

EUROPEAN PATENT APPLICATION

Application number: **87100520.3**

Int. Cl.4: **B41J 3/04 , H01L 49/02**

Date of filing: **16.01.87**

A request for correction of the description has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 2.2).

Priority: **30.01.86 US 824335**

Date of publication of application:
12.08.87 Bulletin 87/33

Designated Contracting States:
DE FR GB IT

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Process for fabricating laminated structures of improved structural integrity.

This patent application discloses a process for fabricating printhead structures for use in thermal ink jet printers. In this process, a thin film resistor substrate (10) is bonded to a flat orifice plate (12) by means of an adhesive polymer (14) to which heat and pressure are applied for a predetermined time. This pressure is applied to the outer surfaces of the orifice plate (12) and substrate (10) respectively and hydrostatically transmitted to the adhesive polymer (14) in such a manner as to apply pressure uniformly across the surface of the polymer (14). This application of uniform pressure is accomplished in spite of contours and other surface irregularities that may exist on either the materials being bonded or the heat staker members which apply heat and pressure to these members.

In a preferred embodiment of the invention, the above hydrostatic transmission of pressure is accomplished by means of a "waterbed" sandwich structure (16) in which a liquifiable material (22) is enclosed between layers (18,20) of flexible foil material.

PROCESS FOR FABRICATING LAMINATED STRUCTURES OF IMPROVED STRUCTURAL INTEGRITY

This invention relates generally to the fabrication of laminated structures having improved structural properties especially useful in thermal ink jet print heads. More particularly, the invention is directed to increasing the adhesive forces which bond together adjacent laminated layers without degrading portions of the laminated structure during the process.

In certain arts such as the manufacture of printheads for thermal ink jet printers, diverse materials are often bonded together in the formation of a unitary composite structure. In such bonding processes, a chosen adhesive material is frequently provided between adjacent layers and thereafter subjected to a predetermined heat and pressure for a time sufficient to produce a good adhesive bond between these layers. An example of such construction is in the fabrication of a thin film resistor thermal ink jet print head where typically a metal orifice plate is adhesively bonded atop a silicon substrate including thermal heater resistors and corresponding ink reservoirs. However, it quite often happens that non-uniform surface irregularities and contours exist on the facing surfaces between which the adhesive is thermal compression bonded. These irregularities and contours may also exist on the surface of the top layer in contact with a member for applying heat and pressure and known in the art as a "heat staker". When such non-uniform surface irregularities and contours are brought together under predetermined conditions of heat and pressure, there are produced corresponding variations in pressure and temperature across the surface areas of the laminated layers. These pressure variations result in weak spots in the cured laminated structure and consequently result in undesirable failures of the laminated structures under conditions of actual use.

Accordingly, it is an object of this invention to provide a new and improved process for fabricating laminated structures wherein the above problem of adhesion variation with surface contour variation has been substantially eliminated. This object is accomplished by the provision of a pressure equalizing member between the structure undergoing adhesive bonding and lamination and the heat and pressure applicator ("heat staker") therefor. The pressure equalizing member comprises a pair of thin outer flexible foil layers between which is located a liquifiable material of a chosen volume. The liquifiable material is wholly contained within the confines of the pair of thin outer flexible foil layers which are effectively sealed around their outer edges by the unmelted region of the liquifiable material.

When two adjacent members, such as a thin film resistor semiconductor substrate and a metal orifice plate of the laminated device being constructed are to be adhesively bonded, they are covered with the pressure equalizing member which then is positioned to receive the heat staker on one surface thereof. Upon receiving heat and pressure from the heat staker, the material within the thin flexible foil layers of the pressure equalizing member will liquify and provide a hydrostatic force on the lower flexible layer thereof which then conforms, for example, to the irregular surface contours of the orifice plate and transmits equal pressure over the entire surface area of the laminated structure. Thus, the pressure applied to the adhesive bond is applied with substantial uniformity laterally across the laminated surfaces as compared with known prior art processes. Thus, this invention is capable of producing a composite laminated structure with greater bonding adherence strength.

The significant advance provided by the present invention will be better understood with reference to the following description of the accompanying drawings.

Brief Description of the Drawings

Figures 1a through 1e are schematic cross-sectional views illustrating the laminating and adhesive bonding process according to the present invention.

Figures 2a -2d illustrate various modes of adhesive failure including the cohesive adhesive failure mode in accordance with the present invention.

Best Mode for Carrying Out the Invention

Referring now to Figures 1a through 1e, there is shown in Figure 1a a thin film resistor silicon substrate 10 which will typically provide a support for the ink reservoirs and thermal heater resistors - (not shown) of well-known semiconductor device construction for use in a thermal ink jet printer. Each of the resistors and reservoirs (not shown) are associated with nozzle patterns in a nozzle plate 12, and the nozzle plate 12, typically fabricated of nickel, as well as the silicon substrate 10 are generally well-known in the thermal ink jet printing art and will not be described herein in further detail. However, for reference to a thin film resistor print head construction including a description of the

various layer materials used therein, reference may be made to the Hewlett Packard Journal, Volume 36, Number 5, May 1985, incorporated herein by reference. This type of printhead construction is also described in U.S. Patent 4,535,343 issued to Conrad L. Wright et al and assigned to the present assignee and also incorporated herein by reference.

The metal nozzle plate 12 is bonded to the underlying silicon substrate 10 by means of an ultraviolet-cured polymer 14 shown in Figure 1b and known generically as a parafilm. This parafilm is sold by the DuPont Company of Wilmington, Delaware under the tradename VACREL. The VACREL layer 14 will undergo thermal curing by the application of heat and pressure thereto in a manner to be further described.

With the nozzle plate 12 positioned in place as shown in Figure 1c, a pressure equalizing composite member 16 is placed on the upper surface of the nozzle plate 12 and includes a pair of outer aluminum foil layers 18 and 20 between which is encapsulated an uncured VACREL or parafilm material 22. This parafilm material 22 will liquefy when brought to a predetermined elevated temperature of about 115° -120°C. The pressure equalizing composite structure 16 has also been referred to as a "waterbed sandwich" in that the liquefiable material 22 will conform to the contours of and pressures on the materials 10 and 12 being bonded together.

This thermal compression bonding is accomplished by first placing the silicon substrate 10 on a steel holder 24 as shown in Figure 1e. In operation, the heat staker top element 30 is brought into contact with the composite structure 16 under predetermined conditions of heat and pressure and for a time sufficient to provide thermal compression bonding of the VACREL layer 14 between the nozzle plate 12 and the underlying silicon substrate 10. We have found that a pressure in the range of 200 -225 psi applied for between 15 -20 seconds at a temperature between 115° -120°C works exceptionally well in practicing this invention. However, the pressure range may if necessary be extended to 20 to 2000 psi, the time extended from 5 to 60 seconds and the temperature extended from 90°C to 160°C.

Referring now to figures 2a -2d, there is shown in Figure 2a an adhesive failure where the VACREL adhesive is torn away from the nozzle plate. In Figure 2b the VACREL adhesive is torn away from the underlying silicon substrate, and in Figure 2c there is shown a mixed mode failure where the VACREL is torn partially away from the nozzle plate and partially away from the underlying silicon substrate.

However, in Figure 2d there is shown the optimum and desired cohesive failure of the VACREL made possible by this invention. Here the VACREL is torn from neither the nozzle plate nor the underlying silicon substrate, but rather becomes torn internally across the lateral dimension of the adhesive, indicating the strongest bond possible using this type of adhesive bonding.

Various modifications may be made in the above described embodiment without departing from the scope of this invention. For example, this invention is not limited to the lamination of printhead devices or to the specific number of layer-members being laminated.

Claims

1. A process for precisely aligning an orifice plate with an ink jet printhead and then securely bonding the orifice plate and printhead one to another, **characterized** in that cohesive failure mode bonding between the orifice plate (12) and the ink jet printhead substrate (10) is achieved by providing an adhesive layer (14) on one surface of the substrate (10), aligning the orifice plate (12) with the substrate (10) and atop the adhesive layer (14), providing a liquid layer (22) on the structure defined above, and applying predetermined heat and pressure through the liquid layer (22) and to the adhesive layer (14) for a predetermined time.

2. The process defined in claim 1, **characterized** in that the adhesive layer (14) is a thermally curable polymer.

3. The process defined in claims 1 or 2, **characterized** by applying heat and pressure to a sandwich structure (16) disposed on the orifice plate (12) and enclosing a liquefiable material (22) therein, thereby translating hydro-static forces through said liquefiable material (22) and to the plane of the major bonding forces of said substrate (10) and orifice plate (12) respectively, whereby substantially uniform bonding forces are applied across said major surfaces without regard to contours and irregularities in said surfaces to thereby enhance the adhesive bonding therebetween.

4. The process defined in claim 3, **characterized** in that said sandwich structure (16) includes a pair of outer flexible foil layers (18,20) enclosing a liquefiable material (22).

5. The process defined in claims 3 or 4, **characterized** in that said substrate (10) is a silicon die including a thin film resistor structure for a thermal ink jet printhead, and said orifice plate (12) has nozzles therein for receiving ink from reservoirs in the silicon substrate (10).

6. The process defined in one of claims 3,4 or 5, **characterized** in that the pressure is applied to the sandwich structure (16) over a range of 1.3 - 130 bar (20 -2000 PSI) and for the time of 5 to 60 seconds at a predetermined elevated temperature from 90°C to 160°C. 5

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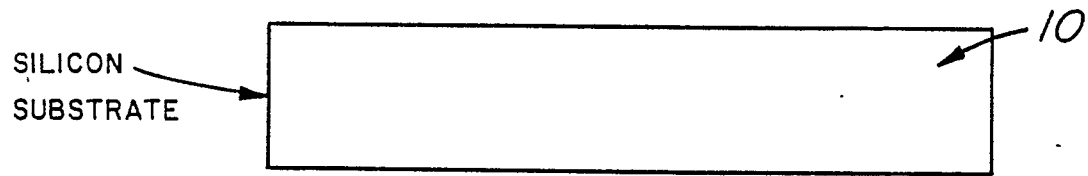
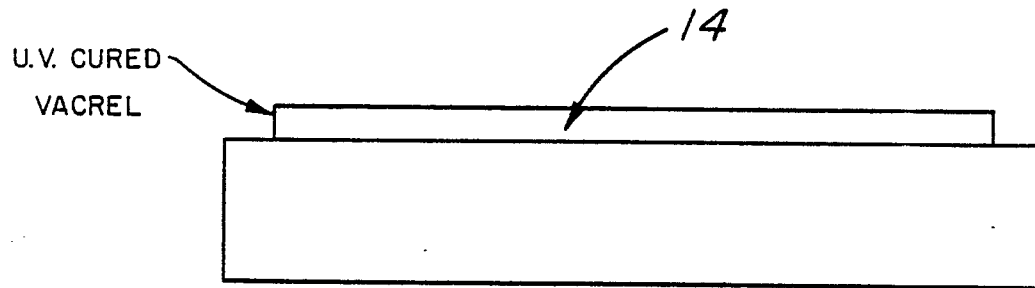
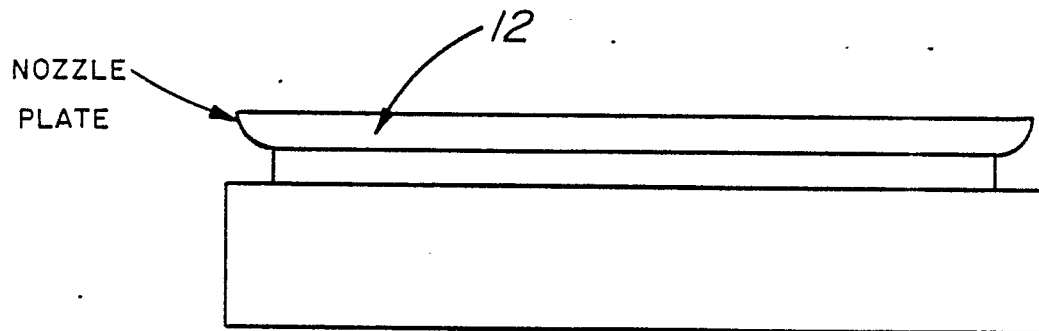
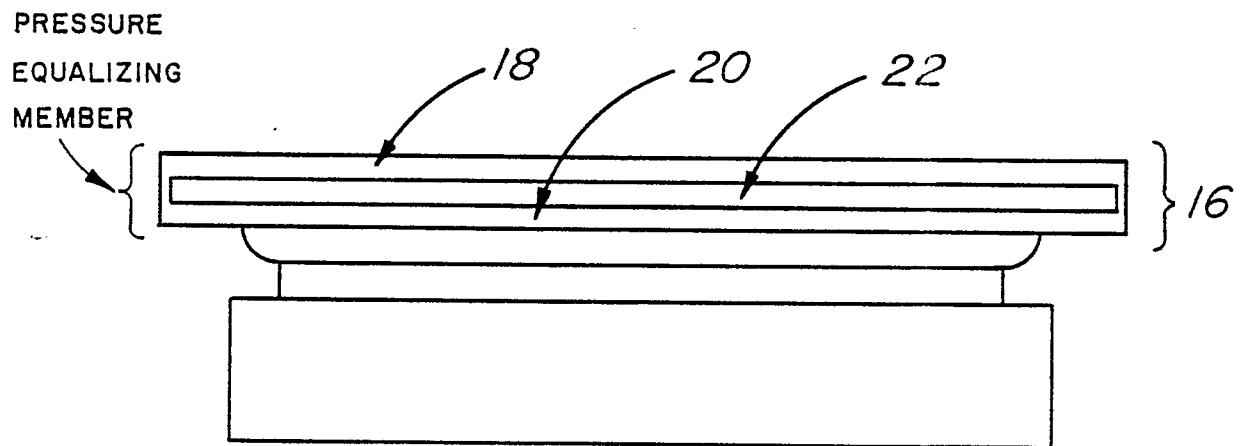
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**Fig. 1A****Fig. 1B****Fig. 1C****Fig. 1D**

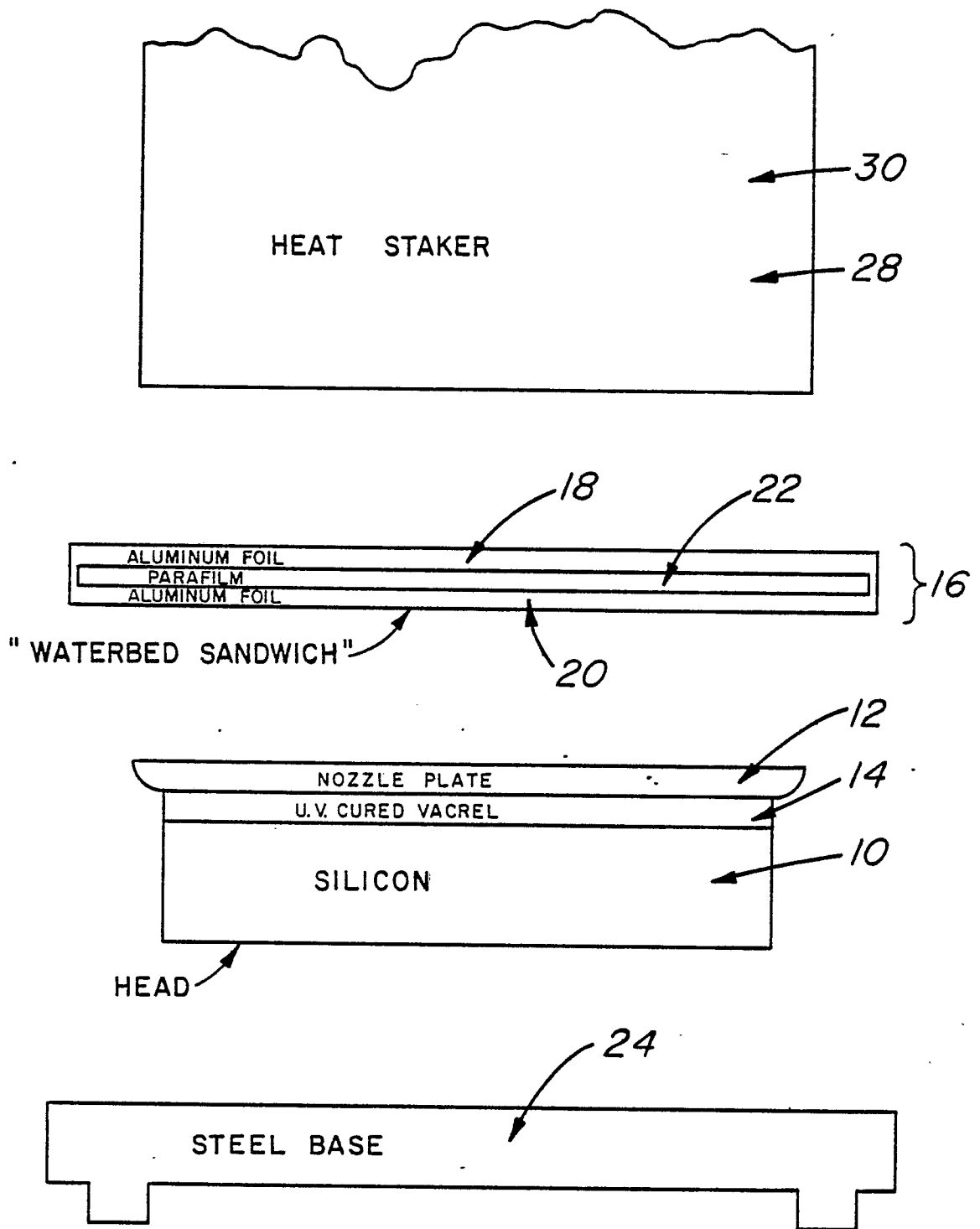


Fig. 1E

ADHESIVE
FAILURE —
TOPPLATE/
VACREL

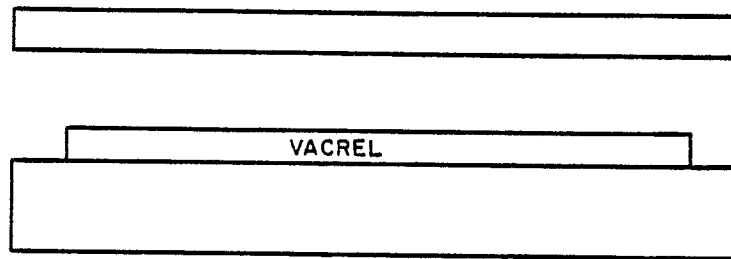


Fig. 2A

ADHESIVE
FAILURE —
VACREL/
SUBSTRATE

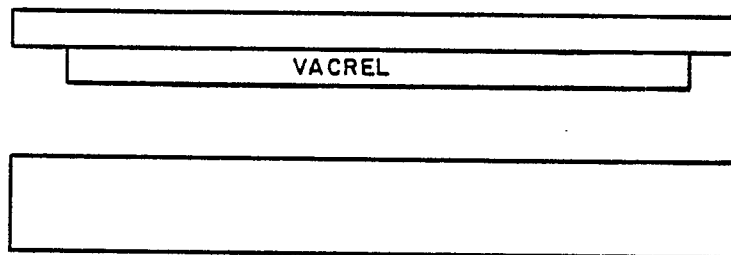


Fig. 2B

MIXED MODE
FAILURE

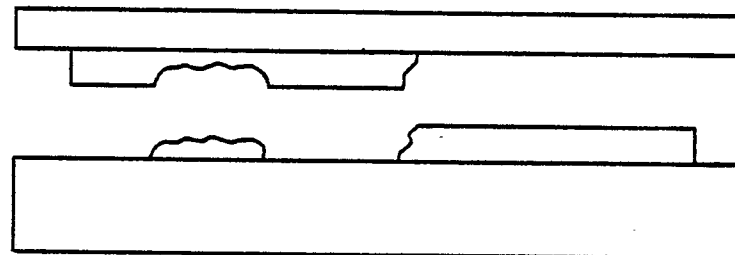


Fig. 2C

COHESIVE
FAILURE —
VACREL

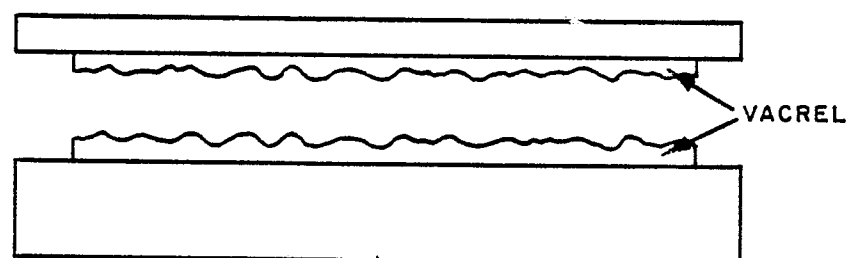


Fig. 2D