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(54) METHODS OF CONNECTING METAL CONTACT AREAS TO METAL CONDUCTORS

(71) We, PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2, a British Company, 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 connecting metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate. The substrate may be a foil of a synthetic resin. The electrical components may consist, for example, of semiconductor devices each comprising a semiconductor body, of resistors, such as thin film or thick film resistors, of capacitors, of inductor coils, or also, for example, of strain gauges.

The connection of contact areas of semiconductor device bodies, for example transistors or integrated circuits, to conductors which are provided on a rigid substrate is known. In this case, after pressing the substrate and the crystal against each other a connection may be obtained by adding thermal energy, for example a thermocompression bond or a soldered joint. The connection may be attempted by means of an ultrasonic welding device; however, this will often present difficulties since the upper side of the contact areas on the semiconductor body must then be located substantially in a flat plane, and only small deviations in the pressure between the various conductors and the contact areas may be permitted. If the semiconductor body is to be provided ultrasonically on conductors of a flexible and supple substrate, the difficulties become even greater since the vibration energy of the welding device is also absorbed in said flexible substrate. However, it is often desirable to be able to connect efficaciously metal conductors on flexible foils to metal contact areas of an electrical component, for example having a

semiconductor body, by means of ultrasonic vibration.

According to the invention, in a method of connecting metal contact areas of electrical components, for example semiconductor devices, to metal conductors on a flexible, insulating substrate, for example a foil of synthetic resin, the electrical components, for example semiconductor devices, to metal conductors on a flexible, insulating substrate, for example a foil of synthetic resin, the electrical component is orientated relative to the flexible substrate in such manner that the contact areas are situated opposite to corresponding conductors, the conductors of the flexible substrate and the contact areas of the electrical components are pressed against each other between two pressure members, the pressure member for the flexible substrate comprising a homogeneous pattern of projections, and one of the two pressure members is then vibrated ultrasonically so that the projections pressing against the flexible substrate penetrate into said substrate to temporarily reinforce the substrate at that region so as to be able to transmit vibrating energy to the conductors on the substrate, after which, as a result of the ultrasonic vibration, the contact areas and the conductors rub over each other and are welded together.

The flexible substrate is temporarily considerably reinforced by the penetrating projections at the region where the welds are to be formed, the vibration absorption in the foil is for the greater part removed, and, furthermore, the penetrating projections ensure that during the ultrasonic vibration the foil does not slip relative to the pressure member. Near the contact areas the foil still retains some elasticity and thus will be adjusted in such a way that the conductors on the foil all press against the corresponding contact areas of the electrical component with approximately equal force. Consequently, the mutual height of the contact areas is now

considerably less critical than in the case of a connection to a rigid substrate.

Prior to orienting the flexible substrate relative to the electrical component, the flexible substrate may be forced against the pressure member which is provided with the homogeneous pattern of projections whereby the projections penetrate at least partly into the substrate.

In a preferred form of the method the projections are arranged at such a pitch that at least three projections are always situated opposite any contact area.

A very favourable operation is obtained if the projections are formed as pyramids the bases of which are situated either adjoining each other or at a distance from each other.

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

Figure 1 shows in perspective view a part of a foil with metal conductors thereon and crystals to be secured thereto;

Figures 2 to 4 show in cross-sectional view various stages in the method of connecting metal contact areas of a crystal to the metal conductors on the foil, and

Figure 5 is a perspective view and Figures 6 and 7 are cross-sectional views of various pressure members comprising sharp projections and for use in various forms of the method illustrated in Figures 2 to 4.

Figure 1 shows an elongate flexible foil 1 which may consist of a synthetic resin, for example a polyimide foil, but which can also consist, for example, of paper. The thickness of the foil 1 is, for example, approximately $25\ \mu$. A pattern of metal conductors 2 is present on this flexible foil 1. A semiconductor crystal body 3, for example of an integrated circuit, has metal contact areas 4 (see Figures 2 to 4). The contact areas 4 are to be connected to the metal conductors 2.

As shown in Figure 2, while the body 3 is spaced from the foil 1, the contact areas 4 of the semiconductor body 3 are oriented relative to the conductors 2 on the foil 1, which flexible foil 1 at the region where the connections are to be made is mounted on a pressure member in the form of an anvil 5 with sharp projections 7 thereon. A second pressure member, the sonotrode 6 of an ultrasonic welding device, holds the crystal 3 by its surface remote from the contact area 4. The pressure members 5 and 6 are now pressed together, see Figure 3, and an ultrasonic generator is actuated as a result of which the sonotrode 6 starts vibrating. In the first instance the occurring vibration is absorbed for a considerable part by the flexible foil 1. As a result of the vibration, the projections 7 present on the anvil 5 will penetrate into the foil 1, see Figure 4, so

that at that region the flexible foil is temporarily reinforced. As a result of this the absorption of the vibrations in the foil is minimized so that the greater part of the power supplied by the ultrasonic welding device is now available for welding. The conductors 2 on the foil 1 are also pressed against corresponding contact areas 4 on the semiconductor body 3, the force on the various contact areas 4 being substantially equal in spite of any differences in height of the said contact areas 4, since the depth of penetration of the projections 7 can adapt automatically. Since the projections 7 penetrating into the foil 1 obtain a good grip on the foil 1 so that no slip occurs, the contact areas 4 as a result of the vibration rub over the conductors 2 so that an ultrasonic weld is obtained.

It will be obvious that a similar result can be obtained if the sonotrode is provided with the projections, in which case the semiconductor body 3 is present on the anvil 5 and the foil 1 is held by the sonotrode 6.

The flexible foil 1 can already be partly reinforced prior to being oriented relative to the crystal 3. For that purpose, the foil 1 may be placed on the anvil which comprises projections after which a pressure is exerted on the foil in such manner that the projections penetrate partly into the foil.

Figure 5 shows an example of the pressure member 5 having sharp projections 7. In this case the projections 7 are regularly provided in the form of pyramids. The height of the projections 7 is approximately $25\ \mu\text{m}$ in this example. The projections 7 will penetrate at least $10\ \mu$ into a foil 1 of a synthetic resin having a thickness of $25\ \mu$. The apex of the projections in this example is 60° but it may also lie between 20° and 100° . The pitch between the projections is such that at least three projections are present opposite any contact area 4, since otherwise the pressure occurring between the contact areas 4 and the conductors 2, will not be evenly distributed. In the example shown in Figure 5, the pitch is nearly $30\ \mu\text{m}$.

In Figure 6 the projections 8 are also pyramidal but the bases are situated at some distance from each other. With the same pitch as the projections 7 of Figure 5, the apex of the projections 8 will be smaller in Figure 6. A particularly favourable effect is obtained in this case with projections having an apex α of 20 to 30° and a height of $25\ \mu\text{m}$, have a pitch of $40\ \mu\text{m}$.

The projections may also be shaped differently. As is shown in Figure 7, the projections 9 may be given, for example, a slightly bell-like variation. The angle β between the broken-lines in Figure 7 which extend from the apex to the foot of the bell is preferably between 20° and 100° .

Although in the drawings the projections

are shown as forming part of the pressure member, it will be evident that such projections may be provided in, for example, a plate-shaped body which is subsequently secured to either the sonotrode or to the anvil.

WHAT WE CLAIM IS:—

1. A method of connecting metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, in which the electrical component is oriented relative to the flexible substrate in such manner that the contact areas are situated opposite to corresponding conductors, the conductors on the flexible substrate and the contact areas of the electrical components are pressed against each other between two pressure members, the pressure member for the flexible substrate comprising a homogeneous pattern of projections, and one of the two pressure members is then vibrated ultrasonically so that the projections pressing against the flexible substrate penetrate into said substrate to temporarily reinforce the substrate at that region so as to be able to transmit vibrating energy to the conductors on the substrate, after which, as a result of the ultrasonic vibration, the contact areas and the conductors rub over each other and are welded together.

2. A method as claimed in Claim 1, in which prior to orienting the flexible substrate relative to the electrical component, the flexible substrate is pressed against the pressure member with the homogeneous pattern of projections whereby the projections penetrate at least partly into the substrate.

3. A method as claimed in Claim 1 or Claim 2, in which the projections are provided at such pitch that at least three projections are always present opposite any contact area.

4. A method as claimed in any of the preceding Claims, in which the projections

are in the form of pyramids, the bases of which are situated adjoining each other.

5. A method as claimed in any of Claims 1 to 3, in which the projections are in the form of pyramids, the bases of which are situated at a distance from each other.

6. A method as claimed in any of the preceding Claims, in which the flexible substrate is a paper foil.

7. A method as claimed in any of Claims 1 to 6, in which the flexible substrate is a foil of synthetic resin.

8. A method as claimed in any of the preceding Claims, in which the electrical component is a semiconductor device comprising a semiconductor body having the metal contact areas on one major surface of the body.

9. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 5 of the accompanying drawings.

10. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 4 and Figure 6 of the accompanying drawings.

11. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 4 and Figure 7 of the accompanying drawings.

12. A flexible, insulating substrate having an electrical component secured thereto obtained using a method as claimed in any of the preceding Claims.

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2. A method as claimed in Claim 1, in which prior to orienting the flexible substrate relative to the electrical component, the flexible substrate is pressed against the pressure member with the homogeneous pattern of projections whereby the projections penetrate at least partly into the substrate.

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6. A method as claimed in any of the preceding Claims, in which the flexible substrate is a paper foil.

7. A method as claimed in any of Claims 1 to 6, in which the flexible substrate is a foil of synthetic resin.

8. A method as claimed in any of the preceding Claims, in which the electrical component is a semiconductor device comprising a semiconductor body having the metal contact areas on one major surface of the body.

9. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 5 of the accompanying drawings.

10. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 4 and Figure 6 of the accompanying drawings.

11. A method of connecting the metal contact areas of an electrical component to metal conductors on a flexible, insulating substrate, substantially as herein described with reference to Figures 1 to 4 and Figure 7 of the accompanying drawings.

12. A flexible, insulating substrate having an electrical component secured thereto obtained using a method as claimed in any of the preceding Claims.

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