

imaging means 101 while in operating in chipping detection. The chipping detection system further comprises a conveyor belt 104 for transporting the solar wafer horizontally in the course of chipping detection operation and a sensing means 105 (a presence sensor) to provide a signal to trigger the imaging means 101 to start an image capture. A strobe light driver 107 is provided in the system which is used to trigger the imaging means 101 to drive the illumination means 102 such that the imaging means 101 provides an exposure time which coincides with the illumination means 102. In other words, the chipping detection system of the present preferred embodiment provides a plurality of cameras, for instance at this case, four cameras, each equipped with lens 101, with 4 sets of illumination means (illuminators) 102. The cameras 101 are positioned horizontally and oriented in such a way that the camera focusing plane 201 is parallel to and coincide with each chamfer edge 202 of the solar wafer 103. The solar wafer 103 is loaded on a conveyor belt 104 and when the solar wafer 103 is transported by the conveyor belt 104, and sensed by the presence sensor 105 which is mounted around the conveyor belt 104 or any appropriate location enabling the detection of the presence of solar wafers at a time (t_0), the presence sensor 105 triggers the cameras 101 to start an image capture. The cameras 101 also trigger the strobe light driver 107 which drives the illuminator 102 such that the camera exposure time coincides with the illumination.

In the present preferred embodiment, in view of the camera orientation, the chamfer edges 202 of the solar wafer 103 and the camera focusing planes 201 are parallel to each other, and therefore it is possible to obtain sharp images of chamfer side wall and therefore detects chippings on the chamfer side wall of the solar wafer 103.

Figure 8 schematically shows one corner of the chipping detection system in accordance with the preferred embodiment of the present invention. As shown, the camera focusing plane 201 is directly parallel to the chamfer edge of the solar wafer 103. In order to obtain sharp images of the chamfer side wall, it requires very precise control of the solar wafer position 103 on the conveyor belt 104. Figure 9 schematically illustrates the position variation of ΔX of the solar cell 103 on the conveyor belt 104. When a solar wafer 103 has a position variation of ΔX on the conveyor belt 104, the chamfer edges 202 can be located at the out-of-focus position at the same position being sensed by the presence sensor 105. As a result, the image captured by the cameras 101 is not sharp and chippings detection performance is affected.

Figure 10 schematically illustrates capturing sharp chamfer edges 202 in accordance with the present invention. In other words, the chamfer edges 202 images should fall within the camera focusing plane 201 even though the solar wafer 103 position variation is ΔX . To accomplish this, the presence sensor 105 is moved forward so that camera image capture starts earlier. Once the camera is triggered by the presence sensor 105, it will capture images in burst mode

CLAIMS

1. A chipping defect detection system comprising:
 a conveyor configured to move a solar wafer in a first direction through an image capture location;
 and
 a first camera horizontally offset from the conveyor and disposed on a first side of the image capture location, the first camera having an orientation that positions a focal plane of the first camera within the image capture location at an angle greater than zero degrees and less than ninety degrees relative to the first direction.
2. The chipping defect detection system of claim 1, wherein the angle is 45 degrees.
3. The chipping defect detection system wherein the angle is parallel to a chamfered edge of the solar wafer that couples adjacent sides of the solar wafer disposed on the conveyor in the image capture location.
4. The chipping defect detection system of claim 1, further comprising an illuminator configured to illuminate the image capture location.
5. The chipping defect detection system of claim 4, wherein the illuminator further comprises a strobe.
6. The chipping defect detection system of claim 1 further comprising:
 a presence sensor configured to trigger image capture by the first camera of a chamfered edge of the solar wafer.
7. The chipping defect detection system of claim 6, wherein the first camera is configured, in response to being triggered by the presence sensor, to capture a plurality of images of the chamfered edge of the solar wafer.
8. The chipping defect detection system of claim 7 further comprising:

a computer configured to locate a sharpest image from the plurality of images and to analyze the sharpest image to detect presence of a chipping defect in the chamfered edge.

9. The chipping defect detection system of claim 7, wherein the presence sensor is located in a position configured to trigger image capture by the first camera prior to the solar wafer passing through the focal plane of the first camera.

10. The chipping defect detection system of claim 7, wherein the first camera is configured to operate at a frame per second (FPS) that is at least $(2 \times v \times \cos 45^\circ) / \text{DOF}$, wherein v is the speed of the solar wafer moving in the first direction, and DOF is the Depth-Of-Focus range of the first camera.

11. The chipping defect detection system of claim 1 further comprising:
a second camera configured to obtain images of the solar wafer disposed within the image capture location, wherein the images of the solar wafer obtained by the second camera are from a second side of the image capture location that is opposite of the first side of image capture location.

12. The chipping defect detection system of claim 11, wherein the second camera has an orientation that positions a focal plane of the second camera within the image capture location at an angle greater than zero degrees and less than ninety degrees relative to the first direction.

13. A method of chipping defect detection for a solar wafer, the method comprising:
transporting a solar wafer in a first direction through an image capture location having a plurality of cameras, each of the plurality of cameras horizontally offset from the solar wafer and having a focusing plane arranged in a parallel orientation relative to a chamfered edge of the solar wafer;
detecting chipping of the solar wafer utilizing images captured by the cameras.

14. The method of claim 13 further comprising:
capturing a burst of images as the chamfered edges of the solar wafer pass through the image capture location.

15. The method of claim 14 further comprising:
selecting images with maximum image sharpness from the burst of images; and
analyzing the sharpest image to detect presence of a chipping defect in one of the chamfered edges.
16. The chipping defect detection system of claim 11 further comprising:
a presence sensor configured to trigger image capture by the first and second cameras.
17. The chipping defect detection system of claim 16, wherein each of the first and second cameras are configured, in response to being triggered by the presence sensor, capture a plurality of images of corresponding chamfered edges of the solar wafer.
18. The chipping defect detection system of claim 11 further comprising:
a third camera configured to obtain images of the solar wafer disposed within the image capture location, the images of the solar wafer obtained by the third camera from the first side of the image capture location, a focal plane of the third camera perpendicular to the focal plane of the first camera; and
a fourth camera configured to obtain images of the solar wafer disposed within the image capture location, the images of the solar wafer obtained by the fourth camera from the second side of the image capture location, a focal plane of the fourth camera parallel to the focal plane of the first camera and perpendicular to the focal plane of the third camera.
19. The chipping defect detection system of claim 12, wherein the second camera has an orientation that positions a focal plane of the second camera within the image capture location at a 45 degree angle relative to the first direction.