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(71) Applicant: **Hewlett-Packard Company, 3000 Hanover Street, Palo Alto California 94304 (US)**

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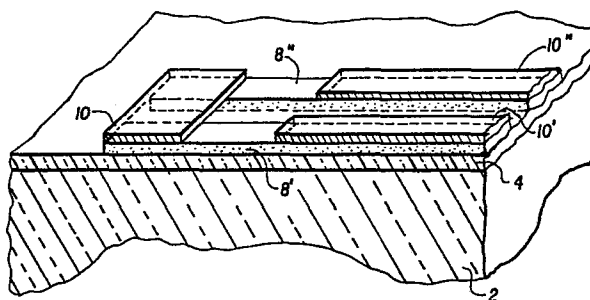
(72) Inventor: **Camis, Tommie, 4283 Nystrom Way, Boise Idaho 83704 (US)**
Inventor: **Hay, Robert R., 5650 Fieldcrest Drive, Boise Idaho 83704 (US)**
Inventor: **Spencer, Paul R., 6045 Becky Drive, Meridian Idaho 83642 (US)**

(84) Designated Contracting States: **DE FR GB**

(74) Representative: **Oliver, Peter Anthony, Hewlett-Packard Limited Nine Mile Ride Easthampstead, Wokingham, Berkshire RG11 3LL (GB)**

(54) **Resistor structures for thermal ink jet printers.**

(57) A resistive heater is disclosed which comprises two spaced resistive elements (8', 8'') separated by a gap so that cavitation of an ink bubble occurs over the gap, thereby minimizing damage to the resistive elements.



RESISTOR STRUCTURES FOR THERMAL INK JET PRINTERS

This invention is concerned with resistor structures for thermal ink jet printers.

The rapidity of modern-day data processing imposes
5 severe demands on the ability to produce a printout record at very high speed. Impact printing, in which permanently shaped character elements physically contact a recording medium, are proving to be too slow and too bulky for many applications. Thus, the industry has turned to other
10 alternatives involving non-impact printing schemes using various techniques to cause a desired character to be formed on the recording medium. Some of these involve the use of electrostatic or magnetic fields to control the deposition of a visible character-forming substance, either solid
15 (i.e., dry powder) or liquid (i.e., ink) on the medium, which is usually paper. Other systems utilize electro-photographic or ionic systems in which an electron or ion beam impinges on the medium and causes a change in coloration at the point of impingement. Still another
20 system employs a thermal image to achieve the desired shape coloration change. Of more recent import is a printing technique, called ink jet printing, in which tiny droplets of ink are electronically caused to impinge on a recording medium to form any selected character at any location at
25 very high speed. Ink jet printing is a non-contact system which requires no specially treated recording media,

ordinary plain paper being suitable, and which requires no vacuum equipment or bulky mechanisms. The present invention relates to this kind of printing system.

Ink jet systems may be classified as follows: (1) continuous, in which ink droplets are continuously ejected out from a nozzle at a constant rate under constant ink pressure; (2) electrostatic, in which an electrostatically charged ink jet is impelled by controllable electrostatic fields; and (3) impulse, or ink-on-demand, in which ink droplets are impelled on demand from a nozzle by a controllable mechanical force. The invention is concerned with a nozzle head for this latter type of system.

Typical of the ink-on-demand systems is the approach set forth in U.S. Patent Specification no. 3,832,579. Here a cylindrical piezoelectric transducer is tightly bound to the outer surface of a cylindrical nozzle. Ink is delivered to the nozzle by means of a hose connected between one end of the nozzle and an ink reservoir. As the piezoelectric transducer receives an electrical impulse, it squeezes the nozzle which in turn generates a pressure wave resulting in the acceleration of the ink toward both ends of the nozzle. An ink droplet is formed when the ink pressure wave exceeds the surface tension of the meniscus at the orifice on the small end of the nozzle.

Another type of ink-on-demand printing is described in U.S. Patent Specification no. 3,174,042. This system utilizes a number of ink-containing tubes, electric current being passed through the ink itself. Because of the high resistance of the ink, it is heated so that a portion thereof is vaporized in the tubes causing ink and ink vapor to be expelled from the tubes.

In the specification of our co-pending UK patent application no. 8217720 an ink-on-demand printing system is described which utilizes an ink-containing capillary having an orifice from which ink is ejected. Located closely

adjacent to this orifice is an ink-heating mechanism which may be a resistor located either within or adjacent to the capillary. Upon the application of a suitable current to the resistor, it is rapidly heated. A significant amount
5 of thermal energy is transferred to the ink resulting in vaporization of a small portion of the ink adjacent the orifice and producing a bubble in the capillary. The formation of this bubble in turn creates a pressure wave which propels a single ink droplet from the orifice onto a
10 nearby writing surface or recording medium. By properly selecting the location of the ink-heating mechanism with respect to the orifice and with careful control of the energy transfer from the heating mechanism to the ink, the ink bubble will quickly collapse on or near the ink-heating
15 mechanism before any vapor escapes from the orifice.

It will be appreciated that the lifetime of thermal ink jet printers is dependent upon resistor lifetime. It has been found that a majority of resistor failures is due to cavitation damage which occurs during bubble collapse.
20 Hence it is desirable that resistor wear due to cavitation damage should be minimized as much as possible. In the specification of our co-pending EPO application no. 83304152.8 the resistive element is provided with a central "cold" spot formed of a conductive material, it being
25 assumed that most of the bubble damage occurs at or near the center of the resistor. The cold spot causes the formation of a toroidal bubble which upon collapse is randomly distributed across the resistor surface instead of being concentrated in a small central area of the resistor.

30 The cold spot is actually formed by means of a gold deposition in the center of the resistive element. The gold spot thus effectively serves to short out the resistor or the resistive portion beneath it, thus preventing heat from being generated in that area. It will be appreciated
35 that with this cold central spot, the heating of the ink

immediately thereabove will be non-uniform which may not be efficacious for optimum bubble formation. Nor is it at all sure that the bubble collapse will not also occur in the central area of the resistive element albeit being separated
5 from the resistive material by the gold spot in the center thereof. Should this occur, erosion of the gold spot or layer may result eventually causing resistor failure.

The present invention provides a resistive heater for use in thermal ink jet printers of the type having discrete
10 ink-ejecting nozzles associated with discrete heaters, said heater being characterized by (a) a pair of resistive elements spaced apart from each other and adjacent to one of said ink-ejecting nozzles, and (b) electrically conductive means connecting said resistive elements in series with each
15 other.

The resistive elements are preferably two-dimensional thin films.

Preferably each of said resistive elements has a sheet resistance which is multiple of the resistance of a single
20 square.

The preferred embodiment of the present invention provides a resistive area in the form of two resistive legs, having an open central portion extending therebetween. Thus the collapse of the bubble in the central portion of
25 the resistive area will not act upon the resistive material in either of the resistive legs. Furthermore, by making each resistive leg constitute two squares, the resistance of each leg will be doubled or twice the resistance of a single square of resistance material as practiced heretofore in the
30 art of thermal ink jet printers. Thus, for example, whereas a single square of resistive material in prior thermal ink jet printers may have provided a resistance of 50 ohms per square, each leg of the resistive structure according to the present invention, will provide 100 ohms per square for a
35 total resistance of 200 ohms.

Thus, the present invention not only enhances resistor lifetime by eliminating bubble collapse/cavitation damage in the center of the thin film resistive area, but also reduces power losses in the conductors leading to the resistors by using lower operating currents. The reduced current requirements also enhances the overall reliability of the thermal ink jet printhead.

There now follows a detailed description, which is to be read with reference to the accompanying drawings, of a resistive heater according to the present invention; it is to be clearly understood that this resistive heater has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the accompanying drawings:-

Figure 1 is a perspective view, partly in section, of a portion of thermal ink jet printhead showing a single orifice (nozzle) with its associated resistor;

Figure 2 is a planned view of an array of resistor structures as if taken along Line A-A in Figure 1 and continued;

Figure 3 is a perspective view, partly in section, of the resistor-conductor structure according to the invention;

Figure 4 is a plan view of the resistor-conductor structure according to another embodiment of the invention and including barrier members associated with the resistor-conductor structure;

Figure 5 is a side view in section of the resistor structure according to the invention and shows the position of an ink bubble as it begins to collapse;

Figure 6-A is a plan view of a resistor conductor structure useful in explaining the advantages and operation of the resistor conductor structure of the present invention; and

Figure 6-B is a plan view of the resistor structure according to the present invention for use in explaining the

operation of the invention with reference to Figure 6-A.

Referring now to the drawings, and to Figure 1 in particular, there is shown a portion of a typical printhead structure for a single orifice. The principal support structure is a substrate 2 of single crystalline silicon. Disposed on the upper surface of the silicon substrate 2 is a thermally insulating layer 4 of silicon dioxide which may typically be 3.5 microns in thickness. Formed on the upper surface of the silicon dioxide layer 4 is a resistive element 8 formed of tantalum and aluminium, for example. Likewise, disposed on the silicon dioxide layer 4 are conductor elements or strips, 10 and 10', which may be of aluminium or of an alloy of aluminium and copper. The conductors overlay the resistive element 8 except where it is desired to have resistive heating occur. The next structure disposed over the resistive element 8 and its associated conductors 10 and 10' may be a passivation layer 12 of silicon carbide, for example, of from 0.5 to 2.5 microns in thickness.

Disposed on the upper surface of the silicon carbide layer 12 are barrier elements 14 and 16. The barrier elements may comprise photo-definable organic plastic materials such as RISTON and VACREL. These barriers may take various configurations. As shown in Figure 1, they are formed on each side of the underlying resistor element 8. As shown in Figure 2, these barrier structures may surround each resistive element on three sides. The barriers 14 and 16 serve to control refilling and collapse of the bubble, and prevent spattering from an adjacent orifice, as well as minimizing cross-talk or acoustic reflections between adjacent resistors. The particular materials RISTON and VACREL are organic polymers manufactured and sold by E.I. DuPont de Nemours and Company of Wilmington, Delaware, U.S.A. The barriers 14 and 16 serve to space and hold an orifice plate 18 in position on the upper

surface of the printhead assembly. In addition, the materials used can withstand temperatures as high as 300°C.

The orifice plate 18 may be formed of nickel. As shown, the orifice 20 itself is disposed immediately above and in line with its associated resistive element 8. While only a single orifice has been shown, it will be understood that the complete printhead may comprise an array of orifices each having respective underlying resistive elements and conductors to permit the selective ejection of a droplet of ink from any particular orifice. With particular reference to Figure 2, it will be appreciated that the barriers 14, 14' and 16, 16' serve to space the orifice plate 20 above the passivation layer 12B permitting ink to flow in this space and between the barriers so as to be available in each orifice and over and above respective resistive elements 8, 8' and 8''. The barriers 14, 14' and 16, 16' may simply extend between the resistive areas 8, 8', 8'' or the barriers may be joined at one end, as shown, to form a three-sided barrier structure around each resistive element.

Upon energizing of the resistive element 8, the thermal energy developed thereby is transmitted through the passivation layer 12 to heat and vaporize a portion of a quantity of the ink 22 disposed in the orifice 20 and immediately above the resistive element 8. The vaporization of the ink 22 eventually results in the expulsion of a droplet 22' of ink which impinges upon an immediately adjacent recording medium (not shown). The bubble of ink vapor formed during the heating and vaporization thereof then collapses back onto the area immediately above the resistive element 8. The resistor 8 is protected from any deleterious effects due to collapse of the ink bubble by means of the passivation layers 12. The silicon carbide layer 12, being the layer in immediate contact with the ink, provides protection to

the underlying materials due to its extreme hardness and resistance to cavitation.

In fabricating the printhead structure according to the invention, it will be appreciated that the particular
5 geometry of any particular element or layer may be achieved by techniques well known in the art of film deposition and formation. These techniques involve the utilization of photo-resists and etching procedures to expose desired areas of the layer or structure where an element is to be formed
10 followed by the deposition of the material of which the particular element is to be formed. These processes for forming the various layers and elements of the printhead assembly are well known in the art and will not be described in greater detail herein.

15 Referring now to Figures 3 and 4, a somewhat simplified view of a resistive structure according to the present invention is shown. It will be appreciated that the passivation layer as well as the orifice plate have been omitted from the structure shown in these Figures in order
20 to permit a better showing and explanation of the novel resistive structure of the invention. As described hereinbefore, the resistive structures 8, 8'' may be formed by depositing tantalum and aluminium onto the silicon dioxide layer 4 formed on the silicon substrate 2. Instead of a
25 single resistive element, a pair of resistive elements 8', 8'' are provided in the area previously occupied by the single resistive element 8. This split resistive structure comprises two rectangular regions or legs 8' and 8'' each being about 2 x 4 mils and spaced from each other by about
30 .6 mil, for example. Electrical energy to produce heating is supplied to the resistive elements 8' and 8'' by means of conductors 10' and 10'', each contacting corresponding respective end portions of the two resistive elements. The circuit connections for these resistive elements is
35 completed by the common conductor 10 which contacts the

opposite ends of the resistive elements 8' and 8''. It will also be appreciated that in actual practice, a passivation layer (not shown) may be applied over the surface of the structure shown in Figures 3 and 4.

5 As seen in Figure 5, with this split resistive structure the collapsing ink bubble 22'', formed above the resistive elements 8' and 8'', will act upon the non-resistive area lying between the resistive elements, thus minimizing or avoiding altogether any damage to these resistive
10 elements.

Figure 6A depicts the typical geometry of a resistive element 8 according to the prior art. As shown, the resistive element 8, mounted on a base b, is provided with conductors 10, 10' contacting opposed ends of the element.
15 In addition, it will be noted that the resistive element is a square (typically 4 mils on a side). Thus the sheet resistance of the resistive element 8 as shown in Figure 6A may be 50 ohms per square. In Figure 6B the resistive structure according to the present invention is shown
20 wherein each resistor element or leg, 8' and 8'', may be about 3 mils x 1.5 mils. It will thus be appreciated that each leg comprises two squares about 1.5 x 1.5 mils. Since the sheet resistance of one square is about 50 ohms, it will be understood that each leg now has a resistivity of 100
25 ohms while the total resistive structure, comprising both legs, provides a resistivity of 200 ohms. Since the total resistance is now four times that of a single square, considerably lower operating current is required in order to achieve the same degree of heating. For example the prior
30 art arrangement comprising a single resistor element of about 50 ohms required about 400 ma to achieve the necessary heat to generate a mature bubble and droplet. The resistive structure, according to the present invention comprising four squares of 50 ohms per square each, reduces the
35 required operating current to about 200 ma. This means

that the power loss in the conductors typically may now be only about five percent.

Thus the resistive structure according to the present invention not only reduces or eliminates damage to the resistive structure itself, but that structure also provides the opportunity to substantially decrease the operating current for the resistive structure. Thus, both the geometry of the resistive structure and the reduced current requirements attainable with this structure enhance the overall reliability and lifetime of the resistive structure.

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CLAIMS

1. A resistive heater for use in thermal ink jet printers of the type having discrete ink-ejecting nozzles (20) associated with discrete heaters, said heater being characterized by

- 5 (a) a pair of resistive elements (8', 8'') spaced apart from each other and adjacent to one of said ink-ejecting nozzles (20); and
- (b) electrically conductive means (10, 10', 10'') connecting said resistive elements in series with
- 10 each other.

2. A resistive heater according to claim 1 wherein said resistive elements (8', 8'') are two-dimensional thin films.

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3. A resistive heater according to either one of claims 1 and 2 wherein each of said resistive elements (8', 8'') has a sheet resistance which is a multiple of the resistance of a single square.

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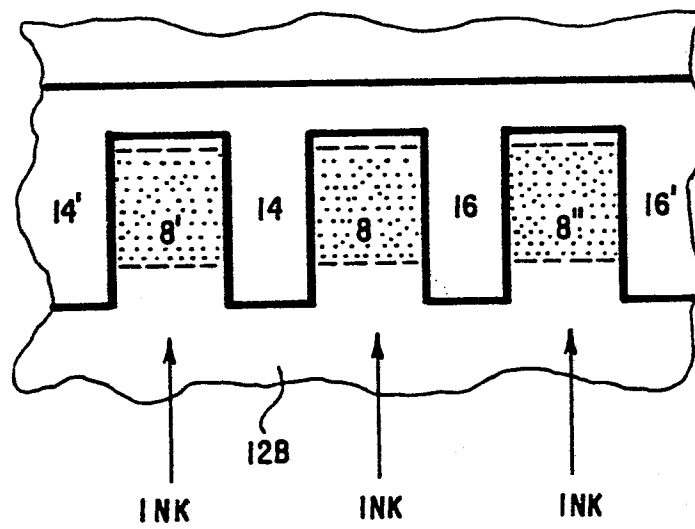
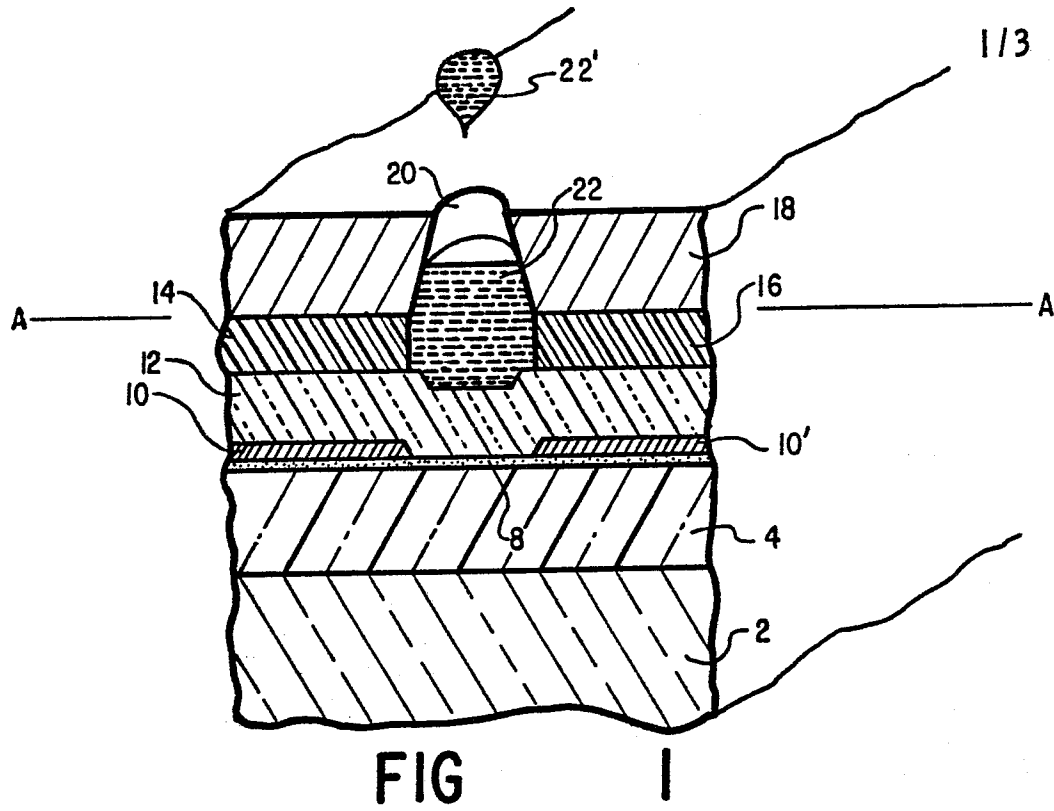


FIG 2

