

**APPARATUS AND METHOD FOR MOUNTING SEMICONDUCTOR CHIPS
ON A SUBSTRATE**

BACKGROUND OF THE INVENTION

5 **Field of the Invention**

The present invention relates to an apparatus and method for mounting semiconductor chips on a substrate.

Background of the Prior Art

10 In semiconductor manufacture, semiconductor elements are provided on a wafer in large numbers in mutually juxtaposed relationship with an integrated circuit. Each wafer is then mounted on a carrier and the individual elements are mechanically separated from each other. In the subsequent semiconductor mounting operation, in a first working step, the chips produced in that way have to be individually mounted on a substrate. That operation is implemented by so-called
15 pick-and-place apparatus which lift a chip at a first location from a chip carrier, then displace it sideways and deposit it on a substrate place at a second location.

A known apparatus of that kind includes:

- a manipulator which has a chip gripper movable with a reciprocating motion between two mechanically defined limit positions,
- 20 - a displacement table arranged in the region of one limit position of the manipulator, for providing a respective chip at the first location for the purposes of being received by the chip gripper, and a first measuring camera directed onto the first location for ascertaining the position of the provided chip, and
- a substrate feed unit arranged in the region of the other limit position of the
25 manipulator, for providing a respective substrate place at the second location for the purposes of receiving the chip from the chip gripper, and a second measuring camera or sensor means directed onto the second location for ascertaining the position of the provided substrate place.

Such a pick-and-place apparatus is a component of an automatic mounting

assembly which is referred to as a "die bonder". Apparatus of that kind are subject to extremely high demands in regard to a short cycle time, mechanical stiffness and a precise position for the chips on the respective substrate place. A high degree of positional accuracy on the substrate in the range of a few micrometres is required
5 for further processing of the chips on the so-called wire bonder where the integrated circuit on the chip is provided at its connecting locations or bond pads with wire connections.

In the pick-and-place operation the limit position of the chip relative to the substrate is basically influenced by the position of the chip provided at the first
10 location, the two limit positions of the manipulator or the chip gripper moved thereby, and the position of the substrate place which is provided at the second location. Therefore, in order to satisfy the requirements in respect of accuracy in previously known mounting apparatus the crucial units - the displacement table at the first location (the so-called wafer table), the manipulator and the feed unit at the
15 second location (the so-called indexer) - must enjoy the correspondingly high degree of precision. Measuring cameras at both locations serve to monitor the position of the provided chip and substrate place respectively, and to control the wafer table and the indexer respectively on the basis of image processing. In accordance with the state of the art, at any event in regard to the wafer table, firstly a coarse
20 displacement is effected and then, on the basis of the camera measuring signal, fine positioning is implemented. To ascertain the position of the substrate place it is possible to use other sensor means at the second location instead of a (second) measuring camera. If the substrate is formed by so-called lead frames, then it is possible to use for example photoelectric edge detectors which co-operate with
25 indexing (fitting) bores on the lead frame edge or directly with edges of the chip islands (substrate places); sensors of that kind can also supply measuring signals which characterise the respective position of the substrate place in the plane.

The known structure of such mounting apparatus involves a very high level of resources and expenditure in terms of manufacture of the specified sub-

assemblies and in assembly and calibration of the apparatus. The procedure for operational adjustment to a respective new product is also time-consuming. There is also the disadvantage that the image processing operation which is to be effected during each working cycle and which takes up a relatively large amount of time, with subsequent fine movement, prolongs the cycle time. An increase in output (increased cycle rate) while maintaining an adequate level of accuracy and satisfying all other requirements scarcely seems possible with the present design concept of the apparatus, or would result in unacceptable costs.

It is an object of the present invention to provide a mounting apparatus of the kind set forth in the opening part of this specification, which overcomes the difficulties and disadvantages which are encountered in the state of the art. In particular, it is an object of the invention to enable a reduction in the length of the cycle time without correspondingly increased expenditure in relation to the wafer table, the indexer and the manipulator.

SUMMARY OF THE INVENTION

Viewed from a first aspect, the present invention provides apparatus for mounting semiconductor chips on a substrate, wherein a respective chip is lifted from a chip carrier at a first location, displaced sideways and deposited on a substrate place at a second location, comprising:

- a manipulator having a chip gripper which is movable with a reciprocating motion between two mechanically defined limit positions,
- a displacement table arranged in the region of one limit position of the manipulator for providing a respective chip at the first location for said provided chip to be received by the chip gripper, and a first measuring camera directed onto the first location for ascertaining the position of the provided chip,
- a substrate feed unit arranged in the region of the other limit position of the manipulator for providing a respective substrate place at the second location for receiving the provided chip from the chip gripper and a second measuring camera or sensor means directed onto the second location for ascertaining the position of

the provided substrate place,

a correction motion unit associated with the manipulator, which is controllable on the basis of positional measurement values from the two measuring cameras or the sensor means in order to compensate for positional errors of the provided chip, which are measured at the first location, and positional errors of the provided substrate place, which are measured at the second location, in each case at the latest prior to a respective chip being deposited on the substrate place.

Accordingly, in preferred embodiments, associated with the manipulator is a correction motion unit which is controllable on the basis of positional measurement values of the two measuring cameras - or the measuring camera at the first location and the sensor means at the second location. It is provided in order to compensate for positional errors in respect of the provided chip, which are measured at the first location, and positional errors in respect of the provided substrate place, which are measured at the second location, in each case at the latest prior to deposit of the respective chip on the substrate place.

The invention provides in particular that, in both those parts of the operating procedure - providing the chip and providing the substrate place - certain positional deviations can be tolerated. They are compensated by means of correction motions, preferably in a procedure towards the end of the working cycle, immediately prior to deposit of the chip. In that way it is also possible to eliminate the division of the movement into a coarse movement and a fine movement in regard to the specified sub-units, which also makes it possible to save time. The correction motion unit used in the case of the present invention requires only a small travel range (order of magnitude of a few tenths of a millimetre) and can perform the required motions very quickly and accurately.

In an embodiment of the invention, position sensors are additionally provided for detecting the limit positions of the manipulator and the chip gripper respectively. The measurement values thereof are also included in the compensation procedure performed by the correction motion unit. In that way

inaccuracies which occur in regard to the manipulator, in particular long-term drift phenomena, can also be detected and compensated.

Viewed from a second aspect, the present invention provides a mounting process using an apparatus according to the first aspect of the invention, wherein

5 lateral positional errors

- of the chip after provision thereof at the first location,

- of the chip gripper prior to lifting-off the provided chip at the first location,

- of the substrate place after provision at the second location, and

10 - of the chip gripper prior to deposit at the second location,

are measured during each working cycle,

the measured positional errors are at least partially vectorially added and stored, and

for the purposes of positionally accurate deposit of the chip the ascertained
15 error sum is compensated at the manipulator immediately prior to deposit of the chip by control of the correction motion unit.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention is described in greater detail hereinafter by means of embodiments and with reference to the drawing in which:

20 Figure 1 shows an embodiment of an apparatus with a highly simplified diagrammatic view of the manipulator and associated sub-units,

Figure 2 is a perspective view in greater detail of an alternative configuration of the apparatus,

Figure 3 is a functional diagram of the apparatus shown in Figure 2, and

25 Figure 4 shows a time graph over a working cycle.

DESCRIPTION OF EMBODIMENTS OF THE PRESENT INVENTION

The apparatus shown in simplified form in Figure 1 is part of a die bonder, as is used in the semiconductor mounting procedure in order to lift semiconductor chips 10 individually out of the wafer formation in per se known manner and

position them on a substrate 5 and in so doing fix them preferably by means of adhesive or soft soldering. That procedure is implemented by a manipulator 1 provided with a chip gripper 2. The chip gripper 2 is a component of a bond head 19 moved by the manipulator, and it can also be raised and lowered. The bond head and the chip gripper are moved with a reciprocating motion by the manipulator between two mechanically defined limit positions. Arranged in the region of the one limit position of the manipulator is a displacement table 3 (the so-called wafer table) on which are disposed the chips 10 of a wafer, which adhere to a chip carrier 11. The displacement table 3 provides a respective chip 10' at a given first location A for it to be received by the chip gripper 2. Disposed in the region of the other limit position of the manipulator is a feed unit 4 (so-called indexer) for a substrate 5 provided with substrate places (for example a metal lead frame). The feed unit 4 moves the substrate 5 with a stepwise movement in order to provide at a second location B a respective substrate place which is intended for receiving the chip 10' supplied thereto by the chip gripper 2.

The first location A and the second location B are each defined by the axis of a measuring camera (7 and 8 respectively in Figure 2). The actual position of the prepared chip (first location A, camera 7) and the prepared storage place (second location B, camera 8) are measured by the measuring cameras by means of per se known image processing processes during each working cycle, that is to say, they are processed to afford corresponding positional measurement values. The use of such measurement values in accordance with an embodiment of the invention is described in greater detail hereinafter. In the illustrated embodiments two measuring cameras are illustrated and described. It is to be noted however that, as mentioned hereinbefore, the position of the prepared storage place at the second location B can also be measured with suitable sensor means (centering sensor, edge detector or the like).

It will be appreciated that, in the case of the illustrated apparatus, the two locations A, B on the one hand and the two mechanically defined limit positions of

the chip gripper - which are initially assumed to be constant - on the other hand are brought into conformity as accurately as possible by suitable adjusting devices and processes. A basic distinction is to be drawn however between the "locations" defined by the cameras and the "limit positions" determined by the manipulator, as
5 will be apparent hereinafter from further aspects of the description.

The manipulator 1 is mounted on a base plate 12 and in the present example is in the form of a so-called thrust crank transmission arrangement. Mounted on the base plate 12 is a drive shaft 13 carrying a swing arm 14. The connecting rod 15 is pivotably connected to the end of the swing arm 14. The end of the connecting rod
10 15 remote from the swing arm 14 is pivotably connected to a slider 16 which in turn carries the bond head 19 with the chip gripper 2. The slider 16 slides on a linear guide means which, like the mounting for the shaft 13, is fixed on the base plate 12. As indicated in Figure 1 the shaft 13 and the swing arm 14 perform rotary movements through 180° in alternate directions, with the slider 16 sliding to and
15 fro. The two straight positions between the swing arm 14 and the connecting rod 15 provide the two mechanical limit positions of the slider 16 and the chip gripper 2 (the one limit position is shown in solid lines and the other in dash-dotted lines). In the present context it is assumed that the arrangement is a manipulator with two stable, mechanically defined limit positions; it is to be noted here however that such
20 limit positions can also be achieved in a different manner from the use of the thrust crank transmission arrangement which is only illustrated by way of example.

Finally Figure 1 shows in purely diagrammatic form a correction motion unit 9 which is associated with the manipulator 1 or connected thereto. The significance and the mode of operation thereof are described hereinafter.

25 Figure 2 is a perspective view of an apparatus given by way of example, which is similar to that shown in Figure 1, wherein components which correspond to each other are denoted by the same references in the two Figures and will not be further referred to. The substrate (lead frame) 5 has substrate places 6 which are advanced with a stepwise motion by the indexer 4 to the location B under the

measuring camera 8. Chips which are fixed on substrate places and which are further transported with the substrate are denoted by reference numeral 10''. Figure 2 additionally shows a drive unit 18 for the shaft 13 of the manipulator 1, and also a motor 19a, mounted on the slider 16, for the vertical movements of the
5 bond head 19. The apparatus is mounted on a base structure 20 as shown in Figure 2. It carries for example a transverse member 22 on which the measuring cameras 7 and 8 are fixed. Adjusting arrangements for aligning the cameras and the bond head 9 and further details which are not essential in the present context are not illustrated.

10 In accordance with an alternative configuration the apparatus of Figure 2 may be provided in the regions of the two limit positions of the manipulator 1 with position sensors 26 and 27 respectively and reference surfaces 28 and 29 respectively which co-operate therewith and which are mounted on the slider 16. Those additional measuring members make it possible to measure the respective
15 position of the slider and therewith the chip gripper 2 in the two limit positions, by the sensors 26, 27 producing positional measurement values (in the x- and y-directions), with respect to the reference or target position. As described hereinafter, use can be made of that procedure in the context of a particular chip mounting process according to the invention.

20 The correction motion unit 9 which is only diagrammatically indicated in Figure 1 and which is associated with the manipulator 1 may be for example embodied as shown in Figure 2 in the form of a so-called microtable (micro-manipulator) or also in some other fashion. That unit is provided to perform very precise and rapid movements within a relatively small working range in the x- and
25 y- directions (Figure 2). The unit 9 is controllable on the basis of positional measurement values of the two measuring cameras 7 and 8 and the correction motions thereof are transmitted to the manipulator and therewith to the chip gripper 2.

As already stated hereinbefore such positional measurement values are

obtained in the course of each working cycle by automatic processing of the images of the two measuring cameras 7 and 8 (or the signals from sensor means) and correspond to positional errors (in the x- and y- directions) of the chip 1 provided at the location A or the substrate place 6 provided at the location B. Positional errors
5 of that kind may be due to various causes, in particular they are caused by limited accuracy in regard to motion of the wafer table 3 and the indexer 4 which must both have a relatively large working range. Insofar now as the motion unit 9 is controlled within the working cycle in accordance with the specified measurement values, the respective positional errors of the prepared chip and the prepared
10 substrate place are compensated and the chip 10' is transferred from the chip gripper 2 onto the substrate place in an accurate position.

It will be appreciated that a correction motion of the unit 9 must be effected at the latest prior to each operation of depositing the respective chip 10' on the substrate place. The positional error in respect of the prepared chip may already be
15 compensated approximately at the "half time" of the cycle, that is to say prior to the chip being lifted off the chip carrier 11, by control of the unit 9. That is desirable if the chip gripper 2 is a so-called die collect tool which engages the chips at their upper edges, which presupposes accurate orientation as between the gripper and the chip. Otherwise - if the chips are engaged at their top side, for example with a
20 suction gripper - it is particularly advantageous to store the respective positional measurement value which is ascertained at the first location A, then add it vectorially to the value subsequently ascertained at the location B, and control the unit 9 with the sum, that is to say only once, towards the end of the cycle; in the vectorial addition operation the values can be partially compensated (in accordance
25 with x- and y- components) so that the correction motion overall turns out to be smaller.

Reference will also be made hereinafter to Figures 3 and 4 to describe the function of the apparatus, and the mounting process, with the inclusion of sensors 26, 27 (Figure 2). The functional diagram in Figure 3 shows the sensors 26 and the

measuring camera 7 at the first location A and the sensors 27 and the measuring camera 8 at the second location B, in each case with the signal lines extending from them. References 32 and 33 denote image processing circuits which are associated with the cameras 7 and 8 respectively and at the outputs of which appear the
5 respective positional measurement values in respect of the prepared chip and the prepared substrate place respectively. The four measurement values respectively ascertained in the course of a working cycle - corresponding to lateral positional errors of the chip, the substrate place and the chip gripper at the locations A and B - are fed to a storage and adding circuit 34. The vectorial sum of the specified
10 positional measurement values is formed in such a per se known circuit. The vector sum formed (x- and y- components) is called up at a suitable moment and, as indicated by the line 35, fed to the correction motion unit 9. On the basis of that control the unit 9 performs the required correction motion at the manipulator 1 in order to accurately position the chip gripper with the chip 10' over the substrate
15 place.

In accordance with the foregoing example all positional errors which are measured in the course of a cycle are vectorially added and compensated with a single correction procedure at the manipulator immediately prior to deposit of the chip on the substrate place (beginning of the bonding operation).

20 In accordance with an alternative form of the process however it may be desirable for example for the measured positional error of the prepared chip (measurement value of the camera 7) to be compensated in itself, without being included in the addition operation in the circuit 34, more specifically before the chip is lifted off the chip carrier 11. This alternative configuration is indicated by the
25 dash-dotted line 35' in Figure 3. In this case therefore the unit 9 performs two correction motions during a respective cycle.

In the time graph shown in Figure 4 the horizontal bars which are shown one beneath the other represent the following function portions and time portions within a working cycle T:

- a. motion of the indexer 4
- b. evaluation of the image of the camera 8 (position of the substrate place at the location B)
- c. correction motion or motions of the unit 9
- 5 d. vertical movements of the bond head 19 with the chip gripper 2 (z-direction, Figure 2)
- e. sideways movements of the manipulator 1 ("fetch" and "bring", y-direction, Figure 2)
- f. measuring operations of the sensors 26, 27 at A and B respectively
- 10 g. movement of the wafer table 3
- h. evaluation of the image of the camera 7 (position of the chip at the location A).

It will be appreciated that all procedures described hereinafter are program-controlled. The moment in time t_1 is assumed to be the beginning of a fresh cycle T, being the time when, after the end of the bonding operation in the preceding cycle (bar d.) the indexer 4 is started in order to prepare a fresh substrate place 6. After the feed movement of the substrate 5 has occurred, evaluation of the image recorded by the measuring camera 8 (bar b.) begins in order to detect the position of the freshly prepared substrate place 6. Simultaneously with the start of the indexer 4 the manipulator 1 is set in movement (bar e.). It guides the bond head 19 to the location A in order there to fetch the chip 10 which was provided (in the course of the preceding cycle) by the wafer table 3. Before the limit position of the manipulator or the bond head 19 with the chip gripper 2 over the wafer table is reached, the measurement values relating to the position of the provided chip from image processing of the camera 7 (bar h.) are available. The chip is now lifted off the chip carrier 11 by rapid downward movement and lifting motion of the bond head 19 (bar d.). The manipulator with the chip 10' engaged by the chip gripper 2 then performs the return movement to the location B. Simultaneously with the manipulator, the wafer table 3 is also started in order to provide a subsequent chip

(bar g.) and that is then followed by the commencement of evaluation of the image recorded by the camera 7 (bar h.). Before the manipulator has moved the bond head to the location B, the results of the image processing of the camera 8 are available, that is to say the precise position of the new substrate place 6 is known.

5 On the basis of the relevant measurement values as well as stored and added further error measurement values ascertained in the course of the cycle, the correction motion unit 9 is now controlled, whereby the chip 10' is positioned precisely over the substrate place 6. Directly thereafter the bond head 19 deposits the chip on the substrate place and the bonding operation then occurs. That - and therewith the

10 working cycle - is terminated with the bond head being raised again (bar d., time t2).

If the apparatus is provided with sensors 26, 27 for the limit positions of the bond head, they come into operation at the respective moments in time in accordance with bar f., and the measurement values thereof are incorporated into

15 the storage operation, the addition operation and the correction motion, as was described hereinbefore with reference to Figure 3. As is further indicated in dash-dotted line in Figure 4, bar c., and as has also been discussed hereinbefore, partial error compensation can already be effected prior to the chip being lifted off the chip carrier 11, by virtue of the unit 9 being controlled on the basis of the positional

20 error measurement values of the prepared chip (camera A, bar h.). This therefore corresponds to the alternative configuration indicated by the line 35' in Figure 3, in which the positional error of the prepared chip is not included in the summing procedure.

I/WE CLAIM:

1. Apparatus for mounting semiconductor chips on a substrate, wherein a respective chip is lifted from a chip carrier at a first location, displaced sideways and deposited on a substrate place at a second location, comprising:

- a manipulator having a chip gripper which is movable with a reciprocating motion between two mechanically defined limit positions,

- a displacement table arranged in the region of one limit position of the manipulator for providing a respective chip at the first location for said provided chip to be received by the chip gripper, and a first measuring camera directed onto the first location for ascertaining the position of the provided chip,

- a substrate feed unit arranged in the region of the other limit position of the manipulator for providing a respective substrate place at the second location for receiving the provided chip from the chip gripper and a second measuring camera or sensor means directed onto the second location for ascertaining the position of the provided substrate place,

a correction motion unit associated with the manipulator, which is controllable on the basis of positional measurement values from the two measuring cameras or the sensor means in order to compensate for positional errors of the provided chip, which are measured at the first location, and positional errors of the provided substrate place, which are measured at the second location, in each case at the latest prior to a respective chip being deposited on the substrate place.

2. Apparatus according to claim 1, further comprising positional sensors intended to co-operate with the chip gripper, which are arranged in the region of the two limit positions of the manipulator in order to measure the position of the chip gripper in relation to the first location and the second location respectively in the respective limit position, the correction motion unit being additionally controllable on the basis of positional measurement values from said sensors.



3. A method for mounting semiconductor chips on a substrate using an apparatus according to claim 2, wherein:

lateral positional errors

- of the chip after provision thereof at the first location,
- of the chip gripper prior to lifting-off the provided chip at the first location,

- of the substrate place after provision at the second location, and

- of the chip gripper prior to deposit at the second location,

are measured during each working cycle,

the measured positional errors are at least partially vectorially added and stored, and

for the purposes of positionally accurate deposit of the chip the ascertained error sum is compensated at the manipulator immediately prior to deposit of the chip by control of the correction motion unit.

4. A process according to claim 3, wherein a measured positional error of the chip after provision thereof at the first location, without being included in the addition operation, is compensated at the manipulator immediately prior to the chip being lifted off by the chip gripper.

