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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO BONDING

(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:—

This invention relates to methods of bonding and apparatus therefor. As used herein the act of "bonding" means solid-phase bonding, i.e. bonding in the absence of any gross melting during bond formation.

Bonding of beam-lead transistor and integrated circuit chips to metallic patterns formed on substrates is preferably carried out by a technique known as compliant bonding in which a deformable compliant member, such as a strip of aluminium for example, is positioned between a rigid heated ram and the leads of the chips to produce a highly uniform thermocompression bond between the leads and the metallic elements formed on the substrate. Compliant bonding provides a very uniform distribution of bonding forces over the leads, good control of lateral bonding forces which cause a phenomenon known as "bugging", and a virtual elimination of excessive bonding forces on the leads that might otherwise cause a reduction of lead strength.

As it is at present practised however, one of the difficulties in compliant bonding is that in many circumstances, particularly when bonding integrated circuit chips, the introduction of the compliant bonding member is often a difficult, and time consuming step. An integrated circuit chip is usually formed of a body portion of crystalline material, such as silicon, which is usually quite brittle and thus a compliant bonding member cannot be placed directly over it because the bonding forces transmitted through the compliant bonding member would crack or otherwise damage the brittle body portion. Consequently compliant bonding members used to bond such brittle chips are

provided with apertures large enough so that the body portions of the chips extend into the apertures. When the chips are bonded to a substrate they must of course be very accurately located with respect to the metallic patterns on the substrates and, very often, several chips are placed on one substrate, thus complicating their location. It has been the practice to use compliant bonding members having a pattern of apertures therein which correspond to the desired pattern of chips on the substrate.

It has also been the practice to pre-position or "tack" the chips to the substrate and then to place a pre-formed, i.e. an apertured compliant bonding member over the assembly of substrate and "tacked" chips. By pressing a heated ram onto the compliant bonding member all of the chips may be simultaneously bonded to the substrate. Naturally the initial tacking of the chips, and accurately locating the compliant member with respect to the substrate are time consuming and costly manufacturing steps.

According to one aspect of this invention apparatus for bonding (as hereinbefore defined) a first workpiece to a second workpiece includes a bonding tip, means adapted to cause engagement of a portion of a compliant bonding member with said tip prior to bonding said workpieces together, means for aligning said first and second workpieces on a bonding axis, and means for moving said tip along said axis to press the engaged portion of said member and said first and second workpieces together to effect a bond between said workpieces.

The said bonding tip may be one of a plurality of bonding tips on a rotatable bonding ram, and the apparatus may include means for rotatably stepping said ram to bring successive bonding tips onto said bonding axis. Preferably each of said plurality of bonding tips extends radially outwards from said bonding ram. There may be provided between each bonding tip a sprocket projection extending radially outwards from said ram for engagement with said member.

There may also be provided means for holding said first workpiece against said

engaged portion prior to bonding. For an engaged portion of said bonding member which is apertured the said holding means may comprise a passageway extending through said or each bonding tip and adapted, when a pressure reduction is established therein, in operation, to hold said first workpiece against said apertured engaged portion.

The said means adapted to cause engagement of a portion of said member with said or each tip may also be adapted to fold one or more edges of said portion around one or more corresponding edges of the tip.

According to another aspect of this invention there is provided a method of bonding (as hereinbefore defined) a first workpiece to a second workpiece, wherein said workpieces are aligned on a bonding axis, a portion of a compliant bonding member is engaged with a bonding tip prior to bonding said workpieces together, and said bonding tip and the engaged portion are moved along said axis to press said engaged portion and said workpieces together to effect a bond between said workpieces.

After bonding the tip and the used portion of the compliant member are removed from the bonded workpieces and the spent portion of the compliant member may then be replaced on the bonding axis by an unspent portion of compliant material.

Prior to bonding the first workpiece may be held against said engaged portion. Where said engaged portion is apertured, said first workpiece may be held against the apertured engaged portion by reducing the pressure in a passageway extending through said bonding tip.

The bonding tip may be one of a plurality of bonding tips extending radially outwards from a rotatable ram, and each successive portion of said member may be caused to engage with a successive one of said bonding tips, and said ram may be rotatably stepped to bring each successive bonding tip and the portion of said member engaged therewith onto said bonding axis to bond successive first workpieces to successive second workpieces.

The engagement of said or each portion may include the folding of one or more edges of said or each portion around one or more corresponding edges of the tip.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a perspective view showing one form of apparatus in accordance with the invention;

Figure 2 shows a portion of a compliant bonding member for use in the apparatus of Figure 1;

Figure 3 is a view of the compliant bonding

member of Figure 2 engaged with the rotatable ram of the apparatus of Figure 1;

Figure 4 is an enlarged view of a bonding tip pressing the compliant bonding member and workpieces together to effect a bond;

Figure 5 is a view of the compliant bonding member engagement assembly of the apparatus of Figure 1 shown in a retracted position;

Figure 6 is a view of the assembly of Figure 5 shown in an engaged position;

Figure 7 is a sectional view of the assembly of Figure 5 taken along the lines 7-7;

Figure 8 is a sectional view of the assembly of Figure 6 taken along the lines 8-8;

Figure 9 is a sectional view of the assembly of Figure 5 taken along the lines 9-9;

Figure 10 is a sectional view of the assembly of Figure 6 taken along the lines 10-10; and

Figure 11 is a view of an engagement position intermediate that shown in Figures 9 and 10.

Referring now to Figure 1, a bonding machine, designated generally as 20, includes a bonding head, designated generally as 22, a support structure, designated generally as 24, and a conventional positioner assembly, designated generally as 26.

The operation of machine 20 is as follows. The positioner assembly 26 is moved to one extremity of its range of motion so that a chip tray 28 is located on a bonding axis indicated by the line 30. First workpieces, in this case, beam-lead integrated circuit chips 32 are supported on the chip tray 28. An optical system, designated generally as 34 is used by an operator to simultaneously view one of the chips 32 and a portion of a compliant bonding member 36 engaged with a bonding tip 48.

After alignment of one of the chips 32 and the selected portion of the compliant bonding member 36, the optical system 34 swings away from the axis 30, the bonding head 22 is lowered and the aligned chip is engaged against the compliant bonding member 36 and held by a vacuum.

The head 22 is then raised, the optical system 34 swings in and the positioner assembly 26 is moved to its other extremity of motion so that a substrate support 38 is brought onto the axis 30. The operator views the engaged chip 32 and a second workpiece, in this case, a substrate 40, simultaneously through the optical system 34 and manipulates the positioner assembly 26 to align a desired portion of the substrate 40 with the chip 32 after which head 22 is lowered and bonding pressure is applied so that the chip 32 is compliantly bonded to the aligned portion of the substrate 40. (See Figure 4).

After bonding is complete, the head 22 is raised and a motor 42 drives a take-up

reel 44 through a portion of a revolution to pull the compliant member 36 and thereby rotate a bonding ram, designated generally as 46, which is positively engaged with member 36. Rotation of take-up reel 44 continues until a next one of a plurality of bonding tips 48 of the ram 46 is aligned on the bonding axis 30.

Motor 42 generates a substantially constant torque, the motor advantageously being of the conventional "torque-motor" design, i.e., a motor which is designed to permit full current in its windings under stalled condition. When operated in this way it will constantly take up any slack in the member 36 that develops and will stall when the member is taut. Thus an actual rotation of the take-up reel 44 only occurs when the ram 46 is released from one of its eight aligned bonding positions.

If the member 36 is particularly fragile the ram 46 can be driven directly and the motor 42 can be used to simply take up slack.

A supply reel 50 has a length of compliant bonding member 36 wound thereon so that successive rotations of take-up reel 44 result in successive portions of member 36 engaging successive ones of the bonding tips 48 so that an unspent portion of member 36 is provided for each successive bonding operation that the machine 20 performs.

Bonding head 22 will be described in greater detail with reference to the remaining figures in conjunction with Figure 1. Figure 2 illustrates a portion of the compliant bonding member 36 as provided on supply reel 50 and formed as a progressively punched part from any one of a number of workable materials, for example, 2024 Type aluminium strip having a thickness of 0.005 inch.

The compliant bonding member 36 is provided with two types of apertures: bonding apertures 52 and advancement apertures 54. The bonding apertures 52 are rectangularly shaped to accommodate a body portion 53 of the chip 32 as shown in Figure 4. The advancement apertures 54 are round and disposed between each of the bonding apertures 52 and are part of the means by which the bonding ram 46 engages with the member 36 to position it accurately with respect to the tip 48.

Notches 56 are formed into the edges of the member 36 to facilitate their bending around the edges of the tips 48 as shown in Figure 3.

Figures 1, 2 and 3 illustrate the relationship of the member 36 with the bonding ram 46. The tips 48 are narrower than the member 36 and the notches 56 are just deep enough so that their inner terminations are at the outer edges of the tips 48. The portions of the member 36 between the notches 56 form tabs 57 which can be bent around the edges of the tips 48.

Sprocket projections 60 extending outwardly from the bonding ram 46 engage with a respective one of the advancement apertures 54. The angular spacing between the sprocket projections 60 and the linear spacing between the various apertures result in the bonding apertures 52 being centrally located on the bonding tips 48 in the X direction shown in Figure 3.

Accurate alignment of each of the tips 48 with respect to the bonding axis 30 is extremely important in the operation of the bonding head 22 and is achieved in part by mounting the ram 46 on a shaft 64 which is supported in conventional precision bearings (not shown). Additionally in the apparatus shown, the rotary motion of the ram 46 is limited to accurately defined 45° steps.

Positive location in the Y direction, shown in Figure 3, is provided by the folding over of the tabs 57 of the member 36 around the edges of the tip 48. The folded tabs 57 hold the member 36 in position very positively.

The combination of the folded tabs 57 and the engaged advancement apertures 54 assures that each of the bonding apertures is positively located on the bonding axis 30 during the bonding cycle.

The particular bonding ram 46 shown, has eight bonding tips 48 spaced at 45° from each other. As shown in Figures 5 and 6, each successive portion of the bonding member 36 becomes engaged with an associated one of the bonding tips 48 when the tip is in the 3 o'clock position. An engaging assembly 62 moves inwardly at the end of each period of rotation of the take-up reel 44 and forces the tabs 57 around the edges of the tip 48 and also presses one of the advancement apertures 54 onto a sprocket projection 60. Thus, when the tip 48, which is in the 3 o'clock position, is finally indexed to a position on the bonding axis 30, the member 36 is positively engaged with the tip and accurately located with respect to the tip.

The ram 46 becomes free to rotate when an index pin 72 is momentarily urged out of engagement with an index plate 74 by momentarily applying pressurised air to a conventional spring-biased cylinder 76 which urges pin 72 away from plate 74. The index plate 74 is provided with eight accurately machined holes 78 that correspond in angular displacement precisely to the centres of the tips 48.

After the pin 72 is released from one of the holes 78, the ram 46 begins to rotate due to the force exerted thereon by the member 36. The plate 74 is rigidly connected to the shaft 64 so that the plate rotates at the same angular velocity as the ram 46. Since the air cylinder 76 is operated only momentarily,

the pin 72 soon becomes urged against the plate 74 by the force of the spring in the cylinder and when a successive one of the holes 78 moves into alignment with the pin 72 the pin snaps into the hole and rotation of the ram 46 stops.

The ram 46 is heated by contact with a heater collar 80 which is spring-biased against the ram at an interface 81. The collar 80 is maintained at a desired temperature with conventional cartridge heaters 82.

The head 22 is constructed to permit application of vacuum at a vacuum port 93 formed in the end of each of the tips 48. The ports 93 are connected by radial passageways 94 to a central passageway (not shown) which runs through the length of the shaft 64. A vacuum source (not shown) is connected to the shaft 64 with a conventional connector 95. Selective actuation of the vacuum source applies vacuum at each of the ports 93. If it is desired to limit vacuum application to selected ones of the ports 93 a sleeve having a desired hole pattern can be inserted into the shaft 64.

A switch 90 is actuated by a cam 88 connected to the index pin 72 when the index pin snaps into one of the holes 78 in the plate 74. The switch is connected to actuate a valve (not shown) which admits air to a cylinder 92 that operates the engagement assembly 62.

It should be noted that even though once used, one side of the member 36 cannot be re-used, it is possible to use the opposite side of the member to make satisfactory compliant bonds. Thus after using a full package on the supply reel 50, the take-up reel 44 can be used as a supply and the opposite side of the compliant member can be used to make another series of compliant bonds and thus, fully utilise the member 36.

One full cycle of operation of the apparatus will now be described in detail.

Referring to Figure 1, the bonding head 22 is in a raised position and the positioner assembly 26 is located so that the chip tray 28 is on the bonding axis 30. The positioner assembly 26 is moved by an operator through the use of a manipulator handle 96 to align any one of the chips 32 on the tray with the bonding aperture 52 in the portion of the compliant member 36, which is engaged with the tip 48 in the 6 o'clock position.

The chip 32 and the aperture 52 can be viewed simultaneously by the operator through the optical system 34 which includes a conventional beam splitter 97 which simultaneously projects an image of the aperture 52 at the 6 o'clock position, and the chip 32 which is on the bonding axis 30 both images being viewed through a conventional microscope, not shown, which is focused on the beam splitter 97.

The operator adjusts the position of the chip with respect to the bonding axis 30 by shifting the positioner assembly 26 with the handle 96, as necessary. After alignment is achieved, the optical system 34 swings away to leave a clear path between the head 22 and the chip tray 28 and the bonding head 22 is lowered under the control of the operator. The entire bonding head 22 rides on slide assemblies 98 as it is lowered and raised.

When the portion of compliant member 36 in the 6 o'clock position contacts the chip 32 which is on the bonding axis 30, vacuum is applied through the connection 95 to the vacuum port 93 to lift the chip 32 into positive engagement with the member 36, and the head 22 is again raised to the position shown in Figure 1.

The operator then slides the positioner assembly 26 to the left so that the substrate support 38 is on the bonding axis 30 and the optical system 34 is again brought on the bonding axis 30 so that he can simultaneously view the engaged chip 32 and the substrate 40 and by means of manipulator handle 96 locate the substrate 40 accurately with respect to the engaged chip 32. After proper alignment is achieved, the optical system 34 is again swung away.

The head 22 is again lowered until beam leads 100 of the chip 32 are in contact with a conductive element 102 of the substrate 40, as shown in Figure 4 and a bonding force is then applied to the head 22 by operation of a diaphragm assembly 104 which uses accurately controlled air pressure to actuate a lever arm 106 which is constructed to apply the bonding force to a hub 108 of the ram 46. By applying the bonding force to the hub 108 the force acts almost directly along the bonding axis 30 which has the advantage of reducing mechanical deflections within the head 22 which in turn contributes to more accurate positioning of the chip 32 on the substrate 40 and to greater uniformity of bonding.

After bonding the leads 100 to the conductive elements 102, the head 22 is again raised to the position shown in Figure 1. The lever arm 106 is spring biased in the raised position shown such that a small clearance exists between it and the hub 108. This eliminates contact drag which would otherwise result in undesirable additional strain on the compliant member 36 during rotation of the ram 46.

The cylinder 76 then releases the pin 72 from the hole 78 with which it is engaged and the motor 42 becomes free to drive the reel 44 which, of course, pulls the compliant member 36 which, in turn, rotates the ram 46. The reel 50 is provided with a conventional drag brake (not shown) to provide a controlled tension in member 36. Rotation

continues until the pin 72 snaps into the next one of the holes 78 at which point another one of the tips 48 is on the bonding axis 30 in the 6 o'clock position.

Movement of the pin 72 into engagement with the hole 78 actuates the switch 90 which in turn operates the cylinder 92 causing the engagement assembly 62 to perform its function of positively engaging a portion of the compliant member 36 with the ram 46 at the 3 o'clock position.

A detailed description of the operation of the engagement assembly will be given with reference to Figures 5 to 11. The engagement assembly 62, mounted on a bracket 109, includes a tip engagement unit designated generally 110 and a sprocket-projection engagement member designated generally 112. Actuation of the cylinder 92 causes the tip engagement unit 110 to move inwardly to the tip 48 which is in the 3 o'clock position.

The tip engagement unit 110 includes two side members 114 and a centre member 116. The centre member 116 is adapted to move longitudinally with respect to the side members 114 against a biasing spring 118.

Figure 9 illustrates the unit 110 fully retracted. In this case, the extremities of both the side members 114 and the centre member 116 are substantially equidistant from the tip 48.

Figure 11 shows the situation in which the unit 110 begins its engagement function. The centre member 116 is urging the compliant member 36 against the tip 48 but the spring 118 is still elongated. As motion of the tip engagement unit 110 continues, centre member 116 is stopped but the side members 114 continue to move to engage with the tabs 57 of the compliant member 36 that overhang the tip 48 and force them over the edges of the tip (Figure 10). A spacer 119 limits the travel of the side members 114 and transmits the force of the cylinder 92 to the centre member 116. Each of the side members is provided with a shaped opening which facilitates sliding engagement with the tabs 57.

Simultaneously with the inward motion of the tip engagement unit 110, the sprocket-projection engagement member 112 presses a portion of the compliant member 36 having one of the advancement apertures 54 therein into positive engagement with one of the sprocket projections 60. The member 112 is formed of a block of plastic material such as tetrafluorethylene which has a channel 120 cut into one side thereof just wide enough to accommodate the width of the compliant member 36.

The member 112 rides on two support pins 122. Camming pins 124 project upwardly from each of the side members 114. Camming apertures 126 are formed in the

member 112 and are engaged with the pins 124. As the side members 114 move horizontally, the pins 124 transmit a horizontal force component to the member 112. The support pins 122 are mounted at the same angle with respect to the bonding axis 30 that the sprocket projection 60 assumes when the engagement assembly 62 is in operation. Thus a horizontal force component exerted on the member 112 causes the member to follow a path which is parallel to the sprocket projection 60 with which it is to engage. The member 112 moves far enough down on the sprocket projection 60 to assure that the advancement aperture is completely engaged with the sprocket projection, its motion being limited by a spacer 119 so that the compliant member 36 assumes a final position which is substantially chordal. Excessive inward motion of the member 112 would cause an undesirable concavity in the compliant member 36. A clearance hole 127 permits the projection 60 to intermesh with the member 112.

Return of the cylinder 92 permits both the tip engagement unit 110 and the member 112 to return to their retracted position under the force of springs 118 and 128. When the engagement assembly 62 is in its retracted position the ram 46 can rotate free of any interference from the assembly.

The operation of machine 20 has been described in a situation wherein individual integrated circuit chips 32 are engaged with the compliant member 36 immediately prior to their being bonded to the substrate 40. It is important to recognise however, that the chips 32 can be incorporated with the member 36 prior to the member being placed on the supply reel 50. In such a case, each rotational step of ram 46 would result in one of the chips 32 being in position for bonding, and only alignment between the chip and the substrate 40 would be required.

Because the compliant member 36 is positioned between the chip 32 and the tip 48, it provides a heat transfer mechanism that serves to maintain the chip temperature lower than the temperature of the tip. Although it is desirable to maintain the temperature of the tip 48 as high as possible, chip temperatures should not exceed 370°C.

In thermocompression bonding in general, the so-called interface temperature, i.e. the temperature which develops within the beam leads that are pressed between the compliant member and the substrate in the case of compliant bonding (and between a bonding tip and the substrate in the case of ordinary hard-tip bonding) preferably lies in the range 240°-300°C. It has also been found in the case of hard-tip bonding, that a tip temperature of something less than 370°C, the maximum allowable temperature of the semiconductor chip, is not sufficient to achieve

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the desired interface temperature and thus it is necessary to either heat the substrate in addition to heating the tip in order to provide sufficient thermal energy to achieve a satisfactory interface temperature, or to exert extremely high bonding pressures to achieve the desired interface temperature.

By virtue of the compliant member 36 engaged with the tip 48, it is possible to raise the tip temperature higher than 370°C and because member 36 acts as a heat transfer medium, the temperature of the chip 32 stays below the critical 370°C limit. When tip 48 is pressed down into engagement with the substrate 40 with member 36 therebetween, the desired interface temperature can be achieved without any additional heating of the substrate 40 and without excessive bonding pressure.

The invention finds particular application where ceramic or glass substrates are used. Such substrates are highly intolerant of heating and excessive pressures.

As will be also appreciated, the folding of tabs 57 around the tip 48 permits bonding where several chips are closely spaced on the substrate. The compliant member shown in Figure 2 can be readily formed in a conventional punching operation because a substantial amount of material, over 0.015 inch, is left remaining between the bonding aperture 52 and the outer edges of the compliant strip 36.

Although the invention has been described in connection with bonding chips one at a time, it would be possible to provide tips which accommodate portions of compliant members having more than one bonding aperture. These multiple apertures could then be engaged with a multiplicity of chips and all of the engaged chips then bonded simultaneously with a single stroke of the bonding head.

Having regard to the provisions of Section 9 of the Patent Act reference is directed to our U.K. Patent No. 1,239,631, which relates to the compliant bonding of workpieces.

WHAT WE CLAIM IS:—

1. Apparatus for bonding (as hereinbefore defined) a first workpiece to a second workpiece, said apparatus including a bonding tip, means adapted to cause engagement of a portion of a compliant bonding member with said tip prior to bonding said workpieces together, means for aligning said first and second workpieces on a bonding axis, and means for moving said tip along said axis to press the engaged portion of said member and said first and second workpieces together to effect a bond between said workpieces.

2. Apparatus as claimed in claim 1 wherein said bonding tip is one of a plurality

of bonding tips on a rotatable bonding ram, said apparatus including means for rotatably stepping said ram to bring successive bonding tips onto said bonding axis.

3. Apparatus as claimed in claim 2 wherein each of said plurality of bonding tips extends radially outwards from said bonding ram.

4. Apparatus as claimed in claim 3 wherein between each bonding tip there is a sprocket projection extending radially outwards from said ram for engagement with said member.

5. Apparatus as claimed in any one preceding claim including means for holding said first workpiece against said engaged portion prior to bonding.

6. Apparatus as claimed in claim 5 wherein said engaged portion is apertured and said holding means comprises a passageway extending through said or each bonding tip and adapted, when a pressure reduction is established therein, in operation, to hold said first workpiece against said apertured engaged portion.

7. Apparatus as claimed in any one preceding claim wherein said means adapted to cause engagement of a portion of said member with said or each tip is also adapted to fold one or more edges of said portion around one or more corresponding edges of the tip.

8. Apparatus as claimed in any one preceding claim including means for heating said bonding tip for thermocompression bonding of said workpieces together.

9. A method of bonding (as hereinbefore defined) a first workpiece to a second workpiece, wherein said workpieces are aligned on a bonding axis, a portion of a compliant bonding member is engaged with a bonding tip prior to bonding said workpieces together, and said bonding tip and the engaged portion are moved along said axis to press said engaged portion and said workpieces together to effect a bond between said workpieces.

10. A method as claimed in claim 9 wherein, prior to bonding, said first workpiece is held against said engaged portion.

11. A method as claimed in claim 10 wherein said engaged portion is apertured and said first workpiece is held against said apertured engaged portion by reducing the pressure in a passageway extending through said bonding tip.

12. A method as claimed in any one of claims 9 to 11 wherein said bonding tip is one of a plurality of bonding tips extending radially outwards from a rotatable ram, and wherein each successive portion of said member is engaged with a successive one of said bonding tips, and wherein said ram is rotatably stepped to bring each successive bonding tip and the portion of said member engaged therewith onto said bonding axis

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the desired interface temperature and thus it is necessary to either heat the substrate in addition to heating the tip in order to provide sufficient thermal energy to achieve a satisfactory interface temperature, or to exert extremely high bonding pressures to achieve the desired interface temperature.

By virtue of the compliant member 36 engaged with the tip 48, it is possible to raise the tip temperature higher than 370°C and because member 36 acts as a heat transfer medium, the temperature of the chip 32 stays below the critical 370°C limit. When tip 48 is pressed down into engagement with the substrate 40 with member 36 therebetween, the desired interface temperature can be achieved without any additional heating of the substrate 40 and without excessive bonding pressure.

The invention finds particular application where ceramic or glass substrates are used. Such substrates are highly intolerant of heating and excessive pressures.

As will be also appreciated, the folding of tabs 57 around the tip 48 permits bonding where several chips are closely spaced on the substrate. The compliant member shown in Figure 2 can be readily formed in a conventional punching operation because a substantial amount of material, over 0.015 inch, is left remaining between the bonding aperture 52 and the outer edges of the compliant strip 36.

Although the invention has been described in connection with bonding chips one at a time, it would be possible to provide tips which accommodate portions of compliant members having more than one bonding aperture. These multiple apertures could then be engaged with a multiplicity of chips and all of the engaged chips then bonded simultaneously with a single stroke of the bonding head.

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WHAT WE CLAIM IS:—

1. Apparatus for bonding (as hereinbefore defined) a first workpiece to a second workpiece, said apparatus including a bonding tip, means adapted to cause engagement of a portion of a compliant bonding member with said tip prior to bonding said workpieces together, means for aligning said first and second workpieces on a bonding axis, and means for moving said tip along said axis to press the engaged portion of said member and said first and second workpieces together to effect a bond between said workpieces.

2. Apparatus as claimed in claim 1 wherein said bonding tip is one of a plurality

of bonding tips on a rotatable bonding ram, said apparatus including means for rotatably stepping said ram to bring successive bonding tips onto said bonding axis.

3. Apparatus as claimed in claim 2 wherein each of said plurality of bonding tips extends radially outwards from said bonding ram.

4. Apparatus as claimed in claim 3 wherein between each bonding tip there is a sprocket projection extending radially outwards from said ram for engagement with said member.

5. Apparatus as claimed in any one preceding claim including means for holding said first workpiece against said engaged portion prior to bonding.

6. Apparatus as claimed in claim 5 wherein said engaged portion is apertured and said holding means comprises a passageway extending through said or each bonding tip and adapted, when a pressure reduction is established therein, in operation, to hold said first workpiece against said apertured engaged portion.

7. Apparatus as claimed in any one preceding claim wherein said means adapted to cause engagement of a portion of said member with said or each tip is also adapted to fold one or more edges of said portion around one or more corresponding edges of the tip.

8. Apparatus as claimed in any one preceding claim including means for heating said bonding tip for thermocompression bonding of said workpieces together.

9. A method of bonding (as hereinbefore defined) a first workpiece to a second workpiece, wherein said workpieces are aligned on a bonding axis, a portion of a compliant bonding member is engaged with a bonding tip prior to bonding said workpieces together, and said bonding tip and the engaged portion are moved along said axis to press said engaged portion and said workpieces together to effect a bond between said workpieces.

10. A method as claimed in claim 9 wherein, prior to bonding, said first workpiece is held against said engaged portion.

11. A method as claimed in claim 10 wherein said engaged portion is apertured and said first workpiece is held against said apertured engaged portion by reducing the pressure in a passageway extending through said bonding tip.

12. A method as claimed in any one of claims 9 to 11 wherein said bonding tip is one of a plurality of bonding tips extending radially outwards from a rotatable ram, and wherein each successive portion of said member is engaged with a successive one of said bonding tips, and wherein said ram is rotatably stepped to bring each successive bonding tip and the portion of said member engaged therewith onto said bonding axis



to bond successive first workpieces to successive second workpieces.

5. 13. A method as claimed in any one of claims 9 to 12 wherein the engagement of said or each portion includes the folding of one or more edges of said or each portion around one or more corresponding edges of the tip.

- 10 14. A method as claimed in any one of claims 9 to 13 wherein said bond is a thermo-compression bond.

15. A method of bonding two workpieces together substantially as herein described with reference to the accompanying drawings.

- 15 16. First and second workpieces bonded together by a method as claimed in any one of claims 9 to 15.

- 20 17. Bonding apparatus substantially as herein described with reference to the accompanying drawings.

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