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(54) **DEVICE FOR MEASURING THE POSITION OF AT LEAST ONE STRUCTURE ON A SUBSTRATE**

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***G01B 11/02*** (2006.01)
***G01N 21/01*** (2006.01)

(52) **U.S. Cl.** ....................................... **356/500**; 356/244

(58) **Field of Classification Search** ................. 356/244, 356/498, 500
See application file for complete search history.

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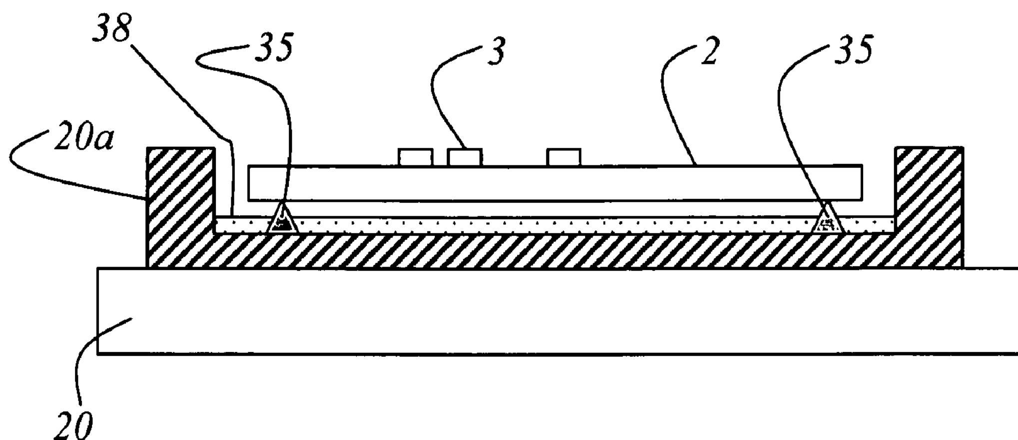
(57) **ABSTRACT**

A device for measuring the position of at least one structure on a substrate is disclosed. The substrate to be measured is positioned in a mirror body. A flat insert is provided in the mirror body and is formed such that the substrate and the insert together always have the same optical thickness, irrespective of the mechanical thickness of the substrate.

**6 Claims, 4 Drawing Sheets**



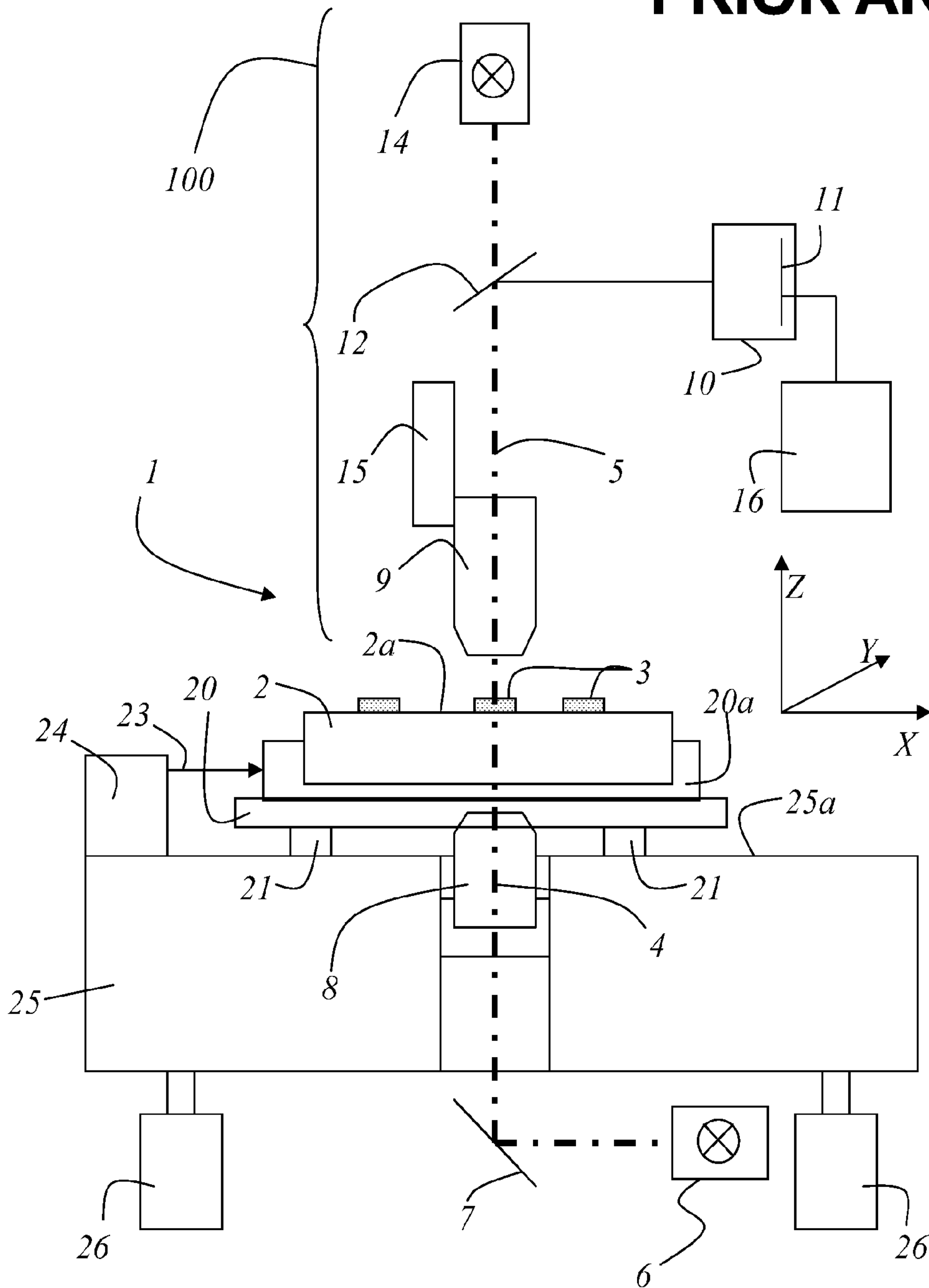



Fig. 1

PRIOR ART

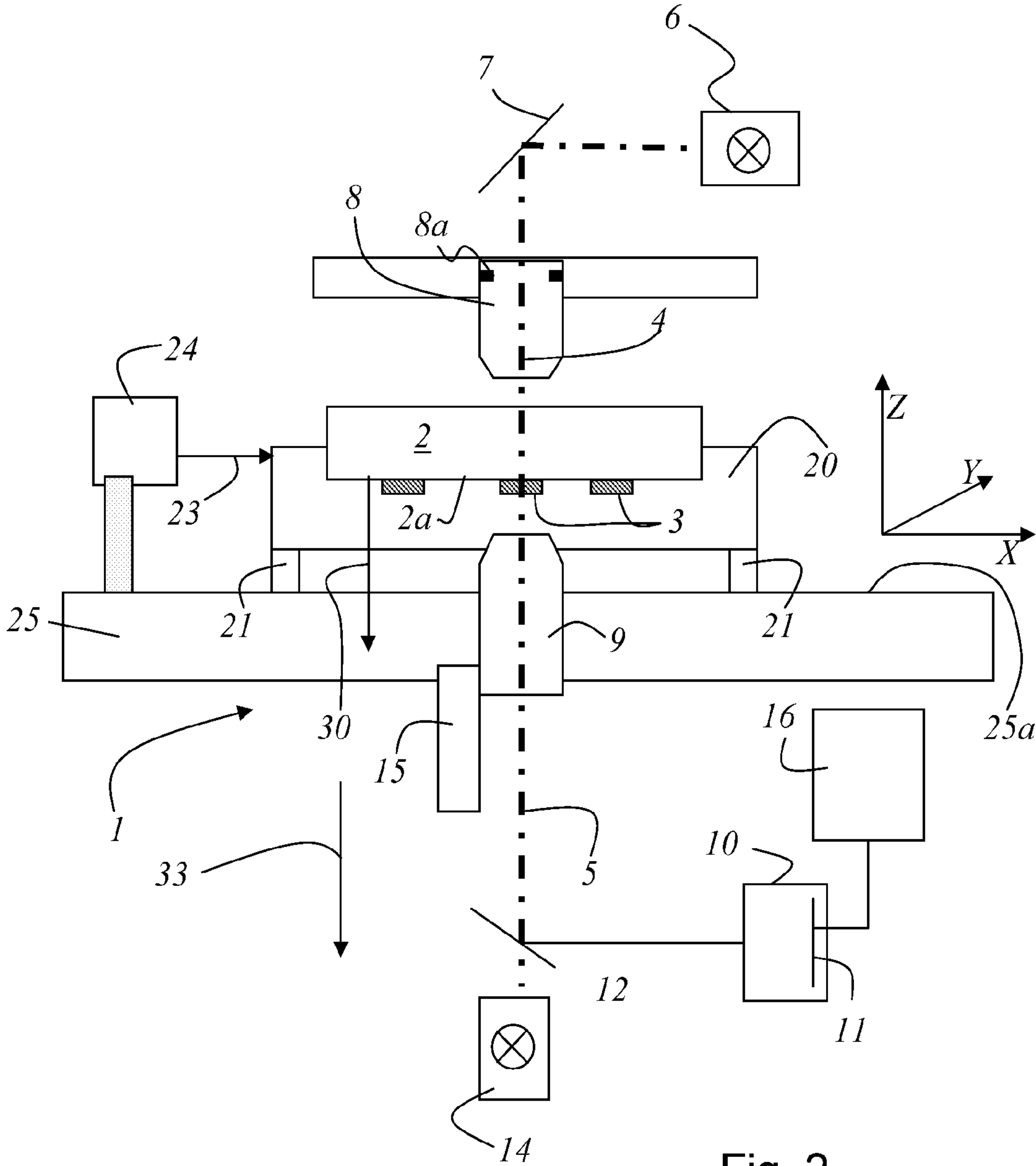



Fig. 2

PRIOR ART

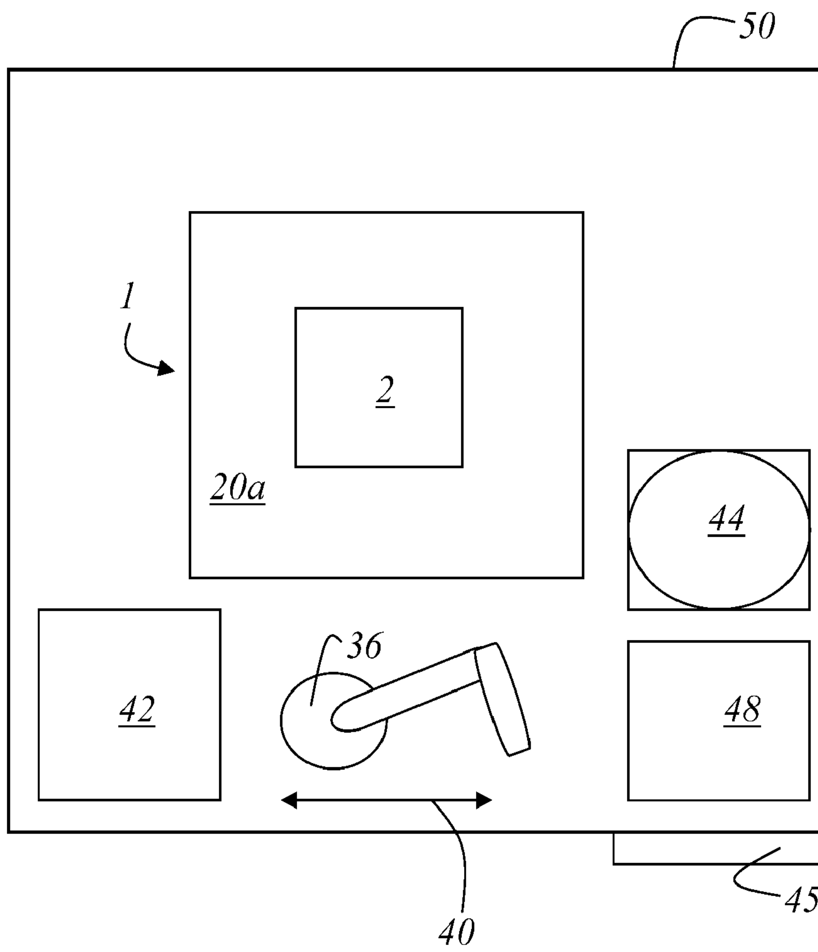



Fig. 3

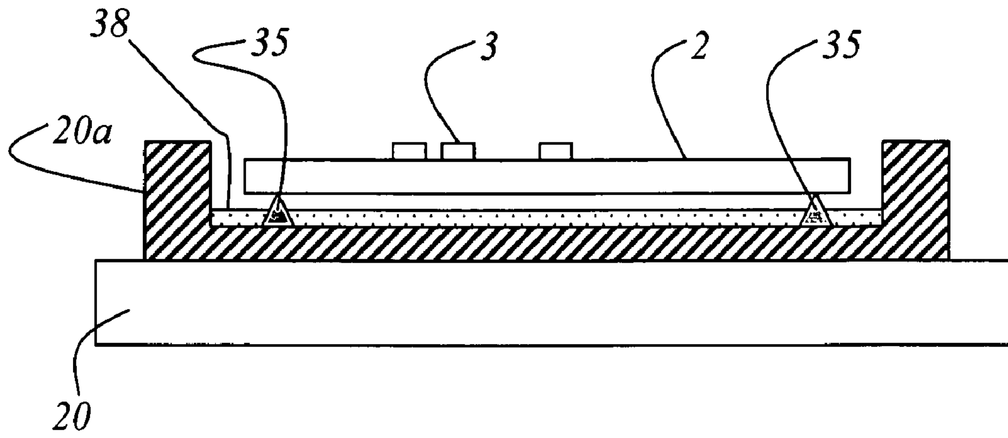



Fig. 4

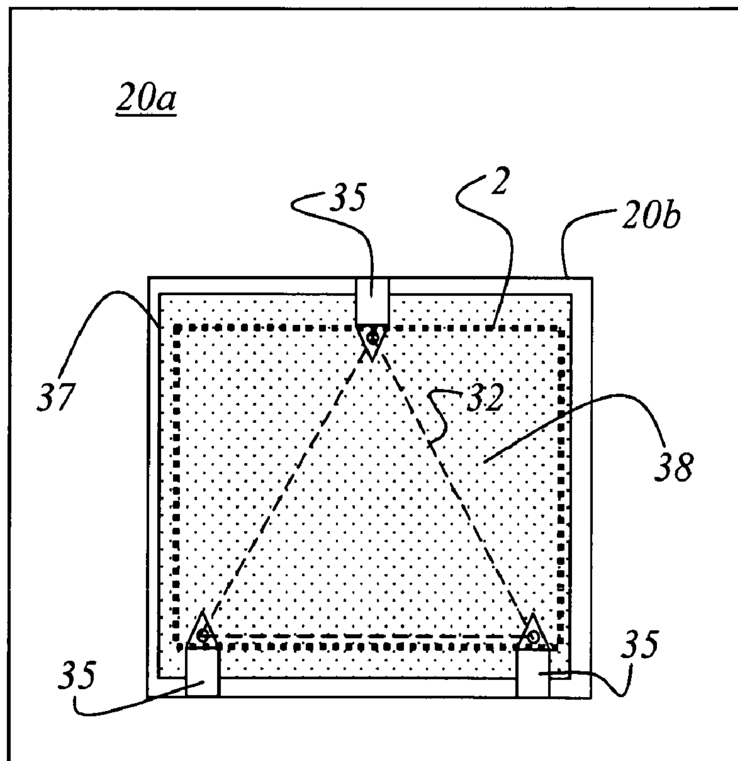



Fig. 5

# DEVICE FOR MEASURING THE POSITION OF AT LEAST ONE STRUCTURE ON A SUBSTRATE

## CROSS REFERENCE TO RELATED APPLICATIONS

This patent application claims priority of German Patent Application No. 10 2007 000 991.9, filed on Nov. 15, 2007, the application is incorporated herein by reference.

## FIELD OF THE INVENTION

The present invention relates to a device for measuring the position of at least one structure on a substrate. There is provided a measurement table movable in the X-coordinate direction and in the Y-coordinate direction. A mirror body, in which the substrate is arranged, is provided on the measurement table.

## BACKGROUND OF THE INVENTION

A coordinate measuring device is well-known from prior art. See, for example, the lecture script "Pattern Placement Metrology for Mask Making" by Dr. Carola Bläsing. The lecture was given on the occasion of the Semicon conference, Education Program, in Geneva on Mar. 31, 1998, and describes the coordinate measuring machine in detail. The structure of a coordinate measuring machine, as it is known, for example, from prior art, will be explained in more detail in the following description associated with FIG. **1**. A method and a measuring device for determining the position of structures on a substrate is known from German published application DE 100 47 211 A1. For details on the mentioned position determination, see that document.

German patent document DE 199 49 019 C2 discloses a measuring device for measuring structures on substrates varying in thickness. The substrates are inserted in an X/Y slide. The X/Y slide comprises a peripheral rim. The measuring device itself is equipped with illumination optics, wherein there are provided several compensation elements needed for compensating the optical path length. These compensation elements are selected corresponding to the substrate to be measured. The compensation elements are located in storage compartments on the peripheral rim of the recess of the X/Y slide. Depending on which compensation element is needed, they are removed from the storage compartment by means of the illumination optics. In this way, an equal optical thickness of the whole system consisting of compensation element and substrate is achieved irrespective of the mechanical thickness of the substrate used. One disadvantage is that the compensation elements merely rest on the illumination optics and may thus constitute a further error source, which may result in faulty measurements with the measuring device.

Document DE 100 31 719 discloses an illumination means having a light source, an optical fiber bundle, a coupling-in optical system upstream of and a coupling-out optical system downstream of the fiber bundle, and an illuminating optical system. A homogenizing optical system between the coupling-out optical system and the illuminating optical system effects a homogenization of the intensity distribution in the image field. The homogenizing optical system consists of a microhoneycomb condenser and a lens member, which superimpose the exit opening of the fiber bundle in an intermediate image plane to form a homogeneous intermediate image. The coordinate measuring device itself includes an X/Y measurement table to receive a substrate having a structure to be measured, and the illumination system mentioned above.

Document DE 198 58 428 discloses a movable x/y measurement table having two measurement mirrors, which are arranged to be orthogonal to each other, for interferometric position determination. The movable measurement table, a mirror body carrying the measurement mirrors, and the receptacle for the substrate (**9**) are implemented as separate elements.

## SUMMARY OF THE INVENTION

It is the object of the invention to provide a device allowing to achieve the same optical thickness for all substrates and to eliminate potential error sources involved in achieving the same optical thickness.

This object is achieved by a device comprising a measurement table movable in a X-coordinate direction and in a Y-coordinate direction; a mirror body provided with the measurement table in which the substrate is positioned; at least one flat insert provided in the mirror body, wherein the flat insert is formed such that the substrate and the insert together always have the same optical thickness, irrespective of the mechanical thickness of the substrate, and that the size of the insert is at least such that, in projection on the substrate, the insert covers at least the whole area of the substrate.

It is advantageous if at least one flat insert may be inserted in the mirror body. The insert is formed such that the substrate and the insert together always have the same optical thickness, irrespective of the mechanical thickness of the substrate.

The size of the insert is at least such that, in projection on the substrate, it covers at least the area of the substrate.

The device is a coordinate measuring machine provided in a housing at least with a storage for several inserts and for several substrates. The inserts differ in optical thickness.

Inside the housing, a transport system is provided which, depending on the optical and/or mechanical thickness of the substrate currently to be measured, selects a corresponding insert and puts it into the mirror body. The substrates may be coded so that the device may select the required inserts automatically such that the same optical thickness is achieved for the combination of insert and substrate. Based on the measuring recipe to be completed, the system further knows which substrates and which type of substrate are used. With this information, the corresponding insert may be selected and positioned in the mirror body before the substrate is deposited in the mirror body.

The coordinate measuring machine comprises a transmitted light illumination means for the substrate. The transmitted light illumination means includes a condenser. The insert is inserted into the mirror body such that the insert is directly opposite to the condenser. The surface of the substrate carrying the structures faces the measurement objective of the coordinate measuring machine. The measurement objective itself is also opposite the condenser.

The coordinate measuring machine has a computer associated therewith, which, based on the code of the substrates, positions an insert in the mirror body by means of a transport system such that a predetermined optical thickness of substrate and insert is set.

At least one laser interferometer is associated with the mirror body so that the position of the measurement table in the X-coordinate direction and in the Y-coordinate direction may be determined with the help of the mirror body located on the measurement table.

In one embodiment, holding elements for the substrate may form the corners of a triangle. The holding elements are

preferably formed to be point-like. It is particularly advantageous for the theoretical calculation of the deflection of the substrate if the holding elements are arranged on the corners of an isosceles triangle. Similarly, it is also contemplated that the point-like holding elements are arranged on the corners of an equilateral triangle.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the following, embodiments will explain the invention and its advantages in more detail with reference to the accompanying drawings, in which:

FIG. **1** schematically shows a prior art coordinate measuring machine;

FIG. **2** schematically shows the inverse arrangement of a coordinate measuring machine;

FIG. **3** shows a schematic top view of the arrangement of a coordinate measuring machine in connection with several depositing positions designed as accessory devices for the coordinate measuring machine;

FIG. **4** shows a schematic side view of the positioning of a substrate in a mirror body provided on a table; and,

FIG. **5** schematically shows a top view of a mirror body having three holding elements formed thereon, on which the substrate is resting.

## DETAILED DESCRIPTION OF THE INVENTION

Several coordinate measuring devices **1** of the type shown in FIG. **1** are known from prior art. For the sake of completeness, however, the operation and arrangement of the individual elements of the coordinate measuring device **1** will be described. The coordinate measuring device **1** includes a measurement table **20** positioned on bearings **21** (the bearings **21** may, for example, be implemented as air bearings) to be movable in the X-coordinate direction and in the Y-coordinate direction in a plane **25***a*. The plane **25***a* is formed of an element **25**. In a preferred embodiment, the element **25** is granite. However, someone skilled in the art will understand that the element **25** may also be formed of any other material guaranteeing an exact plane **25***a* for translating the measurement table **20**. The position of the measurement table **20** is measured by means of at least one laser interferometer **24** emitting a light beam **23** for the measurement. For this purpose, a mirror body **20***a* also carrying the substrate **2** to be measured is positioned on the measurement table. The element itself is positioned on vibration dampers **26** to thus keep building vibrations away from the measuring device.

A substrate **2** carrying the structures **3** to be measured is inserted in the mirror body **20***a*. The substrate **2** may be illuminated with a transmitted light illumination means **6** and/or an incident light illumination means **14**. The light of the transmitted light illumination means **6** reaches the substrate **2** via a deflecting mirror **7** and a condenser **8**. Similarly, the light of the incident light illumination means **14** reaches the substrate **2** via a measurement objective **9**. The measurement objective **9** is provided with an adjusting means **15**, which allows the adjustment of the measurement objective **9** in the Z-coordinate direction. The measurement objective **9** collects the light coming from the substrate **2** and directs it out of the incident light illumination axis **5** by means of a semi-transparent deflecting mirror **12** and directs it to a camera **10** provided with a detector **11**. The detector **11** is connected to a computer system **16** generating digital images from the values measured by the detector **11**.

It is also contemplated that the coordinate measuring machine **1** is designed such that a mask or a substrate **2** is inserted such that the surface **2***a* of the mask carrying the structures **3** faces in the direction of gravity. This arrangement is a so-called inverse set-up of a coordinate measuring machine **1**. This has the advantage that the masks **2** in the coordinate measuring machine have the same orientation as when they are arranged in a stepper for exposing the masks on a wafer. In this context, see also FIG. **2**, which describes the inverse set-up in detail.

The description of FIG. **2** uses the same reference numerals as in FIG. **1** for the same elements. FIG. **2** shows the coordinate measuring machine **1** having the inverse set-up. The substrate **2** carrying several structures **3** on a surface **2***a* is inserted in a measurement table **20**. The position of the measurement table **20** is also measured by means of a laser beam **23** emitted by a laser interferometer **24**. Illumination light for the transmitted light illumination of the substrate **2** may be introduced by an illumination means **6** via a deflecting mirror **7** or a light guide, if necessary. The illumination light propagates along the optical illumination path **4**, which coincides with the optical axis of at least one measurement objective **9**. The measurement objective **9** is arranged opposite to the structures **3** on the substrate **2**. The illumination means **14** is provided for the incident light illumination of the structures **3**. The terms "substrate" and "mask" for the semiconductor production are used as synonyms herein.

While the position of the structures **3** is measured and/or the structure widths of the structures **3** are determined, the substrate **2** is held in the coordinate measuring machine **1** such that the surface **2***a* carrying the structures **3** faces in the direction of the weight **30**. In other words, a normal vector **30** with respect to the surface carrying the structures **3** is essentially parallel to the vector **33** of the weight.

FIG. **3** shows a schematic top view of the system for determining positions of structures on a substrate or a mask **2**. The arrangement of the individual elements of the system inside the housing **50** is shown. The coordinate measuring device **1** is only schematically represented by the measurement table **20** (movable in the X-coordinate direction and/or Y-coordinate direction) and the substrate **2** positioned on the mirror body **20***a*. Inside the housing **50**, which is designed as a climatic chamber, a magazine **42** may, for example, be arranged, in which the substrates **2** to be measured may, for example, be deposited for temperature adaptation. Similarly, the substrates **2** (masks for the semiconductor production) already measured may be deposited in the magazine **42** before they are output again via a loading aperture **45**. The loading aperture **45** has a loading station **48** associated therewith, via which the substrates **2** may be introduced into the system or the housing **50**. A transport means **46** capable of moving along the double arrow **40** is arranged between the loading station **48**, the magazine **42** and the coordinate measuring machine **1**. The transport means **46** allows transporting the substrates **2** to the stations or elements within the housing **50**. Someone skilled in the art will understand that the loading apertures for the substrates **2** are designed to be closable. Obviously, the transport means **46** also serves to deposit the substrates **2** on the measurement table **20** or the mirror body **20***a*.

FIG. **4** shows a schematic view of the mirror body **20***a* arranged on a measurement table **20**. Several holding elements **35** are provided in the mirror body **20***a*, with the substrate **2** to be measured resting thereon. In the embodiment shown, the holding elements are arranged such that they contact the surface of the substrate **2** that does not carry any structures **3**. The holding elements **35** for the substrate are designed such that they contact the substrate in a point-like way. Generally, ruby balls are used as holding elements **35** so

that the substrate is seated on one point of the ball. An insert **38** is also provided in the mirror body **20***a*. The insert **38** is formed to have such a large area that it covers the whole surface of the substrate **2**. In other words, the insert **38** is designed to be so large that, in projection on the substrate **2**, it covers the whole area of the substrate **2**. In the embodiment shown, the insert is designed such that it has an opening formed at the position of each holding element **35** so that the insert **38** is additionally guided by the holding elements **35**. Someone skilled in the art will understand that the insert **38** may also have a different design. The insert design described in FIG. **4** is not meant to limit the invention in any way.

FIG. **5** shows a schematic top view of the mirror body **20***a*, in which the substrate is held by means of three holding elements **35**. In the embodiment shown, the three holding elements are arranged on the corners of a triangle. Generally, the mirror body has a recess **20***b* formed therein, where the substrate is inserted. The mirror body **20***a* further comprises a recess **37** where the insert **38** may be deposited. In the embodiment shown, the recess **37** is formed to be somewhat larger than the substrate **2**. Thus the area of the insert **38** is larger than that of the substrate **2**. As described above, the coordinate measuring machine is arranged inside a housing **50**. A plurality of storage elements is provided in the housing **50**. Both the substrates **2** and the inserts **38** required for the various substrates **2** may be deposited in the storage elements. In a preferred embodiment, the housing **50** is implemented as a climatic chamber. This is required for the substrate **2** and/or the inserts **38** to reach a thermal equilibrium and a mechanical equilibrium. In the storage elements, the required relaxation processes may take place so that no changes in the equilibrium will affect the measured values obtained by the coordinate measuring machine **1**. Thus the substrates and/or the inserts may be inserted into the mirror body **20***a* by means of the transport system **36**.

The invention has been described with reference to a preferred embodiment of the invention. However, it is contemplated that modifications or changes may be made without departing from the scope of the following claims.

What is claimed is:

**1**. A device for measuring a position of at least one structure on a substrate, the device comprising:

a measurement table movable in a X-coordinate direction and in a Y-coordinate direction;

a mirror body arranged on the measurement table and in which the substrate is positioned; and,

at least one flat insert arranged in the mirror body, wherein the flat insert has a size and is formed such that both the substrate and the insert together have the same optical thickness, irrespective of the mechanical thickness of the substrate, and the size of the insert is at least large enough such that the insert covers at least the whole area of the substrate, in projection on the substrate.

**2**. The device recited in claim **1**, wherein the device is in the form of a coordinate measuring machine having a housing and at least one storage for a plurality of inserts and for a plurality of substrates, wherein the plurality of inserts have differing optical thicknesses.

**3**. The device recited in claim **2**, including a transport system which is arranged to select a corresponding insert and place the corresponding insert into the mirror body, based upon the optical and/or mechanical thickness of the substrate.

**4**. The device recited in claim **2**, wherein the coordinate measuring machine comprises a transmitted light illumination means for the substrate, the transmitted light illumination means including a condenser, wherein the insert in the mirror body is arranged directly opposite to the condenser, and a surface of the substrate carrying at least one structure faces a measurement objective of the coordinate measuring machine, and a measurement objective is arranged opposite the condenser.

**5**. The device recited in claim **4**, including a computer arranged to position an insert in the mirror body by means of the transport system, based on a code of the substrate, such that a predetermined optical thickness of the substrate and the insert is set.

**6**. The device recited in claim **1**, wherein at least one laser interferometer is associated with the mirror body such that a position of the measurement table in the X-coordinate direction and in the Y-coordinate direction is determinable by means of the mirror body.

* * * * *