

Claims

1. A method for 3D inspection of packaged semiconductor devices, each packaged semiconductor device comprising a main body having a top surface, a bottom surface, and a plurality of sidewalls vertically extending between the top surface and the bottom surface of the device in a z-axis direction, the method comprising:

capturing a 3D profile image of the device bottom surface and generating a corresponding bottom surface 3D profile image dataset while (a) the device top surface freely rests upon a first device seating surface and the device is not subjected to external compressive forces other than the force of gravity, or (b) the device top surface is held by a first suction tip by way of suction force and forcible compression of the top surface of the device against a first reference structure distinct from a first suction tip is avoided;

capturing a 3D profile image of the device top surface and generating a corresponding top surface 3D profile image dataset while (c) the device bottom surface freely rests upon the first or a second device seating surface and the device is not subjected to external compressive forces other than the force of gravity, or (d) the device bottom surface is held by the first or a second suction tip by way of suction force and forcible compression of the bottom surface of the device against each of the first reference structure and a second reference structure distinct from the second suction tip is avoided;

capturing a plurality of sidewall images of the device and generating a corresponding sidewall image dataset; and

generating a 3D composite image dataset corresponding to a 3D digital reconstruction or estimation of the device based upon or using the bottom surface 3D profile image dataset, the top surface 3D profile image dataset, and the sidewall image dataset.

2. The method of claim 1, wherein the bottom surface 3D profile image dataset is generated by way of a bottom surface 3D scan line imaging procedure performed across the area of the bottom surface of the device, and the top surface 3D profile image dataset is generated by way of a top surface 3D scan line imaging procedure performed across the area of the top surface of the device.

3. The method of claim 1, wherein the first device seating surface is planar with respect to the surface area of at least one of the top surface and the bottom surface of the device, and/or the

second device seating surface is planar with respect to the surface area of at least one of the top surface and the bottom surface of the device.

4. The method of claim 1, wherein (a) the device top surface freely rests upon the first device seating surface and the device is not subjected to external compression forces other than the force of gravity during the capture of the 3D profile image of the device bottom surface, and (c) the device bottom surface freely rests upon the first or a second device seating surface and the device is not subjected to external compressive forces other than the force of gravity during the capture of the 3D profile image of the device top surface.

5. The method of claim 1, wherein:

while capturing the 3D bottom surface profile, (a) the device top surface freely rests upon the first device seating surface and the device is not subjected to external compression forces other than the force of gravity during the capture of the 3D profile image of the device bottom surface, and while capturing the 3D top surface profile, (d) the device bottom surface is held by the first or the second suction tip by way of suction force and forcible compression of the bottom surface of the device against each of the first reference structure and a second reference structure is avoided;

or

while capturing the 3D bottom surface profile, (b) the device top surface is held by the first suction tip by way of suction force and forcible compression of the top surface of the device against the first reference structure is avoided, and while capturing the 3D top surface profile(c) the device bottom surface freely rests upon one of first seating structure and the second seating structure.

6. The method of claim 1, wherein one of the 3D profile image of the device top surface and the 3D profile image of the device bottom surface is captured while the device sits in a carrier, platform, or medium having a standardized design with respect to the semiconductor industry and which is used for storing or transporting packaged semiconductor devices.

7. The method of claim 6, wherein the standard carrier, platform, or medium comprises one of an industry standard tray, an industry standard boat, or an industry standard tape structure configured for carrying packaged semiconductor devices of predetermined sizes.

8. The method of claim 1, wherein generating the 3D composite image dataset comprises generating each of a bottom surface of curvature image dataset and a top surface of curvature image dataset.

9. The method of claim 8, wherein generating the bottom surface of curvature image dataset comprises:

numerically determining an array of (x, y) values that defines a reference bottom surface plane corresponding to the physical bottom surface of the device; and

numerically determining z-axis deviations between the bottom surface 3D profile image dataset and the reference bottom surface plane for each (x, y) value within the array of (x, y) values within the reference bottom surface plane.

10. The method of claim 9, further comprising storing the z-axis deviations between the bottom surface 3D profile image dataset and the bottom surface reference plane for each (x, y) value as a bottom surface profile (BSP) dataset comprising an (x, y) array of bottom surface profile values corresponding to physical device top surface non-uniformity relative to the z-axis.

11. The method of claim 10, wherein generating the top surface of curvature image dataset comprises:

numerically determining an array of (x, y) values that defines a reference top surface plane corresponding to the physical top surface of the device; and

numerically determining z-axis deviations between the top surface 3D profile image dataset and the reference bottom surface plane for each (x, y) value within the array of (x, y) values within the reference bottom surface plane.

12. The method of claim 11, further comprising storing the z-axis deviations between the top surface 3D profile image dataset and the top surface reference plane for each (x, y) value as a top surface profile (TSP) dataset comprising an (x, y) array of top surface profile values corresponding to physical device top surface non-uniformity relative to the z-axis.

13. The method of claim 12, wherein generating the 3D composite image dataset further comprises digitally aligning or registering the BSP dataset, the TSP dataset, and the sidewall image dataset relative to each other, and stitching together the digitally aligned or registered BSP dataset, TSP dataset, and sidewall dataset.

14. The method of claim 12, further comprising generating a True Object Main Body Thickness (TOMBT) dataset in which any given TOMBT(x, y) value represents a z-axis distance between the TSP and the BSP within the 3D composite image at a specific (x, y) point.

15. The method of claim 1, further comprising determining a Total Object Thickness (TOT) value by way of analysing the 3D profile image of the device bottom surface and the 3D profile image of the device top surface; and determining a largest z-axis distance between a lowest physical device structure in the 3D profile image of the device bottom surface and a highest physical device structure in the 3D profile image of the device top surface.

16. A system for 3D inspection of packaged semiconductor devices, each packaged semiconductor device comprising a main body having a top surface, a bottom surface, and a plurality of sidewalls vertically extending between the top surface and the bottom surface of the device in a z-axis direction, the apparatus comprising:

a set of 3D imaging or scanning stations configured for imaging or scanning each of the device bottom surface and the device top surface and generating a 3D device bottom surface dataset and a 3D device top surface dataset, respectively, by way of:

(i) capturing a 3D profile image of the device bottom surface and generating a corresponding bottom surface 3D profile image dataset while (a) the device top surface freely rests upon a first device seating surface and the device is not subjected to external compressive forces other than the force of gravity, or (b) the device top surface is held by a first suction tip by way of suction force and forcible compression of the top surface of the device against a first reference structure distinct from a first suction tip is avoided; and

(ii) capturing a 3D profile image of the device top surface and generating a corresponding top surface 3D profile image dataset while (c) the device bottom surface freely rests upon the first or a second device seating surface and the device is not subjected to external compressive forces other than the force of gravity, or (d) the device bottom surface is held by the first or a second suction tip by way of suction force and forcible compression of the bottom surface of the device against each of the first reference structure and a second reference structure distinct from the second suction tip is avoided;

an sidewall scanning station configured for imaging or scanning a plurality of device sidewalls;

at least one processing unit; and

a memory storing a set of program instructions configured for generating a 3D composite image dataset corresponding to a 3D digital reconstruction or estimation of the device based upon or using the bottom surface 3D profile image dataset, the top surface 3D profile image dataset, and the sidewall image dataset.

17. The system of claim 16, wherein the set of 3D imaging or scanning stations comprises at least one 3D scan line profile imaging apparatus.

18. The system of claim 16, wherein the sidewall scanning station comprises an apparatus configured for simultaneously imaging or scanning multiple device sidewalls.