Oct. 29, 1963 P. A. STOWELL 3,108,894

ELECTROSTATIC CHARGE PRODUCTION

Filed May 18, 1959

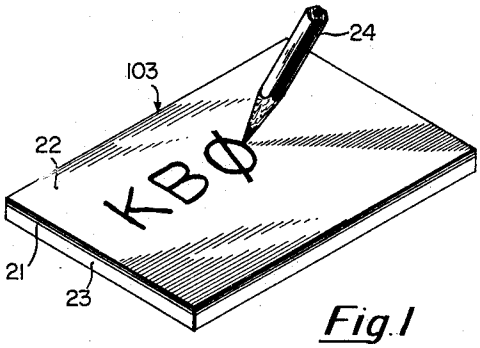


Fig. 1

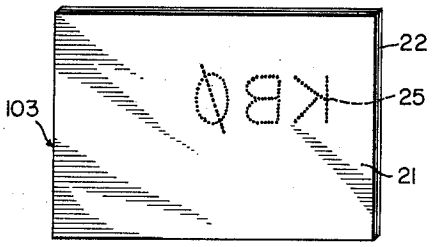


Fig. 2

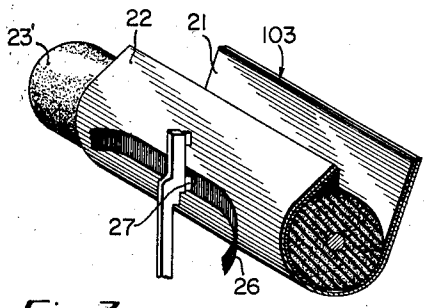


Fig. 3

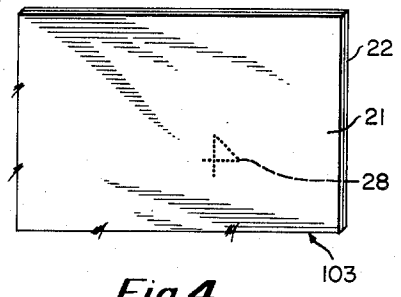


Fig. 4

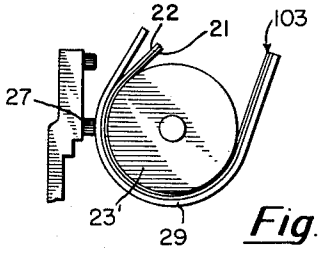


Fig. 5

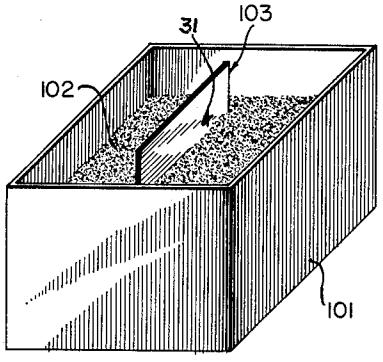


Fig. 7

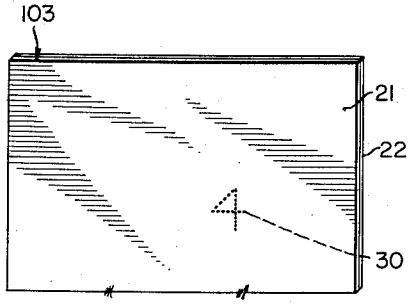


Fig. 6

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ELECTROSTATIC CHARGE PRODUCTION

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This invention relates to the production of electrostatic charges on a dielectric medium by application of pressure or physical impact and more particularly to the method of and apparatus for printing information-bearing visible patterns thereby.

In application for United States Patent Serial No. 714,767, by Herman Epstein and Robert E. Benn, filed February 12, 1958, which application is assigned to the assignee of this application, there is described a method of reproduction of information-bearing visible patterns by the production of patterns of electric charges on a dielectric medium; the pattern of electric charges being made visible by development with a conductive ink which may particularly easily be employed to develop patterns of electric charges on dielectric surfaces or films backed by an electrically conductive layer. Exposing a mass of such electrically conductive ink to contact with the charge patterns upon the dielectric film, and establishing electrical contact between such mass of ink and the conductive backing layer, permits the flow of bound charges from the conductive backing layer into the mass of ink Such flowing charges will chiefly move to the ink particles immediately adjacent to the charge patterns in the dielectric film, and the forces between the charges on the ink particles and the charges in the dielectric film will suffice to hold the ink particles to the charge patterns on the dielectric film, in such fashion as to constitute a visible reproduction of the charge patterns.

In application for United States Patent Serial No. 784,300, by David Seymour, filed December 31, 1958, entitled "Electrostatic Recording," which is assigned to the same assignee as this application, there is described a particulate ink which is preferably composed of small electrically conductive spheres of relatively non-friable character and of moderate density, preferably not greatly in excess of about 4 grams per milliliter. In the Seymour patent application it is disclosed in detail how such developed charge patterns may be used as reproduction masters for production of copies by causing the ink particles to be pressed against carbon paper backed by copy paper; and also how such developed charge patterns may be used as reproduction masters for processes similar to lithography, by taking advantage of the fact that reproducing inks wet the ink particles, but not the dielectric backing. It is further disclosed in the Seymour application how such developed charge patterns of ink particles may be fixed in place by being pressed into and thus embedded in the dielectric layer.

A variety of methods and means are known for producing patterns of electric charges. United States Patent 2,221,776 to Carlson, issued November 19, 1940, describes photographic means. The patent application of Epstein and Benn referenced above describes direct use of electrical means. However, all the previously known methods require some fairly elaborate physical and electrical means to produce a well defined charge pattern upon a dielectric.

The extreme simplicity of reproduction achieved by the methods described in the aforesaid patent application of Seymour renders it desirable that electric charge patterns be produced on a dielectric surface in some simpler manner not requiring any equipment other than that ordinarily available in the business office or the home. I have invented a manner of accomplishing this desirable end by the application of pressure to the dielectric medium.

Thus one important object of my invention is to produce electrical charge patterns on a dielectric material without the application of directly electrical means for charge formation.

Another important object of my invention is to produce, by ordinary writing means, electrical charge patterns representing information.

Further objects, benefits and meritorious features of my invention will appear in the course of the following specification and appended claims.

For the better description of my invention, I provide figures of drawing, as follows:

FIGURE 1 represents a dielectric recording medium in contact with a supporting surface, and undergoing recording by a pencil;

FIGURE 2 represents the charge pattern established by the operation represented in FIGURE 1;

FIGURE 3 represents a dielectric recording medium undergoing recording by a type face and associated apparatus;

FIGURE 4 represents the charge pattern established by the operation represented in FIGURE 3;

FIGURE 5 represents an alternate mode of recording by a type face;

FIGURE 6 represents the charge pattern resulting from the operation of FIGURE 5; and

FIGURE 7 represents a charged dielectric medium partly immersed in developing ink.

I have found that the physical phenomenon that the application of pressure to a dielectric medium in contact with the surface of another medium produces an electric charge on or in the dielectric at the regions where such pressure has been applied; and that these charges remain after the two media have been separated can be employed usefully to form predetermined desired patterns. FIGURE 1 represents a dielectric layer **21** attached to, or overlying, a backing layer **22**, which may conveniently be of paper, the combination **103** of the two layers constituting a dielectric record member for electrostatic printing. The opposite or unattached surface of dielectric **21** is represented as resting on the smooth surface of a solid body **23** suitable for support purposes, and having electrical properties suited to its use in combination with the material constituting dielectric **21**, as will be discussed in more detail below. A writing instrument **24**, here represented as a conventional lead pencil, although its effective function is as a stylus, in the process of writing visible marks on the exposed surface of the backing **22**, presses the surface of dielectric **21** against the supporting surface of material **23**, causing a transfer of charges between the dielectric **21** and material **23**. FIGURE 2 represents the charge pattern **25** established on surface **21** by the operation described; charge pattern **25**, being invisible, is represented by dots. It will be observed that the process described produces a charge pattern **25** which is the mirror image of the written pattern produced on backing layer **22** as represented in FIGURE 1; this fact is not objectionable since, as is described in the Seymour application for United States patent, to which reference has already been made, a developed mirror image charge pattern may be used as a reproduction master to produce a reproduced direct image.

It must be emphasized that the mechanism of production of electric charges by mechanical means, although first reported by Aristotle, has not enjoyed explanation comparable in completeness or lucidity with those provided for much more recently discovered phenomena. In particular, it is not certainly known whether the separation of the phenomena into categories such as frictional electrification and contact electrification is justified by any actual difference between the two processes; nor

is it possible to determine with certainty whether the processes operative in the various embodiments of the present invention are to be considered as exclusively frictional electrification, contact electrification, or a combination of both, assuming that the two terms actually do describe different phenomena.

It is suspected that the pressure or friction causes such intimate momentary junction of the two materials that the contact potential difference between the two materials causes a charge transfer; and that the pressure may also produce an adiabatic heating which enhances this effect. At all events, I have found that even the moderate pressure produced by writing with a stylus such as a pencil, a ball-point pen, or a common pen sufficies to produce, in addition to the conventional written record, a pattern of electrostatic charges which can be developed by the usual methods of electrostatic printing techniques to produce a visible record of the pattern. In particular, the techniques described in the aforesaid Seymour patent application may be employed to produce a development having such mechanical properties that the developed pattern may serve as a master for production of numerous duplicates by conventional methods such as the one employing carbon paper.

While the capability of recording charge patterns by conventional purely manual writing instruments is a great convenience, it is also desirable to make charge patterns representing the marks produced by type faces as in an ordinary typewriter.

FIGURE 3 represents the performance of such a process. In FIGURE 3, the surface of a dielectric **21** is represented in contact with a relatively solid supporting body **23'** here represented as having the general form of a typewriter platen, which may be of some rubber composition. It may be profitable to point out here that, while rubber compounds in general and many other substances conduct, at ordinary power supply voltages of the order of a hundred volts, currents which are negligibly small either as sources of shock hazard or in their effect on the power system, they are not for that reason insulators. The term dielectric as used herein includes the somewhat restrictive assumption that the dielectric material is of such high resistivity that it has a time constant of at least seconds, and possibly very much longer periods. Since the charges employed in electrostatics are of the order of fractions of microcoulombs, and the potentials at which these are stored may be of the order of kilovolts, to be an insulator in the true and original sense of the word a material must be of resistivity in the region of 10^{12} or higher ohm-centimeters. A great many rubber compounds, especially after exposure to normal contamination in use, are not insulators from the viewpoint of electrostatics.

In normal typing, the type face **27** will strike the inked ribbon **26** against the backing layer **22**, marking the surface of the backing **22** with ink from the ribbon **26**, and transmitting through backing **22** localized forces which press the surface of the dielectric layer **21** against the surface of the roller **23'**. As I have found, there results from this operation the formation of a pattern of charges such as represented in FIGURE 4 by the element **28**. Pattern **28** is represented by dots because it is in fact an invisible but physically detectable charge distribution. It is a true image of the type face **27** because it was formed on the side of member **103** away from type face **27**, and in contact with the material of supporting member **23'**. However, as was explained in connection with the formation of a mirror image **25** of the desired symbols in FIGURE 2, a mirror image of symbols may be used as a reproduction master to produce true images of the desired symbols. The procedure represented in FIGURE 3 will, of course, produce by ordinary ink from the inked ribbon **26** a visible mirror image of the type face **27** on the backing **22**, as in ordinary typing.

If there is a cogent reason for requiring the production of a pattern of electrostatic charges which shall be a true image of the desired symbol, it is possible to produce a mirror image of the type face **27** by the method represented in FIGURE 5. In FIGURE 5 the assembly **103** of dielectric **21** and backing **22** is supported by the support **23'** as in FIGURE 3, except that in FIGURE 5 the assembly **103** is reversed so that backing **22** is supported, and dielectric **21** is away from the support, and would receive directly the stroke of type face **27** except that a sheet **29** is interposed between type face **27** and dielectric **21**. Sheet **29** may be of any material sufficiently strong mechanically to stand typing and sufficiently flexible to transmit sufficiently faithfully the forces applied to it by the impact of type face **27**, and sufficiently different in its electrical properties from the material of dielectric **21** to produce a charge transfer between sheet **29** and dielectric **21** under the forces produced by the impact of type face **27**. The nature of these differences will be discussed in detail hereinafter. Since the forces produced by the impact of type face **27** will, in FIGURE 5, be received by a surface of dielectric **21** facing the type face, there will be produced on dielectric **21**, by electrical charge transfer between sheet **29** and dielectric **21**, an invisible charge pattern as represented by **30** in FIGURE 6. It will be understood that the process described as represented by FIGURE 5 will produce a charge pattern **30** which is a mirror image of the type face **27**. It is true that the sheet **29** is not necessary to the formation of a charge pattern as represented by **30** of FIGURE 6. If the type faces **27** are carefully cleaned of any contaminations which would form a conducting or lubricious coating, the intermediate sheet **29** may be eliminated and the formation of charge pattern **30** may occur by the direct exchange of charges between dielectric **21** and the type face **27**. (It will be observed that no ribbon **26** is represented in FIGURE 5, since it is assumed that the formation of an inked visible image on sheet **29** is not required.) Obviously, as a practical matter in an operating business office, to keep type faces of a typewriter scrupulously clean would be somewhat more bothersome than to insert an extra sheet **29** whenever true images of symbols are to be produced as electric charge patterns by typing. For this reason the somewhat more elaborate method of FIGURE 5 has been described in detail.

While numerous techniques of development of electrostatic charge patterns to produce visible images have been made known in the art, in order to complete the teaching of the use of my invention, I represent in FIGURE 7 a simple means for such development., FIGURE 7 represents a container **101** in which a mass of conducting particulate ink **102** is brought into contact with an assembly **103** consisting of a dielectric bearing a charge pattern, and a conductive backing. This assembly **103** may be as represented in FIGURE 1, with **21** being the dielectric and backing **22** being electrically conductive. That backing **22** be conductive is beneficial, as discussed in the Epstein-Benn application for United States patent to which reference has already been made; and for the satisfactory operation of the method of development represented in FIGURE 7, it is necessary. However, it is not necessary for the operation of other, more elaborate and difficult methods of development that the backing **22** be conductive and therefore, since it is not my purpose to disclose my invention as applicable to only one method of development, I have not required, that, in general, backing **22** be conductive. Immersion of the assembly **103** in the conducting particulate ink **102** will, as described in detail in the Epstein-Benn patent application referenced, cause ink to adhere to the electrostatically charged areas of the dielectric **21** in such wise as to render visible any pattern of electric charges existing thereon or therein. The character **31** represented by continuous lines represents the visible, developed image of charge pattern **30** represented in FIGURE 6.

It is true that not all materials, when pressed against

a chosen dielectric material, will produce a charge on the dielectric. I have found that polystyrene, polyethylene, and carboxyl polyvinyl acetate resin all, when formed into dielectric films or coatings, may be charged by the methods above disclosed by pressure against vulcanized rubber, glass, paper, and metals. Supplement Number 2 of the British Journal of Applied Physics, published by the Institute of Physics, 47 Belgrave Square, London S.W. 1, England, in 1953, entitled "Static Electrification," in pages S1 through S5 inclusive contains an article entitled "Theory of Contact Electrification" by F. A. Vick. In the referenced article the theory is advanced that contact electrification results from differences in work function between two materials in contact. This hypothesis is consistent with the observation that most different materials when pressed suddenly together do acquire charges; some very few pairs of materials do not do so. By the hypothesis cited, the pairs of materials which do not develop charges when pressed together would be those which happened to have approximately equal work functions or electrical contact potentials. Considering the extreme precautions which it is common knowledge must be taken in explosive manufacturing factories, grain elevators, hospital operating rooms, and similar hazardous locations in order to avoid the generation of static charges, it is evident that pairs of materials having substantially equal contact potentials are comparatively rare, and may readily be voided by substitution of a different material of similar required mechanical or other properties. Thus, while it may occasionally be necessary to avoid particular combinations of materials in the practice of my invention, such exceptions are sufficiently rare so that they do not impair the general utility of my invention.

As a matter of convenience in the practice of my invention, it is usually desirable that the supporting surface, against which the sheets of dielectric material are pressed to produce a charge pattern, should not itself be such an excellent insulator that it will retain the impressed charge patterns. Such retention of charge by the surface against which the dielectric material is pressed would tend to produce upon a second sheet of dielectric material a copy of the pattern of charges developed upon the first sheet. This, for obvious reasons, may be undesirable. However, since many substances commonly regarded as non-conductors (such as ordinary papers at ordinary humidities) are not sufficiently good insulators to retain a charge for any appreciable length of time, it is easy to find substitutes for any insulating materials which it may be desired to employ as backing surfaces.

Having described the practice and use of my invention, I claim the following:

1. In a method of electrostatic printing which comprises producing charge patterns on a dielectric surface and developing the charge patterns into a visible image, the producing of patterns of electric charge comprising: the steps of placing a sheet of dielectric material of resistivity of the order of at least 10^{12} ohm-centimeters upon a support surface of a material having an electrical contact potential differing from that of the said dielectric material, applying a paper sheet to bring one surface thereof in surface contact with the said sheet of dielectric material, and writing or drawing the desired pencilled pattern by drawing the point of a pencil type implement over the exposed other surface of the said paper sheet while simultaneously pressing the said point against the said surface of the paper, without relative movement between the said dielectric material and the said paper or between the said dielectric material and the said support surface.

2. In a method of electrostatic printing which comprises producing charge patterns on a dielectric surface and developing the charge patterns into a visible image, the producing of patterns of electric charge comprising: the steps of placing a first surface of a sheet of dielectric material of resistivity of the order of at least 10^{12} ohm-centimeters against a support surface of a material having a contact potential differing from that of the said dielectric material, placing a first surface of a paper sheet against the second surface of the dielectric, and typing a record upon the second surface of the paper sheet by pressure means.

3. In a method of electrostatic printing which comprises producing charge patterns on a dielectric surface and developing the charge patterns into a visible image, the producing of patterns of electric charge comprising the steps of placing a sheet of dielectric material of resistivity of the order of at least 10^{12} ohm-centimeters in contact with a surface of a material having a difference in contact potential with respect to the said dielectric material, superimposing a sheet of paper upon one of the two said materials, and producing a visible record by pressure-applying recording means upon the exposed surface of the said sheet of paper, whereby an electrostatic charge pattern of the said visible record is produced upon the said dielectric material.

4. In a method of electrostatic printing which comprises producing charge patterns on one surface of a dielectric and developing the charge patterns into a visible image, the charging comprising positioning the dielectric between a thin, flexible sheet of material and a support of material which has a contact potential differing from that of said one dielectric surface, and subjecting discrete areas of said dielectric to the pressure of a writing implement through said flexible material to produce on said one dielectric surface one or more electric charge patterns representative of the areas to which such pressure is applied, the said dielectric having a resistivity of the order of at least 10^{12} ohm-centimeters.

5. The method of claim 4 wherein said dielectric material of high resistivity includes one of the materials selected from the group consisting of polyethylene, polystyrene, and carboxyl polyvinyl acetate.

6. The method of claim 5 wherein said differing contact potential material is paper.

7. The method of claim 5 wherein said differing contact potential material is metal.

8. The method of claim 5 wherein said differing contact potential material is rubber.

9. In a method of electrostatic printing which comprises producing charge patterns on a dielectric surface and developing the charge patterns into a visible image, the producing of patterns of electric charge comprising the step of positioning a dielectric record member having a high resistivity dielectric layer of the order of at least 10^{12} ohm-centimeters and a backing layer of material other than the dielectric layer between a type face and a support with the backing layer facing the type face and the step of striking against the backing layer to force the dielectric surface against the support by a blow from the type face.

10. The method of claim 9 wherein said dielectric material of high resistivity of the order of at least 10^{12} ohm-centimeters includes one of the materials selected from the group consisting of polyethylene, polystyrene, and carboxyl polyvinyl acetate.

11. The method of claim 10 wherein said backing layer material is paper.

12. In the process of producing a reproducing master which comprises the steps of producing a pattern of electric charges upon the surface of a dielectric layer, and causing the adherence to the said pattern of a developing ink, the improvement comprising the step of positioning material having a first surface contact potential contiguous to said layer of dielectric material between a source of pressure which can be applied in a direction substantially normal to the dielectric layer to compress said material and said dielectric surfaces together in localized areas where applied, said dielectric layer having a second surface contact potential differing from said first surface contact potential, and the step of producing the said pattern of electric charges upon the

said dielectric by applying said localized pressures to press the said dielectric against said surface of material of a first surface contact potential, said dielectric layer having a high resistivity at least of the order of 10^{12} ohm-centimeters.

References Cited in the file of this patent

UNITED STATES PATENTS

32,353	Cornelius	May 21, 1861
2,221,776	Carlson	Nov. 19, 1940
2,297,691	Carlson	Oct. 6, 1942
2,681,473	Carlson	June 22, 1954
2,851,373	Tregay et al.	Sept. 9, 1958
2,962,339	Woo et al.	Nov. 29, 1960

FOREIGN PATENTS

734,909	Great Britain	Aug. 10, 1955

OTHER REFERENCES

N.B.S., Circular C438, Static Electricity, 1942, pp. 8, 9, 10, and 34.