(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 443 339 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **91100871.2**

(22) Date of filing: **24.01.91**

(51) Int. Cl.5: **B41J 2/335**, B41J 2/395

(30) Priority: **21.02.90 US 482578**

(43) Date of publication of application:
28.08.91 Bulletin 91/35

(84) Designated Contracting States:
DE FR GB

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(54) Thermal transfer printing head and method for making same.

(57) A thermal transfer printing head comprising tungsten electrodes and copper circuitry, in which 50 electrodes/mm can be used thereby resulting in high resolution printing capabilities. The method of making the electrodes using a reactive ion etching process to form e.g. 88μm on 100μm centers is disclosed.

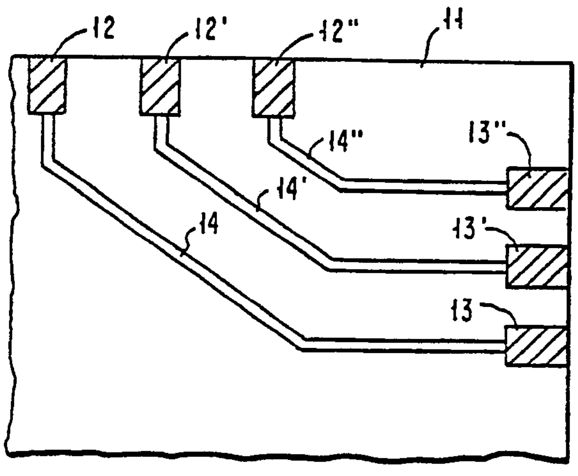

FIG. 2

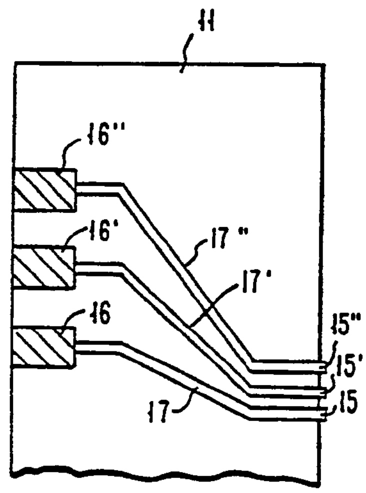

FIG. 3

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This invention relates to a resistive ribbon thermal transfer printing head having multiple refractory metal electrodes (also known as "styli") which are electrically energized to locally melt ink in a ribbon. The refractory metals which can be used are tungsten (W), molybdenum (Mo) and tantalum (Ta), most preferably, tungsten. The electrodes are part of a current distributing circuit which are connected via leads and contact pads to copper cable pads also in the circuit. This entire circuit is disposed on a substrate which is in turn adhered to a pliable backing and contained in a rigid casing. The refractory metal, most preferably tungsten, is used only to form the electrodes, and the balance of the circuit is predominately copper.

One embodiment of the resistive ribbon printer technology used in products today has a print head fabricated from a 25μm thick tungsten sheet which is laminated to a substrate or backing sheet for mechanical support during and after etching of the electrodes. Tungsten is at present the material of choice for print head fabrication because it has proved to provide long life without over heating while printing.

U.S. Patent 3,795,010 recognizes the benefit of using tungsten as the styli material of choice due to its hardness property, however the reference acknowledges the problems of fabrication because hard materials such as tungsten are difficult to place on etched copper conductors.

According to one method found in the prior art, the tungsten sheet is wet-etched to form the head pattern, and then the etched laminate is molded to silicone rubber to provide a flexible structure. Wet etching is a process that unfortunately undercuts sideways into the material while etching downwards, and this phenomenon limits the extent to which gap width between adjacent electrodes can be narrowed, as is required for higher resolution print heads. Thus to etch narrow gaps, i.e. less than about 50μm, in a sheet of tungsten to be formed into a thermal printing head, a wet chemical etching process will not suffice. The use of controlled spray etching extends the typical print head electrode dimensions to about 60μm wide on 100μm centers.

According to the aforementioned prior art methods, a standard printing head made entirely from a sheet of tungsten is approximately 2.5 cm by approximately 5 cm by 25μm thick.

An object of the present invention is to provide a thermal print head that provides the benefits of the print heads of the type described above comprised entirely of tungsten, while reducing the amount of tungsten used in the assembly of the print head.

According to the present invention, the thermal print head is not made entirely of tungsten and the tungsten thus eliminated in the print head is replaced with copper, a much less expensive material.

It is another object of this invention to utilize reactive ion etching (R.I.E.) method to form wide electrodes (e.g. 88μm on 100μm centers) which is not possible by the conventional wet etching method described above.

These objects are solved basically by the solution given in the main independent claims.

Further advantageous embodiments of the present invention are laid down in the subclaims.

The invention will be shown in more detail in the following description in accordance with the drawing in which embodiments are shown and in which:

FIG. 1 is an isometric view of the thermal transfer printing head as embodied in the present invention in place in a typical typewriter application,

FIG. 2 is a top view of the copper component of the two component thermal printing head of the present invention showing the contact pads, leads and cable pads disposed on the substrate,

FIG. 3 is a top view of the tungsten component of the two component thermal printing head of the present invention showing the electrode tips and contact pads and fan out of conductors disposed on a substrate, and

FIG. 4 depicts the manner for securing the contact pads of Figure 2 to the contact pads of Figure 3.

In order to decrease the amount of tungsten used in the manufacture of the print head of the present invention, the structure embodied within the scope of the present invention comprises two parts or components, one component formed from a copper-substrate laminate and the other component formed from, a tungsten-substrate laminate.

According to the present invention, tungsten is used only to form the electrodes or styli, as this is the part of the thermal printing head that is most susceptible to wear as a result of printing. The balance of the circuit of thermal printing head contains a fan-out distribution of the leads that make contact with the cable contact pads present therein.

Figure 1 shows the arrangement of the resistive thermal transfer printing head of the present invention in position on an electric typewriter. A rigid casing 1 supports a pliable elastomeric layer (not shown) within the casing. The rigid casing 1 can be any of the natural or synthetic materials available today having the required properties, i.e. impact strength modulus, etc. to satisfactorily encase the rest of the system.

The pliable elastomeric layer should be a flexible material which is compressible and resilient and can absorb or diffuse impacts and return to its original shape.

A substrate (also not specifically shown in FIG. 1) is bonded adhesively or fixed by any other convenient means to the elastomeric layer. Both are contained within the casing after the printing head has been assembled.

The substrate can be made of any material which is strong enough to support the current distributing circuit having electrodes 2 secured to it. The substrate is substantially inert, and can withstand the temperatures, pressures and reactive gases present in the reaction chamber without substantial degradation. A particularly suitable material for example is the polyimide bearing the trademark Kapton. In order to maintain the adhesive bond between the tungsten and substrate, the temperature of the process to make the print head as described hereinafter should be less than about 125°C during the etching process.

Referring to Figure 1, as the electrodes 2 in casing 1 move along paper 3, signals travel through line 4 to electrodes 2 which cause imprint 5 to be left on paper 3 through ribbon 6.

The current distributing circuit contained within casing 1, which connected to line 4 is depicted in greater detail in Figs. 2 and 3.

Figure 2 is a simplified depiction of an etched copper-substrate laminate which forms a part of the current distributing circuit. As shown, substrate 11 supports copper cable pads 12, 12' and 12", the copper contact pads 13, 13' and 13" each of which is connected by respective copper leads 14, 14' and 14" to the corresponding cable pads noted.

Figure 3 is a simplified depiction of the tungsten-containing component of the printing head which contains the tungsten electrode tips 15, 15' and 15" and contact pads 16, 16' and 16" which are connected the "fan-out" leads 17, 17' and 17." These components are also all disposed on substrate 11.

As noted, the electrodes, leads, contact pads and cable pads forming a layer in the laminar printing head structure are collectively referred to as the electric current distributing circuit, as these elements provide the means for the operation of the printing head.

The electric current distributing circuit in operation comprises a combination of the elements disclosed in Figs. 2 and 3. The plurality of tungsten electrode tips 15 are disposed at one edge of said substrate, each said electrode tip being connected to a tungsten contact pad 16 by means of a tungsten lead 17. The plurality of tungsten contact pads 16 of FIG. 3 are secured in contact with a plurality of corresponding copper contact pads 13 depicted in FIG. 2.

Connecting the elements depicted in FIGS. 2 and 3 requires special consideration. The R.I.E. process which is used to make the electrodes 15 depicted in FIG. 3 requires that a copper film be deposited on the tungsten sheet from which the electrodes will be formed. In general, bonding to tungsten is normally very difficult. This is due to the formation of a native oxide on the tungsten surface. Thus, a very important part of the R.I.E. process as described hereinafter is getting the copper film (also called "mask") used, to adhere to the tungsten. Hence a very careful etching of the tungsten is needed prior to depositing the copper mask. Good adhesion is necessary so that the mask material can withstand the R.I.E. etching process. Thus the tungsten sheet from which the electrodes are to be formed using the R.I.E. process has a copper film on it both before and after the R.I.E. process. After the R.I.E. process, the copper film remaining on the tungsten can be put to good use, in that it, by virtue of the efficient etching treatment has formed a strong bond to the tungsten sheet surface. Solder or conducting epoxy can be adhered to the part containing the tungsten. Thus the electrode section is made out of tungsten and the remainder of the head out of copper.

FIG. 4 is a perspective view depicting copper contact pad 13 and tungsten pad 16 having copper film 20 bonded thereto. The copper underside 20 of tungsten contact connecting pad can be either tinned with solder or it can be wet with conducting epoxy 21 at the area shown in FIG. 7. The two sections can now be bonded together by securing copper contact pad 13 with tungsten contact pad 16 using epoxy or solder 21. The contact area is far enough away from the electrode tips that no heat from the tip will affect it.

The bond between 13, 16 through material 21 is electrically conducting.

After the sections are joined, the resultant part, i.e., substrate and conducting circuit is molded into a plastic holder with silicone rubber.

Thus the head package is formed having much less tungsten material, the tungsten having been replaced by copper.

Referring to FIG. 2, there are copper cable pads 12 generally disposed along at least one of the remaining edges of said substrate, each of the copper cable pads 13 being connected to a corresponding copper contact pad by means of a copper lead 14. Alternatively contact pads 13 can be modified to also serve as the cable pad, thereby eliminating the need for lead 14.

The tungsten metal used in the system in the instant invention is a rolled sheet material having a thickness between 15 and 50μm preferably 25μm, and the thickness variation should not generally exceed about • 2μm after the rolling process. The substrate of the laminated samples has to be heat sunk efficiently so as to protect the adhesive from excessive heating leading to loss of adhesion properties during etching.

Using the method hereinafter described, an improved thermal transfer printing head is obtained. One embodiment of the thermal transfer printing head possesses up to 10 electrodes/mm, preferably 10 electrodes/mm, with a relatively large footprint (i.e., the end cross-sectional view of the electrode showing the width and height area). The benefit of this embodiment is that the larger footprint reduces the contact resistance, with the net result that the electrode runs cooler and thus has an extended life.

In the 10 electrodes/mm embodiment, the width of the footprint is between about 80 μm and 90 μm, preferably 88 μm, the height as noted above is 15 μm to 50 μm, preferably 25 μm, and the electrodes with said footprint are located on 100 μm centers.

Alternatively, another effective embodiment comprises a smaller footprint with the electrodes packaged closer together, i.e., at up to about 50 electrodes/mm. A higher number of electrodes/mm is possible, but it must be kept in mind that as the number of electrodes/mm increases, the thickness of the tungsten must decrease proportionally. Good results have been obtained using 40 electrodes/mm printheads; for example, the 40 electrodes/mm printhead has 160,000 dots/cm^2 printing capability.

In this embodiment the width of the footprint is between about 13μ and 21μ, preferably 16μm, the height is between about 13μm to 25μm, preferably 25μm, and the electrodes with said footprint are located on 25μm centers.

In accordance with the invention, 10 electrodes/mm can be raised up to 40 electrodes/mm, for example by reducing the gap width and electrode width to have a 25 μm center to center distance.

According to the method of the present invention, a R.I.E. system is used in forming the complete print head structure described above. The R.I.E. process used in the present invention is a plasma process wherein reactive gases are used with ion bombardment to cause chemical reactions at the surface of the material being etched. To etch the narrow gaps needed in making a thermal printing head according to the present invention an anisotropic etching process is required. Hence the use of the R.I.E. system in this process. It has been determined that a problem associated with the R.I.E. process is "loading." This means that increasing the amount of material to be etched has the effect of reducing the etch rate. It has been theorized that this phenomenon is due to the rapid consumption of the gas available for etching. Experiments have demonstrated that the pressure in the R.I.E. system during the etching procedure has to be kept at or below 20 mtorr. This pressure limitation maintains the anisotropic etching of the tungsten. There is a limit to the amount of gas flow in the R.I.E. system that can exist while accordingly maintaining the desired vacuum pressure. Therefore the flow rate of the gas used in the system must be increased to provide sufficient gas for etching while the pumping speed must be correspondingly increased to maintain the desired pressure for anisotropic etching. A reduction of the amount of tungsten i.e. the surface area in the system to be etched, greatly improves the throughput of product in the R.I.E. process.

For an efficient manufacturing etching process, it is desirable to optimize the throughput which means getting as many samples into the vacuum system as possible. Because of the low vacuum pressure, the etch rate will decrease due to the limited amount of reaction gas.

To overcome this problem the present invention reduces the amount of tungsten to be etched. The reduction allows the R.I.E. of 10 times the number of print heads.

A practical advantage of the instant invention is the reduction in cost of the print head. The copper-substrate laminate is much less expensive than the tungsten substrate laminate.

When preparing a thermal printing head of tungsten, a copper film is deposited on the surface of the tungsten sheet. The copper acts as a mask for the R.I.E. of the tungsten. Prior to any deposition of copper, tungsten samples are first etched in a cleaning solution (such as sodium hypochlorite, Chlorox), for a minute to remove the surface oxide, followed by a rinse in deionized water for about another minute. Then the surface is prepared for vacuum deposition by giving a light etch for 30 seconds in a solution of equal parts of NH_4OH, H_2O_2 and deionized water.

Prolonged R.I.E. runs (i.e.greater than one hour) which are required in accordance with the present invention because the process embodies etching thick tungsten films. As noted above, the prolonged run necessitates the use of metal masks for delineating the pattern, since a photoresist cannot withstand exposures in excess of about 1 hour. In general, copper is used as the masking material.

The next step in the sequence is to sputter etch the copper film forming the mask for the R.I.E. step. To achieve good adhesion of the sputtered copper film, a 500°A thick film of titanium or chromium was first sputtered on to the tungsten sheet as an adhesion promoter. The thickness of this copper mask ranges between about 1 and 4μm which range has proved to be sufficient thickness to withstand the R.I.E. processing times in excess of 1 hour. The copper film thus applied is thereafter delineated into the required print head pattern by the use of photolithography and wet chemical etching. The resist usually remains on the copper masking pattern prior to R.I.E. etching.

Printing heads falling within the scope of the instant invention are conveniently prepared in a parallel plate R.I.E. machine operating at about 13.6 MHz.

The machine comprises a chamber and a pumping section.

The heat generated in the tungsten due to R.I.E. etching efficiently conducted away to the water cooled cathode.

The chamber and the electrodes are conveniently made of aluminum. The cathode in the chamber is water-cooled and the temperature can be vary between 20°C and 80°C (as measured by the water temperature at the outlet).

The pumping system consists of a turbo molecular pump and a mechanical roughing pump.

The system pressure is regulated by a automatic throttle valve. The chamber is pumped via a 11 cm^2 diameter port in the center of the cathode electrode, and this effects the uniformity of the etch rate. The pumping capabilities of this system permit operation at about 10mtorr pressure with a flow rate at of about 100cmin for the reactive gas mixtures.

The backs of the samples to be treated are directly affixed to the R.I.E. electrode by one of two methods: either a thermal grease used for vacuum coupling, or double sided masking tape. It was found that the samples that were thermally coupled with the double side adhesive tape consistently had a more uniform etched rate both across the sample and from sample-to-sample on a densely populated cathode. A variation of about 1 to 2μm is measured for a total etching time of about 75 minutes and this is close to the variation in the surface finish of the tungsten sheet.

The gas mixtures used in the chamber in the R.I.E. process comprise a number of different halogen based gases such as CF_4, NF_3, SF_6 alone and in combination, and also with the addition of various inhibitors ($CHCl_3$, CHF_3, CH_4). The mixture of SF_6 and $CHCl_3$ was found to be most effective and is therefore preferred.

In general, a higher etch rate is achieved at higher pressures. The higher pressures usually lead to under-cutting, and the upper limit is generally thought to be about 25 mtorr to avoid any potential problems in etching thick films such as encountered in the present invention.

The gas flow rate is linked to the total loading of the tungsten being etched in the system, i.e. the etch rate will decrease if there is an insufficient amount of gas available for the exposed tungsten surface area. Thus, at any constant pressure, increasing the gas flow allows an increase in the amount of tungsten being etched at a fixed rate.

Using the R.I.E. procedure described above, a two component (tungsten-copper) thermal printing head was made using the R.I.E. system wherein the prepared tungsten sample was contacted with 90% SF_6 and 10% $CHCl_3$. The fragile electrodes of the head were potted with silicone rubber solution whereupon the electrode tips are then mechanically dressed to fit the curved platen of the printer.

The gas mixture of SF_6 and $CHCl_3$ was selected and used to R.I.E. the tungsten because of its etch rate of the tungsten. This gas mixture has an etch rate of 20μm/hr in region between the electrodes, while only etching the sidewalls of the electrodes less than 2μm/hr. These rates are achieved at a power level of 1w/cm^2.

The use of $CHCl_3$ as an inhibitor gas gives excellent side wall protection to the narrow electrodes during the R.I.E. step, the measured amount of under cut is only 1μm per wall. Other inhibitor gases that have acceptable etch rates have produced greater than 2μm of undercut.

The process described herein allows one to obtain straight walls between the electrodes for the dimensions listed which the wet etch process does not allow. By "straight walls" is meant that the top width of the electrode is < 2μm narrower than the bottom width of the electrode when the electrode height is 25μm. If the height of the electrode is <25μm the difference in the width of the top and bottom is proportionately reduced.

A possible problem with using $CHCl_3$ for the extended etch times associated with the present invention is that while in the plasma phase it reacts with copper forming a film, which can dislodge from the copper surface. During the R.I.E. step, this film has frequently flaked off and deposited between the electrodes, stopping any further etching of the tungsten below the flaked film. To control this problem it has been found experimentally that a photo resist film thick enough to withstand both the sputter etch step and the R.I.E. step will protect the copper surface from the $CHCl_3$.

The photo resist mentioned above must be thin enough to resolve the 12μm gap between the electrodes, but thick enough to withstand the two subsequent etch steps and passivate the copper mask during the R.I.E. etching of the tungsten. Keeping the copper mask thin minimizes the length of time the photo resist is exposed to the sputter etch process. A copper thickness between about 0.5 and 2.0μm is thick enough to survive the R.I.E. step. The optimum photo resist thickness that survived both the etching steps is >2.0μm, i.e. about 2.25-2.50 μm. At this thickness the 12μm gap in the photoresist that is required between the electrodes is still defined.

After the R.I.E. step, it is important to protect the electrodes, which are very fragile by means providing mechanical stability to the electrodes. This protection is achieved by potting the entire electrode area in a thin mixture of a cleaner such as Dow Corning 1200 prime coat and 732 RTV. The mixture has to be thin enough so as to wick into the narrow gaps between the electrodes. An added benefit of using this mixture is that is has the needed good high temperature properties. For example it can be heated to 400°C without breaking down. This high temperature stability of the potting solution keeps the electrodes from being damaged by the heat generated during the printing process. The potting also allows the mechanical dressing of the print head to the shape of the curved platen and optimization of the fit of each electrode foot print.

Claims

1. A resistive ribbon thermal transfer printing head comprising:

   a rigid casing supporting,

   a pliable elastomeric layer,

   an inert substrate capable of withstanding temperatures up to about 125°C mounted on said elastomeric layer, and

   a signal distributing circuit bonded to said substrate,

   said circuit comprising: a plurality of tungsten electrode tips (15, 15', 15") disposed at one edge of said substrate (11), each said electrode tip being connected to a tungsten contact pad (16, 16', 16") by means of a tungsten lead,

   a plurality of copper contact pads (12, 12', 12"), each of which is in contact with a corresponding tungsten contact pad,

   means for securing an electrically conducting bond between said tungsten contact pad and said copper contact pad,

   copper cable pads (13, 13', 13") disposed on said substrate (11), each said copper cable pad being connected to a said corresponding copper contact pad by means of a copper lead.

2. The printing head defined in Claim 1, wherein said inert substrate is polyimide.

3. The printing head defined in Claim 1 or 2, wherein said elastomeric layer comprises silicone.

4. The printing head defined in Claim 1, 2 or 3, wherein a single copper pad comprises said copper contact pad, said copper lead and said copper cable pad.

5. The printing head defined in Claim 1, 2, 3 or 4, wherein said circuit comprises 10 electrodes/mm, wherein the width of the electrode footprint is between about 80μm and 95μm, the height of the electrode footprint is between about 15 μm and 50μm, and said electrodes with said footprint are located on about 100μm centers, wherein the width of said electrode footprint is preferably about 88μm and said height of said electrode footprint is preferably about 25μm.

6. The printing head defined in Claim 1, 2, 3 or 4, wherein the circuit comprises up to about 50 electrodes/mm preferably about 40 electrodes/mm, wherein the width of the electrode footprint is between about 13μm and 21μm, the height of the electrode footprint is between about 13μm and 25μm and the electrodes are located on about 25μm centers, wherein the width of said electrode footprint is preferably about 16μm and the height of said electrode footprint is preferably about 25μm.

7. A method for making the resistive thermal transfer printing head defined in any one of claim 1 to 6 comprising:

   depositing a mask over the entire surface of an oxide-free refractory metal;

   delineating said mask with a photoresist material;

   etching said mask material to obtain an exposed surface of said refractory metal;

   contacting said exposed refractory metal surface with a gas phase reactive ion etch comprising halogen based gases selected from the group consisting of CF_4, NF_3 and SF_6 optionally containing an inhibitor selected from the group consisting of $CHCl_3$, CHF_3 and CH_4 at a pressure of between about 10 and 20 mtorr, a temperature between about 10°C and 60°C and an applied power of about 1 watt/cm^2, to form electrode tips,

   thereafter applying means to provide mechanical stability to said electrodes, and

securing said resultant electrode tips to a support assembly.

8. The method defined in Claim 7, wherein said support assembly comprises a rigid casing supporting a pliable elastomeric layer.

9. The method defined in Claim 7 or 8, wherein said refractory metal is selected from the group consisting of W, Mo and Ta, wherein said refractory metal is preferably W.

10. The method defined in Claim 7, 8 or 9, wherein the composition of said gas phase reactive ion etch is between about 85% and 95% SF_6 and between about 5% and 15% $CHCl_3$.

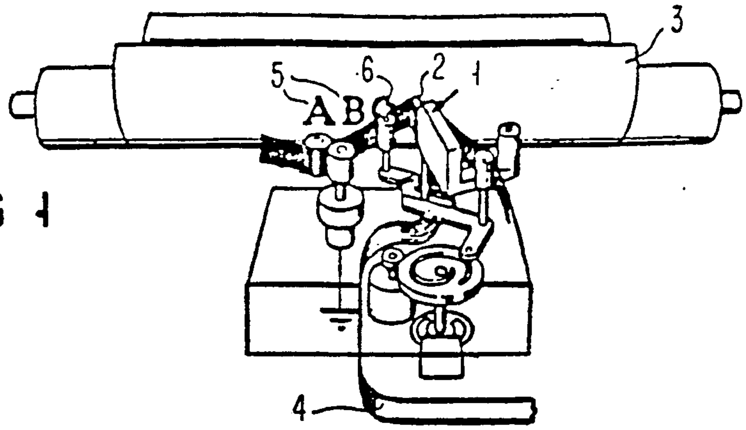

FIG 1

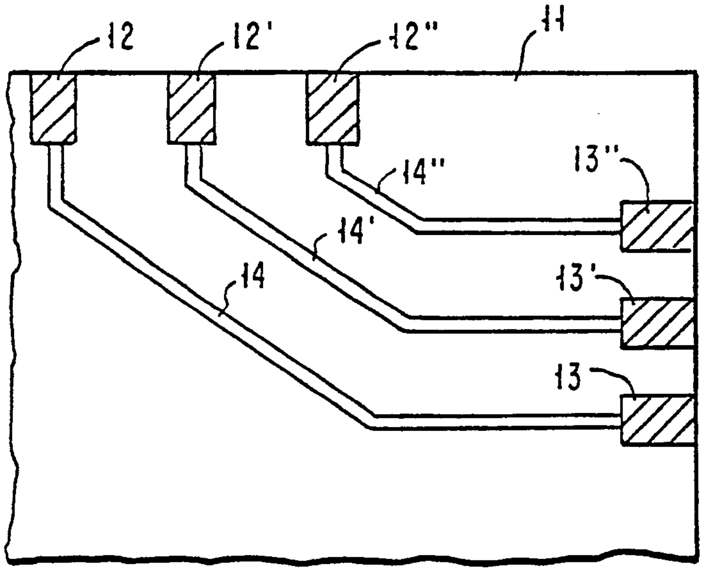

FIG. 2

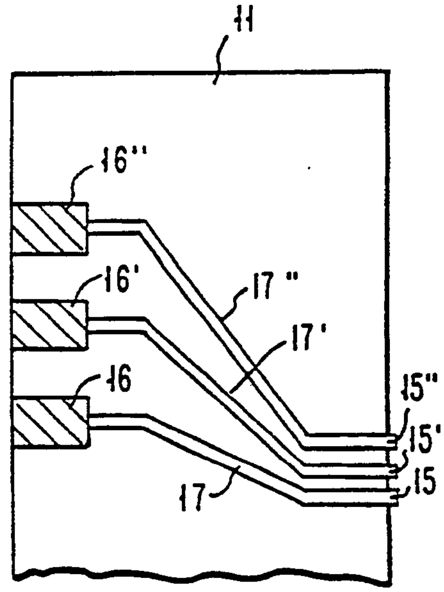

FIG. 3

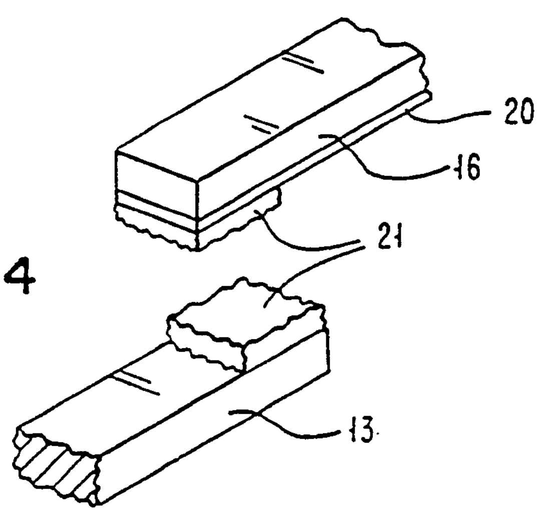

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91100871.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP - A2 - 0 274 062 (IBM) * Column 5, lines 36-53 * --	1-3	B 41 J 2/335 B 41 J 2/395
A	EP - A2 - 0 067 953 (IBM) * Claims * --	1	
A	US - A - 4 546 364 (TODOH) * Fig. 2 * --	1	
A	US - A - 4 415 403 (BAKEWELL) --		
A	US - A - 4 689 638 (MATSUZAKI) --		
A	DE - A1 - 2 712 638 (OKI ELECTRIC IND.) ----		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B 41 J
G 01 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	17-05-1991	WITTMANN

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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