

Claims

1. An optical measurement device, comprising:

a substrate carrier, configured to carry a substrate;

an optical detection platform frame, configured to bear and support an optical detection slider above the substrate carrier, the optical detection slider being able to slide along the optical detection platform frame;

an optical detection unit, located above the substrate carrier and attached to the optical detection slider, and able to move along the optical detection platform frame with the optical detection slider, the optical detection unit comprising a mark position measurement module;

a substrate carrier position measurement module, configured to measure a position of the substrate carrier;

an optical detection unit position measurement module, configured to measure a position of the optical detection unit; and

a correction module, configured to obtain, based on the position of the substrate carrier and the position of the optical detection unit, deviations in measurement of mark positions induced by movements of the substrate carrier and the optical detection unit, and further configured to correct the mark positions measured by the mark position measurement module based on the deviations in measurement of the mark positions.

2. The optical measurement device of claim 1, wherein the substrate carrier position measurement module comprises a substrate carrier Y-direction measuring component and a substrate carrier X-direction measuring component; the substrate carrier Y-direction measuring component is configured to measure a displacement of the substrate carrier in a Y direction; and the substrate carrier X-direction measuring component is configured to measure an offset of the substrate carrier in an X direction during Y-direction movement of the substrate carrier.

3. The optical measurement device of claim 1, wherein the optical detection unit position measurement module comprises: an optical detection unit X-direction

measuring component, an optical detection slider X-direction measuring component, and an optical detection unit Y-direction measuring component, wherein the optical detection unit X-direction measuring component is configured to measure a displacement of the optical detection unit in an X direction; the optical detection slider X-direction measuring component is configured to measure a displacement of the optical detection slider in the X direction; and the optical detection unit Y-direction measuring component is configured to measure an offset of the optical detection unit with respect to the optical detection platform frame in a Y direction during X-direction movement of the optical detection unit.

4. The optical measurement device of claim 2, wherein the substrate carrier Y-direction measuring component and the substrate carrier X-direction measuring component are both interferometers.

5. The optical measurement device of claim 3, wherein the optical detection unit X-direction measuring component and the optical detection slider X-direction measuring component are both interferometers, and the optical detection unit Y-direction measuring component is a laser displacement sensor.

6. The optical measurement device of claim 1, wherein the optical detection unit further comprises a height adjustment module for measuring and adjusting a distance from the optical detection unit to an upper surface of the substrate.

7. The optical measurement device of claim 1, wherein a reference board having calibration marks is further provided on the substrate carrier, and the reference board is configured to correct the position of the substrate carrier and the position of the optical detection unit.

8. The optical measurement device of claim 7, wherein the reference board having calibration marks comprises a horizontal reference board and a vertical reference board perpendicular to the horizontal reference board; the horizontal reference board is arranged along an X direction of the substrate carrier and is used for calibrating a positional deviation of the substrate from the optical detection unit in a Y direction which occurs when the optical detection unit moves along the X direction; and the vertical reference board is arranged along the Y direction of the substrate

carrier and is used for calibrating a positional deviation of the substrate from the optical detection unit in the X direction which occurs when the substrate carrier moves along the Y direction.

9. The optical measurement device of claim 1, further comprising a support base for carrying the substrate carrier and the optical detection platform frame.

10. The optical measurement device of claim 1, wherein the support base comprises a vibration damper and a marble platform from bottom to top.

11. The optical measurement device of claim 1, wherein the optical detection unit is further used for detecting a line width of a pattern formed on the substrate after exposure, an overlay deviation, a mark position deviation, and/or a photoresist thickness.

12. A measurement method using the optical measurement device of claim 1, wherein a direction in which an optical detection slider moves along an optical detection platform frame is defined as an X direction, a direction perpendicular to the X direction in a horizontal plane is defined as a Y direction, and a vertical direction is defined as a Z direction, to establish a three-dimensional coordinate system in the X, Y, Z directions; and the method comprises the following steps:

providing a substrate having detection marks and placing the substrate on a substrate carrier;

controlling the substrate carrier to move along the Y direction, and controlling an optical detection unit to move along the X direction, such that a detection mark i is located below a mark position measurement module, wherein the mark position measurement module measures an alignment deviation (dx_{i_align} , dy_{i_align}) of the detection mark i from a center of the mark position measurement module;

measuring, by a substrate carrier Y-direction measuring component, a displacement Y_i of the substrate carrier in the Y direction, a magnitude R_{zy_wsi} of rotation of the substrate carrier in a ZY plane, and an inclination R_{x_wsi} of the substrate about an X axis; and measuring, by a substrate carrier X-direction measuring component, an offset X_wsi of the substrate carrier in the X direction when the substrate carrier moves to a position Y_i ; and then calculating an alignment deviation

(dx_{i_align1} , dy_{i_align1}) of the detection mark i from the center of the mark position measurement module, which alignment deviation (dx_{i_align1} , dy_{i_align1}) is induced when the substrate carrier moves to the position Y_i , according to the offset $X_{_wsi}$ of the substrate carrier in the X direction when the substrate carrier moves to the position Y_i , the magnitude R_{zy_wsi} of rotation of the substrate carrier in the ZY plane, and the inclination R_{x_wsi} of the substrate about the X axis;

measuring, by an optical detection unit X-direction measuring component, a displacement X_i of the optical detection unit in the X direction; measuring, by an optical detection slider X-direction measuring component, a displacement X'_i of the optical detection slider in the X direction and a magnitude R_{zx_omi} of rotation of the optical detection slider in a ZX plane; measuring, by an optical detection unit Y-direction measuring component, an offset $Y_{_omi}$ of the optical detection unit with respect to the optical detection platform frame in the Y direction when the optical detection unit moves to a position X_i , and an inclination R_{x_omi} of the optical detection unit about the X axis; calculating an inclination R_{y_omi} of the optical detection unit about a Y axis when the optical detection unit moves to the position X_i according to the displacement X_i of the optical detection unit in the X direction and the displacement X'_i of the optical detection slider in the X direction; and afterwards, calculating an alignment deviation (dx_{i_align2} , dy_{i_align2}) of the detection mark i from the center of the mark position measurement module, which alignment deviation (dx_{i_align2} , dy_{i_align2}) is induced when the optical detection unit moves to the position X_i , according to a magnitude R_{zx_omi} of rotation of the optical detection unit in the ZX plane when the optical detection unit moves to the position X_i and the inclination R_{y_omi} about the Y axis, and the offset $Y_{_omi}$ of the optical detection unit with respect to the optical detection platform frame in the Y direction and the inclination R_{x_omi} about the X axis; and

correcting the alignment deviation (dx_{i_align} , dy_{i_align}) of the detection mark i from the center of the mark position measurement module according to the alignment deviation (dx_{i_align1} , dy_{i_align1}) of the detection mark i from the center of the mark position measurement module which is induced when the substrate carrier moves to

the position Y_i and the alignment deviation (dx_{i_align2} , dy_{i_align2}) of the detection mark i from the center of the mark position measurement module which is induced when the optical detection unit moves to the position X_i .

13. The optical measurement method of claim 12, wherein the alignment deviation (dx_{i_align1} , dy_{i_align1}) of the detection mark i from the center of the mark position measurement module which is induced when the substrate carrier moves to the position Y_i is calculated according to the following formula:

$$\begin{aligned} dx_{i_align1} &= X_wsi + A_ws \times Rzy_wsi ; \\ dy_{i_align1} &= B_ws \times Rzy_wsi + H_ws \times Rx_wsi ; \end{aligned}$$

wherein A_ws is a deviation of a center of a measurement spot from a rotation center of the substrate carrier in the Y direction, the measurement spot being projected by the substrate carrier X -direction measuring component onto the substrate carrier;

B_ws is a deviation of a center of a measurement spot from the rotation center of the substrate carrier in the X direction, the measurement spot being projected by the substrate carrier Y -direction measuring component onto the substrate carrier; and

H_ws is a distance from a center of the measurement spot to an optimal focal plane of the mark position measurement module in the Z direction, the measurement spot being projected by the substrate carrier Y -direction measuring component onto the substrate carrier.

14. The optical measurement method of claim 13, wherein the alignment deviation (dx_{i_align2} , dy_{i_align2}) of the detection mark i from the center of the mark position measurement module which is induced when the optical detection unit moves to the position X_i is calculated according to the following formula:

$$\begin{aligned} dx_{i_align2} &= A_om \times Rzx_omi + H_om \times Ry_omi ; \\ dy_{i_align2} &= Y_omi + B_om \times Rzx_omi + H'_om \times Rx_omi , \end{aligned}$$

wherein A_om is a deviation of a center of a measurement spot from a rotation center of the optical detection unit in the Y direction, the measurement spot being projected by the optical detection unit X -direction measuring component onto the optical detection unit;

B_{om} is a deviation of a center of a measurement spot from the rotation center of the optical detection unit in the X direction, the measurement spot being projected by the optical detection unit Y-direction measuring component onto the optical detection unit;

H_{om} is a distance from the center of the measurement spot to the optimal focal plane of the mark position measurement module in the Z direction, the measurement spot being projected by the optical detection unit X-direction measuring component onto the optical detection unit; and

H'_{om} is a distance from a center of a measurement spot to the optimal focal plane of the mark position measurement module in the Z direction, the measurement spot being projected by the optical detection slider X-direction measuring component onto the optical detection slider.

15. The optical measurement method of claim 12, further comprising calibrating a position of the substrate carrier and a position of the optical detection unit, which specifically comprises the following steps:

measuring calibration marks on a reference board on the substrate carrier, by: controlling the substrate carrier to move along the Y direction and the optical detection unit to move along the X direction, such that a calibration mark j on the reference board is located below the mark position measurement module; measuring, by the mark position measurement module, a position of the calibration mark j ; and calculating an alignment deviation (dxj_align , dyj_align) of the calibration mark j from the center of the mark position measurement module;

measuring, by the substrate carrier Y-direction measuring component, a displacement Y_j of the substrate carrier in the Y direction, a magnitude Rzy_wsj of rotation of the substrate carrier in the ZY plane, and an inclination Rx_wsj of the substrate carrier about the X axis; measuring, by the substrate carrier X-direction measuring component, an offset X_wsj of the substrate carrier in the X direction when the substrate carrier moves to a position Y_j ; and then, calculating an alignment deviation (dxj_align1 , dyj_align1) of the calibration mark j from the center of the mark position measurement module, which alignment deviation (dxj_align1 , dyj_align1) is

induced when the substrate carrier moves to the position Y_j , according to the offset X_{wsj} of the substrate carrier in the X direction when the substrate carrier moves to the position Y_j , the magnitude R_{zy_wsj} of rotation of the substrate carrier in the ZY plane, and the inclination R_{x_wsj} of the substrate carrier about the X axis;

measuring, by the optical detection unit X-direction measuring component, a displacement X_j of the optical detection unit in the X direction; measuring, by the optical detection slider X-direction measuring component, a displacement X'_j of the optical detection slider in the X direction and a magnitude R_{zx_omj} of rotation of the optical detection slider in the ZX plane; measuring, by the optical detection unit Y-direction measuring component, an offset Y_{omj} of the optical detection unit with respect to the optical detection platform frame in the Y direction when the optical detection unit moves to the position X_j , and an inclination R_{x_omj} of the optical detection unit about the X axis; calculating an inclination R_{y_omj} of the optical detection unit about the Y axis when the optical detection unit moves to the position X_j according to the displacement X_j of the optical detection unit in the X direction and the displacement X'_j of the optical detection slider in the X direction; and afterwards, calculating an alignment deviation (dxj_align2 , dyj_align2) of the calibration mark j from the center of the mark position measurement module, which alignment deviation (dxj_align2 , dyj_align2) is induced when the optical detection unit moves to the position X_j , according to the magnitude R_{zx_omj} of rotation of the optical detection unit in the ZX plane and the inclination R_{y_omj} about the Y axis when the optical detection unit moves to the position X_j , and the offset Y_{omj} of the optical detection unit with respect to the optical detection platform frame in the Y direction and the inclination R_{x_omj} about the X axis;

correcting the alignment deviation (dxj_align , dyj_align) of the calibration mark j from the center of the mark position measurement module according to the alignment deviation (dxj_align1 , dyj_align1) of the calibration mark j from the center of the mark position measurement module which is induced when the substrate carrier moves to the position Y_j and the alignment deviation (dxj_align2 , dyj_align2) of the calibration mark j from the center of the mark position measurement module which is induced

when the optical detection unit moves to the position X_j ;

repeating the foregoing steps, to obtain corrected alignment deviations (dx_j_align , dy_j_align) of all the calibration marks from the center of the mark position measurement module, wherein $j=1, 2, \dots, n$;

processing the corrected alignment deviations (dx_j_align , dy_j_align), $j=1, 2, \dots, n$, of all the calibration marks from the center of the mark position measurement module, to obtain an alignment residual ΔX_i between the reference board and the center of the mark position measurement module when the substrate carrier is at the position Y_i and an alignment residual ΔY_i between the reference board and the center of the mark position measurement module when the optical detection unit is at the position X_i ; and

finally, compensating the alignment deviation (dx_i_align1 , dy_i_align1) of the detection mark i from the center of the mark position measurement module which is induced when the substrate carrier moves to the position Y_i , with the alignment residual ΔX_i between the reference board and the center of the mark position measurement module when the substrate carrier is at the position Y_i ; and compensating the alignment deviation (dx_i_align2 , dy_i_align2) of the detection mark i from the center of the mark position measurement module which is induced when the optical detection unit moves to the position X_i , with the alignment residual ΔY_i between the reference board and the center of the mark position measurement module when the optical detection unit is at the position X_i .

16. The optical measurement method of claim 15, wherein the alignment deviation (dx_i_align1 , dy_i_align1) of the detection mark i from the center of the mark position measurement module which is induced when the substrate carrier moves to the position Y_i is compensated with the alignment residual ΔX_i between the reference board and the center of the mark position measurement module when the substrate carrier is at the position Y_i , according to the following formula:

$$dx_i_align1 = X_wsi + A_ws \times Rzy_wsi + \Delta X_i,$$

$$dy_i_align1 = B_ws \times Rzy_wsi + H_ws \times Rx_wsi,$$

wherein A_ws is a deviation of a center of a measurement spot from a rotation center of the substrate carrier in the Y direction, the measurement spot being projected

by the substrate carrier X-direction measuring component onto the substrate carrier;

B_ws is a deviation of a center of a measurement spot from the rotation center of the substrate carrier in the X direction, the measurement spot being projected by the substrate carrier Y-direction measuring component onto the substrate carrier; and

H_ws is a distance from the center of the measurement spot to an optimal focal plane of the mark position measurement module in the Z direction, the measurement spot being projected by the substrate carrier Y-direction measuring component onto the substrate carrier.

17. The optical measurement method of claim 15, wherein the alignment deviation (dxi_align2, dyi_align2) of the detection mark i from the center of the mark position measurement module which is induced when the optical detection unit moves to the position Xi is compensated with the alignment residual ΔY_i between the reference board and the center of the mark position measurement module when the optical detection unit is at the position Xi, according to the following formula:

$$dxi_align2 = A_om \times Rzx_omi + H_om \times Ry_omi ;$$

$$dyi_align2 = Y_omi + B_om \times Rzx_omi + H'_om \times Rx_omi + \Delta Y_i ,$$

wherein A_om is a deviation of a center of a measurement spot from a rotation center of the optical detection unit in the Y direction, the measurement spot being projected by the optical detection unit X-direction measuring component onto the optical detection unit;

B_om is a deviation of a center of a measurement spot from the rotation center of the optical detection unit in the X direction, the measurement spot being projected by the optical detection unit Y-direction measuring component onto the optical detection unit;

H_om is a distance from the center of the measurement spot to the optimal focal plane of the mark position measurement module in the Z direction, the measurement spot being projected by the optical detection unit X-direction measuring component onto the optical detection unit; and

H'_om is a distance from a center of a measurement spot to the optimal focal plane of the mark position measurement module in the Z direction, the measurement

spot being projected by the optical detection slider X-direction measuring component onto the optical detection slider.

18. The optical measurement method of claim 15, wherein a Y-direction reference board parallel with the Y direction is arranged on the substrate carrier, and is used for measuring an alignment residual ΔX_i between the Y-direction reference board and the center of the mark position measurement module when the substrate carrier is at the position Y_i ; and an X-direction reference board parallel with the X direction is arranged on the substrate carrier, and is used for measuring an alignment residual ΔY_i between the X-direction reference board and the center of the mark position measurement module when the optical detection unit is at the position X_i .

19. The optical measurement method of claim 15, wherein the corrected alignment deviations (dx_{j_align} , dy_{j_align}) of all the reference marks from the center of the mark position measurement module are processed by using a linear interpolation method, wherein $j=1, 2, \dots, n$, to obtain the alignment residual ΔX_i between the reference board and the center of the mark position measurement module when the substrate carrier is at the position Y_i and the alignment residual ΔY_i between the reference board and the center of the mark position measurement module when the optical detection unit is at the position X_i .

20. The optical measurement method of claim 12, wherein detecting a detection mark by the mark position measurement module further comprises: measuring a current height value Z_1 from the mark position measurement module to the detection mark;

calculating a height difference dZ between the height value Z_1 and a height value Z_2 of an optimal focal plane of the mark position measurement module as $dZ=Z_1-Z_2$; and

controlling the mark position measurement module to vertically move by a distance of dZ , such that the detection mark is located on the optimal focal plane of the mark position measurement module.