

May 26, 1970

R. E. MacDOUGALL ET AL

3,514,378

ELECTRO-CHEMICAL METHOD OF PRODUCING THIN METAL FLEXURES

Filed Sept. 8, 1967

5 Sheets-Sheet 1

Fig. 1

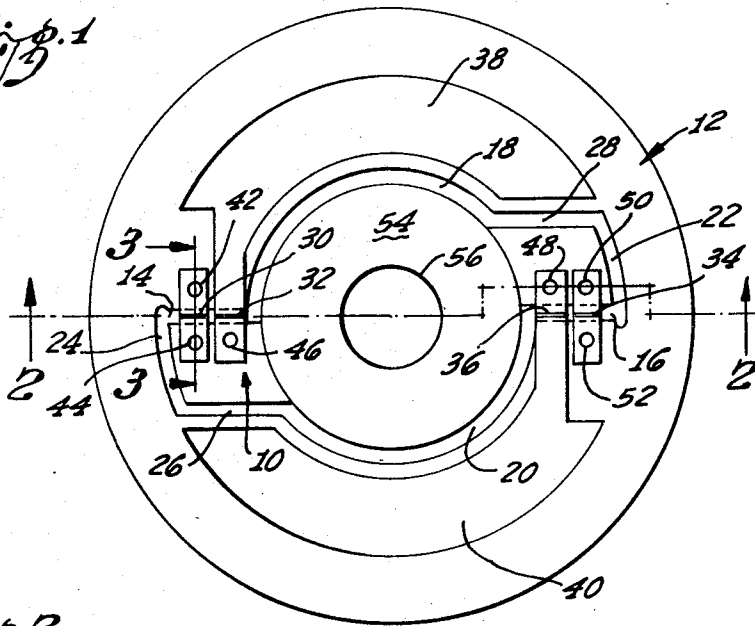


Fig. 2

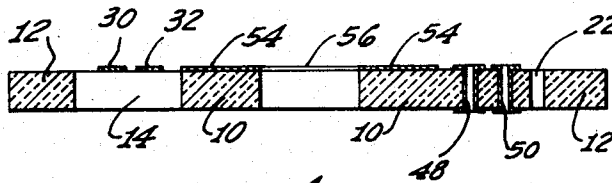


Fig. 3

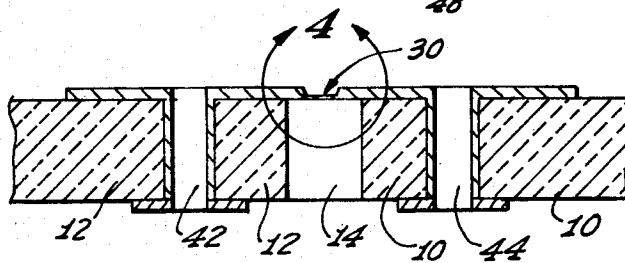
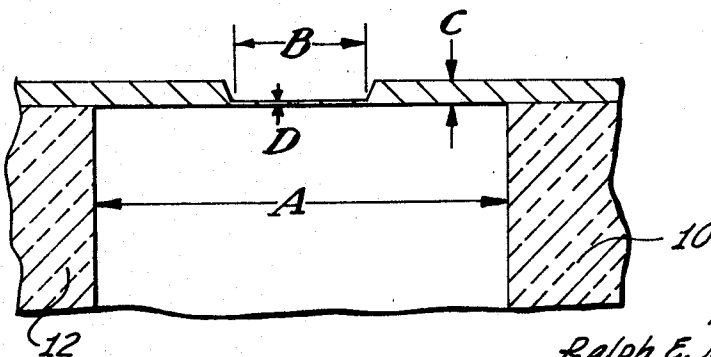


Fig. 4



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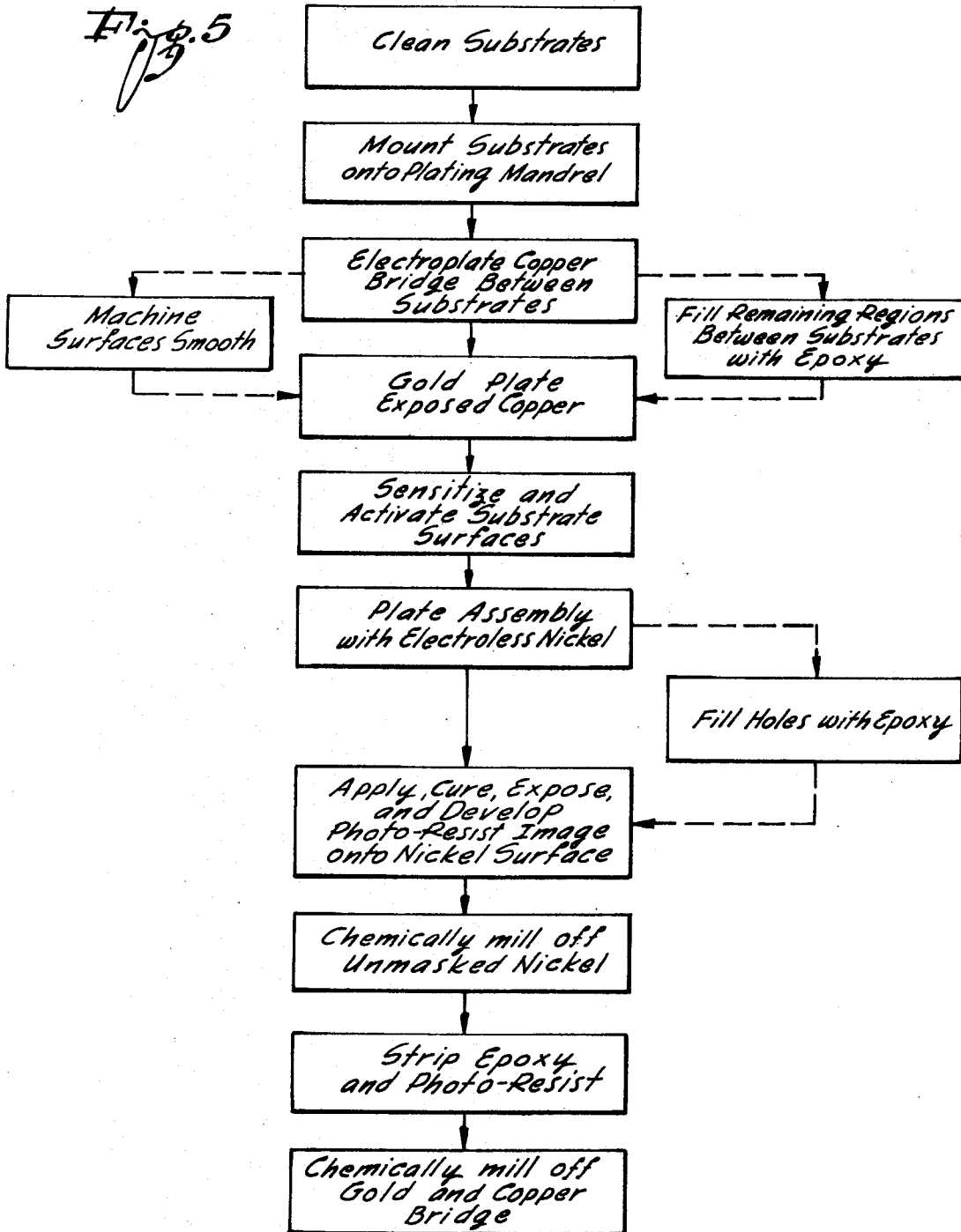
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Fig. 6

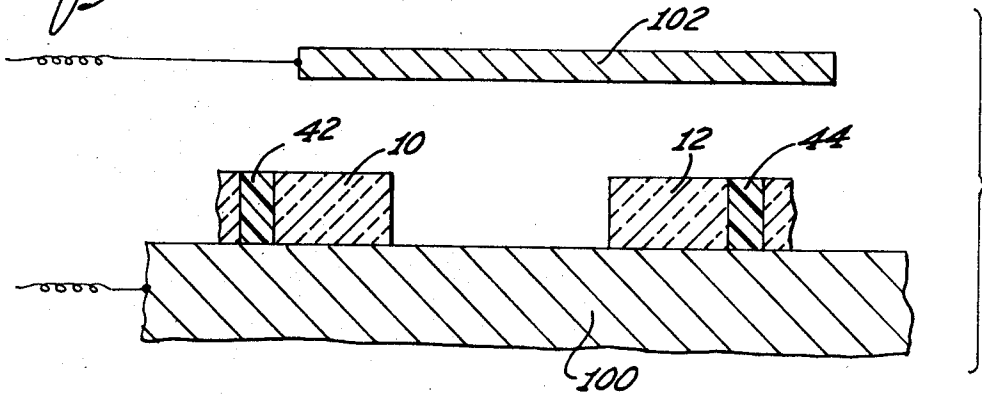


Fig. 7

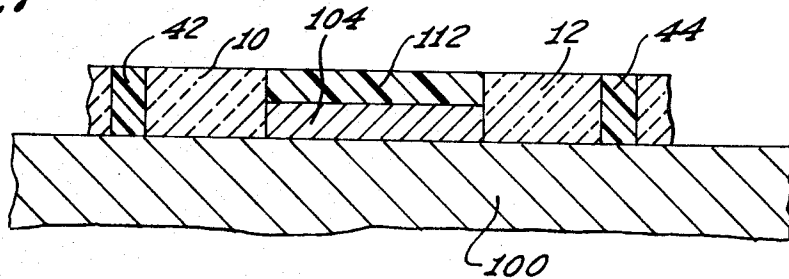
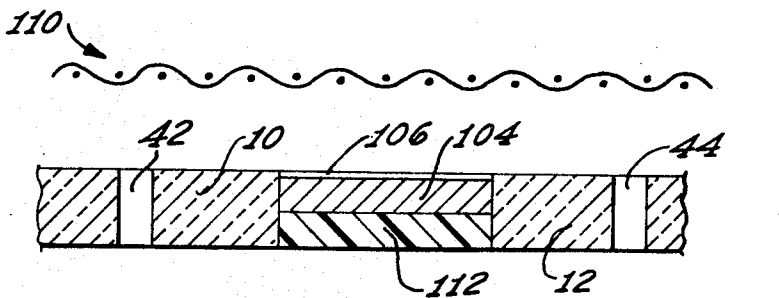


Fig. 8



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Fig. 9

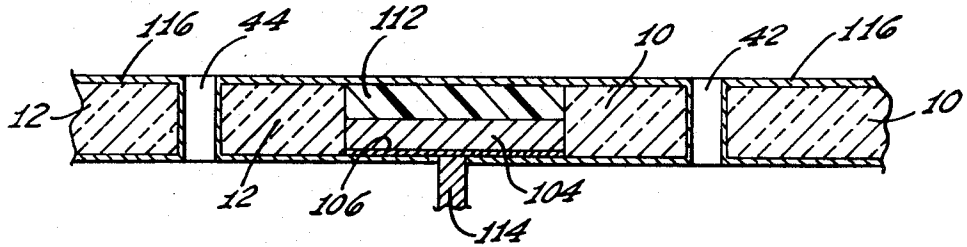


Fig. 10

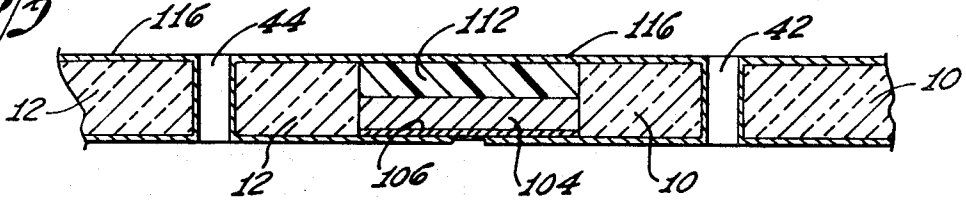


Fig. 11

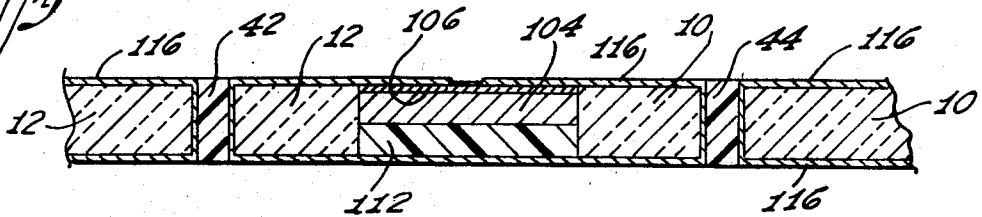
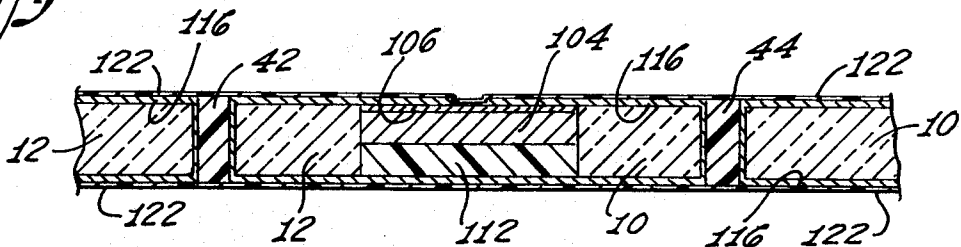


Fig. 12



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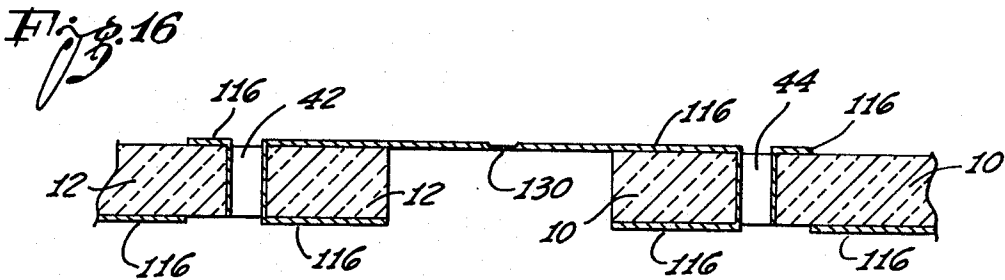
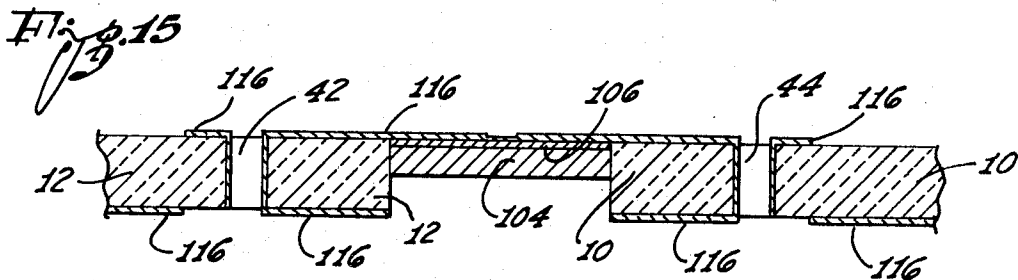
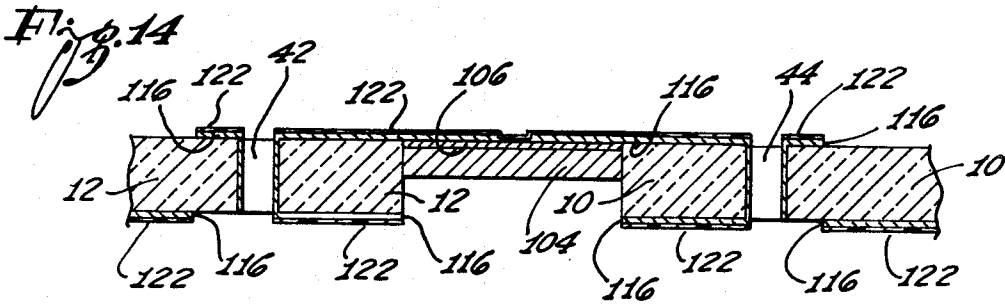
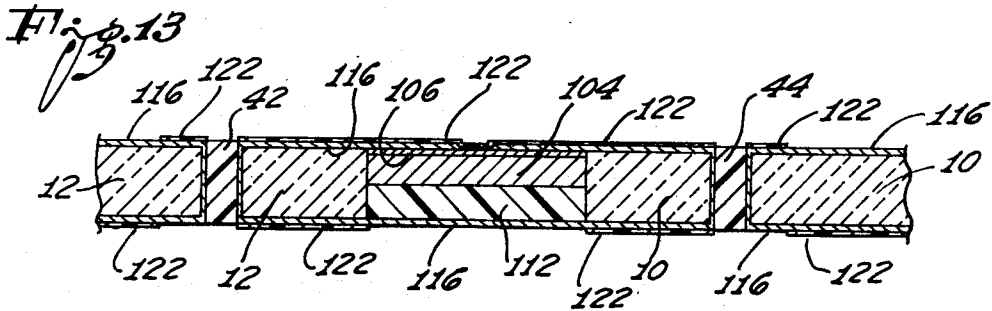
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5 Sheets-Sheet 5



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**ELECTRO-CHEMICAL METHOD OF PRODUCING THIN METAL FLEXURES**

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U.S. Cl. 204-3

12 Claims

**ABSTRACT OF THE DISCLOSURE**

A method or process for producing thin metal flexures, particularly of nickel, bridging a gap between two supporting members, particularly electrically insulating supporting members.

**SHORT DESCRIPTION OF THE INVENTION**

In accelerometers of the type shown, described, and claimed in U.S. Patent Application, Ser. No. 578,172, filed Sept. 9, 1966, for an "Accelerometer," by Robert E. Stewart, it is desirable to provide thin, substantially planar, metal as flexures or hinges between a relatively immovable portion of the device and a slightly rotatable portion of the device which is designated as the sensing mass. To provide those flexures with a minimum of hysteresis and creep, the process of this invention was conceived. It is of course obvious that, although the process was conceived to be used in a specific device, it may be used wherever thin metal flexures are desired in other devices.

Briefly, the process of this invention comprises the filling of at least part of the gap between two supporting structures, the deposition of a thin film across the gap between the two supporting structures, and removing the filled material leaving a thin film flexure bridging the gap between the two pieces of supporting material. Minimum resilience of the flexures is obtained by fabricating it of plated electroless nickel. The electroless nickel is plated onto the supporting structures and across the gap between them with a minimum of agitation and without interruption, whereby stresses in the plated material are minimized with resulting minimization of hysteresis effects and creep.

In the process of the invention, the substrate members are cleaned and mounted adjacent each other in their final position with a gap therebetween across which a metal flexure is to be fabricated. Copper is electro-plated between the two substrates, and a gold flashing is plated over the copper. The composite structure is then sensitized and activated to enable it to receive electroless nickel. Electroless nickel is then plated over the entire assembly. To make a portion of the electroless nickel of thinner cross-section, in the flexure region, the portion which is to have the thinner cross-section is masked off during a portion of the electroless nickel plating process. When the masking is removed to allow the thin cross-section portion to plate, the assembly must not be removed from the electroless nickel plating solution, nor should the solution be agitated. A photo-resist image is next applied and cured to the electroless nickel surface. After the photo-resist is exposed and developed, the unmasked nickel is chemically removed. The remaining photo-resist material is stripped off. The copper and gold is next chemically removed from the remaining structure, leaving a desired pattern of electroless nickel upon the substrates and bridging the gap between the substrates to produce a low resilience, low hysteresis, low creep flexure or hinge across the gap between the two substrates.

It is therefore an object of this invention to produce thin metal flexures or hinge members.

It is another object of this invention to produce thin metal flexures bridging a gap between a pair of supporting members.

It is yet another object of this invention to produce thin metal flexures between a pair of electrically non-conducting, separated, supporting members.

It is an important object of this invention to create a flexure or hinge across a gap formed by supporting substrates, in which hysteresis and creep are minimized in the flexure.

It is a more specific object of this invention to produce a thin metal flexure, substantially of electroless nickel, between a pair of ceramic like, separated, supporting members.

It is a specific object of this invention to provide a process or method for achieving the above enumerated objects.

Other objects will become apparent from the following description, taken in connection with the accompanying drawings, in which:

FIG. 1 is a profile view of two supporting members, separated by a gap, across which is displayed thin metal flexures produced in accordance with this invention;

FIG. 2 is a sectional view, taken at 2-2 in FIG. 1;

FIG. 3 is a sectional view taken at 3-3 in FIG. 1;

FIG. 4 is an enlarged view of the portion of FIG. 3 designated by the numeral 4;

FIG. 5 is a block diagram enumerating the steps of a typical process of the invention; and

FIGS. 6-16 are views which are useful in describing the various steps of the process of this invention.

In FIGS. 1-3 is shown a profile view of a pair of substantially coplanar members 10 and 12 which are separated by a gap which is radially directed at 14 and 16, which is circumferentially directed at 18, 20, 22 and 24, and which is chord-wise directed at 26 and 28. A pair of flexures or hinges 30 and 32, bridging the gap 14, and a pair of flexures or hinges 34 and 36 bridging the gap 16, are fabricated in accordance with the process or method of this invention. Additional metal electrode material 38, 40, and 54 may be fabricated at the same time, with the same process that is used to produce the flexures. Holes are shown in the supporting structures, or substrates 10 and 12 at 42, 44, 46, 48, 50, 52, into which electrical contacts are inserted or fabricated to contact electrically the flexures 30, 32, 34, and 36 so that the flexures may serve the double purpose of providing a hinge and an electrical conduction path across the gap separating the members 10 and 12.

A metallic film upon the member 10 in the circular region 54 may also have conductors (not shown) penetrating through the substrate member 10. The film in region 54 may be divided as desired, the particular division and electrical interconnection, not being part of this invention, are not particularly described. A central hole 56, which is used in the above mentioned accelerometer for centering purposes, is shown for convenience only.

An enlarged view of the section of FIG. 3 in the region of the numeral 4 is shown in FIG. 4. Typical dimensions, designated A, B, C, and D are: A=0.015 inch, B=0.005 inch, C=0.0012 inch, and D=0.0002 inch.

The main steps of the process of this invention are shown in FIG. 5. It is clear that each of the major steps may be varied and may include sub-steps as described in detail hereinafter. Further, it is clear that certain sub-combinations of steps, in themselves, are novel.

The process of FIG. 5 is described with the help of FIGS. 6 through 16 which are schematic in nature rather than being absolutely true sections of the finished device.

For example, where square corners are shown in FIGS. 6 through 16, the finished structure may be rounded.

Referring to FIG. 5, the substrate is first cleaned to remove all foreign substances. Next, the substrates are mounted onto a plating mandrel, the plating mandrel being preferably a flat piece of stainless steel. Next, a copper bridge is electroplated between the substrates. After a sufficient amount of copper has been electroplated to form a bridge, the remaining region between the substrates may, if desired, be filled with an epoxy. The exposed copper is next gold plated to protect the copper. The substrate surfaces are then sensitized and activated to receive an electroless nickel coating. After application of the electroless nickel coating, if desired, holes in the substrate may be filled or masked with an epoxy. A predetermined pattern is then applied to the electroless nickel by using, for example, photo-resist material which is cured, exposed, and developed. The unmasked nickel is then etched away by a chemical process. The epoxy and photo-resist material are then removed. Next, the copper bridge and gold flashing is removed.

The following detailed description of one embodiment of the process is not intended to limit the process, but is only typical.

Although the substrate material of the members 10 and 12 could be made from any inorganic or organic material having appropriate dielectric, mechanical and physical properties compatible with the process and use requirements, e.g. glass or filled epoxy, in a preferred embodiment, the substrate material is made of aluminum oxide.

The first step of the process is to remove foreign material from the substrate members. Obviously, if the substrate members are received without foreign material, such foreign material need not be removed. One could—for example—soak the substrate material in a suitable solvent such as acetone, to remove the foreign materials. It is preferable, however, to clean the substrate components ultrasonically in acetone for a nominal or typical time duration of, for example, one minute.

To continue the cleaning cycle, the substrate is next rinsed in running water, preferably de-ionized water, and preferably on the order of at least 30 seconds. When used herein, the phrase "water rinse" is preferably, although not necessarily, with de-ionized water.

To remove organic and metallic compounds—for example, carbonaceous materials deposited from diamond drills during a machining process—the two substrate members should next be leached in aqua-regia for the necessary time to remove the foreign materials, for example, one-half hour. Obviously if the substrate components contain no organic or metallic compounds, the leaching step is not necessary.

The aqua-regia and sludge materials are then removed by water rinsing, preferably with de-ionized water, for a sufficient time, e.g. 30 seconds.

The substrate members should next be dried, they may, for example, be dried by air drying or, alternatively, a good uncontaminated towel, particularly one which was not impregnated with silicone material, may be used to pat the substrate members gently to dryness.

The substrate members are then "roasted" in a furnace in an air atmosphere at a temperature on the order of 1200° F. for a period on the order of one-half hour. The substrate components, for example, may be placed in a ceramic or glass boat at room temperature before loading into the hot furnace. After the roast, the boat is taken out of the furnace and the substrate is allowed to air-cool to room temperature. Thus, the cleaning step is completed.

The two substrate members 10 and 12 are next mounted in position (for example, by means of a jig or fixture not shown) upon a flat plating fixture or mandrel 100, as shown in FIG. 6. The plating mandrel's surface should be scratch-free and polished to a mirror finish. The plating mandrel 100 may—for example—be made of stainless steel which has the characteristics of being electrically con-

ductive while still allowing the plate to be freely stripped from the smooth surface of the fixture 100. The polishing of the surface of the fixture 100 may be accomplished—for example—by the use of an aluminum oxide polish. The holes 42 and 44 are plugged so that the interior thereof is not plated during the next successive step of electroplating a copper bridge between the substrates.

To electroplate a copper bridge between the substrates 10 and 12, a sheet of copper 102, the plating mandrel 100, and the substrates 10 and 12 are inserted into an electroplating solution. The two electrodes of the plating operation, the mandrel 100 and the copper anode 102, are electrically connected to a source of plating current. The copper anode 102 is positioned to provide a substantially uniform throw into the region between the substrates 10 and 12. During the plating process, it is desirable to agitate the bath slowly.

A typical plating bath is a copper sulfate bath, together with supplementary materials, as known in the art, to maintain a desirable acid balance. A plating solution having micro throwing power (i.e. an ability to fill small holes) is preferred. A typical plating current which is desirable is on the order of twenty amperes per square foot of surface to be plated. It is desirable to mask off exposed conductive surfaces of the plating mandrel 100 and lead wires by using a white epoxy paint. The bath temperature, typically, should be on the order of between 70 and 80 degrees Fahrenheit. The rate of deposit is preferably on the order of 3 mils of thickness per hour of plating.

In the plating operation, a good commercial grade of white epoxy paint for masking off portions of the plating mandrel 100 is mixed in the ratio of 100 parts resin to 6 parts catalyst. The paint should then be air cured at 210° F. preferably for at least 15 minutes so that the plating solution is not contaminated by the epoxy paint. The plated-on copper, bridging the gap between substrates 10 and 12, is shown at 104 in FIG. 7.

The portion of the region between substrates 10 and 12, which is not filled with copper may next be filled with a masking material, such as an epoxy 112. This step is optional and is inserted to simplify the process. The epoxy used may be the same types as the epoxy paint mentioned above. The epoxy is cured—for example—for 15 minutes at a temperature of 210° F. It is obvious that the time duration of curing and the curing temperature depends upon the particular epoxy which is used. The surfaces of the substrates, next to the epoxy, are then sanded to remove excess epoxy. A coarse (180–320) sandpaper with medium pressure may be used until all traces of excess epoxy are removed.

The composite structure of FIG. 7 is removed from the mandrel 100 by sliding it. The resultant composite structure is sufficiently strong to be handled. It should not be pried from the mandrel 100 because of danger of loosening the bond between the copper 100 and the substrate members 10 and 12.

After removal of the composite of the substrates 10 and 12 and the copper bridge material 104, an optional step is to lap both sides of the substrates 10 and 12 to make them flatter. For example, a 15 micron diamond disc could be used, taking care to lap the hinge side of the substrate last. Typically, the flatness should be to a tolerance of—for example— $\pm 50$  micro inches. The hinge side, mentioned above, is the side of the composite with the copper bridge 104 level with the surfaces of the ceramic members 10 and 12.

If the substrates are to be lapped flat, it follows that the copper bridge will also be lapped flat. However, the 15 micron diamond disc is too coarse for the copper material. The copper material should then be smoothed or dressed using—for example—a 600-mesh carbide paper until all of the scratches from the lapping operation are removed from the copper bridge 104. The direction of final dressing of the copper bridge 104 is preferably perpendicular to the parallel straight segments of the copper

bridge, i.e. is across the bridge. During the dressing operation, no organic lubricants should be used because of the danger of contamination of the continuing steps of the process. Water may be used as a lubricant, if desired.

If a lapping dye is used it should be removed. Removal of the dye may be accomplished by soaking the composite member in an acetone solution until any excess dye is removed. The composite structure is then rinsed in de-ionized water to remove the acetone.

To prepare the composite member, including the substrates and the copper bridge for the application of a gold plate, the composite is next scrubbed in a hot detergent solution until both sides of the substrate are hydrophilic. An excellent cleaning solution is a 140° F. solution made up of one part water and one part detergent.

The composite structure is then rinsed in de-ionized water to remove the detergent and to observe the wetting of the surface to determine if it has been adequately cleaned to make it hydrophilic.

To activate the copper to make it susceptible to gold plating, the composite structure is next dipped into a one part hydrochloric acid and one part water solution. Typically, the dipping time is on the order of 15 seconds.

The composite structure is then rinsed in de-ionized water to remove excess hydrochloric acid.

The copper bridge 104 is next plated with gold, as shown at 106 in FIG. 8. It should be noted that the composite structure of substrates 10 and 12 and gold bridge 104 is inverted, for convenience, in FIG. 8. As a practical matter, it is likely that the actual configuration during the gold plating process would be as shown in FIG. 8. The gold plating process uses a platinumized metal screen anode 110 and any standard gold plating solution with agitation. The hinge side of the substrates 10 and 12 is positioned substantially parallel to the anode 110 at a distance—for example—of approximately one-half inch. The cathode lead is attached to the copper 104 at some non-critical point, i.e. at a point outside of the hinge region. The cathode lead is typically attached by means such as alligator clip to the copper bridge 104 at a point approximately midway on one of the arc segments of the bridge. The thickness of the resulting gold plate is a mirror flash, i.e. a few millionths of an inch thickness. A typical thickness would be on the order of 20-millionths of an inch. The plating current density is on the order of one-half ampere per square foot at a recommended bath temperature of 140° F. The time required for a typical gold flash is on the order of 12 minutes under these specified conditions. After six minutes of plating, the cathode contact should be moved to another point—for example, the mid point of another arc segment—of the bridge. After completing the gold plating, the entire structure is rinsed with de-ionized water to rinse off the plating solution.

The entire structure is then dried by hanging it in a re-circulating air oven at a temperature—for example—of 210° F. for a time duration on the order of 15 minutes. The purpose of the raised temperature drying is to remove excess water from the pores of the structure.

The next step in the process is to sensitize and activate the surface of the substrate. To sensitize the primarily ceramic surface, the composite is immersed in a stannous chloride solution for at least three minutes. A typical sensitizing solution uses 20 grams of stannous chloride, 40 milliliters of hydrochloric acid, and sufficient water to fill out a 2,000 milliliter solution. The range on the values just recited is  $\pm 20$  percent. The solution should be kept fresh and is preferably changed every 24 hours.

The composite is then rinsed under a direct stream of running de-ionized water for at least one minute to remove the chlorine ions and excess solution. To avoid oxidation of the tin ions, the composite is immediately activated.

To activate the surface, the composite is immersed in a hot (on the order of 140° F.  $\pm 5$ ° F.) palladium chloride solution for 15 seconds. A typical activating solution

(with  $\pm 10\%$ ) is 0.1 gram of palladium chloride, 5 milliliters of hydrochloric acid, and sufficient water to fill out 2,000 milliliters of solution.

It is important that excess solution next be removed. This may be done by rinsing the composite under a direct stream of running de-ionized water for at least two minutes ensuring that all surfaces and holes are exposed to the direct stream.

The composite is then dried using uncontaminated towels (particularly without silicone) and patting the composite gently to dryness. The composite should be dried at room temperature.

The composite should next be placed in its plating fixture and the electroless nickel deposition process should be started immediately. A freshly honed stainless steel blade 114 (see FIG. 9) is positioned against the gold flashing 106 in a position to bisect the gold plated bridge between substrate members 10 and 12 in the hinge region of the bridge 104. The proper cross section of the blade is the dimension B of FIG. 4. The entire composite, with the blade 114 masking off a portion of the gold flashing 106, is placed in a fixture for immersion in the electroless nickel plating solution. The steel blade acts as a mask to prevent deposition of nickel until after the blade is removed. In this fashion, a bridge of controlled dimensions and reduced section is formed.

A typical sulfamate electroless nickel plating bath composition which has been found to give the best results is prepared as follows:

Place 1000 milliliters of de-ionized water into a 2000 milliliter beaker stirring in 72 milliliters of filtered concentrated nickel sulfamate solution (on the order of 150 grams per liter of nickel ions), 28 grams of succinic acid disodium salt, 32 grams of lactic acid, and 48 grams of sodium hypophosphite. A one percent weighing error is allowed. Stirring should continue for on the order of 5 minutes during which additional de-ionized water is added to bring the total solution level to substantially 1800 milliliters. The pH of the plating bath is adjusted to 4.5 ( $\pm 0.1$ ) by adding a one part ammonium hydroxide to one part water solution. The bath is then filtered using number 40 paper. Additional de-ionized water is then added to make the total volume 2000 milliliters. On the order of 36 drops of organic wetting agent are then added and stirred or shaken into the solution.

The plating solution is maintained at 190° F.  $\pm 2$ ° F. while the composite is plated for three hours. The bath is brought to temperature just prior to introducing the fixture and the composite for plating in order to control the pH and the temperature of the bath in a proper manner. The fixture and composite, with the masking blade 114 attached, should be placed into the plating solution with the hinge side down as shown in FIG. 9. The hinge side should also be positioned close to the bottom of the bath tank for example, 1 inch) and maintained in a horizontal position. In this position, hydrogen bubbles are properly released without affecting the plating in an adverse manner. During the three hours of plating (the length of plating depends upon the desired thickness) the bath and fixture should not be disturbed in any manner. The knife blade or masking fixture 114 is then removed. During the removal of the knife blade, the composite must not be removed from the plating solution, for if it is removed from the plating solution boundary layers form which affect the creep and hysteresis of the flexure.

At the time the blade 114 is removed, a test sample may be placed with the copper side up into the plating solution, positioned so that the bubble stream from the test sample does not interfere with the plating of the substrate. To minimize heat loss during the removal of the knife blade and the insertion of the test sample, the removal and insertion should be accomplished as rapidly as possible. It is not essential that a test sample be used. If used, the test sample is merely a device for observing the thickness



of plating without having to remove the composite from the plating solution.

The plating is continued for an additional 45 minutes. The times of these platings, i.e. the three hour time and the 45 minute time are those which have been found necessary for the specified thicknesses C and B of FIG. 4. Upon completion of the plating schedule, the composite is removed and immediately plunged into a solution of hot water at 190° F. Thus, thermal shock is avoided, and consequent stress build up in the metal and between the substrate and metal is minimized. With the time of plating specified as above, the dimension C of FIG. 4 is on the order of 0.001 inch, and the dimensions of B of FIG. 4 is on the order of 0.00025 inch. The composite plated member, with the plated on electroless nickel **116** is shown in FIG. 10. The electroless nickel covered composite is then lightly dressed on the front and back sides with 600 mesh silicon carbide paper to remove any plating nodules.

The entire composite is then cleansed using hot one part detergent to one part water solution until both surfaces of the composite are hydrophilic. The composite is then rinsed in a de-ionized water to remove the detergent solution and to observe the hydrophilic action.

A photo-resist image is then applied to, cured, exposed, and developed on the nickel surface **120**. In a safe light area, e.g. a yellow light area, the composite is sprayed with a photo-resist film. A typical photo-resist film is made from a solution mixed in the ratio of 4 parts of photo-resist polymer to 5 parts thinner. Spraying is usually accomplished by holding the gun nozzle approximately 5 to 6 inches from the composite and by utilizing a fine spray and sweeping motion. A glossy coating is evident at the time of a second spray pass. The spraying should be discontinued immediately when the glossy surface appears. Still under safe light conditions, the composite is air-dried at room temperature for on the order of 30 minutes. The photo-resist coating is then cured by baking. The pre-dried composite is placed in an oven at 120° C. and baked for on the order of 30 minutes. The composite is then removed, still under safe light conditions, and air cooled to room temperature. Obviously the time of baking and temperature depends on the particular photo-resist material which is used, and the manufacturer's recommendations should be followed.

Still observing safe light conditions, the composite is placed in an exposure fixture with overlying artwork film which has a predetermined pattern. The loaded fixture is then transferred to a vacuum system and is placed in an evacuated atmosphere after which it is exposed to an appropriate light source. Typically the light source is a long wave ultra violet light source which is placed on the order of 3 inches above the fixture, and the exposure time is typically on the order of ten minutes. After one side has been exposed, the composite is turned over and a second predetermined pattern of artwork film is placed on the other side of the composite. The other side is then exposed in a vacuum with the long wave ultra violet light. As soon as possible after exposure, the photo-resist coating is developed using the appropriate developer and a spray gun adjusted to deliver a fine spray. Both sides of the composite should be given a general initial spraying. Then proceed by concentrated spraying first on one side and then on the other until the patterns have cleanly developed. As soon as the patterns are cleanly developed, immediately rinse the composite under a gentle stream of de-ionized water so that the patterns will not over develop.

The developed photo-resist pattern is then cured by hanging the composite in an oven at about 120° C. for on the order of 20 minutes, then air cooling it. During the curing, the flexure should be suspended from an appropriate hanger, such as light gauge copper wire.

To protect the holes, the holes are painted over with epoxy ink and are hanged in an oven at 100° C. for 10 minutes to cure the epoxy. The composite is then removed and allowed to air cool.

The nickel not protected by the photo-resist is next chemically removed from both sides of the composite part. A typical nickel removing solution comprises 110 milliliters of water, 125 milliliters of nitric acid and 15 milliliters of hydrofluoric acid. The tolerances on these values are approximately  $\pm 10\%$ . The composite part is immersed in the nickel removing solution and the solution is agitated. When any hinge edge is exposed, that edge should be carefully burnished, exercising caution to avoid damaging the hinge. The etching-burnishing procedures should be repeated until all hinge edges have been burnished. Then continue etching until the remaining exposed nickel is completely stripped. Immediately plunge the composite part in de-ionized water and neutralize it in a calcium carbonate solution. The remaining calcium carbonate solution is then washed off with de-ionized water.

The remaining photo-resist and epoxy masking is next removed. The epoxy masking is removed by soaking the epoxy in an epoxy stripper material for approximately 5 minutes or sufficiently long to soften the epoxy material, after which it may be removed mechanically. Next, the composite is immersed in a photo-resist developer until the remaining photo-resist material strips readily with the aid of a cotton swab from the composite part. Finally, using a fine gauge wire, any remaining epoxy paint is removed mechanically from the holes.

The composite part is then cleaned using a hot (on the order of 140° F.) one part detergent to one part water and a cotton swab. The composite part should be scrubbed until all surfaces are hydrophilic. The entire composite part is then rinsed in de-ionized water to remove the detergent solution.

The composite part is shown in FIG. 14 with the excess nickel and epoxy material removed, but before the remaining photo-resist material is removed.

FIG. 15 shows the composite member after the photo-resist material is removed.

The copper bridge **104** is next removed by placing the entire composite part in a fixture (to hold it rigid) and immersing the composite part in an etching solution with stirring, for example, approximately 45 minutes until the copper is completely removed. A typical etching solution contains a mixture of ammonium hydroxide and sodium hypochlorite. The composite part is placed in the fixture with the hinge side down to permit inspection of the degree of copper removal of the copper bridge **104**.

With the composite part still in the fixture, the part is immersed in a gold stripping solution, of cyanides to remove the gold flashing **106**. The gold stripping solution is on the order of 140° F. and the solution is gently stirred while removing the flashing **106**. Caution should be observed when removing the composite part to avoid damage to the flexure due to the surface tension of the fluid.

The composite part is then rinsed in de-ionized water by gently immersing it in the de-ionized water.

The composite part is then gently dried by immersing it in ethyl alcohol and allowing it to dry in the air. The resulting part is shown in FIG. 16, with the fragile flexure area designated at **130**.

Thus, the process of this invention comprises the creating particularly by electroplating, a temporary bridge between a pair of spaced-apart dielectric substrates; building a metal flexure, particularly of electroless nickel, upon the bridge and the substrates; and removing the temporary bridge. It is a further important feature that the entire deposited flexure be fabricated without interruption to prevent the forming of internal discontinuities in the metal and therefore to minimize creep and hysteresis in the flexure.

Although the invention has been described in detail above, it is to be stressed that the invention is not to be

limited by that description, but only in accordance with the following claims:

What is claimed is:

1. A process for building an electroless metal flexure across a gap between a pair of electrically non-conducting substrates comprising the steps of:

mounting said substrates onto an electroplating mandrel;

creating a temporary bridge between said substrates by electroplating bridge material between said substrates;

plating a metal onto at least a portion of at least one surface of said substrates and onto at least one surface of said bridge material by electroless deposition; and

removing, by chemical means, said bridge material; thereby forming an electroless metal flexure across said gap.

2. The process of claim 1 and further including the step of sensitizing the surface of said substrates, at least in a region immediately adjacent said gap, to receive the electroless coating of said metal prior to the plating by electroless deposition step; and said plating by electroless deposition step includes electroless plating said metal upon said sensitized portion of said substrate and across the bridge material between said substrates.

3. The process of claim 1 wherein said bridge material is copper.

4. The process of claim 3 wherein said metal plated by the electroless deposition is nickel.

5. The process of claim 4 wherein said step of removing the bridge material includes chemically removing said temporary bridge.

6. A process for creating a metallic flexure across a gap between a pair of electrically non-conducting substrate members comprising the steps of:

mounting said substrates onto an electroplating mandrel;

electroplating bridge material between said substrates; plating a protective flashing onto the exposed surfaces of said bridge material;

sensitizing and activating selected portions of the surfaces of said substrates to receive an electroless nickel coating;

plating said assembly, including said flash-covered bridge material, with electroless nickel;

applying, curing, exposing, and developing a photo-resist image onto the surface of said nickel;

removing, by chemical means, the portions of said nickel which are not covered by said developed photo-resist material;

removing excess masking and photo-resist material; and removing said bridge material and flashing material to leave said electroless nickel material in predetermined positions including across said gap.

7. A process as recited in claim 6 in which, during the step of deposition of said electroless nickel, a portion of said bridge surface is masked for a portion of the time of said electroless nickel deposition;

in which said last named mask is removed, during the

continuous deposition of electroless nickel plating, to allow a thinner deposition of electroless nickel to be deposited in the region where said mask has been removed.

8. A process for creating an electroless nickel flexure across a gap between two separated pieces of dielectric substrate comprising the steps of:

mounting said substrates onto a plating mandrel;

electroplating a copper bridge between said substrates; gold plating the exposed surface of said copper;

sensitizing and activating the surfaces of said substrates; plating the assembly with electroless nickel;

applying, curing, exposing, and developing photo-resist material into a predetermined image onto the surface of said nickel;

chemically removing the unmasked nickel;

stripping said photo-resist material; and

chemically removing said gold and copper bridge.

9. A process as recited in claim 8 in which during the step of plating electroless nickel, a portion of the bridge across said gap is masked to prevent electroless nickel deposition; and

during the uninterrupted deposition of said electroless nickel, removing said mask to allow a thinner film of electroless nickel to be deposited in the region of said removed mask.

10. A process as recited in claim 9 in which, between the step of electroplating a copper bridge between said substrates and the step of gold plating of the exposed surface of said copper, the non-plated region of the gap between said substrates is filled with masking material and at least the side of said substrates adjacent said bridge and said bridge are polished; and

wherein between the step of plating the assembly with electroless nickel and the step of applying, curing, exposing and developing photo-resist material into an image onto said nickel surface, all holes are filled with a masking material.

11. A process as recited in claim 10 in which said last named masking material is an epoxy.

12. A process as recited in claim 11 in which, before the recited steps of the process, said substrates are cleaned; and

between steps of said process, residues left from preceding steps are removed.

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