Device and Method for Determination of Alignment Errors

Specification

The invention relates to a device for determination of alignment errors and/or distortions of structures which are present on a substrate or which have been applied to it according to Claim 1 and a corresponding method according to Claim 7.

Hereinafter structures are defined as all types of elements which are produced by various chemical and/or physical processes directly on a wafer or which are externally produced and are joined to the wafer by any alignment process or placement process.

Examples of structures which are produced directly on the wafer are vapor-deposited conductor paths, ICs produced lithographically on the wafer, for example CMOS or TTL logics, sensors, etching structures, MEMS, etc.

On the other hand, a wafer can also be provided with components by an insertion process, therefore can be expanded. The most common example for this insertion process would be the application of chips in a chip-to-wafer process by a pick-and-place device. These components represent 3D expansions of the basic structure of the wafer. These components are also encompassed by the term.

All the aforementioned structures can have deviations from the ideal. For example, conductor paths can have slight distortions due to faults in the mask. It would furthermore be conceivable that the conductor paths have indeed been correctly produced on the wafer, but in a subsequent bond process such a high pressure is applied to the wafer that its surface and thus also

the conductor paths are distorted. Furthermore distortions of the surface can arise due to other technical-physical and/or chemical influences, for example by thermal stresses, thermal shock, inherent stresses, etc. Similar considerations apply to all structures which have been applied directly to a wafer.

In structures which are applied by an insertion process to the wafer surface, the positioning and/or alignment of the structure can be faulty. In this case distortion is defined as distortion of the applied structure itself, predominantly caused by torsion and shearing.

Alignment in bond processes, especially chip-to-wafer methods, is becoming increasingly more important due to the 3D technology which is becoming more and more important in combination with advancing miniaturization. This acquires importance mainly in applications in which alignment accuracies of less than 2 µm for all sites located on the wafer are desired. The importance and demands on the accuracy of alignment technology are still increasing greatly for desired accuracies less than 1 µm, especially less than 0.5 µm, or less than 0.25 µm.

Due to the fact that the structures are becoming smaller and smaller, but the wafers at the same time are becoming larger and larger, structures which are very well aligned to one another can be present in the vicinity of alignment marks, while at other positions of the wafer the structures have not been correctly or at least not optimally placed.

For this reason, in addition metrology tools are used for checking of alignment accuracies. EP 2299472 shows a method using which it is possible to measure the entire surface of a wafer in order to obtain information about the positions of the structures on the surface of each wafer.

The structures mentioned here can be deformed in exactly the same manner by high pressures, thermal stresses, inherent stress, thermal shocks, etc.

The object of this invention is to develop a generic device and a generic method such that checking of the alignment accuracy and/or of the distortion more efficiently and more accurately is enabled.

This object is achieved with the features of Claims 1 and 7. Advantageous developments of the invention are given in the dependent claims. All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the scope of the invention. At the given value ranges, values within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination.

As claimed in the invention there are two coordinate systems, the X-Y coordinate system, also called the first coordinate system, and the X'-Y' coordinate system, also called the second coordinate system.

The first coordinate system allows translational and/or rotary motion of the receiving unit and thus of the substrate holder with the wafer loaded onto it and the positioning relative to at least one, preferably several optics which have been mounted in a fixed manner. The optics can preferably also move in translation and rotation, in any case preferably only for calibration of the optical axis or of the optics relative to the first coordinate system. Conversely, the receiving unit with the substrate holder can also be fixed during the determination of the alignment errors and the optics can be movable. In this case, at the start a position of the substrate holder or substrate would be fixed as the origin of the first coordinate system.

The origin of the first coordinate system lies preferably in the optical axis of the detections means, especially one of the optics.

The second coordinate system is a coordinate system which is defined in the computer and

with reference to which a structure position field is defined.

The invention is based on the idea of comparing the actual X-Y positions (detected in the first coordinate system), especially also their actual alignment in the X-Y plane, for the structures which are present on the substrate, to the ideal X'-Y' structure positions of a structure position field which has been generated in the computer, which latter positions are stored in the second coordinate system. The structure position field is preferably defined with respect to the second coordinate system which is joined in a fixed manner to the alignment unit and the sample holder.

As claimed in the invention the substrate (wafer) is positioned by alignment mark (markings on the substrate) relative to the second coordinate system, preferably by translational and/or rotary motion. The structure position field is then in the ideal case congruent with the X-Y positions of the structures present on the wafer. Alternatively, a software correlation with the second coordinate system takes place so that a transformation of the two coordinate systems is possible.

Due to the alignment of the substrate by means of its alignment marks (markings) to the second coordinate system, not only are errors in the movement/assignment/detection by the detection means and their movement relative to the substrate holder or the substrate minimized, if not even precluded, but also much more efficient and faster detection is enabled.

Substrates are especially wafers and the structures as claimed in the invention are especially chips which are applied to wafers, especially in several layers (so-called 3DIC chips), or structures which have been produced directly on the wafer by various processes which are not mentioned in detail. Due to the independence of the X-Y structure positions assigned to the second coordinate system the invention is especially suited for applying several layers of chips (or several layers of structures applied directly on the wafer by different processes which are not mentioned in detail)

since error propagation or error multiplication is avoided by the measure as claimed in the invention.

Based on the detection in an external coordinate system (second coordinate system) (assigned to the machine/device) the method as claimed in the invention is also suited for determining the distortions of the X-Y structures on the substrate which are caused for example by stresses which are induced in wafer bonding. The method can also be used especially when only one substrate to be bonded has been structured. This is the case for example in the production of back side illuminated image sensors.

The two coordinate systems are especially Cartesian coordinate systems which are each determined by X vectors (X direction) and Y vectors (Y direction) which intersect at the origin of the coordinate systems.

The device as claimed in the invention has detection means, especially optics, preferably several optics, preferably at least a microscope and/or a laser and/or a camera. The detection means can be moved in rotation by three degrees of freedom and in translation by three degrees of freedom in order to allow calibration, in any case preferably they are fixed/can be fixed during the method steps as claimed in the invention. The relative motion between the wafer and the optics takes place as claimed in the invention by the active movement of the receiving unit with reference to the first coordinate system.

As claimed in the invention the distance of the X-Y positions of the first and/or second markings in the X direction and/or the Y direction in the second coordinate system to the given X-Y structure positions can be determined especially by preferably digitized superposition of the X-Y structure position assigned to each structure with the X-Y positions of the second markings,

especially by preferably digital image acquisition of the structure.

The first markings, especially so-called alignment marks, are used especially for coarse and/or fine alignment of the substrate which has been fixed on the substrate holder and/or for correlation of the position of the substrate in a first coordinate system to the second coordinate system in the X and Y direction, preferably in addition in the direction of rotation. According to one preferred version solely more finely resolved second markings are used to determine the origin of the second coordinate system so that it can be determined more accurately.

According to one advantageous embodiment of the invention, it is provided that the detection means comprise at least one optics which can be fixed in the first coordinate system and which can be moved especially at least in the X and Y direction in the first coordinate system, preferably controlled by a control apparatus, especially for setting the origin of the first coordinate system. The detection means can comprise especially a single microscope or several microscopes which can be triggered preferably independently of one another.

Here it is especially advantageous if according to another advantageous embodiment it is provided that the optics, especially by focussing and/or moving in one Z direction which is perpendicular to the X and Y direction, has a field of view with which at least one structure at a time can be detected at the same time, preferably less than 17 structures at the same time, even more preferably less than 5 structures at the same time, ideally exactly one structure at the same time.

In a development of the invention it is provided that alignment means, especially in the form of a receiving apparatus which accommodates the substrate holder and which can moved at least in the X and Y direction of the first coordinate system, are intended for alignment of the

substrate which is fixed on the substrate holder relative to the second coordinate system, especially by detecting the first markings on the substrate with the detection means.

To the extent the X-Y positions and/or the X-Y structure positions can be stored especially jointly in a position map which is assigned especially to the second coordinate system or which is correlated with it, especially prompt and efficient evaluation of the structures is possible so at any instant, especially when several structures are stacked on top of one another, a faulty structure alignment can be ascertained and corresponding countermeasures such as for example re-alignment or marking as scrap can be initiated.

One important aspect of this invention is moreover that the device (or measurement device) as claimed in the invention in one preferred embodiment is provided separately from the alignment device as an independent module.

Features disclosed according to the device and also method features should be considered disclosed as an independent or combined invention and vice versa.

To the extent the method as claimed in the invention or the device as claimed in the invention are used in BSI CIS (back side illuminated contact image sensors), the determination of distortions in an exposure field for lithography, especially with a maximum size of 26x32 mm, is important. The order of magnitude of deviations is especially less than 250 nm, preferably less than 100 nm, still more preferably less than 70 nm, even more preferably less than 50 nm.

Here according to one alternative or development of this invention it is conceivable for the accuracy of detection of fields of view adjacent to distortions which are referenced to the respectively detected field of view to be considered by interpolation or other suitable transformation methods.

Other advantages, features and details of the invention will become apparent from the following description of preferred exemplary embodiments and using the drawings.

Figure 1a shows a schematic cross sectional view of a device as claimed in the invention,

Figure 1b shows a schematic plan view of the device according to Figure 1a,

Figure 2a shows a schematic cross sectional view of a device as claimed in the invention with a loaded wafer which has not yet been coarsely adjusted,

Figure 2b shows a schematic plan view of the device according to Figure 2a,

Figure 3a shows a schematic cross sectional view of a device as claimed in the invention with a loaded wafer which has already been coarsely adjusted,

Figure 3b shows a schematic plan view of the device according to Figure 3a,

Figure 4a shows a schematic cross sectional view of a device as claimed in the invention, with optics position over a first alignment mark,

Figure 4b shows a schematic plan view of the device according to Figure 4a,

Figure 5a shows a schematic cross sectional view of a device as claimed in the invention with optics position over a second alignment mark,

Figure 5b shows a schematic plan view of the device according to Figure 5a,

Figure 6 shows a plan view of a substrate with structures,

Figure 7 shows a schematic of X-Y structure positions as claimed in the invention,

Figure 8 shows an enlargement of a substrate with a perfectly aligned and contacted structure and

Figure 9 shows an enlargement of a substrate with an imperfectly aligned and contacted structure.

The same components/features and those with the same effect are identified by the same reference numbers in the figures.

Figures 1a and 1b of the illustrated embodiment of this invention show a receiving apparatus 1 which can be moved in the X and Y direction (first coordinate system), especially in translation, preferably in addition in one Z direction (perpendicular to the X and Y direction), especially in translation. Moreover it is advantageous if the receiving apparatus 1 can be rotated, especially around an axis R of rotation at the centroid or center of the receiving region of a substrate holder 2. The substrate holder 2 can be fixed on the receiving apparatus 1.

In Figures 2a and 2b of the illustrated embodiment of this invention, the substrate 5 is located on the substrate holder 2. The type of fixing takes place preferably by a vacuum, especially controlled by an especially software-supported control apparatus of the device, which apparatus is not shown. Alternatively the fixing can also take place electrostatically or mechanically or by a combination of the aforementioned fixing techniques. The substrate 5 has not yet been coarsely adjusted in this process step; this can be easily recognized by the incorrect position of the substrate 5 in Figure 2b.

The device furthermore comprises optics 3 (detection means) which is fixed on an optics receiver which is not shown.

The optics 3 is used to detect first markings 7 which have been applied on one surface 5o of the substrate 5 and to detect second markings 11, 11' on structures 6 which have been applied on the substrate 5. The optics 3 can be designed for the visible, infrared, ultraviolet or any other wavelength range of the electromagnetic spectrum. It is important as claimed in the invention that the optics 3 allows pattern recognition of the first and second markings 7, 11, 11', especially in a

digitizable form. To increase the speed and/or efficiency of detection it is conceivable as claimed in the invention to provide several optics 3. In such a case the coordinate origin of the first coordinate system lies preferably on the optical axis of any optics.

In a first step the substrate 5 is positioned (Figure 2a, 2b) on the substrate receiver 2 of the receiving apparatus 1 and coarsely aligned (Figure 3a, 3b). The coarse alignment of the substrate 5 takes place especially via a contour 8 provided on the periphery 5u of the substrate 5, in particular a notch or a flat. The coarse alignment has an accuracy of less than 1000 µm, preferably less than 500 µm, still more preferably less than 100 µm, even more preferably less than 50 µm, still more preferably less than 15 µm. Here the substrate 5 is aligned in the direction of rotation around one axis R of rotation with a rotational accuracy of less than 1 degree, preferably less than 0.5 degree, still more preferably less than 0.1 degree, even more preferably less than 0.01 degree. Coarse alignment is defined here as a positioning of the substrate 5 in which the optics 3 has focussed the first alignment marks 7 which are distributed on the surface 5o in the field of view. According to one preferred version solely the more finely resolved second markings 11, 11' are used for determination of the origin and of the alignment of the second X-Y coordinate system so that it can be determined more accurately. The second X-Y coordinate system is fixed especially by comparison and optionally positioning of the X-Y structures or markings with the corresponding given (stored) X-Y structure positions.

If the surface of the wafer and thus the markings 11, 11' and/or the alignment marks 7, 7' should already have been distorted, it is possible as claimed in the invention to detect all possible markings 11, 11' and/or alignment marks 7, 7' and deduce the origin of the second coordinate system by an algorithm. These algorithms are algorithms which are known to one skilled in the art.

The coarse alignment can also comprise a wedge fault compensation, especially with respect to the optics 3. This can take place on the one hand as claimed in the invention by orthogonal alignment of one optical axis of the optics 3 or by acquisition of a focus map. The focus map is acquired by the focus setting of the optics 3 being determined at several locations and then the expected focus setting being computed for all other X-Y positions by interpolation. This leads to a further increase of efficiency of the method as claimed in the invention.

Using the X-Y positions of the first markings 7 on the substrate 5 the position of the first coordinate system is known and by fixing of the substrate 5 on the substrate holder 2 and of the receiving apparatus 1 the first coordinate system is fixed. As claimed in the invention it is decisive here that the receiving apparatus 1 need not be designed for an especially precise positioning accuracy. A positioning accuracy of > 1 μm, especially > 5 μm, preferably > 10 μm is sufficient as claimed in the invention.

In one preferred embodiment of the invention the position of the receiving apparatus 1 can be exactly detected, especially by a precise measurement system, preferably with a precision of less than 1000 nm, preferably less than 100 nm, still more preferably less than 10 nm, even more preferably less than 1 nm. Alternatively, instead of moving and detecting the receiving apparatus 1 the optics 3 can be moved, in this case there being preferably a corresponding detection of the optics 3 or of the optics receiver relative to the device.

With reference to the second coordinate system, ideal X-Y structure positions for the structures 6 which are distributed on the surface 5o are given, especially in the form of position crosses 9, stored in the control apparatus as the structure position map 12 (see Figure 3) with a border 10 which corresponds to the outer contour of the substrate 5. The position crosses 9

preferably consist of a line 9x which runs in the x direction and a line 9y which runs in the Y direction, which lines cross at the ideal position (middle of the structure 6, see Figure 8).

The X-Y structure positions can be fixed and optionally changed especially by software of the control apparatus so that the user can influence the positioning of the structures 6 on the surface 5o.

The device as claimed in the invention is used to determine alignment errors and/or distortions of structures 6 on the substrate 5. A deviation from this ideal position is determined by the device as claimed in the invention in order to be able to take corresponding measures in the case of an overly large deviation (metrology tool).

For further optimization of alignment errors the first coordinate system and the second coordinate system are aligned as well as possible to one another, preferably exactly (fine adjustment), especially by parallel alignment of the X axes and Y axes of the two X-Y coordinate systems.

According to one invention alternative, it is also conceivable that instead of a fine adjustment, an especially software-supported coordinate transformation matrix is prepared. Due to the possibility of determining the position of the two coordinate systems to one another there is in any case an unambiguous mathematical relationship between the two coordinate systems. The translational and/or rotary position of the one coordinate system with reference to the other one at the time can be detected in the form of a transformation matrix and automatically allows the actuation of each position from the standpoint of each coordinate system. These coordinate transformations are known to one skilled in the art.

The coarse alignment of the substrate 5 allows the optics 3 to quickly find the first markings

7. The number of first markings 7 as claimed in the invention is at least two, preferably at least three, even more preferably at least four, still more preferably at least six, even more preferably at least ten. The more markings there are for alignment, the more accurate the alignment of the coordinate systems to one another becomes.

The accuracy of the degrees of freedom of translation, especially in fine adjustment, as claimed in the invention is less than 1000 nm, preferably less than 100 nm, still more preferably less than 10 nm, even more preferably less than 1 nm. The accuracy of the degrees of freedom of rotation here is less than 0.01 degree, preferably less than 0.001 degree, still more preferably less than 0.0001 degree. Alternatively, as claimed in the invention the position of the receiving apparatus 1 can be measured so that in this case such translational movement accuracy can be omitted as claimed in the invention.

Since the X-Y structure positions for the structures 6 are given, each structure 6 on the surface 5o can be moved into a field of view 13 of the optics 3 by a precise approach of the X-Y structure positions. In the field of view 13 the deviation of the X-Y structure positions can be determined by the X-Y positions of the second markings 11, 11' on the structures 6, especially separately in the X direction (dx) and Y direction (dy).

Figure 8 shows an enlargement of the structures 6, recorded by an objective lens of the optics 3, therefore enlarged accordingly. One surface 6o and one edge 6r of the recorded structure 6, especially of a chip, can be recognized. Second markings 11, 11' are also features of the structure 6 itself, for example its surface structure or the structure of the edge 6r. Preferably on each structure 6 at least two, preferably four second markings 11, 11' are attached especially respectively on opposing corners of the structure 6. The position cross 9 relative to the structure 6 is displayed

especially controlled by software based on the stored X-Y positions of the pertinent structure 6. The position cross 9 is thus not physically applied to the structure and is not a second marking 11, 11'.

The recorded image of the structure 6 is thus more or less superimposed with the position cross 9, especially with a live image so that the position cross 9 is not necessarily present in the storage of the digital image of the structure 6 for recording and determining the positions of the second markings 11, 11'. Likewise the position cross 9 can be stored superimposed together with the digital image.

The structure 6 shown in Figure 8 is ideally positioned and/or undistorted since the position cross 9 is located exactly in the middle of the structure 6, with an identical distance of the position cross 9 to the two second markings 11, 11' which are located in opposite corners.

In the structure 6 which is shown in Figure 5 it can be recognized that both the distances of the second markings 11, 11' from the position cross 9 and also their alignment in the direction of rotation are different from the ideal position. Based on boundary values which can be fixed especially in the software, it can be directly ascertained whether the structure 6 is suitable for further processing or must be treated as scrap.

These boundary values can be established especially for each deviation vector, vector V_1, V_2, or for their vector sum and/or the rotational position.

As claimed in the invention the receiving apparatus 1 can also be fixed, while the optics 3 is moving. All the inventive ideas named in the patent specification apply analogously since the method depends only on a relative movement between the receiving apparatus 1 and the optics 3. The movement of the optics 3 instead of the receiving apparatus 1 has the advantage that only a relatively small optics, with relatively little mass, must be moved. Furthermore the embodiment of

the apparatus as claimed in the invention is more compact since the large-area receiving apparatus 1 need not be moved over a still larger area. The disadvantage of this embodiment is the high susceptibility to vibration of the optics due to its small mass which adversely affects the determination of the alignment errors and/or distortion errors as claimed in the invention.

Accordingly, at any instant of a process sequence, especially after treatment of the substrate, it can be checked by means of the invention whether the X-Y position have [sic] changed significantly relative to the given X-Y structure positions and/or the X-Y positions determined prior to the treatment step.

Therefore the method as claimed in the invention in the illustrated embodiment has the following steps, especially the following sequence, and individual steps can be replaced by the alternatives named above:

1. loading of a substrate 5 with structures 6 into the device,

2. coarse positioning of the substrate 5,

3. fixing of the substrate 5 relative to the receiving apparatus 1,

4. fine alignment of the substrate 5 using the first alignment marks 7 and/or markings 11, 11' by translational and/or rotary movement of the receiving apparatus 1,

5. scanning/following of all X-Y structure positions by moving the receiving apparatus 1,

6. recording of an especially digital image on each X-Y structure position by the optics 3,

7. determination of the deviation of the X-Y positions of each structure 6, especially of the second markings 11, 11' of each structure, from the X-Y structure position and

8. output and/or storage of the movement data, especially in the form of a position map, especially encompassing X-Y positions and X-Y structure positions of each structure 6.

Reference number list

1	receiving apparatus
2	substrate holder
3	optics
5	substrate
5u	periphery
5o	surface
6	structures
6o	surface
6r	edge
7	first markings
8	contour
9	position cross
9x	line
9y	line
10	border
11, 11'	second markings
12	structure position map
13	field of view
V_1, V_2	deviation vectors
R	axis of rotation
X	X direction

Y	Y direction
Z	Z direction

Claims

1. A device for determination of alignment errors of structures (6) which are present on a substrate (5) or which have been applied to it with the following features:

- a substrate holder (2) for accommodating the substrate (5) with the structures (6)
- detection means for detecting X-Y positions of first markings (7) on the substrate (5) and/or second markings (11, 11') on the structures (6) by moving the substrate (5) or the detection means in a first coordinate system,

characterized in that

in a second coordinate system which is independent of the first coordinate system X'-Y' structure positions for the structures (6) are given whose respective distance from the X-Y positions of the first markings (7) and/or second markings (11, 11') can be determined by the device.

2. The device as claimed in Claim 1, wherein the detection means comprise at least one optics (3) which can be fixed in the first coordinate system for detection and which can be moved especially at least in the X and Y direction in the first coordinate system, preferably controlled by a control apparatus, especially for setting the origin of the first coordinate system,

3. The device as claimed in Claim 2, wherein the optics (3), especially by focussing and/or moving in one Z direction which is perpendicular to the X and Y direction, has a field of view (13) with which are least one structure (6) at a time can be detected at the same time, preferably less than 17 structures at the same time, even more preferably less than five structures at the same time, ideally exactly one structure at the same time.

4. The device as claimed in at least one of the preceding claims, wherein the second

coordinate system is a coordinate system which is defined in the computer and with reference to which a structure position field with the X'-Y' structure positions is defined.

5. The device as claimed in at least one of the preceding claims, wherein alignment means, especially in the form of a receiving apparatus (1) which accommodates the substrate holder (2) and which can moved at least in the X and Y direction of the first coordinate system, are intended for alignment of the substrate (5) which is fixed on the substrate holder (2) relative to the second coordinate system, especially by detecting the first markings and/or second markings (7, 11, 11') on the substrate (5) with the detection means.

6. The device as claimed in at least one of the preceding claims, wherein the X-Y positions and/or the X'-Y' structure positions can be stored especially jointly in a position map which is assigned especially to the second X-Y coordinate system or which is correlated with it.

7. A method for determination of alignment errors of structures (6) which are present on a substrate (5) or which have been applied to it with the following steps, especially the following sequence:

- detection of X-Y positions of first markings (7) on the substrate (5) and/or second markings (11, 11') on the structures (6) by detection means by moving the substrate (5) or the detection means in a first coordinate system,

characterized in that

in a second coordinate system which is independent of the first coordinate system X'-Y' structure positions for the structures (6) are given whose respective distance from the X-Y positions of the first markings (7) and/or second markings (11, 11') is determined.

8. The method as claimed in Claim 7, wherein at least one structure (6) at a time is detected

at the same time, preferably less than 17 structures at the same time, even more preferably less than five structures at the same time, ideally exactly one structure at the same time.

9. The method as claimed in one Claims 7 or 8, wherein the detection means are moved by means of an optics receiver which is assigned to the first X-Y coordinate system for setting the origin of the first coordinate system at least in the X and Y direction and are then fixed in a first coordinate system for detection.

10. The method as claimed in at least one of Claims 7 to 9, wherein an alignment of the substrate (5) which is fixed on the substrate holder (2) relative to the second X-Y coordinate system takes place by alignment means, especially in the form of a receiving apparatus which accommodates the substrate holder (2) and which can be moved at least in the X and Y direction of the first X-Y coordinate system, especially by detection of the first markings (7) on the substrate (5) with the detection means.

11. The method as claimed in at least one of Claims 7 to 10, wherein the X-Y positions and/or the X-Y structure positions are stored especially jointly in a position map which is assigned especially to the second X-Y coordinate system or which is correlated with it.