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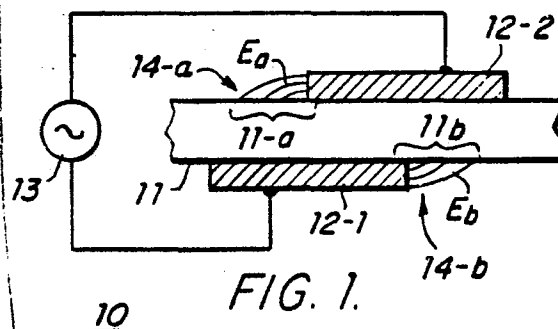
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(54) **Method and apparatus for generating charged particles.**

(57) Generation of charged particles, e.g. ions, by extracting them from a high density source provided by an electrical gas breakdown in an electric field between two conducting electrodes separated by an insulator. When a high frequency electric field is applied, surprisingly high ion current densities can be obtained, providing numerous advantages over conventional ion forming techniques for use in electrostatic printing and office copying.



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Method and Apparatus for Generating Charged Particles

This invention relates to the generation of charged particles, and more particularly, to the generation of ions with high current densities.

Ions can be generated in a wide variety of ways. Common techniques include the use of air gap breakdown, corona discharges and spark discharges. Other techniques employ triboelectricity, radiation (Alpha, Beta, and Gamma, as well as x-rays and ultra-violet light) and microwave breakdown.

Air gap breakdown, i.e., discharges occurring in small gaps between a stylus or wire and the surface of a dielectric material, are widely employed in the formation of electrostatic images. Representative U.S. patents are G.R. Mott 3.208.076; E.W. Marshall 3.631.509; A.D. Brown, Jr. 3.662 396; A.E. Bliss et al. 3.792.495; R.F. Borelli 3.958.251; and R.T. Lamb 3.725.950.

In the case of an air gap breakdown, it is necessary that the gap spacing be maintained between about .0002 and .0008 inches in order to be able to operate with applied potentials at reasonable levels and maintain charge image integrity. Even

- 2 -

then, the latent charge image is not uniform, so that the resultant electrostatically toned image lacks good definition and dot fill.

An alternative to air gap breakdown is the corona discharge from a small diameter wire or a point source. Illustrative U.S. patents are P. Lee 3.358.289; Lee F. Frank 3.611.414; A.E. Jvirblis 3.623.123; H. Bresnik 3.765.027; P.J. Magill et al. 3.715.762; and R.A. Fotland 3.961.574. Corona discharges are widely employed in electrostatic precipitation, and are used almost exclusively in electrostatic copiers to charge photoconductive surface prior to exposure. Corona discharges are also extensively employed in electrostatic separators and in electrostatic coating and spraying equipment.

Unfortunately, standard corona discharges provide limited currents. The maximum discharge current density heretofore obtained has been on the order of 10 microamperes per square centimeter. This can impose a severe printing speed limitation. In addition, coronas can create significant maintenance problems. Corona wires are small and fragile and easily broken. Because of their high operating potentials, they collect dirt and dust and must be frequently cleaned or replaced.

An alternative technique for forming high density corona discharges is to use high velocity air streams. For example, if high pressure air is employed with a small orifice at the corona discharge point, current densities as high as 1000 microamperes per square centimeter are reportedly obtainable (Proceedings of the Conference on Static Electrification, London 1967, Page 139 of The Institute of Physics and Physical Society, London SW1). This technique is awkward, however, and requires both a pressurized air source and critical geometry in order to prevent premature electrical breakdown.

Another method of forming ions, which is particularly useful

in electrostatic applications, uses an electrical spark discharge. Representative U.S. patents are B.E. Byrd 3.321.768; H. Epstein 3.335.322; C.D. Hendricks, Jr. 3.545.374; and W.P. Foster 3.362.325. A low energy spark discharge technique is described by Krekow and Schram in IEEE transactions on Electronic Devices, E.D.-21 // 3, Page 189, March 1974. The electrical spark discharge is objectionable, however, where uniform ion currents are desired or required. This is particularly true where the discharge occurs over the surface of a dielectric.

Accordingly, it is an object of the invention to facilitate the generation of ions, particularly at high current densities.

Another object is to provide a reliable and stable source of ions. A related object is to provide an ion generating system which does not require critical periodic maintenance. Another related object is to simplify maintenance and eliminate the objectionable characteristics of corona wires, including the fragility and tendency to collect dirt and dust.

A further object of the invention is to provide an easily controlled source of ions. A related object is to provide a multiplexable source of ions using different voltage sources to supply an alternating breakdown field and an ion extraction field.

Yet another object of the invention is to generate ion currents for use in producing electrostatic images in which charge image integrity is maintained. A related object is to achieve comparatively uniform charge images which can be toned with good definition and dot fill.

Further objects are to achieve increased electrostatic printing speed; suitable charge densities without requiring a pressurized air source and critical electrode geometry; and uniform ion density.

- 4 -

In accomplishing the foregoing and related objects, the invention provides for applying a potential between two electrodes separated by a dielectric member to cause an electrical air gap breakdown in fringing field regions. Ions thus produced can then be extracted from the discharge and applied to a further member.

In accordance with one aspect of the invention, the further member can be a conductive support with a dielectric coating.

In accordance with another aspect of the invention, the discharge initiating potential is a high frequency alternating voltage, and the extraction is accomplished using a direct voltage.

In accordance with yet another aspect of the invention the extracted ions can be used directly or applied to particulate matter, which is moved under the action of an electric field. Such charged particles can be used in forming an electrostatic pattern using, for example, a discharge electrode with a gap patterned in accordance with the configuration of a character or symbol for which a charge image is desired.

According to a further aspect of the invention the electrodes can be multiple electrodes forming cross points in a matrix array. Ions are extracted from electrode apertures at selected matrix crossover points by simultaneously providing both an electrical discharge at the selected apertures and an external ion extraction field.

The extracted ions can be used to form an electrostatic latent image which is subsequently toned and fused. The image can be formed on a dielectric layer and transferred to plain paper. Alternatively, charged particulate matter can be deposited on plain paper to form a visible image, or collected on a conducting surface.

According to still another aspect of the invention the apparatus

is formed by a dielectric member which separates two electrodes, at least one of which has an edge on the surface of the dielectric member. When a voltage is applied between the electrodes, for example, an alternating voltage in the frequency range from about 60 hertz to about 4 megahertz, an electrical discharge is produced between one of the electrodes and the dielectric surface. The electrodes, which can be alike or different, can take a wide variety of forms.

The alternating potential may be in an essentially sinusoidal, square or triangular wave form.

The apparatus may include means for transferring the charges generated by said electrical discharge to a further member. This further member can be a dielectric. Alternatively, it may have a conductive base with a dielectric coating. In this case the further member can be conductive paper with a dielectric coating. It is also possible to use as further member a conductor.

The apparatus may include a solid dielectric member. This solid dielectric member may comprise a plastic film or glass or a ceramic.

Other aspects of the invention will become apparent after considering several illustrative embodiments, taken in conjunction with the drawings in which:

Figure 1 is a schematic and sectional view of an ion generator in accordance with the invention;

Figure 2 is a schematic and sectional view of a generator and ion extractor in accordance with the invention;

Figure 3 is a plan view of an ion generator for use in electrostatic printing;

Figure 4 is a plan view of a matrix ion generator for implementing the invention in dot matrix printing;

Figure 5 is a partial perspective view of a physical model of an ion generator in accordance with the invention;

Figure 6 is a schematic view of an illustrative copier implemented using the invention;

Figure 7 is a graph illustrating the relationship between electrode voltage and paper voltage in accordance with the invention.

Turning to the drawings, an ion generator 10 in accordance with the invention is used in producing an air gap breakdown between a dielectric 11 and respective conducting electrodes 12-1 and 12-2 using a source 13 of alternating potential. When electric fringing fields E_A and E_B in the air gaps 14-a and 14-b exceed the breakdown field of air, an electric discharge occurs which results in the charging of the dielectric 11 in regions 11-a and 11-b adjacent electrode edges. Upon reversal of the alternating potential of the source 13, there is a charge reversal in the breakdown regions 11-a and 11-b. The generator 10 of Figure 1, therefore, produces an air gap breakdown twice per cycle of applied alternating potentials from the source 13 and thus generates an alternating polarity supply of ions.

The extraction of ions produced in accordance with the generator 10 of Figure 1 is illustrated by the generator-extractor 20 of Figure 2. The generator 20_A includes a dielectric 21 between conducting electrodes 21-1 and 21-2. In order to prevent air gap breakdown near electrode 22-1, the electrode 22-1 is encapsulated or surrounded by an insulating material 23. Alternating potential is applied between the conducting electrodes 22-1 and 22-2 by a source 24_A. In addition, the second electrode 22-2 has a hole 22-h where the desired air gap breakdown occurs relative to a region 21-r of the dielectric 21 to provide a source of ions.

The ions formed in the gap 21-h may be extracted by a direct current potential applied from a source 24-B to provide an external electric field between the electrode 22-2 and a grounded auxiliary electrode 22-3. An illustrative insulating surface to be charged by the ion source in

- 7 -

Figure 2 is a dielectric (electrographic) paper 25 consisting of a conducting base 25-P coated with a thin dielectric layer 25-d.

When a switch 26 is switched to position X and is grounded as shown, the electrode 22-2 is also at ground potential and no external field is present in the region between the ion generator 20_A and the dielectric paper 25. However, when the switch 26 is switched to position Y, the potential of the source 24_B is applied to the electrode 21-2. This provides an electric field between the ion reservoir 21-r and the backing of dielectric paper 25. The ions extracted from the air gap breakdown region then charge the surface of the dielectric layer 25-d.

The generator and ion extractor 20 of Figure 2 is readily employed, for example, in the formation of characters on dielectric paper in high speed electrographic printing. Illustrative sources for the electrographic printing of characters in accordance with the invention are shown in Figures 3 and 4.

In Figure 3 a character generator 30 is formed by a dielectric member 31 which is sandwiched between an etched conducting sheet 32-1 and a set of counterelectrodes 32-2, 32-3 and 32-4.

The etched or mask electrode 32-1 illustratively is shown with etched characters A, B and C. The fringing fields at the edges of the etched characters provide a high density source of ions when an air gap breakdown according to the invention is produced by alternating potential applied between the etched electrode 32-1 and the counterelectrodes. Thus when it is desired to generate ions for printing a selected character, such as the letter B, a source of high frequency alternating voltage (not shown) is applied between the etched electrode 32-1 and the associated counterelectrode 32-3. This provides a high

density supply of ions in the region of the dielectric 31 at the edges of the etched character B in the mask 32-1.

The ions are then extracted and transferred to a suitable dielectric surface, for example the dielectric coated paper 25 of Figure 2, by the application of a direct voltage between the paper backing and the mask 32-1, resulting in the formation of the electrographic latent image B on the dielectric surface of the paper 25.

To employ the invention in the formation of dot matrix characters on dielectric paper, the matrix ion generator 40 Figure 4 may be employed. The generator 40 makes use of a dielectric sheet 41 with a set of apertured air gap breakdown electrodes 42-1 through 42-4 on one side and a set of selector bars 43-1 through 43-4 on the other side, with a separate selector 43 being provided for each different aperture 45 in each different finger electrode 42.

When an alternating potential is applied between any selector bar 43 and ground, ions are generated in apertures at the intersections of that selector bar and the finger electrodes. Ions can only be extracted from an aperture when both its selector bar is energized with a high voltage alternating potential and its finger electrode is energized with a direct current potential applied between the finger electrode and the counterelectrode of the dielectric surface to be charged. Matrix location 45₂₃, for example, is printed by simultaneously applying a high frequency potential between selector bar 43-3 and ground and a direct current potential between finger electrode 42-2 and a dielectric receptor member's counterelectrode. Unselected fingers as well as the dielectric members counter-electrode are maintained at ground potential.

By multiplexing a dot matrix array in this manner, the number of required voltage drivers is significantly reduced. If, for example, it is desired to print a dot matrix array across an 8" wide area at a dot matrix resolution of 200 dots per inch, 1600 separate drivers would be required if

multiplexing were not employed. By utilizing the array of Figure 4 with, for example, 20 alternating frequency driven fingers, only 80 finger electrodes would be required and the total number of drivers is reduced from 1600 to 100.

In order to prevent air gap breakdown from electrodes 42 to the dielectric member 41 in regions not associated with apertures 45, it is desirable to coat the edges of electrodes 42 with an insulating material. Unnecessary air gap breakdown around electrodes 43 may be eliminated by potting these electrodes.

The invention may be employed to form a rectangular area of charge using geometry of the module 50 shown in Figure 5. Charging electrodes 52-1 and 52 are separated from the electrode 52-3 by a dielectric member 51, with the electrode 52-3 potted in an insulator 55. The region between the electrode 52-1 and 52-2 provides a slot in which an air gap discharge is formed when a high frequency alternating potential is applied between electrodes 52-1 and 52-2 and electrode 52-3.

The charging array of Figure 5 may be employed in a plain paper copier to replace the coronas normally found in such a copier.

Figure 6 illustrates schematically a plain paper copier employing charging arrays of the kind shown in Figure 5. A copier drum 61 is charged using a charging element 62-1, having the configuration shown in Figure 5. If the drum is selenium or a selenium alloy and it is desired to charge the surface, for example, to a positive potential of 600 volts, then the slotted electrode 62-1 is maintained at 600 volts. After charging, the drum 61 is discharged with an optical image provided by a scanner at station 63. The resulting latent electrostatic image is toned at station 66 and the toner is transferred to a plain paper sheet 68, using a transfer ion generator 62-2 according to Figure 5,

- 10 -

with the slotted electrode again maintained at a positive potential. The latent residual electrostatic image in the surface of the drum and any uncharged toner may be electrically discharged by employing a discharge unit 62-3, also according to Figure 5. Here the slotted electrode is maintained at ground potential and any residual charge on the surface of the drum and toner causes ions to be extracted from the air gap breakdown in the slot, thus effectively discharging the surface. A cleaning brush 64 is employed to remove residual toner remaining on the surface and the drum is then ready to be recharged.

Also shown in Figure 6 is a dot matrix charging head 65 which may be configured according to Figure 4. This permits a plain paper copier to be employed as a printer. In that event the drum 61 is discharged at station 63 and recharged by the dot matrix printing head 65, permitting the machine 60 to function both as a copier and a printer. In addition, the apparatus 60 may function simultaneously as a copier and printer where overlays are desired.

Examples

The foregoing description illustrates the general principles and features of the invention. The following specific and non-limiting examples illustrate specific applications of the invention.

Example I

A 1-mil stainless steel foil is laminated on both sides of corning code 8871 capacitor ribbon glass. The stainless foil is coated with resist and photo etched with a pattern similar to that shown in Figure 4, with holes or apertures in the fingers approximately 0.006" in diameter. This provides a charging head which can be employed to generate latent electrostatic dot matrix character images on dielectric paper according to Figure 2.

Charging occurs only when there is simultaneously a potential of negative 400 volts on the fingers containing the holes and

- 11 -

an alternating potential of 2 kilovolts peak at a frequency of 500 kilohertz supplied between the finger and the counter electrode. A spacing of 0.0008" is maintained between the print head assembly and the dielectric surface of the electrographic sheet. The duration of the print pulse is 20 microseconds. Under these conditions, it is found that a latent electrostatic image of approximately 300 volts is produced on the dielectric sheet. This image is subsequently toned and fused to provide a dense dot matrix character image. The ion current extracted from this charging head, as collected by an electrode spaced 0.008" away from the head, is found to be 1 milliampere per square centimeter.

Example II

Example I is repeated employing a polyimide dielectric rather than capacitor glass. As before, a 1-mil stainless steel foil is laminated to 1-mil thick Kapton[®] polyimide film. Results equivalent to those of Example I are obtained at an applied high frequency potential of 1.5 kilovolts peak.

Example III

An electrostatic charging head of the type shown in Figure 3 is fabricated employing 1-mil stainless steel foil laminated to both sides of 1-mil polyimide sheet. In order to print fully formed characters on a dielectric surface, 1/10" high characters are etched in the foil on one side of the sheet, while fingers covering each character are etched on the other side of the foil as indicated in Figure 3. In order to establish conductivity within normally isolated areas of characters, bridges 1 to 2-mils in thickness are left unetched. The character stroke width is etched to 6-mils. Printing is carried out by applying the potentials of Example II with a pulse width of 40 microseconds. The toned images exhibit sharp edges and high optical density. The character stroke width in the image is 0.012".

Example IV

The invention is applied to provide continuous tone imagery by extracting a number of ions from the charging head per unit time in proportion to the applied ion extraction potential. This is illustrated in Figure 7 where the apparent surface

potential on a dielectric surface is plotted as a function of the potential difference between the ion generating electrode and the dielectric counter electrode. The ion generating electrode dielectric surface spacing is 0.006" and the charging time is 50 microseconds.

The foregoing description and examples are illustrative only and other adaptations, modifications and equivalents of the invention will be apparent to those of ordinary skill in the art.

The foregoing examples of the use of the ion generating system of the invention illustrate its wide applicability. In general, the corona wires or points of any present system may be replaced by the apparatus of the invention. In addition to the illustrated applications, the method and apparatus of the invention may be used in numerous other applications, not illustrated, such as those dealing with electrostatic separation and coatings.

C l a i m s

1. The method of generating ions which comprises applying an alternating potential between first and second electrodes separated by a solid dielectric member, with an air gap region at a junction of the first electrode and said solid dielectric member, to cause an electrical discharge in said air gap region.
2. The method of claim 1 further including the step of extracting ions from said discharge.
3. The method of claim 2 further including the step of applying the extracted ions to a further member.
4. The method of claim 2 further including the step of applying the extracted ions to a dielectric surface with a conductive backing.
5. The method of claim 2 further including the step of applying the extracted ions to particulate matter.
6. The method of claim 2 wherein said ions are extracted by a direct voltage.
7. The method of claim 2 further comprising the step of forming an electrostatic pattern with said extracted ions.
8. The method of claim 7 wherein the ions are extracted by a direct voltage applied to the first electrode, with a gap patterned in accordance with the configuration of a character or symbol for which a charge image is desired.
9. The method of claim 1 wherein the first electrode comprises an open mesh woven metal screen.

10. The method of claim 5 further including the step of physically moving the charged particulate matter under the action of an electric field.

11. The method of claim 1 wherein said electrodes consist of a multiplicity of electrodes forming crosspoints in a matrix array configured such that all electrodes on one side of said solid dielectric member contain apertures at said matrix electrode crossover regions.

12. The method of claim 11 wherein the ions are extracted from selected matrix crossover apertures by simultaneously providing both an electrical discharge in said aperture and an external ion extraction field.

13. The method of generating and extracting ions as recited in claim 12, for electrostatic printing, further comprising the steps of forming an electrostatic latent image with said extracted ions, and toning and fusing the electrostatic latent image.

14. The method of electrostatic printing of claim 13 wherein the electrostatic latent image is formed on a dielectric layer, further comprising the step of transferring the toned electrostatic latent image to plain paper.

15. The method of claim 10 further comprising the step of collecting the charged particulate matter on a conductive surface.

16. The method of claim 10 further comprising the step of collecting the charged particulate matter onto plain paper to form a visible image.

17. Apparatus for generating ions which comprises a solid dielectric member;

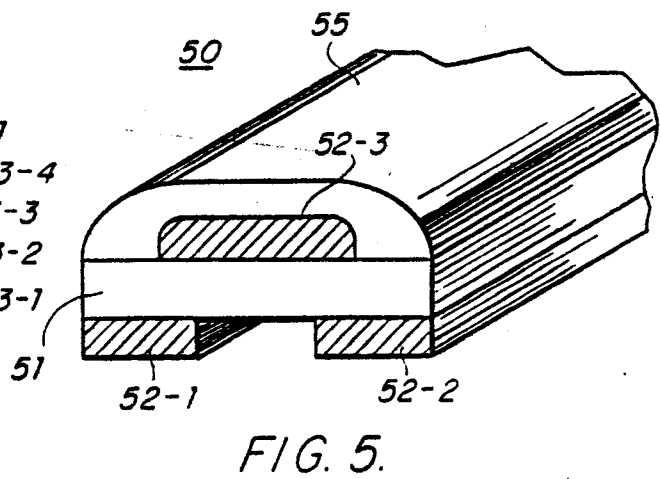
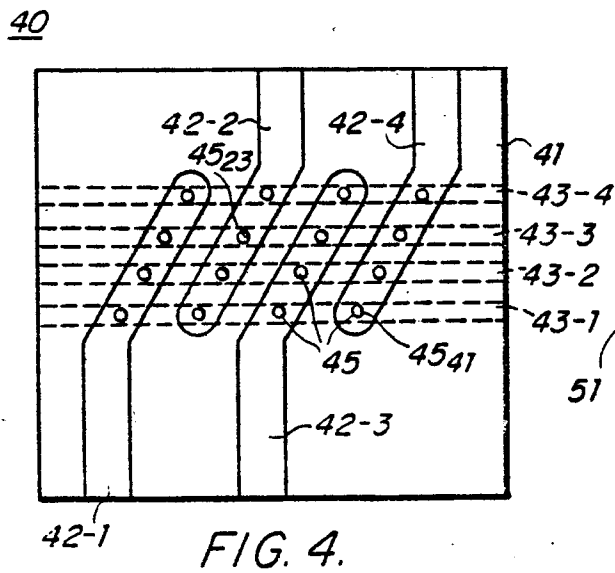
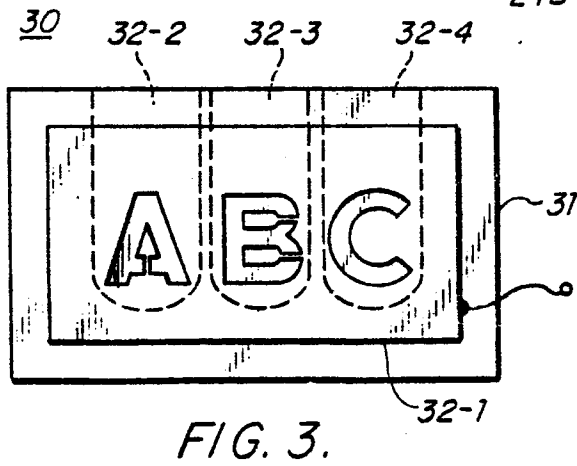
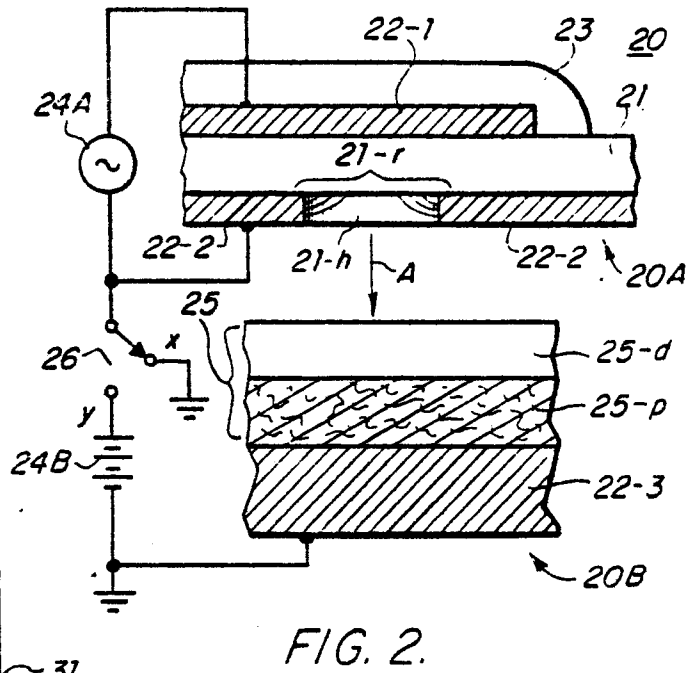
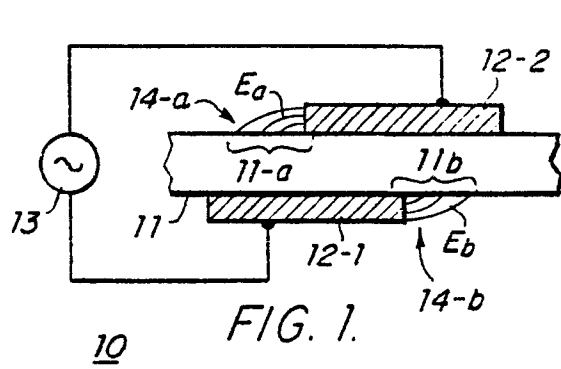
- 15 -

a first electrode on one side of said solid dielectric member, with an air gap region at a junction of the first electrode and the solid dielectric member;
a second electrode on an opposite side of said solid dielectric member; and
means for applying an alternating potential between said electrodes to produce an electrical discharge in said air gap region.

18. Apparatus as defined in claim 17 wherein said first electrode is an apertured mask.

19. Apparatus as defined in claim 17 wherein said first electrode comprises a plurality of edge electrodes.

20. Apparatus as defined in claim 17 wherein said second electrode comprises a plurality of selector bars.



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2 / 2

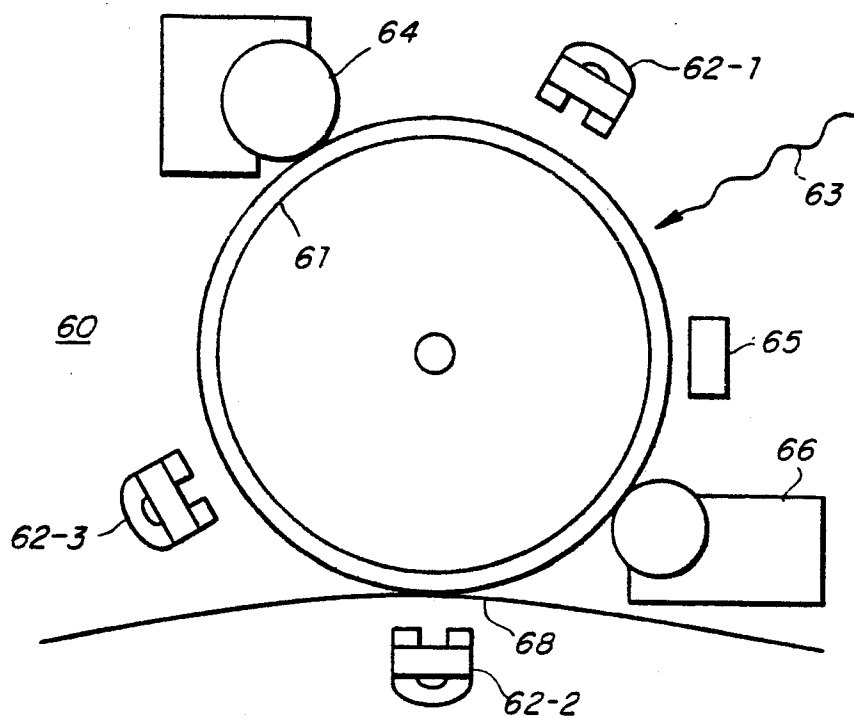


FIG. 6.

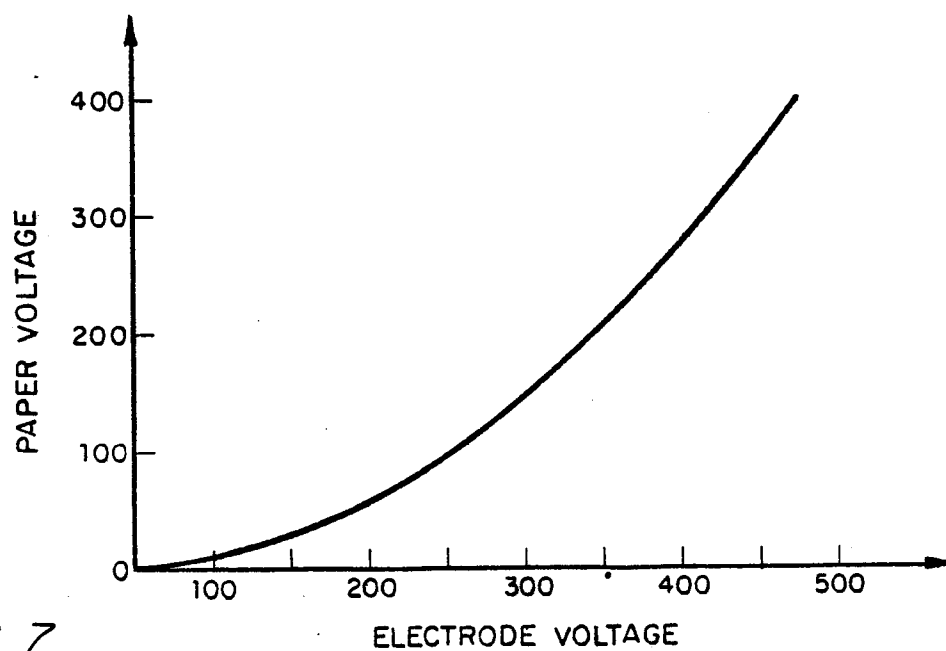


FIG. 7.