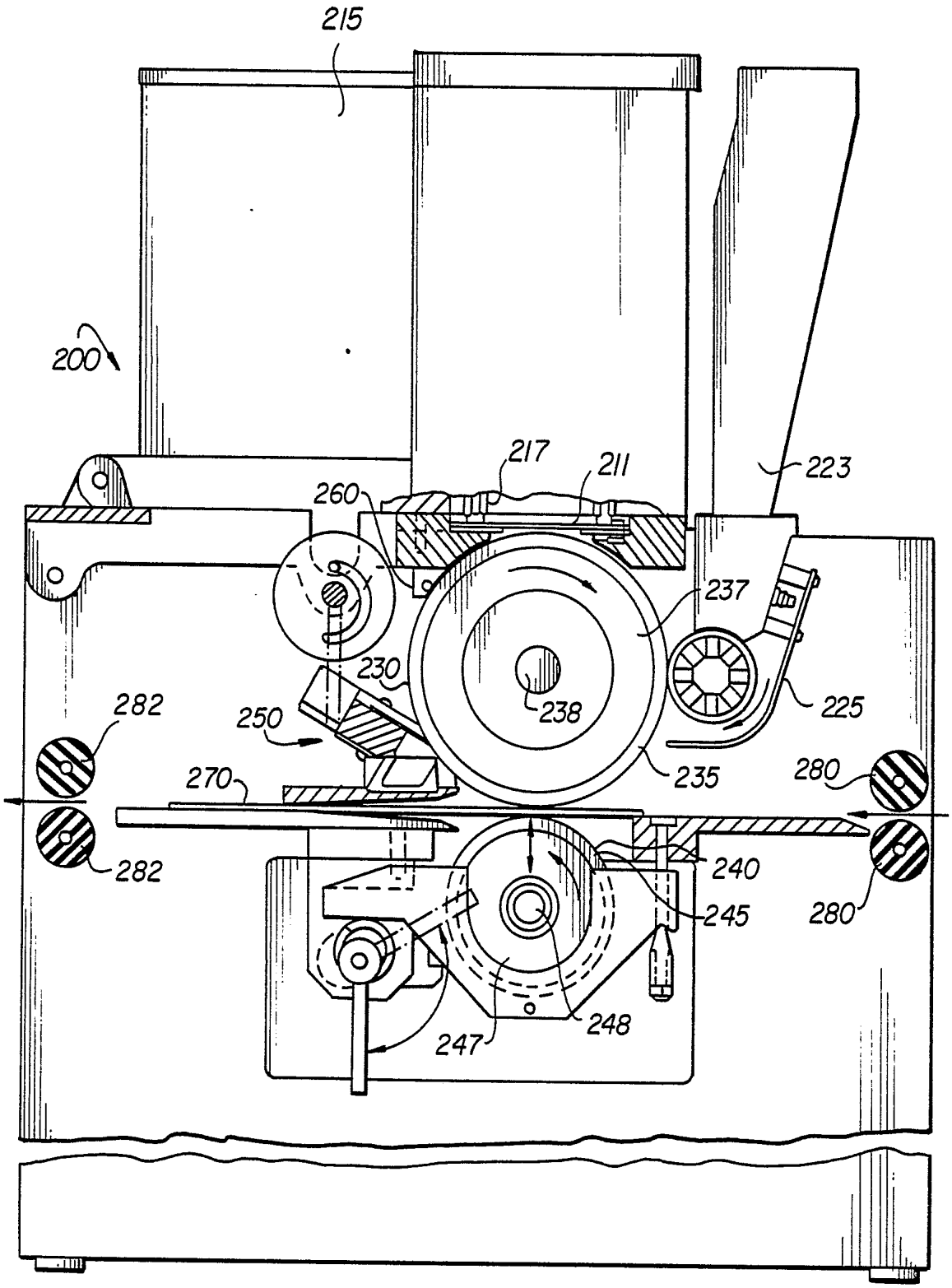
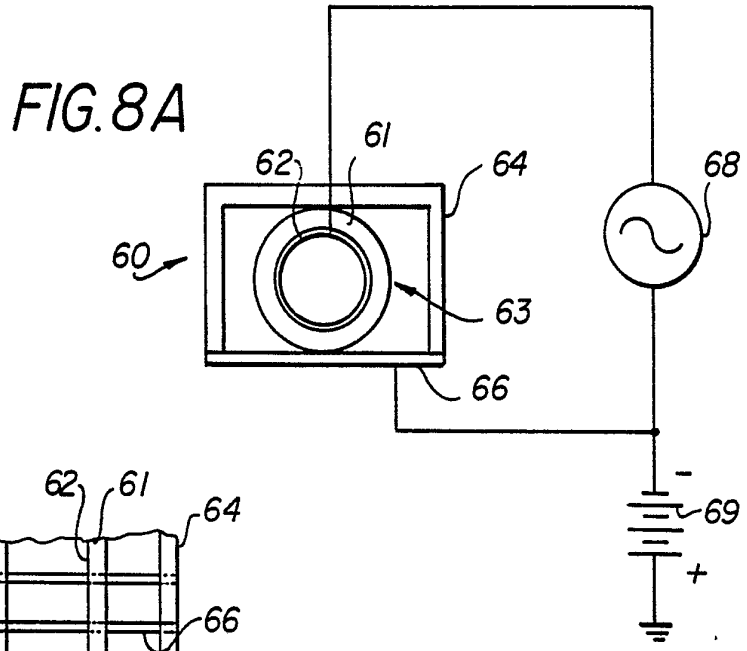

215
200
217
211
223
260
237
230
238
225
282
250
270
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280
248
247

FIG.8A



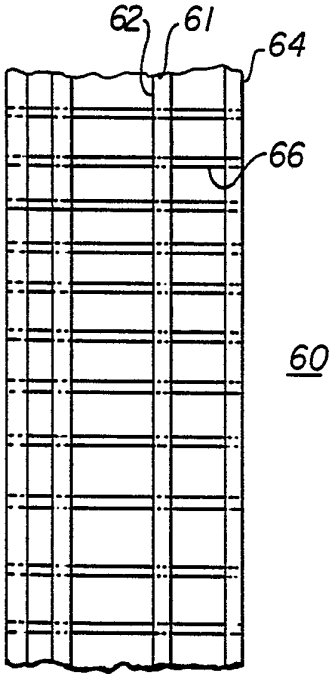
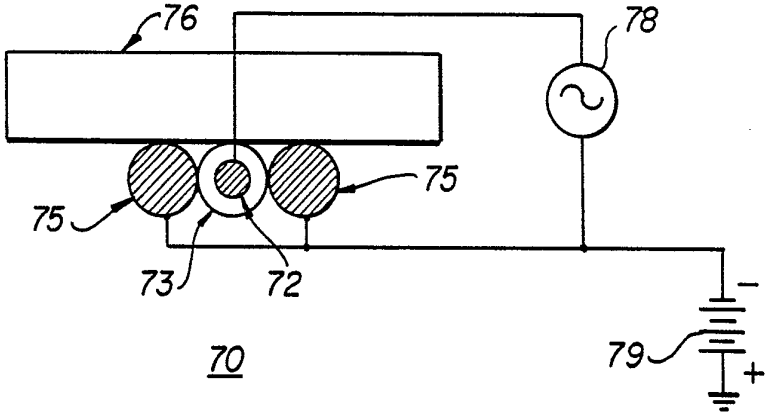


FIG.8B

FIG.9



INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/01989

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[4] G01D 15/06

U.S. CL. 346/159

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U. S.	346/158, 159; 315/111.81, 111.91 250/324-326, 396R. 398, 426 313/360.1, 363.1, 597, 599, 600

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 4,160,257 Published 03 July 1979, CARRISH	1-10
Y	US, A, 4,425,035 Published 10 January 1984, TARUMI et al.	2,3,6,8
A	US, A, 4,320,408 Published 16 March 1982 IWASA et al.	2,3,6,8
Y	US, A, 4,498,090 Published 5 February 1985, HONDA et al.	2,3,6,8
Y	US, A, 4,365,549 Published 28 December 1982, FOTLAND et al.	3,7-10
A	US, A, 4,476,387 Published 9 October 1984, COBB et al.	
Y	US, 4,463,363 Published 31 July 1984, GUNDLACH	4,10
A	US, A, 4,255,043 Published 10 March 1981, HOSHINO et al.	2, 6, 8

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
25 November 1985	22 JAN 1986
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	L. M. PECO