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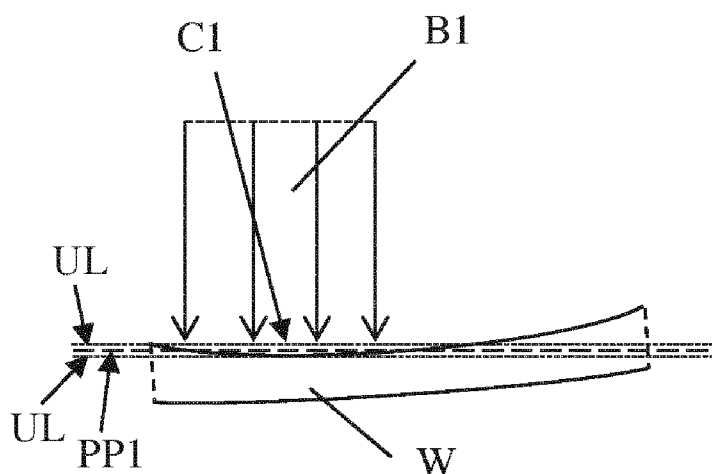
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- (54) Title: LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD

Figure 3c



(57) Abstract: A lithographic apparatus to image a pattern onto a target portion of a substrate includes a control system operative to move a support supporting the substrate and configured to determine whether flatness data of the target portion complies with a requirement, wherein, in case the data of the target portion complies with the requirement, the system is operative to move the support in a projection orientation, and wherein, in case the data of the target portion does not comply with the requirement, the system is operative to determine a first part of the target portion and a second part of the target portion of which portions the data complies with the requirement, and wherein the system is operative to move, in a first projection step, the support in a first projection orientation, and to move, in a second projection step, the support in a second projection orientation.

LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD

BACKGROUND

5 Cross-reference to related applications

This application claims priority of EP application 15176421.4 which was filed on 13 July 2015 and which is incorporated herein in its entirety by reference.

Field of the Invention

10 The present invention relates to a lithographic apparatus and a device manufacturing method.

Description of the Related Art

A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually
15 onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. including part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via
20 imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned. Conventional lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion at once, and so-called scanners, in which each target portion is irradiated by scanning the pattern through a radiation beam in a given
25 direction (the “scanning”-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction. It is also possible to transfer the pattern from the patterning device to the substrate by imprinting the pattern onto the substrate.

In the known lithographic apparatus a substrate support is provided to support a substrate during transfer of a pattern of the patterning device onto the substrate. To ensure that the pattern is
30 properly transferred from the patterning device to the target portion of the substrate, it is of importance that the upper surface is properly aligned with the patterned beam incident on the upper

surface.

Unflatness of the upper surface of the substrate is therefore undesirable. However, in practice the upper surface of the substrate may be unflat for example caused by wafer shape deformation or by unflatness of the support surface supporting the substrate.

5 To compensate the effect of the unflatness of the upper surface of the substrate, the relative position of the substrate with respect to the patterned beam incident on the substrate is adjusted to improve the position of the target portion with respect to the patterned beam. For each target portion a suitable projection orientation may be determined. In this projection orientation a plane may be suitably aligned with the patterned beam. This so-called leveling may compensate first
10 order unflatness of the upper surface of the substrate within the target portion.

However within a target portion, also higher order unflatness of the upper surface of the substrate loaded on the substrate support may occur. This means that within the target portion the unflatness may not sufficiently be compensated by defining a suitable projection plane and associated projection orientation. The focus error in such projection orientation may still be
15 unacceptable large and, as a result, dies within this target portion may not be approved.

SUMMARY

It is desirable to provide a lithographic apparatus that is capable of improving the yield of substrates.

20 Furthermore, it is desirable to provide a device manufacturing method that is capable of taking unflatness of the upper surface of a substrate into account in order to increase yield of a substrate.

According to an aspect of the invention, there is provided a lithographic apparatus configured to image a pattern via a projection system onto a target portion of a substrate, wherein
25 the lithographic apparatus comprises:

a support constructed to support the substrate, and

a control system operative to move the support during imaging of the pattern ,

wherein the control system is configured to determine whether flatness data of the target portion complies with a pre-determined requirement,

30 wherein, in case the flatness data of the target portion complies with a pre-determined requirement, the control system is operative to move the support in a projection orientation during

projection of the pattern onto the target portion, and

wherein, in case the flatness data of the target portion does not comply with the pre-determined requirement, the control system is operative to determine at least a first part of the target portion of which the flatness data complies with the pre-determined requirement and a second part of the target portion of which the flatness data complies with the pre-determined requirement, and wherein the control system is operative to move, in a first projection step, the support in a first projection orientation during projection of the pattern onto the first part the target portion, and to move, in a second projection step, the support in a second projection orientation during projection of the pattern onto a second part the target portion.

According to an aspect of the invention, there is provided a device manufacturing method comprising transferring a pattern from a patterning device onto a target portion of a substrate, wherein the method comprises the steps of:

determining whether flatness data of the target portion complies with a pre-determined requirement,

in case the flatness data of the target portion complies with a pre-determined requirement, moving the support in a projection orientation during projection of the pattern onto the target portion, and

in case the flatness data of the target portion does not comply with the pre-determined requirement, determining at least a first part of the target portion of which the flatness data complies with the pre-determined requirement and a second part of the target portion of which the flatness data complies with the pre-determined requirement, moving, in a first projection step, the support in a first projection orientation during projection of the pattern onto a first part the target portion, and moving, in a second projection step, the support in a second projection orientation during projection of the pattern onto a second part the target portion.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

- Figure 1 depicts a lithographic apparatus according to an embodiment of the invention;
- Figures 2a and 2b depict a cross section of a substrate at a first target portion of a substrate;

- Figures 3a, 3b, 3c and 3d depict a cross section of the substrate at a second target portion of a substrate; and
- Figures 4, 5, 6 and 7 show top views of three adjacent target portions on a substrate and a sequence of scanning movements to transfer a pattern to the substrate.

5

DETAILED DESCRIPTION

Figure 1 schematically depicts a lithographic apparatus according to one embodiment of the invention. The apparatus includes an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. UV radiation or any other suitable radiation), a mask support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask) MA and connected to a first positioning system PM configured to accurately position the patterning device in accordance with certain parameters. The apparatus also includes a substrate table (e.g. a wafer table) WT or "substrate support" constructed to hold a substrate (e.g. a resist-coated wafer) W and connected to a second positioning system PW configured to accurately position the substrate in accordance with certain parameters. The apparatus further includes a projection system (e.g. a refractive projection lens system) PS configured to project a pattern imparted to the radiation beam B by patterning system MA onto a target portion C (e.g. including one or more dies) of the substrate W.

The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

The mask support structure supports, i.e. bears the weight of, the patterning device. It holds the patterning device in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The mask support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The mask support structure may be a frame or a table, for example, which may be fixed or movable as required. The mask support structure may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of the terms "reticle" or "mask" herein may be considered synonymous with the more general term "patterning device."

The term "patterning device" used herein should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section so as to create

a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the radiation beam may not exactly correspond to the desired pattern in the target portion of the substrate, for example if the pattern includes phase-shifting features or so called assist features. Generally, the pattern imparted to the radiation beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

The term "projection system" used herein should be broadly interpreted as encompassing any type of projection system, including refractive, reflective, catadioptric, magnetic, electromagnetic and electrostatic optical systems, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of an immersion liquid or the use of a vacuum. Any use of the term "projection lens" herein may be considered as synonymous with the more general term "projection system".

As here depicted, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above, or employing a reflective mask).

The lithographic apparatus may be of a type having two (dual stage) or more substrate tables or "substrate supports" (and/or two or more mask tables or "mask supports"). In such "multiple stage" machines the additional tables or supports may be used in parallel, or preparatory steps may be carried out on one or more tables or supports while one or more other tables or supports are being used for exposure.

The lithographic apparatus may also be of a type wherein at least a portion of the substrate may be covered by a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the projection system and the substrate. An immersion liquid may also be applied to other spaces in the lithographic apparatus, for example, between the mask and the projection system. Immersion techniques can be used to increase the numerical aperture of projection systems. The

term “immersion” as used herein does not mean that a structure, such as a substrate, must be submerged in liquid, but rather only means that a liquid is located between the projection system and the substrate during exposure.

Referring to figure 1, the illuminator IL receives a radiation beam from a radiation source
5 SO. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source SO to the illuminator IL with the aid of a beam delivery system BD including, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the lithographic
10 apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, together with the beam delivery system BD if required, may be referred to as a radiation system.

The illuminator IL may include an adjuster AD configured to adjust the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in a pupil
15 plane of the illuminator can be adjusted. In addition, the illuminator IL may include various other components, such as an integrator IN and a condenser CO. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

The radiation beam B is incident on the patterning device (e.g., mask MA), which is held on
20 the mask support structure (e.g., mask table MT), and is patterned by the patterning device. Having traversed the mask MA, the radiation beam B passes through the projection system PS, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioning system PW and position sensor IF (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g. so as to position different target
25 portions C in the path of the radiation beam B. Similarly, the first positioning system PM and another position sensor (which is not explicitly depicted in Figure 1) can be used to accurately position the mask MA with respect to the path of the radiation beam B, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the mask table MT may be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine
30 positioning), which form part of the first positioning system PM. Similarly, movement of the substrate table WT or "substrate support" may be realized using a long-stroke module and a

short-stroke module, which form part of the second positioner PW. In the case of a stepper (as opposed to a scanner) the mask table MT may be connected to a short-stroke actuator only, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2. Although the substrate alignment marks as illustrated occupy
5 dedicated target portions, they may be located in spaces between target portions (these are known as scribe-lane alignment marks). Similarly, in situations in which more than one die is provided on the mask MA, the mask alignment marks may be located between the dies.

Figure 2a and 3a show cross sections of a part of a substrate W and a radiation beam B incident onto a target portion C of the substrate W. To properly transfer the pattern of the
10 patterning device MA to the target portion C, the positioning system PW of Figure 1 is configured to hold the target portion C aligned with the projection system PS during projection of the pattern onto the target portion C of the substrate C.

In practice, unflatness of the target portion C occurs. For example, the substrate W may be warped, or any unflatness of a support surface of the substrate support WT may cause unflatness of
15 the upper surface of the substrate W, when this substrate W is loaded on the substrate support WT.

It is known to adjust the orientation of the target portion C of the substrate 20 for each target portion C of the substrate, i.e. for each target portion C a projection orientation of the target portion C is determined and the substrate support WT is moved to hold the target position C in this projection orientation for the optimal transfer of the desired pattern onto the substrate W.

This so-called leveling is in particular useful if the unflatness within the target portion C can
20 be modeled as a first order unflatness so that the surface of the target portion C can be properly estimated by a plane. This estimated plane for a respective target portion C is herein described as a projection plane.

To determine the projection orientation for each target portion, a measuring system MD is
25 provided in the lithographic apparatus LA. This measuring system MD is configured to determine a height map of the upper surface of the substrate W before the transfer of a pattern onto the substrate is started. On the basis of this height map, the control system CD may determine for each target portion C, an projection orientation, and actuate the positioning system PW to position the substrate W in this projection orientation during transfer of the pattern onto the respective target
30 portion C.

But in this projection orientation, there may be a difference between the height of the

projection plane PP and the actual local height of a location within the target portion C. When this difference is large, the projection beam B may be out of focus with respect to this specific location within the target portion C. As a result, the dies within this target portion may not fulfill production requirements.

5 In Figures 2b and 3b, the target portions C of Figures 2a and 3a, are depicted with an estimated projection plane PP and held in the associated projection orientation so that the beam B is suitably focused on the surface of the target portion C.

In order to avoid or at least decrease focus errors during the transfer of the pattern to the target portion, there is defined a maximum allowable height deviation, i.e. a flatness requirement,
10 between the projection plane PP and the actual local height of a location of the target portion C.

In the lithographic apparatus LA of Figure 1, the control system CD is configured to determine for each target portion C whether this respective target portion C fulfills the flatness requirements. Hereto the control system CD uses the height map of the substrate W to determine the projection plane PP of each target portion C and to determine for each target portion C whether
15 the height deviation of any location within the target portion C with respect to the projection plane PP does not fulfill the flatness requirement.

The maximum allowed deviation is indicated in Figures 2b and 3b by upper and lower unflatness limit lines UL that run parallel to the projection plane PP.

It can be seen that the target portion C, i.e. the area of the surface of the substrate W on which
20 the radiation beam is incident, of Figure 2b completely falls within the unflatness limit lines UL, and therewith fulfills the flatness requirement. However, the target portion C of Figure 3b does not fall within the upper and lower unflatness limits UL and therefore does not fulfill the flatness requirement.

Since in the cross section of Figure 2b the flatness requirement is fulfilled, the target portion
25 C can be arranged in the projection orientation and the pattern can be projected onto the target portion C in a single scanning movement.

In the cross section of Figure 3b, the flatness requirement is not fulfilled since parts of the target portion are not within the unflatness limit lines UL. When the pattern would be transferred onto the target portion C, there is a considerable risk that the projection will be substantially out of
30 focus.

In accordance with the invention, the control system CD is operative to determine at least a

first part C1 of the target portion and a second part C2 of the target portion, wherein for each of the first part C1 and the second part C2 of the target portion the flatness requirement is fulfilled. The first part C1 of the target portion and the second part C2 of the target portion are shown in Figures 3c and 3d, whereby for each part C1, C2 of the target portion, upper and lower flatness limits UL
5 are indicated. It can be seen that for each part C1, C2 of the target portion, the flatness requirement is fulfilled. For the first part C1 of the target portion and the second part C2 of the target portion, a respective projection plane PP1, PP2 may be determined.

The pattern of the patterning device MA can now be projected on the target portion C in two projection steps.

10 In the first projection step, shown in Figure 3c, the first part C1 of the target portion is positioned by the positioning system PW in a first projection orientation, and a first part of the pattern is projected onto the first part C1 of the target portion.

To transfer only the first part of the pattern associated with the first part C1 of the target portion, only a beam part B1 of the beam B is incident on the surface of the substrate W. The rest of
15 the beam B is blocked by a light blocking system LBD (shown in Figure 1). This light blocking system LBD is configured to selectively block a part of the radiation beam B. For example, a so-called REMA blade system may be used for blocking a part of the radiation beam B. Such REMA blade system may block, by using one or more light blocking blades, parts of the radiation beam to obtain a radiation beam having a desired cross section. Also other suitable systems may be
20 used, such as a mechanism configured to control the spatial uniformity or non-uniformity of the illumination across the illumination slit. Such a mechanism employs one or more blades or fingers to at least partially block light from the radiation beam B in order to obtain a desired radiation beam. An example of such latter mechanism is referred to as "Unicom".

The expression "REMA blade" stands for "reticle masking blade". A REMA blade is a
25 component of a reticle masking (REMA) unit of a lithographic apparatus. The REMA unit is used to limit the projection beam to the desired projection window used for projection of the pattern on the reticle onto the target portion of the substrate. The REMA blocks light from specific areas of the reticle during a scan with metal blades, e.g., two Y-blades in the scan-direction (Y direction), and two X-blades perpendicular to the scan direction and extending in the X-direction. The
30 X-blades are not scanning, the Y-blades are scanning. For background information on REMA, please see, e.g., US patent application publication 20040239283 of Daniel N. Galburt et al., which

is incorporated herein by reference.

The expression “Unicom” stands for “uniformity correction mechanism” and refers to a module that is used to improve uniformity of the illumination across the illumination slit at the reticle level. The module is mounted in front of the REMA unit and is operative to control the uniformity. For some background information on the Unicom see, e.g., US patent application publication 20130022901 of Erik Petrus Buurman et al., and US patent application publication 20060126036 of Alexander Kremer et al., both documents incorporated herein by reference.

In the second projection step, shown in Figure 3d, the target portion C is positioned by the positioning system PW in a second projection orientation, and a second part of the pattern is projected onto the second part C2 of the target portion. In this second projection step only a beam part B2 of the beam B is incident on the surface of the substrate W to transfer only the second part of the pattern associated with the second part C2 of the target portion. The rest of the beam B, i.e. beam part B1, is blocked by the light blocking system LBD.

By using in the projection of the pattern a first projection step and a second projection step, whereby in each step a part of the pattern is transferred to the target portion C, it is ensured that the complete pattern is transferred to the target portion, while at the same time the flatness requirement is fulfilled.

In the above example the target portion C is split in two parts C1, C2 and the beam B is split in two distinct parts B1, B2, that are adjacent to each other and have substantially the same cross section. The subdivision may also be different. For example, the target portion may be subdivided in two parts having different size. Also, the target portion may be subdivided in three or more part of the target portions, having the same size or different sizes.

It is advantageous to arrange the transition line, i.e. the dividing line of the first part C1 of the target portion and the second part C2 of the target portion in an area between two dies. If this is not possible, it may be advantageous to make the two beam parts B1, B2 to have an overlapping area. Thereby a smooth dose decrease in the two beam parts B1, B2 in the overlapping area towards the edge may be provided to further create a smooth transition between the first part of the pattern and the second part of the pattern transferred to the target portion C.

Figure 4 shows a top view of three adjacent target portions C, each comprising four dies. For each of the target portions C, it is determined by the control system CD, as described above, whether the flatness requirements are fulfilled. In the embodiment of Figure 4, the flatness

requirement is fulfilled for each of the target portions C. As a result, the pattern of the patterning device MA can be transferred onto each target portion C during a single scanning movement over the respective target portion C, while the projection plane PP is held in an projection orientation. The three subsequent scanning movements are indicated by dashed arrows in Figure 4.

Figure 5 also shows a top view of three adjacent target portions C, whereby the middle target portion C does not fulfill the flatness requirement and the other two adjacent target portions C fulfill the flatness requirement. When the control system CD determines that the middle target portion C does not fulfill the flatness requirement, it will determine for the middle target portion C two or more part of the target portions for each of which the flatness requirement is fulfilled.

In the embodiment of Figure 5, the target portion C is split in two parts. Projection of the pattern onto these two parts of the target portion will be carried out in two projection steps. Each projection step requires a scanning movement of the substrate W with respect to the projection system PS. A possible sequence of movements is shown in Figure 5.

In a first scanning movement the pattern is transferred onto the left-side target portion C, in a second scanning movement a first part of the pattern is transferred onto the first part of the middle target portion C, in a third scanning movement a second part of the pattern is transferred onto the second part of the middle target portion C, and in a fourth scanning movement the pattern is transferred onto the right-side target portion C.

The consequence of the double scanning movement over the middle target portion C shown in Figure 5 is that the direction of the scanning movement over the right-side target portion and all following target portions is opposite to the scanning direction in case the flatness requirement is fulfilled (Figure 4). Also, the scanning movements over the first part of the target portion and the second part of the target portion are in opposite directions. If this is undesirable, other scanning movement sequences can be used as for example shown in Figures 6 and 7.

In Figure 6, it is shown that between the second scanning movement in which a first part of the pattern is transferred onto the first part of the middle target portion C, and the third scanning movement in which a second part of the pattern is transferred onto the second part of the middle target portion C, the substrate is moved back to the other side of the middle target portion C. This movement is indicated by a solid line. As a result, the second scanning movement and the third scanning movement are in the same direction, and the fourth scanning movement over the right-side target portion C is in the same direction as in Figure 4.

In Figure 7, it is shown that after the second scanning movement in which a first part of the pattern is transferred onto the first part of the middle target portion C, the scanning movement in which a second part of the pattern is transferred onto the second part of the middle target portion C is skipped. After the second scanning movement, the transfer of the pattern onto the right-side target portion C is directly started.

The pattern transfer process will later return to the middle target portion C in order to transfer the second part of the pattern onto the second part of the middle target portion C. This scanning movement can be carried out in the same direction as the second scanning movement, as shown in Figure 7, or in the opposite direction.

The scanning movement over the right-side target portion C is in the same direction as in Figure 4.

Hereinabove, flatness data of the target portion is used in order to predict the imaging quality obtained during imaging of a pattern onto a target portion, and to take proper action when required. In the shown embodiments this flatness data is flatness data representative for the flatness of the target portion of the substrate itself. In other embodiments this flatness data may also be related to data that is relevant for the "flatness" of the pattern projected by the radiation beam. This flatness may for example be influenced by the shape of the patterning device MA or a curvature induced by the lens PS. Such flatness may also be measured and taken into account when the flatness data is compared with the pre-determined requirement.

Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the term "wafer" herein may be considered as synonymous with the more general terms "substrate", respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology tool and/or an inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already

contains multiple processed layers.

Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention may be used in other applications, for example imprint lithography, and where the context allows, is not limited to optical lithography. In imprint lithography a topography in a patterning device defines the pattern created on a substrate. The topography of the patterning device may be pressed into a layer of resist supplied to the substrate whereupon the resist is cured by applying electromagnetic radiation, heat, pressure or a combination thereof. The patterning device is moved out of the resist leaving a pattern in it after the resist is cured.

The terms “radiation” and “beam” used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of or about 365, 248, 193, 157 or 126 nm) and extreme ultra-violet (EUV) radiation (e.g. having a wavelength in the range of 5-20 nm), as well as particle beams, such as ion beams or electron beams.

The term “lens”, where the context allows, may refer to any one or combination of various types of optical components, including refractive, reflective, magnetic, electromagnetic and electrostatic optical components.

While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the invention may take the form of a computer program containing one or more sequences of machine-readable instructions describing a method as disclosed above, or a data storage medium (e.g. semiconductor memory, magnetic or optical disk) having such a computer program stored therein.

The descriptions above are intended to be illustrative, not limiting. Thus, it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

WHAT IS CLAIMED IS:

1. A lithographic apparatus configured to image a pattern via a projection system onto a target portion of a substrate, wherein the lithographic apparatus comprises:

5 a support constructed to support the substrate, and

a control system operative to move the support during imaging of the pattern ,

wherein the control system is configured to determine whether flatness data of the target portion complies with a pre-determined requirement,

10 wherein, in case the flatness data of the target portion complies with a pre-determined requirement, the control system is operative to move the support in a projection orientation during projection of the pattern onto the target portion, and

wherein, in case the flatness data of the target portion does not comply with the pre-determined requirement, the control system is operative to determine at least a first part of the target portion of which the flatness data complies with the pre-determined requirement and a
15 second part of the target portion of which the flatness data complies with the pre-determined requirement, and wherein the control system is operative to move, in a first projection step, the support in a first projection orientation during projection of the pattern onto the first part the target portion, and to move, in a second projection step, the support in a second projection orientation during projection of the pattern onto a second part the target portion.

20 2. The lithographic apparatus of claim 1, wherein the lithographic apparatus comprises a light blocking system configured to block partially the radiation beam, and wherein the light blocking system is configured to block, in the first projection step, a first part of the radiation beam running to the second part of the target portion, and wherein the light blocking system is configured to
25 block, in the second projection step, a second part of the radiation beam running to the first part of the target portion.

3. The lithographic apparatus of claim 1, wherein the first part of the target portion and the second part of the target portion cover the complete target portion.

30 4. The lithographic apparatus of claim 1, wherein the first part of the target portion and the

second part of the target portion are adjacent or wherein the first part of the target portion and the second part of the target portion partially overlap.

5. The lithographic apparatus of claim 1, wherein the pattern to be projected onto the target portion comprises multiple dies, and wherein only complete dies of the pattern fall within the first part of the target portion and within the second part of the target portion.

6. The lithographic apparatus of claim 1, wherein the control system is operative to move the support in a scanning movement during projection of the pattern onto the target portion of the substrate.

7. A device manufacturing method comprising transferring a pattern from a patterning device onto a target portion of a substrate, wherein the method comprises the steps of:

determining whether flatness data of the target portion complies with a pre-determined requirement,

in case the flatness data of the target portion complies with a pre-determined requirement, moving the support in a projection orientation during projection of the pattern onto the target portion, and

in case the flatness data of the target portion does not comply with the pre-determined requirement, determining at least a first part of the target portion of which the flatness data complies with the pre-determined requirement and a second part of the target portion of which the flatness data complies with the pre-determined requirement, moving, in a first projection step, the support in a first projection orientation during projection of the pattern onto a first part the target portion, and moving, in a second projection step, the support in a second projection orientation during projection of the pattern onto a second part the target portion.

8. The method of claim 7, wherein the method comprises:

blocking, in the first projection step, a first part of the radiation beam running to the second part of the target portion, and

blocking, in the second projection step, a second part of the radiation beam running to the first part of the target portion.

9. The method of claim 7, wherein the first projection step and the second projection step are subsequent projection steps.
10. The method of claim 7, wherein the method comprises projecting the pattern onto further
5 target portions between the first projection step and the second projection step.
11. The method of claim 7, wherein the first part of the target portion and the second part of the target portion cover the complete target portion.
- 10 12. The method of claim 7, wherein the method comprises carrying out a scanning movement during transfer of the pattern onto the target portion.
13. The method of claim 12, wherein the scanning movement during the first projection step and the scanning movement during the second projection step are in the same direction or in an
15 opposite direction.
14. The method of claim 7, comprising the step of providing flatness data of the target portion representative for flatness of the target portion.
- 20 15. The method of claim 14, wherein the step of providing flatness data comprises measuring flatness of one or more target portions.
16. A device manufacturing method comprising repeating the steps of claim 7 for each target portion of the substrate.

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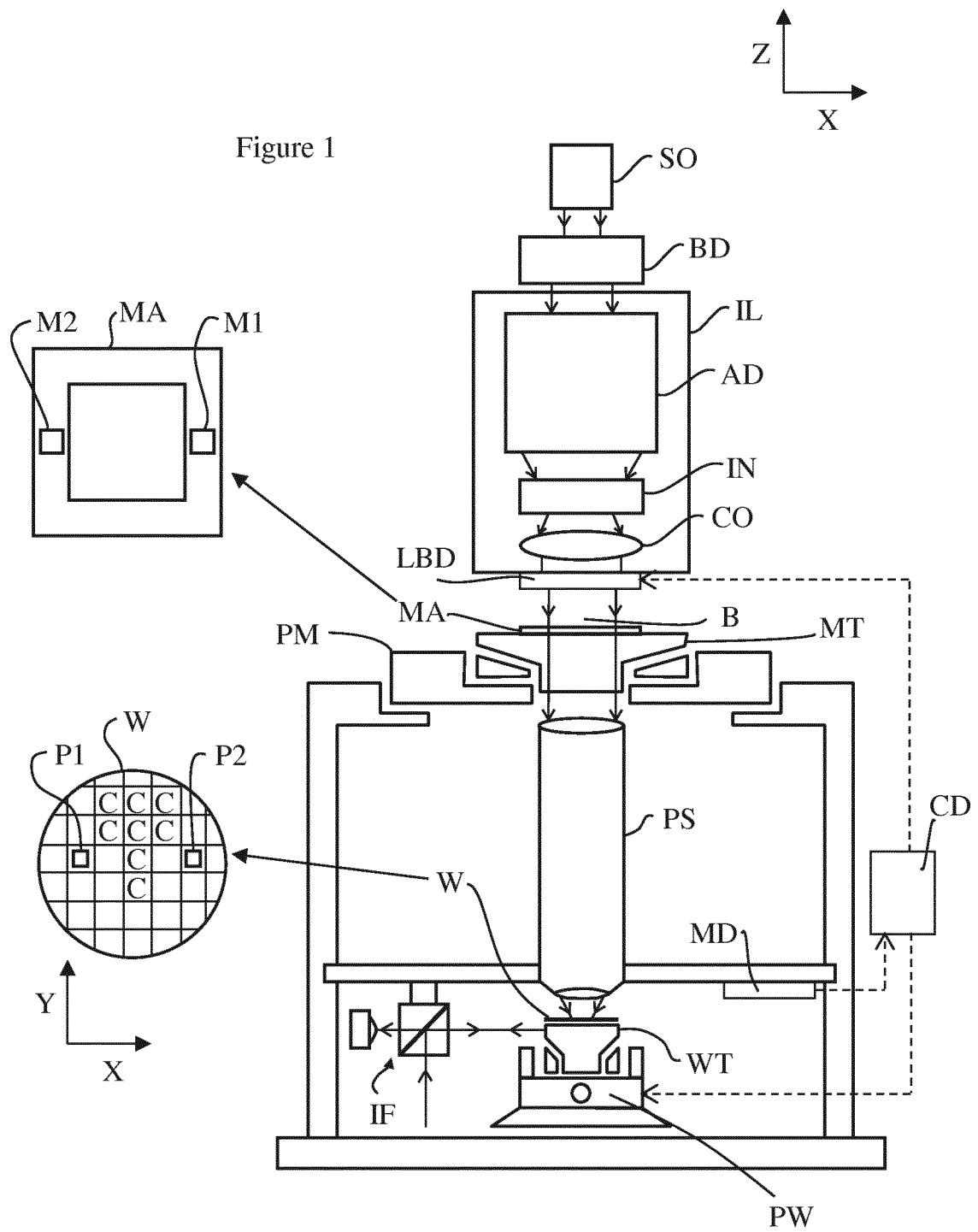


Figure 2a

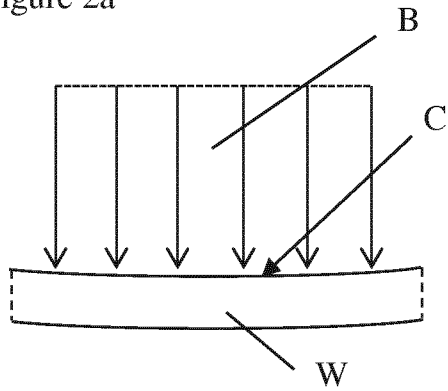


Figure 2b

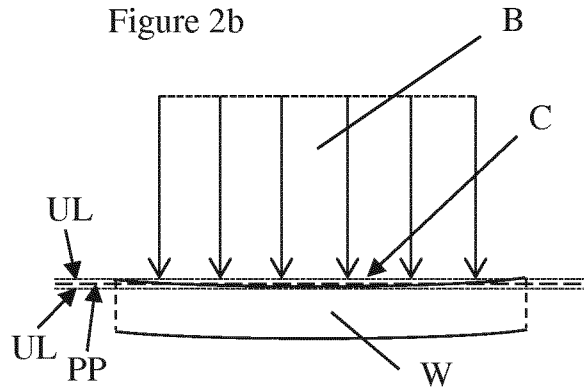


Figure 3a

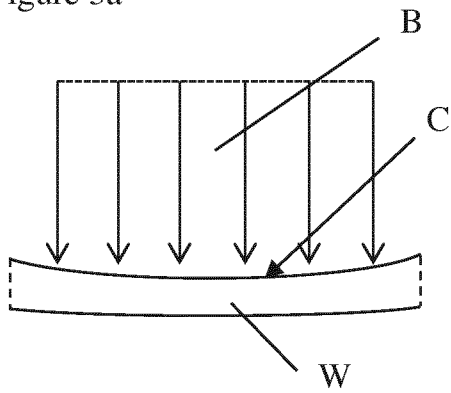


Figure 3b

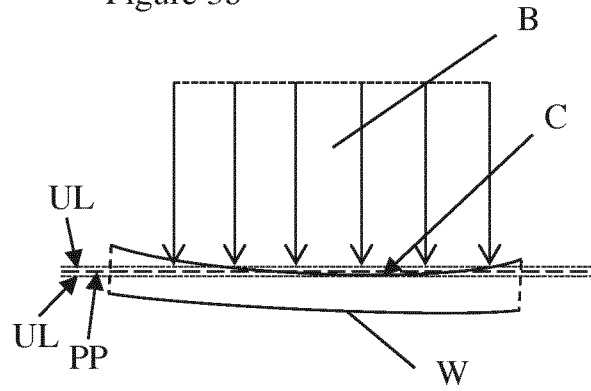


Figure 3c

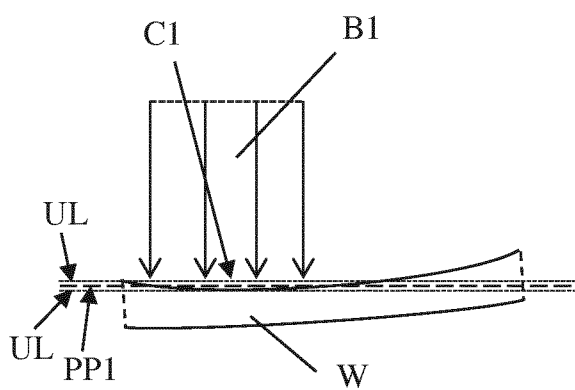


Figure 3d

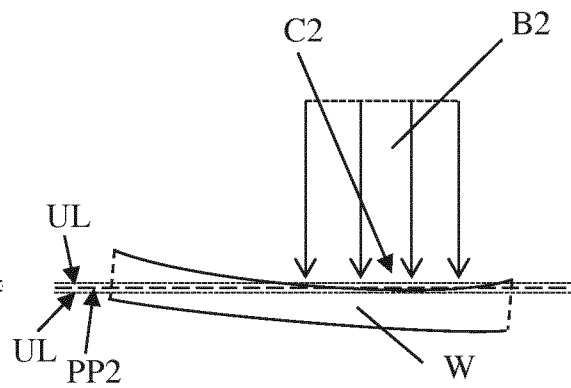


Figure 4

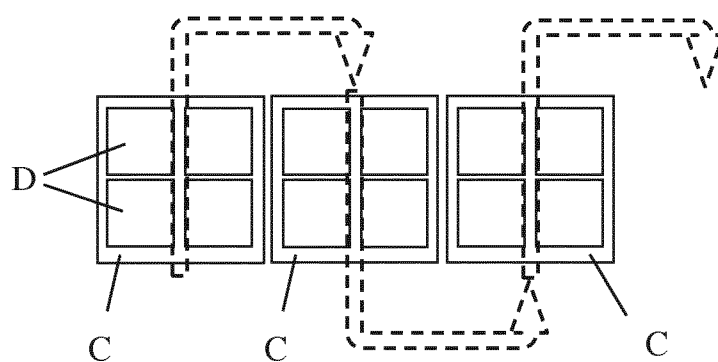


Figure 5

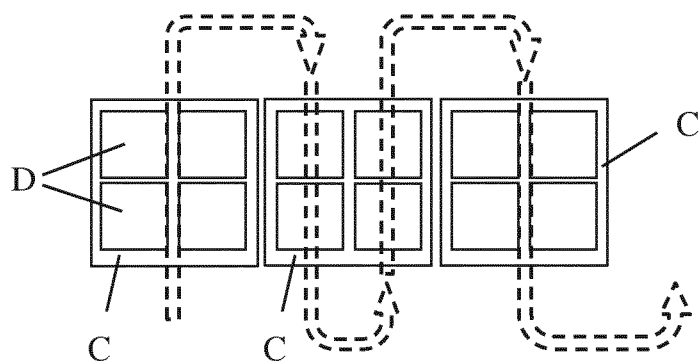


Figure 6

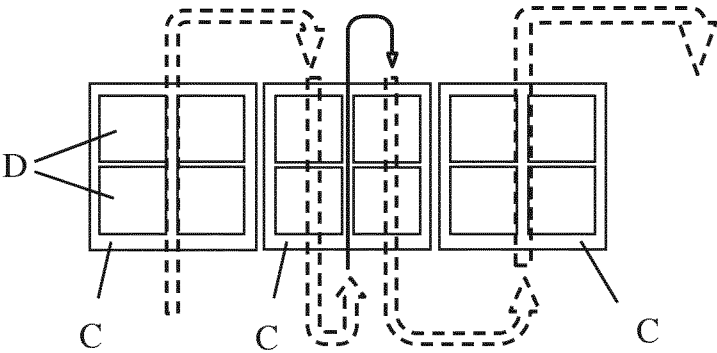
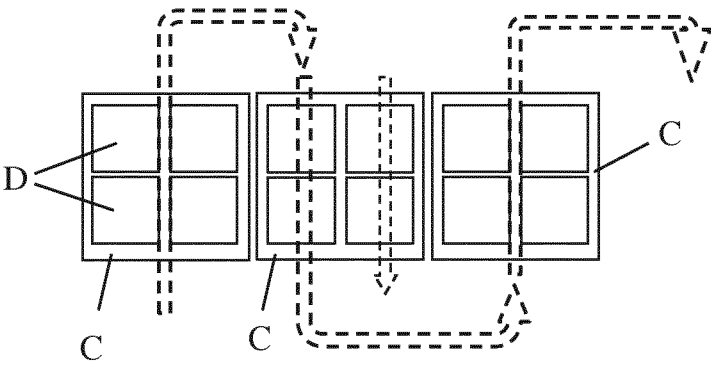


Figure 7



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/063238

A. CLASSIFICATION OF SUBJECT MATTER

INV. G03F7/20 G03F9/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/285099 A1 (SINKE ARNOLD [NL] ET AL) 21 December 2006 (2006-12-21) abstract paragraphs [0007], [0008], [0039] - [0067]; figures 2-4	1-16
X	US 2009/190108 A1 (EMA TATSUHIKO [US] ET AL) 30 July 2009 (2009-07-30) abstract paragraphs [0033] - [0038]; figures 7,8	1-4,6-9, 11-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 September 2016

Date of mailing of the international search report

30/09/2016

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Weckesser, Jens

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/063238

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