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 and a corresponding method.

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

Embodiments of this invention disclose 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.

According to a first aspect, there is provided a device for determination of alignment errors of structures which are present on a substrate or which have been applied to it for checking of the alignment accuracy and/or of the distortion of the structures, with the following features:

- a substrate holder for accommodating the substrate with the structures
- detection means for detecting X-Y positions of first markings on the substrate and/or second markings on the structures by moving the substrate or the detection means in a first coordinate system, wherein an image of the structures is recorded by the detection means, characterized in that

in a second coordinate system which is independent of the first coordinate system ideal X'-Y' structure positions for the structures are given whose respective distance from the X-Y positions of the first markings on the substrate and/or second markings on the structures can be determined by the device, wherein the recorded image of the structures is superimposed with the ideal X'-Y' structure positions for the structures.

According to a second aspect, there is provided a method for determination of alignment errors of structures which are present on a substrate or which have been applied to it for checking of the alignment accuracy and/or of the distortion of the structures, with the following steps, especially the following sequence:

- detection of X-Y positions of first markings on the substrate and/or second markings on the structures by detection means by moving the substrate or the detection means in a first coordinate system, wherein an image of the structures is recorded by the detection means, characterized in that

in a second coordinate system which is independent of the first coordinate system X'-Y' structure positions for the structures are given whose respective distance from the X-Y positions of the first markings on the substrate and/or second markings on the structures is determined, wherein the recorded image of the structures is superimposed with the ideal X'-Y' structure positions for the structures.

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 per embodiments of 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.

Embodiments of the invention are 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 per embodiments of 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 per embodiments of 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 embodiments of the invention are 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 per embodiments of the invention.

Based on the detection in an external coordinate system (second coordinate system) (assigned to the machine/device) the method as per embodiments of 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 per embodiments of 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 per embodiments of the invention. The relative motion between the wafer and the optics takes place as per embodiments of the invention by the active movement of the receiving unit with reference to the first coordinate system.

As per embodiments of 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 an embodiment 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 embodiment of this invention is moreover that the device (or measurement device) as per 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 per embodiments of the invention or the device as per embodiments of 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 embodiment 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.