Feb. 17, 1970 E. G. ALEXANDER ET AL 3,496,333

THERMAL PRINTER

Original Filed Oct. 1, 1965 5 Sheets-Sheet 1

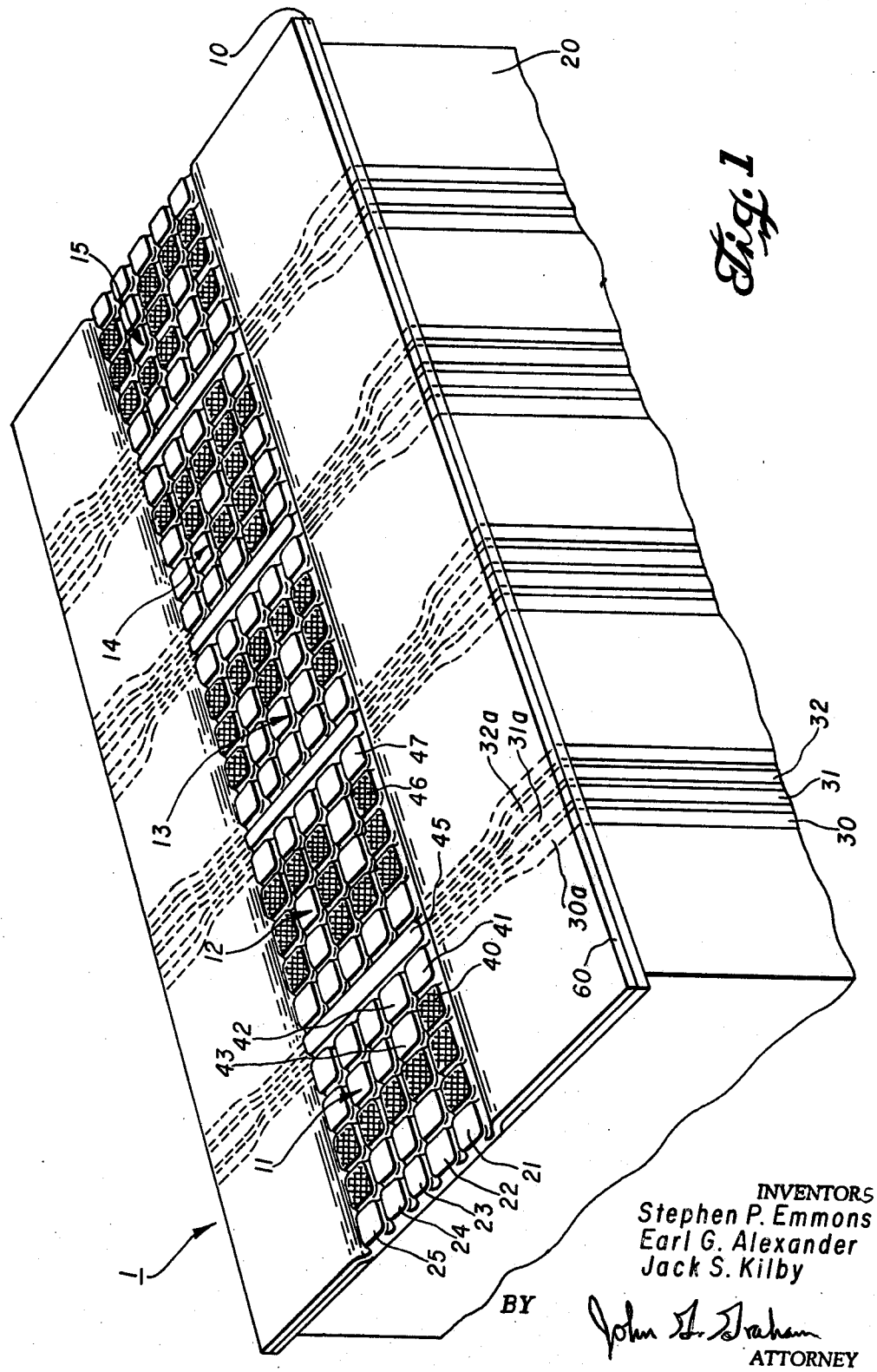


Fig. 1

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THERMAL PRINTER

Original Filed Oct. 1, 1965 5 Sheets-Sheet 2

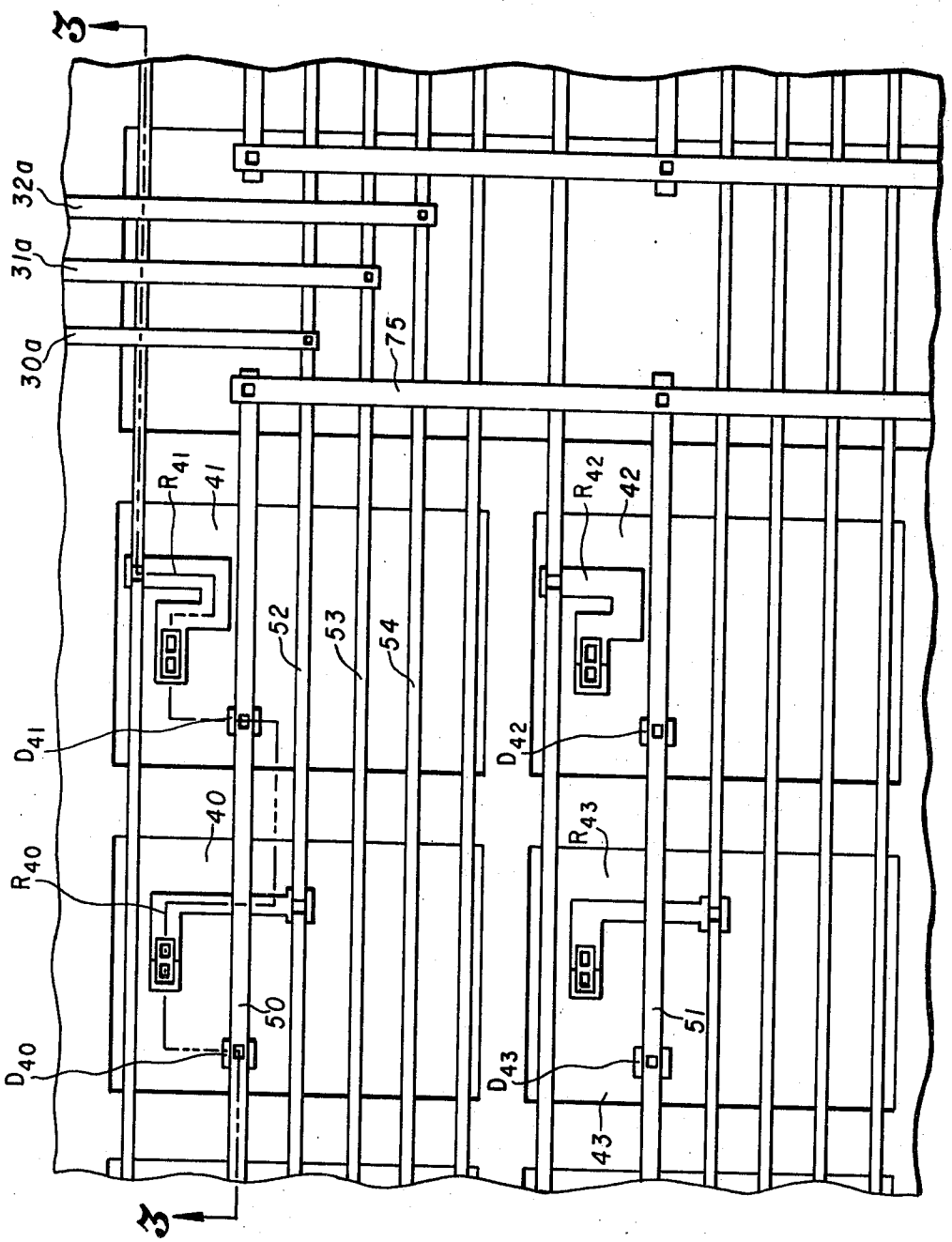


Fig. 2

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THERMAL PRINTER

Original Filed Oct. 1, 1965 5 Sheets-Sheet 3

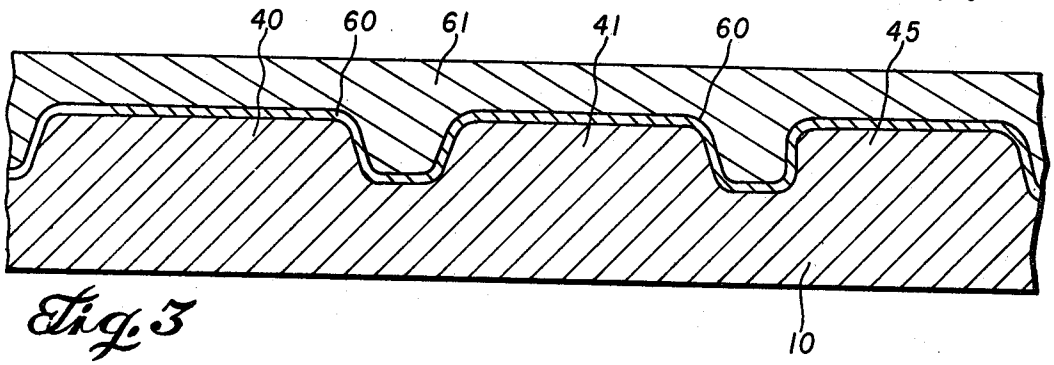


Fig. 3

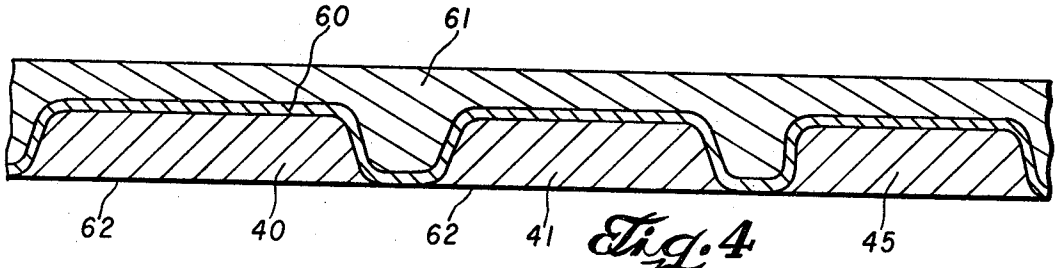


Fig. 4

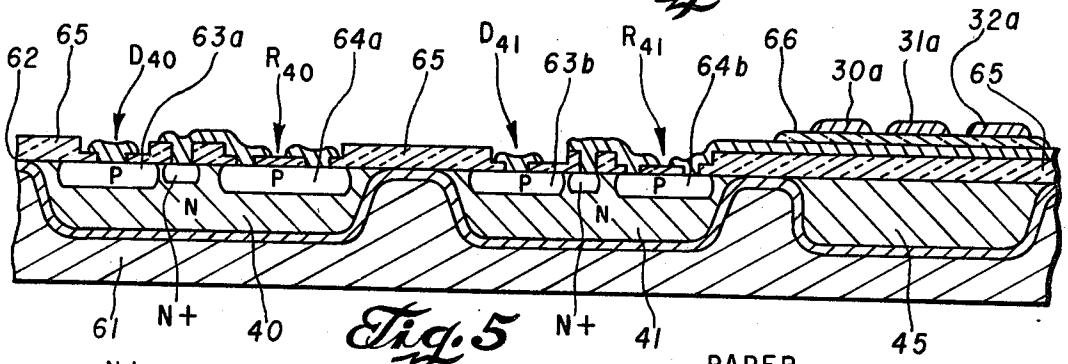


Fig. 5

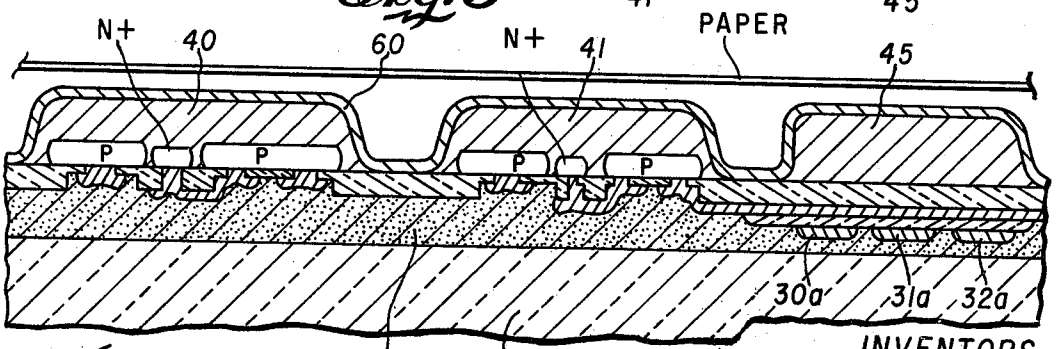


Fig. 6

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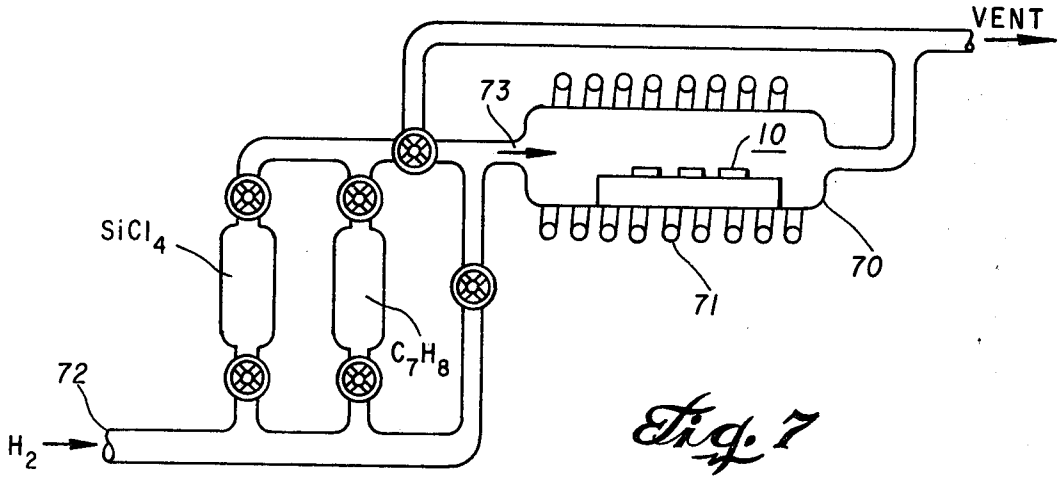


Fig. 7

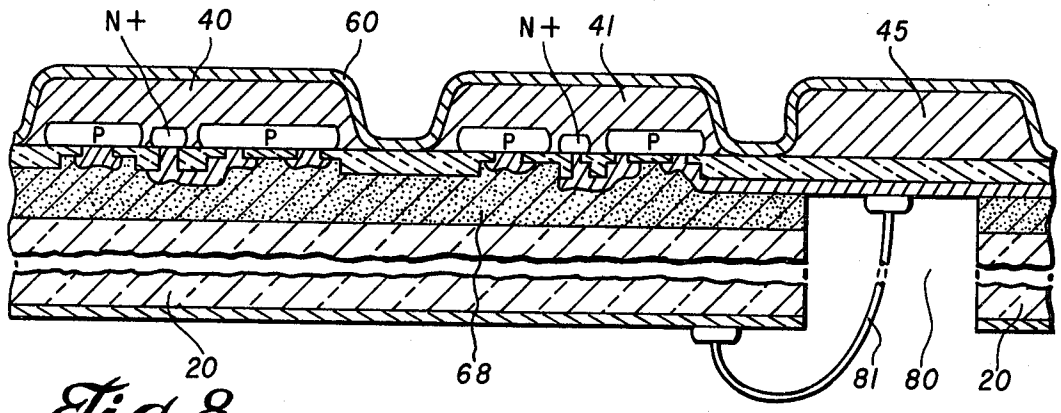


Fig. 8

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Feb. 17, 1970 E. G. ALEXANDER ET AL 3,496,333

THERMAL PRINTER

Original Filed Oct. 1, 1965 5 Sheets-Sheet 5

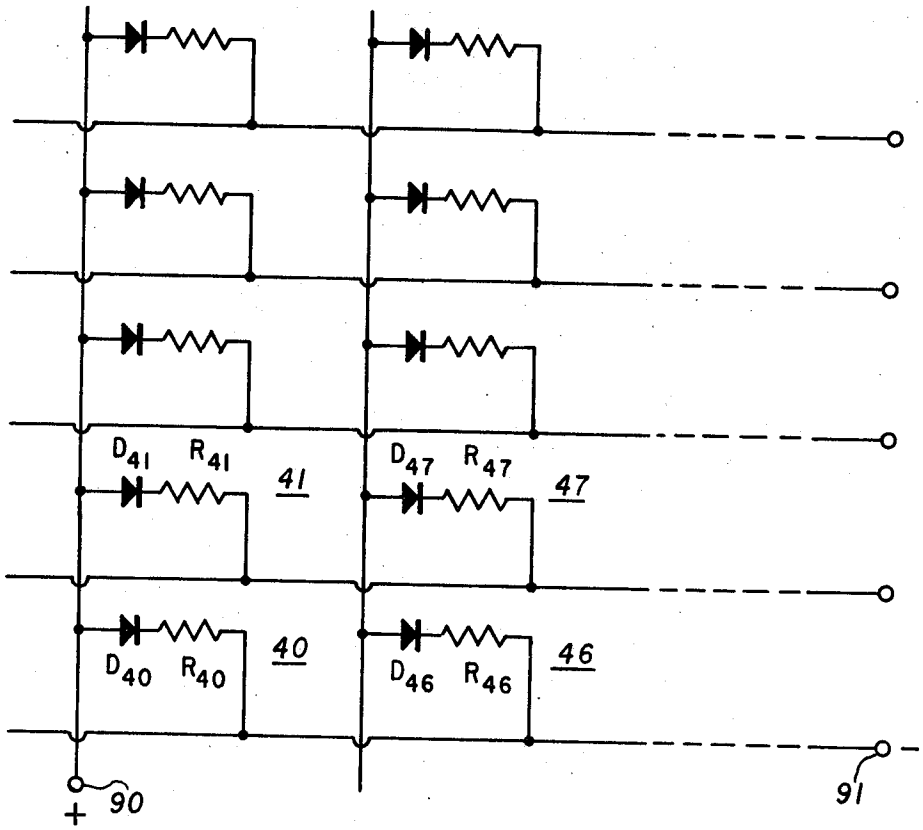


Fig. 9

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United States Patent Office 3,496,333
Patented Feb. 17, 1970

3,496,333

THERMAL PRINTER

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Continuation of application Ser. No. 492,174, Oct. 1, 1965. This application Sept. 26, 1968, Ser. No. 768,607
Int. Cl. H05b 3/00
U.S. Cl. 219—216 22 Claims

ABSTRACT OF THE DISCLOSURE

A thermal display having an array of substantially thermally isolated semiconductor bodies each including a semiconductor heating element arranged at one surface of a substrate, means for selectively electrically energiving said heating elements to produce heat which defines a form of information representation, and means thermally coupled to said bodies for displaying said form of information representation. P-N junctions are provided in the semiconductor bodies and conductors are located between the bodies and the one surface of the substrate for selectively electrically energizing the heater elements.

This application is a continuation of U.S. patent application Ser. No. 492,174, filed Oct. 1, 1965, now abandoned.

This invention pertains to thermal printing, and more particularly to a novel form of thermal print head.

In the printing art there is a continuing search for new and better printing methods and apparatus. One of the more recent improvements has been the development of a process which uses heat rather than impact for the printing energy. According to this process, a matrix of heating elements is selectively energized to heat a specially treated paper sensitive to changes in temperature, the paper being in physical contact with the heating elements at the time the printing takes place. For example, if the letter A is desired to be printed, the heating matrix will be energized in a pattern corresponding to this letter, the letter A thereby being defined, or "printed," upon the heat sensitive paper.

The advantages of thermal printing over impact printing include a minimum of mechanical motion (the primary mechanism being only that required to advance the heat sensitive paper); a reduction in the problems associated with any change of information representation from one form of representation to another (the information up to the time of printing appearing as an electrical signal); and a substantial increase in printing speed.

The heart of the thermal printer is the thermal print head which contains the matrix of heating elements. These thermal print heads are generally fabricated by several different processes. By one process, for example, resistors composed of a conductive compound, for example, tin oxide, are selectively deposited by evaporation or the like upon a ceramic substrate, the resistors forming the heating elements. By another process, the fabrication of the print head involves planar techniques, whereby resistors are formed by diffusion into one face of a flat semiconductor wafer, the heat sensitive paper passing in contact with this face.

There are problems associated with these techniques, however, which result in thermal print heads that are unsatisfactory for various reasons. First, the heating elements of the print head are subject to degradation due to the abrasive action of the paper when passing over the print head. Second, in the planar approach, leads to and between the resistor heating elements are ordinarily exposed, providing unreliable connections. Also, where the diffused resistors are formed in a monolithic semiconductor planar substrate, a large amount of power is required to heat the elements to the proper printing temperature, and a substantial amount of "spillover" heat occurs from one element to another, due to the lack of thermal isolation between elements, thereby reducing the ability to achieve a sharp print-out.

With these difficulties in mind, it is an object of the present invention to provide an improved print head for a thermal printer. Accordingly, it is another object to provide a print head whose heating elements, leads and interconnections are not degraded by the abrasive action of the heat sensitive paper. It is still another object of the invention to provide a print head having a structure that requires a minimum of power to heat each of the elements to the proper printing temperature, and has sufficient thermal isolation between elements to effect a very sharp and well-defined print-out.

In accordance with these and other objects, features and improvements, the present invention constitutes a thermal print head comprising a matrix of semiconductor means, each mesa forming an individual printing element and having an interconnected resistor and diode formed therein by solid state techniques. The mesas are mounted upon a ceramic substrate so that the diodes and resistors are located at the interface of the mesas and the ceramic substrate away from the upper surfaces of the mesas over which passes the temperature sensitive paper to be printed. Metallized leads deposited upon the ceramic substrate make ohmic contact to an expanded contact structure on excess semiconductor material adjacent the mesas, and also to the external thermal printing system. A layer of wear-resistant material such as silicon carbide or the like, is located upon the upper surface of the mesas.

Due to the wear protection afforded by the silicon carbide layer, and the fact that the components (diodes and resistors), as well a their leads and interconnections, are not exposed, the resulting structure provides greater reliability. The raised mesas, being substantially thermally isolated from one another, avoid heat "spillover," thereby producing sharp and well-defined printouts. Additionally, because there will be practically no loss of heat between elements due to this thermal isolation, less power is required to operate the device.

The novel features believed to be characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as other objects and advantages thereof, may best be understood by reference to the following detailed description when read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a top view of the thermal print head of the present invention, showing an array of mesa heating elements disposed in the form of a plurality of characters with selected elements in each character energized to define the numbers 1, 2, 3, 4, and 5;

FIGURE 2 is an underside view of a portion of the array shown in FIGURE 1, illustrating the formation of a diode-resistor pair within each mesa element, and the lead and expanded interconnection pattern between elements;

FIGURES 3–6 are sectional views of a portion of the heating elements shown in FIGURE 2, taken along the section line 3—3, and showing subsequent steps in the fabrication of the print head of the present invention;

FIGURE 7 is a front elevation, partly in section, showing one form of apparatus utilized in the fabrication of this invention;

FIGURE 8 is another embodiment of the invention showing an alternative interconnection scheme; and

FIGURE 9 is a schematic circuit diagram illustrating,

by way of example, the operation of the present invention.

Referring now to FIGURE 1, there is depicted a top view of the thermal print head **1** comprising a wafer **10** of semiconductor material, silicon for example, having five "characters" **11–15** formed therein. Each of the characters is composed of a matrix of thermal printing elements such as the elements **21–25** of the character **11**. Each element is a raised mesa of semiconductor material with a layer of silicon carbide **60** over the top of the mesas and the rest of the slice **10** (the fabrication of which will be subsequently described with reference to FIGURES 3–7), each mesa containing an interconnected diode and resistor. The particular array or the dimensions of the characters are not critical to the invention. In the particular embodiment herein shown and described however, each character is composed of a 5 x 5 array of printing elements, each of the printing elements, **21–25** for example, being approximately 0.016 inch in length and 0.012 inch in width, the spacing between each element being approximately 0.004 inch. The silicon wafer **10** may be approximately 0.3 inch in width by 0.5 inch in length and have a thickness of approximately 0.001 to 0.002 inch. The active printing surface (in other words, the "characters" and their spacing) occupies an area of approximately 0.1 inch by 0.5 inch, and is centrally located upon the wafer **10**.

The silicon wafer **10** with the mesas therein is mounted upon a ceramic substrate **20** so that the metallized leads **30–32**, for example, formed upon the sides of the substrate **20** interconnect with the expanded leads **30***a*–**32***a*, respectively, located on the underside of the excess material of the wafer **10**. These expanded leads, as well as the other expanded leads, are actually extensions of the second level interconnections which make contact to the various first level interconnections of the printing elements shown in FIGURE 2. The metallized leads **30–32** may be formed directly upon the surface of the ceramic substrate **20**, or may be formed within slots within the sides of the ceramic. The joining of the expanded leads **30***a*–**32***a* to the external metallized leads **30–32** may be accomplished by any conventional technique, as, for example, by flow solder fillets. An epoxy may then be placed under the overhanging portions of the silicon slice to provide added mechanical support.

The actual operation of the thermal printer may be accomplished by various techniques and is not restricted to any one method of excitation of the appropriate heating elements. For example, a short high power pulse may be applied to selected external leads, such as **30–32**, the pulse causing current to flow through resistors of select printing elements, the selected printing elements heating up to say 300° C. in a pattern corresponding to the letters or numbers to be printed. The selection of the proper leads to be energized may be accomplished manually or by a separate diode digital decoder, for example. Accordingly, as shown in FIGURE 1, select elements of the "characters" **11–15** may be heated to define the number 1, 2, 3, 4, and 5, respectively, which then are printed on heat sensitive paper which has been indexed over the face of the thermal print head **1**. (The select elements which have been heated are represented on FIGURE 1 by a double cross-hatching, and may be best seen by holding the drawing at arms length from the eye.) Depending upon the interconnection scheme used, the printing may be accomplished, for example, by simultaneously heating select elements of "characters" **11–15**, thereby printing a whole line at a time, or by heating the select elements of the characters in a manner so as to sequentially print out the numbers 1 through 5.

Referring now to FIGURE 2, there is depicted an underside plan view of a portion of one of the "characters" **11**, showing some of its heating elements **40**, **41**, **42**, and **43** and a typical but not restrictive, pattern of interconnections. Each of the heating elements comprises a raised mesa of semiconductor material (as observed in the cross-section view of FIGURES 3–6), a diode and resistor pair such as D_{40} and R_{40} being formed by conventional masking and diffusion techniques, for example, in the base of the mesa, the pair being interconnected with each other and with the rest of the system. The function of the resistors R_{40}, R_{41}, R_{42}, and R_{43} is to provide the source of heat for each printing element, and the function of the diodes D_{40}, D_{41}, D_{42}, and D_{43} is to direct the current flow through only those resistors which are to be heated. First level interconnectors such as **50** and **51** ohmically connect the P-type regions of the diodes D_{40} and D_{41} and the P-type regions of diodes D_{42} and D_{43} to the second level interconnector **75** respectively, and first level interconnectors **52**, **53**, and **54** connect the ends of the resistor R_{40} and other resistors of the other mesas (not shown in FIGURE 2) to the second level interconnectors **30***a*, **31***a*, and **32***a*, respectively.

The function of the diodes may be further understood by reference to the schematic representation shown in FIGURE 9. The diode-resistor pairs within the elements **40**, **41**, **46** and **47** are interconnected as shown. Assume that the element **40** is to be heated (i.e., a current made to flow through the resistor R_{40} of element **40**), but the elements **41**, **47**, and **46** are to remain "cool"; i.e., no current is to flow through the resistors R_{41}, R_{47} and R_{46}. A source of positive potential is applied to the terminal **90** while a source of negative or ground potential is applied to terminal **91**. Due to the blocking effect of the diode D_{46}, the only current path between the positive and negative terminals is the one through the diode D_{40} and resistor R_{40}. Consequently, only the element **40** heats up. Similarly, utilizing the same principle and arrangement, the remaining diodes and resistors of the other elements may be wired in like manner or in any other conventional manner, to selectively heat desired elements, the diodes functioning as current blocks. It is to be pointed out that the use of the diodes allows one to limit the number of external leads; if a pair of leads is applied to each element of each character, there is no need for the diodes.

With reference to the cross-section views of FIGURES 3–6 there is now described the fabrication of the novel print head of this invention, particularly the formation of the silicon mesa thermal printing elements. Single crystal semiconductor material, such as silicon, is used as the starting material for a slice **10**. A portion of this slice is shown in FIGURE 3. The top surface of the slice is first masked and etched to form a pattern of raised mesas such as **40**, **41** and **45**. The masking may be by a material such as wax or preferably by photoresist techniques which permit excellent geometry control. The height of the mesas **40**, **41** and **45**, for example, or in other words, the depth of the etching may be approximately 1.5 to 2 mils. After the mesas are formed, the top surface of the slice is covered with a coating **60** of silicon carbide which may be formed by any technique to a thickness of perhaps 0.3 to 0.8 mil.

One method of depositing the silicon carbide is described with reference to FIGURE 7. Apparatus for depositing the silicon carbide in accordance with this process comprises a reactor in the form of a furnace tube **70** having heating coils **71**. The furnace may be of a horizontal or vertical type, may be suited for single or multiple slices, and may be either resistively or inductively heated. Silicon slices, including the slice **10**, with the mesas formed therein, are disposed within the furnace in such a position as to expose the slices to gases directed into the tube through a conduit **73**. Toulene (C_7H_8) and silicon tetrachloride ($SiCl_4$) vapors are respectively introduced into the conduit **73** from cylinders containing liquid toluene and liquid silicon tetrachloride, through which hydrogen gas is bubbled. Purified dried hydrogen enters end **72** of the conduit. The flow of gases into the tube furnace **70** is regulated by conventional valves.

The rate of deposition is determined largely by the temperature at which the reactor is maintained, the flow rate through the conduit **73**, and the percentage composi-

tion of the constituents. For example, when the flow rate was kept at approximately 10 liters per minute, the temperature at approximately 1080° C., and the reactive mixture consisted of 0.87 mol percent of $SiCl_4$, 0.18 mol percent C_7H_8, and the remaining mol percent H_2, a layer of silicon carbide was deposited upon slice **10** as seen in FIGURE 3 at a rate of approximately 1 micron per minute.

A layer **61** of material, for example polycrystalline semiconductor material, is now deposited over the top surface of the slice **10** adjacent the silicon carbide layer **60**, as seen in FIGURE 3. The most common method of deposition is by the hydrogen reduction of silicon tetrachloride, a technique well known in the art and requiring no elaboration here. The conductivity type of the layer **61** is not critical; the crystalline structure may also be either single crystalline or amorphous, and should be, perhaps, six or eight mils or more to facilitate handling.

As the next step in the fabrication of the themal printing head of this invention, the structure of FIGURE 3 is subjected to a lapping and polishing treatment on its lower face to remove all the original silicon material except that portion remaining within the mesas **40**, **41** and **45**, as illustrated in FIGURE 4. It is to be noted at this point, and as a particular feature of the invention, that the silicon carbide coating **60** functions as a substantially continuous "stop" to the lapping and polishing operation, enabling precision control to be maintained over the amount of semiconductor material left within the mesa regions. This is important for a variety of reasons. First, as a consequence of the various steps preceeding the lapping operation, the silicon slice will bow, presenting a somewhat convex or concave surface to the lapping apparatus. Hence when the lapping and polishing operations are carried out to remove the substrate material from below the mesa regions, a considerable number of the mesas will be cut through and destroyed. The silicon carbide layer **60** tends to halt the lapping operation at the lower face **62** so that none of the mesas will be cut through. Second, because of the precision control that can be maintained, the actual thickness of the semiconductor material within the mesa regions may be controlled to a precise degree. This is important since the thickness of each of the mesas influences their rate of heating and cooling (in other words, the thermal response) which, in turn, determines the speed of the printing.

Inverting the structure and looking at what was the bottom surface of face **62** of FIGURE 4, but what will now be considered the top face of the unit, the structure appears as in FIGURE 5. The mesa regions **40** and **41** now serve as regions into which subsequent diffusions or upon which epitaxial depositions, may be made in order to fabricate the diode-resistor pair of each printing element. In this particular embodiment the diode-resistor pair D_{40} and R_{40} and D_{41} and R_{41} are formed by conventional oxide masking and diffusion operations in the N type material of mesa elements **40** and **41**, respectively.

P-type diffused regions **63***a* and **63***b* provide the respective anodes of the diodes D_{40} and D_{41}, while elongated P-type regions **64***a* and **64***b*, formed simultaneously with the anode regions, provide the resistors R_{40} and R_{41}. The N-type material of the mesas **40** and **41** provide the cathodes of the diodes D_{40} and D_{41}. Contact to the N region is made through low resistivity N+ regions as shown. The diffusion operations utilize silicon oxide masking as mentioned so that an oxide layer **65** is formed which acquires a stepped configuration in the final device. Openings are made in the oxide where contact is necessary, then metal film is deposited over the oxide and selectively removed to provide the desired contacts and interconnections.

It is to be observed that the silicon mesa **45** is masked with the silicon oxide layer **65** during the formation of the diodes and resistors in the various printing elements. This region provides the spacing between the individual characters as also observed in FIGURES 1 and 2. The second level interconnections **30***a*, **31***a*, and **32***a*, for example, are formed over these regions, between the characters rather than over the printing elements in order to prevent exposure of the insulation between these leads to the high temperature thermal transients associated with the thermal printing elements. An insulating layer **66** capable of withstanding high temperatures is formed by conventional techniques intermediate the first level interconnections and the second level interconnections **30***a* and **30***b*, as shown in FIGURE 5.

As the final steps in the fabrication of the thermal print head of the present invention, the composite structure with the individual printing elements in sawed into the individual wafers and inverted and mounted upon ceramic substrate **20** with a suitable adhesive **68**, such as epoxy, as shown in FIGURE 6. The wafer with the mesa printing elements is aligned so that the second level interconnections **30***a*, **31***a*, and **32***a*, for example, engage the appropriate metallized lead pattern on the ceramic substrate, as shown in FIGURE 1, the joining of the metal being accomplished by soldering. As the next step in the process, the polycrystalline semiconductor layer **61** is completely removed, resulting in a structure shown in FIGURE 6, whereby each of the mesa thermal printing elements **40** and **41**, for example, are isolated from each other by the layer **60** of silicon carbide and the surrounding ambient (air, for example). This removal is accomplished by applying an etchant such as a mixture of hydrofluoric acid (2 parts per volume), nitric acid (15 parts per volume) and acetic acid (5 parts per volume) to the top surface, whereby all of the polycrystalline material **61** is etched away, while the semiconductor material within the individual mesas is protected from the etchant by the layer **60** of silicon carbide acting as an etch barrier.

As a result of the above described process, a matrix of meas printing elements, such as **40** and **41**, is produced, the complete structure providing numerous advantages. As seen in FIGURE 6, the diode-resistor pair of each element is positioned away from the surface over which the thermal sensitive paper passes, the silicon material within the mess and the silicon carbide coating **60** providing the protection for these components. The final structure, even without the silicon carbide, will offer considerable wear resistance, the silicon material itself affording substantial protection from the abrasive action of the thermal sensitive paper. The presence of the silicon carbide layer **60**, however, affords much greater protection for both the components and the overlying silicon material. In addition, since the interconnections are also formed away from the upper surface, they will be protected, providing greater reliability.

The removal of the polycrystalline material between each mesa, resulting in the gaps between each printing element, provide thermal isolation between each of the printing elements, thereby reducing heat "spillovers" into the adjacent elements and keeping the quantity of power required to heat each element at a minimium.

In addition to the interconnection scheme described above, alternate interconnection schemes may be utilized. One such scheme is shown in FIGURE 8. The mesa printing elements, with the diode-resistor pairs and the silicon carbide layer are fabricated as previously described with reference to FIGURES 3–7, and the first level interconnection pattern deposited as before. The ceramic substrate **20** with the slot **80**, for example, has the second level interconnecttion pattern, for example second level interconnection **69**, formed on its lower face, as shown in FIGURE 8. The silicon wafer with the mesa printing elements is then mounted face down upon the ceramic, the mesa **45**, for example, containing no diode-resistor pairs located over the slot **80**. The first and second level interconnections are then selectively joined by way of individual wires such as **81**, which are ball bonded at

the appropriate points. The polycrystalline material is then removed as before. The ceramic substrate **20** and the slot **80** then provide the necessary insulation between the two levels of leads.

Various modifications may also be made in the material used for the insulating substrate **20**. Since the substrate **20** physically connects the individual mesas, it should be fabricated of a material that provides adequate thermal isolation between the mesas while at the same time having sufficient thermal conductivity to provide a cooling path for the mesas after the print. An example of one material which may be used is alumina.

Although a 5 x 5 array has been described, any matrix or array of printing elements is deemed to be within the scope of the present invention. In addition, the thermal print head may be used to print many forms of information as letters, figures, symbols, etc. The starting material of the semiconductor slice may be either P-type or N-type.

Various other modifications of the disclosed embodiments, as well as other embodiments of the invention, may become apparent to persons skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. In a thermal printing device:
a substrate,
an array of semiconductor mesas upon one surface of said substrate, said array being so arranged that select ones of said mesas of said array define a form of information representation, said mesas being substantially thermally isolated from one another,
a semiconductor resistor within each of said select ones of said mesas, and
means for producing current in each of said resistors, thereby to heat said select ones of said mesas which defines a form of information representation.

2. The device as described in claim **1** wherein the said form of information representation is a letter of an alphabet.

3. The device as described in claim **1** wherein the said form of information representation is a number.

4. In a thermal printing device:
a substrate,
an array of semiconductor mesas upon one surface of said substrate, said array being so arranged that select ones of said mesas define a form of information representation, said mesas being substantially thermally isolated from one another,
a semiconductor resistor within each of said select ones of said mesas, said resistor being vertically spaced from the top surface of each of said mesas,
a layer of wear-resistant material overlying said top surface of said plurality of semiconductor mesas, and
means for producing current in each of said resistors, thereby to heat said select ones of said mesas which defines a form of information representation.

5. In a thermal printing device:,
a substrate,
an array of semiconductor mesas upon one surface of said substrate, said array being so arranged that selected ones of said mesas define a form of information representation, said mesas being substantially thermally isolated from one another,
a semiconductor resistor within each of said select ones of said mesas, said resistor being vertically spaced from the top surface of each of said mesas,
a layer of silicon carbide overlying said top surface of said plurality of semiconductor mesas, and
means for producing current in each of said resistors, thereby to heat said select ones of said mesas which defines a form of information representation.

6. A thermal print head comprising:
a substrate,
an array of semiconductor mesas upon one surface of said substrate, said mesas being substantially thermally isolated from one another, said array being so arranged that select ones of said mesas define a form of information representation,
a diffused diode and resistor within each of said select ones of said mesas, said diode and resistor being vertically spaced from the top surface of each of said select ones of said mesas, and near said one surface of said substrate, and
a layer of silicon carbide overlying the top surface of said mesas, said layer of silicon carbide providing wear-resistant protection for said mesas.

7. A thermal print head comprising:
a ceramic substrate,
an array of silicon semiconductor mesas upon said ceramic substrate, said mesas being substantially thermally isolated from one another, said array being so arranged to form a plurality of characters laterally spaced from one another, selected mesas of said characters defining a form of information representation,
an interconnected diode and resistor within each of said selected mesas, said diode and resistor being vertically spaced from the top surface of each of said selected mesas and near said ceramic substrate,
a layer of silicon carbide overlying the top surface of said array of silicon semiconductor mesas, and means for selectively producing current in each of said interconnected diode and resistor, thereby to heat said selected mesas.

8. A thermal print head of the type used for printing on thermally sensitive paper comprising:
a substrate,
an array of semiconductor mesas upon said substrate, said array being so arranged that select ones of said mesas define a form of information representation, said mesas being substantially thermally isolated from one another,
a semiconductor heating element wtihin each of said select ones of said mesas, and
means for selectively producing current in each of said heating elements to heat said select ones of said mesas which causes printing of said form of information on a thermally sensitive paper disposed in thermal communication with said mesas.

9. A semiconductor device comprising:
an electrically insulating substrate having a slot formed therein,
a plurality of semiconductor mesas upon one surface of said substrate, said plurality having at least one circuit component formed therein, said at least one circuit component being near said one surface of said substrate,
a first level interconnection between at least two of said at least one circuit component, said first level interconnection extending across said slot,
a second level interconnection upon another surface of said electrically insulating substrate, and a wire within said slot electrically connecting said first and second level interconnections.

10. A semiconductor device comprising:
a ceramic substrate having a slot therein,
a plurality of semiconductor mesas upon one surface of said ceramic substrate,
a circuit component within each of said plurality of mesas, said circuit component being near said one surface,
a first level interconnection between at least two of said circuit components, said first level interconnection extending across said slot,
a second level interconnection upon another surface of said ceramic substrate, and
a wire within said slot electrically connecting said first and second level interconnections, said wire being

ball bonded to said first and second level interconnections.

11. A thermal display device comprising:

a substrate,

an array of semiconductor bodies each including a semiconductor heating element arranged at one surface of said substrate, said bodies being substantially thermally isolated from one another, and

means for selectively electrically energizing said elements to produce heat which defines a form of information representation.

12. A thermal display device according to calim 11 wherein each body includes said element spaced from the outer surface of the body and a P-N junction therein.

13. A thermal display device adapted to selectively energize a thermally sensitive media in thermal communication with said device comprising:

a substrate,

an array of semiconductor bodies each including a semiconductor heating element arranged upon one surface of said substrate, said bodies being substantially thermally isolated from one another, and

means for selectively electrically energizing said semiconductor elements to produce heat which defines a form of information representation said means including conductors positioned on said one surface and disposed between said bodies and said substrate interconnecting selected ones of said elements.

14. A thermal display device according to calim 13 wherein each body includes said element spaced from the outer surface of the body and a P–N junction therein.

15. A thermal printing system comprising:

a substrate,

an array of semiconductor bodies each including a semiconductor heating element arranged at one surface of said substrate,

said bodies being substantially thermally isolated from one another, means for selectively electrically energizing said semiconductor heating elements to produce heat which defines a form of information representation and means responsive to said heat for printing said form of information representation.

16. A thermal printing system according to claim 15 wherein each element is spaced from the outer surface of its respective body and said means for selectively electrically energizing includes conductors positioned on said one surface and disposed between said bodies and said substrate interconnecting selected ones of said elements.

17. A thermal display device comprising a substrate, an array of semiconductor bodies on one surface of said substrate, said bodies being substantially thermally isolated from one another, said array being so arrayed that select ones of said bodies define a form of information representation, a P–N junction and a heating element in each of said select one of said bodies, said P–N junction and heating element being spaced from the outer surface of each of said select ones of said bodies and adjacent said one surface of said substrate, and means including said P–N junctions for selectively electrically energizing said heating elements to produce heat which defines a form of information representation.

18. A thermal display device according to claim 17, wherein said means includes conductors on said one surface of said substrate underlying said bodies and connecting selected ones of said P–N junctions and heating elements.

19. A thermal display comprising a substrate, an array of semiconductor bodies on one surface of said substrate, said bodies being substantially thermally isolated from one another, said array being so arranged that selected ones of said bodies define a form of information representation, a semiconductor heat dissipative circuit element in each of said bodies adjacent said one surface of said substrate and spaced from the body surface remote from said one surface, means electrically connected to said circuit elements for selectively electrically energizing said circuit elements and causing corresponding localized hot spots at the selected body surfaces remote from said one surface of said substrate and means thermally coupled to said body surfaces for displaying information corresponding to said hot spots.

20. A thermal display comprising an insulating substrate having at least one opening therein, an array of semiconductor heating elements on one surface of said substrate, a first level interconnection means disposed between said heating elements and said one surface and being positioned on said one surface for interconnecting selected ones of said heating elements, said first means having a portion exposed by said opening, second level interconnection means upon another surface of said substrate, means electrically connecting said second means to said portion through said opening, and means responsive to said heating elements for displaying information.

21. A thermal display device according to claim 11, including a wear-resistant layer on the outer surface of each of said bodies.

22. A thermal display comprising a substrate, a plurality of like arrays of semiconductor bodies on one surface of said substrate, said bodies being substantially thermally isolated from one another, said arrays being laterally spaced from one another on said substrate, a semiconductor heating element in each of said bodies disposed near said substrate and spaced from the outer surface of its respective body, means for selectively electrically energizing the heating elements of each array to heat selected bodies in each array and define a form of information representation for each array and means thermally coupled to said bodies for displaying said form of information representation.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,496,333 February 17, 1970

Stephen P. Emmons et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading to the drawings, Sheets 1 through 5, "E. G. ALEXANDER ET AL", each occurrence, should read -- S. P. EMMONS ET AL --. In the heading to the printed specification, lines 3 and 4, "Earl G. Alexander, Richardson, and Stephen P. Emmons and Jack S. Kilby, Dallas, Tex.," should read -- Stephen P. Emmons, Dallas, Tex., Earl G. Alexander, Richardson, and Jack S. Kilby, Dallas, Tex., --. Column 1, lines 18 and 19, "energiving" should read -- energizing --. Column 2, line 23, "means" should read -- mesas --.

Signed and sealed this 24th day of November 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.
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Commissioner of Patents