United States Patent

Klose et al.

[15] **3,659,936**

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[54] APPARATUS FOR ELECTROSTATIC PRINTING

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[21] Appl. No.: **1,265**

[52] **U.S. Cl.** **355/3**, 96/1, 346/74, 340/173

[51] **Int. Cl.** **G03g 15/00**

[58] **Field of Search** ..... 96/1, 1.4; 355/3, 17; 346/74 P, 74 ES; 340/173 LM

[56] **References Cited**

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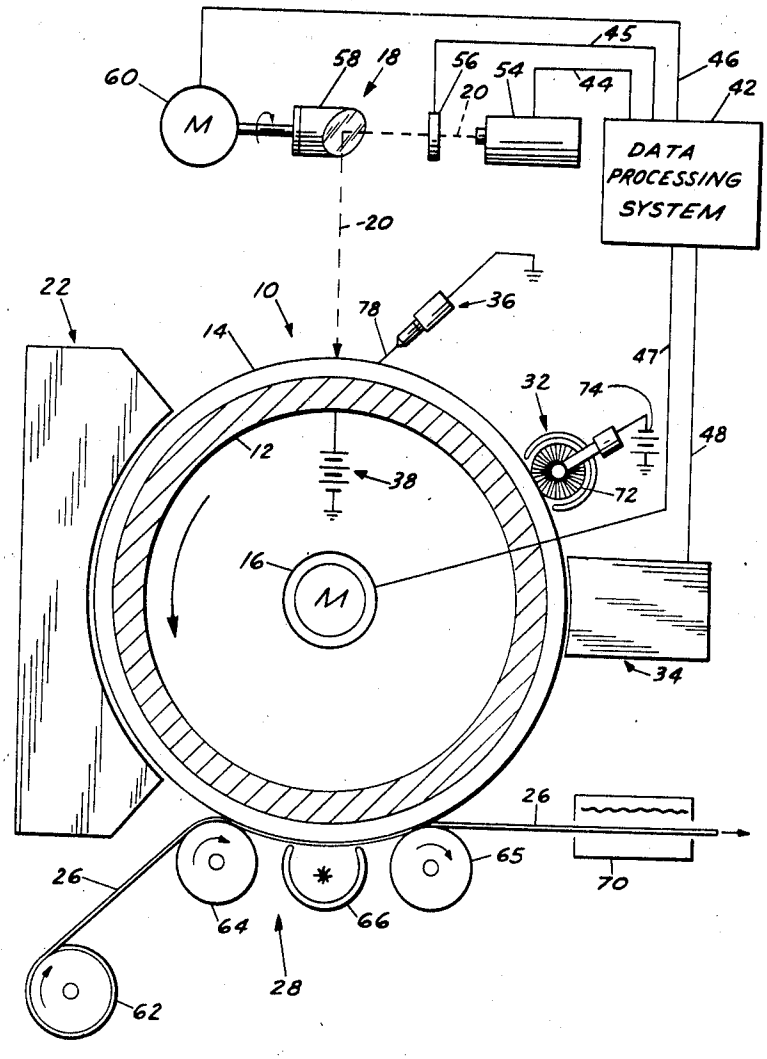
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[57] **ABSTRACT**

An electrostatic printer employs a metallic drum coated with a semiconductor film. The resistance of the film is varied from its high resistance or insulating state to its low resistance or conducting state in response to a scanning laser beam. A DC voltage source is connected to the metallic drum. The voltage is conducted through the semiconductor and appears at the surface in those regions where the laser beam impinges on the semiconductor. The semiconductor is then dusted with ink particles which cling to the regions where the voltage appears. Printing is accomplished by transferring the ink particles to a document. Multiple copies may be made by employing a semiconductor material exhibiting a memory characteristic.

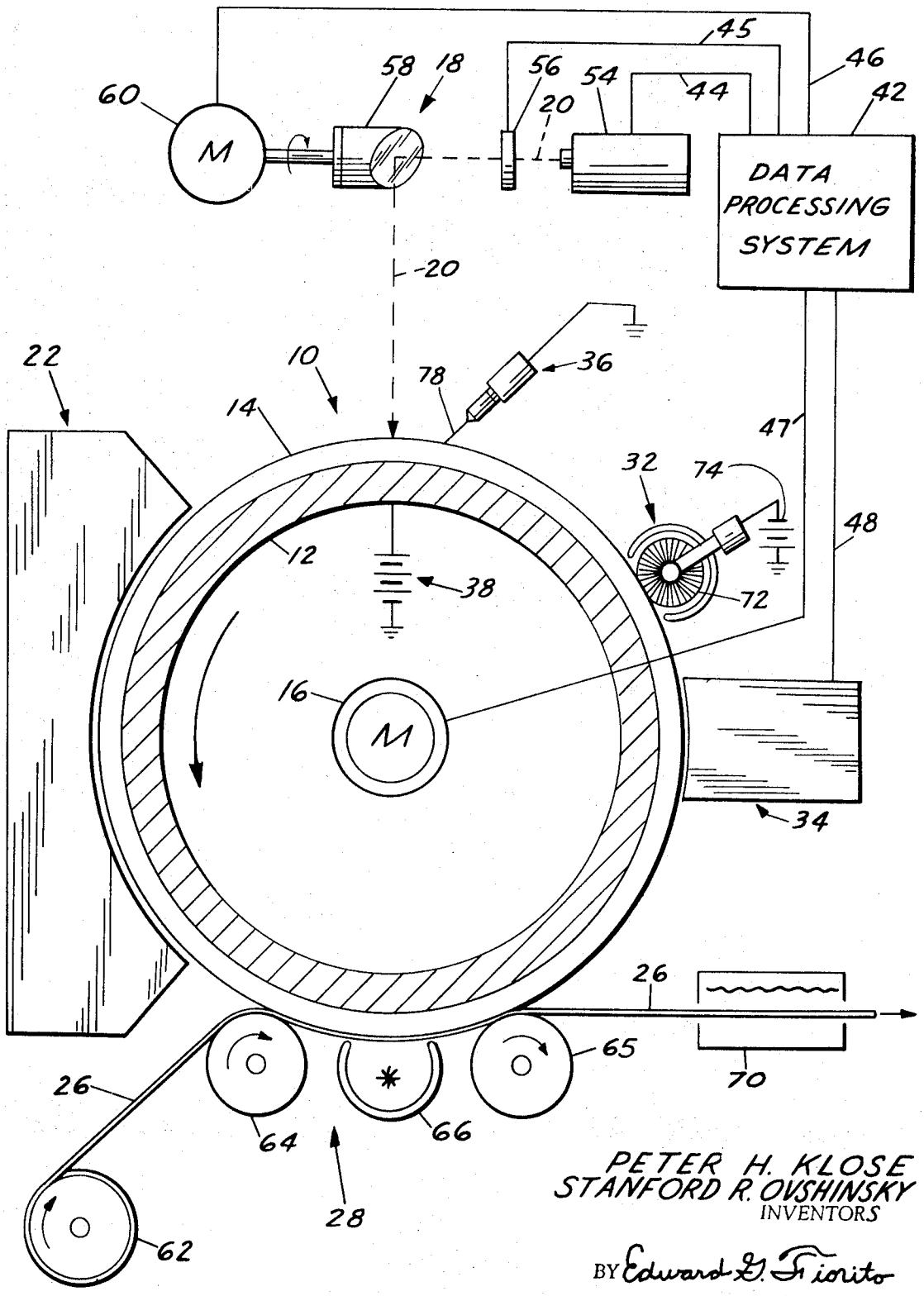
17 Claims, 6 Drawing Figures



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2 Sheets-Sheet 1

FIG. 1



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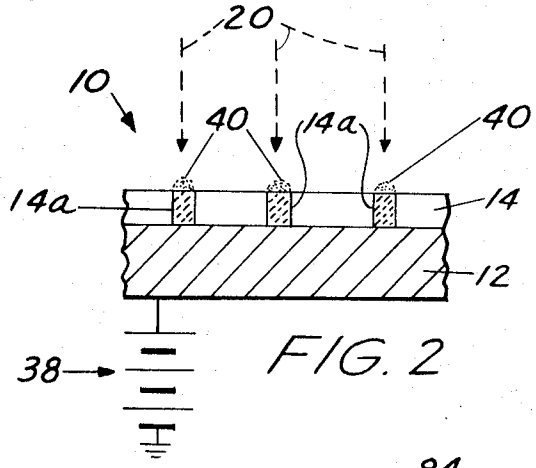


FIG. 2

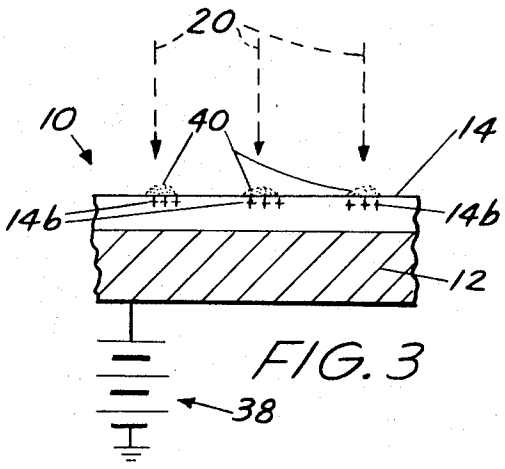


FIG. 3

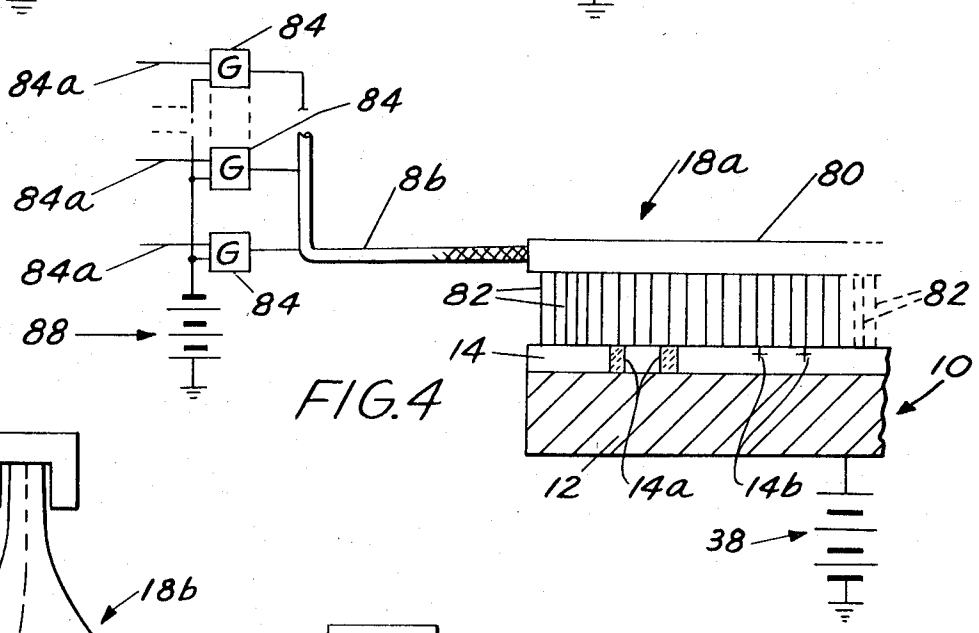


FIG. 4

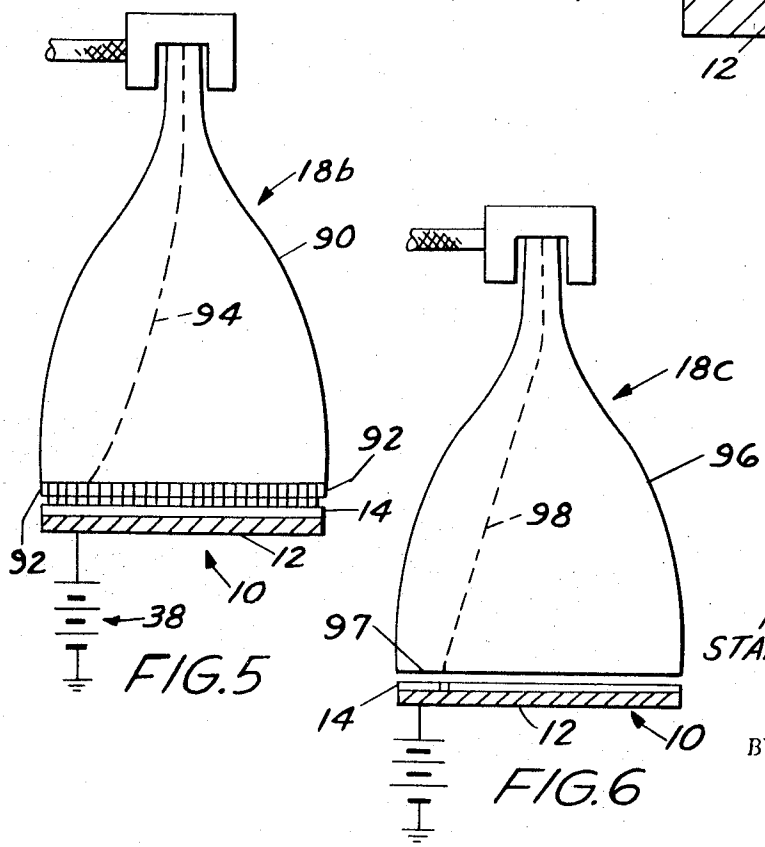


FIG. 5

FIG. 6

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APPARATUS FOR ELECTROSTATIC PRINTING

This invention relates to printers of the type generally known as electrostatic printers. An electrostatic image is normally formed on the surface of a printing plate. The plate is dusted with particles of ink which cling to the charged areas. The ink particles are subsequently transferred to a document and the printing plate is cleaned in preparation for the next printing cycle.

One form of printing plate employs a photoconductive surface applied to a supporting structure. The surface of the photoconductor is charged to a high potential, typically with a corotron, such as that described in the text "Xerography and Related Processes" edited by J. Dessauer and H. Clark, published by Focal Press Limited, 1965. The photoconductor material once charged must normally be kept in the dark until a light image can be applied. Those areas of the photoconductor which are illuminated conduct the charge down to the supporting structure. The unexposed area of the photoconductor sustains the original charge for normally only a short period of time during which it must be developed by dusting with ink particles. The original charge also tends to migrate toward the outer boundary of the unexposed areas of the photoconductor thereby distorting the printed image.

The principle object of the present invention is to provide new and improved methods and apparatus for producing an electrostatic image which can be used to print single or multiple copies from a single image. A printing plate is constructed with a conductive base having a coating composed of semiconductor material which exhibits variable resistance in response to energy applied thereto. Such materials may be, for example, the materials disclosed in U.S. Pat. No. 3,271,591, granted on Sept. 6, 1966 to Stanford R. Ovshinsky, and generally known as amorphous semiconductors. Other suitable semiconductor materials may be used in cooperation with an appropriate source of energy such as a laser, electron beam, heat, light, or voltage source. The source of energy is directed onto the printing plate to change the semiconductor material at selected regions from a high resistance condition to a low resistance condition.

In accordance with the present invention a source of potential is applied to the conductive base. When the semiconductor coating is in its high resistance condition the potential applied to the conductive base is effectively insulated from the outer surface of the printing plate. In order to insure that the outer surface of the printing plate is initially at a substantially zero potential a grounding brush, for example, may be used to sweep the surface at the beginning of the printing cycle.

The semiconductor material employed in the present invention may exhibit a memory characteristic, switching between two stable resistance states, or a non-memory characteristic, shifting temporarily from a high resistance stable state to a low resistance condition, and then returning automatically to the high resistance state. The semiconductor material exhibiting the memory characteristic retains its low resistance state until it is switched back by the reapplication of energy. While the semiconductor is in its low resistance state the potential applied to the conductive base is transmitted through the semiconductor to the outer surface of the printing plate. Accordingly selected regions of the printing plate exhibit a positive or negative potential depending upon the polarity of the potential applied to the conductive base. Other regions of the printing plate, where the semiconductor material is in its high resistance state, are effectively insulated from the potential applied to the conductive base and therefore reside at approximately ground potential. In this manner an electrostatic image is formed corresponding to the pattern of energy applied to the semiconductor material. The electrostatic image may be developed by dusting with ink particles which cling to the regions of the semiconductor material residing in the low resistance state. The ink particles are then transferred to a document where they may be fixed to the document by the application of heat, for example. When a semiconductor material exhibiting a memory characteristic is employed in the present invention, it may be developed once again by dusting with ink particles to produce another copy. Any charge that may be carried off during development, or during transfer of the ink to the document, is replenished by transmission of the potential from the conductive base through the low resistance regions of the semiconductor materials. Therefore, many copies can be produced during successive print cycles.

In order to prepare the memory semiconductor material for printing a new image, it is preferable to reset the material into the high resistance state. This may be accomplished by exposing the material to an energy source such as a laser, electron beam, R.F. heating source, quartz heat lamp or voltage source. Following reset, the semiconductor material may be swept with a grounding brush to eliminate any residual charge prior to applying a pattern of energy during the next printing cycle.

If a non-memory semiconductive material is employed in this invention, the operation is similar to that described above for the memory material. At the beginning of the printing cycle the semiconductor material is in its high resistance or insulating state. The material is shifted temporarily to its low resistance condition by the application of a pattern of energy, which may be, for example, in the form of light passing through a transparency, or in the form of a scanning laser beam pulsed on and off in response to signals from a data processing system such as that disclosed in U.S. application Ser. No. 828,859 filed May 29, 1969 entitled "HIGH SPEED PRINTER OF MULTIPLE COPIES FOR COMPUTER OUTPUT INFORMATION" by Stanford R. Ovshinsky, Ronald G. Neale and Edgar J. Evans. The material shifts to its low resistance condition for a short interval of time since this condition is an unstable condition normally requiring a holding current to sustain it. During this interval the potential applied to the conductive base is transmitted through the semiconductor to the surface thereof where it is trapped upon the return of the semiconductor material to its high resistance state. The trapped potential forms a layer of charge on the upper surface of the semiconductor material thereby contributing to the formation of an electrostatic image corresponding to the scanning pattern of the pulsed laser beam. The electrostatic charge pattern is developed by dusting with ink particles and the particles are then transferred to a document and fixed thereon. In order to prepare this semiconductor material for the next printing cycle a grounding brush may be employed to sweep the trapped charge from the surface of the semiconductor.

From the above description it can be seen that the present invention does not require the use of a high voltage source such as a corotron to deposit a charge on the surface of the printing plate, either prior to the electrostatic image forming process, or during development thereof. Also, the semiconductor material of the present invention need not be maintained in a dark environment but may be exposed to ambient or spurious light introduced from the surrounding environment.

Another feature of the present invention is its ability to maintain the electrostatic charge pattern for a relatively long period of time, without migration of the charge from the regions of the semiconductor material switched to the low resistance state. This latter feature of the present invention permits the development of an electrostatic charge pattern having a grey scale. The amount of electrostatic charge produced at any point on the printing plate can be varied by the level of energy applied thereto. The charge raised to the surface of the semiconductor material has very little mobility, and accordingly remains in the same spot on the surface of the printing plate. Upon dusting with ink particles varying amounts of particles cling to surface dependent upon the charge at each point. When the ink particles are transferred to a document, varying shades of grey can be observed as a function of the level of energy originally applied to the semiconductor material.

Still another advantage of the present invention is the low level of energy required to switch the semiconductor material,

particularly the non-memory material which need only become conductive for a short interval of time in order to trap charge at its surface.

Other objects, advantages and features of this invention will become apparent to those skilled in the art upon reference to the accompanying specification, claims and drawings in which:

FIG. 1 is a diagrammatic illustration of one embodiment of an electrostatic printer according to the present invention;

FIG. 2 is an enlarged partial view of the printing plate in FIG. 1, employing semiconductor material exhibiting a memory characteristic;

FIG. 3 is an enlarged partial view of the printing plate in FIG. 1, employing semiconductor material exhibiting a temporary or non-memory characteristic;

FIG. 4 is a partial view of another embodiment of the present invention employing slide wires as a source of energy for varying the resistance of the semiconductor material;

FIG. 5 is a partial diagram of another embodiment of the present invention employing a cathode ray tube having slide wires mounted in the face thereof, for conducting energy from the electron beam to the semiconductor material coating on the printing plate; and

FIG. 6 is a partial diagram illustrating another embodiment of the present invention employing a cathode ray tube located adjacent to the surface of a printing plate so that the electron beam provides energy sufficient to vary the resistance of the semiconductor material on the surface of the printing plate.

In FIG. 1 the printing plate designated generally as **10** is shaped in the form of a drum having a conductive base **12** and a semiconductor coating **14**. The conductive base **12** may be composed of any metallic substance that exhibits sufficient rigidity to provide a structural support for the printing plate **10**, and also exhibits the electrical characteristics of a conductor. Suitable materials for the conductive base **12** are aluminum, stainless steel, and tantalum.

The semiconductor material **14** exhibits a variable resistance in response to energy applied thereto. As will be described in more detail below this change in resistance may be a relatively stable change, or a transient unstable change.

The printing plate **10** is mounted for rotational movement, and is driven by a motor **16**. Located about the periphery of the plate **10** are a number of stations for performing operations on the semiconductor coating **14**. At a write station **18** a laser beam **20** scans across the printing plate **10** perpendicular to the direction of rotation of the plate **10**. A developing station **22** dusts the printing plate **10** with ink particles (not shown in FIG. 1). The ink particles are transferred to a document **26** at a printing station **28**. After printing, the ink particles are removed at a wiper station **32**. If required, the semiconductor **14** is switched to its original resistance condition at a reset station **34**. A grounding station **36** removes any residual charge on the surface of semiconductor **14**.

A DC potential source **38** is connected to the conductive base **12**. In the embodiment illustrated in FIG. 1 source **38** supplies a positive potential of 400 volts to conductive base **12**. However, a range of potentials between 300 and 800 volts can be employed. The potential of source **38** is effectively insulated from the outer surface of printing plate **10** by the semiconductor material **14** when in its high resistance state.

The same numerals are used to designate the same elements in FIGS. 1 through 6. FIG. 2 illustrates an enlarged section of printing plate **10**. Regions **14a** illustrate points in the semiconductor material **14** which have been switched to the low resistance state in response to laser beams **20**. The positive potential of source **38** travels through base **12**, and up through semiconductor **14** at points **14*a*** to the surface of printing plate **10**. When the printing plate **10** is passed through the developing station **22** shown in FIG. 1, ink particles designated **40** in FIG. 2 cling to the regions of low resistance **14*a***. These regions remain in the low resistance state when a memory type semiconductor **14** is employed. Suitable materials exhibiting this characteristic are generally known as amorphous semiconductors and may be found in U. S. Pat. No. 3,271,591. They may comprise tellurium and germanium at about 85 percent tellurium 50 percent germanium in atomic percent with inclusions of some oxygen and/or sulphur. Other compositions may comprise $Se_{83}Te_{6.5}Ga_{.5}$; $Se_{83}Te_{6.5}M_{.5}$; or $Se_{83}Te_{6.9}Te_{.1}$. The thickness of the semiconductor coating **14** may be in the range of 40 to 60 microns. The resistivity of semiconductor **14** when in the high resistance condition may be approximately 10^{12} ohm-cm and when in the low resistance condition the semiconductor **14** may have a resistivity of 10^{9} ohm-cm or less.

FIG. 3 illustrates the resultant charge pattern where a non-memory semiconductor material **14** is employed. A group of charge areas **14*b*** are formed on the surface by varying the resistance of the semiconductor material **14** temporarily to its low resistance condition in response to pulses of energy from laser beam **20**. Upon the application of a pulse from laser beam **20** the semiconductor material **14** forms a temporary path of low resistance from the surface of printing plate **10** to the conductive base **12**, similar to that shown in FIG. 2. When the semiconductor material **14** returns to its high resistance state the charge **14*b*** is trapped at the surface. Ink particles **40** cling to the trapped charge **14*b*** when the printing plate **10** is passed through the developing station **22** in FIG. 1. Examples of amorphous non-memory semiconductor material **14** suitable for use in the present invention are $Se_{92}Te_7S_1$; $Se_{30}S_{60}As_{10}$; and $S_{80}As_{20}Se_{20}$. Other compositions are described in U.S. Pat. No. 3,271,591 (such materials being referred to therein as Mechanism devices).

The compositions referred to above in connection with the memory semiconductor material may also be used as non-memory semiconductor material by decreasing the intensity of the laser beam **20**, or decreasing the pulse width, thereby lowering the Joule heating of the semiconductor material **14** so that it does not completely switch into its low resistance state.

The operation of the electrostatic printer illustrated in FIG. 1 is controlled by a Data Processing System **42** which coordinates the operation of stations **18** and **34**, and motor **16** through a group of lines **44–48**. A source **54** generates laser beam **20** in response to signals on control line **44**. The beam **20** is modulated into a series of pulses by optical shutter **56** controlled by line **45**. The combination of source **54** and shutter **56** may be employed to produce a train the laser pulses of varying amplitude, duration and separation. A rotating mirror **58** causes the laser beam **20** to scan across the semiconductor **14** in a direction perpendicular to the rotation of printing plate **10**. The speed of the rotating mirror **58** is controlled by a motor **60** in response to signals on line **46**. Laser beam **20** may have a wavelength of 1.06 microns, and source **54** may produce 0.1 micro joule/image element **14*a*** or **14*b***.

By coordinating the rotation of printing plate **10** and mirror **58** with the shutter **56** a pattern of laser energy can be applied to semiconductor **14**. Selected regions are switched into the low resistance state thereby establishing an electrostatic charge pattern on the surface of printing plate **10**. This pattern is rotated through developing station **22** where it is dusted with ink particles which cling to the regions of positive potential. The developed electrostatic image continues to rotate into the printing station **28** where a continuous form document **26** is fed from a roll **62** around a pair of rollers **64** and **65** which keep the document **26** in contact with the printing plate **10**. A corotron **66** attracts the ink from the surface of plate **10** onto the document **26**. The inked document **26** passes through a heater **70** which fixes the ink to the paper.

Prior to forming a new electrostatic image the surface of plate **10** is cleaned at wiper station **32**, removing any remaining ink particles. The wiper station **30** includes a rotating brush **72**, and a source of negative potential **74** in the range between −300 to −500 volts. The source **74** is connected to the brush **72** enabling it to lift the ink particles from the plate **10** more readily. If a memory type semiconductor **14** is employed, and additional copies are desired, the semipermanent

electrostatic image generated by the laser during the first cycle is passed through developer station **22** where is it dusted again and another copy is printed at station **28**. After the desired number of copies are printed, the memory type semiconductor material **14** is reset at station **34** in response to a signal on line **48**. The reset at station **34** may include a source of energy such as an RF heating source, a quartz heat lamp, a voltage source, a laser or an electron beam.

Any residual charge is removed from the surface of plate **10** by a brush **78** connected to ground. Where a non-memory semiconductor material such as that illustrated in FIG. **3** is employed in the electrostatic printer of FIG. **1**, the operation is similar to that described above when using a memory type semiconductor material **14**, except that reset station **34** is not required, since the semiconductor material **14** returns to its original resistance state without any external assistance.

In the event gray scale printing is desired, the energy applied to semiconductor **14** is varied at the write station **18**. This may be accomplished by varying the intensity level of source **54** or the pulse width produced by shutter **56**. Still another way may be by varying the speed of motors **16** or **60** so that the dwell time of the laser beam **20** on any point on the surface of plate **10** can be varied. The semiconductor material **14** changes its resistance as a function of the laser energy applied to plate **10**. In a corresponding manner the amount of charge conducted from base **12** to the surface of plate **10** is controlled. The electrostatic charge pattern thus produced is passed through the developing station **22** where ink particles cling to each point on the surface of plate **10** as a function of the amount of charge residing at such point. Accordingly, after the ink particles are transferred at print station **28**, varying shades of gray are observed on the document **26**. In the event additional copies are desired, the print cycle is repeated in the manner described above.

Other sources of energy may be employed in addition to the laser beam **20** shown in FIG. **1**. A writing station designated **18*a*** in FIG. **4** performs the equivalent function of writing station **18** in FIG. **1**. Station **18*a*** includes a block **80** having a row of slide wires **82** extending therefrom and engaging semiconductor material **14**. The slide wires are connected to a plurality of gates **84** through a cable **86**. The gates **84** each connect a negative potential source **88** to a different one of the slide wires **82**. The gates **84** may be turned on and off by any suitable source of signals on a set of control lines **84a** which may be provided by a Data Processing System such as that shown in FIG. **1**. The slide wires **82** conduct negative pulses to the surface of semiconductor material **14** thereby establishing a potential gradient across the material **14**. The potential gradient may be sufficient to switch the material **14** permanently to its low resistance stable state. Alternatively, the resistance of semiconductor material **14** may be varied temporarily. When the negative pulses on slide wires **82** terminate, or when the slide wires move to a new location, the positive potential on base **12** extends up through semiconductor material **14** to form the positive charge illustrated at **14*b*** in FIG. **4**. By selectively operating gates **84** a train of negative pulses can be generated on slide wires **82** which in turn produce an electrostatic charge pattern on semiconductor material **14**. In a manner described with regard to FIG. **1** the printing plate **10** of FIG. **4** can be developed and documents printed therefrom.

FIG. **5** illustrates still another writing station designated **18*b*** which may be employed in the present invention. A pin tube **90** is located adjacent to printing plate **10** so that a row of slide wires **92** are in contact with the plate **10**. An electron beam **94** selectively applies charge to wires **92** which in turn vary the resistance of the semiconductor material of plate **10** in a manner similar to that described in FIG. **4**. The electron beam **94** may be controlled in any suitable manner in cooperation with the movement of plate **10** so that an electrostatic image is formed on the surface of plate **10**. The electrostatic image is developed and copies are printed in the same manner as that described with reference to FIG. **1**.

FIG. **6** illustrates another source of energy designated **18c** which includes a cathode ray tube **96**, having a face **97** located sufficiently close to printing plate **10** so that an electron beam **98** supplies energy to semiconductor **14** changing its resistance to the low resistance condition. The thickness of the semiconductor material **14** can be varied so that it will change its resistance in response to the low energy supplied by beam **98**. Additionally, the face **97** may be coated with a phosphor which illuminates in response to the beam **98**. The semiconductor material **14** may be selected to exhibit a change in resistance in response to the illumination of the phosphor on face **97**. An example of such material is Se with 5 percent arsenic.

Another modification may be made to the present invention by reversing the polarity of DC sources **38** and **88** in FIG. **4**. Also, reset of the memory type semiconductor material **14** can be accomplished by defocusing the laser beam **20** instead of employing a separate reset station **34**.

While a single laser beam **20** is illustrated in the system of FIG. **1**, multiple laser beams may be used in parallel to simultaneously develop an image on the surface of printing plate **10**. Additionally, an entire image may be applied to plate **10** at one time by illuminating the surface thereof through a transparency, or by reflection from a surface containing the image to be copied. Suitable adjustments in the thickness and sensitivity of semiconductor material **14** may be made depending upon the type of electromagnetic radiation source employed in this embodiment of the present invention.

Numerous other modifications may be made to the various forms of the invention described above without departing from the spirit and scope of the present invention.

What is claimed is:

1. Apparatus for electrostatic printing comprising:

a printing plate including a conductive base having a coating of a semiconductor material thereon, said semiconductor material being capable of varying its resistance from a high resistance condition to a low resistance condition in response to energy applied thereto:

a substantially constant DC voltage source one pole of which is conductively connected to said base for providing a charge which is conducted through said semiconductor material in those areas where said semiconductor is in said low resistance condition;

writing means for applying energy to selected regions of said coating, in an amount sufficient to vary the resistance of said semiconductor material from said high condition to said low condition to permit passage of said voltage to the surface of said semiconductor material in said selected regions;

modulating means for varying the amount of energy applied to other regions of said coating to a level which is insufficient for varying the resistance of said semiconductor material in said other regions to said low condition,

developing means for applying particles to said printing plate which cling to said coating at said selected regions; and

transfer means for engaging said printing plate with a record medium to transfer at least a portion of said clinging particles to said record whereby an image of said selected regions is printed on said record.

2. Apparatus as defined in claim **1** wherein said coating has a single stable state in said high resistance condition and shifts temporarily from said high resistance condition to said low resistance condition in response to said energy applied thereto to permit voltage from said source connected to said base to travel through said coating during said temporary shift thereby trapping said charge on said coating when said coating returns to said high resistance condition.

3. Apparatus as defined in claim **2** further characterized by the addition of a grounding means for removing said charge trapped on said coating after said image is printed on said record.

4. Apparatus as defined in claim 3 further characterized by the addition of cleaning means for wiping said clinging particles from said coating after said image is printed on said record to prepare said material for printing another image.

5. Apparatus as defined in claim 1 wherein said coating comprises a semiconductor material which has two stable states, a high resistance state and a low resistance state, and which is capable of being switched between said states in response to said energy applied thereto.

6. Apparatus as defined in claim 5 further characterized by the addition of means for applying energy to said coating to switch said coating from said low resistance state to said high resistance state.

7. Apparatus as defined in claim 1 wherein said writing means includes a modulated laser beam.

8. Apparatus as defined in claim 1 wherein said writing means includes a modulated electron beam.

9. Apparatus as defined in claim 1 wherein said writing means includes a plurality of slide wires in contact with said coating.

10. Apparatus as defined in claim 9 wherein an electron beam selectively applies a charge to said slide wires.

11. Apparatus as defined in claim 1 wherein said coating is an amorphous semiconductor.

12. Apparatus for electrostatic printing comprising:

a rotatable printing drum including a metal cylinder having an amorphous semiconductor coating applied to the outer surface thereof, said amorphous semiconductor having a bistable characteristic including a high resistance state and a low resistance state;

drive means for rotating said drum;

a constant DC voltage source one pole of which is conductively connected to said base;

writing means for applying a pattern of energy to said amorphous semiconductor at selected regions, said pattern having an energy content sufficient to switch said coating from said high resistance state to said low resistance state to permit passage of said voltage to the surface of said amorphous semiconductor material in said selected regions;

developing means for dusting said amorphous semiconductor coating with particles of ink as said drum rotates, said ink clinging to said regions of said amorphous semiconductor residing in said low resistance state;

printing means for placing a document in contact with said amorphous semiconductor and transferring at least a portion of said ink particles to said document;

reset means for applying a uniform field of energy across said amorphous semiconductor, said field having an energy content sufficient to switch said amorphous semiconductor from said low resistance state to said high resistance state;

grounding means for removing charge from said amorphous semiconductor coating; and

control means connected to said reset means for selectively rendering said reset means inoperative during certain revolutions of said drum, whereby said developing means applies ink to said coating during said certain revolutions, and said printing means prints a plurality of copies of said image.

13. Apparatus as defined in claim 12 further characterized by the addition of cleaning means for wiping said clinging particles from said coating of said drum.

14. Apparatus as defined in claim 12 wherein said writing means includes a modulated laser beam.

15. Apparatus as defined in claim 12 wherein said writing means includes a modulated electron beam.

16. Apparatus as defined in claim 12 wherein said writing means includes a plurality of slide wires in contact with said amorphous semiconductor coating.

17. Apparatus as defined in claim 16 wherein an electron beam selectively applies a charge to said slide wires.

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