

DEVICE AND PROCESS FOR THE MEASUREMENT OF OBJECTS AT SELECTED MEASUREMENT POSITIONS

The invention relates to the measurement of objects at selected measurement positions by processing images with a vertically adjustable, rotatable platform as a carrier for the object, a camera, and an illumination system, wherein the camera and the object are adjustable relative to one another for adjusting measurement positions.

In the fabrication of integrated circuits, the substrates, e.g., semiconductor wafers, must be transported between different machining steps to individual machining apparatus. This usually takes place in transport containers which either accommodate removable cassettes with shelves for the substrates or which are themselves constructed as cassettes. Wear phenomena during use in semiconductor fabrication, especially the loss of shape continuity, require periodic monitoring of the cassettes with respect to dimensional stability. Otherwise, the loading and unloading process would be threatened by exceeding permissible tolerances for the handling of the substrates. This can result in destruction of the substrates or failure of the machining apparatus.

In a known device, a cassette is held on a vertically adjustable, rotatable platform and can be moved past the front of at least one CCD camera. In the measurement position, a light source working by transillumination is adjacent to the cassette on the side opposite from the camera. The CCD camera is adjustable in different coordinates for scanning the cassette, wherein a plurality of measurement positions can be selected along the cassette.

A disadvantage in the device operating by the shadow-casting method is its limited applicability, especially as concerns the above-mentioned cassettes which are simultaneously transport containers. These containers are only open on one side and can therefore not be transilluminated. Also, measurement positions inside the cassettes cannot be reached by the known device due to insufficient illumination.

It is the object of the invention to expand the extent of measurement positions accessible to measurement with an increased degree of measurement accuracy, especially in the case of objects not suited to transillumination.

5 According to the invention, this object is met through a device for the measurement of objects at selected measurement positions through the processing of images which contains a vertically adjustable, rotatable platform as a carrier for the object, a camera and an illumination system, wherein the camera and the object are adjustable relative to one another for adjusting measurement positions. The illumination system comprises partial devices, at least one of which is formed of
10 regions with various radiation characteristics. Combinations of the partial devices and regions are adapted to the object to be measured.

A first region of the different regions of a partial device constructed as an incident light device surrounds the front region of the camera as a ring radiator, wherein additional regions are adjacent to the first region as surface radiators.

15 The surface radiators have means for adjusting their radiating direction. The radiators are composed of individual radiating elements of different wavelengths.

When measuring objects capable of transillumination, it is advantageous when an additional partial device is constructed as a transillumination
20 device.

The transillumination device can be formed either by a dimmable cold cathode tube provided with a scatter plate or by a dimmable light emitting diode strip.

The light emitting diode strip is advantageously formed of individually switchable rows of radiating elements.

25 The subject matter of the invention is further directed to a process for the measurement of objects at selected measurement positions by processing images of the illuminated object and correlating the processing results with a material measure in which the objects are classified into object types, the illumination is divided into regions with different radiation characteristics, and a selected
30 combination of regions with different radiation characteristics is allocated to every object type.

The correlation is carried out based on the image quality of images, wherein different combinations of regions are used for recording these images.

A contrast analysis is advantageously used for evaluation of the image quality.

5 The evaluation of the image quality can also be carried out based on the degree of reproducible measurement results, wherein the minimum width of spread of the measurement results can be used to measure this degree.

10 In order to reduce measurement errors caused by illumination, it is advantageous when the surrounding gray values of an edge transition of contours detected by image processing are represented as a histogram and the position of the maxima of the gray value distributions is determined and when a threshold necessary in the image processing for contour searching is located between the positions of the maxima.

15 The threshold can assume a mean gray value between the gray values of the maxima. It is also possible to take into account different amplitudes of the maxima as weighting when determining the threshold.

The invention will be explained more fully hereinafter with reference to the schematic drawing.

20 Fig. 1 shows a device according to the invention which is encased by a housing;

Fig. 2 shows the device without enclosure;

Fig. 3 shows movement systems for the object to be measured and the camera;

Fig. 4 shows the camera together with an illumination device;

25 Fig. 5 is a block diagram showing the construction of the device;

Fig. 6 shows the position of a measurement window at an edge transition for determining the threshold;

Fig. 7 shows a histogram for the distribution of the gray values around an edge transition;

5 Fig. 8 shows an edge image.

In order to ensure the requisite cleanroom conditions, the device shown in Fig. 1 contains the elements used for measurement within a housing 1 comprising a frame 2 and casing 3. Only a control group 4 with keyboard 5, trackball 6 and monitor 7 are located externally.

10 An opening 9 is incorporated in the upper cover 8 through which an object 10 to be measured can be fed to the device. Feet 12 serving to support the device contain systems for insulation against vibrations. For reasons of purity and safety, the opening 9 is closed during measurement by a cover hood, not shown, which prevents access to the mechanical system.

15 As shown in Fig. 2 and Fig. 3 which are slightly different, two movement systems 13 and 14 are provided within the device, wherein a first movement system serves to adjust the object 10 vertically and a second movement system serves to adjust a measurement system 15 horizontally.

20 The first movement system 13 contains a z-drive 16, a stationary part 18 which is rigidly connected with the frame 2 via a mounting cabinet 17, and an angled movable part 19 which is guided at the stationary part 18. The movable part 19 serves as a carrier for the object 10, wherein an adapter 20 ensures its correct fit on a turntable 21. By means of the turntable 21 which is fastened to the horizontal leg of the movable part 19, the object 10 can be rotated about a vertical axis Z-Z and
25 all of its sides are accordingly accessible to the measurement system 15.

The second movement system 14 for horizontal adjustment of the measurement system 15 comprises two table systems 22, 23 with associated drives which ensure an adjustment in the x-direction and y-direction. The table system 22 for adjustment in the x-direction is fastened to a carrying arm 24 connected with the

mounting cabinet 17 and receives the table system 23 for the y-direction via a plate 25. The measurement system 15, whose optical axis O-O extends parallel to the y-direction, comprises a CCD matrix camera 26, optics 27, and an illumination system comprising partial devices 28, 37.

5 The drive 16 and the drives of the table systems 22 and 23 are outfitted, in each instance, with a drive motor, a path measurement system, and a drive spindle with accompanying guide.

 An electronic unit 29, a control computer 30 and a ventilator 31 are likewise accommodated within the housing.

10 The partial device 28 shown in Fig. 4 is constructed as an incident light device and comprises regions with different radiation characteristics. The regions are radiators, one of which encloses the optics 27 of the camera 26 in the shape of a ring 32. Surface radiators 33, 34 adjacent to the ring 32 can be changed with respect to their inclination to the optical axis O-O of the measurement system 15 by
15 adjusting means 35.

 The partial device 28 comprises individual radiating elements 36 in the form of light emitting diodes which are divided into groups of different wavelengths. Red light and infrared radiation are especially suitable for these groups. In the present embodiment example, the light emitting diodes in the ring 32 are divided into
20 four groups, oppositely located groups being outfitted with light emitting diodes of the same wavelength. One pair of groups radiates a wavelength of $\lambda = 654 \text{ nm}$ and the other pair of groups radiates a wavelength of $\lambda_2 = 626 \text{ nm}$. Radiators 33, 34 have light emitting diodes working in the infrared at $\lambda_3 = 875 \text{ nm}$.

 Of course, it is also possible to use different radiation sources with
25 different radiation characteristics or to employ different combinations of radiation sources.

 The partial device 37 of the illumination system is constructed as a transillumination device which is adjacent to the object 10 on the opposite side to that of the measurement system 15. The transillumination device is formed either by
30 a dimmable cold cathode tube 38 or by a dimmable light emitting diode strip 39 which are fastened to the housing wall in such a way that all measurement positions are uniformly illuminated in a horizontal plane in which the optical axis O-O extends.

For purposes of uniform illumination, the cold cathode tube 38 is provided with a scatter plate 40 which is colored red for wavelength selection. Light emitting diodes of different wavelengths are arranged in rows and columns in the light emitting diode strip 39, wherein every column of the light emitting diode strip 39 has a separate control for switching on or off.

Because of shapes, colors and accessibility of the objects to be measured, but also because of changed technical characteristics with respect to the device, the imaging quality depends on material, geometry and wavelength, particularly in the case of incident light. In order to achieve a high degree of measurement accuracy, the objects 10 are classified into object types for which an illumination is provided by different combinations of partial devices 28, 37 and regions.

Appropriate correlations or correspondences are determined, e.g., by learning, in that the image quality of a sequence of images is subjected to defined evaluation criteria. Various combinations of the partial devices 28, 37 and regions are used to record the images, e.g., transillumination and/or incident illumination, incident illumination ring 32 and/or lateral surface radiators 33, 34, surface radiators 33 and/or 34, wavelengths red light and/or infrared radiation. In this respect, each of these combinations is controllable with respect to intensity.

In the block diagram of the device according to the invention shown in Fig. 5, output connections proceed from a program control unit 41 to couple the latter with the camera 26, a framegrabber 42, a display 43, a statistics unit 44 and an illumination control unit 45, wherein the operating group 4 is provided for operating the program control unit 41. The program unit 45 is connected on the input side and output side with an image processing and analysis unit 46 and with an axial control 47 for axial drives 48 to which signals are supplied by path measurement systems 49. The axial drives 48 are divided into the drives for the table systems 22, 23 in the x-direction and y-direction, the z-drive 16 and a drive 50 for the turntable 21. The path measurement systems 49 correspond in quantity to the drives and are associated therewith.

Further, the framegrabber 42 which is connected to the camera 26 is coupled with the image processing and analysis unit 46.

The illumination control unit 45 is connected with regions 32, 33, 34 of the incident light device and the regions 38 or 39 of the transillumination device. Connections of power supply units 51, 52 and of a circuit closer 53 and emergency key 54 are not shown for the sake of clarity.

5 The program control unit 41, in which sequences of measurements of the object 10 and combinations of regions 32, 33 and 34, as well as 38 or 39 associated with object types through learning in accordance with different radiation characteristics are stored as data records, sends the axial control 47 a control command comprising distance data and speed data. The axial drives 48 are moved
10 in a regulated manner into the respective measurement position with the assistance of the path measurement systems 49.

 When the programmed position is reached, a synchronization signal of the axial control 47 delivered to the program control unit 41 initiates a readout pulse. By means of the combinations of regions of the illumination device 28 associated
15 with the object type, including wavelength adjustment and intensity adjustment, an image recorded by the CCD camera 26 is made available to the image processing and analysis unit 46 via the framegrabber 42. The program control unit 41 and the illumination control unit 45 take over the adjustment of the illumination system.

 The image processing and analysis unit 46 delivers coordinates of
20 measured contours and shape elements (circles, straight lines, corners) which are in a fixed relationship with the coordinate systems of the movement systems 13, 14.

 Rectangular, axial-parallel measurement windows are used for circular measurements, wherein an inner contrast sampling is to be distinguishing from an outer contrast sampling. This distinction is particularly important when interference
25 occurs around the circular contour due to light reflections or light conduction in transparent object materials.

 It is also possible to sample in a rectangular, axially parallel measurement window to measure a straight-line contour. However, a starting point search on a measurement line oriented in any manner can also be carried out by
30 specifying the order number of the edge transition, wherein the rectangular measurement window is correspondingly rotated. This results in a regression line over all found contour points.

For corner measurements, regression lines of two straight-line contour pieces whose intersection forms the searched measurement point are calculated from the determined contour when using a rectangular, axially parallel measurement window. More complex contours can likewise be processed with rectangular, axially parallel measurement windows, wherein the evaluation must be carried out so as to be adapted to the contour.

The determined coordinates are delivered, together with the spatial coordinates of the movement systems 13, 14, to the statistics unit 44 for determining the deviations from the reference value. The deviations can be displayed and stored for trend tracking. Pertinent geometric dimensions of the object 10 can now be determined by calculation from the determined data.

The optimum adjustment of the illumination system in the form of the correlation of different combinations of regions 32, 33 and 34, as well as 38 or 39, including the wavelength and intensity, to different object types is checked in every image recording in that a contrast comparison with a reference image is carried out in the image processing and analysis unit 46 for the recorded image.

The reference images result from the learning phase which precedes the actual measurement process. An illumination program is started for every pertinent measurement point on the object of the respective object type by means of the program unit 41 and the illumination control unit 45 for testing the different illumination combinations. The image selection can be carried out via the monitor 7 through direct evaluation of the image quality according to contrast and brightness or by evaluation by means of a contrast processing function. The illumination parameters belonging to the selected image are taken over in the program control unit 41 to use for measurement.

An evaluation of the adjustment of the illumination system can also be carried out in that the minimum width of spread of the deviations of the measurement results is determined after detection of the contours in various images of different illumination devices. Further criteria familiar to the person skilled in the art are also applicable.

If greater deviations from the reference value are determined when checking the illumination adjustment, the adjustment of the illumination system is

corrected by means of the program control unit 41 and illumination control unit 45 until the actual contrast values and reference contrast values correspond to one another.

5 In case of smaller deviations from the reference value, the threshold which is used in the image processing for contour detection with a measurement window and which has already been learned in the same way from an object of acceptable quality is adapted.

10 According to Figs. 6 to 8, a measurement window 55 is placed on a bright-dark transition 56 determined by gray value differences. Within the measurement window, the gray value distribution around the transition is subsequently shown in a histogram and the position of the maxima 57, 58 is determined. A threshold 59 for contour searching is advantageously set to a mean value m between the gray values of the maxima 57, 58. Of course, other conditions can be taken in account in determining the threshold, e.g., different amplitudes of the
15 maxima 57, 58, by weighting. The edge position k in the edge image can now be determined by means of the threshold 59.

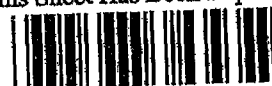
By proceeding in this way, changes in the illumination conditions brought about by reflection or extraneous incident light can be compensated and measurement errors caused by illumination can be reduced.



Patent Claims

1. Device for the measurement of objects at selected measurement positions by processing images with a vertically adjustable, rotatable platform as a carrier for the object, a camera, and an illumination system, wherein the camera and the object are adjustable relative to one another for adjusting measurement positions, characterized in that the illumination system comprises partial devices, at least one of which is formed of regions with various radiation characteristics, and in that combinations of the partial devices and regions are adapted to the object to be measured.
2. Device according to claim 1, characterized in that a first region of the different regions of a partial device constructed as an incident light device surrounds the front region of the camera as a ring radiator, wherein additional regions are adjacent to the first region as surface radiators.
3. Device according to claim 2, characterized in that the surface radiators have means for adjusting their radiating direction.
4. Device according to claim 3, characterized in that the radiators are composed of individual radiating elements of different wavelengths.
5. Device according to claim 4, characterized in that an additional partial device is constructed as a transillumination device.
6. Device according to claim 5, characterized in that the transillumination device is formed of a dimmable cold cathode tube provided with a scatter plate.
7. Device according to claim 4, characterized in that the transillumination device is formed of a dimmable light emitting diode strip.

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8. Device according to claim 7, characterized in that the light emitting diode strip is formed of individually switchable rows of radiating elements.

9. Process for the measurement of objects at selected measurement positions by processing images of the illuminated object and correlating the processing results with a material measure, characterized in that the objects are classified into object types, the illumination is divided into regions with different radiation characteristics, and in that a selected combination of regions with different radiation characteristics is allocated to every object type.

10. Process according to claim 9, characterized in that the correlation is carried out based on the image quality of images, wherein different combinations of regions are used for recording these images.

11. Process according to claim 10, characterized in that a contrast analysis is used for evaluation of the image quality.

12. Process according to claim 10, characterized in that the evaluation of the image quality is carried out based on the degree of reproducible measurement results.

13. Process according to claim 12, characterized in that a minimum width of spread of the measurement results is used as a measure of the reproducibility of the measurement results.

14. Process according to one of claims 9 or 10, characterized in that in order to reduce measurement errors caused by illumination, the surrounding gray values of an edge transition of contours detected by image processing are represented as a histogram and the position of the maxima of the gray value distributions is determined, and in that a threshold necessary in the image processing for contour searching is located between the maxima.





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15. Process according to claim 14, characterized in that the threshold assumes a mean gray value between the gray values of the maxima.

16. Process according to claim 14, characterized in that different amplitudes of the maxima are taken into account as weighting when determining the threshold.

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