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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Electro-Mechanical Contacts

We, TEXAS INSTRUMENTS INCORPORATED, a corporation organised according to the laws of the State of Delaware, United States of America, of 13500 North Central Expressway, Dallas, Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to contacts, for example of the type utilised in tantalum film circuits and, more particularly, to a contact arrangement employing a particular combination of materials to provide improved electrical and mechanical characteristics for contacts, lands and interconnections on glass or glazed insulating substrates.

In the manufacture of thin film circuits, components such as resistors and capacitors are formed by depositing resistive, conductive and dielectric materials on a substrate which may be glass or glazed alumina, for example. Typically, the resistors would be composed of tantalum in accordance with well-known techniques. Active circuit components such as transistors may be secured to the substrate, or possibly may be formed by deposition of layers of appropriate materials directly on to the substrate. In any event, a problem which has heretofore been of concern in the manufacture of these thin film devices is that of providing high mechanical strength, low resistance, external electrical connections to the deposited tantalum films or to the substrate itself. These connections must be formed by techniques which are not detrimental to the circuit elements previously deposited on the substrate.

Attempts have been made to provide these contacts by means of thermal setting metal suspensions but these materials require high temperatures for the setting operation if high-strength, solderable contacts are to be made to the glass. Metal suspension films having

a low curing temperature are not suitable since the film would be easily separated from the substrate to which it is applied. In this regard, "high" temperatures refer to levels in the region of 400°C where thermosetting materials must be cured. In contrast, it is necessary to use much lower temperatures in the region of 175°C. to avoid damage to the deposited elements on the substrate. Generally, good contacts to glass may be made at high temperatures by conventional techniques, but an important feature of the present invention is that low temperatures may be used.

It has been reported that evaporated chromium-gold films perform the function of providing contacts and lands on glass or glazed alumina and sputtered tantalum films. Here, chromium is first vapour deposited or evaporated in a thin film on to the substrate in the positions where contacts or interconnections are needed. Then, a gold film is applied on top of the chromium or intermixed to some extent therewith. These chromium-gold contacts have been found to be difficult to apply because of the necessity of blending both metals to a certain composition during the vapour deposition period. The blending establishes adhesion between the two metal films but reduces the solderability of the contact and reduces the mechanical strengths of the bond to the substrate because of the insolubility of lead and chromium, lead being present in the solder used for making contact.

The present invention is concerned with the provision of contacts to insulating substrates, particularly glass-like substrates, with the contacts being of high mechanical strength and low electrical resistance while at the same time being formed by techniques which are not incompatible with circuit elements which might be formed on such substrates. The invention is also concerned with the provision of improved electromechanical contacts for tantalum film circuits of the type wherein a glass, glazed



Temperatures

alumina, or a similar substrate is used. Another object is to provide high strength, solderable contacts for thin film circuits.

5 In accordance with this invention, contacts are made to an insulating substrate by a combination of materials which together exhibit good adherence to the substrate and, as well, provide good solderability properties and are of low electrical resistivity. This particular
10 combination of materials may be applied by techniques very similar in nature and therefore compatible with the procedures used to form tantalum film resistors, capacitors and other elements of a thin film circuit. In particular,
15 the improved high-strength electro-mechanical contacts of this invention are formed by first depositing a thin film of an iron-nickel-cobalt alloy on a glass or glazed material substrate. Such an alloy is selected to have a coefficient
20 of thermal expansion compatible with that of glass and typically would consist of 54% iron, 28% nickel and 18% cobalt. This alloy is commercially available under the Trade Mark "Kovar". A highly conductive material, for
25 example gold, is deposited over the alloy film. The gold film is not detrimental to the inherent adhesive properties between the alloy film and the glass or sputtered tantalum. Good solder contacts can then be made to these films
30 which will exhibit exceptional mechanical strength over wide temperature ranges.

By way of example, an embodiment of the invention will be described in greater detail with reference to the accompanying drawings,
35 in which:—

Figure 1 is a pictorial view in section of a contact arrangement made in accordance with this invention;

40 Figure 2 is an enlarged sectional view of a portion of Figure 1; and

Figure 3 is a schematic representation of apparatus for performing the method of this invention.

45 With reference now to Figure 1, there is illustrated a portion of a thin film circuit which is formed on a substrate 10 which can be composed of glass, glazed alumina or other suitable vitreous material. One of the circuit elements formed on this substrate is a resistor
50 11 which is composed of vapour-deposited tantalum and is a thin film of only a few thousand angstrom units thickness. Other circuit components such as additional resistors, capacitors, etc. may also be formed on the top surface
55 of this substrate but only this one resistor is shown since it illustrates the use of contacts in accordance with this invention. On the top surface of the substrate 10 there is selectively deposited at predetermined locations the multilayered contact material. This material is shown as forming a pair of contacts 12 and
60 13 to opposite ends of the resistor 11 and, in addition, an interconnection 14 from the contact 12 to a land 15. To this land 15 may be secured solder contacts (not shown)

to the other elements of the system or connections to external circuitry. The contact 13 is connected by an interconnection (not shown) to another circuit element on the substrate or to another land.

The contacts 12 and 13, the interconnection 14, and the land 15 are all composed of contact material in accordance with this invention. These elements are made up of two layers, Figure 2 illustrating this formation in respect
75 of the interconnection 14 and contacts 12 and 13 as well as the land 15 being similarly composed. The first layer is a thin vapour-deposited layer or film 16 of an iron-nickel-cobalt (Fe-Ni-Co) alloy. This alloy is preferably the
80 54% iron, 28% nickel and 18% cobalt as mentioned above which is commercially available under the Trade Mark "Kovar".

The thickness of the layer 16 may be several thousand angstrom units. On top of the layer 16 is disposed a vapour-deposited layer 17 which is a thin film of gold. In a like manner, the thickness of this layer 17 is not particularly critical and may be several thousand angstrom
85 units. The interface between the layers 16 and 17 is not precisely defined but instead the two materials merge to some extent as will appear hereinafter.

With reference now to Figure 3, a technique for producing contacts in accordance with this invention will be described. A conventional evaporation chamber is utilised and can include a bell jar 20 vacuum sealed to a base plate 21 through which is coupled a conduit 22 to a vacuum pump. Within the evaporation chamber is positioned a substrate holder 23 which has an open coil heater behind it. This substrate holder is mounted from the base plate by means not shown. Over holes in the holder 23 may be placed one or more of the
95 ~~substrate holder is mounted from the base~~

1. These substrates are composed of glass or glazed alumina, and would have thereon one or more thin film tantalum resistors such as the resistor 11 and one or more thin film capacitors formed by conventional techniques such as vapour deposition of tantalum, a dielectric and a conductor. It is important that the process used to produce the contacts, lands, etc., is not detrimental to these circuit components which have already been formed on the substrates 10. The heater behind the holder 23 is energised by electrical current brought in by conductors passing through the base plate 21 (not shown). This heating arrangement for the substrates is utilised to bring the temperature of the substrates up to the proper level to provide optimum adherence of the evaporated material to the substrates.

At positions spaced perhaps 10 inches below the substrates there are provided a spiral evaporation coil 24 and a tungsten evaporation boat 25. The coil and the boat may be separately energised with electrical current by means of conductors also going out through
130



Substrates 10 of the type shown in Figure 1

the base plate 21 but insulated therefrom. Within the coil 24 there is provided a charge 26 of the Fe-Ni-Co alloy which is first evaporated on to the substrates. In a like manner, within the boat 25 there is provided a charge 27 of the gold which is the second material to be evaporated on to the substrates. An appropriate mask can be placed over each of the substrates 10 to limit the area onto which the material deposits to the positions where contacts, interconnections or lands are needed.

Having thus described the apparatus with which contacts according to this invention may be fabricated, a preferred method of depositing the contacts will now be set forth. First, it should be emphasised that the substrates must be very clean prior to the deposition of contacts in accordance with this invention. The substrates are thoroughly cleaned prior to sputtering of the tantalum resistors, etc., but then no cleaning is done after the tantalum sputtering. This is because the tantalum should not be touched with any foreign matter before putting the contacts on. In the interim between tantalum sputtering and contact evaporation, exposure to air should be avoided as much as possible. Then, with clean substrates 10 in place, the pressure within the bell jar 20 is reduced down to a level within the vicinity of 10-5 Torr by means of a vacuum pump. Next, the temperature of the substrates is brought up to the level of about 175°C. This substrate temperature is chosen to produce the optimum in reliability of solderable contacts without ill effects on the adjacent elements such as thin film capacitors. Generally, the adherence of an evaporated metal film increases with increasing substrate temperature during evaporation. However, temperature levels in excess of about 175°C are undesirable in that the circuit elements already on the substrates will be degraded. Now, with suitable masks in place, the filament 24 containing the alloy charge 26 is first energised, brought up to a temperature sufficient to melt the charge and then on to the evaporation range. Control is accomplished by visual observation of the deposition with the rate of deposition being varied by changing the filament voltage. As an example, about 600 milligrams of the Fe-Ni-Co alloy may be placed in the filament 24 as the charge 26 with the filament about 10 inches from the substrates 10. This charge will evaporate in a period of around one half-minute. During the latter part of the period during which the charge 24 is evaporating the boat 25 is energised so that the gold charge 27 is brought up to the melting range. As the evaporation of the charge 26 terminates the evaporation of the charge 27 begins. The volume of the charge 27 may be approximately the same as that of the charge 26 and the time for evaporation would be of the same order. After the deposition of the gold is completed, heating of the substrates is terminated

and the assembly is allowed to cool down to at least 100°C before the substrates are exposed to air.

The contacts which result from this method include an initial layer of the Fe-Ni-Co alloy followed by a mixture of the alloy and gold, and then a final top layer of gold itself. This arrangement makes good high-strength mechanical contact to the substrate materials as described above and also to the sputtered tantalum films which are used for some of the components. The oxide present on sputtered tantalum at room temperature does not prevent good electrical contact between the Fe-Ni-Co and gold and the tantalum. It has been found that these contacts with areas of 0.0025 square inches can withstand a five to ten pound pull test which means that in most cases the substrate material itself would fracture before the metal film and the substrate would separate.

While gold is preferred as the uppermost film of the contacts of this invention, copper may also be deposited over the iron-nickel-cobalt alloy to provide the function of low resistance electrical connection. The Fe-Ni-Co alloy itself has a fairly high electrical resistivity and so the upper layer functions to lower the overall resistance of the contact structure.

WHAT WE CLAIM IS:—

1. A contact to a vitreous surface comprising a first film of an iron-nickel-cobalt alloy contiguous to said surface, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a second film of a highly-conductive metal overlying said first film.
2. A contact to a vitreous surface comprising a first film of an iron-nickel-cobalt alloy adherent to said surface, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a second film of highly-conductive metal adherent to the first film and intermixed therewith at the interface between the first and second films.
3. A contact to a vitreous surface as claimed in claim 2, in which the highly-conductive metal is gold.
4. An electrical device including a substrate having a vitreous surface, a thin film of an iron-nickel-cobalt alloy overlying said surface and adhering thereto, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a thin coating of gold overlying said thin film.
5. A contact arrangement for a thin film circuit of the type wherein a plurality of deposited electrical components are provided on a vitreous substrate, said contact comprising a first film adherent to said substrate and composed of an iron-nickel-cobalt alloy having a thermal coefficient of expansion compatible with that of the substrate, and a thin film of gold overlying and adherent to said first film.
6. A thin film circuit device of the type



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the base plate 21 but insulated therefrom. Within the coil 24 there is provided a charge 26 of the Fe-Ni-Co alloy which is first evaporated on to the substrates. In a like manner, within the boat 25 there is provided a charge 27 of the gold which is the second material to be evaporated on to the substrates. An appropriate mask can be placed over each of the substrates 10 to limit the area onto which the material deposits to the positions where contacts, interconnections or lands are needed.

Having thus described the apparatus with which contacts according to this invention may be fabricated, a preferred method of depositing the contacts will now be set forth. First, it should be emphasised that the substrates must be very clean prior to the deposition of contacts in accordance with this invention. The substrates are thoroughly cleaned prior to sputtering of the tantalum resistors, etc., but then no cleaning is done after the tantalum sputtering. This is because the tantalum should not be touched with any foreign matter before putting the contacts on. In the interim between tantalum sputtering and contact evaporation, exposure to air should be avoided as much as possible. Then, with clean substrates 10 in place, the pressure within the bell jar 20 is reduced down to a level within the vicinity of 10—5 Torr by means of a vacuum pump. Next, the temperature of the substrates is brought up to the level of about 175°C. This substrate temperature is chosen to produce the optimum in reliability of solderable contacts without ill effects on the adjacent elements such as thin film capacitors. Generally, the adherence of an evaporated metal film increases with increasing substrate temperature during evaporation. However, temperature levels in excess of about 175°C are undesirable in that the circuit elements already on the substrates will be degraded. Now, with suitable masks in place, the filament 24 containing the alloy charge 26 is first energised, brought up to a temperature sufficient to melt the charge and then on to the evaporation range. Control is accomplished by visual observation of the deposition with the rate of deposition being varied by changing the filament voltage. As an example, about 600 milligrams of the Fe-Ni-Co alloy may be placed in the filament 24 as the charge 26 with the filament about 10 inches from the substrates 10. This charge will evaporate in a period of around one half-minute. During the latter part of the period during which the charge 24 is evaporating the boat 25 is energised so that the gold charge 27 is brought up to the melting range. As the evaporation of the charge 26 terminates the evaporation of the charge 27 begins. The volume of the charge 27 may be approximately the same as that of the charge 26 and the time for evaporation would be of the same order. After the deposition of the gold is completed, heating of the substrates is terminated

and the assembly is allowed to cool down to at least 100°C before the substrates are exposed to air.

The contacts which result from this method include an initial layer of the Fe-Ni-Co alloy followed by a mixture of the alloy and gold, and then a final top layer of gold itself. This arrangement makes good high-strength mechanical contact to the substrate materials as described above and also to the sputtered tantalum films which are used for some of the components. The oxide present on sputtered tantalum at room temperature does not prevent good electrical contact between the Fe-Ni-Co and gold and the tantalum. It has been found that these contacts with areas of 0.0025 square inches can withstand a five to ten pound pull test which means that in most cases the substrate material itself would fracture before the metal film and the substrate would separate.

While gold is preferred as the upper-most film of the contacts of this invention, copper may also be deposited over the iron-nickel-cobalt alloy to provide the function of low resistance electrical connection. The Fe-Ni-Co alloy itself has a fairly high electrical resistivity and so the upper layer functions to lower the overall resistance of the contact structure.

WHAT WE CLAIM IS:—

1. A contact to a vitreous surface comprising a first film of an iron-nickel-cobalt alloy contiguous to said surface, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a second film of a highly-conductive metal overlying said first film.

2. A contact to a vitreous surface comprising a first film of an iron-nickel-cobalt alloy adherent to said surface, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a second film of highly-conductive metal adherent to the first film and intermixed therewith at the interface between the first and second films.

3. A contact to a vitreous surface as claimed in claim 2, in which the highly-conductive metal is gold.

4. An electrical device including a substrate having a vitreous surface, a thin film of an iron-nickel-cobalt alloy overlying said surface and adhering thereto, the alloy and the vitreous surface having compatible thermal coefficients of expansion, and a thin coating of gold overlying said thin film.

5. A contact arrangement for a thin film circuit of the type wherein a plurality of deposited electrical components are provided on a vitreous substrate, said contact comprising a first film adherent to said substrate and composed of an iron-nickel-cobalt alloy having a thermal coefficient of expansion compatible with that of the substrate, and a thin film of gold overlying and adherent to said first film.

6. A thin film circuit device of the type

- having circuit elements deposited on an insulating substrate, including a thin film of an iron-nickel-cobalt alloy, having a thermal coefficient of expansion compatible with that of the substrate, deposited on said substrate in selected areas and on parts of said circuit elements, and a thin coating of a highly-conductive metal deposited over the thin film.
7. A thin film circuit device having an insulating substrate and including a circuit component adherent to said substrate, a thin elongated film of an iron-nickel-cobalt alloy overlying and adherent to the substrate and overlying said circuit component at one end, the alloy and the substrate having compatible thermal coefficients of expansion, and a thin coating of gold overlying and adherent to said thin elongated film.
8. A thin film circuit device according to claim 6 or claim 7, in which the circuit element or elements having a part or parts overlaid by the alloy film is or includes a thin film tantalum resistor.
9. A method of forming an electro-mechanical contact to a surface of a vitreous substrate, comprising the steps of heating the substrate and depositing on the surface a first film of iron-nickel-cobalt alloy having a thermal coefficient of expansion compatible with that of the substrate, and depositing on the first film a second film of a highly-conductive metal.
10. A method of forming electro-mechanical contacts to a thin film circuit device of the type including circuit elements deposited on an insulating substrate in which the substrate is heated to about 175°C, and a first film of iron-nickel-cobalt alloy, having a thermal coefficient of expansion compatible with that of the substrate, is deposited over selected portions thereof and over parts of at least some of the circuit elements, and then a second film of highly conductive metal is deposited over the first film.
11. A method of forming electro-mechanical contacts to a thin film circuit device of the type including a thin film tantalum resistor, deposited on an insulating substrate, including the steps of heating the substrate to about 175°C, depositing a film of iron-nickel-cobalt alloy over end portions of the resistor and at least adjacent regions of the substrate, the alloy and the substrate having compatible thermal coefficients of expansion, and depositing a film of highly conductive metal over the alloy film.
12. A method according to claim 9, claim 10 or claim 11, in which the electro-mechanical contact(s) are formed on a glass or glazed alumina substrate.
13. A contact to a vitreous surface, substantially as described herein with reference to and as shown by Figures 1 and 2 of the accompanying drawings.
14. A method of forming a contact to a vitreous surface, substantially as described herein with reference to Figure 3 of the accompanying drawings.
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