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METHOD OF MAKING SEMICONDUCTOR UNITS AND THE LIKE

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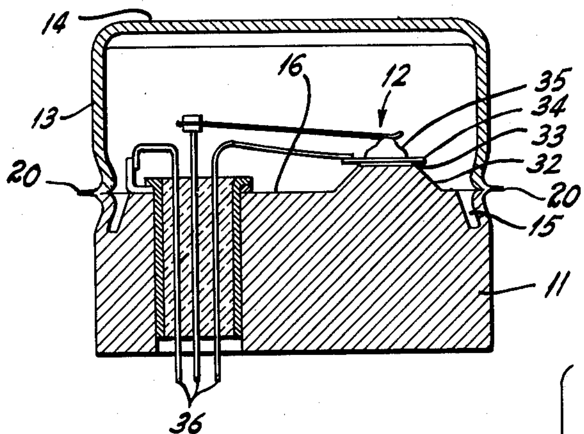


FIG. 1.

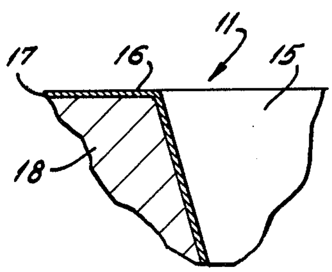
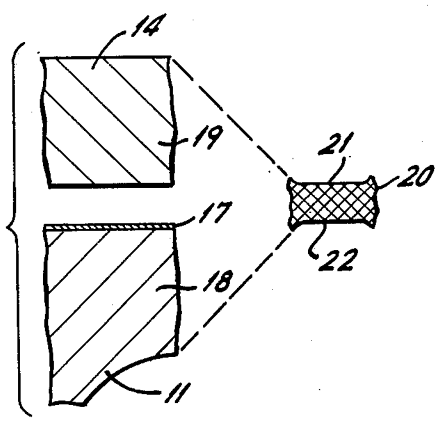


FIG. 2.

FIG. 3.



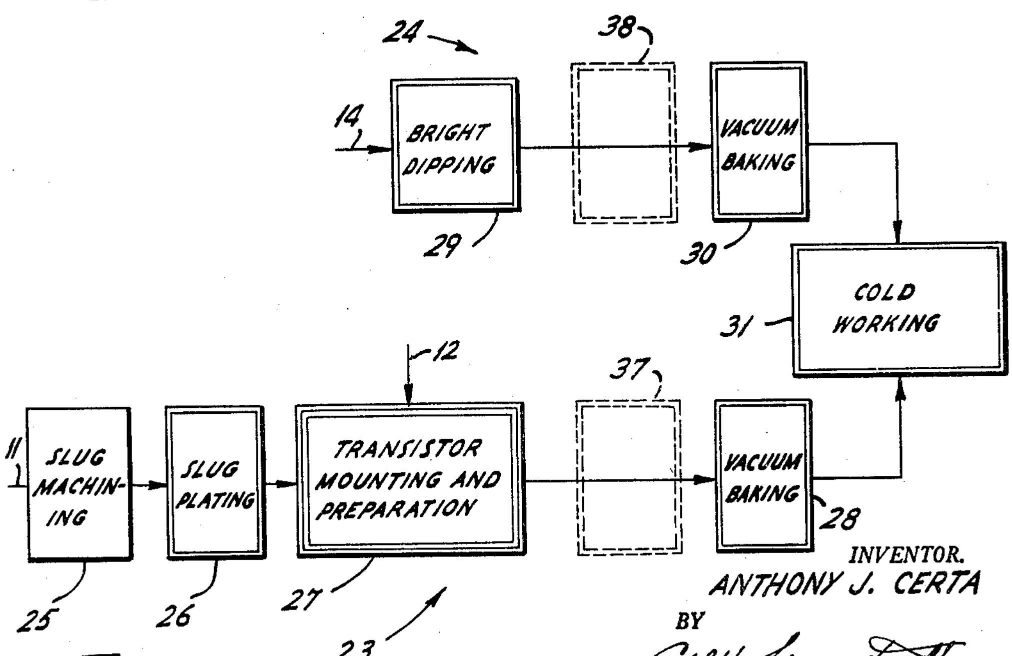


FIG. 4.

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METHOD OF MAKING SEMICONDUCTOR UNITS AND THE LIKE

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9 Claims. (Cl. 29—155.5)

This is a continuation-in-part of parent application Serial No. 620,822 filed November 7, 1956, now abandoned.

This invention pertains to a metal-working method. It has been developed in connection with problems of the fabrication of encapsulated semiconductor units of the power transistor type; but the invention relates more broadly to operations for strongly joining metallic members to one another. It includes a novel and characteristic utilization, in a cold-working process, of a generally known, plating treatment of metallic parts.

A specific object of the invention is connected with the encapsulation of delicate devices between metallic members; and still more particularly, the invention is concerned with mass-fabrication of the product. At least one of the encapsulating members, which also serves as a mounting member for the device to be encapsulated, is plated with a special, chemical-resistant substance on surfaces which include a peripheral joint area; and the members can then be effectively joined together without the conventional but difficult scratch-brushing, by cold-welding said area to an opposite area of the other member. The entire fabrication of small and delicate devices, such as semiconductor units, is greatly facilitated by this procedure; yet the strength and the sealing effects of the joints produced can be at least as good as those heretofore available.

A second specific object is to provide for the fabrication, including the hermetic encapsulation, of highly effective and dependable electronic devices, by a novel sequence of batch-continuous operations and the like, involving a minimum of time loss and complexity in connection with set-up procedures. Thus the method makes the difficult processes of producing said devices at least relatively simpler and thereby cheaper, mainly in their mass-fabrication.

These and other objects, which will appear from the following description, have been achieved by providing a metallic structural or encapsulating element, prepared for cold-welding by plating it with a certain type of phosphorus-containing nickel, and by cold-welding this element to another metallic element which may be prepared for such cold-welding by a variety of procedures. Formerly, it was necessary for effective cold-welding to use, in association with one another, two metallic elements both of which were treated by scratch-brushing directly before cold-welding.

A typical form of elements joined by the new method with associated parts is shown in the drawing, wherein:

FIGURE 1 is an enlarged cross-section of a typical semiconductor encapsulated by the new method. FIGURE 2 is an additionally enlarged, fragmentary, cross-sectional view of an encapsulating mounting element. FIGURE 3 is a similar view of encapsulating flange elements, these flange elements being shown in the left hand portion of the figure as they appear prior to the encapsulation process, and in the right hand portion of the figure as they appear pursuant thereto. FIGURE 4 is a block diagram of a process for fabricating semiconductor units, according to this invention.

Before the new method is described, reference may best be made to the completed semiconductor unit illustrated in FIGURE 1. In this unit a cold-worked flange structure 20 joins a peripheral part of a "slug" 11, a central part of which has a power transistor 12 thereon, with the wall 13 of an overlying "hat" 14. The slug provides a relatively large thermal mass of high conductivity to dissipate heat, generated during the use of the transistor. Both the slug and the hat desirably consist of oxygen-free high conductivity copper. The encapsulation of the transistor may be facilitated by an annular groove 15, machined into the transistor-mounting surface 16 of the slug, adjacent and concentrically with the flange structure 20, as more fully explained in Patent Number 2,932,684 of Kenneth R. Hales and Harry E. Godshall, which patent is assigned to the assignee of the present invention.

The present invention relates to the preparation of the elements of such and similar flange structures 20, for the cold-working thereof.

A small portion of a suitably prepared top surface 16 of slug 11, including a small portion of the groove 15, is shown in FIGURE 2; and it will be noted that the surface is provided with a plated surface layer 17. This layer consists of so-called "electroless nickel," that is, nickel containing from about three to about eleven percent of phosphorus, preferably the higher amount, such material probably containing phosphorus as a dissolved nickel-phosphorus compound, and being applied to the copper by chemical procedures, not including electro-plating.

Heretofore, preparation for the cold-working of similar structures was generally effected by scratch-brushing both members to be joined: slug 11 and hat 14. Various attempts had been made to effect satisfactory joints for transistor casings and the like by simpler methods; for instance, only to clean the metal of slug 11 or hat 14 by a procedure such as that known as "bright-dip," that is, the application of a mixture of materials such as sulphuric acid, nitric acid, hydrochloric acid and water. However, joints of poor quality according to transistor standards were then obtained; and such was the case even if one or both of the metal surfaces to be joined were coated or plated with various protecting substances, or treated by bright-dipping or the like; even if the cold-welding followed immediately after such coating or dipping, difficulty was encountered. It was therefore assumed to be necessary and was accepted as conventional practice, to prepare for the cold-welding by scratch-brushing of the metal surfaces to be joined.

This was inconvenient for several reasons. For instance, when semiconductors were encapsulated by such processes, they had to be protected from contact with waste products of the scratch-brushing operation. In all cases the scratch-brushed flange metal surfaces had to be joined together by a squeezing operation very promptly after the scratch-brushing, to avoid renewed oxidation of metal; and in the fabrication of delicate devices, this was another requirement which interfered seriously with expediency and efficacy, mainly in mass production.

These difficulties are entirely avoided by plating at least one of the metal members to be joined, in transistor fabrication at least the flange area of the slug 11, with electroless nickel. For one thing, this allows the use of a relatively simple protective treatment, such as bright-dipping, on the other member. In addition it eliminates the necessity of "immediate" performance of the cold-welding treatment, as to the electroless nickel plated part.

The electroless nickel coating 17, as originally applied in the region of the flange structure 20, and elsewhere on top surface 16 is clearly visible in FIGURES 2 and 3. On the other hand I have found, and have indicated in FIGURE 3, that the layer 17 substantially disappears from this region, incident to the application of the cold-working forces which intermingle the particles of the original copper layers 18, 19 of the slug 11 and hat 14.

FIGURE 3 is limited to illustrations, before and after the joining process, of metal portions which are forcibly squeezed in this process. A more complete sectional representation of the flange structure 20, including portions thereof which are deformed in particular ways, may have, for instance, either of the forms shown in the Hales-Godshall patent mentioned above. The original total thickness of this structure (left hand portion) may in a typical example amount to about .03"; it may be locally reduced (right hand portion) to a fraction thereof, such as about .004". The flange structure 20 so produced is substantially homogeneous, from a top surface 21 to a bottom surface 22 thereof. This structure 20 comprises intermingled copper particles of both original flange bodies 18, 19, as schematically indicated by double cross hatching; and the actual metallic cross-section of body 20, which can be seen if a semiconductor unit is destroyed for purposes of inspection, shows the appearance of metal of the type known as mingled by cold-working. No separation between original flange elements is recognizable, even on strong magnification of the sectioned surfaces. Likewise, so far as appears on observation with magnifications up to almost 1000 diameters, no visible trace of the coating 17 of phosphorus-containing nickel remains in the mingled copper 20. On the other hand the original coating 17 is readily recognizable everywhere, in metallic cross-sections of the original copper slug, as diagrammatically represented in FIGURES 2 and 3.

As mentioned above, I have found that the application of a chemical bright-dipping procedure, shortly before the sealing operation, is satisfactory for the member to be joined to the electroless nickel plated member; particularly to the hat 14. If desired, this member may also be scratch-brushed immediately before cold-welding, or it may be plated with electroless nickel at any time.

A hermetic seal is obtained by properly squeezing a nickel-phosphorus plated and otherwise untreated copper flange 18, together with a copper flange 19 similarly prepared or freshly bright-dipped or scratch-brushed. No such seal, as mentioned, was obtained by merely squeezing two freshly bright-dipped flanges, or two flanges freshly scratch-brushed and bright-dipped respectively.

It should thus be understood that, in a broad sense, the present method may involve the use of nickel-phosphorus plating 17 either on the flanges of the slug 11 alone, with bright-dipping of the hat 14, as is preferred, or the use of such plating on the flanges of the slug 11 and of the hat 14, among other variations.

The practical significance of the former scratch-brushing problems and of their elimination by this invention may be explained additionally in connection with FIGURE 4. In this view, 23 designates a series of fabricating stations for the preparation of and work upon the copper slugs 11, while 24 designates a similar but simpler sequence of fabricating stations for the copper hats 14. Four basic fabricating stations from the line 23: station 25 for machining slugs 11 and mounting certain connector parts thereon; station 26 for electroless nickel plating of the slugs; station 27 for mounting and preparing the transistors 12 on the plated slugs 11; and—without intervening scratch-brushing—station 28 for vacuum-baking the slugs and transistors. Correspondingly the line 24 has a station 29 for bright-dipping hats 14—in lieu of scratch-brushing; and a station 30 for vacuum-baking the bright-dipped hats. Immediately after the vacuum-baking 28, 30, the two lines merge in a cold-working station 31.

around the stations 26, 28, 29 and 30 that high precautions must be applied at those points. A triple line frame around station 27 indicates the necessity of relatively extreme precautions for providing each slug 11, and particularly a pedestal 32 on its surface 16 (FIGURE 1), with a transistor 12 comprising a thin collector 33, a blank 34 of germanium or the like, and an emitter 35, so as to properly connect the emitter and collector, directly or indirectly, with lead wires 36 previously installed on the slug in station 25, and for finally preparing the transistor by certain cleaning operations and the like. For these purposes the transistor assembling, mounting and preparing station 27 must be operated under strict control; and this again, is best achieved by running station 27 as a batch-series operation, wherein a predetermined number of slugs 11, suitably mounted, are initially received and are then successively operated upon, under strictly controlled operating conditions as to atmosphere and the like. This results in the gradual production of a corresponding batch of semifinished slug and transistor combinations. This latter batch, according to the present method, can be transferred directly and readily into the vacuum-baking station 28, which may provide most effectively a plain batch operation.

Heretofore, as mentioned, a scratch-brushing treatment was applied for the supposed elimination of metal-contaminating impurities interfering with the cold-working to join the prepared slugs 11 to the prepared hats 14. This scratch-brushing had to be performed at a point 37 between the transistor mounting and preparing 27 and the vacuum-baking 28 of the prepared transistors; it being necessary to perform the vacuum-baking directly before the final stage 31 of the encapsulating process. It was impossible to perform the scratch-brushing 37 on slugs 11 mounted as in station 27, as each slug practically had to be rotated about its axis. On the other hand it was prohibitive, as indicated, to store the scratch-brushed units in contact with atmospheric oxygen or the like for any length of time. Thus it was necessary in the operation 37 not only to specially protect each sensitive transistor 12 from the waste products of the brushing but also to specially protect the entire batch of units by providing an added station, protected by an inert atmosphere or the like. Still further, as mentioned, the scratch-brushing had to be extended also to the hats 14.

All these requirements and complexities inherent in or connected with station 37 are completely eliminated by the present procedure. In fact the scratch-brushing operation 37 itself, and all steps auxiliary thereto, are omitted and, in line 24, a corresponding change and simplification becomes possible by the use of bright-dipping 29 instead of scratch-brushing 38. Storage of the prepared slugs 11, even in an oxygen-containing atmopshere, becomes possible, between station 26 and any successive station. Nevertheless, the encapsulated units produced by the present method are amply as sound, from the start, and amply as safe against subsequent contamination, as were the units produced by the much more complex, earlier methods.

Because of the above-mentioned disappearance of the nickel phosphorus layer from the region of commingled copper 20, which was observed even under strong magnification, I believed for some time that the nickel phosphorus compound alloys with the copper. I briefly stated this belief in my above-identified, original application.

Later I was able more thoroughly to analyze metal seals produced by this method, using extremely high magnification (e.g. more than 1000 diameters). I then determined that no such alloying takes place. It rather appears that the above-described application of cold-working results in fragmentation of the electroless nickel phosphorus layer 17 of FIGURE 3. Minute particles of this layer became visible in the mingled metal 20 of FIGURE 3, right hand portion, on application of said extremely high magnification.

I then also noted that the minute particles of phosphorus-containing nickel, which became present in the commingled portions of ductile metal 20 of FIGURE 3, are widely separated by such metal. Thus it now appears that the method steps, indicated herein, result in breakage of the layer of phosphorus-containing nickel, converting such layer into minute fragments which become separated and which accordingly seem to be driven into and through the metal by the cold-working process.

In the light of these newly discovered effects I now believe that the remarkable success of the method of my invention can be explained by concluding that, when driven through the ductile metal, fragments of layer 17 disturb such metal. The formation of an intimately mingled mass of metal constituents, with consequent establishment of a truly hermetic seal, seems to occur by virtue of such disturbance of the metal.

While only a single embodiment of the invention has been described, it should be understood that the details thereof are not to be construed as limitative of the invention, except insofar as set forth in the following claims.

I claim:

1. In the fabrication of hermetically enclosed semiconductor devices and the like: plating metallic flanges of mounting elements for such devices with a phosphorus-containing metal; securing said devices to such mounting elements; cleaning similar flanges of a batch of cover elements, so as to expose substantially pure metal thereof; immediately upon such cleaning of the cover flanges, vacuum baking the cover and mounting elements; and immediately upon such baking, cold-working plated, vacuum baked flanges of mounting elements, together with juxtaposed, cleaned, vacuum-baked flanges of cover elements, so as to intermingle metal portions of the juxtaposed flanges.

2. In a fabrication as described in claim 1, the feature that said mounting elements are metallic slugs having surface grooves concentric with their flanges, and wherein said cold-working displaces part of said metal portions into said grooves.

3. A method of hermetic, non-contaminating encapsulation of semiconductor devices and the like, comprising the steps of: plating annular flanges of metallic base elements for such devices with a phosphorus-containing metal; mounting said devices on such base members; bright-dipping matching flanges of housing elements formed of substantially pure copper, so as to expose the substantially pure copper of the latter flanges; and immediately thereupon joining plated flanges of base elements having said devices mounted thereon, to bright-dipped flanges of housing elements by compressing and thereby intermingling plated and bright-dipped metal portions of the respective flanges, at sufficiently low temperatures thereof to prevent evaporation of any portions and traces of such materials.

4. In a method as described in claim 3, performing said plating with electroless nickel.

5. In the hermetic, non-contaminating encapsulation of a semiconductor device: plating metal support means for said device, including a ductile metal flange of said support means, with a corrosion-resistant, phosphorus-containing metal; mounting the device on the plated support means; disposing a ductile metal flange of a cover means opposite the plated support means; and then cold-working said flanges, without substantial extraneous application of heat, whereby ductile metal portions of said flanges are commingled and said phosphorus-containing metal substantially disappears into the commingled metal.

6. In the pressure joining of members of ductile metals: interposing a layer of phosphorus-containing metal between solid surfaces of said members and then cold-working said members and layer, without substantial extraneous application of heat, to commingle the metals of said members, whereby said interposed layer substantially disappears into the commingled metals.

7. In the pressure joining of members of ductile metals: applying a coating of electroless nickel to at least one of two opposed solid surfaces of said members and then cold-working said members and coating, without substantial extraneous application of heat, to commingle the metals of said members.

8. A metal-working method comprising: chemically lining at least one of a pair of solid surfaces of ductile metal members with a frangible coating of phosphorus-containing metal and then applying pressure to said surfaces of said members without substantial extraneous application of heat.

9. In the pressure joining of members of ductile metals: juxtaposing a pair of members having surfaces shaped and disposed for pressure joining and at least one of which surfaces is coated with electroless nickel; and cold-working said members and coating, without substantial extraneous application of heat, to commingle the metals of said members.

No references cited.