

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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 (72) Inventor ALEXANDER COUCOULAS



(54) IMPROVEMENTS IN OR RELATING TO BONDING METHODS

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation organized 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:—

This invention relates to methods of bonding a plurality of electrically conducting leads to space-apart locations on at least one substrate. One example of the field of use of the invention is for bonding lead wires to electronic components such as thin-film devices, integrated circuits, and printed circuit boards.

In the manufacture of workpieces, for example integrated circuits, it is frequently necessary to bond a plurality of electrical lead wires to the workpiece. These lead wires are required to complete the electrical interconnections between the workpiece and any external components with which it is to work.

Any of several known bonding techniques may be used to provide these bonds. For example, our copending Application No. 311259/68 (Serial No. 1,239,631) discloses several methods which, by the use of a compliant bonding medium, produce high quality bonds eminently suitable for bonding applications such as above-described. The bonds to the integrated circuit, or other workpiece, may be produced one at a time, but it is preferable if a large number of bonds are produced simultaneously. The above-identified copending application discloses a method for simultaneously bonding the plurality of beam leads which extend from a beam lead semiconductor device, and the compliant bonding techniques disclosed therein may also be used to simultaneously bond a plurality of leads to a conventional integrated circuit. In that event,

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a lead frame would be used, the lead frame being positioned intermediate the compliant bonding medium and the integrated circuit to be bonded. A lead frame is, of course, a device which is manufactured by stamping out a pattern of leads and lead supports from a sheet of relatively soft material, such as copper. The stamping die is designed so that the free ends of the lead wires which extend outward from the lead supports align with the terminal land areas of the integrated circuit when the lead frame is superimposed over, and registered with respect to, the integrated circuit.

After the lead frame is registered with respect to the workpiece, a suitably patterned compliant member, for example a sheet of aluminium alloy having a central aperture therein corresponding to the shape of the integrated circuit, is placed over the lead frame and vibratory and/or mechanical bonding energy applied through the compliant member to bond the free end of each lead to the corresponding terminal land area of the workpiece.

The results which have been obtained by applying the compliant bonding techniques disclosed in the above-mentioned copending application to lead frame applications are uniformly excellent. However, at least two steps are involved in making simultaneous bonds. These steps are: (1) the lead frame must be registered with respect to the workpiece and (2) the compliant member must be positioned over both the lead frame and the workpiece prior to bonding. In addition, by virtue of the manner in which lead frames are manufactured, the leads themselves have a generally flat cross-section. This is also true, it should be noted, of the plated beam leads on a beam lead device. As is well known, however, in some applications, for example where the integrated circuit draws a considerable amount of current, it is advantageous for the leads which interconnect the workpiece and the associated external circuitry to have a circular cross-section.

tion and hence a lower resistance to the passage of current. Unfortunately, leads of such a circular cross-section cannot be easily obtained with conventional lead frame devices or with beam lead devices.

Accordingly the invention provides a method of simultaneously bonding a plurality of metallic wires to spaced regions on one or more substrates, the method including the steps of winding a wire about the securing it to a compliant member, severing the compliant member and the wire to leave wire portions secured to the compliant member in a spatial relationship corresponding to the regions, and to deform the member and wire to produce visible marks suitable for use in aligning the wire portions with the desired regions on the one or more substrates, aligning the marks with the regions so as to position the wire portions on the regions and applying bonding energy through the compliant member to bond the wire portions to the regions.

The advantage of the invention is that it achieves the required simplification without any loss of precision. It is also possible to prepare complete bonding assemblies in advance, so that all that is necessary, is to align the first and second workpieces in the appropriate manner and applying the bonding energy.

In the case of providing leads for small electrical assemblies the method comprises the steps of (1) winding a filament about a compliant support member and (2) securing the filament to at least one surface of the support member as by means of an adhesive. In one specific embodiment of the invention an aluminium support member which is wound with a continuous gold filament is used. The filament is secured to one surface of the support member by a strip of adhesive tape. The second workpiece typically comprises an integrated circuit having a plurality of gold plated terminal land areas along the edges thereof.

FIG. 1 is a plan view of a thin-film integrated circuit after it has been bonded to the leads of a typical prior art lead frame;

FIG. 2 is a plan view of a compliant support member, showing a continuous filament spirally wound thereabout;

FIG. 3a and FIG. 3b are plan views of the front and rear faces, respectively, of the support member shown in FIG. 2 after both edges thereof have been sheared;

FIG. 4 is a plan view of the support member shown in FIG. 3a and FIG. 3b after registration with, and bonding to, an integrated circuit of the type shown in FIG. 1a; and

FIGS. 5a, 5b and 5c are partial side elevation views of one of the lead wires and a portion of the integrated circuit depicting the various states of the lead wire during the bonding process and FIG. 5d is a partial plan view showing the completed pattern of spaced bonds.

FIG. 1 depicts a typical prior art integrated circuit 10 bonded to a prior art lead frame 14. The integrated circuit 10 comprises an insulated substrate 11 having thin-film resistors 12 and other components (not shown) deposited thereon. The resistors 12 are connected to a plurality of gold-plated terminal land areas 13 which are used to make connections between the integrated circuit and external circuitry. As previously discussed, lead wires may be bonded to land areas 13 one by one, but this is a very inefficient and time-consuming operation and it is highly desirable to bond all of the lead wires to the integrated circuit simultaneously. Lead frame 14 has been used in the prior art to accomplish the simultaneous bonding of all the lead wires to integrated circuit 10. Lead frame 14 is depicted as having been stamped out of a sheet of soft material, such as copper, to form a plurality of leads 16 supported from the edges 17 of lead frame 14. A plurality of holes 18 are formed in edges 17 so that the lead frame 14 may be registered with respect to land areas 13 of integrated circuit 10. Each of the leads 16 has a generally flat cross-section.

As previously discussed, the use of a lead frame together with the compliant bonding technique disclosed in the above-mentioned copending application permits the simultaneous bonding of a plurality of leads to an integrated circuit but requires at least two distinct operating steps. Also, as discussed, it is advantageous in some applications that the leads to be bonded to land areas 13 be of a circular cross-section. It is not practical, however, to further process the leads of a lead frame to alter the cross-section thereof.

When a lead frame of the type shown in FIG. 1 is used in a compliant bonding operation, a suitably shaped compliant member, for example a piece of aluminium tape, is positioned thereover after the lead frame has been precisely aligned with respect to the integrated circuit and suitable vibratory and/or mechanical bonding energy supplied through the compliant member to bond the leads to the land areas of the integrated circuit.

Referring now to FIG. 2, an embodiment of this invention is described. A support member 19 of compliant material, for example aluminium or polytetrafluorethylene, is advantageously wound in spiral fashion with a continuous metallic filament 20. Other winding configurations are, of course possible, for example serpentine. Indeed, any filament pattern or configuration which is laid onto or about the support member including one which is laid down only on one surface thereof may be used. Generally speaking any winding pattern or configuration will be satisfactory which results in portions of the filament lying over or lying near the edges of the support member so that segments of the filament may act as

electrical leads for the integrated circuit 10 or other workpiece when severed from the winding pattern.

Assuming a spiral winding operation has been performed, the individual spiral segments 21 are secured to at least one surface of support member 19 by any suitable adhesive means, for example, by means of a strip of adhesive tape 22, or by means of an easily-dissolvable, electrically nonconducting, adhesive, such as varnish, applied to the central portion of support member 19. The adhesive means serves to retain the continuous metallic filament 20 in a fixed relation to support member 19. As will be more fully discussed herebelow, the use of an electrically non-conducting adhesive has the additional advantage of insulating the spiral segments 21, which are formed from filament 20, one from another.

A plurality of indentations, or slots 23, are formed along one, and preferably both, edges of support member 19. These indentations serve the dual purpose of: (1) restraining spiral segments 21 from movement on the surface of support member 19, prior to the application of adhesive means 22; and (2) controlling the spacing between the turns of the spiral. The spacing between adjacent slots is, of course, chosen to correspond to the spacing between adjacent spaced-apart locations on the second workpiece. If for any reason the spacing between adjacent spaced-apart locations is non-uniform, then a corresponding non-uniform spacing of the slots in the compliant support member will ensure precise alignment of the plurality of first workpieces and the spaced-apart locations on the second workpiece when the bonds are made, as more fully explained below. As an alternative to the slots 23, a plurality of apertures (not shown) may be punched or drilled along one or more edges of support member 19, and in that event, the filament 20 is threaded through the apertures, rather than being wound about the support member 19, as shown in FIG. 2.

In the embodiment of FIG. 2, the support member 19 is shown as having a generally rectangular configuration. However, it will be appreciated that support member 19 may have any desired configuration, the shape being dictated primarily by the configuration of integrated circuit 10, or other workpiece, to which the bonds are to be made. More specifically, support member 19 could be formed, for example, in the shape of the letter "E" if the land areas on integrated circuit 10 were arranged in such a pattern and were not as shown in FIG. 1. It will also be appreciated that slots 23 may be omitted, if desired, provided that sufficient friction and/or tension exists to ensure that the windings of the spiral do not shift unacceptably.

Advantageously, support member 19 has a generally flat cross-section. Again, however, this is not mandatory and the cross-section of

support member 19 may be selected as dictated by the configuration of integrated circuit 10, or other workpiece, to which the bonds are to be made.

After filament 20 has been spirally wound about support member 19 and secured thereto by adhesive means 22, at least one edge, and preferably both edges, of support member 19 are cut along section lines a—a to produce the configuration shown in FIG. 3a. Any suitable means may be utilized to cut the edges of support member 19, for example a conventional metal shearing process. The unaffixed segments 21 of the former spiral laying on the rear face, and those few segments 21 on the front face which were not secured by adhesive means 22 to support member 19, are removed during, or immediately after, the cutting step and no longer play any part in the described bonding process.

Because support member 19 is formed from a compliant, deformable material, when the edges thereof are sheared, the material which comprises support member 19 deforms slightly about those segments 21 which remain secured by adhesive means 22 to the front face of support member 19. As shown in FIG. 3b, this produces a series of small marks 24 on the rear surface of support member 19. These marks may be concave or convex depending upon the particular shearing or cutting process used and upon the winding configuration. The visible marks which are formed on the rear face of the support member, correspond precisely to the locations of segments 21 on the front face and may advantageously be used to accurately position support member 19 with respect to integrated circuit 10, or other workpiece, so that segments 21, which now act as the lead wires to be bonded, are precisely aligned with respect to the terminal land areas 13 of integrated circuit 10.

FIG. 4 shows support member 19 after it has been aligned with respect to terminal land areas 13 and illustrates the use of visible marks 24 to accomplish this alignment. After the alignment has been completed, vibratory and/or mechanical bonding energy is applied by means (not shown), through support member 19, to bond each of the segments 21 to the corresponding terminal land area 13. The vibratory bonding energy may comprise, for example ultrasonic or audible vibratory energy and the mechanical bonding energy may comprise, for example heat and ram pressure applied through the support member. The material from which support member 19 is manufactured may advantageously comprise a metal, such as aluminium, having an adherent oxide coating thereon, the metal being such as to deform plastically around the plurality of first workpieces when the vibratory and/or mechanical bonding energy is applied thereto.

FIG. 5a is a side-elevation view showing

a portion of support member 19 positioned so that visible marks 24 and segment 21 are adjacent to a land area 13 of integrated circuit 10. The vertical scale of the figure has been distorted so that the slight deformation of support member 19 around segment 21 and the corresponding visible mark 24 which is formed is clearly seen. Practically, however, even if no appreciable deformation is formed, the rear face of support member 19 will nevertheless be sufficiently marked by the shearing or cutting step to permit satisfactory alignment. FIG. 5b shows the same cross-section after the application of vibratory and/or mechanical bonding energy through support member 19 and shows the flattening of the terminal end of segment 21 and the bonding thereof to land area 13. This flattening is not sufficient to materially affect the current-carrying capability of the lead 21 connecting integrated circuit 10 to the external circuitry with which it is to work. The circular configuration of segment 21, when subjected to bonding energy applied through compliant support member 19, initially produces a relatively high pressure between segment 21 and the terminal land area 13, which pressure is greater than that which would be obtained if segment 21 were to have the generally flat cross-section found in the prior art. This is believed to be the reason why the bond which is obtained by the use of the present invention is superior to that obtained with the use of a flat lead wire.

After the bonding energy has been applied to support member 19 to simultaneously bond all segments 21 to the corresponding land areas 13, the adhesive tape is removed, or the easily-dissolvable adhesive dissolved, and support member 19 withdrawn, leaving only segments 21 which, of course, now act as the leads, bonded to integrated circuit 10. As previously discussed, if the adhesive used is an electrically non-conducting adhesive, for example varnish, the lead wires will be partially insulated one from the other, a distinct advantage, as this insulation will tend to prevent electrical short circuits if the lead wires should accidentally touch one another when the integrated circuit is ultimately assembled in a working electronic circuit or during a testing operation. FIG. 5c and FIG. 5d are partial side and top elevation views of completed bonds showing the configuration thereof.

The method may also be used to interconnect two or more integrated circuits 10, or other workpieces, together. FIG. 4 shows compliant support member 19 with its right edge aligned with respect to an integrated circuit 10. However, if a second integrated circuit 10 were to be positioned with respect to the left edge of support member 19, then the application of bonding energy to support member 19 would bond both ends of each filament segment 21 to a terminal land area 13 on two integrated circuits 10, thereby interconnecting

the terminal land areas thereof on a one-to-one basis. Further, by the choice of a suitably patterned support member 19, and by an appropriate arrangement of the slots 23 and/or an appropriate choice of a filament winding pattern, the method of this invention could be used to simultaneously interconnect a plurality of workpieces, should this be desired.

WHAT WE CLAIM IS:—

1. A method of simultaneously bonding a plurality of metallic wires to spaced regions on one or more substrates, the method including the steps of winding a wire about and securing it to a compliant member, severing the compliant member and the wire to leave wire portions secured to the compliant member in a spatial relationship corresponding to the regions, and to deform the member and the wire to produce visible marks suitable for use in aligning the wire portions with the desired regions on the one or more substrates, aligning the marks with the regions so as to position the wire portions on the regions and applying bonding energy through the compliant member to bond the wire portions to the regions.
2. A method according to claim 1, wherein the bonding is effected by vibratory energy.
3. A method according to claim 1, wherein the bonding is effected by heat and pressure.
4. A method according to claim 1, 2 or 3, wherein the compliant member comprises a metal strip having an adherent oxide coating thereon.
5. A method according to any preceding claim, wherein the wire portions are secured to the compliant member by an adhesive.
6. A method according to claim 5, wherein the wire portions are electrically conducting leads and the adhesive is an electrical insulator.
7. A method according to claim 6, including the step of releasing the leads from the compliant member after bonding so that the adhesive remains on the leads to form an insulating layer thereon.
8. A method according to any preceding claim, wherein the wire portions are in the form of filaments.
9. A method according to claim 8, wherein the compliant member is in the form of a flat rectangular strip and the said wire winding is severed at one or both edges.
10. A method according to claim 9, wherein the metal strip is of aluminium and has an insulating oxide coating thereon.
11. A substrate having a plurality of electrically conducting wires bonded to spaced regions thereon according to the method of any one of claims 1—10.
12. A method of simultaneously bonding a plurality of metallic wires of spaced regions on one or more substrates substantially as herein described with reference to FIGS. 2 to 5 of the accompanying drawings.

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P. S. BROWN,
Chartered Patent Agent,
5, Mornington Road,
Woodford Green, Essex.
Agent for the Applicants.

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