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(54) IMPROVEMENTS IN OR RELATING TO METHODS OF ELECTROPLATING OR OTHERWISE TREATING ARTICLES IN A FLUID

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation organised and existing under the laws of the State of New York, 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:—

The invention relates to methods of electroplating or otherwise treating planar articles, and in particular to depositing a non-uniform layer of a metal on a conductive article.

The invention may be used in the manufacture of semiconductive devices such as transistors or diodes. While this invention is particularly suited for electroplating a non-uniform gold layer on a nickel lead frame for transistors, it is also equally well suited for other chemical applications in a fluid treating medium, such as electroless plating, anodizing, polishing or cleaning, wherein different degrees of interaction by the treating medium and the treated article are desired.

In the manufacture of transistors, leads for the transistors are formed from a lead frame stamped from a sheet of conductive metal such as nickel. Each lead frame has one group of three leads for each transistor. Each group includes one outer lead having a curved end portion upon which a semiconductive chip is bonded, an inner lead having a straight end portion upon which a fine wire extending from the chip is bonded, and another outer lead having another straight end portion upon which another fine wire extending from the chip is bonded.

The individual leads of each frame are joined together by a perforated carrier strip at one end so that the ends of the leads

where bonding is to be performed are free of the strip. The leads are joined together intermediate their ends by a relatively narrow support strip. Both of the strips are severed to separate the individual leads prior to the completion of the ultimate transistor. (see Maguire, Koons and Jarrett, "Plastic Encapsulated Transistors," *The Western Electric Engineer*, pp. 41—51, October, 1970).

Because an increased and controlled thickness of gold on the free end portions of the leads improves any bonds formed on these ends, it is desirable to have a greater thickness of gold on such ends than on the remainder of the leads. Since chip bonds normally require a greater thickness of gold to obtain good bonds than do wire bonds, it is also desirable that the curved free end portion of the leads have a greater thickness of gold than the straight free ends of the leads. Since the perforated carrier strip is ultimately trimmed away, it is further desirable to have the least thickness of gold on it. While the leads themselves require some gold for thermal protection of the semiconductive chip and for corrosion protection and solderability of the leads, they do not require as much thickness of gold as do the free ends where the chip and wire bonds are to be formed, but require more gold than the carrier strip. Such a non-uniform distribution of gold can result in a very desirable efficient use and substantial savings of gold.

In treating the lead frames by plating or similar techniques, it is also desirable to arrange them so as to treat a maximum number of frames at a time using a minimum volume of a tank holding a treating medium. Such an arrangement minimizes the space required for the treating tank. In addition, it is desirable that the treating time be

minimized and that the treating rate be maximized. Further, it is desirable to improve the control over the treating operation.

While it is desirable that the leads and the carrier strip have a non-uniform thickness of gold, it is also desirable that each frame be treated the same.

Accordingly, the invention provides a method of treating portions of planar articles differentially in a fluid treating medium, comprising arranging the articles in a spaced radial configuration about a longitudinal axis with the radially-outer side portions of the articles spaced a greater distance from each other than the radially-inner side portions of the articles, the articles being engaged to secure them against centrifugal displacement and wherein the articles are rotated about the axis through the treating medium so that the flow of fluid over the radially-inner side surface portions of the articles is limited to provide relatively more interaction of the radially-outer side portions of each article with the treating medium and relatively less interaction of the radially-inner side portions with the treating medium.

The invention also provides a method of treating portions of planar articles differentially, comprising arranging the articles in a spaced radial configuration about a longitudinal axis with the radially-outer side portions of the articles spaced a greater distance from each other than the radially-inner side portions of the articles, the said articles being engaged to secure them against centrifugal displacement, placing the arranged articles in an electroplating solution, passing an electric current between an anode and a cathode electrically connected to the articles and rotating the articles about the axis through the solution so that the flow of the solution over the radially-inner side surface portions of the articles is limited to provide relatively more interaction of the radially-outer side portions of the articles with the solution and relatively less interaction of the radially-inner side portions with the solution and provide non-uniform electrodeposition on each article, the thickest deposition being on the radially-outer portions of the articles.

Two embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:—

Fig. 1 is an enlarged, fragmentary, perspective view of a lead frame;

Fig. 2 is a sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is a perspective view, partly in section, showing a tubular member in which the lead frame of Fig. 1 is to be mounted;

Fig. 4 is an enlarged view of a portion of Fig. 2;

Fig. 5 is a front elevational view, partly

in section of the tubular member of Fig. 3; and

Fig. 6 is a perspective view of a second embodiment showing an alternative manner of mounting a plurality of lead frames cylindrically.

Referring to Fig. 1 of the drawings, a lead frame, designated generally by the numeral 11, has a plurality of groups of leads, designated generally by the numeral 12; one group being associated with each transistor which is ultimately to be fabricated using the lead frame 11. Each group 12 includes an outer lead 13 having a curved end portion 14 to which a semi-conductive chip 17 is bonded. Each group also has another outer lead 18 and an inner lead 21, both of which have straight end portions 22 and 23 to which fine gold wires 24 extending from the chip 17 are bonded.

Each lead frame 11 includes a carrier strip 25 having perforations 26 therein. The perforated carrier strip 25 joins the individual leads 13, 21 and 18 together at one of their ends so that the opposite end portions 14, 23 and 22 where bonds are to be formed are free. The leads 13, 21 and 18 are joined together intermediate their end portions 14, 23 and 22 by a relatively narrow support strip 28.

Typically, the lead frame 11 is stamped from a nickel sheet about 10 mils thick. In the prior art a uniform layer of gold of about 0.255 to about 0.315 mils was plated on the nickel lead frame 11.

In accordance with the present invention, a plurality of planar articles, such as the lead frame 11 (Fig. 1) or the like, is non-uniformly treated. While the treatment may be any of a number of different chemical treatments in a fluid treating medium, such as electroplating, electroless plating, anodizing, polishing or cleaning, the present embodiment of the invention will be described in connection with electroplating. However, it is to be understood that treatments other than electroplating are within the scope of this invention.

More specifically, a non-uniform layer 29 (Fig. 2) of a metal, such as gold, is electroplated on the lead frame 11 so that the layer 29 has a least thickness on the carrier strip 25, a greater thickness on the leads 13, 21 and 18, a still greater thickness at the straight free end portions 22 and 23 where wire bonding is to be performed, and the greatest thickness at the curved free end portion 14 where chip bonding is to be performed.

Referring to Fig. 3, in a cup 30 is placed an assembly including a base 31, a rotatable shaft 32 mounted in and extending from the top surface of the base 31 and a hollow coaxial tubular member 33 with its bottom end also fixed to the top surface of the base

31. The placing of this assembly in the cup 30 positions the bottom side of the base 31 in a central depression 42 in the cup 30.

5 As shown in Figs. 3 and 4, the hollow tubular member 33 has a plurality of spaced slots 46 formed in its outer surface that are parallel to each other and to the axis of the member 33. The bottom ends of the slots 46 are closed by an annular indentation 49 formed in the top surface of the base 31.

10 Typically, the slots 46 have a width of about 15 to 20 mils so that they easily receive the lead frames 11 which have a thickness of about 10 mils. The inner side portions 47 (Figs. 1 and 3) of a plurality of lead frames 11 are individually placed in the slots 46. By so placing these frames 11, they are arranged in a cylindrical configuration with the outer side portions 48 of the frames 11 on the outer periphery of the configuration and spaced one from the other, as shown in Fig. 3.

25 Since the bottom ends of the slots 46 are enclosed by the annular indentation 49 in the base 31, the frames 11 are axially retained in the slots 46 to prevent them from dropping out. Also, the frames 11 are laterally retained in the slots 46 by the loading cup 30 and a rim 51 formed by the indentation 49 in the base 31.

30 After the frames 11 are loaded in the slots 46, a capping member 52 (Fig. 3) of insulation material and having an annular indentation 54 is removably mounted at the top end of the tubular member 33 by conventional securing devices, such as machine screws 56.

35 By so mounting the capping member 52, the top end of the tubular member 33 fits into the annular indentation 54 and closes the top ends of the slots 46 to axially retain the frames 11 in the slots 46. Also, rim 57 formed by the indentation 54 laterally retains the frames 11 in the slots 46. Thus, the combination of the slots 46 in the tubular member 33, the indentations 49 and 54 in the base 31 and in capping member 52, and the rims 51 and 57 in the base 31 and in capping member 52 support and retain the frames 11 in the cylindrical configuration. Therefore after the capping member 52 is mounted upon the tubular member 33, the loading cup 30 is no longer necessary to support and retain the frames 11.

60 Next, the assembly of the base 31, the shaft 32, the tubular member 33, the frames 11, and the capping member 52 are removed from the loading cup 30 by lifting such assembly by the shaft 32 from the cup 30. The shaft 32 is then connected to a conventional rotating device, such as a motor 61 (Fig. 5).

65 The assembly is next immersed in a treating medium with the shaft 32 extending

therefrom by suspending the motor 61 from a fixed hook 62 by an eyelet 63 fastened to the motor 61. Also, the motor 61 is provided with a handle 64 to facilitate the manipulation of the motor and the assembly connected thereto. While the assembly is shown in Fig. 5 as being suspended vertically by the hook 62 and the eyelet 63, it should be understood that as the assembly may be positioned other than vertically in the treating medium by the use of conventional supporting devices.

70 The treating medium may be a gold electroplating bath 65 held in a tank 66. Typically, the bath 65 is an acidic plating solution containing ammonium citrate and potassium gold cyanide. Also, it may be desirable to preplate electrolytically the frames 11 in a plating solution containing potassium phosphate with low concentrations of potassium gold cyanide.

75 In addition to the assembly, the electroplating bath 65 contains an anode 67 of a plating source 68 which also has a cathode 69 connected to the shaft 32 by conventional expedients such as a brush 71 and a slip ring 72.

80 In order to deposit the non-uniform layer 29 (Fig. 2) of gold on the lead frames 11 the motor 61 (Fig. 5) is energized to revolve the lead frames 11 past the anode 67. The power source 68 is then activated to pass current from such source 68 to the anode 67, the bath 65, the lead frames 11, the walls of the slots 46 of the tubular member 33, the remaining structure of the tubular member 33, the base 31, the shaft 32, the slip ring 72, the brush 71 to the cathode 69 and back to the source 68.

85 By revolving the frames 11 in the bath 65 past the anode 67 and by activating the power source 68, gold is plated from the bath 65 onto the lead frames 11 to form the non-uniform gold layer 29 (Fig. 2) thereon. The gold layer 29 has its greatest thickness at the outer side portions 48 of the lead frames 11, which include the curved end portion 14 and the straight end portions 22 and 23, and has its least thickness at the inner side portions 47 of the frames 11, which include the perforated carrier strip 25. Further, the layer 29 has a thickness on the leads 13, 18 and 21 greater than that on the carrier strip 25, a still greater thickness on the straight end portions 22 and 23 where the wires 24 and 25 are to be bonded, and its greatest thickness on the curved end portion 14 where the chip 17 is to be bonded.

90 The gold layer 29 is thicker at the outer side portions 48 of the frames 11 than at the inner side portions 47 of the frames 11, because, it is believed there is a greater interaction of the portions 48 with the plating bath 65 than there is of the portions 47 with such bath 65. More specifically, it 130

is believed that the layer 29 is thicker at the portions 48 than at the portions 47 because the portions 48 have the greatest velocity through the plating bath 65 and are spaced further apart. Also, the portions 48 are closer to the anode 64 than the portions 47, (see the lefthand side of Fig. 5).

Typically, the thickness of the non-uniform gold layer 29 on the frames 11 varies linearly with distance from approximately 0.300 mils at the curved end portion 14 decreasing to approximately 0.060 mils at the carrier trip 25. Such thickness of the layer 29 has been achieved with plating current of about 30 amps and a rotational speed of 50 rpm. The degree to which the thickness of the deposited gold layer is non-uniform is controlled by such factors as the rotational speed of the frames in the bath 65, the spacing of the frames 11, the plating current, and the composition of the plating bath.

It will be appreciated that by plating the lead frames 11 as hereinbefore described, substantial savings in gold result and at the same time adequate amounts of gold are plated on the curved end portion 14 of the lead 13 for making good chip bonds and on the straight end portions 22 and 23 of the lead 18 and 21 for making good wire bonds. Also, by arranging the lead frames 11 in the cylindrical configuration a large number of frames 11 can be simultaneously plated using a small-volume tank holding the plating bath. In addition, the plating time can be decreased over prior art techniques and at the same time the treating rate and control over the treating operation is increased.

To prevent gold from being plated from the bath 65 on the shaft 32, the base 31, and the tubular member 33, which are electrically conductive; these elements 32, 31 and 33 are completely coated with a non-conductive film, such as "Kynar," (Registered Trade Mark). However, the walls of the slots 46 which must make electrical contact with the frames 11 to plate them are not coated. The shaft 32 is also coated with the film except where the slip ring 72 is attached. The capping member 52 is made of an electrically non-conducting material and therefore, no gold is plated from the bath on it.

The walls of the slots 46 receive a minimum thickness of plated gold, since the frames 11 are inserted therein exposing only a small amount of the walls of the slots 46 to the plating bath 65. Also, the slots 46 are positioned relatively far away from the anode 64. After being used numerous times to plate large quantities of frames 11, any gold plated on the walls of the slots 46 can be chemically stripped therefrom.

An alternative embodiment of the invention is shown in Fig. 6. More specifically, the lead frames 11 are formed in a hollow cylindrical configuration for immersion in

the plating bath 65 by first inserting a wire-like member 76 alternately into the uppermost perforations 26 of the carrier strips 25 of the lead frames 11 and then into a plurality of conductive washers 77 spaced from each other by the frames 11.

Also, another wire-like member 78 is inserted alternately into the lowermost perforations 26 of the carrier strips 25 and into a plurality of conductive washers 79 spaced from each other by the frames 11, as shown in Fig. 6.

Next, the wire-like members 76 and 78 are formed into a substantially circular configuration. This results in the arranging of the lead frames 11 in the hollow cylindrical configurations so that the outer portions 48 are located on the outer periphery of the configuration and also have the greatest spacing one from the other.

Non-conducting disc element 80 is positioned in the centre of the hollow configuration of the lead frames 11 adjacent the uppermost perforations 26 of the carrier strips 25. The ends of the wire-like member 76 are then joined together to force the frames 11 and washers 77 against the element 80, as shown in Fig. 6. Next, the ends of the wire-like member 76 are fastened with a conventional holding device 81 to retain the member 76 in a ring-like configuration.

A conductive base plate 82 having a conductive disc element 83 fixed thereto is then positioned beneath the lead frames 11 in electrical contact therewith and the washers 79 so that the element 83 is in the centre of the cylindrical configuration, as shown in Fig. 6. The ends of the wire-like member 78 are next joined together to force the frames 11 and the washers 79 against the disc element 83. The ends of the wire-like member 78 are then fastened with a conventional holding device 84.

A conductive rotatable shaft 86 is connected through the disc element 80 to the disc element 83. The lead frames 11 joined in a cylindrical configuration by the wire-like members 76 and 78 along with the shaft 86, the base plate 82, and the disc element 83 are immersed in the plating bath 65 (see Fig. 5). The cathode 69 is appropriately connected to the shaft 86 and the frames 11 are revolved by the motor 61 past the anode 67 to plate gold from the bath 65 on the frames 11 in the same way that gold was plated on the frames 11 in the embodiment of Fig. 5.

The shaft 86 may be coated with a non-conductive film to prevent gold from the plating bath from being deposited thereon.

WHAT WE CLAIM IS:—

1. A method of treating portions of planar articles differentially in a fluid treat-

ing medium, comprising arranging the articles in a spaced radial configuration about a longitudinal axis with the radially-outer side portions of the articles spaced a greater distance from each other than the radially-inner side portions of the articles, the articles being engaged to secure them against centrifugal displacement and wherein the articles are rotated about the axis through the treating medium so that the flow of fluid over the radially-inner side surface portions of the articles is limited to provide relatively more interaction of the radially-outer side portions of each article with the treating medium and relatively less interaction of the radially-inner side portions with the treating medium.

2. A method of treating portions of planar articles differentially, comprising arranging the articles in a spaced radial configuration about a longitudinal axis with the radially-outer side portions of the articles spaced a greater distance from each other than the radially-inner side portions of the articles, the said articles being engaged to secure them against centrifugal displacement, placing the arranged articles in an electroplating solution, passing an electric current between an anode and a cathode electrically connected to the articles and rotating the articles about the axis through the solution so that the flow of the solution over the radially-inner side surface portions of the articles is limited to provide relatively more interaction of the radially-outer side portions of the articles with the solution and relatively less interaction of the radially-inner side portions with the solution and provide non-uniform electrodeposition on each article, the thickest deposition being on the radially-outer portions of the articles.

3. A method as claimed in claim 2, wherein before placing the articles in the electroplating solution, the articles are inserted into a plurality of spaced parallel slots on the outer wall of a cylinder which is closed at one end with an electrically

lar abutment which engages the articles and retains them in the slots.

4. A method as claimed in claim 3, wherein the cylinder and the first end portions containing the articles are placed within a capping member in which the side of the capping member further retains the articles.

5. A method as claimed in claim 3 or claim 4, wherein a second end portion is placed over the other end of the cylinder, the second end portion having an annular abutment which engages the articles in the slots.

6. A method as claimed in claim 3 and claim 5, wherein the cylinder, having first and second end portions thereon, is removed from the capping member and placed in the electroplating solution.

7. A method as claimed in any one of the preceding claims, wherein the articles comprise a plurality of strips.

8. A method as claimed in claim 7, wherein the strips are hung in a cylindrical configuration from at least one support.

9. A method as claimed in claim 8, wherein the strips are hung on two supports.

10. A method as claimed in claim 8 or claim 9, wherein the supports comprise flexible wire members which are passed through apertures in the strips.

11. A method as claimed in claim 10, wherein the wire members are inserted alternately into the apertures in the strips and then into washers, said washers being intermediate adjacent strips.

12. A method as claimed in any one of claims 2-11, wherein the articles are of nickel and the electrodeposited material is gold.

13. A method of treating articles substantially as hereinbefore described with reference to and illustrated in Figs. 1-5 or Fig. 6 of the accompanying drawings.

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