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DETECTION METHOD AND SYSTEM

Field of the Invention

The invention relates to the processing of substrates having integrated circuits
5 (IC) deposited thereon. In particular, the invention relates to a system and method for
inspecting the substrates for certain defects such as warping.

Background

Multiple integrated circuits are deposited upon substrates so as to manufacture
10 as many integrated circuits at one time in a batch process. Whilst this favours a more
efficient process for production costs, the size of the substrate is such that the process of
deposition applies significant heat to the substrate which, following the completion of
the deposition process, can cause warping due to a differential heat, differential
expansion rates and other causes of internal stresses which may lead to the substrate
15 deforming from a flat planar object to one that may be curved or twisted about one of
the planar axes.

Conventional measurement defines warp as being the maximum distance from
one point on the substrate to the corresponding point on a theoretical flat substrate. For
20 example one deformed shape caused by warping maybe a convex curvature that is the
substrate going upwards. The warp would therefore be the offset from the extreme end
of the substrate to the corresponding point on a theoretical flat substrate.



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For a substrate having plan dimensions of about 200 mm by 60mm, a warp up to 2.0 mm is an acceptable deformation.

Following the deposition process, the substrate undergoes dicing to singulate the
5 integrated circuits from the substrate. Subsequently, the singulated ICs are divided into
units which are acceptable, units which are required for reworking and those units
which are to be rejected because the warp is outside acceptable limits. This presents the
problem, however, of having to dice a certain percentage of units that will inevitably be
rejected. Thus, the time taken to process these units, and the reduced capacity to
10 accommodate the units, reduces the overall units per hour (UPH) which is the governing
parameter for cost effective production. This could be avoided by inspecting the units
prior to dicing. However, the vacuum imposed by the dicing table used to hold the
substrate in place prior to dicing tends to artificially flatten the substrate and thus make
inspection meaningless, as any warp of the substrate will be undetectable.

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Statement of Invention

It is therefore an object of the invention to provide a means of early detection
and so improve UPH for the process.

20 In a first aspect the invention provides a system for the detection of warp in an
IC substrate, said substrate having at least two of fiducial marks, said fiducial marks
defining a line parallel to a first axis of the substrate, the system comprising an
inspection zone, a detection means for detection of the at least two fiducial marks and
measurement of the distance between said marks whilst the substrate is in the inspection

zone, a computational means in communication with the detection means for making a comparison between the measured distance and a pre-determined plan distance between corresponding fiducial marks of a theoretical unwarped substrate, said computational means capable of calculating the warp of the substrate based on the comparison of the measured distance and the pre-determined plan distance..

In a second aspect the invention provides a method for detecting warp in an IC substrate, said substrate having at least two of fiducial marks, said fiducial marks defining a line parallel to a first axis of the substrate, the method comprising the steps of detecting the at least two fiducial marks whilst the substrate is in an inspection zone, measuring the distance between said marks, comparing the measured distance with a pre-determined plan distance between corresponding fiducial marks of a theoretical unwarped substrate, calculating the warp of the substrate based on the comparison of the measured distance and the pre-determined plan distance.

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Thus, the invention provides a system whereby the substrate undergoes detection to measure the actual distance between at least two fiducial marks and compare this to the theoretical linear distance. The fiducial marks maybe set at a standard distance apart but in any event will be known to the system and thus the theoretical distance between fiducial marks will be known. A detection means is employed to measure the actual planned distance between the fiducial marks. If the distance is the same between the theoretical end of the measure, then the substrate must be flat. However, if the distances vary, it follows that the substrate must be warped. Whether the substrate is convex or

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concave relative to the detection means will not matter for the purposes of calculating the offset.

In a preferred embodiment, the system may assume a circular curvature and therefore model the measured distance as a chord of the theoretical linear distance. A simple geometric calculation can then provide a calculated warp being equal to the gap between a theoretical flat substrate and an actual curved substrate.

In a preferred embodiment, detection of the fiducial marks may be achieved by a detection means comprising a camera and a means of recognizing a fiducial mark. In a more preferred embodiment the camera may scan the substrate with the recognition means recognizing a particular shape of fiducial mark with the detection means then measuring the distance from that mark until the next recognized mark.

In a preferred embodiment, the system according to the invention may detect several forms of warping such as curvature, both convex and concave, as well as twisting along the substrate about either planar axis of the substrate. In a more preferred embodiment, fiducial marks may be located adjacent to the peripheral edge of the substrate. In a more preferred embodiment the fiducial marks may also be located parallel to a second axis, said second axis being orthogonal to the first, with said fiducial marks located adjacent to a peripheral edge parallel to said second axis.

In a preferred embodiment, fiducial marks may be located adjacent to all four peripheral edges with the detection means capable of detecting the location and making

measurements of said fiducial marks for all four sides. It follows that based upon this measurement, more complex two dimensional shapes of the substrate may be detected beyond mere circular curvature of said substrate.

5 **Brief Description of Drawings**

Figure 1 is a plan view of a substrate comprising a plurality of integrated circuits;

Figure 2 is a flow chart according to one embodiment of the present invention;

Figure 3 is an example calculation according to a second embodiment of the
10 present invention;

Figure 4 is an example calculation according to a third embodiment of the present invention.

Description of Preferred Embodiment

15 It will be convenient to further describe the present invention with respect to the accompanying drawings, which illustrate possible arrangements of the invention. Other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

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Figure 1 shows a standard substrate 5 comprising four groups 10a to 10b of 4 x 4 integrated circuits 15. In particular, Figure 1 shows the division of the substrate 5, whereby fiducial marks 30 are located upon a first axis 20 parallel to the longitudinal axis of the substrate and a second axis 25 orthogonal to the first axis 20. Fiducial marks are located at each intersection of an integrated circuit 15 with the first and second axes.
25 The fiducial marks located upon the first axis are designated X1 to X10 symmetrically about a centre point 40. Similarly, fiducial marks along the second axis 25 are

designated Y0 to Y2 symmetrically about the central point Y0. Thus, the substrate is marked with a co-ordinate system so as to be camera readable in anticipation of the inspection phase.

5 Figure 2 shows a flow diagram describing the method according to one embodiment of the present invention. In the method, a substrate is provided at the inspection zone 50 ready to be inspected by a camera 55. The camera and associated recognition means locate fiducial marks 60 on the substrate and then calculates the distance between extreme fiducial marks 65. Alternatively, the camera and recognition
10 means may calculate the distance of each fiducial mark from a central fiducial mark so as to create a profile of the distances incrementally along the substrate.

 In this embodiment, the theoretical flat distance between the extreme fiducial marks is recorded by the system. It uses this value to compare the calculated distance
15 with the measured distance 70. Using a geometric calculation, the offset of the flat theoretical substrate to a maximum curvature of the provided substrate will yield a warp based upon an assumed circular curvature.

 The inspection system will then determine if this warp is greater than a preset
20 maximum, say 2.0 mm. If so, the substrate is sent to a reject zone 85. If, however, the warp is less than 2.0, the substrate is sent to the next processing step 90 and the warp and curvature data are sent to the next processing station so as to accommodate the curvature of the substrate in future processing steps, such as dicing.

25 It should be noted that the preset limit for warpage may vary with material, varying industry standards and applications of the singulated IC's. For instance, in some circumstances it may be preferable to use a soft metal substrate, such as copper. In this case, the susceptibility to warping may require the limit to be as low as 0.3 mm. Alternatively, better processing techniques may increase the tolerance for warp. In any
30 event, it will be appreciated by the skilled addressee that the actual warp, or preset limit, does not limit the invention, but merely offers a number for use with the system. Any such number conforming to the users requirements may be used, and does not have an

effect on the scope of protection offered by the invention.

Further, the invention may also include a means for rejecting a substrate that doesn't exceed the present limit. Thus, the ability to reject a substrate using the reject
5 means may be user definable.

Figure 3 shows a worked example for two measured substrates. The substrates have been labeled according to the coordinate system shown in Figure 1 and relate to curvature along the first axis 20 for one half of the substrate, about the centre line 40 to
10 the extreme fiducial mark 35 designated X10.

In this worked example, three substrates are shown being the flat theoretical substrate 100, a first actual substrate 105 and a second actual substrate 115. It will be noted from both the first and actual substrates 105 and 115 that distances have been
15 measured from the centre line 125 at each of the fiducial marks X1 to X10. These compare to the distances shown for the flat theoretical substrate 100. As would be anticipated, the distances in plan for the curved substrates 105 and 115 are fractionally shorter than the distances shown for the flat theoretical substrate 100.

20 The system operates by measuring the actual planar distances of a substrate being inspected and comparing to the distance of corresponding fiducial marks for a flat theoretical substrate 100. The system may then calculate the warp based upon, for instance, in one embodiment assuming the substrate has adopted a circular curve and that the distance around the segment of the curve is that of the flat substrate with the
25 chord having a distance equal to the planar dimensions taken from the actual substrates. By performing a standard calculation making the assumption of a circular curve in this embodiment, the first actual substrate has a curvature of 0.15mm. Similarly, making a similar calculation for the second actual substrate 115, the warp is measured as 0.35mm. In both cases, the warp is below 0.5mm and therefore is acceptable for further
30 processing.

The calculated dimensions 130 are specific to the particular substrate and may

be used by downstream processes to accurately dice the substrate. Because the dicing process may use a significantly stronger vacuum, the substrate may be partially flattened and therefore corrective factors can be applied to the known data to accommodate this effect. In a further embodiment, corrective factors may depend upon and vary with the degree of warp measured. In a more preferred embodiment, the following table may provide corrective factors based upon specific bands of deformation.

Warpage	W_n	V_n
Less than 0.5mm	0.5	0.5
0.5 – 1.0	0.55	0.45
1.2	0.6	0.4
1.5	0.7	0.3
2.0	0.8	0.2

In an alternative embodiment, standard corrective factors may be applied based upon whether the curvature is about the first axis or the second axis. In this further embodiment, the corrective factors may be $W = 0.8$ and $V = 0.2$. In either case, the corrective factors W and V are essentially corrective weighting between the theoretical flat substrate 100 and the actual substrate 115. The corrective factor W is applied to the theoretical dimensions with V applied to the measured values. Accordingly, the expected distances provided in the example 130 on application of a vacuum during dicing can be calculated based upon known corrective factors.

Figure 4 shows a similar worked example. In this case, the worked example is based upon curvature along the second axis 25. Further, the distances are based upon the entire axis rather than half the distance for the first axis 20 shown in Figure 3.

In the example shown in Figure 4, seven cases are provided 140, 145, 150, 155, 160, 165 and 170. In each of the cases, the warp has been based upon a known theoretical dimension 135 and compared to measured planar dimensions in each of the examples. Correspondingly, a warp has been calculated for each of these different

examples. For instance, the least warp has a substrate 140 curved about a central point Y0 with a warp of 0.3mm. This compares to the last example having a substrate 170 again curved about a central point Y0 with a total warp of 2.0.

- 5 The corrected dimensions, once a vacuum is applied, are then calculated 175 for each case adopting different corrective factors based upon the variation and curvature.

The Claims:

1. A system for the detection of warp in an IC substrate, said substrate having at least two of fiducial marks, said fiducial marks defining a line parallel to a first
5 axis of the substrate, the system comprising :

An inspection zone;

A detection means for detection of the at least two fiducial marks and measurement of the distance between said marks whilst the substrate is in the inspection zone;

10 A computational means in communication with the detection means for making a comparison between the measured distance and a pre-determined plan distance between corresponding fiducial marks of a theoretical unwarped substrate;

Said computational means capable of calculating the warp of the substrate based on the comparison of the measured distance and the pre-determined plan
15 distance.
2. The system according to claim 1, wherein the detection means comprises a camera and a recognition means, such that the recognition means recognizes the at least two fiducial marks based on a pre-determined shape of the fiducial marks
20 when said shape is captured by the camera.
3. The system according to claim 1 or 2, wherein the fiducial marks are located adjacent to a peripheral edge of said substrate.

4. The system according to any one of the preceding claims, wherein the substrate further includes at least two fiducial marks parallel to a second axis, said second axis being orthogonal to the first axis.
- 5 5. The system according to any one of the preceding claims, wherein the warp is calculated as a distance of the fiducial mark having a maximum offset from a plane of the theoretical unwarped substrate.
6. The system according to any one of the preceding claims, wherein the warp is
10 caused by the substrate having a convex or concave curvature about the first axis.
7. The system according to claim 4 to 6 , wherein the warp is caused by the substrate having a convex or concave curvature about the second axis.
- 15 8. The system according to any one of the preceding claims, wherein the warp is caused by the substrate having a twist about the first axis.
9. The system according to any one of claims 4 to 8, wherein the warp is caused by
20 the substrate having a twist about the second axis.
10. The system according to any one of the preceding claims, wherein the computational means is adapted to output a reject signal if the warp exceeds a maximum limit, or otherwise output an acceptance signal.

11. The system according to claim 10, wherein the maximum limit is 2.0 mm.
12. The system according to claim 10 or 11, further including a rejection means in
5 communication with the computational means, said rejection means adapted to
remove the substrate from the inspection zone to a reject zone on receipt of the
reject signal from the computational means.
13. The system according to claim 10 to 12, further including a progression means
10 in communication with the computational means, said progression means
adapted to progress the substrate from the inspection zone to a processing zone
on receipt of the acceptance signal from the computational means.
14. The system according to claim 13, further including a data logging means in
15 communication with the processing zone, said data logging means adapted to
communicate the warp of the substrate to the processing zone.
15. A method for detecting warp in an IC substrate, said substrate having at least
two of fiducial marks, said fiducial marks defining a line parallel to a first axis
20 of the substrate, the method comprising the steps of :
detecting the at least two fiducial marks whilst the substrate is in an inspection
zone;
measuring the distance between said marks;

comparing the measured distance with a pre-determined plan distance between corresponding fiducial marks of a theoretical unwarped substrate;
calculating the warp of the substrate based on the comparison of the measured distance and the pre-determined plan distance.

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16. The method according to claim 15, wherein the warp is calculated as a distance of the fiducial mark having a maximum offset from a plane of the theoretical unwarped substrate.

10 17. The method according to any one of claims 15 or 16, further comprising the step of outputting a reject signal if the warp exceeds a maximum limit, or otherwise outputting an acceptance signal.

18. The method according to claim 17, wherein the maximum limit is 2.0 mm.

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19. The method according to claim 17 or 18, further comprising the step of removing the substrate from the inspection zone to a reject zone on receiving the reject signal.

20 20. The method according to claim 17 to 19, further comprising the step progressing the substrate from the inspection zone to a processing zone on receiving the acceptance signal.

21. The method according to claim 20, further comprising the step of communicating the warp of the substrate to the processing zone.