

[54] **BOND PREPARATION IN ELECTRICAL
DEFLECTION-SENSITIVE TRANSDUCER**

[76] Inventor: **Thomas B. Hutchins, IV**, 310 N.W.
Brynwood Ln., Portland, Oreg.
97229

[22] Filed: **June 14, 1973**

[21] Appl. No.: **369,784**

[52] U.S. Cl. **29/487**, 29/473.1, 29/25.35

[51] Int. Cl. **B23k 1/12**

[58] Field of Search 29/437.1, 487, 25.35

[56] **References Cited**

UNITED STATES PATENTS

2,366,954	1/1945	Brooks.....	29/473.1 X
2,614,144	10/1952	Howatt	29/25.35 X
2,636,920	4/1953	Lockery et al.....	29/473.1 X

3,132,419 5/1964 Takikawa..... 29/473.1

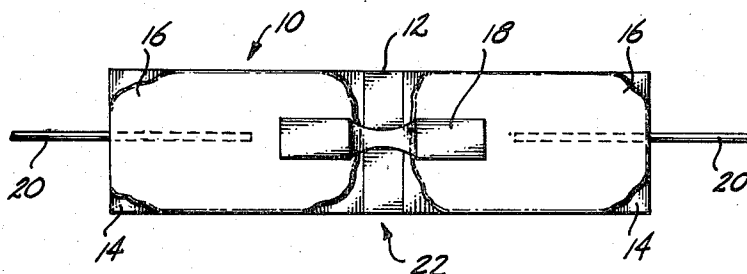
Primary Examiner—Roy Lake

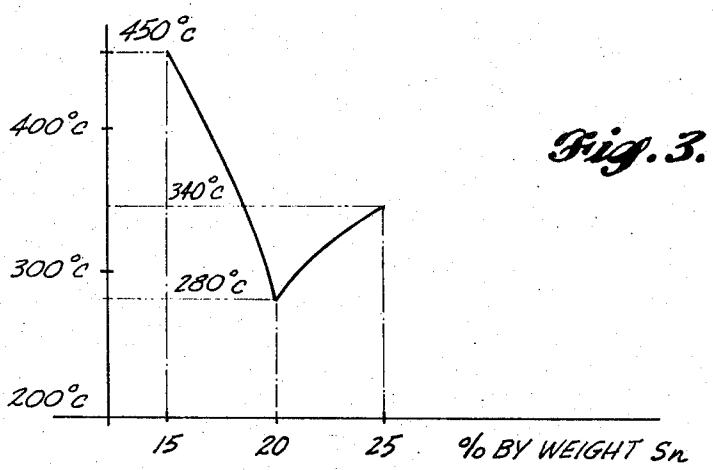
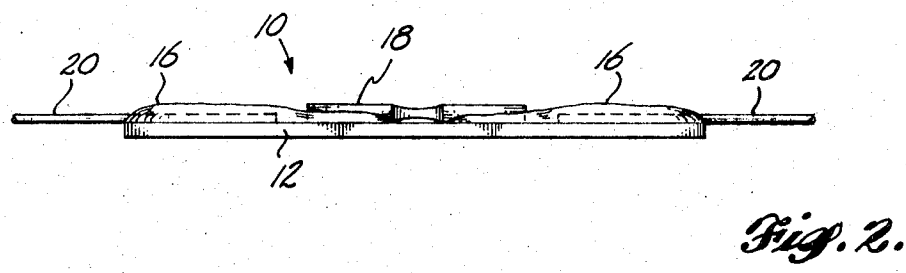
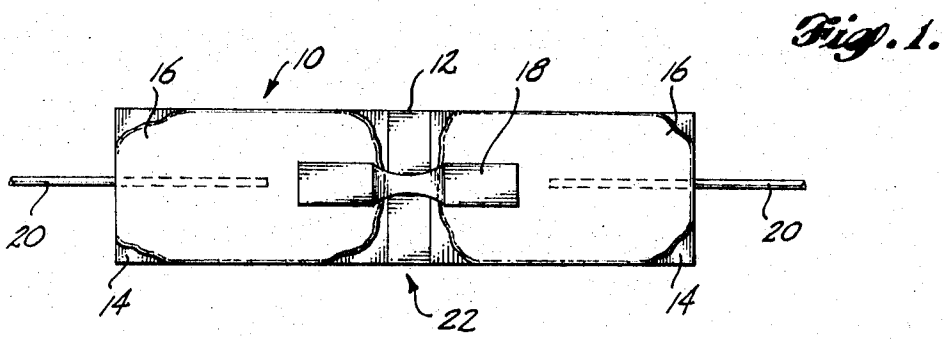
Assistant Examiner—Paul A. Bell

[57] **ABSTRACT**

A method of preparing in an electrical deflection-sensitive transducer a bond between a piezoresistive element and a carrier therefor. The method includes the flowing of a mass of a gold-tin alloy (about 80 percent gold and about 20 percent tin, by weight) into intimate contact with the element and carrier, the solidifying of the flowed mass into a deposit joining the two, and the subsequent alternate heating (without liquefying) and chilling of the deposit to relieve stresses therein.

23 Claims, 3 Drawing Figures





BOND PREPARATION IN ELECTRICAL DEFLECTION-SENSITIVE TRANSDUCER

BACKGROUND AND SUMMARY OF THE INVENTION

This invention pertains to the assembly of an electrical deflection-sensitive transducer. More particularly, it pertains to the preparation of a bond between a piezoresistive element and a carrier therefor used in such a transducer.

One form of a typical modern electrical deflection-sensitive transducer includes a piezoresistive element joined to a carrier through which deforming forces are transmitted to the element. A critical component in such a transducer is the bond which exists between the element and carrier. Normally, the piezoresistive element is an elongated slender bar, for which two end bonds are employed to join it to its associated carrier.

In order to obtain the most satisfactory and accurate performance with such a transducer, it is important that the bond mentioned have certain structural characteristics. To begin with, a bond should be of a type which is capable of being prepared in a manner which minimizes the likelihood of introducing undesirable built-in stresses in either the associated carrier or piezo-resistive element. In addition, the final bond should be characterized by relatively high hardness and elasticity. These characteristics contribute to accurate force transmission to an element. Also, they tend to minimize the likelihood that "creep" (i.e., nonreversing relative movement) will occur between an element and its associated carrier. A further characteristic which is important is that a bond should have good dimensional stability, whereby its aging over time does not produce any appreciable stresses in a piezoresistive element.

A general object of the present invention is to provide a method of preparing a bond having all of the desirable characteristics mentioned above.

According to a preferred way of practicing the invention, the proposed method includes: the flowing of a mass of a gold-tin alloy (about 80 percent gold and about 20 percent tin, by weight) into intimate contact with an element and carrier at the region of intended joiner; the solidifying of the flowed mass into a deposit joining these two parts; and the subsequent alternate heating (without liquefying) and chilling of the deposit to relieve any stresses therein. Such heating and chilling is preferably accomplished by immersing a solidified deposit alternately in water at about 0° C. and water at about 100° C.

Experience has shown that such a method is capable of producing a satisfactory and highly reliable bond possessing all of the structural characteristics discussed above. The gold-tin alloy employed is one which can be liquefied at a relatively low temperature--and particularly at a temperature which does not result in the introduction of any appreciable stresses in the parts being joined. Further, this alloy, on solidifying, forms a very hard, yet elastic, dimensionally stable deposit which offers the kind of wanted performance discussed earlier.

These and other objects and advantages of the invention will become more fully apparent as the below de-

scription thereof is read in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a transducer including a pair of bonds prepared in accordance with the method of the present invention.

FIG. 2 is a side elevation taken generally from the bottom side of FIG. 1.

FIG. 3 is a portion of a phase diagram for different alloys of gold and tin.

DETAILED DESCRIPTION OF THE INVENTION

Indicated generally at 10 in FIGS. 1 and 2 is an electrical deflection-sensitive transducer including bonds which have been prepared in accordance with the method of the present invention. The particular transducer illustrated is one which is especially adapted for use in the tip of a blood-pressure-monitoring catheter, such as that disclosed in U.S. Pat. No. 3,710,781. To this end, transducer 10 is, of course, sized appropriately to fit within the relatively small dimensions of such a tip. It will be understood, however, that the method of the invention is usable in the construction of various other transducers of different sizes.

Transducer 10 includes a generally flat, rectangular, aluminum oxide carrier plate, or carrier, 12, to which is anchored, through spaced-apart metal blankets 14 and bonds 16 the ends of an elongated, slender, silicon piezoresistive element 18, and ends of a pair of conductors 20. Bonds 16, according to the invention, are formed on a gold-tin alloy. The composition of this alloy, and ways of preparing the bonds, will be described more fully below. Metal blankets 14 serve as anchoring interfaces between the surface of carrier 12 and bonds 16.

The specific materials named as forming the carrier and piezoresistive element are conventionally used in such a device, and are in no way critical to the present invention. In other words, various materials may be used for these components of the transducer. Metal blankets 14 might typically comprise, and herein do comprise, an inner layer (directly against the carrier) of a metal mixture containing molybdenum and manganese, on top of which has been applied a layer of nickel. These two layers may be prepared in any suitable conventional manner. The inner "moly-manganese" layer is useful in that it bonds extremely well to ceramic material such as aluminum oxide. A nickel overlayer is used since it has been found to afford a good adhering structure for bonds 16. As will be explained later, there may be instances where yet a third layer is applied over the nickel layer--this third layer consisting of gold. Such a gold outer layer might typically be used to minimize oxidation of the nickel layer, as well as to enable bonds 16 better to wet to the underlying nickel layer.

With transducer 10 sized for the specific purpose indicated earlier, carrier 12 has a length of about 0.2-inches, a width of about 0.05-inches, and a thickness of about 0.006-inches. Blankets 14 each have a length of about 0.09-inches, a width of about 0.05-inches, and a thickness of about 0.001-inches. These two blankets are spaced apart longitudinally axially on the carrier (as can be seen in FIG. 1) by about 0.02-inches--this spacing being indicated generally at 22 in FIG. 1. Bonds 16 extend nearly completely over the tops of

blankets 14, and have a thickness, in most areas, of about 0.0013-inches. Element 18 is about 0.075-inches long, with its opposite end portions having rectangular cross sections with dimensions of about 0.025-inches by about 0.005-inches. In the center of its reduced cross section central portion, the element has cross-sectional dimensions of about 0.01-inches by about 0.003-inches. Conductors 20 have diameters of about 0.004-inches.

It should be understood that the particular dimensions just identified have been given for illustrative purposes only.

When transducer 10 is put into use, carrier 12 is suitably mounted in such a manner as to be deflected or deformed by the forces whose characteristics are intended to be monitored. On such a deflection occurring, and as is well understood, a related stress is set up in element 18 which causes the electrical resistance of this element to change.

It is, of course, desirable that the resistance change which occurs in the piezoresistive element as nearly as possible exactly follow, i.e., directly proportionally follow, changes in the force causing the deflection of the carrier. It is further intended that such a resistance change be "communicated" electrically through bonds 16 and conductors 20 to apparatus external to the transducer wherein the change can be followed as desired. To these ends, and as has been indicated earlier, it is extremely important that bonds 16 be prepared in a manner avoiding the setting up of permanent, distorting stresses within parts in the transducer, and further be prepared in such a manner that the final bonds will accurately and reliably telegraph information from carrier 12 to element 18. Additionally, of course, the bonds must afford good electrical connections between conductors 20 and the piezoresistive element.

According to the present invention, bonds prepared, as will now be described, of an alloy consisting of gold and tin, and comprising, by weight, about 80 percent gold and about 20 percent tin have been found to provide superior performance in respect to the indicated desired characteristics. The term "about," as used in the previous statement concerning the weight percentages of gold and tin in the alloy, is intended to encompass a range of compositions from about 75 percent gold and 25 percent tin at one end to about 85 percent gold and 15 percent tin at the other end, all computed on a weight basis. It should be further pointed out that while gold-tin alloys falling within this range are entirely satisfactory for the purpose indicated, an alloy consisting, by weight, of 80 percent gold and 20 percent tin is preferred.

The phase diagram of FIG. 3 identifies the different respective melting points of gold-tin alloys falling within the range just mentioned. The vertical axis in the diagram represents °C., and the horizontal axis represents the percentage, by weight, of tin in the alloy—the balance being gold. This diagram has been taken from p. 233, "Constitution of Binary Alloys," Second Edition, by Max Hansen, published in 1958 by McGraw Hill Book Company, Inc. It will be noted that of all the alloy compositions within the range, that consisting by weight of 80 percent gold and 20 percent tin has the lowest melting point, namely, 280° C. An alloy containing 15 percent tin and 85 percent gold has a melting point of about 450° C. An alloy containing 25 percent

tin and 75 percent gold has a melting point of about 340° C.

Describing in general terms the method of the present invention, and assuming that carrier 12, element 18 and conductors 20 are suitably held in the relative positions shown in FIGS. 1 and 2, the first step of the method is to flow into intimate contact with the element, carrier and conductors, a suitable quantity of an alloy which has been selected from the above-defined range of alloys. This might typically be done by placing a mass of the selected alloy on a blanket 14 adjacent the confronting ends of element 18 and a conductor 20, and by then heating the alloy mass to melt it, and causing it to flow as indicated. The next general step in the method, after completion of the flowing step, is to solidify the flowed mass into a deposit which then is joined to and joins the associated ends of a conductor 20 and element 18 through the associated blanket 14 to the carrier. Such solidifying may be done by allowing the flowed molten mass simply to cool to ambient room temperature which might typically be in the range of about 18° to 28° C. Following the solidification of the mass into a deposit, and without reliequifying the deposit, stresses are relieved therein through alternately heating and chilling it. A preferred way of accomplishing this has been found to be simply alternately immersing the deposit in boiling water (water at 100° C.) and ice water (water at 0° C.).

Preferably during the melting, flowing and solidifying steps of the method, the alloy mass is surrounded by a flowing, predominantly forming gas atmosphere (i.e., an atmosphere comprising by volume about 10 percent hydrogen and about 90 percent nitrogen). During each of these steps the presence of such an atmosphere prevents or at least minimizes the chance of undesirable oxidation occurring in the region where the bond is being formed. Additionally, during the solidifying step, the flowing of such gas serves quickly to cool and thus solidify the mass into a deposit, which action has been found to produce a bond having greater dimensional stability than one produced in the absence of such as gas flow.

EXAMPLE

Describing one way in which a satisfactory bond 16 may be prepared, and considering the case where metal blankets 14 have already been applied to the carrier, with each blanket including but an inner "moly-manganese" layer and an outer nickel layer, the carrier, piezoresistive element, and conductors are suitably placed and held in the relative positions shown in FIGS. 1 and 2. For each bond, a chip, or mass, of an alloy consisting by weight of 80 percent gold and 20 percent tin is placed on a blanket 14 adjacent the confronting ends of a wire 20 and element 18. A suitable quantity of this alloy for each bond in a transducer having parts sized as previously indicated, comprises a substantially flat rectangular solid chip thereof about 0.07-inches long 0.04-inches wide and 0.002-inches thick.

Heat is then applied in any suitable fashion to raise the temperature of this chip to about 300° C., thus causing it to melt. This temperature is well below the melting temperatures of the materials in the metal blankets. Such heating and melting of the chip are preferably performed with the chip and adjacent parts in the transducer surrounded by a predominantly forming gas atmosphere. Preferably, such an atmosphere is pro-

duced by directing one or more streams of such gas over and around these elements.

With melting of the alloy chip, and with continued application of heat sufficient to maintain the melt in a liquid state, the same flows over the associated metal blanket into intimate contact with the ends of conductor 20 and element 18. The flow of forming gas preferably is maintained during this flowing of the melt. After the molten alloy has flowed as just described, the same is cooled to solidify it. This is best accomplished by removing the source of heat which originally melted the alloy chip, and by continuing the flow of forming gas as before until the alloy has completely solidified and returned, essentially, to room temperature. Such cooling and solidifying might typically take about 10 to 15 seconds.

Next to be accomplished is the removal of substantially all internal stresses in the flowed and solidified alloy deposit. According to the invention this is accomplished by alternately, and without relieving the alloy, heating and chilling it. A preferred way of accomplishing this has been found to be by alternately immersing the assembly in boiling water (water at 100° C.) and ice water (water at 0° C.). Satisfactory stress relief is obtained with about twenty heating-chilling cycles—i.e., 10 immersions in boiling water alternating with ten immersions in ice water. A satisfactory time for each immersion has been found to be about 5 seconds.

What results from the process just described is a bond possessing all of the desirable functional and structural characteristics discussed earlier.

EXAMPLE

Another way of making a satisfactory bond is by performing all of the steps just described, but instead of using an alloy consisting exactly of 80 percent gold and 20 percent tin, using an alloy of some other composition within the described range. A higher melting temperature must, of course, be used. Such a process will also result in an entirely satisfactory bond.

EXAMPLE

Describing still another way of producing a bond 16, let us consider the case where a metal blanket includes an outer coating of gold. Let us assume further that it is desired to obtain in the final bond an alloy deposit consisting exactly by weight of 80 percent gold and 20 percent tin.

In a transducer having parts dimensioned as previously described, such a gold coating, if applied by conventional plating techniques, would extend completely over the nickel layer, and would typically have a thickness of between about 5 to 10×10^{-6} inches. Assuming such a situation to be the case, and with the carrier, piezoresistive element and conductors properly positioned relative to one another, an alloy chip consisting by weight of 78 percent gold and 22 percent tin, and having the same dimensions indicated earlier is placed as described above. As also was earlier described, heat is suitably applied to melt this chip. With such melting, where the melt contacts the gold layer, gold in the layer liquefies and is absorbed in the melt. With the dimensions given, a final melt results consisting by weight of 80 percent gold and 20 percent tin. The remaining steps of the preparation procedure are then exactly the same as those described in the first two examples. Pref-

erably, here also a flow of forming gas is used as before.

The bond produced in accordance with this example is structurally and functionally essentially identical to that produced in accordance with the first example.

It will thus be evident that satisfactory bonds may be produced in a number of slightly different ways in accordance with the invention. Where there is no gold coating to contend with, a bond may be prepared by beginning with a chip or mass of an alloy having the preferred exact weight composition of 80 percent gold and 20 percent tin. Or, a satisfactory bond can be prepared, also when there is no gold coating, by using a gold-tin alloy falling anywhere within the range indicated. Where there is a gold coating, it is possible by properly selecting the composition of the starting alloy chip, to end up with a final bond exactly consisting by weight of the preferred 80 percent gold and 20 percent tin. Further, by selecting the appropriate gold-tin alloy composition, even where a gold coating is present in a metal blanket, it will be possible to end up with a final bond having a composition falling within the composition range described.

As has already been stated, a bond which results in having a composition within the described range, and heated and chilled as indicated, offers all of the desirable structural and functional characteristics which lead to accuracy and reliability in the performance of the final transducer. Because of the relatively low melting points of the different gold-tin alloys within the range described, the heat which is required to melt these alloys during the preparation steps does not introduce undesirable internal stresses in other parts in the transducer. Heating and chilling of a bond relieves stresses therein, and thus greatly enhances the performance longevity of the bond. Performing the steps of melting, flowing, and solidifying in a predominantly forming gas atmosphere minimizes the likelihood of getting undesirable oxidation in a bond. Further, during the solidifying step, a flow of forming gas speeds the step.

While several different examples of practicing the invention have been described, it will be appreciated by those skilled in the art that certain variations may be made without departing from the spirit of the invention.

It is claimed and desired to secure by Letters Patent:

1. A method of preparing in an electrical deflection-sensitive transducer an electrically conductive, dimensionally stable, substantially nondistorting force-transmitting bond between a piezoresistive element and a carrier therefor used in the transducer, said method comprising

flowing into intimate contact with the element and carrier a liquid mass of an alloy consisting of gold and tin and comprising, by weight, about 80% gold and about 20% tin, solidifying the flowed mass to form a deposit of said alloy joined to and joining the element and carrier,

without relieving the deposit, alternately, and a plurality of times, heating and chilling it, and by said heating and chilling relieving stresses in the deposit.

2. The method of claim 1 which further comprises, during said flowing, surrounding said liquid mass with a predominantly forming gas atmosphere.

3. The method of claim 2, wherein said surrounding is accomplished by directing a stream of forming gas 5 over said mass.

4. The method of claim 1 which further comprises, during said flowing and solidifying steps, surrounding said mass with a predominantly forming gas atmosphere.

5. The method of claim 4, wherein said surrounding is accomplished by directing a stream of forming gas over said mass.

6. The method of claim 1, wherein said heating is accomplished by immersing said deposit in water at about 100° C., and said chilling is accomplished by immersing the deposit in water at about 0° C.

7. A method of preparing in an electrical deflection-sensitive transducer an electrically conductive, dimensionally stable, substantially nondistorting force-transmitting bond between a piezoresistive element and a carrier therefor used in the transducer, wherein on the carrier at the location of intended joiner between it and the element there is a coating of gold, said method comprising

placing adjacent said location a solid mass of a metal alloy consisting of gold and tin and comprising, by weight, about but less than 80 percent gold and about but more than 20 percent tin,

liquefying said mass,

flowing the liquefied mass into intimate contact with the element and carrier at said location,

by said liquefying and flowing liquefying at least a portion of said coating,

merging said liquefied coating portion with the liquefied mass to produce an alloy blend consisting, by 35 weight, of 80 percent gold and 20 percent tin,

solidifying such blend to produce a deposit thereof joined to and joining the element and carrier,

without reliequifying the deposit, alternately, and a plurality of times, heating and chilling it, and 40 by said heating and chilling relieving stresses in the deposit.

8. The method of claim 7 which further comprises, during said liquefying, flowing and merging steps, surrounding said location with a predominantly forming gas atmosphere.

9. The method of claim 8, wherein said surrounding is accomplished by directing a stream of forming gas over said location.

10. The method of claim 7 which further comprises during said liquefying, flowing, merging and solidifying steps, surrounding said location with a predominantly forming gas atmosphere.

11. The method of claim 10, wherein said surrounding is accomplished by directing a stream of forming gas over said location.

12. The method of claim 7, wherein said heating is accomplished by immersing the deposit in water at about 100° C., and said chilling is accomplished by immersing the deposit in water at about 0° C.

13. A method of preparing in an electrical deflection-sensitive transducer an electrically conductive, dimensionally stable, substantially nondistorting force-transmitting bond between a piezoresistive element and 65

a carrier therefor used in the transducer, said method comprising

flowing into intimate contact with the element and carrier a liquid mass of a gold-tin alloy consisting, by weight, of 80 percent gold and 20 percent tin,

solidifying the flowed mass to form a deposit of said alloy joined to and joining the element and carrier,

10 without reliequifying the deposit, alternately, and a plurality of times, heating and chilling it, and by said heating and chilling relieving stresses in the deposit.

14. The method of claim 13, which further comprises, during said flowing, surrounding the liquid mass with a predominantly forming gas atmosphere.

15. The method of claim 14, wherein said surrounding is accomplished by directing a stream of forming gas over the mass.

20 16. The method of claim 13, which further comprises, during said flowing and solidifying steps, surrounding the mass with a predominantly forming gas atmosphere.

17. The method of claim 16, wherein said surrounding is accomplished by directing a stream of forming gas over the mass.

18. The method of claim 13, wherein said heating is accomplished by immersing the deposit in water at about 100° C., and said chilling is accomplished by immersing the deposit in water at about 0° C.

19. A method of preparing in an electrical deflection-sensitive transducer an electrically conductive, dimensionally stable, substantially nondistorting force-transmitting bond between a piezoresistive element and a carrier therefor used in the transducer, said method comprising

at a location where the element and carrier are to be joined, and with these parts disposed as desired adjacent one another, placing a mass of an alloy consisting of gold and tin and comprising, by weight, about 80 percent gold and about 20 percent tin, melting said mass,

flowing the melted mass into intimate contact with the element and carrier at said location,

cooling the flowed mass to solidify it as a deposit joined to and joining the element and carrier,

at temperatures below the melting point of said deposit alternately, and a plurality of times, heating and chilling it, and

50 by said heating and chilling relieving stresses in the deposit.

20. The method of claim 19 which further comprises, during said melting, surrounding the mass with a predominantly forming gas atmosphere.

21. The method of claim 20 which further comprises, during said flowing, surrounding the melted mass with a predominantly forming gas atmosphere.

22. The method of claim 21 which further comprises, during said cooling, surrounding the flowed mass with a predominantly forming gas atmosphere.

23. The method of claim 19, wherein said heating is accomplished by immersing the deposit in water at about 100° C., and said chilling is accomplished by immersing the deposit in water at about 0° C.

* * * * *