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Lunde

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[45] **Apr. 22, 1975**

[54] **INTEGRATED ELECTROGRAPHIC RECORDING AND DEVELOPING STYLUS ASSEMBLY**

[75] Inventor: **George G. Lunde**, White Bear Lake, Minn.

[73] Assignee: **Minnesota Mining and Manufacturing Company**, St. Paul, Minn.

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[52] **U.S. Cl.** ..... **346/74 ES**; 118/637; 355/3 DD

[51] **Int. Cl.** **G01d 15/06**; G01d 15/12

[58] **Field of Search** ..... 346/74 ES, 74 IB, 74 EB, 346/74 S, 74 EX, 139 C; 118/637; 355/3 DD; 96/1.3; 178/6.6 A

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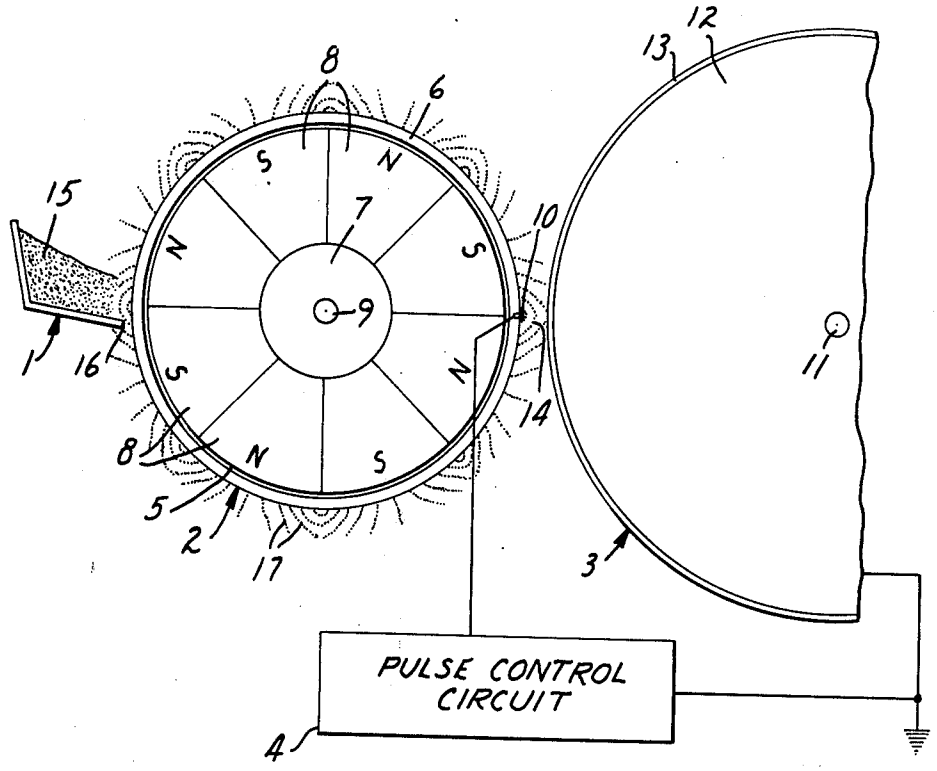
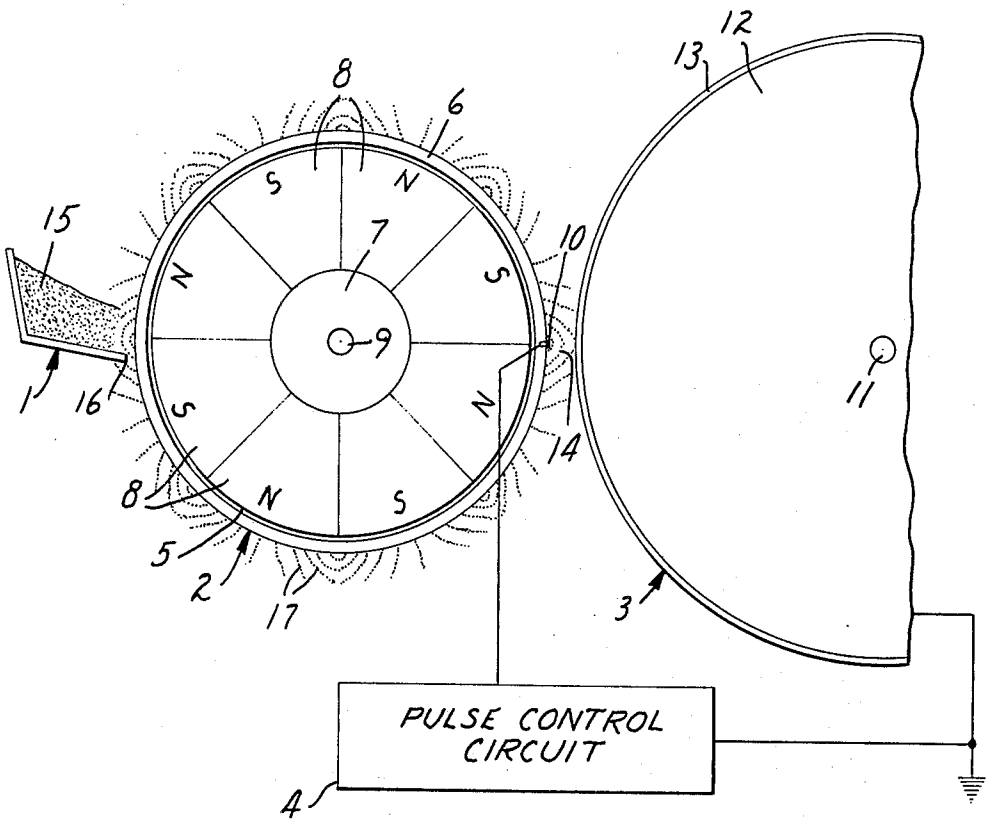
Primary Examiner—Bernard Konick
Assistant Examiner—Jay P. Lucas
Attorney, Agent, or Firm—Alexander, Sell, Steldt & DeLaHunt

[57] **ABSTRACT**

An improved electrographic recording stylus for electrographic recording systems includes a magnetic flux concentrating portion and a separate and distinct electrode portion connected to electronic circuitry furnishing voltage potential record pulses to the stylus for electronically charging toner that is in contact therewith.

7 Claims, 7 Drawing Figures

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PULSE CONTROL CIRCUIT
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FIG. 1

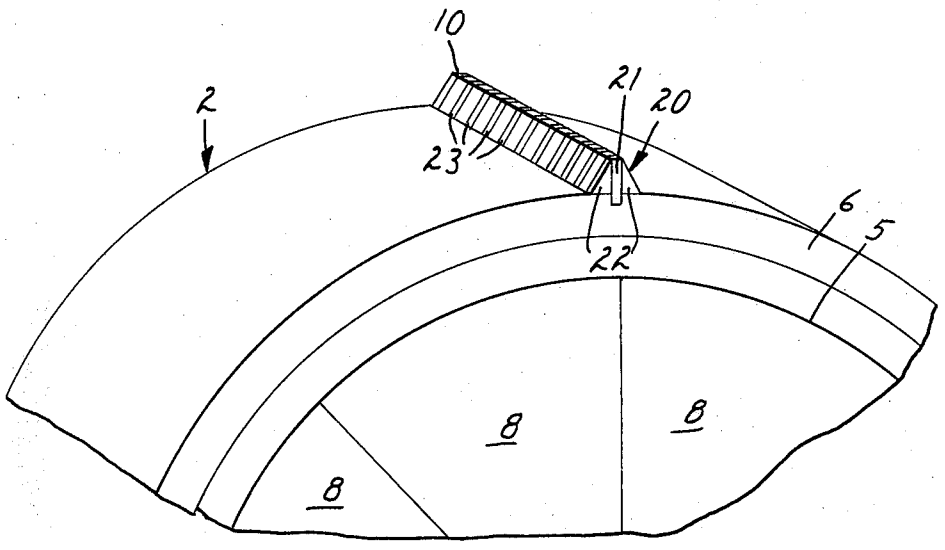
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FIG. 2

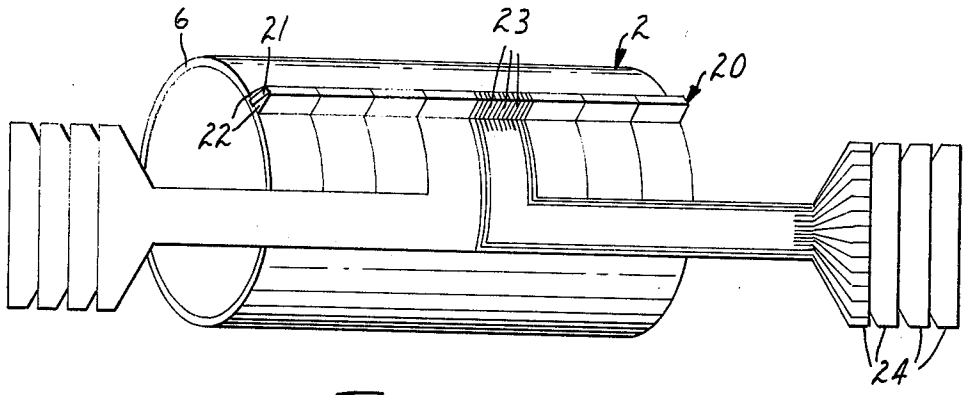

FIG. 3

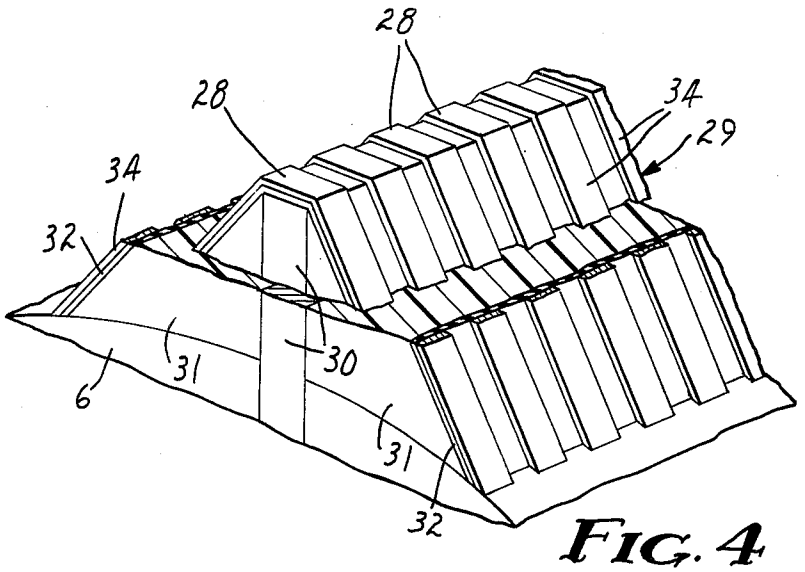

FIG. 4

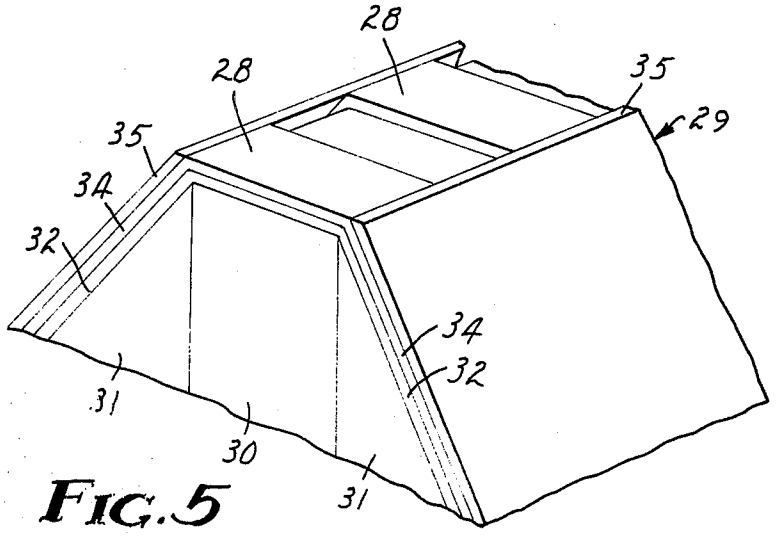

FIG. 5

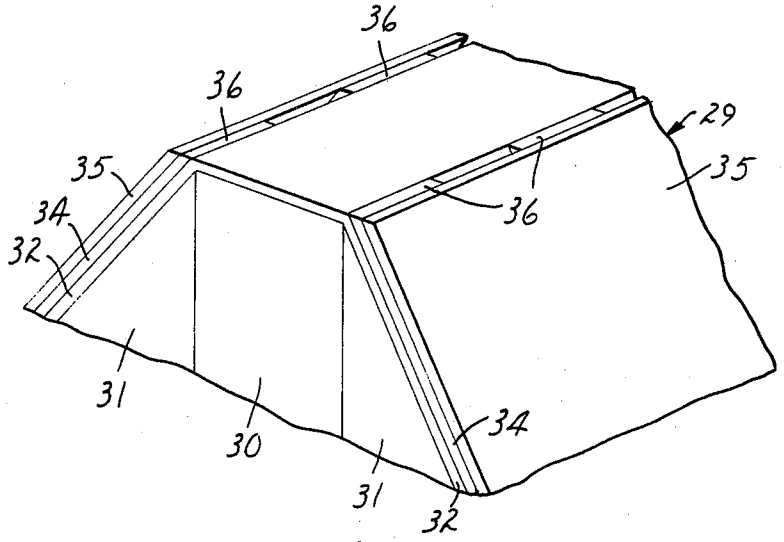
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FIG. 6

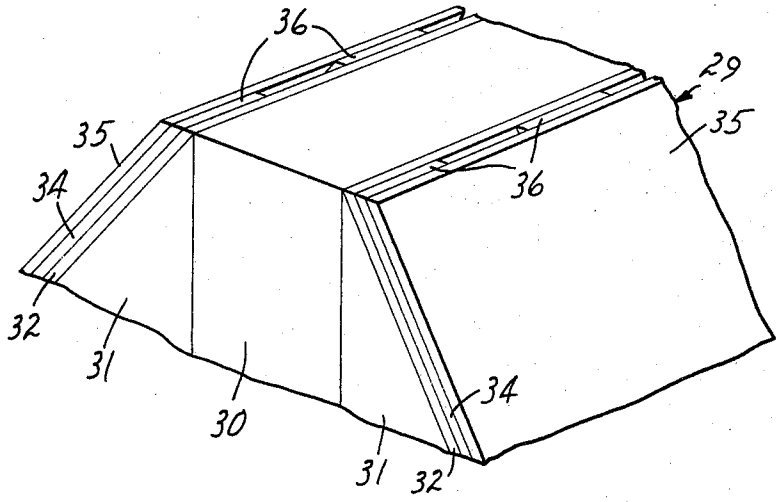
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FIG. 7

INTEGRATED ELECTROGRAPHIC RECORDING AND DEVELOPING STYLUS ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to electrographic apparatus for the recording of toner images on a recording medium, and more specifically to a recording stylus that is employed in such apparatus.

2. Description of the Prior Art

Prior art recording systems to which the present invention is related are disclosed in U.S. Pat. application Ser. No. 353,139, filed Apr. 20, 1973 now U.S. Pat. No. 3816840, and U.S. Pat. application Ser. No. 415,623, filed Nov. 14, 1973, both of which are assigned to the assignee of the present invention. The recording systems disclosed in these prior applications include a cylindrical developer roll with permanent magnet sectors and an array of magnetically permeable recording styli that are disposed on the developer roll. The magnetic fields of the magnet sectors are concentrated in the recording styli, thus providing a relatively strong magnetic flux density at the outer ends of the styli, and the styli are selectively pulsed with voltage potentials by drive electronics to produce dot depositions of magnetic toner powder on a recording medium, which powder is presented to the recording medium by the developer roll. There is a magnetic attractive force at the recording end of each stylus that is significantly higher than the surrounding magnetic field; consequently a dense concentration of powder at the outer end of each stylus results. The net effect on the quality of the recorded deposition is an increase of dot density and dot definition (resolution) with relatively low recording voltages.

All of the prior art styli constructions include the magnetic portion of the stylus as an integral, electrically continuous portion of the electrode portion, i.e., the magnetic portion provides both the magnetic control of the toner and the electrical control of the toner. To provide optimum toner deposition, the cross sectional area of such styli should be relatively large, the ultimate stylus having a solid iron wire electrode. With styli spacings of 50 to 200 styli/inch (representing the usual range for character or facsimile printing) the diameter of such styli can range from 0.010 inch down to 0.003 inch. In general, the spacing between two styli is about equal to the styli diameter. One problem with the use of iron wire styli electrodes is that when they are wrapped around a cylindrical developer roll and brought out to a connecting point for the drive electronics, they form a partial shield that shunts the magnetic field emanating from the inner magnet sectors of the developer roll. This has the effect of weakening magnetic forces that cause the toner to tumble about the developer roll. Another disadvantage of using wire styli electrodes is the difficulty of connecting a large number of individual wires to the electronic drive circuitry.

In the aforementioned U.S. Pat. application Ser. No. 415,623, the styli are each entirely formed of magnetic material having a high magnetic permeability, and are each connected by a nonmagnetic, conductive lead of a low magnetic permeability to the drive electronic circuitry that provides record voltage potential pulses thereto. Such construction provides good recording performance because the low magnetically permeable

leads connecting the styli with the drive circuitry do not shunt the magnetic field of the developer roll magnet sectors. However, when a dense array of a large number of styli are utilized, individual connections between each stylus and the drive circuitry are difficult to make and often shorting between styli results. Thus, methods and forms of construction become important in terms of cost as well as in terms of image quality and reliability.

In contrast to known prior art styli, an ideal styli array preferably should have styli electrode portions formed by a reliable technique such as etching a metal pattern on an insulating substrate as done in printed circuits for the electronics industry and the electrode portions should be capable of being connected to the drive electronics without interfering with toner flow or shorting to one another or to ground. In addition, the magnetic portions of the styli should provide a strong, well defined magnetic field at the printing end of the styli electrodes to concentrate and align toner particles in continuous chains from the styli to the surface of a recording medium, but should not shunt the magnetic field away from the styli or from the surface of the styli developer roll. Furthermore, the resulting styli array should present no obstructions on the surface of the developer roll to hinder the flow of toner. No prior art magnetic styli construction completely satisfies these "ideal" styli array criteria.

The present invention provides an improved stylus construction that separates the magnetic stylus into two functionally separate constituents that are inseparable as far as the recording process is concerned. The magnetic portion of the stylus does not contribute to the electrical current flow to the recording toner, and the electrical portion of the stylus does not contribute to the magnetic control of the toner. This approach gives startling simplicity to the construction of the styli array, and high quality in the recording process results.

SUMMARY OF THE INVENTION

The present invention resides in improved recording styli for electrographic recording systems having a recording electrode contacting one side of a recording medium, a developing means with a rotating inner magnet assembly, and an array of the recording styli spaced from said recording medium to define a recording region therebetween. The improved styli each include a first portion in which the magnet assembly of the developing means induces a magnetic flux density and a second portion that is connected to electronic circuitry furnishing voltage potential record pulses to the styli for electronically charging toner powder bridging the recording region to produce depositions of toner on the medium.

A plurality of the improved styli may be formed in a dense printing array by using a magnetically permeable crossbar positioned axially of the surface of the recording member to serve as the first portion of the styli, and overlying the crossbar are a plurality of spaced apart electrically conductive leads that serve as second portions of the styli. In a first preferred embodiment, the crossbar is electrically nonconductive, and each electrically conductive lead together with the crossbar forms an individual stylus. To facilitate fabrication of the styli, flexible printed circuitry may be employed to provide a plurality of conductive leads that are densely arranged in contact with the crossbar, and yet can be

fanned out to standard connector spacing to readily connect to the electronic circuitry that furnishes the voltage record pulses. The flexible printed circuitry is bonded on the developer roll in a smooth arrangement to provide relatively no obstruction to the flow of toner as it tumbles around the circumference of the tube.

In a second preferred embodiment, the conductive leads are insulated from the crossbar to prevent electrical contact between the two portions of the styli. Thus, the crossbar may be formed from a wide variety of magnetic materials including those that are electrically conductive, such as iron, without the danger of electrical shorting between adjacent styli.

In both of the above described embodiments, the conductive leads are formed from a nonmagnetic material with relatively little shunting effect on the magnetic field induced in the crossbar of the styli. The crossbar serves as a path of high permeability for the magnetic flux lines of force emanating from the developing means magnet assembly. As a result, a high magnetic gradient exists at the outer edge of the styli crossbar to provide a strong attractive force for toner presented at the recording region. The magnetic toner is attracted to the styli and is concentrated in the form of toner chains that bridge between the recording medium and the styli cauusing dense quantities of toner to be deposited on the recording medium when a record pulse is applied to the styli.

The foregoing and other advantages of the present invention will appear from the following description. In the description reference is made to the accompanying drawings, which form a part hereof, and in which there is shown by way of illustration, and not of limitation, specific forms in which the invention may be embodied. Such embodiments do not represent the full scope of the invention, but rather the invention may be employed in a variety of embodiments, and reference is made to the claims herein for interpreting the breadth of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic side view of an electrographic recording system incorporating the present invention and including a toner powder reservoir, a developer roll, a recording member, and a pulse control circuit;

FIG. 2 is a fragmentary perspective view of the developer roll of FIG. 1 illustrating an enlarged view of a first embodiment of a printing array disposed thereon;

FIG. 3 is an enlarged view of flexible circuitry that forms a portion of the printing array of FIG. 2;

FIG. 4 is an enlarged, fragmentary view of a second embodiment of the printing array that mounts on the developer roll of FIG. 1;

FIG. 5 is an enlarged, fragmentary view of a modified embodiment of the printing array of FIG. 4;

FIG. 6 is an enlarged, fragmentary view of another modified embodiment of the printing array of FIG. 4; and

FIG. 7 is an enlarged, fragmentary view of yet another modified embodiment of the printing array of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, a schematic view is shown of a prior art electrographic recording system for which the present invention is particularly adapted to be used. This prior art system includes a toner powder reservoir **1**, a cylindrical developer roll **2**, a rotatable recording member **3**, and a pulse control electronic circuit **4**.

The developer roll **2** may be of the type disclosed in Anderson, U.S. Pat. No. 3,455,276, and has an inner magnet rotor **5** and an outer cylindrical shell **6** that is electrically nonconductive and is nonmagnetic. The term "nonmagnetic" with reference to a material is used herein to mean that the material acts nearly the same as air or a vacuum in the presence of a magnetic field. A magnetic circuit (field passing between North and South magnetic poles) is not affected by the introduction of the material, and the material itself is not magnetized due to the magnetic field. The term "magnetic material" is herein used to mean a material that easily passes magnetic flux (has a high permeability to the magnetic field) and therefore has a high susceptibility to being magnetized by a magnetic field. The magnet rotor **5** includes a cylindrical, magnet support core **7** and a plurality of permanent magnet sectors **8** arranged about the cylindrical surface of the support core **7**, the sectors **8** defining an outer surface of alternate North and South magnetic poles. The developer roll **2** is mounted on an axle **9** with the support core **7** preferably rotated in a clockwise direction, whereas the outer shell **6** is spaced from the magnet rotor **5** and is preferably fixed in position.

Arranged on a line that runs axially of the exterior surface of the shell **6** are a plurality of individual, spaced apart recording styli **10** (only one of which is shown in FIG. 1). The styli **10** are normally utilized to form a printing matrix and the number of styli included in the matrix is dependent upon the printing application for which the matrix is to be used. In the case of a standard computer output line width of 136, 5 × 7 dot matrix characters, nearly 1,000 styli are employed, spaced at 70 styli/inch. For more complex character fonts and simple graphic applications, styli spacings of 100/inch to over 200/inch are required.

The recording member **3** mounts an axle **11** that is parallel to the developer roll axle **9**, and is rotatably driven clockwise. The recording member **3** is preferably formed of an electronically conductive, cylindrical electrode **12** and an endless recording medium **13** that overlies the cylindrical surface of the electrode **12**. The electrode **12** is positioned in a spaced, opposed relationship with the styli **10** to define a recording region **14** therebetween. The electrode **12** also serves as a support means for the recording medium **13**, which is preferably formed from an anodized aluminum.

The toner powder reservoir **1** is filled with a magnetically attractable, electronically conducting toner powder **15**, such as the powder disclosed in Nelson, U.S. Pat. No. 3,639,245. The reservoir **1** includes a doctor blade **16** for metering the toner **15** in an even layer onto the outer shell **6** of the developer roll **2**. The toner **15** is held on the periphery of the outer shell **6** by the magnetic fields of the magnet sectors **8** and becomes arranged in the form of toner particle chains **17**. The toner chains **17** are transported by the developer roll **2** to the recording region **14**. While in the recording region **14** certain of the toner chains **17** bridge between the recording medium **13** and the styli **10**, and portions of the toner chains **17** in contact with the recording medium **13** are deposited thereon.

Deposition of portions of the toner chains **17** occurs when recording voltage pulses of sufficient magnitude are applied to various ones of the styli **10** by the electronic recording pulse circuit **4.** The record pulses produce a voltage potential between the cylindrical electrode **12** and the styli **10,** which results in a force pattern of intelligence that exerts a force on the portions of the toner chains **17** contacting the medium **13.** Such force opposes and overcomes the magnetic attraction of the magnet sectors **8** for portions of the toner chains **17** associated with the styli **10** to which the record pulses have been applied. This action is described in detail in U.S. Pat. application Ser. No. 353,139, filed Apr. 20, 1973, and naming Arthur R. Kotz as inventor, which application is herein incorporated by reference.

Although the present invention encompasses the basic electrographic recording process taught by Kotz, the present invention adds a new dimension to the teachings of Kotz in the form of the recording styli **10.** The construction of the styli **10** is uniquely adapted for providing a large number of the styli **10** in a small area to form printing arrays that are reliable and readily fabricated. Thus, the styli **10** are particularly advantageous for forming styli printing arrays having a high density of printing styli.

Referring now to FIG. **2,** a first preferred embodiment of the styli **10** of the present invention is shown forming a printing array **20** mounted on the developer roll **2.** The printing array **20** includes a magnetically soft cross bar **21** having one lengthwise edge seated in a slot cut in the periphery of the developer roll outer shell **6,** and an opposite edge that protrudes radially outward from the periphery of the shell **6.** The bar **21** is formed of a magnetic material that is substantially electrically nonconductive. Each lengthwise side of the bar **21** is shielded by an encapsulating material in the form of two wedge shaped ramps **22.** The bar **21** extends axially of the exterior surface of the outer shell **6** and a plurality of spaced apart nonmagnetic electrodes **23** are fixed on the ramps **22** to extend across and overlie the outer edge of the bar **21.** A relatively electrically nonconductive material forms the bar **21** so that the electrodes **23** are electrically isolated from one another. Each electrode **23** together with the bar **21** defines one of the printing styli **10.** For purposes of clarity the electrodes **23** are shown considerably enlarged in the drawings, and normally over **100** electrodes per inch would be employed in the array **20.** The particular dimensions of the styli **10** are not critical and may vary depending upon the recording application. However, it has been found that for magnetically optimum conditions, the distance between the outer and inner lengthwise edges of the bar **21** should be ten times greater than the distance between the ramps **22.**

Sheets of flexible printed circuitry **24,** as indicated by FIG. **3,** are preferably used to provide the plurality of electrodes **23** for the styli **10.** The circuitry **24** is well known in the electronic art and is formed of a plurality of electrically conductive leads that are bound together by an electrically insulative material. One end of each sheet of the circuitry **24** is bonded to the bar **21** and the ramps **22** and the leads on the sheet provide electrodes **23** that are closely aligned together. The opposite end of the electrodes **23** of the sheets of circuitry **24** are fanned out to furnish a relatively wide separation therebetween for making a suitable connection with the record pulse circuitry **4.** By use of the flexible circuitry **24** the possibility of a short occurring between the electrodes **23** is significantly diminished in comparison to that presented by former styli constructions.

The above described styli construction thus provides a two portion stylus including an electrically conducting portion and a magnetic portion. High quality recording of toner images is provided by the styli **10** because the bar **21** provides a path of high magnetic permeability for the magnetic flux of each of the magnet sectors **8.** Accordingly, when a magnet sector **8** is aligned with the bar **21** a narrow area of high density magnetic flux along the length of the bar **21** extends out from the outer edge of the bar **21** in a perpendicular relationship with the recording medium **13** and back to the magnet rotor **5.** The quality of the images provided by the styli **10** is in part dependent upon the radial length and positioning of the bar **21** for two reasons. First, the closer the inner edge of the bar **21** is brought to the magnet rotor **5,** the greater the magnetic flux density in the bar **21** due to a narrowing of the low permeability air gap between the bar **21** and rotor **5.** Secondly, if the protrusion of the outer edge of the bar **21** is increased, the differential between the flux extending from the outer edge of the bar **21** and the surrounding flux field emanating from the magnet rotor **5** also increases. The bar **21** furnishes a narrow planar surface in the recording region **14** having a strong magnetization for attracting and aligning the toner chains **17** in the region **14.** When the toner chains **17** approach the printing array **20,** they are attracted to and concentrated at the outer end of the bar **21,** whereas the areas on either side of the bar **21** are substantially void of toner. The electrodes **23** may be conductive along their entire length but the printing area of a given styli **10** is determined by the intersection of the electrode **23** for the given styli **10** and the magnetic lines of force extending from the bar **21** adjacent to the given styli **10.**

It is not essential to the present invention that the electrodes **23** are in electrical contact with the bar **21** since the bar **21** functions only as a means of supplying a strong magnetic field to the electrodes **23.** This is evidenced by a second embodiment of the present invention represented by printing styli **28,** as shown in FIG. **4,** forming a printing array **29.** The array **29** is similar to the array **20** in that it includes a bar **30** formed of a magnetic material positioned on the shell **6** in the same manner as the bar **21,** and is bordered on both lengthwise sides by wedge shaped ramps **31.** However, the array **29** differs from the array **20** in that overlying and bonded to the exterior of the ramps **31** and the outer edge of the bar **30** is a flexible printed circuit that includes both an electrically insulating support layer **32** and a copper layer etched to furnish an appropriate pattern of electrodes **34** that extend across the outer edge of the bar **30.** Consequently, the bar **30** is electrically insulated from the electrodes **34** by the layer **32,** and as a result the bar **30** may be formed from a material that is electrically conductive, such as iron. Cover sheets **35** of insulative material, as shown in FIG. **5,** may be bonded to the ramp surfaces of the electrodes **34** to provide a smoother surface for the toner chains to flow over, but such sheets are merely a matter of preference.

The above described embodiments are not exhaustive in describing the present invention for a number of variations of the above embodiments would readily be perceived to fall within the inventive spirit of the pres-

ent invention. For example, referring now to FIG. **6**, in which a modified form of the second embodiment is illustrated, it may be seen that it is not essential to the present invention that the electrodes **34** bridge across the outer edge of the bar **30.** Instead the bridging portion of the electrodes **34** and the end portion of the cover sheet **35,** if present, may be removed to leave only end portions **36** of the electrodes **34** exposed. Also, as shown in FIG. **7**, the portion of the insulating layer **32** covering the outer end of the bar **30** may be ground away to expose the outer end of the bar **30.** An advantage of this latter configuration is that the bar **30** can be electrically grounded when desired to aid in erasing previously recorded material on the recording medium **13.**

Other variations of the present invention may include shaping of the bars **21, 30** to change the shape of the magnetic field near the exposed ends of the electrodes **23, 34.** The bars **21, 30** can also have slots cut to form teeth which are each located directly under the exposed ends of the electrodes **23, 34.** Moreover, the top of the bars **21, 30** can be cut at an angle to form a sharp edge which is located in a line under the exposed ends of the electrodes **23, 34.** Either of these modifications tend to increase the strength of the magnetic field at the exposed portion of the electrodes **23, 34,** but also make construction of the styli arrays **20, 29** more difficult.

The following non-limiting example is now provided.

EXAMPLE 1

Referring to FIG. **5**, the iron bar **30,** 0.010 inches by 0.094 inches (after machining) by 9 inches long, was made from 1,010 steel shim stock and inserted into a 0.031 inch deep slot cut into the developer roll **2.** The bar **30** was then bonded onto the roll **2** using a two part room cure epoxy that was then machined to form the ramps **31** shown. The height of the ramps **31** from the developer roll outside diameter was 0.063 inches, and the angle of the two ramps was 45° from the outer end of the bar **30.** The top of the bar **30** was ground flat within 0.001 inches for the 9 inch length of the top of the ramp. The array of styli **28** was formed using flexible printed circuit material of 1 ounce (approximately 1.5 mil thick) electrolytic copper bonded to a 1 mil thick polyimid substrate with an epoxy thermoset adhesive. The copper was etched to form electrodes **34** each 7 mils wide with the electrodes **34** on 13.5 mil centers. The electrodes **34** were fanned out to 50 mil centerline spacing to mate with a printed circuit board or connector. Six such flexible circuits were combined to form an assembly providing a styli array of 576 styli with a spacing of 74 styli/inch. The array of styli **28** was then bonded to the ramps **31** and bar **30,** with an intimate bond achieved by using a press with an elastic insert to form the flexible circuits to the shape of the ramps **31.** The remainder of the circuit was wrapped around the developer roll and cemented down with epoxy adhesive.

What is claimed is:

1. In an electrographic recording system that includes a recording electrode electrically connected to one side of a recording medium, a toner developing means having an inner rotating magnet assembly and an outer shell, a plurality of recording styli fixed on the outer shell of said developing means and spaced from the opposite side of said recording medium to define a recording region therebetween that is bridged by toner powder transported on said developing means, and electronic circuitry for providing voltage potential record pulses to said styli, each recording stylus comprising the combination of:

a magnetic portion having one end positioned radially outward from said outer shell and formed of a magnetic material such that magnetic flux provided by the magnetic field of said inner magnet assembly is concentrated at the outer end of said stylus to cause a concentration thereat of the toner; and

a nonmagnetic electrode portion positioned near said end of said magnetic portion and connected to said electronic circuitry in order that voltage potential record pulses may be applied to said electrode portion to electronically charge the toner powder bridging the recording region and produce deposition of toner on said recording medium in accordance with applied record pulses.

2. In a recording system as recited in claim **1** wherein the magnetic portion of each of said recording styli is formed from an electrically nonconductive material and said electrode portion of each of said styli overlies and is in physical contact with said magnetic portion.

3. In a recording system as recited in claim **1** wherein the magnetic portion of each of said styli is electrically insulated from said electrode portion.

4. In a recording system as recited in claim **3** wherein said magnetic portion is electrically conductive.

5. In a recording system as recited in claim **1** wherein an electrically insulating layer overlies the end of said magnetic portion and said electrode portion overlies said insulative layer.

6. In an electrographic recording system that includes a recording electrode electrically contacting one side of a recording medium, a toner developing means having an inner rotating magnet assembly and an outer shell, a plurality of recording styli fixed on the outer shell of said developing means and spaced from the opposite side of said recording medium to define a recording region therebetween that is bridged by toner powder transported on said developing means, and electronic circuitry for providing voltage potential record pulses to the styli, said recording styli comprising the combination of:

at least one magnetic portion having an end positioned radially outward from said outer shell such that the magnetic flux provided by the magnetic field of said inner magnet assembly is concentrated at the outer end of said styli; and

a plurality of spaced apart nonmagnetic electrode portions positioned near said end of said magnetic portions and connected to said electronic circuitry in order that voltage potential record pulses may be applied to said electrode portions to electronically charge the toner bridging the recording region to produce deposition of toner on said recording medium in accordance with applied record pulses.

7. In an apparatus for the electrographic recording of toner powder images on a recording medium and having a stylus means and electrode means in spaced opposed relationship to provide a recording region therebetween, a developing means having an outer shell and an inner rotor member that rotates with respect to said outer shell and includes a plurality of alternating North and South magnetic poles on its circumference, toner supply means for supplying electronically conductive,

magnetically attractable toner to said developing means to be transported about the periphery of the developing means outer shell and electronic circuitry for providing voltage potential pulses to said stylus means, which stylus means is mounted on the outer shell of said developing means and comprises the combination of:

a magnetic portion aligned with the rotor member of said developing means such that the magnetic flux provided by said North and South poles of said developing means is concentrated at one end of said stylus means; and

an electrically conductive nonmagnetic portion positioned with respect to said magnetic portion to intersect the magnetic lines of flux at the end of said stylus means, which conductive portion has record voltage potential pulses applied thereto to electronically charge toner powder that is in electrical contact with said conductive portion and said recording medium at the time of the application of said pulses.

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