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McCurry

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[54] ELECTRO-IONIC PRINTING

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[52] U.S. Cl. 346/74 ES, 250/49.5 GC

[51] Int. Cl. G01d 15/06, H01j 29/84

[58] Field of Search 346/74 ES, 74 EB, 75; 250/49.5 GC, 41.9 SE

[56] References Cited

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3,103,582	9/1963	Morgan	250/41.9 SE
3,611,422	10/1971	Rourke	346/75
3,495,269	2/1970	Mutschler et al.	346/74 EB
3,117,022	1/1964	Bronson et al.	346/74 EB

Primary Examiner—Bernard Konick
Assistant Examiner—Jay P. Lucas
Attorney—Andrew Taras et al.

[57] ABSTRACT

A method of forming electrostatic images on a dielectric surface by controlling the relative ion concentration in a gas stream moving through a channel and directed upon said dielectric surface. Application of an electric field across the channel enables the stream to vary in ion concentration so as to cause the formation of a desired linear charge configuration on the dielectric. Selective application of electric fields to an array of channels causes formation of desired image charge configurations on the dielectric surface.

4 Claims, 10 Drawing Figures

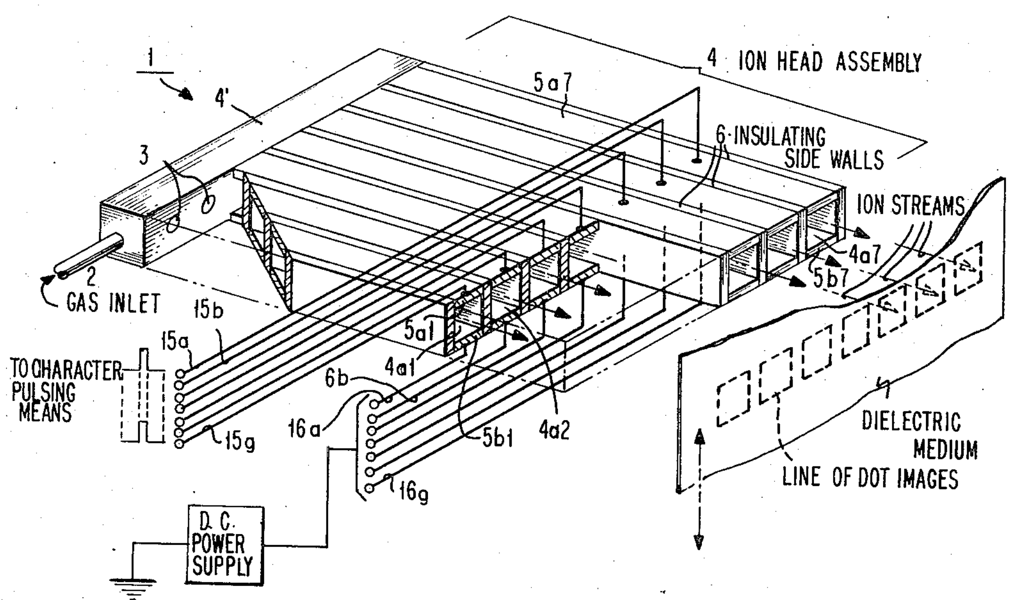
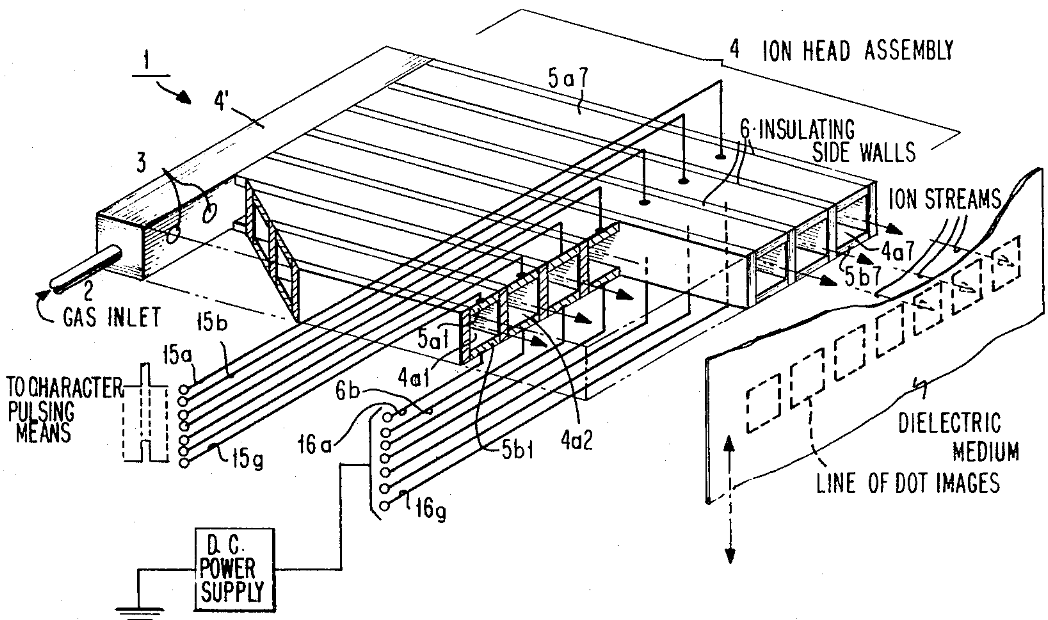


FIG. 1



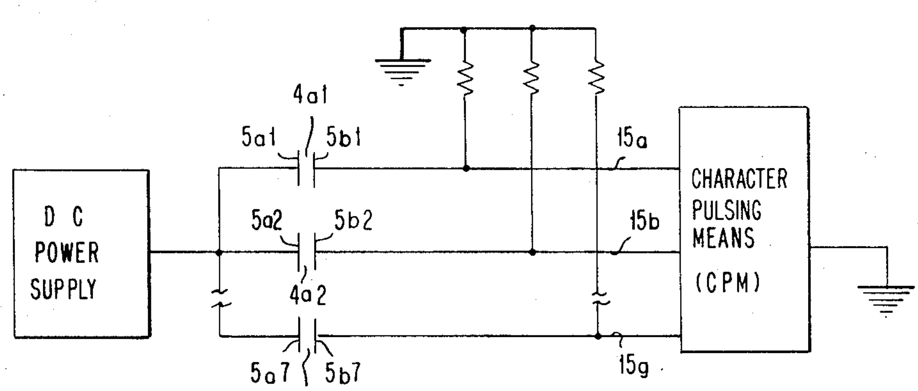


FIG. 2

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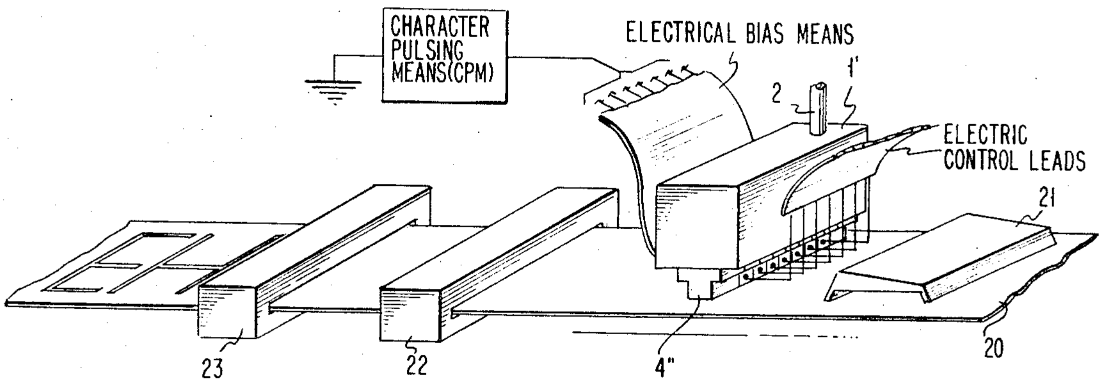


FIG. 3

FIG. 4a

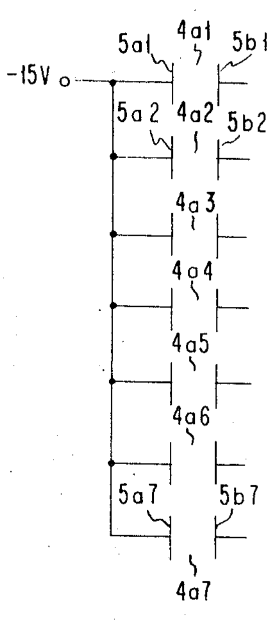


FIG. 4b

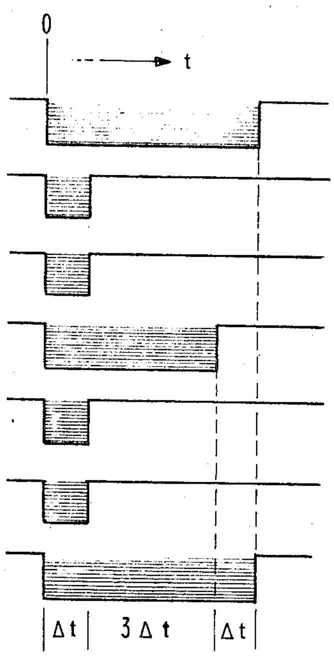
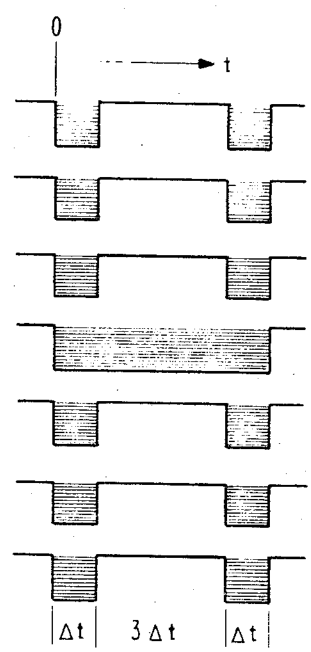


FIG. 4c



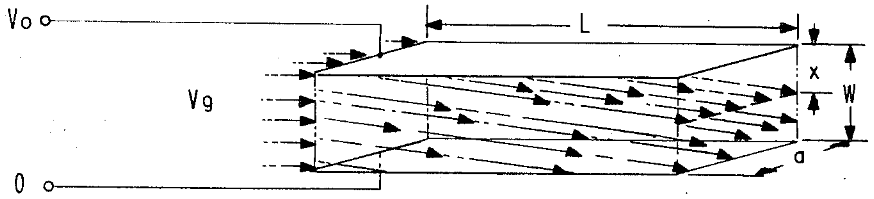


FIG.5a

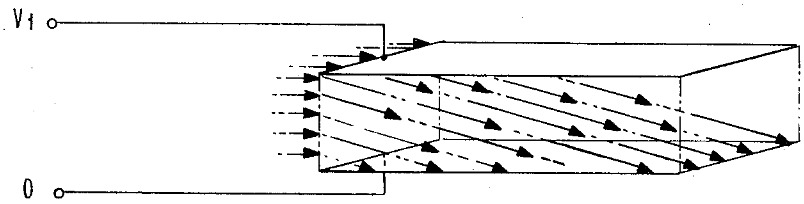


FIG.5b

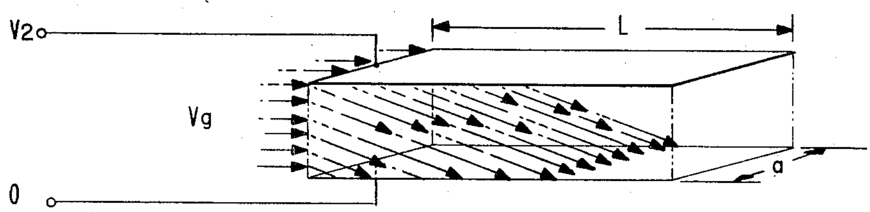


FIG.5c

ION CURRENT PULSE BEHAVIOUR · (SAMPLE THEORY)

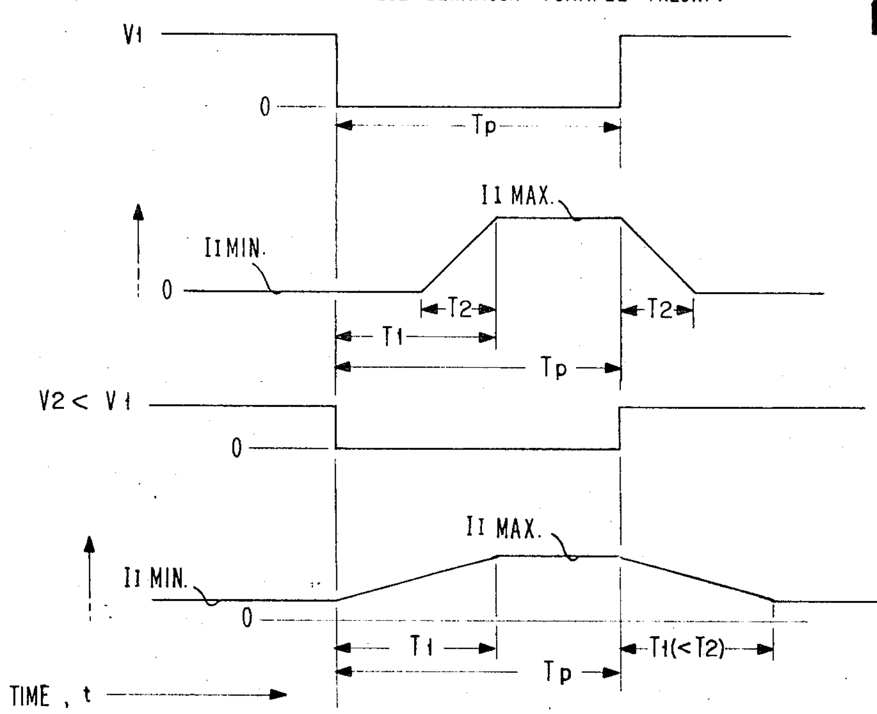


FIG. 6

ELECTRO-IONIC PRINTING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates broadly to the control of the ion concentration in a gas stream, and more particularly to the formation of an image on a dielectric surface by directing thereon a controlled concentration of ions borne by the gas stream.

2. Description of the Prior Art

The prior art is replete with a wide variety of means for and methods of forming latent images on surfaces that are eventually transformed, by well known means, into visible readable patterns. Many of these means utilize the various forms of optical systems directing light energy upon light sensitive surfaces for the formation of the images. These optical systems, however, are rather expensive and somewhat bulky. Other systems employ a variety of electrostatic techniques for the formation of the latent images. These, however, suffer from the drawback that relatively high voltages are required that necessitate mechanical and electrical instrumentalities that are expensive and require rather extensive maintenance procedures.

The most pertinent art is found in U.S. Pat. No. 3,495,269 issued to Mutschler et al. in which latent image formation is produced as a result of an ion charge produced in the air gap between the head and the image receiving surface. This charge is the result of electrical breakdown in the air gap caused by de-excitation of Metastable Helium atoms, the latter being generated by the application of high electric fields to helium atoms.

SUMMARY OF THE INVENTION

The present invention, on the other hand, employs a relatively simple means for controlling the ion concentration in a moving gas stream directed upon a dielectric surface to cause the formation of a desired latent image.

Accordingly, it is the principal object of the invention to provide a unique method for controlling ion concentration in a moving gas stream.

Another object is to provide a relatively simple and inexpensive method for forming latent images on a dielectric surface.

Yet another object is to provide a relatively simple and inexpensive method for forming latent images on an image receiving surface by controlling ion concentration in a moving gas stream directed on said surface.

Still another object is to provide electrostatic images of a high quality and resolution on a dielectric surface.

Aside from these various objects, the invention has a decided advantage over the prior art printing techniques by virtue of the fact that:

Any gas can be used in which stable corona can be generated. It is not limited to He or inert gases.

Ions are transported primarily by the gas stream rather than by an accelerating electric field.

There is no electrical breakdown in control region, hence no erosion or other deterioration effects.

Electrical control has only to move ions across a gap, it does not have to cause breakdown; hence the control voltage and power are reduced by orders of magnitude compared with other techniques.

Metastable atoms are not required.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an ion head assembly generating a plurality of individual ion streams.

FIG. 2 is a schematic arrangement of the invention showing 3 channels of the head assembly interconnected between a DC power supply and a character pulsing means.

FIG. 3 is a schematic arrangement of a printer utilizing the head assembly of FIG. 1.

FIGS. *4a*, *4b*, and *4c* show schematically the 7 channels of a write head and the pulse patterns for forming images of the alphabetic characters E and H, respectively.

FIGS. *5a*, *5b*, and *5c* show diagramatically how ion concentration is controlled in a channel of the ion head.

FIG. 6 shows ion current pulse behavior according to theory.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The method of controlling a stream of gas borne ions may be explained in connection with FIG. 1 herein is shown an ion generating chamber 1, similar to the one shown and described in a copending application, Ser. No. 69,647, filed Sept. 4, 1970, titled "Method and Apparatus for Generating Electrostatic Images." A gas, for example air under pressure is admitted into the ion chamber by way of an inlet 2 and the ions are generated in the manner described in said copending application. The gas exiting from ports 3 is laden with a very high concentration of ions. Each port 3 communicates with an individual channel of which there are 7 such channels namely *4a1*–*4a7* constituting a head assembly 4. Each channel is constituted of electrical conducting top and bottom wall members *5a*, *5b* and insulating side walls 6. The head assembly 4 is held together and attached to the ion chamber by any suitable means not shown. It is thus seen that the head assembly 4 provides a plurality of longitudinal channels insulated from each other to provide a plurality of individual ion streams, each of high ion concentration. The cross-section of each channel may be any suitable configuration, for example, square, rectangular, or any other desired cross-section. Attached to the top and bottom walls *5a1*–*5a7*, *5b1*–*5b7* are electrical lines *15a*–*15g*, *16a*–*16g*. Lines *16a*–16 are connected in common to a DC power supply, while the lines *15a*–*15g* are individually controlled by differentially timed pulses issued by a character pulsing means, cpm.

As the gas streams pass through their respective channels ion concentration decreases as a result of recombination and neutralization at the channel walls. The ion loss through a conductive wall may be substantially increased by superimposing an electrical field across opposing channel walls, for example, the top and bottom walls. Application of a sufficiently large electrical field will remove substantially 100 percent of the ion concentration in the gas stream. Conversely, the reduction of this electrical field reduces the extent of recombination and neutralization, thus by reducing the electrical field to substantially zero the maximum concentration of ions may be transmitted through the channels. The concentration of ions and, hence the electrical charge transmitted through each individual channel is controlled by an appropriate electrical field applied transversely to the direction of stream flow. The electrical field is induced by application of an electrical potential through the lines **15*a*–15*g*** connected to the opposing walls of the channels shown in the drawing of FIG. 1. The "write state" of a channel is attained when a low or zero transverse electrical field is applied, and the "off state" is attained with the application of a greater biasing electrical field to remove more ions from the gas stream. In the case of a printing application, the variation of the electrical potentials to produce character printing is controlled by the character pulsing means, cpm.

The application of desired electrical fields to a write head **4'** is schematically illustrated in FIG. 2 In this schematic arrangement, the write head **4'** partially shown with **3** capacitors, representing **3** channels shown in FIG. **1**. The plates **5*a*1**, **5*b*1**, of the capacitors, correspond to the top and bottom channel walls respectively. Each capacitor is seen connected between the character pulsing means (cpm) by way of lines **15*a*–15*g*** and the DC power supply, the latter being adjusted to a desired potential V to obtain the desired ion output. The character pulsing means, cpm, supplies pulses of appropriate polarity and magnitude substantially equal to the potential V of the power supply. During the interval of time that a "write" operation is desired the field across the capacitors (the channel) is reduced to enable the ion concentration to attain its maximum concentration and be directed against an image receiving surface for the formation of a desired image configuration.

An application of this type of ionic control is seen in FIG. **3** which shows schematically a printer arrangement for forming a latent electrostatic image upon a dielectric medium **20** moving from right to left underneath a precharging unit **21** that precharges the medium **20** with a desired potential with polarity opposite the ion polarity. The precharged dielectric medium moves underneath a write head **4''** similar to that described above. The write head communicates with ion generator **1'**. By controlling the individual channels of the write head with suitable voltage pulses, a latent image of alphabetical characters is formed upon the precharged dielectric surface of medium **20**. The medium **20** with its latent image passes through a developer **22** and thereafter through a fixer **23**, both of which are well known in the art. After passing through the fixer the latent image is developed and fixed to provide a visible image comprised of two alphabetic characters E and H. The character pulse means as mentioned herein above, may provide any desired combination of electrical pulses to the individual channels of the write head to provide any desired configured latent image on the dielectric surface of medium **20**. For the particular line arrangement of the channels in the write head a line image of dots is formed transversely of the dielectric medium for a short interval of time ∇T during which there is no electrical field present on the walls of the write head channels. The formation of alphabetical characters by means of printer arrangement of FIG. **3** may be described with reference to FIG. **4*a***, **4*b***, and **4*c***.

The schematic arrangement of FIG. **4*a*** shows a line arrangement of **7** capacitors representing **7** channels of the write head. The left sides, **5*a*1–5*a*7** of the capacitors are connected to −15 volt DC supply whereas the right sides, **5*b*1–5*b*7** of the capacitors are connected to the character pulsing means, cpm, not shown, that selectively pulses the right sides of these capacitors to cause formation of the desired latent image on the dielectric medium **20**. From an inspection of FIG. **4*b*** it may be appreciated that in the formation of the image of the character E the vertical segment of the character E is formed during the interval ∇T during which there is no electrical field present across the channels of the write head and during this interval ∇T the character pulsing means supplies −15v pulse potential to the appropriate channel walls of all channels. From a further inspection of FIG. **4*b*** it is seen that the upper and lower horizontal lines, as well as the central horizontal line, of the character E are formed during the application of −15v potentials to the channel walls represented respectively by capacitors **4*a*1**, **4*a*4**, and **4*a*7** shown in FIG. **4*a*** for approximately 5 time intervals. At the end of the first time interval ∇T the character pulsing means applies zero voltage to channel walls represented by **5*b*2**, **5*b*3**, **5*b*5**, and **5*b*6**. These four walls are maintained at zero potential for the duration of the character formation. The −15v potential on wall **5*b*4** is maintained on for 4 time intervals. It is understood that the latent image is being formed on the dielectric medium as the latter moves from right to left under the respective channels of the write head.

From an inspection of FIG. **4*c*** it can be appreciated that the pattern of pulses applied to the respective channels **4*a*1** through **4*a*7** is consistent for the formation of the alphabetical character H.

Although the precise mechanism may not be fully known, nevertheless a discussion of the theoretical aspects and behavior of ionic action can be offered to provide a reasonable explanation of what occurs in the control of ion concentration in a moving gas stream passing through a channel head without in any way limiting or restricting the scope of the invention. In this vein the following theoretical discussion is submitted as a plausible explanation of ionic action that may occur in the formation of a desired image utilized, for example, in the printing of characters using a head configured according to certain desired parameters.

Suppose ions of concentration n are distributed uniformly across the entrance to a rectangular cross-section channel head in a uniform electric field and that the velocity of gas through the channel head is V_g.

The time required for a molecule or ion to pass through the channel head of Length, L, is $T_1=L/V_g$.

The time for an ion of mobility μ to drift across the channel head width is

$$T_2=W/V_D=W^2/\mu V \qquad (2)$$

Neglecting neutralization time substantially all ions can be removed from the flowing gas stream by adjusting the bias potential V to make

$$T_2 \leq T_1 \qquad (3)$$

or

$$V_g/V \leq \mu L/W^2 \qquad (4)$$

When this condition is not satisfied, ions that are transmitted are non-uniformly distributed, i.e., substantially all ions will be removed from the cross-sectional area ($a \times X$) where a' is the electrode width and

$$X = T_1 \times V_D \qquad (5)$$

See FIGS. 5a–5c.
Under these conditions, the transmitted ion current is

$$I = nq\, V_g\, a(W-X) \qquad (6)$$

Where q is the charge per ion.

The ion current density changes from 0 to $nq\, V_g$ at a distance X from the collector electrode. From this point of view the difference between "ON" and "OFF" conditions is the cross-sectional area through which ions are transmitted.

If we now consider the charge density which can be delivered to and deposited on a dielectric (relative velocity, V_p.) moving parallel to the direction in which W and X are measured, ignoring spreading caused by space charge and viscosity effects, then charge density deposited is

$$Q_{Sd} = nq\, V_g\,(W-X)/V_p = ng/V_p W\,(W^2 V_g - \mu L V) \qquad (7)$$

As in other electrostatic image formation techniques, the voltage contrast produced is proportional to the difference in surface charge density. The proportionality constant being the reciprocal of capacitance per unit area. Thus in the case above the change in surface potential produced on a dielectric sheet of thickness d, and dielectric constant K is

$$V_s = d/kk_0\, Q_s \qquad (8)$$

And the width of a written line would be a and its length $V_p \times T_p$, where T_p is the "on time."

Thus far it has been assumed that transients, i.e., "-turn on" and "turn off" times are not limiting factors, hence surface charge density will change as indicated by (7) rather than by some smaller amount. It is, however, of interest to consider the "on-off" transient behavior expected from this type of write-head.

In the simple theory considered here, the ion trajectories are just straight lines. If we consider "turn-on" time first, (in response to a step input), we see that the total turn-on transient time is equal to the transmission time, T_1, given by (1).

A part of this time will, however, be a simple delay if $T_2 < T$ that delay time is just $T_D = T_1 - T_2$. After T_D has elapsed, the ion current rises linearly to its "on-value," reaching it at time T_1.

Notice that if $T_2 \geq T_1$, then $T_D = 0$, and the ion current begins to rise immediately. The situation is illustrated in FIG. 6.

If we now consider "turn-off" time, we note first that there is no comparable delay time, i.e., the ion current immediately begins to decrease. However, transient time in this case is given completely by T_2 up to a maximum of T_1.

One can therefore expect on the basis of these transient time considerations that line "length" for short pulses will be a function of control or bias voltage as well as of pulse length.

Thus far we have neglected the uniformity of ion distribution emerging from the head cross-section and considered only total current. Since the transients considered above are, in the simple theory, just associated with a one-dimensional change of the area of the head through which ions are transmitted, and since with present geometry the changing one dimension is parallel to the direction of V_p one expects that written lines may show a directional effect associated with dielectric motion. Hence, the leading and trailing edges of a line may differ and the leading edge should be "sharper" than the trailing edge for dielectric motion from the ion collector channel wall to the opposite wall and also sharper for this motion from rather than toward the collector.

Typical bias voltage values that work fairly well are 15 volts and it is estimated that ion mobility is 1–2 cm^2/v-sec. Hence, $T_2 \sim 5$ to 10×10^{-6} sec. This value of T_2 represents a factor of 10 smaller than one would expect.

The value of T_1 is expected to be much more reliable, and one may take T_1 as best estimate of the transient "on-time" some part of which may be a complete delay. An important point here is that this time is approximately equal to the transient time (i.e., a point on the dielectric sheet will traverse the slot width in approximately the same time as the transit time). This should lead to a much sharper edge in one direction than in the other, i.e., gradient of charge density is much larger on one edge than on the other.

It may be worthwhile at this point to get a more quantitative idea of the magnitude of this effect. Considering that the "off" ion profile in a head is simply a wedge, and that during "turn-on" and "turn-off" transients the wedge moves down the channel toward the paper or back up toward the ion generator respectively, one can calculate the "sharpness of the edges," i.e., the distance over which charge density varies.

The result is

$$W_{es} = W[1-(T_p/T_2)^{\pm 1}] \leq W \qquad (9)$$

for V_p and V_{it} in the same direction, the + or − exponent is chosen so that

$$(T_p/T_2) \leq 1$$

and

$$W_{eo} = W + T_2 V_p > W \qquad (10)$$

for V_p and V_{it} in opposite directions.

In these expressions, T_p is the surface transport time across the slot width, i.e., $T_p = W/V_p$

V_{it} is the velocity of the ion profile across the channel width, i.e., $V_{it} = W/T_2$, velocity in the forward direction is just V_g, the gas flow velocity.

From expressions 9 and 10 the charge density gradient depends on the direction of relative motion of the dielectric surface, and the polarity of the head that determines which electrode acts as ion collector. In particular, from (9), a leading or trailing edge can be made ideally sharp for $T_p = T_2$, while the other cannot, i.e., the gradient of charge density will be non-zero over a distance greater than the slot width. The result is a directional nature which can be minimized by minimizing T_2, i.e., this procedure makes $W_{es} \rightarrow W$.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

We claim:

1. A method of forming a latent electrostatic image on a dielectric surface comprising:

generating a high concentration of ions in a pressurized gas in a chamber;

forming a plurality of individual ion streams from the ionized pressurized gas chamber;

selectively applying a transverse electric field to said streams to produce ionically modulated streams; and

directing said modulated streams upon said dielectric surface to form said latent image, the potential across said field being substantially less than the breakdown potential of said gas.

2. The method of claim 1 in which said individual ion streams are configured with a desired cross section.

3. The method of claim 1 in which said electric fields are varied so to provide variations in the intensity of said images.

4. The method of claim 1 in which said dielectric surface is moved during formation of the image.

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