

Three-Motors Configuration for Adjusting Wafer Tilt and Focus

TECHNICAL FIELD

[0001] This disclosure relates to adjusting wafer tilt and focus in a wafer measurement tool.

BACKGROUND

[0002] Semiconductor fabrication includes depositing layers of film on a semiconductor wafer and patterning the layers. This deposition stresses the wafer, causing the wafer to warp. As the number of layers of film increases, the warpage increases. For modern three-dimensional (3D) semiconductor memories, which may have over 100 layers, the warpage may be 500 microns to one millimeter or more. Interferometry may be used to measure this warpage. For high warpage, however, an interferometer may not be able to focus on the entire wafer. Even if the wafer is tilted to allow the shape of the wafer in different regions to be measured separately, measuring the shape of the entire wafer may still not be possible.

SUMMARY

[0003] Accordingly, systems and methods are needed to allow effective measurement of the shape of semiconductor wafers.

[0004] In some embodiments, a system includes a first interferometer to measure the shape of a first side of a semiconductor wafer, a pallet to hold the semiconductor wafer and expose the first side of the semiconductor wafer to the first interferometer, and three motors coupled to the pallet. The three motors include a first motor coupled to the pallet at a first position, a second motor coupled to the pallet at a second position, and a third motor coupled to the pallet at a third position.

[0005] The system may further include a second interferometer to measure the shape of a second side of the semiconductor wafer, and the pallet may have an aperture to expose the

second side of the semiconductor wafer to the second interferometer. The pallet holds the semiconductor wafer between the first interferometer and the second interferometer.

[0006] In some embodiments, a method includes holding a semiconductor wafer in a pallet between a first interferometer and a second interferometer. A first side of the semiconductor wafer is exposed to the first interferometer and a second side of the semiconductor wafer is exposed to the second interferometer. A first motor is coupled to the pallet at a first position, a second motor is coupled to the pallet at a second position, and a third motor is coupled to the pallet at a third position. The method also includes translating the first motor and the second motor to null a tilt of the semiconductor wafer and, with the tilt of the semiconductor wafer nulled, centering the semiconductor wafer between the first interferometer and the second interferometer. Centering the semiconductor wafer includes translating the first motor, the second motor, and the third motor.

[0007] The method may further include, after centering the semiconductor wafer between the first interferometer and the second interferometer, calculating a plurality of tilts to be used to measure the shape of the semiconductor wafer in a plurality of respective regions. For the plurality of tilts, a plurality of sets of target positions is calculated for the first, second, and third motors. Each set of target positions of the plurality of sets of target positions corresponds to a respective tilt of the plurality of tilts. The first, second, and third motors are translated to each set of target positions of the plurality of sets of target positions, to successively position the semiconductor wafer to have each tilt of the plurality of tilts. With the semiconductor wafer successively positioned to have each tilt of the plurality of tilts, the shape of the semiconductor wafer is measured in each respective region of the plurality of respective regions.

[0008] In some embodiments, a system includes a first interferometer, a second interferometer, a pallet to hold a semiconductor wafer between the first interferometer and the second interferometer with a first side of the semiconductor wafer exposed to the first interferometer and a second side of the semiconductor wafer exposed to the second interferometer, and three motors coupled to the pallet. The three motors include a first motor coupled to the pallet at a first position, a second motor coupled to the pallet at a second position, and a third motor coupled to the pallet at a third position. The system also includes one or more

processors and memory storing one or more programs for execution by the one or more processors. The one or more programs include instructions for performing the above method.

[0009] In some embodiments, a non-transitory computer-readable storage medium stores one or more programs or execution by one or more processors of an interferometry system. The one or more programs include instructions for performing the above method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a better understanding of the various described implementations, reference should be made to the Detailed Description below, in conjunction with the following drawings.

[0011] Figure 1 shows an interferometry system used to measure the shape of a semiconductor wafer, in accordance with some embodiments.

[0012] Figures 2A and 2B show a pallet used to hold a semiconductor wafer in accordance with some embodiments.

[0013] Figures 3A-3C are cross-sectional side views of a warped semiconductor wafer showing respective tilts that may be achieved using the pallet and three motors of Figures 2A and 2B, in accordance with some embodiments.

[0014] Figure 4 shows a simulated example of a wafer map for a semiconductor wafer, with a center region and a plurality of regions that collectively cover the semiconductor wafer, in accordance with some embodiments.

[0015] Figure 5 shows a simulated example of a wafer map for a semiconductor wafer for a scenario in which the third motor of Figures 2A and 2B is omitted and replaced with a pivot joint.

[0016] Figure 6A is a flowchart showing a method of positioning a semiconductor wafer in an interferometry system in preparation for measuring the shape of the semiconductor wafer, in accordance with some embodiments.

[0017] Figure 6B is a flowchart showing a method of measuring the shape of a semiconductor wafer in an interferometry system, in accordance with some embodiments.

[0018] Figure 7 is a block diagram of a semiconductor-wafer measurement system in accordance with some embodiments.

[0019] Like reference numerals refer to corresponding parts throughout the drawings and specification.

DETAILED DESCRIPTION

[0020] Reference will now be made in detail to various embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the various described embodiments. However, it will be apparent to one of ordinary skill in the art that the various described embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, components, circuits, and networks have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.

[0021] Figure 1 shows an interferometry system 100 used to measure the shape of a semiconductor wafer 102, in accordance with some embodiments. The interferometry system 100 may be situated in a wafer measurement tool (e.g., semiconductor-wafer measurement tool 730, Figure 7). The semiconductor wafer 102 may be a patterned wafer (e.g., for which the patterning, and thus the wafer fabrication, is complete or in process) on which layers of film have been deposited and patterned. For example, the semiconductor wafer 102 may be a three-dimensional (3D) memory wafer (i.e., a wafer with a plurality of 3D memory die) (e.g., a 3D flash memory wafer). The semiconductor wafer 102 is held in the interferometry system 100 on a pallet 104. In some embodiments, the pallet 104 holds the semiconductor wafer 102 vertically in the interferometry system 100, to minimize the effect of gravity on warpage of the semiconductor wafer 102.

[0022] The interferometry system 100 includes a first interferometer 106-1 for measuring a first side (e.g., the top side, or alternatively the bottom side) of the semiconductor wafer 102 and a second interferometer 106-2 for measuring a second side (e.g., the bottom side, or alternatively the top side) of the semiconductor wafer 102. The first side is opposite to the second side. In some embodiments, the interferometers 106-1 and 106-2 are Fizeau interferometers: the first interferometer 106-1 is a first Fizeau interferometer and the second

interferometer 106-2 is a second Fizeau interferometer. Each Fizeau interferometer includes a reference flat 108, a lens 110 to focus a respective laser beam 124-1 or 124-2 onto the reference flat 108 and the semiconductor wafer 102, a beam splitter to direct the respective laser beam 124-1 or 124-2 to the lens 110 and to transmit the respective laser beam 124-1 or 124-2 as reflected by the reference flat 108 and the semiconductor wafer 102, a lens 114 to focus the reflected respective laser beam 124-1 or 124-2, a digital camera 116 to receive the reflected respective laser beam 124-1 or 124-2 as focused by the lens 114, and a computer 118 to process data from the digital camera 116. The laser beams 124-1 and 124-2 are generated by a laser 120 and provided to the beam splitters 112 of respective interferometers 106-1 and 106-2 by respective fibers 122-1 and 122-2.

[0023] In each interferometer 106-1 and 106-2, the portion of the respective laser beam 124-1 or 124-2 reflected by the reference flat 108 interferes with the portion of the respective laser beam 124-1 or 124-2 reflected by the semiconductor wafer 102, producing an interferogram that is captured by the camera 116. Using interferogram analysis, the distance of points on the semiconductor wafer 102 from the reference flat 108, and thereby the heights of the points, are measured. The measured heights of the points indicate the shape of the semiconductor wafer 102 (e.g., the warpage of the semiconductor wafer 102 resulting from film deposition). By using two interferometers 106-1 and 106-2, heights and thus the shape of both sides (i.e., the top and bottom sides) of the semiconductor wafer 102 are measured. The camera 116 of each interferometer 106-1 and 106-2 may have a dedicated computer 118 to process its interferogram data, such that the interferometry system 100 has a total of two computers 118 to process interferogram data. In some embodiments, each camera 116 is a 90-megapixel camera.

[0024] Figures 2A and 2B show a pallet 200 used to hold a semiconductor wafer 102 (Figure 2B) in accordance with some embodiments. The pallet 200 may be an example of the pallet 104 (Figure 1). In Figure 2B the pallet 200 is shown holding the semiconductor wafer 102, while in Figure 2A the pallet 200 is shown without the semiconductor wafer 102. In some embodiments, the pallet 200 has an aperture 202 (Figure 2A) (e.g., a round aperture) over which the semiconductor wafer 102 may be held, to allow both sides (i.e., the top and bottom sides) of the semiconductor wafer 102 to be exposed to respective interferometers (e.g., interferometers 106-1 and 106-2, Figure 1) so that the shape of both sides of the semiconductor wafer 102 can be measured. One side of the semiconductor wafer 102 faces outward from the pallet 200 and thus

is exposed to a first interferometer (e.g., interferometer 106-1, or alternatively interferometer 106-2), while the other side of the semiconductor wafer 102 is exposed to a second interferometer (e.g., interferometer 106-2, or alternatively interferometer 106-1) through the aperture 202. In some embodiments, the pallet has grips 218 (e.g., three grips 218) for holding the semiconductor wafer 102. The grips 218 may use a minimum of force to avoid or minimize distorting the shape of the semiconductor wafer 102 during measurement.

[0025] Three motors – a first motor 204, a second motor 208, and a third motor 212 – are coupled to the pallet 200 to tilt and translate the pallet 200. The first motor 204 is coupled to the pallet 200 at a first position, the second motor 208 is coupled to the pallet 200 at a second position, and the third motor 212 is coupled to the pallet 200 at a third position. In some embodiments, the first position is along a first side 206 of the pallet 200, the second position is at a first corner 210 of the pallet 200, and the third position is at a second corner 214 of the pallet 200. The first corner 210 and second corner 214 are at opposite ends of a second side 216 of the pallet 200, which is opposite to the first side 206.

[0026] In some embodiments, the first motor 204, second motor 208, and third motor 212 are translatable in substantially the same direction 220 (e.g., in the same direction to within manufacturing tolerances). For example, the first motor 204, second motor 208, and third motor 212 may each have a single degree of freedom, such that they only move back and forth in the direction 220. The direction 220 may be substantially parallel (e.g., parallel to within manufacturing tolerances) to optical axes 111 (Figure 1) of the first interferometer 106-1 and/or second interferometer 106-2. The motors (e.g., one or two of the motors) 204, 208, and/or 212 may be used to achieve a desired tilt of the pallet 200 and thus the semiconductor wafer 102. All three of the motors 204, 208, and 212 may be used (e.g., simultaneously) to translate the position of the pallet 200 and semiconductor wafer 102 while maintaining a desired tilt. In some embodiments, the motors 204, 208, and 212 have a minimum motion of 50 nm with a repeatability of 2 microns. In some embodiments, the motors 204, 208, and 212 each have a travel (i.e., maximum possible translation) in the range of +/- 4-5 microns. Different ones of the motors 204, 208, and 212 may have different travels (e.g., each within a range of +/- 4-5 microns).

[0027] Figures 3A-3C are cross-sectional side views of the semiconductor wafer 102, with warpage of the semiconductor wafer 102 exaggerated for effect. Figures 3A-3C show respective tilts 300A, 300B, and 300C that may be achieved using the pallet 200 and motors 204, 208, and/or 212 (Figures 2A-2B), in accordance with some embodiments. Figure 3A shows a null tilt 300A: the motors 204, 208, and/or 212 have been used to null the tilt of the semiconductor wafer 102 (as held by the pallet 200), such that a tangent for a center portion of the semiconductor wafer 102 is not tilted (e.g., is vertical, such that semiconductor wafer 102 is positioned vertically). With the null tilt 300A (e.g., and a centered position between the interferometers 106-1 and 106-2), the interferometers 106-1 and/or 106-2 (Figure 1) are able to focus on, and thus measure the shape of, a center region 302 of the semiconductor wafer 102. With the null tilt 300A (and suitable translational positioning), the center region 302 thus may be within the depth of focus of the interferometers 106-1 and/or 106-2. The high warpage of the semiconductor wafer 102, however, prevents the interferometers 106-1 and/or 106-2 from focusing on a top region 304 and a bottom region 306 of the semiconductor wafer 102 with the tilt 300A. With the tilt 300A, the regions 304 and 306 are therefore defocused, such that the interferometers 106-1 and/or 106-2 cannot measure the shape of the regions 304 and 306. That is, with the null tilt 300A, the regions 304 and 306 are out of the depth of focus of the interferometers 106-1 and/or 106-2.

[0028] Figure 3B shows a tilt 300B in which the motors 204, 208, and/or 212 have been used to tilt the semiconductor wafer 102 (as held by the pallet 200) forward, to allow the interferometers 106-1 and/or 106-2 to focus on the region 304. The tilt 300B (along with suitable translational positioning) allows the interferometers 106-1 and/or 106-2 to measure the shape of the top region 304. With the tilt 300B (and suitable translational positioning), the top region 304 is within the depth of focus of the interferometers 106-1 and/or 106-2. Figure 3C shows a tilt 300C in which the motors 204, 208, and/or 212 have been used to tilt the semiconductor wafer 102 (as held by the pallet 200) backward, to allow the interferometers 106-1 and/or 106-2 to focus on the region 306. The tilt 300C (along with suitable translational positioning) allows the interferometers 106-1 and/or 106-2 to measure the shape of the bottom region 306. With the tilt 300C (and suitable translational positioning), the bottom region 306 is within the depth of focus of the interferometers 106-1 and/or 106-2.

[0029] Figure 4 shows a simulated example of a wafer map 400 for the semiconductor wafer 102 in accordance with some embodiments. The wafer map 400 shows a center region 402 and a plurality of regions 404 that collectively cover the semiconductor wafer 102. Each region 404 of the plurality of regions 404 corresponds to a respective tilt (i.e., non-null tilt) of the semiconductor wafer 102 (as held by the pallet 200) that may be achieved using the motors 204, 208, and/or 212 (Figures 2A-2B). For example, two of the regions 404 correspond to respective tilts 300B and 300C (Figures 3B-3C), and thus are examples of regions 304 and 306. The center region 402 corresponds to a null tilt of the semiconductor wafer 102 as held by the pallet 200 (e.g., null tilt 300A, Figure 3A), and thus is an example of the center region 302. The shape of the semiconductor wafer 102 in each region 404 may be measured by the interferometers 106-1 and/or 106-2 (Figure 1) with the semiconductor wafer 102 (as held by the pallet 200) positioned, using the motors 204, 208, and/or 212, to have the respective tilt that corresponds to the region 404 (and suitable translational positioning). The shape of the semiconductor wafer 102 in the center region 402 may be measured by the interferometers 106-1 and/or 106-2 (Figure 1) with the semiconductor wafer 102 (as held by the pallet 200) positioned, using the motors 204, 208, and/or 212, to have the null tilt (and suitable translational positioning).

[0030] For comparison, Figure 5 shows a simulated example of a wafer map 500 for the semiconductor wafer 102 for a scenario in which the motor 212 (Figures 2A-2B) is omitted and replaced with a pivot joint, such that only two motors are available to tilt the pallet 200. In this scenario, tilts may be achieved for the center region 402 and respective regions 504. The interferometers 106-1 and/or 106-2 (Figure 1) may measure the shape of the semiconductor wafer 102 in the center region 402 and the respective regions 504, but not in regions outside of both the respective regions 504 and the center region 402. The respective regions 504 and center region 402 do not collectively cover the semiconductor wafer 102. The interferometers 106-1 and/or 106-2 (Figure 1) thus cannot measure the shape of the entire semiconductor wafer 102 in the absence of the third motor 212.

[0031] Figure 6A is a flowchart showing a method 600A of positioning a semiconductor wafer (e.g., semiconductor wafer 102, Figures 1-4) in an interferometry system (e.g., interferometry system 100, Figure 1) in preparation for measuring the shape (e.g., warpage) of the semiconductor wafer, in accordance with some embodiments. In the method 600A, the semiconductor wafer is held (602) in a pallet between a first interferometer and a second

interferometer. A first side of the semiconductor wafer is exposed to the first interferometer. A second side of the semiconductor wafer is exposed to the second interferometer. A first motor (e.g., motor 204, Figures 2A-2B) is coupled to the pallet at a first position. A second motor (e.g., motor 208, Figures 2A-2B) is coupled to the pallet at a second position. A third motor (e.g., motor 212, Figures 2A-2B) is coupled to the pallet at a third position. In some embodiments, the first interferometer (e.g., interferometer 106-1, Figure 1) is (604) a first Fizeau interferometer and the second interferometer (e.g., interferometer 106-2, Figure 1) is a second Fizeau interferometer.

[0032] The first motor and the second motor are translated (606) to null a tilt of the semiconductor wafer (e.g., to have a null tilt 300A, Figure 3A). Nulling the tilt of the semiconductor wafer may involve translating the first motor and the second motor by different amounts, to tilt the pallet by an amount that nulls the tilt of the semiconductor wafer.

[0033] With the tilt of the semiconductor wafer nulled, the semiconductor wafer is centered (608) between the first interferometer and the second interferometer. To center the semiconductor wafer, the first motor, the second motor, and the third motor are translated (e.g., all three motors are translated the same distance). In some embodiments, the first motor, the second motor, and the third motor are translated (610) to center the semiconductor wafer between a first reference flat 108 (Figure 1) of the first Fizeau interferometer and a second reference flat 108 (Figure 1) of the second Fizeau interferometer, while maintaining the null tilt of the semiconductor wafer. Centering the semiconductor wafer puts the semiconductor wafer (e.g., a center region 402, Figure 4, of the semiconductor wafer) in focus for both the first interferometer and the second interferometer.

[0034] Figure 6B is a flowchart showing a method 600B of measuring the shape (e.g., warpage) of a semiconductor wafer (e.g., semiconductor wafer 102, Figures 1-4) in an interferometry system (e.g., interferometry system 100, Figure 1), in accordance with some embodiments. The method 600B may be performed as a continuation of the method 600A.

[0035] In the method 600B, a plurality of tilts (e.g., including tilts 300B and 300C, Figures 3B-3C, along with other tilts) to be used to measure the shape of the semiconductor wafer in a plurality of respective regions (e.g., the plurality of regions 404 along with the center

region 402, Figure 4) are calculated (612). In some embodiments, the plurality of respective regions collectively covers (614) the entire semiconductor wafer (e.g., as shown in Figure 4).

[0036] In some embodiments, to calculate the plurality of tilts, the shape of a center region (e.g., center region 302, Figure 3A; center region 402, Figure 4) of the semiconductor wafer is measured (616) using at least one of a first interferometer or a second interferometer (e.g., the first and/or second interferometer of step 602 of the method 600A, Figure 6A) (e.g., interferometer 106-1 and/or 106-2, Figure 1). A wafer map of the semiconductor wafer is predicted (618) using the measured shape of the center region. The wafer map shows a predicted shape of the wafer (i.e., predicted heights of the wafer at respective positions on the wafer). The wafer map may be predicted assuming that the semiconductor wafer has a specified shape (e.g., that the shape of the semiconductor wafer is parabolic). For example, the wafer map may be predicted by extrapolating from the shape of the center region based on the assumption that the shape of the entire wafer is as specified (e.g., is parabolic). The plurality of tilts is determined (620) using the predicted wafer map.

[0037] For the plurality of tilts, a plurality of sets of target positions for the first, second, and third motors is calculated (622). Each set of target positions of the plurality of sets of target positions corresponds to a respective tilt of the plurality of tilts.

[0038] The first, second, and third motors (e.g., motors 204, 208, and 212, Figures 2A-2B) are translated (624) to a set of target positions of the plurality of sets of target positions, to position the semiconductor wafer to have a tilt of the plurality of tilts. With the semiconductor wafer positioned to have this tilt, the shape of the semiconductor wafer is measured (626) in a respective region of the plurality of respective regions. If, after measuring the shape of the semiconductor wafer in the respective region, there are any remaining sets of target positions to which the first, second, and third motors have not yet been translated to allow any respective regions to be measured (628-Yes), then a next set of target positions is selected (630) and steps 624, 626, and 628 are performed again. If there are no remaining sets of target positions, (628-No), then the method 600B ends (632).

[0039] The loop for steps 624, 626, 628, and 630 results in translating the first, second, and third motors to each set of target positions of the plurality of sets of target positions, to successively position the semiconductor wafer to have each tilt of the plurality of tilts. And with

the semiconductor wafer successively positioned to have each tilt of the plurality of tilts, the shape of the semiconductor wafer may be measured in each respective region of the plurality of respective regions. A complete measurement of the shape of the semiconductor wafer may thereby be obtained, by compiling the shape measurements for each region (i.e., for the plurality of respective regions).

[0040] The shape-measurement data produced by the method 600B may be used for process control. For example, the measured warpage of the semiconductor wafer 102 may be used for feedback process control, to identify changes to earlier processing steps to reduce the warpage, or variation in warpage, of subsequently processed wafers. In another example, the measured warpage of the semiconductor wafer 102 may be used for feed-forward process control, to identify changes to be made to subsequent processing steps to accommodate the measured warpage. The shape-measurement data may also be used to disposition the semiconductor wafer 102 (e.g., to determine whether to continue to process, rework, or scrap the semiconductor wafer 102).

[0041] Figure 7 is a block diagram of a semiconductor-wafer measurement system 700 in accordance with some embodiments. The semiconductor-wafer measurement system 700 has a semiconductor-wafer measurement tool 730, including one or more (e.g., two) interferometers 732 (e.g., interferometers 106-1 and 106-2, Figure 1) and a tri-motor pallet 734 (e.g., the pallet 200 with motors 204, 208, and 212, Figures 2A-2B).

[0042] The semiconductor-wafer measurement system 700 also includes a computer system 709 (e.g., a local host) with one or more processors 702 (e.g., CPUs), optional user interfaces 706, memory 710, and one or more communication buses 704 interconnecting these components and the semiconductor-wafer measurement tool 730. The user interfaces 706 may include a display 707 and one or more input devices 708 (e.g., a keyboard, mouse, touch-sensitive surface of the display 707, etc.). The display may show results from and the status of the semiconductor-wafer measurement system 700 (e.g., the status of and measurement results from the methods 600A and/or 600B, Figures 6A-6B).

[0043] Memory 710 includes volatile and/or non-volatile memory. Memory 710 (e.g., the non-volatile memory within memory 710) includes a non-transitory computer-readable storage medium. Memory 710 optionally includes one or more storage devices remotely located

from the processor(s) 702 and/or a non-transitory computer-readable storage medium that is removably inserted into the computer system 709. In some embodiments, memory 710 (e.g., the non-transitory computer-readable storage medium of memory 710) stores the following modules and data, or a subset or superset thereof: an operating system 712 that includes procedures for handling various basic system services and for performing hardware-dependent tasks, a motor control module 714 for controlling the motors of the tri-motor pallet 734 (e.g., for controlling the motors 204, 208, and 212, Figures 2A-2B) (e.g., for translating the motors in accordance with the method 600A, Figure 6A; for performing step 624 of the method 600B, Figure 6B), an illumination module 716 for controlling illumination in the interferometer(s) 732 (e.g., for controlling the laser 120, Figure 1), a tilt calculation module 718 (e.g., for calculating the null tilt of step 606 of the method 600A, Figure 6A; for performing step 612 of the method 600B, Figure 6B), a target-position calculation module 720 (e.g., for performing step 622 of the method 600B, Figure 6B), and a wafer measurement module 722 (e.g., for performing step 626 of the method 600B, Figure 6B).

[0044] The memory 710 (e.g., the non-transitory computer-readable storage medium of the memory 710) includes instructions for performing all or a portion of the methods 600A and/or 600B (Figures 6A-6B). Each of the modules stored in the memory 710 corresponds to a set of instructions for performing one or more functions described herein. Separate modules need not be implemented as separate software programs. The modules and various subsets of the modules may be combined or otherwise re-arranged. In some embodiments, the memory 710 stores a subset or superset of the modules and/or data structures identified above.

[0045] Figure 7 is intended more as a functional description of the various features that may be present in the semiconductor-wafer measurement system 700 than as a structural schematic. For example, the functionality of the computer system 709 may be split between multiple devices. All or a portion of the modules stored in the memory 710 may alternatively be stored in one or more other computer systems communicatively coupled with the semiconductor-wafer measurement system 700 through one or more networks.

[0046] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the scope of the claims to the precise forms disclosed. Many

modifications and variations are possible in view of the above teachings. The embodiments were chosen in order to best explain the principles underlying the claims and their practical applications, to thereby enable others skilled in the art to best use the embodiments with various modifications as are suited to the particular uses contemplated.

WHAT IS CLAIMED IS:

1. A system, comprising:
a first interferometer to measure the shape of a first side of a semiconductor wafer;
a pallet to hold the semiconductor wafer and expose the first side of the semiconductor wafer to the first interferometer; and
three motors coupled to the pallet, comprising a first motor coupled to the pallet at a first position, a second motor coupled to the pallet at a second position, and a third motor coupled to the pallet at a third position.
2. The system of claim 1, wherein:
the first position is along a first side of the pallet;
the second position is at a first corner of the pallet;
the third position is at a second corner of the pallet; and
the first corner and the second corner are at opposite ends of a second side of the pallet, wherein the second side is opposite to the first side.
3. The system of claim 1, wherein the first motor, the second motor, and the third motor are translatable in substantially the same direction.
4. The system of claim 3, wherein the same direction is substantially parallel to an optical axis of the first interferometer.
5. The system of claim 1, wherein the first interferometer is a Fizeau interferometer.
6. The system of claim 1, further comprising a second interferometer to measure the shape of a second side of the semiconductor wafer, wherein:
the pallet has an aperture to expose the second side of the semiconductor wafer to the second interferometer; and
the pallet is to hold the semiconductor wafer between the first interferometer and the second interferometer.
7. The system of claim 6, wherein:
the first interferometer is a first Fizeau interferometer; and

the second interferometer is a second Fizeau interferometer.

8. The system of claim 7, wherein the first motor, the second motor, and the third motor are translatable in substantially the same direction.

9. The system of claim 8, wherein the same direction is substantially parallel to optical axes of the first interferometer and the second interferometer.

10. A method, comprising:

holding a semiconductor wafer in a pallet between a first interferometer and a second interferometer, wherein:

a first side of the semiconductor wafer is exposed to the first interferometer,
a second side of the semiconductor wafer is exposed to the second interferometer,
a first motor is coupled to the pallet at a first position,
a second motor is coupled to the pallet at a second position, and
a third motor is coupled to the pallet at a third position;

translating the first motor and the second motor to null a tilt of the semiconductor wafer;
and

with the tilt of the semiconductor wafer nulled, centering the semiconductor wafer between the first interferometer and the second interferometer, comprising translating the first motor, the second motor, and the third motor.

11. The method of claim 10, wherein:

the first interferometer is a first Fizeau interferometer comprising a first reference flat;
the second interferometer is a second Fizeau interferometer comprising a second reference flat; and

centering the semiconductor wafer between the first interferometer and the second interferometer comprises translating the first motor, the second motor, and the third motor to center the semiconductor wafer between the first reference flat and the second reference flat.

12. The method of claim 10, wherein:

the first position is along a first side of the pallet;
the second position is at a first corner of the pallet;

the third position is at a second corner of the pallet; and
the first corner and the second corner are at opposite ends of a second side of the pallet,
wherein the second side is opposite to the first side.

13. The method of claim 10, further comprising, after centering the semiconductor wafer between the first interferometer and the second interferometer:

calculating a plurality of tilts to be used to measure the shape of the semiconductor wafer in a plurality of respective regions;

for the plurality of tilts, calculating a plurality of sets of target positions for the first, second, and third motors, wherein each set of target positions of the plurality of sets of target positions corresponds to a respective tilt of the plurality of tilts;

translating the first, second, and third motors to each set of target positions of the plurality of sets of target positions, to successively position the semiconductor wafer to have each tilt of the plurality of tilts; and

with the semiconductor wafer successively positioned to have each tilt of the plurality of tilts, measuring the shape of the semiconductor wafer in each respective region of the plurality of respective regions.

14. The method of claim 13, wherein the plurality of respective regions collectively covers the entire semiconductor wafer.

15. The method of claim 13, wherein calculating the plurality of tilts comprises:

measuring the shape of a center region of the semiconductor wafer, using at least one of the first interferometer or the second interferometer;

predicting a wafer map of the semiconductor wafer using the measured shape of the center region; and

determining the plurality of tilts using the predicted wafer map.

16. The method of claim 15, wherein predicting the wafer map comprises assuming that the semiconductor wafer has a parabolic shape.

17. A system, comprising:

a first interferometer;

a second interferometer;

a pallet to hold a semiconductor wafer between the first interferometer and the second interferometer with a first side of the semiconductor wafer exposed to the first interferometer and a second side of the semiconductor wafer exposed to the second interferometer;

three motors coupled to the pallet, comprising a first motor coupled to the pallet at a first position, a second motor coupled to the pallet at a second position, and a third motor coupled to the pallet at a third position;

one or more processors; and

memory storing one or more programs for execution by the one or more processors, the one or more programs comprising instructions for:

translating the first motor and the second motor to null a tilt of the semiconductor wafer; and

with the tilt of the semiconductor wafer nulled, centering the semiconductor wafer between the first interferometer and the second interferometer, comprising translating the first motor, the second motor, and the third motor.

18. The system of claim 17, wherein:

the first interferometer is a first Fizeau interferometer comprising a first reference flat;

the second interferometer is a second Fizeau interferometer comprising a second reference flat; and

the instructions for centering the semiconductor wafer between the first interferometer and the second interferometer comprise instructions for translating the first motor, the second motor, and the third motor to center the semiconductor wafer between the first reference flat and the second reference flat.

19. The system of claim 17, wherein:

the first position is along a first side of the pallet;

the second position is at a first corner of the pallet;

the third position is at a second corner of the pallet; and

the first corner and the second corner are at opposite ends of a second side of the pallet, wherein the second side is opposite to the first side.

20. The system of claim 17, the one or more programs further comprising instructions, to be executed after centering the semiconductor wafer between the first interferometer and the second interferometer, for:

calculating a plurality of tilts to be used to measure the shape of the semiconductor wafer in a plurality of respective regions;

for the plurality of tilts, calculating a plurality of sets of target positions for the first, second, and third motors, wherein each set of target positions of the plurality of sets of target positions corresponds to a respective tilt of the plurality of tilts;

translating the first, second, and third motors to each set of target positions of the plurality of sets of target positions, to successively position the semiconductor wafer to have each tilt of the plurality of tilts; and

with the semiconductor wafer successively positioned to have each tilt of the plurality of tilts, measuring the shape of the semiconductor wafer in each respective region of the plurality of respective regions.

21. The system of claim 20, wherein the plurality of respective regions collectively covers the entire semiconductor wafer.

22. The system of claim 20, wherein the instructions for calculating the plurality of tilts comprise instructions for:

measuring the shape of a center region of the semiconductor wafer, using at least one of the first interferometer or the second interferometer;

predicting a wafer map of the semiconductor wafer using the measured shape of the center region; and

determining the plurality of tilts using the predicted wafer map.

23. The system of claim 22, wherein the instructions for predicting the wafer map assume that the semiconductor wafer has a parabolic shape.