

ELLIPSOMETRY DEVICE AND METHOD FOR OBTAINING INFORMATION OF SURFACE OF OBJECT TO BE MEASURED

Technical Field

5 **[0001]** Embodiments of the present disclosure relate generally to the field of optical measurement, and more specifically to an ellipsometry device and a method for obtaining information of a surface of an object to be measured.

Background Art

10 **[0002]** As an effective optical measurement technique, spectral ellipsometry is widely used in fields including but not limited to semiconductor manufacturing. FIG. 1 shows a partial schematic structural diagram of a conventional ellipsometry device 100. The ellipsometry device 100 comprises a polarizer 102, a reflecting device 104, and an analyzer 106. The reflecting device 104 is an integrally formed parabolic reflecting device. Although such an ellipsometry device 100 can avoid the chromatic aberration correction and other problems that exist in ellipsometry devices based on optical lenses or lens groups, due to the limitation of the structure of the reflecting device 104, it is required that a polarized light beam must be incident in a direction parallel to an axis A1 of the paraboloid of the reflecting device 104. This results in
15 a larger angle at which the polarized light beam is incident on a reflective surface of the reflecting device 104, thereby significantly changing the polarization state of the light beam, which brings about adverse effects on the spectrum inversion calculation.
20 **[0003]** In summary, the conventional ellipsometry device makes the incident angle of the polarized light beam larger, thereby significantly changing the original polarization state of the incident polarized light beam.
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Summary of the Invention

30 **[0004]** To address the above problem, embodiments of the present disclosure provide an ellipsometry device and a method for obtaining information of a surface of an object to be measured. The embodiments of the present disclosure can significantly reduce the incident angle of a polarized light beam incident on an off-axis parabolic mirror, thereby effectively ensuring the polarization state of the polarized light beam.

[0005] According to a first aspect of the present disclosure, an ellipsometry device

is provided. The ellipsometry device comprises: a polarized light beam providing device configured to provide a plurality of parallel polarized light beams; a first off-axis parabolic mirror, configured to reflect the plurality of parallel polarized light beams such that a plurality of reflected first light beams are focused on a target point
5 on a surface of an object to be measured, an included angle between each polarized light beam of the plurality of parallel polarized light beams and the corresponding first light beam of the plurality of reflected first light beams being any angle between 20 and 40 degrees; a second off-axis parabolic mirror, configured to reflect a plurality of second light beams formed of the reflected first light beams reflected by
10 the surface of the object to be measured, so as to form a plurality of parallel third light beams, an included angle between each second light beam of the plurality of second light beams and the corresponding third light beam of the plurality of parallel third light beams being any angle between 20 and 40 degrees; and a polarization analysis device, configured to analyze the polarization of the plurality of parallel
15 third light beams.

[0006] In some embodiments, an optical path corresponding to the plurality of parallel polarized light beams intersects with an optical path corresponding to the plurality of parallel third light beams.

[0007] In some embodiments, the polarized light beam providing device comprises:
20 a polarizer, configured to polarize incident light beams so as to form a plurality of parallel first polarized light beams; and a first planar reflecting mirror, configured to reflect the plurality of parallel first polarized light beams to form a plurality of parallel polarized light beams, an included angle between each first polarized light beam of the plurality of parallel first polarized light beams and the corresponding
25 polarized light beam of the plurality of parallel polarized light beams being any angle between 20 and 40 degrees; and the polarization analysis device comprises: a second planar reflecting mirror, configured to reflect the plurality of parallel third light beams to form a plurality of parallel fourth light beams, an included angle between each fourth light beam of the plurality of parallel fourth light beams and the
30 corresponding third light beam of the plurality of parallel third light beams being any angle between 20 and 40 degrees; and an analyzer, configured to analyze the polarization of the plurality of parallel fourth light beams.

[0008] In some embodiments, the polarizer, the second planar reflecting mirror and the first off-axis parabolic mirror are arranged on one side of a target normal plane;

and the analyzer, the first planar reflecting mirror and the second off-axis parabolic mirror are arranged on the other side of the target normal plane.

5 **[0009]** In some embodiments, the heights of the first planar reflecting mirror and the second planar reflecting mirror relative to the surface of the object to be measured are greater than the heights of the first off-axis parabolic mirror and the second off-axis parabolic mirror relative to the surface of the object to be measured.

[0010] In some embodiments, a lateral distance between the first planar reflecting mirror and the second planar reflecting mirror is greater than a lateral distance between the first off-axis parabolic mirror and the second off-axis parabolic mirror.

10 **[0011]** In some embodiments, the first polarized light beams are parallel to the third light beams, and the fourth light beams are parallel to the polarized light beams.

[0012] In some embodiments, the polarizer, one of the first planar reflecting mirror and the second planar reflecting mirror, and the first off-axis parabolic mirror are arranged on one side of a target normal plane which is a normal plane of the object to be measured passing through the target point; and the second off-axis parabolic mirror, the other of the first planar reflecting mirror and the second planar reflecting mirror, and the analyzer are arranged on the other side of the target normal plane.

15 **[0013]** In some embodiments, the polarized light beam providing device comprises: a polarizer, configured to polarize incident light beams so as to form a plurality of parallel polarized light beams; the polarization analysis device comprises: an analyzer, configured to analyze the polarization of the plurality of parallel third light beams; and the polarizer and the second off-axis parabolic mirror are arranged on one side of a target normal plane which is a normal plane of the object to be measured passing through the target point, and the first off-axis parabolic mirror and the analyzer are arranged on the other side of the target normal plane.

[0014] In some embodiments, an included angle between each first light beam of the plurality of reflected first light beams and a normal direction of the object to be measured is any angle between 60 degrees and 70 degrees.

20 **[0015]** In some embodiments, the first off-axis parabolic mirror and the second off-axis parabolic mirror comprise at least one of: a metal off-axis parabolic mirror, which has a surface profile accuracy less than 1/10 wavelength and a surface roughness less than 5 nanometers; and a glass off-axis parabolic mirror, which has a surface profile accuracy less than 1/20 wavelength and a surface roughness less than 1 nanometer.

[0016] In some embodiments, a surface of each of the first off-axis parabolic mirror, the second off-axis parabolic mirror, the first planar reflecting mirror and the second planar reflecting mirror is provided with a coating, which comprises at least one of a metal reflective film and a multi-layer dielectric film.

5 [0017] In some embodiments, the metal off-axis parabolic mirror is manufactured by using a single-point diamond processing process.

[0018] In some embodiments, the metal reflective film comprises: an aluminum reflective layer, and a magnesium fluoride protective layer arranged on a surface of the aluminum reflective layer.

10 [0019] In some embodiments, the first off-axis parabolic mirror is arranged opposite the second off-axis parabolic mirror.

[0020] According to a second aspect of the present disclosure, a method for obtaining information of a surface of an object to be measured is provided. The method is implemented by the ellipsometry device according to the first aspect of
15 the present disclosure. The method comprises: providing a plurality of parallel polarized light beams by a polarized light beam providing device; reflecting the plurality of parallel polarized light beams by a first off-axis parabolic mirror such that a plurality of reflected first light beams are focused on a target point on the surface of the object to be measured; reflecting a plurality of second light beams
20 formed of the reflected first light beams reflected by the surface of the object to be measured, by a second off-axis parabolic mirror, so as to form a plurality of parallel third light beams; and analyzing the polarization of the plurality of parallel third light beams by a polarization analysis device, so as to obtain the information of the surface of the object to be measured.

25 [0021] It should be understood that the content described in this section is not intended to identify critical or important features of the embodiments of the present disclosure, and is not used to limit the scope of the present disclosure. Other features of the present disclosure will be easily understood through the following description.

30 **Brief Description of the Drawings**

[0022] The foregoing and other features, advantages and aspects of embodiments of the present disclosure become more apparent with reference to the accompanying drawings and in conjunction with the following detailed description. In the figures, like or similar elements are denoted by like or similar reference signs.

[0023] FIG. 1 shows a partial schematic structural diagram of a conventional ellipsometry device.

[0024] FIG. 2 shows a schematic structural diagram of an ellipsometry device according to an embodiment of the present disclosure.

5 [0025] FIG. 3 shows a schematic structural diagram of an ellipsometry device according to an embodiment of the present disclosure.

[0026] FIG. 4 shows measurements of the change in a phase angle between P-polarized light and S-polarized light of an ellipsometry device according to an embodiment of the present disclosure and a conventional ellipsometry device.

10 [0027] FIG. 5 shows a schematic diagram of the pupil polarization state distribution of a conventional ellipsometry device.

[0028] FIG. 6 shows a schematic diagram of the pupil polarization state distribution of an ellipsometry device according to an embodiment of the present disclosure.

15 [0029] FIG. 7 shows a schematic diagram of an ellipsometry device according to an embodiment of the present disclosure with an imaging quality thereof on a wafer reaching a diffraction limit.

[0030] FIG. 8 shows a schematic structural diagram of an ellipsometry device according to an embodiment of the present disclosure.

20 [0031] FIG. 9 shows a schematic structural diagram of an ellipsometry device according to an embodiment of the present disclosure.

[0032] FIG. 10 shows a flowchart of a method for obtaining information of a surface of an object to be measured according to an embodiment of the present disclosure.

Detailed Description of Embodiments

25 [0033] Exemplary embodiments of the present disclosure are described below with reference to the accompanying drawings. Various details of the embodiments of the present disclosure are included to facilitate understanding and should be considered merely exemplary. Accordingly, it should be appreciated by those of ordinary skill in the art that various changes and modifications can be made to the embodiments described herein without departing from the scope and spirit of the present disclosure. Likewise, descriptions of well-known functions and structures are omitted from the following description for clarity and conciseness.

30 [0034] The term “include” and the variations thereof used herein mean an open inclusion, that is, “including but not limited to”. Unless otherwise stated, the term

“or” means “and/or”. The term “based on” denotes “at least partially based on”. The terms “an exemplary embodiment” and “an embodiment” mean “at least one exemplary embodiment”. The term “a further embodiment” means “at least one further embodiment”. The terms “first”, “second” and the like may refer to different objects or the same object. Other explicit and implicit definitions may be included below.

5 [0035] As described above, the conventional ellipsometry device makes the incident angle of the polarized light beam larger, thereby significantly changing the polarization state of the polarized light beam and bringing about adverse effects on the spectrum inversion calculation. As shown in FIG. 1, parallel light beams Li emitted by a light source (not shown) are polarized after passing through a polarizer 102 to form polarized light beams. The polarized light beams are focused by a reflecting device 104 to a point P1 on a surface of a semiconductor wafer 108, and are reflected by the surface of the semiconductor wafer 108, and then reflected to an analyzer 106 by a reflecting device 104. It should be understood that the reflecting device 104 is an integrally formed parabolic reflecting device, and the point P1 is the focus of the paraboloid of the reflecting device 104. In order for the polarized light beam to be focused on the point P1, it is required that the polarized light beam must be incident in a direction parallel to an axis A1 of the paraboloid of the reflecting device 104. Due to this limitation, the incident angle of the polarized light beam incident on a reflective surface of the reflecting device 104 is larger. Accordingly, an included angle between the polarized light beam incident on the paraboloid of the reflecting device 104 and a corresponding reflected light beam is an obtuse angle. Such a large incident angle will significantly change the polarization state of the light beam after passing through the polarizer.

15 [0036] In order to at least partially solve one or more of the above problem and other potential problems, exemplary embodiments of the present disclosure propose an ellipsometry device and a method for obtaining information of a surface of an object to be measured. In the present disclosure, a first off-axis parabolic mirror and a second off-axis parabolic mirror are arranged separately from each other. Therefore, an included angle between each polarized light beam and a corresponding first light beam can be set to be an acute angle (especially any angle between 20 and 40 degrees), and an included angle between a second light beam and a corresponding third light beam can be set to be an acute angle (especially any angle between 20 and

40 degrees), thereby significantly reducing the incident angle of the polarized light beam on the first off-axis parabolic mirror and the incident angle of the second light beam on the second off-axis parabolic mirror, so that the polarization state of the light beam transmitted through the first off-axis parabolic mirror and the second off-axis parabolic mirror can be effectively ensured. Further, an optical path corresponding to a plurality of parallel polarized light beams intersects with an optical path corresponding to a plurality of parallel third light beams, so that the focal length of the off-axis parabolic mirror used can be further shortened, thereby significantly increasing the numerical aperture (NA), and reducing the size of a light spot projected onto a wafer.

[0037] An ellipsometry device according to an embodiment of the present disclosure will be described in detail below.

[0038] FIG. 2 shows a schematic structural diagram of an ellipsometry device 200 according to an embodiment of the present disclosure. The ellipsometry device 200 comprises: a polarized light beam providing device 210, a first off-axis parabolic mirror 204, a second off-axis parabolic mirror 206, and a polarization analysis device 220. The polarized light beam providing device 210 is configured to provide a plurality of parallel polarized light beams L_p . The first off-axis parabolic mirror 204 is configured to reflect the plurality of parallel polarized light beams L_p such that a plurality of reflected first light beams L_1 are focused on a target point P1 on a surface of an object 108 to be measured. An included angle between each polarized light beam L_p of the plurality of parallel polarized light beams L_p and a corresponding first light beam L_1 of the plurality of reflected first light beams L_1 (i.e., a first included angle θ_1) is an acute angle. The second off-axis parabolic mirror 206 is configured to reflect a plurality of second light beams L_2 , which are formed of the reflected first light beams L_1 reflected by the surface of the object 108 to be measured, so as to form a plurality of parallel third light beams L_3 . An included angle between each second light beam L_2 of the plurality of second light beams L_2 and a corresponding third light beam L_3 of the plurality of parallel third light beams L_3 (i.e., a second included angle θ_2) is an acute angle. The polarization analysis device 220 is configured to analyze the polarization of the plurality of parallel third light beams L_3 . The included angle between each polarized light beam L_p of the plurality of parallel polarized light beams L_p and the corresponding first light beam L_1 of the plurality of reflected first light beams L_1 (i.e., the first included angle θ_1)

is any angle between 20 and 40 degrees. The included angle between each second light beam L2 of the plurality of second light beams L2 and the corresponding third light beam L3 of the plurality of parallel third light beams L3 (i.e., the second included angle θ_2) is any angle between 20 and 40 degrees.

5 **[0039]** It should be understood that the first included angle θ_1 is the sum of a first incident angle and a corresponding first reflection angle. The first incident angle is the incident angle of each polarized light beam Lp of the plurality of parallel polarized light beams Lp relative to the first off-axis parabolic mirror 204, and the first reflection angle is the reflection angle of the corresponding first light beam L1
10 of the plurality of reflected first light beams L1 relative to the first off-axis parabolic mirror 204. The second included angle θ_2 is the sum of a second incident angle and a corresponding second reflection angle. The second incident angle is the incident angle of each second light beam L2 of the second light beams L2 relative to the second off-axis parabolic mirror 206, and the second reflection angle is the reflection
15 angle of the corresponding third light beam L3 of the plurality of parallel third light beams L3 relative to the second off-axis parabolic mirror 206.

[0040] In some embodiments, the first included angle θ_1 is any angle between 20 and 40 degrees. The second included angle θ_2 is any angle between 20 and 40 degrees.

20 **[0041]** In some embodiments, the first included angle θ_1 is any angle between 20 and 26 degrees. The second included angle θ_2 is any angle between 20 and 26 degrees.

[0042] In some embodiments, an optical path corresponding to the plurality of parallel polarized light beams intersects with an optical path corresponding to the
25 plurality of parallel third light beams.

[0043] In some embodiments, the first off-axis parabolic mirror is arranged opposite the second off-axis parabolic mirror, that is, a reflective surface of the first off-axis parabolic mirror and a reflective surface of the second off-axis parabolic mirror face each other, which is different from the way in which the first off-axis parabolic
30 mirror and the second off-axis parabolic mirror are arranged facing away from each other.

[0044] In some embodiments, the object 108 to be measured is, for example, a wafer.

[0045] In some embodiments, the polarized light beam providing device comprises, for example, a polarizer, and the polarization analysis device comprises, for example,

an analyzer.

[0046] In some embodiments, the polarized light beam providing device comprises, for example, a polarizer and a first planar reflecting mirror, and the polarization analysis device comprises, for example, an analyzer and a second planar reflecting mirror.

[0047] In some embodiments, the polarizer, one of the first planar reflecting mirror and the second planar reflecting mirror, and the first off-axis parabolic mirror are arranged on one side of a target normal plane which is a normal plane of the object to be measured passing through the target point; and the second off-axis parabolic mirror, the other of the first planar reflecting mirror and the second planar reflecting mirror, and the analyzer are arranged on the other side of the target normal plane.

[0048] In the above solution, the first off-axis parabolic mirror 204 and the second off-axis parabolic mirror 206 are arranged separately from each other. Therefore, the included angle between each polarized light beam L_p and the corresponding first light beam L_1 can be set to be an acute angle (especially any angle between 20 and 40 degrees), and the included angle between the second light beam L_2 and the corresponding third light beam L_3 can be set to be an acute angle (especially any angle between 20 and 40 degrees), thereby significantly reducing the incident angle of the polarized light beam L_p to the first off-axis parabolic mirror 204 and the incident angle of the second light beam L_2 to the second off-axis parabolic mirror 206, so that the polarization state of the light beam transmitted through the first off-axis parabolic mirror 204 and the second off-axis parabolic mirror 206 can be effectively ensured.

[0049] FIG. 3 shows a schematic structural diagram of an ellipsometry device 300 according to an embodiment of the present disclosure. The polarized light beam providing device comprises a polarizer 302, and a first planar reflecting mirror 308. The polarizer 302 is configured to polarize incident light beams so as to form a plurality of parallel first polarized light beams L_{p1} . The first planar reflecting mirror 308 is configured to reflect the plurality of parallel first polarized light beams L_{p1} to form a plurality of parallel polarized light beams L_p . An included angle between each first polarized light beam L_{p1} of the plurality of parallel first polarized light beams L_{p1} and the corresponding polarized light beam L_p of the plurality of parallel polarized light beams L_p (i.e., a third included angle θ_3) is an acute angle (especially any angle between 20 and 40 degrees).

[0050] The first off-axis parabolic mirror 304 is configured to reflect the plurality of parallel polarized light beams L_p such that a plurality of reflected first light beams L_1 are focused on a target point P_1 on a surface of an object 108 to be measured. The included angle between each polarized light beam L_p of the plurality of parallel polarized light beams L_p and the corresponding first light beam L_1 of the plurality of reflected first light beams L_1 (i.e. the first included angle θ_1) is an acute angle (especially any angle between 20 and 40 degrees).

[0051] The second off-axis parabolic mirror 306 is configured to reflect a plurality of second light beams L_2 formed of the reflected first light beams L_1 reflected by the surface of the object 108 to be measured, so as to form a plurality of parallel third light beams L_3 . The included angle between each second light beam L_2 of the plurality of second light beams L_2 and the corresponding third light beam L_3 of the plurality of parallel third light beams L_3 (i.e., the second included angle θ_2) is an acute angle (especially any angle between 20 and 40 degrees).

[0052] It should be understood that the target point P_1 on the surface of the object 108 to be measured is the focus of the first off-axis parabolic mirror 304, and the target point P_1 on the surface of the object 108 to be measured is also the focus of the second off-axis parabolic mirror 306.

[0053] The polarization analysis device comprises a second planar reflecting mirror 310 and an analyzer 312. The second planar reflecting mirror 310 is configured to reflect the plurality of parallel third light beams L_3 to form a plurality of parallel fourth light beams L_4 . A fourth included angle θ_4 between each fourth light beam L_4 of the plurality of parallel fourth light beams L_4 and the corresponding third light beam L_3 of the plurality of parallel third light beams L_3 is an acute angle (especially any angle between 20 and 40 degrees). The analyzer 312 is configured to analyze the polarization of the plurality of parallel fourth light beams L_4 .

[0054] It should be understood that the third included angle θ_3 is the sum of a third incident angle and the corresponding third reflection angle. The third incident angle is the incident angle of each first polarized light beam L_{p1} of the plurality of parallel first polarized light beams L_{p1} relative to the first planar reflecting mirror 308, and the third reflection angle is the reflection angle of each polarized light beam L_p of the plurality of parallel polarized light beams L_p relative to the first planar reflecting mirror 308. The fourth included angle θ_4 is the sum of a fourth incident angle and the corresponding fourth reflection angle. The fourth incident angle is the incident

angle of the corresponding third light beam L3 of the plurality of parallel third light beams L3 relative to the second planar reflecting mirror 310, and the fourth reflection angle is the reflection angle of each fourth light beam L4 of the plurality of parallel fourth light beams L4 relative to the second planar reflecting mirror 310.

5 **[0055]** It should be understood that the polarizer 302, the first planar reflecting mirror 308 and the first off-axis parabolic mirror 304 are arranged on one side of a target normal plane Pn. The target normal plane Pn is a normal plane of the object 108 to be measured passing through the target point P1. The second off-axis parabolic mirror 306, the second planar reflecting mirror 310 and the analyzer 312
10 are arranged on the other side of the target normal plane Pn.

[0056] In this solution, with the arrangement of the polarizer 302, the first planar reflecting mirror 308 and the first off-axis parabolic mirror 304 on the same side of the target normal plane Pn, and the second off-axis parabolic mirror 306, the second planar reflecting mirror 310 and the analyzer 312 on the same side of the target
15 normal plane Pn, it is possible that the distances between the polarizer 302, the first planar reflecting mirror 308 and the first off-axis parabolic mirror 304 are made smaller, and the same is true for the second off-axis parabolic mirror 306, the second planar reflecting mirror 310 and the analyzer 312, thereby reducing the space occupied by the ellipsometry device 300.

20 **[0057]** In some embodiments, an included angle between each first light beam L1 of the plurality of reflected first light beams L1 and a normal direction of the object 108 to be measured (i.e., a fifth included angle θ_5) is any angle between 60 degrees and 70 degrees. It should be understood that the included angle between the first light beam L1 and the normal direction of the object 108 to be measured is equal to
25 the included angle between the first light beam L1 and the target normal plane Pn. In some embodiments, the included angle between a central first light beam L1 of the plurality of reflected first light beams L1 and the normal direction of the object 108 to be measured (i.e., the fifth included angle θ_5) is 65 degrees.

[0058] In this solution, by setting the first included angle θ_1 and the second included
30 angle θ_2 to be acute angles, the influences of the first off-axis parabolic mirror 304 and the second off-axis parabolic mirror 306 on the polarization state of the reflected light beams can be significantly reduced, thereby significantly improving the accuracy of the calibration algorithm, significantly reducing the complexity of the calibration process, and greatly improving the calculation efficiency. Moreover, by

arranging the first off-axis parabolic mirror 304 and the second off-axis parabolic mirror 306 separately from each other, the incident angles of the light beams relative to the first off-axis parabolic mirror 304 and the second off-axis parabolic mirror 306 can be easily adjusted, thereby improving the flexibility of the ellipsometry device so that it can be applied to a wider range of application scenarios. In addition, the ellipsometry device can achieve a diffraction-limited spot size in a wider band of polarized light (including but not limited to deep ultraviolet band, visible light band, and near-infrared band).

[0059] In some embodiments, the first off-axis parabolic mirror 304 and the second off-axis parabolic mirror 306 may be metal off-axis parabolic mirrors. A metal material used in the metal off-axis parabolic mirror includes but is not limited to aluminum and copper. The metal off-axis parabolic mirror is manufactured by using a single-point diamond processing process. The metal off-axis parabolic mirror has a surface profile accuracy less than $1/10$ wavelength and a surface roughness less than 5 nanometers. Based on this metal off-axis parabolic mirror, the reflectivity of a light beam can be significantly increased.

[0060] In some embodiments, the first off-axis parabolic mirror 304 and the second off-axis parabolic mirror 306 may be glass off-axis parabolic mirrors. A glass material used in the glass off-axis parabolic mirror includes but is not limited to fused quartz, quartz crystal, and low expansion coefficient glass-ceramic. The glass off-axis parabolic mirror has a surface profile accuracy less than $1/20$ wavelength and a surface roughness less than 1 nanometer. Based on this glass off-axis parabolic mirror, the reflectivity of a light beam can be significantly increased.

[0061] In some embodiments, a surface of each of the first off-axis parabolic mirror 304, the second off-axis parabolic mirror 306, the first planar reflecting mirror 308 and the second planar reflecting mirror 310 is provided with a coating. The coating comprises at least one of a metal reflective film and a multi-layer dielectric film. The metal reflective film comprises an aluminum reflective layer and a magnesium fluoride protective layer arranged on a surface of the aluminum reflective layer. The multi-layer dielectric film has a plurality of dielectric layers, and a medium corresponding to each dielectric layer is respectively a material with a different refractive index. Based on the matching of the refractive indexes of the plurality of dielectric layers, a higher reflectivity can be achieved, and a higher laser damage threshold can be achieved. Regarding the metal reflective film and the multi-layer

dielectric film, for light beams with wavelengths in the range of 190 to 350 nanometers, the average reflectivity may be greater than 90%; and for light beams with wavelengths in the range of 350 to 2500 nanometers, the average reflectivity may be greater than 85%.

5 **[0062]** FIG. 4 shows measurements of the change in a phase angle between P-polarized light and S-polarized light of an ellipsometry device 300 according to an embodiment of the present disclosure and a conventional ellipsometry device. Solution 1 corresponds to the ellipsometry device 300 according to the embodiment of the present disclosure shown in FIG. 3, and solution 2 corresponds to the
10 conventional ellipsometry device 100 shown in FIG. 1. The measurements of the change in the phase angle between P-polarized light and S-polarized light after reflection of a plurality of polarized light beams of different wavelengths are shown. It can be seen that the ellipsometry device 300 according to the embodiment of the present disclosure is significantly better than the conventional ellipsometry device
15 100.

[0063] FIG. 5 shows a schematic diagram of the pupil polarization state distribution of a conventional ellipsometry device. The conventional ellipsometry device is the conventional ellipsometry device 100 shown in FIG. 1, in which an input light signal (Input) is also shown. FIG. 6 shows a schematic diagram of the pupil polarization
20 state distribution of an ellipsometry device 300 according to an embodiment of the present disclosure. The ellipsometry device according to the embodiment of the present disclosure is the ellipsometry device 300 according to the embodiment of the present disclosure shown in FIG. 3. It can be seen from the comparison that the ellipsometry device 300 according to the embodiment of the present disclosure is
25 significantly better than the conventional ellipsometry device 100.

[0064] FIG. 7 shows a schematic diagram of an ellipsometry device 300 according to an embodiment of the present disclosure with an imaging quality thereof on a wafer reaching a diffraction limit. It can be seen that a light spot projected onto the wafer via the ellipsometry device 300 according to the embodiment of the present
30 disclosure can reach the diffraction limit.

[0065] FIG. 8 shows a schematic structural diagram of an ellipsometry device 800 according to an embodiment of the present disclosure. A polarizer 802, a second planar reflecting mirror 810 and a first off-axis parabolic mirror 804 are arranged on one side of a target normal plane Pn. A second off-axis parabolic mirror 806, a first

planar reflecting mirror 808 and an analyzer 812 are arranged on the other side of the target normal plane P_n . Therefore, an optical path corresponding to a plurality of parallel polarized light beams L_p intersects with an optical path corresponding to a plurality of parallel third light beams L_3 . It should be understood that the optical path corresponding to the plurality of parallel polarized light beams L_p is an optical path through which the plurality of parallel polarized light beams L_p propagate in a straight line before being reflected, for example, an optical path through which the plurality of parallel polarized light beams L_p propagate from the first planar reflecting mirror 808 to the first off-axis parabolic mirror 804; and the optical path corresponding to the plurality of parallel third light beams L_3 is an optical path through which the plurality of parallel third light beams L_3 propagate in a straight line before being reflected, for example, an optical path through which the plurality of parallel third light beams L_3 propagate from the second off-axis parabolic mirror 806 to the second planar reflecting mirror 810.

[0066] For example, the respective heights of the polarizer 802 and the analyzer 812 relative to the surface of the object 108 to be measured may be the same. For example, the respective heights of the second planar reflecting mirror 810 and the first planar reflecting mirror 808 relative to the surface of the object 108 to be measured may be the same. For example, the respective heights of the first off-axis parabolic mirror 804 and the second off-axis parabolic mirror 806 relative to the surface of the object 108 to be measured may be the same. The respective heights of the polarizer 802, the second planar reflecting mirror 810 and the first off-axis parabolic mirror 804 relative to the surface of the object 108 to be measured are different, and the respective heights of the second off-axis parabolic mirror 806, the first planar reflecting mirror 808 and the analyzer 812 relative to the surface of the object 108 to be measured are different. In some embodiments, the respective heights of the polarizer 802, the second planar reflecting mirror 810 and the first off-axis parabolic mirror 804 relative to the surface of the object 108 to be measured decrease in sequence, and the respective heights of the analyzer 812, the first planar reflecting mirror 808 and the second off-axis parabolic mirror 806 relative to the surface of the object 108 to be measured decrease in sequence.

[0067] In some embodiments, a lateral distance between the first planar reflecting mirror 808 and the second planar reflecting mirror 810 is greater than a lateral distance between the first off-axis parabolic mirror 804 and the second off-axis

parabolic mirror 806.

[0068] In this solution, with the arrangement of the polarizer 802 and the first off-axis parabolic mirror 804 on one side of the target normal plane P_n , and the first planar reflecting mirror 808 on the other side of the target normal plane P_n , it is possible to facilitate full utilization of, for example, the lateral space, so as to obtain smaller third included angle θ_3 and first included angle θ_1 . Similarly, with the arrangement of the second planar reflecting mirror 810 on one side of the target normal plane P_n , and the second off-axis parabolic mirror 806 and analyzer 812 on the other side of the target normal plane P_n , it is possible to facilitate full utilization of, for example, the lateral space, so as to obtain smaller fourth included angle θ_4 and second included angle θ_2 . Therefore, compared with the ellipsometry device 300, the ellipsometry device 800 can further shorten the focal length of the off-axis parabolic mirror used, thereby significantly increasing the NA and reducing the size of the light spot projected onto the wafer.

[0069] It should be noted that the height of the second planar reflecting mirror 810 relative to the surface of the object 108 to be measured is greater than the height of the first off-axis parabolic mirror 804 relative to the surface of the object 108 to be measured, and the height of the first planar reflecting mirror 808 relative to the surface of the object 108 to be measured is greater than the height of the second off-axis parabolic mirror 806 relative to the surface of the object 108 to be measured. Therefore, the second planar reflecting mirror 810 and the first planar reflecting mirror 808 do not occupy the lateral space between the first off-axis parabolic mirror 804 and the second off-axis parabolic mirror 806, so that in some application scenarios, the distance between the first off-axis parabolic mirror 804 and the second off-axis parabolic mirror 806 can be made smaller. In some embodiments, the polarized light beams L_p are parallel to a central second light beam L_2 of the plurality of second light beams L_2 , and the third light beams L_3 are parallel to a central first light beam L_1 of the plurality of first light beams L_1 .

[0070] In some embodiments, the first polarized light beams L_{p1} are parallel to the third light beams L_3 , and the fourth light beams L_4 are parallel to the polarized light beams L_p .

[0071] In some embodiments, the polarizer 802, the second planar reflecting mirror 810, the first off-axis parabolic mirror 804, the second off-axis parabolic mirror 806, the first planar reflecting mirror 808 and the analyzer 812 are relatively stationary to

one another. That is, in the ellipsometry device 800, none of the polarizer 802, the second planar reflecting mirror 810, the first off-axis parabolic mirror 804, the second off-axis parabolic mirror 806, the first planar reflecting mirror 808 and the analyzer 812 is a moving component, which helps ensure the system stability.

5 **[0072]** In some embodiments, an included angle between each first light beam L1 of the plurality of reflected first light beams L1 and a normal direction of the object 108 to be measured (i.e., a fifth included angle θ_5) is any angle between 60 degrees and 70 degrees. In some embodiments, the included angle between a central first light beam L1 of the plurality of reflected first light beams L1 and the normal
10 direction of the object 108 to be measured (i.e., the fifth included angle θ_5) is 65 degrees.

[0073] FIG. 9 shows a schematic structural diagram of an ellipsometry device 900 according to an embodiment of the present disclosure. The polarized light beam providing device comprises a polarizer 902, and the polarization analysis device
15 comprises an analyzer 912. The polarizer 902 and a second off-axis parabolic mirror 906 are arranged on one side of a target normal plane Pn, and a first off-axis parabolic mirror 904 and the analyzer 912 are arranged on the other side of the target normal plane Pn. Therefore, an optical path corresponding to a plurality of parallel polarized light beams Lp intersects with an optical path corresponding to a plurality
20 of parallel third light beams L3. It should be understood that the optical path corresponding to the plurality of parallel polarized light beams Lp is an optical path through which the plurality of parallel polarized light beams Lp propagate in a straight line before being reflected, for example, an optical path through which the plurality of parallel polarized light beams Lp propagate from the polarizer 902 to the
25 first off-axis parabolic mirror 904; and the optical path corresponding to the plurality of parallel third light beams L3 is an optical path through which the plurality of parallel third light beams L3 propagate in a straight line before being reflected, for example, an optical path through which the plurality of parallel third light beams L3 propagate from the second off-axis parabolic mirror 906 to the analyzer 912.

30 **[0074]** In this solution, a small number of optical elements are used, so the structure of the ellipsometry device 900 can be simplified, and the manufacturing cost can be effectively reduced. Moreover, compared with the ellipsometry device 800, the ellipsometry device 900 omits the planar reflecting mirror, and the optical efficiency and the system signal-to-noise ratio of the ellipsometry device are significantly

improved. For example, in some implementations, the ellipsometry device 900 is provided with two reflective lenses (the first off-axis parabolic mirror 904 and the second off-axis parabolic mirror 906), and the ellipsometry device 800 is provided with four reflective lenses (the first off-axis parabolic mirror 804, the second off-axis parabolic mirror 806, the first planar reflecting mirror 808 and the second planar reflecting mirror 810). Therefore, compared with the ellipsometry device 800, the number of reflective lenses used in the ellipsometry device 900 is halved (reduced from four to two), so the optical efficiency is doubled, and the system signal-to-noise ratio of the ellipsometry device is also doubled.

10 **[0075]** It should be understood that the size of the light spot projected onto the wafer is directly proportional to $1/NA$. Therefore, to achieve a smaller spot size, the NA of the off-axis parabolic mirror needs to be increased. Where the aperture of the light beam remains unchanged, the focal length of the off-axis parabolic mirror needs to be shortened. If reflecting mirrors (the second planar reflecting mirror and the first planar reflecting mirror) are arranged in the lateral space between the first off-axis parabolic mirror and the second off-axis parabolic mirror in the lateral direction, in the process of reducing the size of the light spot projected onto the wafer, as the lateral distance between the symmetrically arranged first off-axis parabolic mirror and second off-axis parabolic mirror decreases, the distance between the second planar reflecting mirror and the first planar reflecting mirror decreases, and there may even be situations where the second planar reflecting mirror and the first planar reflecting mirror have severe mechanical interference with each other in space. Therefore, in the solution in which the second planar reflecting mirror and the first planar reflecting mirror are laterally arranged between the first off-axis parabolic mirror and the second off-axis parabolic mirror, the NA of the off-axis parabolic mirror (or the size of the light spot projected onto the wafer) is limited by the mechanical space sizes of the planar reflecting mirrors and the off-axis parabolic mirrors in the lateral direction. However, in the ellipsometry device 900, no reflecting mirror is provided in the lateral space between the first off-axis parabolic mirror and the second off-axis parabolic mirror, so that the distance between the first off-axis parabolic mirror and the second off-axis parabolic mirror can be made smaller, thereby increasing the NA and reducing the light spot under the condition that the incident angle is still small. It should be understood that in the solution of omitting the reflecting mirrors, the optical efficiency and the signal-to-noise ratio

can also be improved by reducing the number of lenses.

[0076] FIG. 10 shows a flowchart of a method 1000 for obtaining information of a surface of an object to be measured according to an embodiment of the present disclosure. The method 1000 may be implemented by using any one of the ellipsometry devices 200, 300, 800 and 900. It should be understood that method 1000 may further comprise additional steps not shown, and/or the steps shown may be omitted, and the scope of the present disclosure is not limited in this regard.

[0077] At step 1002, a plurality of parallel polarized light beams are provided by a polarized light beam providing device.

[0078] At step 1004, the plurality of parallel polarized light beams are reflected by a first off-axis parabolic mirror such that a plurality of reflected first light beams are focused on a target point on the surface of the object to be measured.

[0079] At step 1006, a plurality of second light beams, which are formed of the reflected first light beams reflected by the surface of the object to be measured, are reflected by a second off-axis parabolic mirror, so as to form a plurality of parallel third light beams.

[0080] At step 1008, the polarization of the plurality of parallel third light beams is analyzed by a polarization analysis device, so as to obtain the information of the surface of the object to be measured.

[0081] Combined with the embodiments of the present disclosure, those skilled in the art can clearly understand the specific implementation details of the method 1000, which will not be described again here.

[0082] Various embodiments of the present disclosure have been described above, and the explanations are exemplary but not exhaustive, and the present disclosure is not limited to the various embodiments disclosed. Many changes and modifications would be apparent to those of ordinary skill in the art without departing from the scope and spirit of the illustrated embodiments. The selection of terms used herein is intended to best explain the principles of the various embodiments, practical applications or improvements of the techniques in the market, or to enable those skilled in the art to understand the various embodiments disclosed herein.

[0083] The foregoing descriptions are merely optional embodiments of the present disclosure, and are not intended to limit the present disclosure. For those skilled in the art, various modifications and variations may be made to the present disclosure. Any modifications, equivalent substitutions, improvements, and the like made

within the spirit and principle of the present disclosure should fall within the scope of protection of the present disclosure.

CLAIMS

1. An ellipsometry device, comprising:

5 a polarized light beam providing device configured to provide a plurality of parallel polarized light beams;

a first off-axis parabolic mirror configured to reflect the plurality of parallel polarized light beams such that a plurality of reflected first light beams are focused on a target point on a surface of an object to be measured, an included angle between each polarized light beam of the plurality of parallel polarized light beams and a corresponding first light beam of the plurality of reflected first light beams being
10 any angle between 20 and 40 degrees;

a second off-axis parabolic mirror configured to reflect a plurality of second light beams formed of the reflected first light beams reflected by the surface of the object to be measured, so as to form a plurality of parallel third light beams, an included angle between each second light beam of the plurality of second light beams and a corresponding third light beam of the plurality of parallel third light beams being any angle between 20 and 40 degrees; and
15

a polarization analysis device configured to analyze the polarization of the plurality of parallel third light beams;

20 wherein an optical path corresponding to the plurality of parallel polarized light beams intersects with an optical path corresponding to the plurality of parallel third light beams.

2. The ellipsometry device according to claim 1, wherein the polarized light beam providing device comprises:
25

a polarizer configured to polarize incident light beams so as to form a plurality of parallel first polarized light beams; and

a first planar reflecting mirror configured to reflect the plurality of parallel first polarized light beams to form a plurality of parallel polarized light beams, an included angle between each first polarized light beam of the plurality of parallel first polarized light beams and a corresponding polarized light beam of the plurality of parallel polarized light beams being any angle between 20 and 40 degrees; and
30

the polarization analysis device comprises:

a second planar reflecting mirror configured to reflect the plurality of parallel

third light beams to form a plurality of parallel fourth light beams, an included angle between each fourth light beam of the plurality of parallel fourth light beams and a corresponding third light beam of the plurality of parallel third light beams being any angle between 20 and 40 degrees; and

5 an analyzer configured to analyze the polarization of the plurality of parallel fourth light beams.

3. The ellipsometry device according to claim 2, wherein the polarizer, the second planar reflecting mirror and the first off-axis parabolic mirror are arranged
10 on one side of a target normal plane; and the analyzer, the first planar reflecting mirror and the second off-axis parabolic mirror are arranged on the other side of the target normal plane.

4. The ellipsometry device according to claim 2, wherein the heights of the first
15 planar reflecting mirror and the second planar reflecting mirror relative to the surface of the object to be measured are greater than the heights of the first off-axis parabolic mirror and the second off-axis parabolic mirror relative to the surface of the object to be measured.

20 5. The ellipsometry device according to claim 2, wherein a lateral distance between the first planar reflecting mirror and the second planar reflecting mirror is greater than a lateral distance between the first off-axis parabolic mirror and the second off-axis parabolic mirror.

25 6. The ellipsometry device according to claim 2, wherein the polarized light beams are parallel to a central second light beam of the plurality of second light beams, and the third light beams are parallel to a central first light beam of the plurality of first light beams.

30 7. The ellipsometry device according to claim 2, wherein the first polarized light beams are parallel to the third light beams, and the fourth light beams are parallel to the polarized light beams.

8. The ellipsometry device according to claim 1, wherein the polarized light

beam providing device comprises:

a polarizer configured to polarize incident light beams so as to form a plurality of parallel polarized light beams;

the polarization analysis device comprises:

5 an analyzer configured to analyze the polarization of the plurality of parallel third light beams; and

the polarizer and the second off-axis parabolic mirror are arranged on one side of a target normal plane which is a normal plane of the object to be measured passing through the target point, and the first off-axis parabolic mirror and the analyzer are
10 arranged on the other side of the target normal plane.

9. The ellipsometry device according to claim 1, wherein an included angle between each first light beam of the plurality of reflected first light beams and a normal direction of the object to be measured is any angle between 60 degrees and
15 70 degrees.

10. The ellipsometry device according to any one of claims 1 to 9, wherein the first off-axis parabolic mirror and the second off-axis parabolic mirror comprise at least one of:

20 a metal off-axis parabolic mirror having a surface profile accuracy less than 1/10 wavelength and a surface roughness less than 5 nanometers;

and a glass off-axis parabolic mirror having a surface profile accuracy less than 1/20 wavelength and a surface roughness less than 1 nanometer.

25 11. The ellipsometry device according to claim 2, wherein a surface of each of the first off-axis parabolic mirror, the second off-axis parabolic mirror, the first planar reflecting mirror and the second planar reflecting mirror is provided with a coating, the coating comprising at least one of a metal reflective film and a multi-layer dielectric film.

30 12. The ellipsometry device according to any one of claims 1 to 11, wherein the first off-axis parabolic mirror is arranged opposite the second off-axis parabolic mirror.

13. A method for obtaining information of a surface of an object to be measured, wherein the method is implemented by an ellipsometry device according to any one of claims 1 to 12, and the method comprises:

5 providing a plurality of parallel polarized light beams by a polarized light beam providing device;

reflecting the plurality of parallel polarized light beams by a first off-axis parabolic mirror such that a plurality of reflected first light beams are focused on a target point on the surface of the object to be measured;

10 reflecting a plurality of second light beams formed of the reflected first light beams reflected by the surface of the object to be measured, by a second off-axis parabolic mirror, so as to form a plurality of parallel third light beams; and

analyzing the polarization of the plurality of parallel third light beams by a polarization analysis device, so as to obtain the information of the surface of the object to be measured.