

Method and apparatus for inspecting a chip prior to bonding

5 Field of the Invention

The present invention pertains to the field of automation technology. It relates to an apparatus and a method for handling chips, in particular semiconductor dies, in accordance
10 with the preamble of the independent patent claims.

Background of the Invention

15 One of the biggest challenges in semiconductor packaging is picking, handling and processing of very thin semiconductor chips. The semiconductor chips are generally provided on a carrier tape, which generally contains a whole semiconductor wafer that has been cut into small chips, a process frequently referred to as dicing. The semiconductor chips are
20 thus commonly referred to as dies. The carrier tape is often the same tape that supported the wafer during dicing, often referred to as dicing tape. Die thicknesses of down to 25µm are common today, and there is an ongoing trend to decrease
25 thicknesses even further.

Die bonders pick a single die from the carrier tape and place and subsequently attach the picked die onto a substrate or onto another die. In most situations, the die is
30 attached permanently, but configurations where dies are only attached temporarily also exist. Often, a temporary attachment is subsequently turned into a permanent one by an additional heating and/or pressing process. Typically, thin dies come with a wafer backside lamination (WBL) or film or flow

over wire (FOW) lamination, i.e. an adhesive film which is applied to an unstructured side of the wafer or die. A process of thinning wafers, applying an adhesive film to the wafers, mounting the wafers to a carrier tape and frame, and
5 dicing them into individual chips is usually referred to as wafer preparation. The lamination, which allows for the dies to be attached due to its adhesive properties, may be provided either between the carrier tape and the wafer, or on a surface of the wafer facing away from the carrier tape.

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Picking and placing may be carried out by a single chip handling unit in the die bonder. In modern die bonders, however, a plurality of chip handling units can be present: In general, picking takes place from a so called wafer table,
15 and is assisted by a first chip handling unit, also referred to as die ejector. The die ejector facilitates the removal of the die from the carrier tape, e.g. by pushing the die against a second chip handling unit called pick unit - from underneath the carrier tape. The pick unit subsequently
20 picks the die from the carrier tape in a pick process and hands it over to a third chip handling unit, also referred to as place unit. The place unit places the die onto a target position, where it is attached. In some cases, at least one fourth chip handling unit - a so called transfer unit -
25 is provided to hand the die from the pick unit to the place unit. An example is given in WO 07118511 A1 which is hereby incorporated by reference in its entirety. In this manner, a die may be attached to a substrate, e.g. a leadframe, printed circuit board, multilayer board etc., or to another
30 die, which itself may have been attached in the same way.

The fabrication of very thin wafers and the corresponding dies is very expensive as compared to standard thickness wafers without lamination. Sawing, picking as well as handling
35 of very thin dies have significant yield losses. Most of the

yield is lost during wafer preparation, die picking, or subsequent handling, resulting in damaged dies due to typical defects as e.g. broken dies, cracked dies, chipped dies, etc. Both place and attachment processes, in comparison, are more reliable, giving rise to only negligible loss.

Known inspection methods for detecting broken, cracked or chipped dies on die bonders are performed before the pick process - which itself has limited yield - and are generally based on imaging a die surface under surface illumination, followed by image processing. These inspection techniques have limited reliability due to low crack contrast and crack width, die warpage - also referred to as potato chip effect - and due to the interference of crack signatures with other similar looking patterns on the die surface.

In particular for stacked die bond processes where two or more dies are attached onto one another, attaching of a broken die may have dramatic consequences: If a damaged die is attached onto a stack, all previously attached dies in that stack - also referred to as package - are lost. In an extreme situation, for example, a package consisting of 15 stacked dies may thus be lost by attaching a broken 16th die on top of it.

Summary of the invention

Embodiments of the invention seek to allow for an inspection after picking of a die rather than - or in addition to - one before picking of the die, e.g. on a die ejector, and may thus guarantee that only undamaged dies are attached to a substrate or a previously attached die by a die bonder.

In addition, embodiments of the invention seek to allow for an identification of damaged dies before attach, and thus to allow for omitting to place such damaged dies onto a substrate or a stack of previously attached dies. Ideally, inspection of the die should be possible immediately before it is placed and subsequently attached to the substrate or to an already attached die.

Embodiments of the invention also seek to maximize a signal-to-noise ratio and a success rate of a crack detection.

Embodiments of the invention also seek to allow for additional inspections, in particular an inspection of die pattern or structure integrity, a detection of a chip ID, an exact alignment prior to transfer, etc., to be carried out efficiently.

The above may in particular be achieved by generating a back-illumination image of the die - also referred to as an absorption image - in which cracks, missing parts, patterns, etc. are identified as areas of substantial change of the light intensity transmitted through the die. If, for example, a visible light source is used for illumination, cracks appear as bright lines on a fully dark background of practically zero light transmission, with no intrinsic die surface patterns being visible or disturbing subsequent signal processing. A much better signal-to-noise ratio can thus be achieved when compared to known inspection methods based on surface illumination.

In accordance with an aspect of the present invention, a chip handling tool, in particular for use in a semiconductor die bonder, is presented. The chip handling tool is configured

to receive a chip, in particular a semiconductor die, at a takeover location and to hand over said chip to a delivery location, and comprises a work surface configured to be brought into connection with a first surface on a first side of the chip. The chip handling tool further comprises illumination means for illuminating the chip from its first side while said first side of the chip is in connection with the work surface.

In accordance with another aspect of the present invention, a chip handling process, in particular for a die bonding process, is presented in which a chip, in particular a semiconductor die, is received at a takeover location by a chip handling tool, and handed to a delivery location by means of said chip handling tool. At the takeover location, a work surface of the chip handling tool is brought into connection with a first surface on a first side of the chip. The chip is then illuminated from the first side while being in connection with the work surface of the chip handling tool, and light having passed through the chip is detected and analyzed for damages of the chip.

There is also provided a chip processing apparatus which includes the chip handling tool as presented.

The aforementioned and further objectives, advantages and features of the invention will be detailed in the description of preferred embodiments below in combination with the drawings.

Brief Description of the Drawings

The invention is best understood from the following detailed
5 description when read in connection with the accompanying
drawing. It is emphasized that, according to common prac-
tice, the various features of the drawing are not to scale.
On the contrary, the dimensions of the various features are
arbitrarily expanded or reduced for clarity. Included in the
10 drawing are the following figures:

Fig. 1 shows a chip handling tool in accordance with a first
exemplary embodiment of the present invention.

15 Fig. 2 shows chip handling tools in accordance with a second
exemplary embodiment of the present invention.

Fig. 3 shows a die bonder in accordance with an exemplary
embodiment of the present invention.

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Fig. 4 shows a die ejector in accordance with an exemplary
embodiment of the present invention.

Fig. 5 shows a flow diagram illustrating a chip handling process
25 in accordance with an exemplary embodiment of the present inven-
tion.

Detailed Description of the Invention

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Fig. 1 shows a chip handling tool 10 according to a first
exemplary embodiment of the present invention. On a tool
body 101 made from a rigid material, preferably metal, an at
least partially transparent layer 2 is provided that com-
35 prises a surface sublayer 201 which consists of elastic ma-
terial, e.g. silicone rubber, and has a work surface 21,

which may be brought into contact with a first surface on a first side of a chip, in particular a die 5 to be handled by the chip handling tool 10; or vice versa. The die 5 may or may not be provided with a WBL or FOW lamination. The tool body 101 comprises a plurality of light emitting diodes 31 that serve as an integrated light source. Alternatively, one or more light sources may be provided in or on the surface of the tool body 101. Layer 2 comprises a base layer 202 which also consists of a material that is at least partially transparent to the illumination from the light emitting diodes 31. Preferably, sublayer 201 and/or base layer 202 exhibit some scattering to provide for a more uniform illumination of dies 5 handled by the chip handling tool 10. The first surface of the die 5, while in close contact with the work surface 21 of layer 2, may thus be illuminated through said work surface 21. Thin vacuum channels 102 in the chip handling tool 10 allow for a vacuum to be applied in order to temporarily fix the die 5 to the work surface 21, and thus hold the die while it is being transported from a first location to a second location different from the first location by means of the chip handling tool 10. Other means for temporarily fixing the die 5 to the work surface 21 may be provided. In particular, e.g. electrostatic means or an adhesive work surface 21 may be employed.

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In a second exemplary embodiment of the present invention as shown in Fig. 2a-d, the chip handling tool 10 itself does not comprise any light source. However, means for redirecting light are provided so that light from an external light source 33 may be used to illuminate the die 5 held by the work surface 21 of the chip handling tool 10, preferably through the work surface 21. This may be achieved by forming the at least partially transparent layer 2 of a material that scatters, diffracts or reflects light from light source 33, e.g. due to scattering centers 221, 222 provided within

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the volume of layer 2' as shown in Fig. 2a, on a back surface and/or a front surface of layer 2'', or on a front surface of the tool body 101 as shown in Fig 2b; or a combination thereof. It may also be achieved by providing an at least partially reflective zone 223 within layer 2''' as shown in Fig. 2c, or by providing the tool body 101 with a reflective surface 104 that forms an angle with the work surface 21 as shown in Fig. 2d, or any combination of one or more of the different variants shown. Preferably, layers 2', 2'', 2''' are made of or comprise regions made of resilient material. Combinations of the second and first embodiments are also possible.

If a light sensitive element 4 is provided at a location opposite a second surface of the die 5, defects of die 5 may be detected due to the fact that a broken, cracked, chipped or similarly damaged die 5 will allow for a significantly bigger amount of light to reach the light sensitive element 4 than an undamaged die 5. Preferably, an image acquisition tool, e.g. CCD element or CMOS light sensor array, is used as light sensitive element 4. Image processing methods may then be employed to discriminate between undamaged and damaged dies 5. For example, image processing algorithms may be used to detect bright spots in areas that are expected to be dark for undamaged dies. However, when adequately calibrated, one or several light detectors, e.g. an area photo detector measuring peak or total transmission, may also suffice for the purpose of detecting die damage. A threshold operation which may either be implemented in the photo detector itself, or in a control system to which the detector is connected may then perform discrimination between undamaged and damaged dies 5. This may allow for a much faster, simpler and potentially cheaper discrimination procedure, as no image processing and thus no image processing software is required.

Preferably the chip handling tool 10 is configured to be moved in at least two of the six degrees of freedom represented by linear coordinates x , y , z , and angular coordinates θ_x , θ_y , θ_z by means of an associated chip handling unit. This allows for the chip handling tool 10 to actively grab a die 5 to be received. Alternatively, the chip handling tool 10 may also have one degree of freedom only. In this case, in general the die 5 needs to be handed to the chip handling tool 10. In particular, the chip handling tool 10 may be formed as a rotating disc or a conveyor belt, so that a plurality of dies 5 may simultaneously be in contact with the work surface 21, and be transported from the first location to the second location in parallel.

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In all the embodiments described above or to be described below, contactless die handling may alternatively be used to advantage. Rather than by bringing the work surface 21 and the first surface of the die 5 into contact as described above, and establishing a connection between the die 5 and the work surface 21 by fixing the die 5 temporarily to the work surface 21, the die 5 may be held in position with a small gap between its first surface and the work surface 21 as a consequence of an equilibrium of attractive and repulsive forces acting onto the die 5. An example of how this may be achieved for wafers is given in US 5 080 549, which is hereby included by reference in its entirety.

Fig. 3 shows a schematic of an exemplary embodiment of a die bonder according to the present invention. The die bonder comprises a plurality of chip handling units: A first chip handling unit 91, a so called die ejector, ejects a die 5, which may be laminated with a WBL or FOW lamination, from a carrier tape. After the die 5 has been ejected, it is taken over by a second chip handling unit 92 also referred to as

pick unit. The pick unit is capable of rotating around a first axis, and configured to hand the die 5 over to a third chip handling unit 93. Said third chip handling unit 93, also referred to as transfer unit, is capable of rotating about a second axis, and may thus hand the die 5 to a fourth chip handling unit 94 also referred to as place unit, which in turn will take the die 5 over from the transfer unit 93 and transport it to and place it onto a target position on a substrate 6. The transfer unit 93 comprises a chip handling tool 10 according to the present invention as described above by means of examples. When the transfer unit is at a delivery location as represented by a solid line in Fig. 4, and the die 5 is illuminated through the illumination means provided in the chip handling tool 10, light from the integrated light source of the chip handling tool 10 or an external light source 33 having preferably passed through the work surface 21 and passed through the die 5 may be detected by a transfer camera 41. The die bonder further comprises a control system not shown in Fig. 3 to control the movements of the various chip handling units etc.

In an image acquired by the transfer camera 41 when the die 5 is illuminated by the illumination means, cracks, broken or chipped off areas and similar damages appear as bright spots, whereas integrity areas appear as dark areas. In order to achieve sufficiently good contrast, an appropriate illumination wavelength has to be chosen that is sufficiently well absorbed by the semiconductor material of the die 5. Visible light illumination is generally appropriate. Based on a discrimination between damaged and undamaged dies as described above, exception handling controls may then allow for avoiding attaching of broken dies, and for removing them from the transfer unit 93.

In a preferred embodiment of the present invention, the die 5 may also be illuminated by non-visible light, in particular light in the infrared wavelength range in which a semiconductor material is at least partially transparent. Wavelengths between 1.2 and 1.7 μm are particularly well suited, especially for silicon dies as they allow for inspections of an integrated circuit pattern of the die 5. In addition, simple cameras that work without cooling or residual light amplification are readily available for these wavelengths.

10 Dies 5 that are faulty, e.g. due to corrupted circuit patterns etc. may thus be detected and also be regarded and treated as damaged. In addition, die ID markings may be visualized. An illumination allowing for illumination with different wavelengths may also be employed to advantage.

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Heating the die 5 is often necessary for permanent attachment to a substrate or another die. Heating elements, in particular resistive heating elements, may be provided in the chip handling tool 10. The at least partially transparent layer 2, 2', 2'', 2''', or at least sublayer 201, preferably should be made from material that shows both sufficient heat resistance, and preferably good heat conductivity. To avoid damage to the die 5 due to electrostatic discharge, the at least partially transparent layer 2, 2', 2'', 2''', or

20 at least sublayer 201 should preferably also exhibit good electrical conductivity. Alternatively, a thin layer of a conducting transparent material, e.g. indium tin oxide (ITO) may be provided on the work surface 21. Such a thin layer may also be used for heating.

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Preferably, transfer camera 41 may also be used for other inspection or measurement purposes in the die bonder, in particular to determine an exact transfer position of the die 5 held by the transfer unit 91. Exact knowledge of the

35 transfer position may be necessary for the place unit 94 to

take the die 5 over and accurately place it onto a target position on the substrate 6 determined by a place camera 42. For this purpose referred to as die alignment, a transfer position lamp may be provided to illuminate the die 5 while
5 being held by the transfer unit 93 at the transfer position. Preferably, the transfer position lamp is dimmed or turned off when the die 5 is examined for damages. Alternatively, when non-visible light in the infrared wavelength range is used, a single light source may be deployed for both detec-
10 tion of die defects and/or imaging of die alignment patterns on the die surface.

In the inventive die bonder as discussed above, the chip handling tool 10 according to the invention may also be used
15 as part of other chip handling units 91, 92, 93, 94 either instead of or in combination with the chip handling tool 10 of the transfer unit 93. In this respect, it is particularly advantageous to provide the chip handling tool 10 according to the invention as part of the place unit 94. This will al-
20 low detecting all die damage that may be caused prior to attaching the die 5 to the substrate, in particular damage due to a handing over of the die 5 to the place unit 94. Excellent placement accuracy may then be achieved when a place-
ment camera 44 is used as light sensitive element and to de-
25 termine an exact position and/or rotation of the die 5 handled by the place unit.

It may also be of particular interest to use a chip handling tool 10' according to the invention as part of the die ejec-
30 tor unit 91. In this case, removing damaged dies 5 from the carrier tape 59 can be avoided upfront, thus leaving defective parts on the carrier tape and avoiding any handling of those dies 5 on the die bonder. The latter implementation results in higher throughput of the die bonder and reduces
35 operator intervention. Fig. 4a shows an example of a chip

handling tool 10' that comprises ejection pins 111 that may protrude from the chip handling tool 10' as shown in Fig. 4b to eject a die 5 from the carrier tape 59. However, other means to eject or remove the die 5 from the carrier tape may be included in the tool 10', e.g. as described in WO 2005/117072 A1. Light having passed through the die 5 may for example be analyzed by a pick camera 40.

In the die bonders discussed so far, an orientation in which the die 5 is supported by the carrier tape is identical to the orientation in which the die 5 is attached to the substrate 6. In certain applications frequently referred to as flip chip applications, however, the die 5 is to be inverted prior to attachment to the substrate 6. In the die bonder described above, this may be achieved by providing a flip unit that receives the die 5 from the transfer unit 93 and hands it over to the place unit 94. Alternatively, it may be achieved by leaving away the transfer unit 93 so that the pick unit 92 may hand the die 5 over directly to the place unit 94. Of course in this latter case, the inventive chip handling tool 10 has to be provided at a chip handling unit other than the transfer unit, in particular at the pick unit 92 or the place unit 94. Since for flip chip applications, the die 5 is generally attached with a structured surface facing the substrate 6 or an already attached die, placement accuracy is extremely important. Therefore, placement camera 44 is generally provided to allow for acquisition of an image of the structured surface of the die 5 while the die 5 is being held by the place tool 94, and may be used to discriminate between damaged and undamaged dies 5.

In an alternative embodiment of a die bonder according to the present invention, one or more light sensitive elements 49, in particular one or more line scan cameras, may be provided along a path of movement of the chip handling tool 10 in

such a way that light by the illumination means having passed through the die 5, and preferably through the work surface 21, reaches the light sensitive element or elements 49 as the chip handling tool 10 with the die 5 passes by.

5 Similarly, if a chip handling tool 10 as shown in Fig. 2 is deployed, one or more external light sources 39 may also be provided along the path in a vicinity of the light sensitive elements 49, so that the first side of the die 5 is illuminated, preferably through the work surface 21, when the chip
10 handling tool 10 with the die 5 passes by.

Fig. 5 is a flow diagram in accordance with certain exemplary embodiments of the present invention. As is understood by those skilled in the art, certain steps included in the flow diagram
15 may be omitted; certain additional steps may be added, and the order of the steps may be altered from the order illustrated.

Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not
20 intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

In particular, although the invention was described above
25 with respect to semiconductor dies, it may be used for any kind of chip, including any essentially a flat slab of material or materials that is picked from any kind of supply carrier, in particular a tape or belt, and placed onto a target location, in particular on a chip, substrate, tape,
30 belt or a storage means.

Patent Claims

1. A chip handling tool, in particular for use in a semiconductor die bonder, said chip handling tool being configured to receive a chip, in particular a semiconductor die, at a takeover location and to hand over said chip to a delivery location, said chip handling tool comprising
 - a) a work surface configured to be brought into connection with a first surface on a first side of the chip, **characterized in that** the chip handling tool further comprises
 - b) illumination means for illuminating the chip from its first side while the said first side of the chip is in connection with the work surface.
2. The chip handling tool according to claim 1, further comprising means for temporarily fixing the chip to the work surface.
3. A chip handling tool according to one of the previous claims, wherein the tool comprises an at least partially transparent region, and wherein the work surface is formed on said at least partially transparent region.
4. The chip handling tool according to claim 3, wherein means for redirecting light onto the work surface, in particular by means of scattering, diffraction or reflection, are provided in the at least partially transparent region, or at a back surface thereof.

5. The chip handling tool according to claim 3, wherein the at least partially transparent region comprises a resilient material subregion, in particular a rubber layer.
6. The chip handling tool according to claim 5, wherein the work surface is formed on the resilient material subregion.
7. A chip handling tool according to one of the previous claims, wherein the chip handling tool comprises heating means for heating the chip when in connection or proximity with the work surface.
8. A chip handling tool according to one of the previous claims, wherein at least one light source is provided in or on a rigid tool body of said chip handling tool to illuminate the chip through the at least partially transparent region and the work surface.
9. A chip handling process, in particular for a die bonding process, in which
 - a) a chip, in particular a semiconductor die, is received at a takeover location by a chip handling tool, and handed to a delivery location by means of said chip handling tool,
 - b) at the takeover location, a work surface of the chip handling tool is brought into connection with a first surface on a first side of the chip, **characterized in that**

- c) the chip is illuminated from the first side while being in connection with the work surface of the chip handling tool, and that
 - d) light having passed through the chip is detected and analyzed for damages of the chip.
10. The chip handling process according to claim 9, wherein in step a), the chip is temporarily fixed to the work surface of the chip handling tool while it is being transported from the takeover location to the delivery location.
11. The chip handling process according to claim 10, wherein the light having passed through the chip is detected while the chip is being transported.
12. The chip handling process according to claim 9, 10 or 11, wherein in step d), an image of the chip is acquired, and wherein a position/and or rotation of the chip is subsequently determined from the acquired image.
13. A chip processing apparatus, in particular a semiconductor die bonder, said chip processing apparatus comprising
- a) a chip handling tool according to one of claims 1 to 7
 - b) at least one light source for illuminating a chip in connection with the work surface of the chip handling tool in conjunction with the illumination means, and
 - c) a light sensitive element being configured to detect light transmitted through a chip handled by the chip handling tool when illuminated

by the at least one light source in conjunction with the illumination means, and

- d) discrimination means configured to determine whether the chip is damaged based upon properties of the detected light that is transmitted through the chip.

14. A chip processing apparatus, in particular a semiconductor die bonder, said chip processing apparatus comprising

- a) a chip handling tool according to claim 8
- b) a light sensitive element being configured to detect light transmitted through the chip when illuminated by the at least one light source comprised by the chip handling tool, and
- c) discrimination means configured to determine whether the chip is damaged based upon properties of the detected light that is transmitted through the chip.

15. A chip processing apparatus according to claim 13 or 14, wherein the light sensitive element is capable of acquiring an image of the chip that is in connection with the work surface, and wherein the discrimination means comprise image processing means capable of determining a position and/or rotation of the chip.