MANIPULATOR, DOCKING METHOD THEREFOR AND DATA CARRIER USABLE IN THE METHOD

FIELD OF INVENTION

The present invention relates to a manipulator for docking a test head to a peripheral device, a docking method that can be performed with the manipulator, and a data carrier usable in the docking method.

BACKGROUND OF THE INVENTION

Test heads are used in the semiconductor industry to perform functional tests on semiconductor devices at various stages of their manufacture. To do this, the test head must be docked to a connection on a peripheral device that contains the semiconductor devices to be tested and in which, typically, a step of the manufacturing process has been performed, the result of which is to be determined with the aid of the test head.

In order to perform such a test on a large number of integrated circuits or their precursors produced on a common substrate, a large number of test head contacts and lines connected to the test head contacts are required; the power released during a test process requires effective cooling, for which the required cooling medium is usually also supplied and removed via the test head. The mass of such a test head is therefore considerable, and the number of lines connected to it also makes the test head difficult to move.

It is therefore common practice to use a manipulator, such as that described in US 2006/0177298 A1, to move a test head between a rest position when not in use and a docking position on a peripheral device. This prior art manipulator comprises a base and a holder which is movable in relation to the base in three degrees of translational freedom and two degrees of rotational freedom, and to which the test head is suspended so as to be pivotable in a third degree of rotational freedom.

In a typical application situation, the manipulator is pushed under the underside of the peripheral device, where the connection to be docked is located, while the connection surface of the test head is essentially horizontal. Since the test head and manipulator

block the connector from view, it is difficult to position the manipulator under the peripheral device in such a way that simply lifting the test head is sufficient for docking.

To compensate for inaccuracies in placement, the test head and the peripheral device can be equipped with complementary centring pins and receptacles that engage with each other when the test head is lifted, thereby determining the position of the test head relative to the connector with increasing accuracy until both finally meet with the precision required to perform the test. However, if the manipulator is positioned so inaccurately that the centring pins and receptacles fail to engage with each other when lifted, serious damage to the test head or peripheral device may result.

US2024/0036586 A1 describes an autonomously navigating robot that uses an imaging sensor such as a camera or LIDAR to generate a map of its surroundings and orient itself in that environment.

KR 20210125107 A discloses a system in which a camera is temporarily mounted on a substrate processing chamber to calibrate a robot that is to manipulate substrates in the substrate processing chamber. The calibration enables the robot to manipulate substrates precisely after the camera has been removed.

SUMMARY OF THE PRESENT INVENTION

The object of the present invention is to provide a method and means for its implementation that enable a test head to be docked quickly and securely to a port on a peripheral device.

According to one aspect of the invention, the object is achieved by a manipulator with a holder for a test head, which is movable in several degrees of freedom between a standby position and a docking position at a docking port of a peripheral device in order to perform measurements on semiconductor components in the peripheral device, wherein the holder carries a data reading device which is set up to read data from the peripheral device while the holder assumes an intermediate position on the way from the standby position to the docking position, and a navigation unit is set up to navigate to the docking position on the basis of the data read.

To enable fast and safe docking, it is therefore sufficient to place the manipulator in an intermediate position in which it is possible to read the data in order to automatically navigate to the docking position from there.

The data read may include directions that the navigation unit can follow to reach the docking position.

According to a preferred embodiment, the data reading device is an imaging sensor, in particular a camera, and is oriented to capture a surface opposite to and spaced apart from a connection surface of the test head. When the test head is in the intermediate position, this opposite surface is typically a surface of the peripheral device adjacent to its port and to which a data carrier to be read by the data reading device is attached.

In order to ensure reliable and reproducible reading of the data, at least one light source for supplying the light required for reading may be integrated with the imaging sensor in one assembly.

In order to make it easier for the navigation unit to find the docking position from the intermediate position, the manipulator may also have an environment sensor for detecting a reference feature of the peripheral device, the navigation unit being configured to deduce a path to be travelled from the intermediate position towards the docking position from a detected position of the reference feature and the data read.

Preferably, the environment sensor is identical to the imaging sensor; in particular, one and the same camera can perform the functions of both the environment sensor and the imaging sensor.

Since the orientation of the manipulator relative to the peripheral device may vary prior to docking, the direction of a path that the test head must travel from the intermediate position to the docking position can only be unambiguously described in a coordinate system relative to the peripheral device. In order for the navigation unit to find the correct direction in a coordinate system relative to the manipulator or the test head, it should be configured to determine the rotation required for the transition from the intermediate position to the docking position from the orientation of the reference feature in an image

from the imaging sensor. A distance to be travelled, on the other hand, can be determined from the data read.

If the imaging sensor is movable with the holder, preferably mounted on the holder, any deformation of the manipulator under the load of the test head and/or play in the control of the holder's movement by the navigation unit also affects the position of the imaging sensor and, hence, the position of the reference feature in an image generated by the sensor; therefore, no special corrective measures need to be taken to compensate for the effects of deformation or play during docking.

In particular, in order to effectively compensate for play in a degree of rotational freedom of the holder, the camera should be located at a point on the holder that is remote from an axis of rotational movement, such as at the free end of an arm carrying the test head.

If the distance from the intermediate position to the docking position is short enough for the reference feature to remain within the detection range of the imaging sensor even in the docking position, the navigation unit can be configured to derive a target position of the reference feature in an image from the imaging sensor from the data read and to control movement of the holder to the docking position by bringing the position of the reference feature in an image from the imaging sensor into alignment with the target position. Since the navigation unit continuously receives feedback about deviations between the actual and target positions in this way, it is possible to control the target position precisely using simple means.

Conveniently, the reference feature is also the carrier of the data to be read by the data reading device. For example, the reference feature may be an RFID tag, which is glued or attached in another suitable manner to the peripheral device, which can be read by a transponder of the manipulator acting as a data reading device, and which is visible to a camera of the manipulator acting as the environment sensor. According to a preferred embodiment, the reference feature is a flat object, such as a label or sticker, with a first main surface designed to be attached to a surface of the peripheral device and a second surface bearing an electro-optically readable code. For reading the code, a laser scanner may be provided; preferably the same camera is used for this as for detecting the reference feature.

According to a second aspect of the invention, the object is achieved by a method for docking a test head to a peripheral device using a holder that can be moved in several degrees of freedom and on which the test head is supported, comprising the steps of:

a) attaching a data carrier to a peripheral device, wherein the data carrier encodes data that allow conclusions to be drawn about a path (D) to be travelled from an intermediate position of the holder, in which a data reading device carried by the holder is able to read the data from the data carrier, towards a docking position for the test head on the peripheral device;

b) moving the holder from a rest position to the intermediate position and reading the data;

c) navigating the holder with the test head to the docking position based on the data read.

The data carrier may be identical to the reference feature.

Step c) preferably comprises

- generating an image of the reference feature;
- determining a target position of the reference feature in the image based on the data read, and
- navigating the holder such that the position of the reference feature in the image matches the target position.

Based on the data read, it can be determined whether automatic docking is possible, step c) being performed only if it has been determined that such docking is possible. If it has been decided that docking is not possible, an error message can be generated instead to alert a user that docking must be performed manually, provided that the test head is physically compatible with the port of the peripheral device.

The data read in step b) may directly include a description of the path to be travelled to the docking position. This is particularly useful if the reference feature is not identical to the data carrier and has a fixed local relationship to the port, which can be measured and encoded in the data carrier during its manufacture.

According to a preferred alternative, the data read in step b) includes a unique identifier of the peripheral device to which the data carrier is attached. If the navigation unit of the

manipulator receives this identifier from the data reading device and finds no match with stored identifiers, this results in an error message as described above. If docking is then performed manually, it may be provided that the navigation unit records the path travelled during manual docking or the position of the reference feature in the camera image after docking and stores it in conjunction with the read identifier. If the manipulator is to be docked to the same peripheral device again and the identifier is read again, the navigation unit finds the corresponding stored entry and can use it to perform the docking automatically.

It is also conceivable that the identifier does not uniquely identify a particular peripheral device, but only a device type. If it is ensured that the data carrier is attached in the same place on all devices of this type, it makes no difference for the control of the docking by the navigation unit whether the identifier identifies peripheral devices or device types.

If the data carrier is attached in the same place on all devices of a same type, the data on the data carrier may also contain information describing the distance to be travelled from the intermediate position to the docking position instead of a type identifier.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the invention are apparent from the following description of embodiments with reference to the accompanying figures. In these:

Fig. 1 is a perspective view of a manipulator;

Fig. 2 is a perspective view of a peripheral device;

Fig. 3 is a side view of the manipulator in an intermediate position of the docking process, in front of the peripheral device;

Fig. 4 is a block diagram of the manipulator control system;

Fig. 5 is an exemplary image generated by the camera of the manipulator;

Fig. 6 is a flow diagram of a working method of the control system according to a first embodiment of the invention;

Fig. 7 is an exemplary image from the camera according to a second embodiment of the invention; and

Fig. 8 is a flow diagram according to the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a manipulator 1 in perspective view. The manipulator 1 has a base plate 2 with several castors 3, which enable the manipulator 1 to be moved manually, for example from a standby position to an intermediate position, and feet 4, which can be extended against the floor in order to lift the castors 3 off the floor and fix the base plate 2 relative to the floor. A first carriage 5 is movable on the base plate in the x-direction of a coordinate system relative to the base plate 2. Rails guiding the movement are covered by bellows 6. The carriage 5 carries a carriage 7 that is movable in the y-direction, which in turn carries a column 9 that can rotate about a z-oriented, i.e. vertical, axis 8 and has a carriage 10 that is adjustable in the z-direction.

A U-shaped holder 11 for a test head 17 is mounted on the carriage 10 so as to be pivotable about a horizontal axis 12. Two arms 13, 14 of the holder 11 carry brackets 16 that can be pivoted about a further horizontal axis 15, and between which the test head 17 can be mounted, which is shown here schematically as an offset cuboid.

A camera 18 with a viewing direction perpendicular to the plane of the axes 12, 15 is mounted at the distal end of the arm 13.

An exposed cover glass on the top of the camera 18 is shown in a detailed enlargement. Below the centre of the cover glass there is a front lens 35 of the camera 18; light sources 36 such as LEDs are distributed around it. The ring-shaped arrangement of the light sources 36 around the front lens 35 ensures that the field of view of the camera 18 is illuminated with virtually no cast shadows, so that local differences in brightness in the images supplied by the camera 18 can be clearly attributed to differences in the albedo of an illuminated surface.

If the light sources 36 are narrow-band emitting LEDs, the cover glass can be a colour filter that is transparent to the emission wavelength of the LEDs. By not significantly attenuating the emission of the LEDs, but suppressing ambient light whose wavelength does not match the emission wavelength of the LEDs, the sensitivity of the camera 18 to ambient light can be reduced.

As a further measure to improve tolerance to ambient light, it may be provided that the camera is only sensitive during a shutter opening time, and that the light sources are operated in a pulsed manner and synchronised with the shutter opening time in order to provide a higher light output in a flash of light than would be possible in continuous operation.

Fig. 2 shows a peripheral device 20, on which the test head 17 is to be used, viewed at an oblique angle from below. A port 23 for the test head 17 is formed on the exposed underside 22 of a process chamber 21 of the peripheral device 20. A frame 24 surrounding a feed-through opening 25 of the port 23 carries several centring pins 26 which are designed to engage in receptacles 19 of the probe 17 in the course of a docking process.

A reference feature 27 in the form of a label or sticker is arranged on the underside 22 outside the frame 24. To enable automatic docking, when the manipulator 1 has been moved under the process chamber 21 so that the test head 17 is approximately opposite the frame 24, as shown in Fig. 3, the reference feature 27 must be within the field of view of the camera 18. To ensure that this is the case with sufficient certainty, the field of view of the camera 18 in the plane of the underside 22 should have an edge length of not less than 10 cm, preferably at least 20 cm, in both the x and y directions.

In order to ensure easy detection of the reference feature 27 by the camera 18 and reliable evaluation of the data encoded in it, the surface of the reference feature preferably has only two discrete albedo values. By preferably designing part of the surface to be retroreflective, it essentially only reflects the light from the light sources 36 in the direction of the front lens 35, thereby achieving a significantly higher albedo than the surface areas surrounding the reference feature 27 and thus facilitating the identification of the reference feature 27 in the images from the camera 18. Other parts of the surface may be dark in colour and thus have an albedo that is significantly lower than that of the

area surrounding the reference feature 27. In particular, the reference feature 27 may comprise a retroreflective film onto which dark structures are locally printed or which is locally removed to form surface areas with the low albedo.

Fig. 4 shows a block diagram of the control system for the manipulator 1. A navigation unit 28 is connected to the camera 18 in order to receive images generated by the camera and, with the aid of information extracted from these images, to control motors 29 for translating the holder 11 in the x, y and z directions and for rotating it at least about the vertical axis 8. The navigation unit 28 can be built into the manipulator 1 or control it from the outside. Force sensors 30 on the receptacles 19 may be provided to detect forces exerted by the centring pins 26 and, if necessary, by the frame 24, which are used by the navigation unit 28 to control the motors 29 associated with the axes 12 and 15.

Navigation data for various peripheral devices is stored in a memory 31.

A user interface 32 may be provided to enable commands for controlling the motors 29 to also be entered manually.

Fig. 5 shows an example of an image that could be captured by the camera 18 after the manipulator 1 has been manually pushed under the process chamber 21 of the peripheral device 20. A section of the underside 22 with part of the frame 24 and the reference feature 27 can be seen. The reference feature 27 comprises data on the one hand and an orientation mark on the other, shown here as letters and a kind of crosshairs. Both can be replaced or supplemented by a barcode or QR code.

After manipulator 1 has been placed in the intermediate position (S0), navigation unit 28 is activated to control automatic docking of test head 17 to port 23. The operating procedure then executed by the control unit is shown in Fig. 6. In a first step S1, the navigation unit 28 reads the current image from the camera 18. If the evaluation of the image in step S2 reveals that no reference feature can be found in the image, the procedure is terminated with an error message S3, which informs the user that the manipulator 1 must be positioned more accurately. Once this has been done, the procedure can be restarted.

If a reference feature is present in the image, the navigation unit 28 extracts the data contained therein in step S4.

According to a first embodiment of the process, the data contains a unique identifier for the peripheral device 20. In step S5, the navigation unit 28 checks whether a data record associated with this identifier is contained in the navigation data of the memory 31.

If so, it determines from this data record in step S6 a target position and orientation of the reference feature 27, shown in Fig. 5 with dashed lines and spaced from the actual reference feature 27 by a distance D, and controls the motors (S7) associated with the translation in the x and y directions and the rotation about the axis 8, reading new images from the camera 18 as necessary until, in S8, a satisfactory match is found between the position and orientation of the reference feature 27 visible in the current image from the camera 18 and the target position and orientation. In particular, the navigation unit 28 may calculate a correction of the position of the holder 11 in the x and y directions and the orientation around axis 8 from the offset between the target and actual position and orientation of the reference feature 27 determined in an image, make the calculated corrections and then generate another image.

If the actual position and orientation of reference feature 27 correspond to the target values with satisfactory accuracy, then probe 17 is in such a position under port 23 – referred to here as the pre-engagement position – that when holder 11 is lifted, (S9), the centring pins 26 reliably engage in the receptacles of the test head 17 and the latter comes into exact contact with the frame 24.

If no data record associated with the identifier is found in step S5, the procedure can also be terminated with an error message. Preferably, however, as shown in Fig. 6, the user is instead shown a message (S10) indicating that no navigation data is available for this peripheral device 20 and that docking to port 23 must therefore be controlled manually. If the user then performs such control via the user interface 32, the navigation unit 28 records in step S11 the position and orientation of the reference feature 27 in the image of the camera 18 taken immediately before the start of the lifting of the test head, and associates these to the identifier determined in step S4 in the navigation data in memory 31. By such manually controlled lifting, the test head 17 is docked; when the manipulator 1 is later brought back to the intermediate position at the same peripheral device 20, the navigation data is available in the memory 31, and based on these the navigation unit 28 can automatically perform the docking in steps S6-S9.

In order to make an existing peripheral device suitable for use in the context of the invention, it is sufficient to attach reference feature 27 to this device in such a way that it can be seen by camera 18 when test head 17 is in the pre-engagement position. This means that the position of the reference feature 27 on the peripheral device is only roughly defined, and the reference feature 27, e.g. in the form of a sticker, can be placed quickly and without the use of tools or measuring instruments. Apart from the identifier, the reference feature does not need to contain any further data, since the path D corresponding to the identifier is learned individually by the navigation unit 28 for each individual peripheral device on which the manipulator 1 is used.

According to a second embodiment of the invention, the reference feature 27 is placed on the peripheral device 20 in exact local relation to its port 23, e.g., and as shown in Fig. 7, with the aid of a jig 33 (highlighted by hatching in the figure), which is placed on a corner of the frame 24 and which, by its shape, in this case by free edges 34, defines a target position at which the reference feature 27 is to be attached to the underside 22. Since the position of the reference feature 27 relative to the port 23 is thus clearly defined, the target position of the reference feature 27 in the camera image does not have to be learned in each individual case, but can be determined before the reference feature 27 is attached and recorded on the reference feature 27 in machine-readable form.

The operating procedure of the navigation unit 28 according to this embodiment is shown in Fig. 8. In steps S0-S4, it is identical to that of Fig. 6. In step S5', the navigation unit 28 rotates the measuring head 17 about the axis 8 in order to align the orientation of the real reference feature 27, as it appears in the images of the camera 18, with the target orientation. To prevent this from causing the reference feature 27 to leave the field of view of the camera 18, corrective movements of the slides 5, 7 in the x and y directions may be necessary.

Once the orientation has been adjusted, it is sufficient to move the holder 11 in the x and y directions so that the reference feature 27 appears in the images from the camera at a position defined by the data marked on the reference feature 27 (S6'); once this has been done, the engagement position has been reached, from which the measuring head 17 can be raised in step S7' and docked to the port 23.

According to one variant, the navigation unit 18 uses the angle a by which the test head 17 was rotated in step S5' to determine a transformation between the x and y axes of the coordinate system relative to the base plate 2 and axes of a coordinate system defined on the reference feature 27, e.g. as directions of the axes of the crosshairs, in which the path D is recorded on the reference feature 27. This enables the navigation unit 18 to convert the path D into distances to be covered by the test head 17 in the x and y directions and, by controlling a translation over these distances, to bring the measuring head 17 into the engagement position, even if the reference feature 27 is no longer in the field of view of the camera 18 when in the engagement position.

REFERENCE NUMERALS

1	manipulator
2	base plate
3	castor
4	foot
5	carriage
6	bellows
7	carriage
8	axis
9	column
10	carriage
11	holder
12	axis
13	arm
14	arm
15	axis
16	bracket
17	test head
18	camera
19	receptacle
20	peripheral device
21	process chamber
22	underside
23	port
24	frame
25	feed-through opening
26	centring pin
27	reference feature
28	navigation unit
29	motor
30	force sensor
31	memory
32	user interface
33	jig

34 edge

35 front lens

36 light source

CLAIMS

1. A manipulator (1) comprising a holder (11) for a probe (17), the manipulator being movable in several degrees of freedom between a standby position and a docking position at a docking port (23) of a peripheral device (20) in order to perform measurements on semiconductor components in the peripheral device (20), characterised in that the holder (11) carries a data reading device which is configured to read data from the peripheral device (20) in an intermediate position assumed by the holder (11) on the way from the standby position to the docking position, and a navigation unit (28) is configured to navigate to the docking position on the basis of the data read.

2. The manipulator of claim 1, wherein the data reading device is an imaging sensor (18), in particular a camera (18), and is oriented to detect a surface (22) spaced apart from a connection surface of the test head (17), wherein optionally the imaging sensor (18) is integrated with a light source in one assembly.

3. The manipulator of claim 1 or 2, further comprising an environment sensor for detecting a reference feature (27) of the peripheral device (20), wherein the navigation unit (28) is configured to draw a conclusion about a path (D) to be travelled from the intermediate position towards the docking position from a detected position of the reference feature (27) and the data read.

4. The manipulator of claim 3, insofar as it refers back to claim 2, in which the environment sensor is the imaging sensor (18).

5. The manipulator of claim 4, wherein the navigation unit (28) is configured to determine, from the orientation of the reference feature (27) in an image from the imaging sensor (18), a rotation necessary for the transition from the intermediate position to the docking position and, optionally, from the data read, a distance to be travelled for the transition.

6. The manipulator of claim 4 or 5, wherein the imaging sensor (18) is movable with the holder (11) and, optionally, the navigation unit (28) is configured to derive a target position of the reference feature (27) in an image of the imaging sensor (18) from the data read and to steer the holder (11) to the docking position by bringing the position

of the reference feature (27) in an image of the imaging sensor (18) into alignment with the target position.

7. The manipulator of any of claims 3 to 6, wherein the reference feature (27) is a carrier of the data to be read by the data reading device.

8. The manipulator of any of the preceding claims, wherein the navigation unit (28) is configured to decide (S2, S5) on the basis of the data read whether it is capable of controlling docking and, optionally, to move to the docking position (S6-S8) only after it has been decided that docking is possible, and/or to generate an error message (S3, S10) if it has been decided that it is not capable of controlling the docking.

9. A method for docking a test head (17) to a peripheral device (20) with the aid of a holder (11) that is movable in several degrees of freedom and on which the test head (17) is held, comprising the steps of:

a) attaching a data carrier (27) to a peripheral device (20), wherein the data carrier (27) encodes data which allows a conclusion to be drawn about a path (D) to be followed from an intermediate position of the holder (11) in which a data reading device (18) carried by the holder (11) is capable of reading the data from the data carrier (27) towards a docking position for the test head (17) on the peripheral device (20);

b) moving the holder from a rest position to the intermediate position (S0) and reading (S1) the data;

c) steering the holder (11) with the test head (17) into the docking position on the basis of the data read (S4-S9; S4, S5'-S7').

10. The method of claim 9, wherein the data carrier (27) is the reference feature (27).

11. The method of claim 9 or 10, wherein step c) comprises:

- generating (S1) an image of the reference feature (27);
- determining a target position of the reference feature in the image based on the data read, and
- steering (S4-S9) the holder (11) such that the position of the reference feature (27) in the image comes to match the target position.

12. The method of any one of claims 9 to 11, comprising a step of d) deciding (S2, S5) whether docking is possible based on the read data, wherein step c) is performed (S6-S9) only if it has been decided that docking is possible, and/or an error message is generated (S3, S10, S11) if it has been decided that docking is not possible.

13. The method of any one of claims 9 to 12, wherein:

- the data read in step b) include a unique identifier of the peripheral device, and the distance to be travelled from the intermediate position to the docking position is determined based on a memory entry associated with the identifier (S4), or
- the reference feature (27) is attached to a location on the peripheral device specified for a type of peripheral device, the data read in step b) contain a unique identifier for the type of peripheral device, and the distance to be travelled from the intermediate position to the docking position is determined on the basis of a memory entry assigned to the identifier, or
- the reference feature (27) is attached to a location on the peripheral device that is specified for a type of peripheral device, and the data read in step b) contain parameters of a path to be travelled from the intermediate position to the docking position.

14. A data carrier (27) to be attached to a peripheral device (20) in a method according to any one of claims 9-12, which encodes data that allows conclusions to be drawn about a about a path (D) to be followed from an intermediate position of the holder (11) in which a data reading device (18) carried by the holder (11) is capable of reading the data from the data carrier (27) towards a docking position for the test head (17) on the peripheral device (20).

15. The data carrier of claim 14, in the form of a flat object with a first main surface designed to be placed against a surface of the peripheral device and a second surface on which the data is encoded in electro-optically readable form, wherein the encoding optionally comprises light and dark surface areas and, further optionally, the light surface areas are retroreflective.