June 2, 1970 R. C. CADY, JR 3,515,850

THERMAL PRINTING HEAD WITH DIFFUSED PRINTING ELEMENTS

Filed Oct. 2, 1967 5 Sheets-Sheet 1

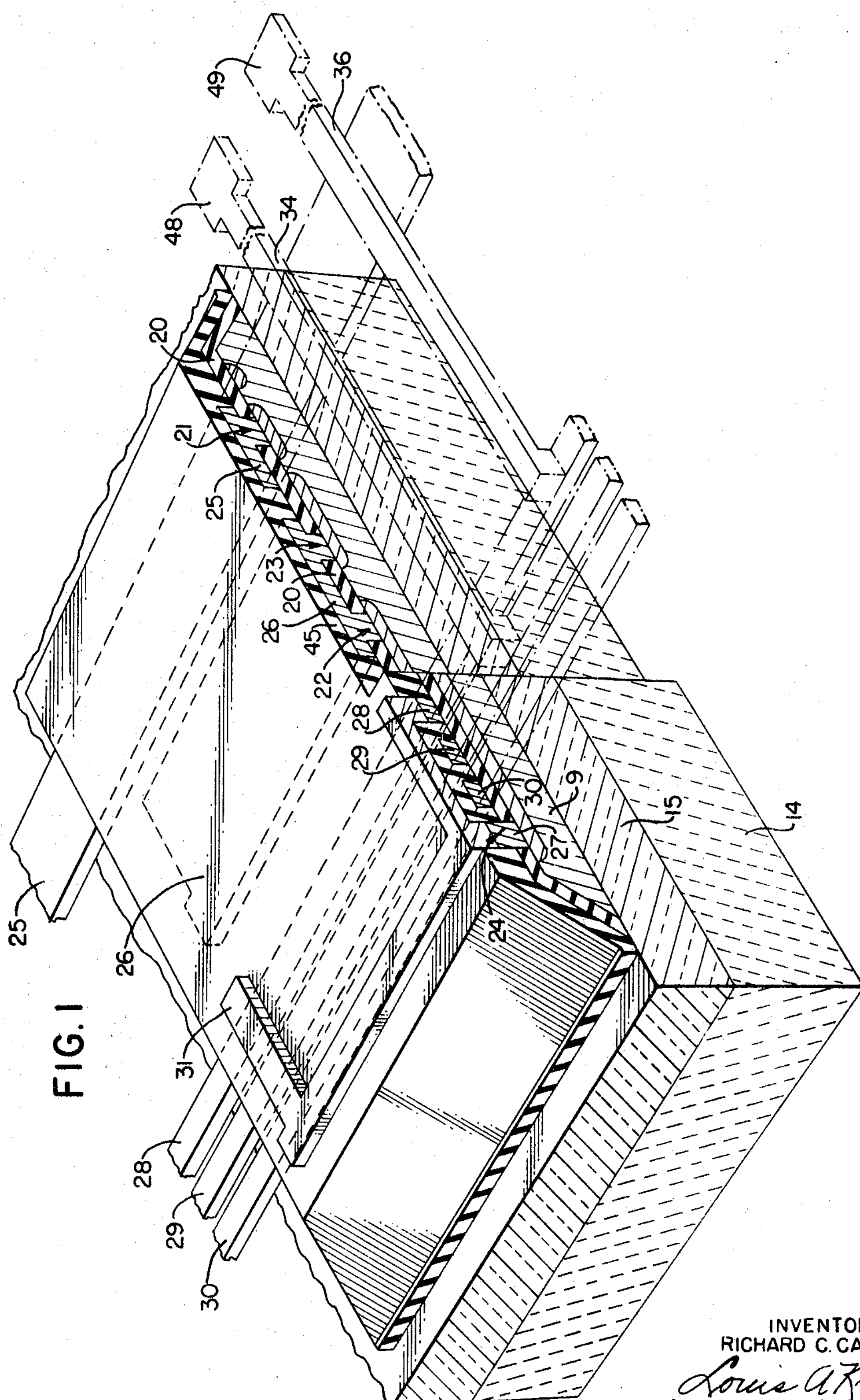

FIG. I

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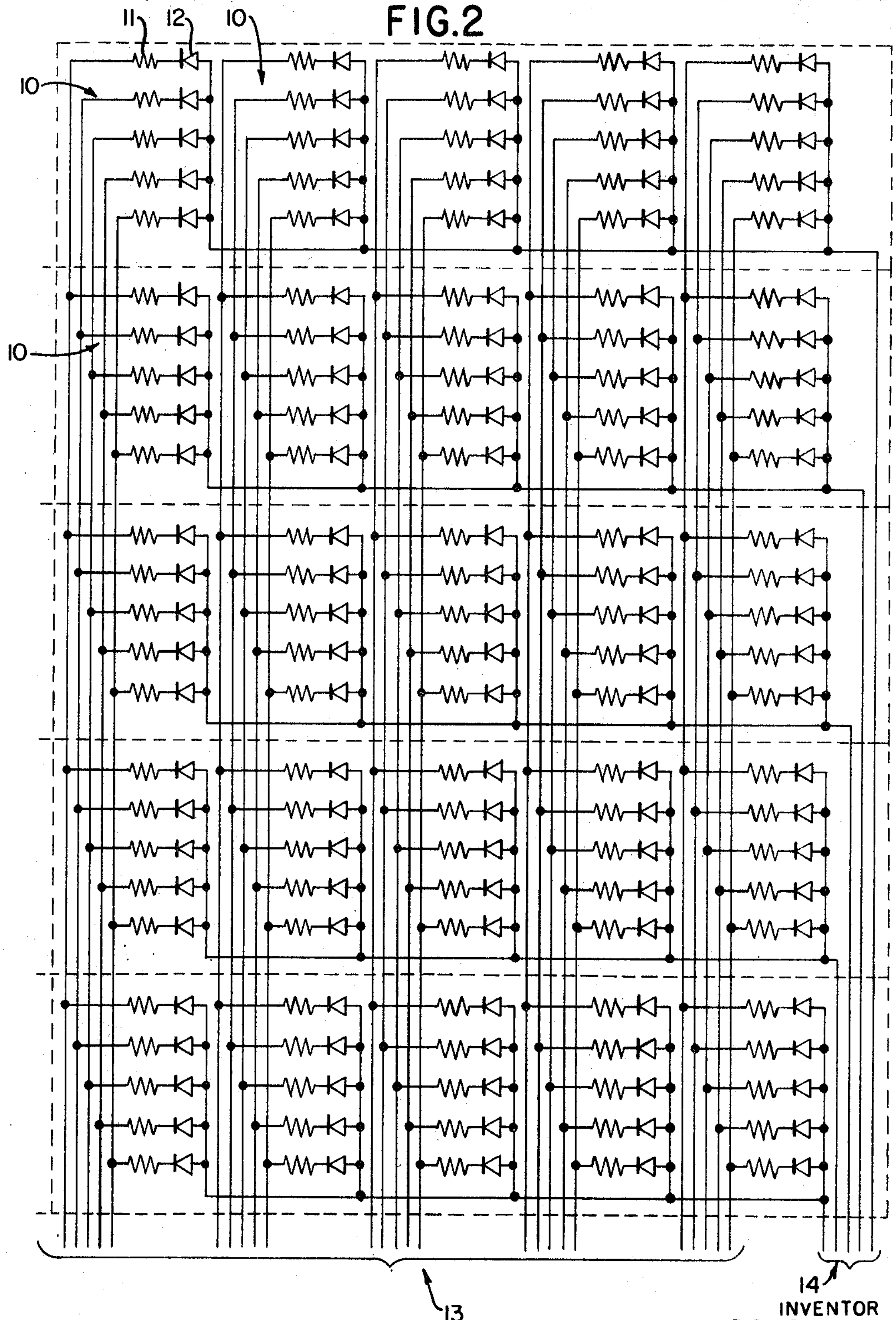
FIG. 2



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THERMAL PRINTING HEAD WITH DIFFUSED PRINTING ELEMENTS

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FIG. 3

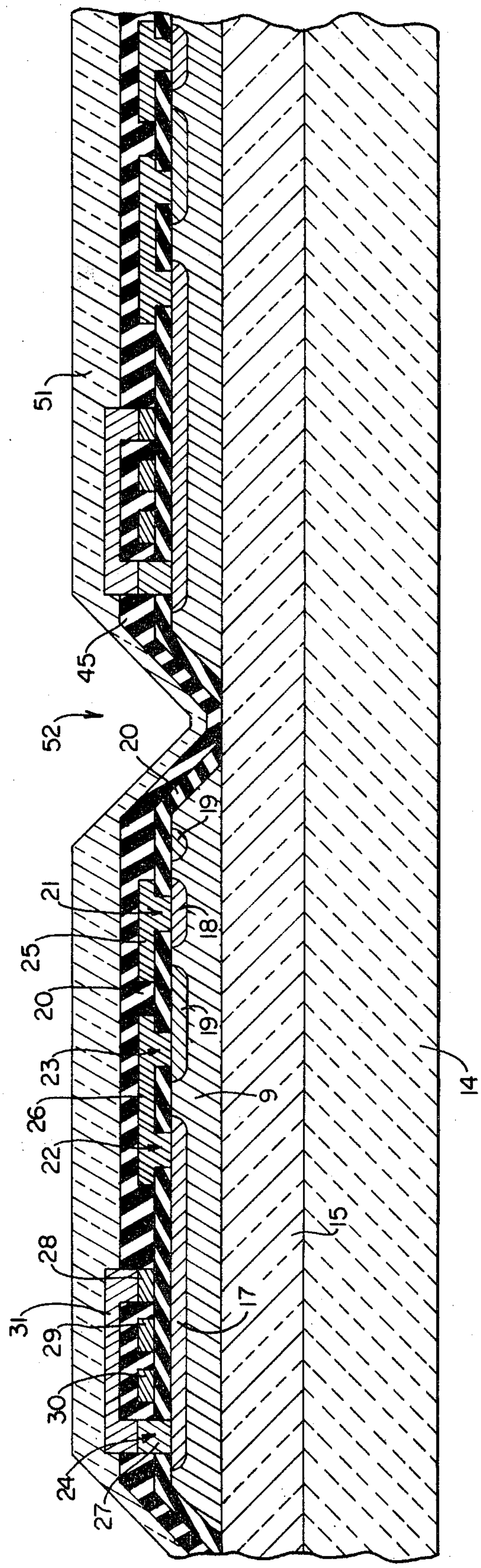

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FIG. 4

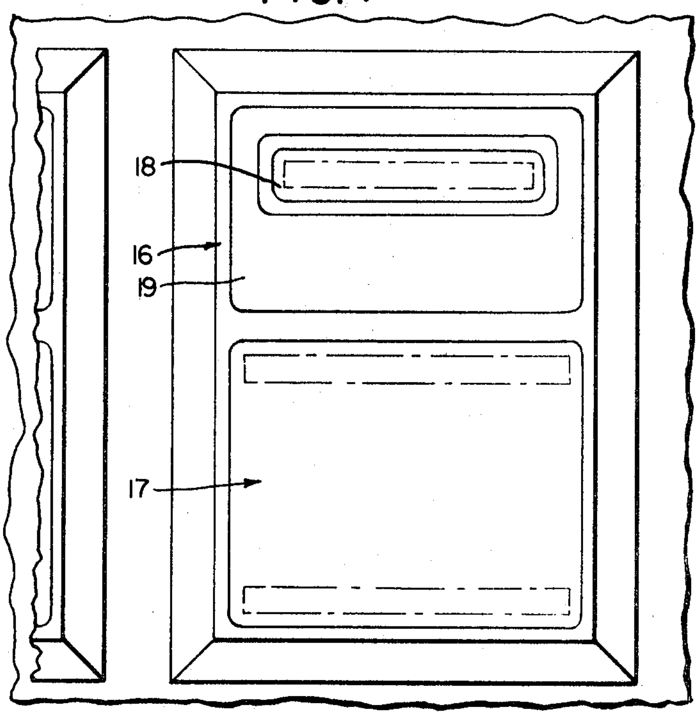

FIG. 5

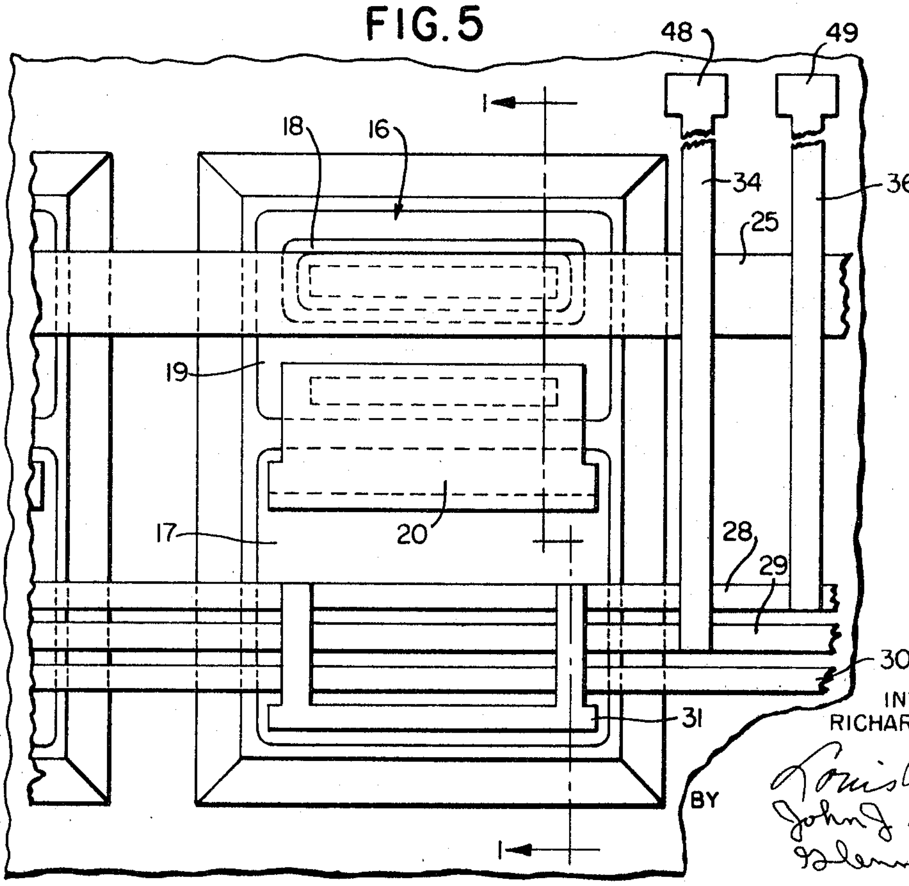

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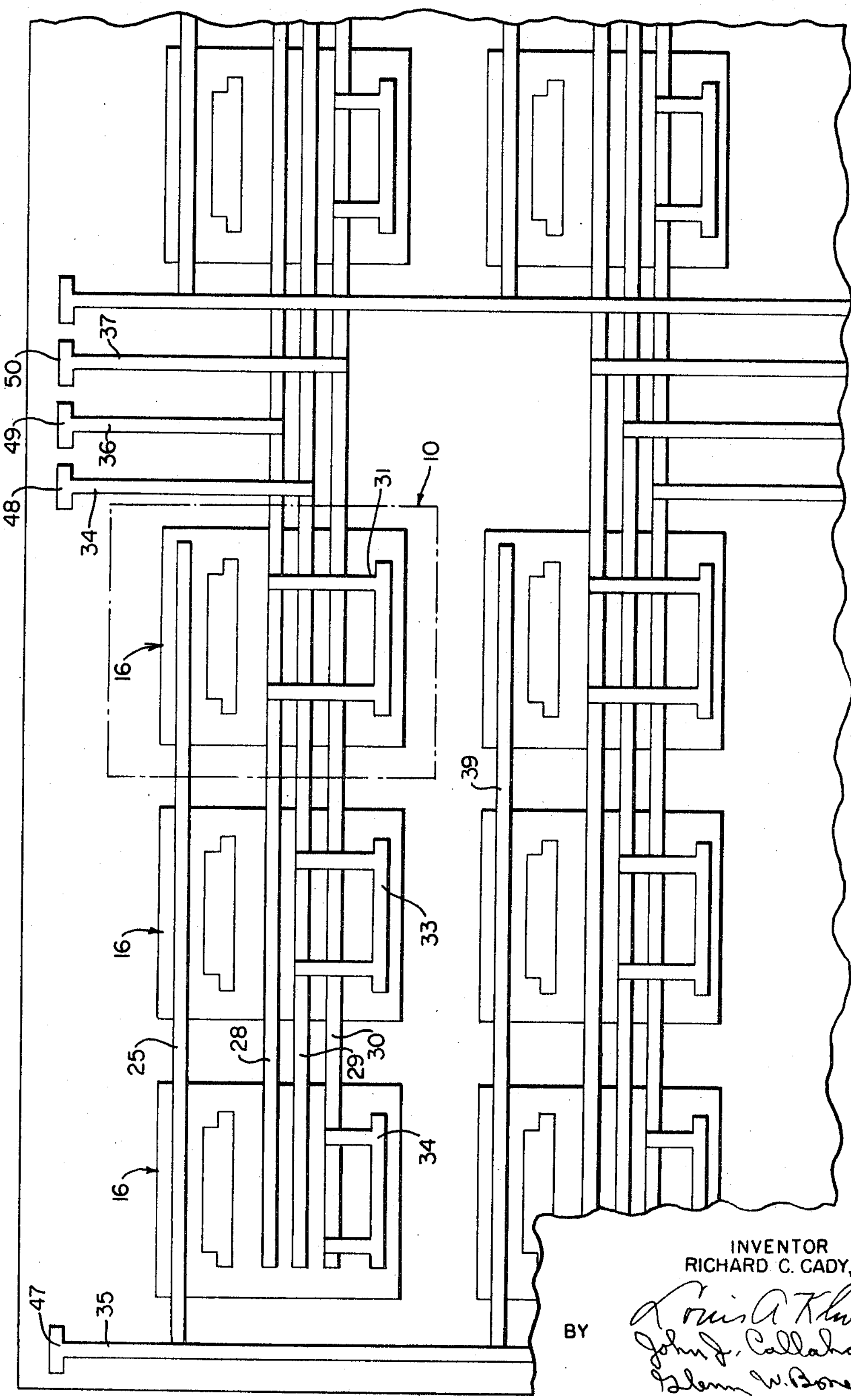
FIG.6



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THERMAL PRINTING HEAD WITH DIFFUSED PRINTING ELEMENTS

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U.S. Cl. 219—216 4 Claims

ABSTRACT OF THE DISCLOSURE

A thermal printing head which includes a number of semi-conductor printing elements diffused into a semi-conductor body for marking a thermally-sensitive record material is disclosed. The diffused thermal printing elements are arranged into a matrix, and matrix selection is provided by an interconnection network consisting of first level electrodes which pass through a dielectric insulating layer to a second level electrical selection conductor. Isolation elements which are also diffused into the semi-conductor body are interconnected with the diffused printing elements. The isolation elements may be a semi-conductor diode, a silicon controlled rectifier, or a semi-conductor threshold device.

A protective overcoating layer is deposited over the entire structure including the semi-conductor printing element and the semi-conductor isolation element. One embodiment of the present invention employs a protective overcoating layer of a material having a substantial thermal conductivity and a substantial electrical resistivity which is shaped to provide a raised area over each of the resistive printing elements so as to provide a plurality of selectively heat-concentratable raised areas for printing.

Background of the invention

Prior thermal printing devices are constructed of a number of individual printing elements which must be aligned in a co-planar array. The number of external connections that are required for such thermal printing heads is fairly large, and, in addition, although a relatively hard material, tin oxide, is employed for the resistive elements, abrasion is a problem with this type of thermal printing head.

The diffused thermal printing matrix structure of the present invention eliminates co-planar alignment requirements, reduces the number of electrical connections that are required by an order of magnitude, and provides an abrasion-resistive overcoating layer.

Brief description of the drawings

FIG. 1 is a sectional perspective view, taken along the line 1—1 of FIG. 5, which shows a single diffused printing element and its associated isolation element.

FIG. 2 is an electrical schematic showing the electrical interconnections for a thermal printing matrix of twenty-five printing elements.

FIG. 3 is a sectional view of two diffused printing elements.

FIG. 4 is a plan view of the diode portion of FIG. 3 with dielectric materials and conductive areas removed.

FIG. 5 is a plan view of the diode portion of FIG. 3 with dielectric materials removed but showing conductive areas.

FIG. 6 is a plan view of part of a thermal printing head matrix and the associated selection conductors.

Description of the preferred embodiment

Referring to FIG. 1, the printing head shown therein includes a substrate **15**, which is single-crystal sapphire,

upon which is deposited, by standard epitaxial deposition techniques, a layer of semi-conductive material **9**, such as single-crystal silicon, of N-type conductivity. A heat-conductive layer **14**, such as aluminum, may be secured to the substrate **15** to conduct heat away from the substrate. The semi-conductive layer **9** has a thickness in the range between 0.0001 inch and 0.0005 inch. The semi-conductive layer **9** is then selectively etched off of the substrate **15** to form a matrix of isolated, rectangular islands or areas **16** (FIGS. 4 to 6). The printing elements **10** of FIG. 2, comprising a resistive member **11** and an isolation diode **12**, are subsequently formed on the islands **16**. The islands **16** are formed to provide electrical and thermal isolation between the printing elements **10**.

The following steps are performed, using photolithographic, etching, and diffusion techniques that are standard in the art. The islands **16** are delineated and etched, and diffused P-type regions **17** and **18** are formed therein (see FIGS. 3 to 5). Then, the islands **16** are again delineated and etched, and a diffused N^+-type region **19** is formed therein. The islands **16** are again delineated, and the silicon dioxide layer **20** (FIG. 3), which was formed during and after each of the prior diffusion steps, is etched away in certain areas to form holes **21** to **24** therein, through which ohmic contact is made to the underlying semi-conductor material. The resistive member **11** of FIG. 2 is the P-type region **17**. The isolation diode **12** is formed of the material of the island **16**, the P-type region **18** is the diode anode, and the N^+-type region **19** is ohmic contact region for the diode cathode.

The foregoing processing steps largely determine the electrical properties of the printing elements **10**. The N-type single-crystal silicon layer formed into the islands **16** largely determines the reverse-breakdown voltage of the isolation diodes **12** and is chosen with the proper N-type impurity concentration so as to provide a satisfactory diode yield. The N^+-type regions **19** are formed so that non-rectifying electrical contact can be made to the isolation diode by means of an electrical conductor. The proximity of an N^+-type region **19** to the anode region **18** of the isolation diode strongly affects the diode forward resistance. The diffusion of impurities into the P-type regions **17** and the geometry of these regions may both be varied to obtain the desired resistance value for the resistive member **11**. Additionally, the geometry of the P-type regions **18**, which form the anodes of the isolation diodes **12**, may be varied, and this effects the reverse leakage of the isolation diodes **12**.

The following steps in the manufacture of the printing head are then performed. First, or bottom level, electrical conductors **25**, **26**, **28**, **29**, and **30** are formed in the holes **21** to **24** in the silicon oxide layer **20**. The electrical conductor **25** extends across all of the printing elements **10** (see FIG. 6) and constitutes the common drive line for them. The electrical conductor **25** makes ohmic contact with the P-type region **18** forming the anode of the isolation diode **12**. The electrical conductor **26** electrically interconnects the N^+-type region **19** and one end of the P-type region **17** which forms the resistive member **11**. The electrical conductor **27** electrically interconnects the other end of the P-type region **17** with a second, or top level, electrical conductor **31**, which is formed later. The electrical conductors **28**, **29**, and **30** extend across the printing elements **10** (see FIG. 6) and form the energization or drive lines for them. The electrical conductor **28** serves as an energization line for the printing element **10**, shown in FIG. 3, and similarly-located printing elements **10** in each matrix, as shown in FIG. 6. The electrical conductors **29** and **30** serve as energization lines for other printing elements in each matrix, as indicated in FIG. 6. Other second level electrical conductors **33** and **34** are provided. The conductor **33** provides a means for supplying energizing current to the first level electrical conductor **29**, and the conductor **34** connects the first level conductor **30** to a first level heating resistor.

The first level electrical conductors **25** to **30** in the described embodiment are formed as molybdenum-gold sandwich structures. These structures comprise a layer of evaporated molybdenum, a layer of gold, and a second layer of molybdenum. The molybdenum adheres tightly to the silicon dioxide layer **20** and other dielectric material. The conductors **25** to **30** may also comprise vacuum-deposited aluminum, which also strongly adheres to the silicon dioxide layer **20** and other dielectric material.

The interconnection pattern for the first level electrical conductors **25** to **30** is delineated by standard photolithographic techniques. The character common drive conductors (such as the conductor **25**), the element drive lines (such as the conductors **28**, **29**, and **30**), and the connection between the isolation diode N^+-type region **19** and one end of the P-type region **17** (forming a resistive member **11**) are formed. The first level interconnection pattern is shown in FIG. 6.

A dielectric insulating layer **45** (FIG. 3) is then deposited over the entire surface of the printing head to electrically isolate the first level electrical conductors **25** to **30** from the second level electrical conductors **31**, **33**, and **34**, and the other second level electrical conductors. The material of the layer **45** should be capable of forming a strong bond with the molybdenum layer of the first level electrical conductors, its temperature coefficient of expansion should match that of the silicon islands **16** reasonably well, and it should form a strong bond to the silicon dioxide layer **20**. Special glasses are commercially available which meet the foregoing criteria. The glass may be deposited by radio frequency sputtering. The layer **45** should have sufficient breakdown voltage to withstand the voltage (about 20 to 25 volts) applied across a printing element **10**, and it must be free of pinholes.

Next, the first level electrical conductors **25** to **30** are exposed in those areas where electrical contact is desired to be made between a first and a second level electrical conductor. This is accomplished by delineating the areas by photolithographic techniques followed by selective etching, or by masking the areas so that the material of the insulating layer **45** will not adhere to them.

The second level interconnection pattern, which comprises the electrical conductors **31**, **33**, and **34**, is deposited and delineated. The electrical conductors, such as the conductors **31**, of each printing element connects the printing element drive conductors, such as the first level conductors **28**, **29**, and **30**, to the P-type regions **17** which form the heating resistive member **11**. The electrical conductors such as the conductor **35** (FIG. 6) connect the character common conductors, such as the conductors **25** and **39**, together and furnish an electrical path to external contact pads, such as the pad **47**. The electrical conductors such as the conductors **34**, **36**, and **37** furnish an electrical path from the printing element drive conductors, such as the first level conductors **28**, **29**, and **30**, to external contact pads, such as the pads **48**, **49**, and **50**. The conductors of the second level interconnection pattern are one of the same materials as the conductors of the first level interconnection pattern and are deposited and delineated in a similar manner.

A protective layer **51** (FIG. 3) is deposited over the entire surface of the printing head except for the external contact pads, such as the pads **47** to **50**. The protective layer **51** should have high thermal conductivity and high electrical resistivity. It should also offer good resistance to abrasion and be capable of withstanding repeated, rapid (cycle time about 25 milliseconds) cycling from room temperature to about 300 degrees centigrade. The metal-oxide-ceramics fulfill these criteria, and preferred material for the protective coating **51** is beryllium oxide (BeO) and aluminum oxide (Al_2O_3). Beryllium oxide is particularly suited to function as a protective coating because of its hardness and its very high thermal conductivity, and because its coefficient of thermal expansion is near to that of silicon (10.0 microinches per inch per degree centigrade for beryllium oxide and 4.68 microinches per inch per degree centigrade for silicon). The protective layer **51** is deposited by standard radio frequency sputtering techniques.

Finally, as much of the protective layer **51** as is possible or practical is removed from between adjacent printing elements **10**, as indicated by the depression at **52** in FIG. 3. These depressions help to produce localized high temperature areas that are confined to the printing elements **10** and help to reduce mutual interaction between adjacent printing elements **10**. These depressions may be made by a photolithographic selective etching technique. The depressions may also be made during the process of depositing the protective layer **51** using a shadow-masking technique in which a wire grid, for example, is placed between the source of coating material and the printing head and casts a "shadow" on the printing head where less material will be deposited than where no shadow is cast.

What is claimed is:

1. A thermal printing device comprising:

(a) an electrically insulating substrate;

(b) a body of semi-conductive material deposited on a supporting surface of the substrate;

(c) a plurality of heat-generating elements of a material having a substantial electrical resistivity, the heat-generating elements being diffused into the body of semi-conductive material so as to define an information pattern;

(d) a plurality of electrical isolation elements, each electrical isolation element being associated with one of the heat-generating elements, each electrical isolation element being diffused into the body of semi-conductive material in the vicinity of its heat-generating element, and each electrical isolation element having at least a first and a second terminal, the first terminal of each electrical isolation element being electrically connected to its associated heat-generating element, the electrical isolation elements being constructed to initially have a high impedance state with respect to the first and second terminals thereof when the voltage across the first and second terminals is at a first predetermined value, and to have a low impedance state with respect to the first and second terminals thereof when the voltage across the first and second terminals is at a second predetermined value;

(e) a first insulating layer of an electrically insulating material which overlies each heat-generating element and each electrical isolation element;

(f) at least one elongated electrical common conductor on the first insulating layer electrically connected to the second terminals of a plurality of electrical isolation elements in common through an opening in the first insulating layer;

(g) a first electrical connecting conductor provided for each heat-generating element on the first insulating layer that electrically connects the first terminal of each electrical isolation element to one portion of a heat-generating element through openings in the first insulating layer;

(h) a second electrical connecting conductor provided for each heat-generating element in electrical contact with another portion of a heat-generating element;

(i) a plurality of elongated electrical selection conductors on the first insulating layer, a predetermined one of said elongated electrical selection conductors being provided for the energization of a heat-generating element associated therewith;

(j) a second insulating layer of an electrically insulating material which overlies the elongated electrical common conductor, the first electrical connecting conductors, and the elongated electrical selection conductors;

(k) and a third electrical connecting conductor provided for each heat-generating element on the second insulating layer that electrically connects each predetermined one of said elongated electrical selection conductors through an opening in the second insulating layer to its associated heat-generating element by way of the second electrical connecting conductor.

2. A device as in claim 1 further comprising a protective layer of an abrasion-resistive material having a substantial thermal conductivity and sufficient electrical resistivity to prevent electrical shorting of the heat-generat-

ing elements deposited on the second insulating layer and the third electrical connecting conductor.

3. A device as in claim 1 wherein the protective layer is beryllium oxide (BeO).

4. A device as in claim 1 wherein the protective layer is aluminum oxide (Al_2O_3).

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U.S. Cl. X.R.

178—30, 94; 219—480, 543; 346—76