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T. W. JOHNSON ET AL

3,478,191

THERMAL PRINT HEAD

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Fig.1. *Fig.2.* *Fig.3.*

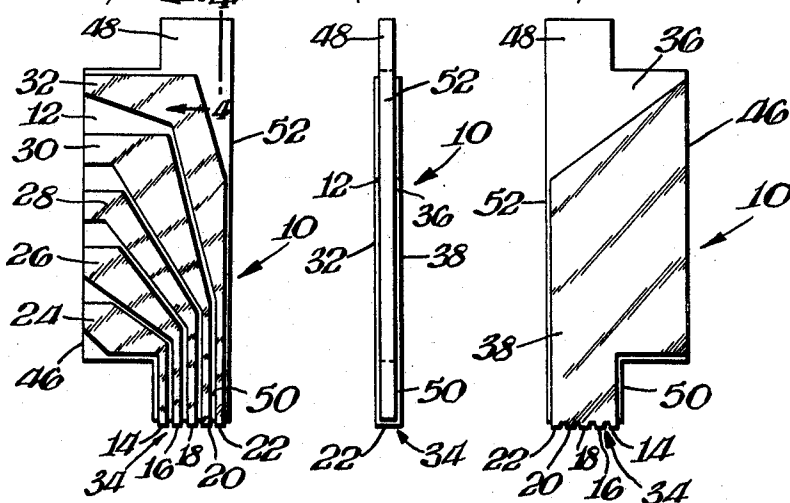


Fig.4.

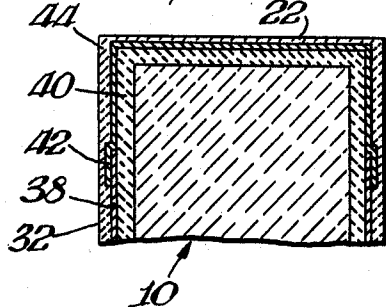


Fig.5.

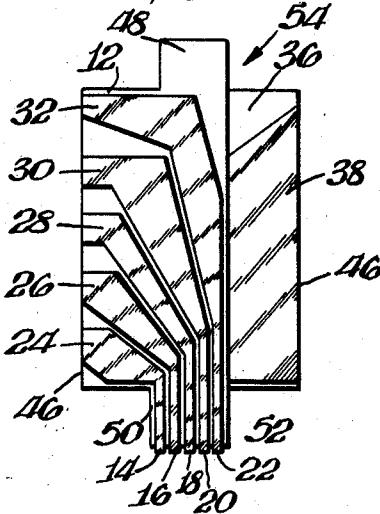


Fig.6.

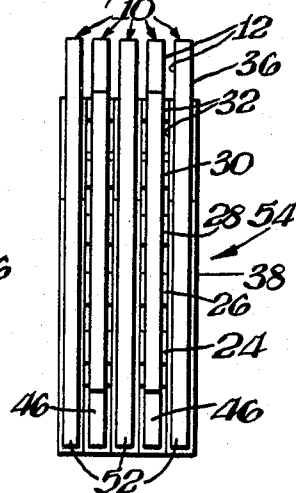
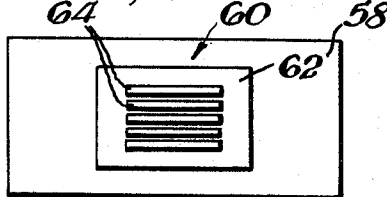


Fig.7.



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THERMAL PRINT HEAD

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4 Claims

ABSTRACT OF THE DISCLOSURE

A thin underlayer member interposed between a substrate and electrical heating element provides high efficiency and fast thermal rise while permitting thermal dissipation between pulses. A protective overlayer, capable of high thermal transmission, protects the element and provides a printing surface having low adhesion capability and a low coefficient of friction.

BACKGROUND OF THE INVENTION

The present invention relates to thermal printing heads and more particularly to a thermal printing head having a thin resistive element in a glazed sandwich configuration and to a method of making the same.

In thermal printing, heated elements are made to contact and mark thermally sensitive material so as to provide characters or symbols. Generally a multiplicity of small electrically controlled resistive elements, mounted on an insulating substrate, are employed to print desired characters by providing sufficient power to selected elements so as to raise them to printing temperature.

This type of construction suffers from several disadvantages. Thus the insulative substrates, such as ceramics which are capable of withstanding the necessary printing temperatures, increase the thermal rise time and reduce the efficiency of the heating element by conducting away the necessary heat. The exposed elements often adhere to the thermally sensitive paper and also provide high friction with respect to the paper, which results in excessive wear of the elements and objectionable amounts of dust.

Furthermore, the separation between exposed elements, which is necessary for electrical insulation, permits an accumulation of foreign material and high resistance short circuits. In addition, the separation results in low printing resolution or graininess.

This composite construction of the indicia, in which printing is accomplished by raising the temperature of selected elements in response to electrical pulses, also requires the consideration of thermal transient as well as steady state conditions. Generally, the printing speed is dependent upon how fast the selected elements are raised to printing temperature in response to an electrical pulse, and how quickly they are cooled in anticipation of further printing.

For efficient operation, it is important to retard the loss of heat backward from the element to the substrate during the heating or printing portion of the cycle (so as to provide high electrical efficiency along with fast thermal rise) and yet quickly remove the heat once the printing is completed. Stated otherwise, it is desirable that the support structure initially retard thermal loss and yet provide a sink for residual heat.

From a theoretical viewpoint, the rate of rise of surface temperature, for an infinitely thick plane having a suddenly impressed heat flux on that surface, is inversely proportional to the square root of the product of the thermal conductivity, the density and the specific heat of material

employed. Thus, for the nonsteady state, where high surface temperature is desired with fast thermal rise and low power input (high electrical efficiency in this case), low values of these parameters are desirable.

Where rapid thermal cycling is desired, however, as in the thermal printing head, a fast dissipation of heat is also required. In the nonsteady state, the latter is proportional to the density, the specific heat and the thermal conductivity of the material. Thus, high thermal transmission is important to promote good dissipation, in contrast to the low value required for efficiency and fast rise time.

SUMMARY OF THE INVENTION

Broadly, a thermal printing head provided in accordance with the invention comprises: a substrate; at least one electrically energizable thermal element member; and a thin underlayer member having low thermal conductivity as compared to said substrate interposed in contiguous arrangement between the substrate and element such that high electrical efficiency and fast thermal rise of the element in response to an electrical pulse are provided, as well as substantial thermal dissipation during the interval between pulses.

In one embodiment of the invention, a protective overlayer member contiguous with the element and underlayer is provided with the element in a sandwich configuration between the layers. A suitable front to back thermal transmission ratio is ensured in this construction by making the overlayer capable of high thermal transmission as compared to the underlayer. This provides fast thermal rise and high electrical efficiency of the element.

In the preferred embodiment, the overlayer and underlayer are made from substantially identical materials, with the former being approximately one-quarter the thickness of the latter, and a vitreous material is employed for the overlayer so as to not only protect the element from ambient conditions and excessive wear, but also, to provide a printing surface of low adhesion and a low coefficient of friction.

In a more limited sense, a printing head provided in accordance with the invention comprises a plurality of thin substrate wafers having resistive elements sandwiched between vitreous layers on the edge of the wafer with conductive strips extended along the planar surfaces to a terminal edge of the wafer, which is perpendicular to the resistor edge. A compact printing unit is provided by a stacked arrangement of the wafers in which the terminal edge of each is alternatively extended from opposite sides of the unit to permit circuit connection to the conductive strips.

Briefly, the method of making a printing head in accordance with the invention includes the steps of forming at least one of the members on a support strip in a decal-like arrangement and transforming and securing it to a suitably prepared substrate.

In the preferred method, each member is separately formed on adhesively coated support strips and then consecutively transferred to the printing head and fired in place. The adhesive of the underlayer member is first partially dissolved so as to permit removal from the support and the member then transferred to the substrate where the remaining adhesive secures it until it is fired. Thereafter, the layer is fired in place, and similar steps are then employed to deposit the resistive member, the electrode member and the overlayer member.

It is an object of this invention to provide a thermal printing head having high electrical efficiency, fast thermal rise time and fast thermal dissipation.

It is another object of this invention to provide a thermal printing head having a coating over the thermal

element which provides a printing surface having low adhesion and low coefficient of friction.

It is a further object of this invention to provide a compact printing head having extended terminal portions.

It is a still further object of this invention to provide an economical method of making a printing head.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a side view of a printing wafer utilized in a preferred embodiment of the invention;

FIGURE 2 is an end view of the wafer of FIGURE 1;

FIGURE 3 is a side view of the other side of the wafer of FIGURE 1;

FIGURE 4 is an enlarged fragmentary view of a section of FIGURE 1 taken along the line 4—4;

FIGURE 5 is a side view of a compact printing head which utilizes the wafer illustrated in FIGURES 1-3;

FIGURE 6 is an end view of the printing head illustrated in FIGURE 5; and

FIGURE 7 is a plan view of a decalcomania employed in a preferred method of construction.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, FIGURES 1, 2 and 3 illustrate a printing wafer 10 having a plurality of resistive elements 14, 16, 18, 20 and 22 positioned along one edge. The elements extend from one planar surface 12 of the wafer, where they are connected to electrodes or conductive strips 24, 26, 28, 30 and 32, over the wafer edge 34 to the other planar surface 36 where they connect to a common electrode or conductive strip 38.

In this embodiment each wafer, or substrate 10, is a thin sheet of electrically nonconductive material, such as alumina, beryllia, or other ceramic, or the like which will withstand high temperatures, provide mechanical support for the thermal elements 14, 16, 18, 20 and 22 and their connecting strips 24, 26, 28, 30, 32 and 38 and quickly dissipate the printing heat once the printing cycle is complete.

Thin film resistors are preferred for elements 14, 16, 18, 20 and 22 since their low mass enhances fast thermal rise and fast dissipation while their thinness provides some flexibility which relieves mechanical stresses due to thermal expansion of the contiguous members.

An insulating glaze 40, of borosilicate glass or the like, is provided over the wafer as a first coat or underlayer which provides a suitable surface for depositing of the resistive elements and, since it has low thermal conductivity, more importantly provides a thermal barrier or shield between it and the substrate; the latter causes a thermal delay, or otherwise appropriately modifies the thermal pulse such that high electrical efficiency and fast thermal rise time of the element is provided, as well as adequate dissipation of the thermal energy during the interval between pulses. Since the thermal conductivity or heat transfer coefficient of the glass layer is .02 to .04 watt/in. deg. C. or one-thirtieth that of alumina and one-two hundredth that of beryllia, which have coefficients of approximately .9 and 6.0, respectively, the underlayer 40 suitably modifies the thermal transient to provide the desired efficiency and rise time.

On the other hand, the layer is made quite thin, approximately .002-.003 in., so as to permit adequate dissipation through it during the interval between printing pulses. Thus, the high thermal conductivity substrate is thermally spaced, far enough, from the heating element so as to allow the printing heat to be generated more rapidly and with less power than would result from the contact of element and substrate, as in the prior art.

Consequently, the low thermal conductivity of the underlayer provides a high thermal gradient between the element and wafer which modifies the thermal pulsing of the elements permitting a very rapid temperature rise with low input power whereas the thinness of the coating

allows a good thermal drain to the substrate which quickly conducts the heat from the underside of the layer once the printing is completed.

The sandwich construction, shown in FIGURE 4, is completed by a suitable protective coating or layer over the resistive elements. This overlayer 44, which may be of similar material as underlayer 40, is employed to not only seal and protect the elements but also to provide a suitable printing surface for contact with the thermally sensitive material.

This overlayer 44, which may extend as a single layer over several or all of the adjacent elements, also covers the gap or separation between elements and thus eliminates any accumulation of dirt and dust in this area and consequently any shorting of the elements.

Thus the overlayer 44 provides a sealing coat for the electrode which mechanically and electrically protects it while also providing an enhanced printing surface. In addition, its thermal transmission also provides thermal fan out which reduces printing graininess. However, it should be understood that any such layer provided between the heat source and the thermal paper will, to some extent, reduce the efficiency and the thermal rise time of the printing head.

This disadvantage is substantially eliminated in the novel printing head by providing an overlayer having high thermal transmission as compared to the previously described underlayer. This can be accomplished by increasing the thermal conductivity or by reducing the density, the specific heat or the thickness of the overlayer, as compared to the underlayer. However, since the thermal conductivity and thickness can be easily and widely varied, these parameters are of more importance, and the thermal transmission, in this case, is controlled by varying either, or both.

In the preferred embodiment, similar materials are employed for both layers with the overlayer made thin as compared to the underlayer; that is the overlayer is approximately .0005 in. or one-quarter the thickness of the underlayer.

Various materials are suitable for both substrate and the layers. As indicated the thermal conductivity or thickness, or both, may be varied to provide the proper thermal properties. For example, the substrate may be any rigid material capable of withstanding the printing temperature and having reasonable thermal conductivity. Metals could actually be employed, however, insulation would then be required beneath the conducting strips. For this reason electrically nonconductive materials which have reasonable values of thermal conductivity, such as alumina and beryllia, are most suitable for the substrate.

Many different materials, such as glass or the like, are also suitable for the layers 40 and 44. As indicated, the underlayer must have low thermal conductivity as compared to the substrate or supporting heat sink, and as in the case of the substrate, electrically nonconductive materials are preferred for the overlayer so as to electrically isolate adjacent elements.

It should also be understood, that the layers should preferably be formed of materials which provide no reaction with the element at elevated temperatures; for example, materials having very low concentrations of alkali metal ions, or materials in which any such ions are chemically bonded or otherwise have low mobility.

For example, some of the lead borosilicate glasses, silicon dioxide, silicon nitride and alumina can be suitable, however, materials having such alkali metal ions may also be employed for either layer if they are sealed off from the resistor by an additional thin coating, or by other suitable means. In this case, the additional coating must, of course, also satisfy the described thermal requirements.

In the construction of the printing head, the surface of substrate 10 must be first suitably cleaned and prepared for the reception of underlayer 40. The undercoat material is mixed with a suitable carrier or binder and applied

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over desired portions of the substrate surface or edge, in any desired pattern, by dipping, printing, screening, painting, rolling or other suitable means. Thereafter the frit or mixture of binder and inorganic material is fired on wafer 10 at a temperature (1800-1900° F.) capable of forming continuous film by fusion. Thereafter, the deposition and firing may be repeated several times until a thick enough vitreous layer is provided so as to insure a satisfactory thermal delay.

Conductive strips or electrodes 24, 26, 28, 30, 31 and 38, are then provided by material which resists diffusion into the underlayer, such as a platinum-gold alloy. This material is deposited along the wafer surfaces 12 and 36 to within a short distance of the resistive edge 34, and fired at approximately 1300-1600° F. Thereafter, a metallic resinate composed of an alloy of precious metals and base metal such as gold, platinum and rhodium is deposited in an appropriate pattern over edge 34, in connection to appropriate electrodes of both planar surfaces, and fired to provide thin film resistors 14, 16, 18, 20 and 22. These thin film resistors may be deposited by a number of means such as printing, screening, vacuum deposition, decals and other means, but are generally not satisfactorily dipped or rolled.

Thus, as shown in FIGURE 4, resistor 22 extends from electrode 32 to electrode 38 with connection to each provided, in this embodiment, by allowing the resistive film to overlap each electrode as illustrated at 42.

The use of thin film resistive elements is preferred since their low mass enhances the thermal rise time and efficiency, however, such elements inherently require a protective overcoat. Thus, an inorganic frit or powder of vitreous material, such as a glass having a lower fusion temperature than the previously deposited materials, is then applied over the resistors and electrodes by dipping or the like, and thereafter fused by firing to provide a glazed overlayer 44 approximately .0005" thick, which completes the sandwich configuration. Lead borosilicate glass, fusible at approximately 1000-1300° F., is suitable for this layer.

The use of vitreous material, for the overlayer 44, provides a glazed printing surface having low adhesion and a low coefficient of friction. The over layer also seals off the separation between elements and, in addition, provides thermal fan-out from each resistor such that contiguous or overlapping printing of the dots results.

As indicated, the thin film resistor and electrode pattern may be suitably provided in a number of ways. The electrodes and resistors may be deposited in a spaced apart configuration, or as a single sheet with the particular pattern subsequently provided by abraiding selected portions, such as by sand blasting or the like through an appropriate mask, to provide the separate elements. In this way, good electrode overlap may be provided while maintaining definition at the edge or corner of the wafer. The resistor elements may also be provided on the planar surface, rather than an edge, when desirable.

Excellent flatness and good edge definition is achieved, in the preferred embodiment, by employing decalcomania-type members similar to the decal techniques of the decorative arts. In this method of application, which may be utilized for one or more of the deposited members (i.e., the layers, resistors or electrodes), the desired member is deposited on wafer 10 by transferring the previously formed member from its support strip to the substrate.

As shown in FIGURE 7, a support 58, such as paper or the like, is first coated with an adhesive, such as a water soluble glue. Thereafter one of the members, for example, a resistor 60 or a plurality 64 is deposited by any of the means described with respect to wafer 10 and a thin organic layer or coat 62 of varnish or the like is applied over the resistor to provide a flexible carrier.

The decal resistor is then transferred to the substrate by first soaking the decal in water, or other liquid in which the adhesive is soluble, and then removing the resistor

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with its carrier film and depositing them on a suitably prepared substrate in the desired position. Thereafter the assembly is fired to burn away the carrier, reset the adhesive and to fuse the deposited element. In this way, any or all of the members may be deposited.

Various adhesives may of course be employed in the decal process. Furthermore, the initial adhesive need not be retained in the transfer since additional or different adhesive may be suitably provided on the substrate. Advantageously, the support strip 58 may be any of a number of materials, such as paper or plastic or the like, which will provide support for the members during their formation. Similarly, any flexible and dimensionally stable material which will support the members during transfer and be removed during firing will be suitable for the carrier 62.

In the decal method, the layers, the resistors and the conductive strips are usually separately formed, transferred and fired; however, in some cases it is possible to form more than one type of member, or all of them, in a decal-like arrangement, and simultaneously transfer and fire them.

In any case, all of the indicated methods may be utilized in the construction of the preferred embodiment, illustrated in FIGURES 1-6. As shown therein, electrodes 24, 26, 28, 30 and 32 extend perpendicularly a short distance from the resistor edge 34 of the substrate and then at an angle to a terminal edge 46 which is perpendicular to resistor edge 34. In a similar manner, electrode 38 extends along the other planar surface to edge 46.

Advantageously, substrate 10 is a thin rectangular wafer which provides a large planar surface for the electrodes, and has portions 48 and 50 extended at top and bottom along the leading edge 52 such that the terminal edge 46 may be alternately extended from the center of the printing unit 54, as shown in FIGURES 5 and 6.

This allows a compact printing unit 54 to be assembled by alternately stacking a plurality of the described wafers in a side by side arrangement with the terminal edge 46 of each adjacent layer extended from opposite sides of the unit. This arrangement allows unencumbered connection to the electrodes since sufficient room is provided on the alternately extended surfaces 12 and 36 for circuit connection.

In this way several wafers may be stacked to provide a versatile unit having the separation between resistive areas of adjacent wafers equal to the thickness of the overglaze 44. However, the latter, since it provides thermal fan out, permits contiguous printing.

Many modifications are possible, of course. Thus, a single resistive element, or any convenient number, may be provided on each wafer. Furthermore, although the low mass of thin film elements is highly advantageous, conventional resistor elements, such as tin oxide or the like, may also be utilized in the described sandwich configuration. Moreover, the elements may also be employed on a planar surface, rather than an edge, and any desirable shape of wafer may be suitably employed.

In addition, the layer or sandwich arrangement need only be employed for the resistors, and thus, need not be applied to the electrodes or over the full surface of the wafer. Thus many different modifications of the invention are possible without departing from the spirit and scope thereof and it should be understood that the invention is to be limited only by the appended claims.

What is claimed is:

1. A printing head capable of marking a thermally sensitive material in response to an electrical pulse, which head comprises: a plurality of substrates disposed in a stack arrangement; at least one electrically energizable thermal element positioned on an adjacent edge of each substrate; an electrode in connection to each end of said element; said electrodes extended along the planar surfaces of each substrate; an underlayer interposed in contiguous arrangement between each substrate and its

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element, said underlayer being a thin layer having low thermal conductance to provide a thermal barrier between said element and substrate; a protective overlayer disposed over each element and contiguous therewith, said overlayer providing an outer surface of low adhesion and a low coefficient of friction; and said overlayer having high thermal transmission as compared to said underlayer so as to provide a high front to back thermal ratio for providing high electrical efficiency and fast thermal rise of said element in response to an electrical pulse while permitting substantial thermal dissipation from said element during the interval between pulses.

2. A printing head as claimed in claim 1 wherein said overlayer extends laterally beyond said element to provide thermal fan out therefrom such that a printing mark of said element is contiguous with that of adjacent elements.

3. A printing head as claimed in claim 1 wherein said overlayer and said underlayer have substantially the same thermal conductance, and said overlayer is thin as compared to said underlayer to provide said high thermal ratio.

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4. A printing head as claimed in claim 1 wherein said electrodes extend along a planar surface of said substrate to a terminal edge thereon, and said substrates are provided in an alternately stacked arrangement with the terminal edge of adjacent substrates alternatively extended from opposite sides of said printing head so as to permit unencumbered connection to said electrodes.

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219—543; 346—76