Process, apparatus and device

Field of the invention

The present invention relates to a process and an apparatus as well as a device. This application claims priority from US patent application 11/607,098, filed on 2006.12.01 ,which is hereby incorporated by reference.

Background of the invention

[0001] A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, 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. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via 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. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion at one time, and so-called scanners, in which each target portion is irradiated by scanning the pattern through a radiation beam in a given 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.

[0002] A mask is typically fabricated by electron beam lithography, in which a desired mask pattern is created on a photosensitive layer on the mask by means of controlled exposure of that layer to the electron beam (e-beam writing process). The pattern in the photosensitive layer is then transferred in a mask pattern layer which is typically a metal layer arranged on a transparent mask base layer.

[0003] It is known that due to the lithographic process the created mask pattern layer may exhibit some distortions or defects. Typical causes of defects are, for example, stress induced distortion (of the mask pattern layer), heating induced distortion during the e-beam writing process or distortions caused by a pellicle that is placed over the mask.

[0004] The creation of the IC involves the creation of a number of patterns overlaying each other in the target portion. The patterns overlaying eachother typically have been created with different mask patterns each on a different mask. The mask patterns each have their own distortions or defects. During a transfer of the mask patterns to the target portion, the distortions will be transferred along with the mask patterns into the pattern created on the target portion. The overlaying patterns on the target portions therefore are typically associated with different distortions contributing to overlay errors within the target portion. Such overlay errors are often referred to as intra-field overlay errors.

Brief Summary of the Invention

[0005] It is desirable to have an apparatus and a process which are capable of reducing or correcting the contribution of mask pattern distortions or defects to distortions of exposed patterns.

[0006] According to an aspect of the invention, there is provided a process for creating overlapping patterns on a target field of a substrate, comprising;
- providing overlay errors between the overlapping patterns, the provided overlay errors corresponding to controlling the process according to a suggested value for each of at least one process parameters of a model of the process;
- determining a value for each of the at least one process parameters corresponding to minimal overlay errors by fitting the model to data comprising the provided overlay errors and the suggested values for each of the at least one process parameters;
- creating the overlapping patterns thereby controlling the process according to the determined values for each of the at least one the process parameters;
characterized by:

creating a first part of one of the overlapping patterns according to a first determined value for each of the at least one process parameters and creating a second part of the one of the overlapping patterns according to a second determined value for each of the at least one the process parameters wherein the first value differs from the second value.

[0007] According to an aspect of the invention, there is provided an apparatus arranged to determine a value of a process parameter of a process for creating overlapping patterns on a substrate by fitting a model of the process to data comprising a suggested value of the process parameter and estimated overlay errors between the overlapping patterns, the estimated overlay errors corresponding to the control of the process according to the suggested value of the process parameter, whereby the determined value of the process parameter corresponds to minimal overlay errors; characterized by:

the apparatus being arranged to determine a first value of the process parameter for creating a first part of one of the overlapping patterns in a first section of the target field and a second value of the process parameter for creating a second part of the one of the overlapping patterns, wherein the first value differs from the second value.

[0008] According to an aspect of the invention, there is provided an apparatus for creating a first pattern of several overlapping patterns on a substrate comprising a substrate table to hold the substrate, and comprising

- creation means to create a first part of a first pattern in a first section of a target field and to create a second part of the first pattern in a second section of the target field, wherein the first part differs from the second part and the first section differs from the second section;

  controller connected to the creation means and the substrate table and arranged to control the overlay between the first pattern and a second pattern of the several overlapping patterns by controlling the substrate table and the creation means based on values of a group of process parameters;

characterized by

the apparatus being arranged to create the first part according to a first value of a first process parameter of the group of process parameters and to create the second part according to a second value of the first process parameter.

[0009] According to an aspect of the invention, there is provided a device manufactured by the process of any of claims 1 to 16.

Brief description of the drawings

[0010] 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:

[0011] Figure 1 depicts a lithographic apparatus according to an embodiment of the invention;

[0012] Figure 2 depicts an overlay of a first mask pattern and a second mask pattern on a target portion;

[0013] Figure 3 depicts an example of residual mask pattern distortion;

[0014] Figures 4a, 4b, 4c depict a first set of corrections for mask pattern distortion-related intra-field overlay error;

[0015] Figures 5a, 5b, 5c depict a second set of corrections for mask pattern distortion-related intra-field overlay error; and

[0016] Figure 6 depicts a lithographic apparatus comprising a computer system arranged for performing a method in accordance with the present invention.

Detailed Description

[0017] Figure 1 schematically depicts a known lithographic apparatus. The apparatus comprises:

- an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. UV radiation or EUV radiation).
- a support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask) MA and connected to a first positioner PM

configured to accurately position the patterning device in accordance with certain parameters;

- a substrate table (e.g. a wafer table) WT constructed to hold a substrate (e.g. a resist-coated wafer) W and connected to a second positioner PW configured to accurately position the substrate in accordance with certain parameters; and
- a projection system (e.g. a refractive projection lens system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

[0018] 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.

[0019] The 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 support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The support structure may be a frame or a table, for example, which may be fixed or movable as required. The 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".

[0020] 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 such 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.

[0021] 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.

[0022] 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".

[0023] 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).

[0024] The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such "multiple stage" machines, the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

[0025] 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 are well known in the art for increasing 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 liquid is located between the projection system and the substrate during exposure.

[0026] Referring to Figure 1, the illuminator IL receives a radiation beam from a radiation source 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 comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the lithographic 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.

[0027] The illuminator IL may comprise an adjuster AD for adjusting 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 plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise 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.

[0028] The radiation beam B is incident on the patterning device (e.g., mask MA), which is held on the 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 positioner 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 portions C in the path of

the radiation beam B. Similarly, the first positioner 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 positioning), which form part of the first positioner PM. Similarly, movement of the substrate table WT 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 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.

[0029] The depicted apparatus could be used in at least one of the following modes:

[0030] 1. In step mode, the mask table MT and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the radiation beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.

[0031] 2. In scan mode, the mask table MT and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the mask table MT may be determined by the (de-)magnification and image reversal characteristics of the projection system PS. In scan mode, the maximum size of the exposure field (or scan field) limits the width (in

the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.

[0032] 3. In mixed mode, a programmable patterning device is kept essentially stationary, and the substrate table WT is moved or scanned while a pattern imparted to the radiation beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes a programmable patterning device, such as a programmable mirror array of a type as referred to above.

[0033] There are also known lithographic apparatus comprising a programmable patterning device, laid out so that the programmable patterning device and the target portion are scanned with respect to each other. This is be achieved by various combinations of a scanning or essentially stationary programmable patterning device and a scanning or substantially stationary substrate table. Where the programmable patterning device is kept essentially stable, it is supported by a support structure without the need for a first positioner PM configured to accurately position the patterning device in accordance with certain parameters.

[0034] The overlay between a first pattern PT1 and a second pattern PT2 in a target portion of a substrate is depicted in Figure 2.

[0035] The first pattern PT1 and the second pattern PT2 have been created on the substrate using a known process comprising:

- providing a photosensitive layer on the substrate
- scanning a patterning device with respect to a projection system thereby patterning a radiation beam
- creating a first image of the patterning device in a slit
- scanning the target field with respect to the slit thereby exposing the photosensitive layer of the substrate to the image and thereby creating the first pattern PT1

[0036] The image created in the slit is usually a factor (here called an image shrink factor) 4 or 5 smaller than the original so as to be able to produce patterns with very small details without having to produce the details on the patterning device in the same scale.

[0037] Figure 3 depicts an example of a residual overlay error map of the first and second patterns PT1, PT2 after overall corrections for translation, rotation and scaling.

Within the overlay error map, local overlay errors are shown. The local overlay errors relate to residual overlay errors after overall correction by the correction model, in this case the 6-parameter overlay correction model.

[0038] The local overlay errors are depicted as vector-lines of which the length relates to the magnitude of the overlay error and of which the direction relates to the direction of the overlay error.

[0039] Within the elliptical area, a relatively abrupt change of the local overlay error is visible.

[0040] In an embodiment of the present invention an intra-field correction is provided during the illumination of the second pattern PT2 for a given local residual overlay error. As explained such local residual overlay error may be due to mask distortion. The intra-field correction is superimposed as a dynamic (temporal) correction on any overall correction provided by the 6-parameter overlay correction model.

[0041] In an embodiment the intra-field correction comprises a first set of corrections which relate to dynamic/temporal adjustments of projection system parameters (or lens parameters), and a second set of corrections which relate to dynamic/temporal adjustments of scan parameters during the scan of the second pattern PT2. The dynamic adjustments of the scan parameters are superimposed on the overall scan parameters set in accordance with the 6-parameter overlay correction model to provide an overall correction of the scan of the second pattern PT2 relative to the first pattern PT1. The first set of corrections and the second set of corrections are applied in parallel to obtain minimal overlay errors.

[0042] A first set of corrections according to an embodiment of the present invention is depicted in figures 4a, 4b, 4c depict a first set of corrections for intra-field overlay error for instance caused by mask pattern distortion. Lens parameters can be used to adjust the lens magnification and third order lens aberrations. Possibly other lens aberrations are also adjustable for use as correction, but this may depend on the design of the projection lens system and the availability of suitable actuators for actuating the lens to correct such other lens aberration. While a scan is performed, the lens magnification can be varied along a scan path in the Y direction, i.e. a trajectory that is traversed during the exposure scan.

[0043] A first type of lens parameter correction according to the present invention, is a linear variation of the lens magnification in the X-direction (which is perpendicular to the scanning direction Y).

[0044] As the skilled man will know, although lens magnification is frequently used a terminology, usually the image in shrunk. For that reason alternatively the terms image shrink factor could be used.

[0045] The first type is schematically depicted in Figure 4a as trapezoid area 4a, which is related to the scan field and its local magnification.

[0046] At the lower region of the scan field (for example, the begin of the scan), the magnification in the X-direction is relatively small. At the upper region of the scan field, the magnification is different, in this example relatively larger. By the first type of lens parameter correction, the magnification of the pattern (in the X-direction) varies linearly during the scan.

[0047] A second type of lens parameter correction according to the present invention, is a non-linear variation of the magnification in the X-direction. The second type is schematically depicted in Figure 4b as a variable area 4b.

[0048] An example of a non-linear variation is illustrated in Figure 4b. At a lower region R1 of the variable area 4b, the lens magnification in the X direction reduces during the scan (illustrated by a first convergence of the left and right boundaries of the area 4b). At a next region R2, the lens magnification in the X direction increases (illustrated by a first divergence of the left and right boundaries of the area 4b). At a

further region R3, the lens magnification in the X direction reduces again (illustrated by a second convergence of the left and right boundaries of the area 4b). Finally, in a still further region R4, the lens magnification in the X direction increases again (illustrated by a second divergence of the left and right boundaries of the area 4b).

[0049] A third type of lens parameter correction according to the present invention, is a variation of the third order lens aberration correction in the X-direction. The third type is schematically depicted in Figure 4c as a scan field area 4c.

[0050] The lens magnification in the X-direction is constant, which results in a rectangular scan field. Within the scan field, the third order lens aberration correction can be varied along the Y-direction. This variation is illustrated by means of arrows directed in the X-direction. The length of the arrows varies as a function of the position in the Y-direction to illustrate the variation of the third order lens aberration in the Y-direction.

[0051] By varying the magnification in the X-direction or the third order lens aberration correction from one region in the scan field to another, a dimension (parallel to the X-direction) of a feature of a pattern within the one region can be adjusted relative to another feature of the pattern in the other region.

[0052] It should be noted that Figures 4a, 4b, and 4c illustrate examples of variations of lens parameters. Variation of lens parameters according to the present invention is not limited to these examples.

[0053] A second set of corrections according to an embodiment of the present invention is depicted in Figures 5a, 5b, and 5c .

[0054] The second set of corrections relates to dynamic adjustments of scan parameters superimposed on the overall scan parameters set in accordance with the 6-parameter overlay correction model to provide an overall correction of the scan of the second pattern PT2 relative to the first pattern PT1.

[0055] By using these dynamic adjustments of scan parameters, a variation of the magnification of the pattern in the Y-direction, a variation of translation and a variation of rotation can be achieved as explained below.

[0056] In an embodiment a variation of the magnification in the Y-direction in a scan field 5a is implemented by a variation of a scan speed between the mask stage and the wafer stage in the Y-direction (figure 5a). In the embodiment some regions correspond to deceleration (regions with arrows pointing downward) and some regions correspond to an acceleration (regions with arrows pointing upward) of the scan speed. By varying the scan speed between the mask stage and the wafer stage from one region in the scan field to another, a dimension (parallel to the Y-direction) of a feature of a pattern within the one region can be adjusted relative to another feature of the pattern in the other region. It is noted that this dimension is adjusted without the need for changing the image shrink factor.

[0057] In a further embodiment a variation of the translation in the X-direction is implemented as a function of the scan path for scan field 5b (figure 5b).

[0058] The translation in the X-direction can be varied along the X-direction in one direction (indicated by arrow X+) or the opposite direction (indicated by arrow X-). The translation directions are shown within the scan field.

[0059] In the embodiment (Figure 5b), in a lower region R5 translation is carried out in the direction X-. In a next region R6, translation in the other direction X+ is performed. In a further region R7, translation is carried out again in the direction X-. In subsequent region R8, translations are again directed in the direction X+. In a next region R9, translations are substantially zero. In a final region R10, a translation is carried out in the direction X+.

[0060] By varying the translation from one region in the scan field to another, a position of a feature of a pattern within the one region can be adjusted relative to a position of another feature of the pattern in the other region.

[0061] In a further embodiment a variation of the rotation is implemented as a function of the scan path for scan field 5c (figure 5c).

[0062] Within the scan field 5c there are regions having a sense of rotation in one direction (regions with arrows pointing downward) or an opposite sense of rotation (regions with arrows pointing upward). The length of the arrows in a region indicates a distance of the arrow from a center of rotation in that region.

[0063] By varying the sense of rotation from one region in the scan field to another, an orientation of a feature of a pattern within the one region can be adjusted relative to an orientation of another feature of the pattern in the other region.

[0064] The dynamic adjustments of lens parameters and scan parameters according to the method of the present invention while executing a scan as illustrated above, are determined from a residual mask distortion for the overlay of a first pattern PT1 and second pattern PT2. The residual local distortion of the mask may be derived from measurement of an overlay pattern created on a semiconductor substrate, but additionally or alternatively from distortion measurements on the first and/or second mask pattern. The procedures for determining residual local distortion are known to the skilled person.

[0065] Corrections by the known 6-parameter overlay correction model can be taken into account when determining the residual local mask distortion.

[0066] In an embodiment of the invention, after determination of the residual local distortion, which can be represented by a residual distortion map, the required adjustments of lens parameters and scan parameters is determined. Due to the projection characteristics of a scan (i.e. projecting a series of line-shaped patterns parallel to the X-direction in a sequence along the scan path in the Y-direction), the dynamic adjustments are determined so as to minimize the residual distortions in both the X-direction and the Y-direction for each point along the scan path in the Y-direction.

[0067] In an embodiment of the invention the local distortion is determined from distortion measurement on a distorted mask pattern, and the pattern image is corrected during exposure.

[0068] The adjustments of lens parameters and scan parameters as required to minimize the residual distortions can be any combination of the adjustments of one or more lens parameters and one or more scan parameters as described with reference to Figures 4a – 4c and 5a – 5c.

[0069] In one embodiment, the pattern image relates to the pattern image of a single mask pattern. In another embodiment, the pattern image relates to an overlay between the first pattern and the second pattern.

[0070] Figure 6 depicts a lithographic apparatus comprising a computer system CA arranged for performing a method in accordance with the present invention.

[0071] In Figure 6, entities with the same reference number as shown in the preceding figures refer to the corresponding entities in the preceding figures.

[0072] To control adjustments of lens parameters and scan parameters during scanning, a lithographic apparatus is equipped with a control system that is capable of controlling the required adjustments for each point along the scan path.

[0073] Typically, such a control system includes a computer system CA comprising a processor PR for performing arithmetical operations, and a memory ME. This is schematically depicted in Fig. 6, showing an example of a lithographic apparatus, similar to the lithographic apparatus as shown in Figure 1, now further comprising the processor PR which is arranged to communicate with memory ME or some other form of machine-readable medium or media. Memory ME may be any type of memory arranged to store instructions and data, such as a tape unit, a hard disk, Read Only Memory (ROM), Non-Volatile Random Access Memory (NVRAM) and Random Access Memory (RAM).

[0074] The processor PR may be arranged to read and execute one or more programs stored in memory ME providing the processor PR with the functionality to perform the method for adjustments described above. In order to be able to perform these methods, the processor PR is arranged to determine and control a position of the mask table MT, a position of the substrate table WT, and/or parameters of the projecting system PS (lens system), and possibly further components of the lithographic apparatus. The processor PR may be specially equipped or configured to perform the described embodiment of the method, but may also be a central processor arranged to control the lithographic apparatus as a whole and now being provided with additional functionality to perform the described implementation or embodiment of the method, or other implementations of the method.

[0075] It should be understood that there may be provided more and/or other units, such as memory units, input devices and read devices known to persons skilled in the art. Moreover, one or more of them may be physically located remotely from the processor PR, if required. The processor PR is shown as one box, however, it may comprise several processing units functioning in parallel or controlled by one main processor PR that may be located remotely from one another, as is known to persons skilled in the art.

[0076] It is observed that, although all connections in Figure 6 are shown as physical connections, one or more of these connections can be made wireless. They are only intended to show that "connected" units are arranged to communicate with one another in some way. The computer system can be any signal processing system with analog and/or digital and/or software technology arranged to perform the functions discussed here.

[0077] The computer system can also be configured to determine residual distortions of an overlay between the first pattern PT1 and the second pattern PT2 in a residual distortion map.

[0078] The overlay data relating to the overlay between the first pattern PT1 and the second pattern PT2 may be obtained from a metrology tool that measures the intra-field local overlay of the first and second patterns PT1,PT2. Alternatively, the overlay data may be obtained from distortion measurements of the first and second mask patterns. In addition, in an embodiment of the invention, the process parameters (i.e. scan parameters and/or lens parameters) are determined in the metrology tool or a stand alone tool. In the embodiment, the process parameters are then fed to for instance a lithographic apparatus operating in scan mode or in mixed mode or a lithographic apparatus comprising a programmable patterning device.

[0079] The computer system can also be configured to determine, for each point along the scan path in the Y-direction, a minimization of the residual distortions in the X-direction and the Y-direction, wherein the minimization is effectuated by an adjustment of at least one lens parameter and/or at least one scan parameter.

[0080] Furthermore, the computer system can be configured to provide during exposure of the second pattern in a scan, for each point along the scan path, the determined minimization of the residual distortions in the X-direction and the Y-direction by carrying out the adjustment of at least one lens parameter and/or at least one scan parameter.

[0081] The dynamic adjustments during the scan relating to the lens parameters can be effectuated by controlling the settings of the projecting system PS. The dynamic adjustments during the scan relating to the scan parameters, alternatively or additionally, can be effectuated by controlling the position of the mask table MT and/or the position of the substrate table WT. The adjustments of the lens parameters and the scan parameters are controlled by the computer system for each point along the scan path in the Y-direction.

[0082] It will be appreciated that although above embodiments may have been described in as applying intra-field correction during the illumination of the second pattern PT2, the present invention may also be applied by applying intra-field correction during creating first pattern PT1 already to improve overlay between first pattern PT1 and second pattern PT2. Alternatively, in an embodiment overlay correction for overlay between those two patterns is obtained by correcting during creating both the first pattern PT1 and the second pattern PT2.

[0083] It also will be appreciated that the present invention relates to determining values for process parameters (such as scan parameters and lens parameters) of a process. The invention is not restricted to superimposing determined values for correcting values of parameters that would also be used without applying the invention. In stead, the invention encompasses determining values of process parameters that replace parameters of process parameters that would be used without applying the invention, for instance in case of non-linear parameters.

[0084] 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 terms "wafer" or "die" herein may be considered as synonymous with the more general terms "substrate" or "target portion", 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.

[0085] 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, and where the context allows, is not limited to optical lithography.

[0086] 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, 355, 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.

[0087] 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.

[0088] 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.

[0089] 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.

Claims

WHAT IS CLAIMED IS:

1 Process for creating overlapping patterns on a target field of a substrate, comprising;
- providing overlay errors between the overlapping patterns, the provided overlay errors corresponding to controlling the process according to a suggested value for each of at least one process parameters of a model of the process;
- determining a value for each of the at least one process parameters corresponding to minimal overlay errors by fitting the model to data comprising the provided overlay errors and the suggested values for each of the at least one process parameters;
- creating the overlapping patterns thereby controlling the process according to the determined values for each of the at least one the process parameters;
characterized by:
creating a first part of one of the overlapping patterns according to a first determined value for each of the at least one process parameters and creating a second part of the one of the overlapping patterns according to a second determined value for each of the at least one the process parameters wherein the first value differs from the second value.

2 Process of any of claims 1, wherein the overlapping patterns comprise a first pattern and a second pattern and wherein the one of the overlapping patterns is the first pattern.

3 Process of claim 2, wherein providing the overlay errors comprises estimating the overlay errors based on data on the creation of only one of the overlapping patterns.

4 Process of claim 3, wherein the only one of the overlapping patterns is the second pattern.

5 Process of claim 2, wherein providing the overlay errors comprises measuring overlay errors on a test substrate processed according to the suggested values for each of the at least one process parameters.

6 Process of any of claims 2 to 4, wherein the second pattern is created on the substrate earlier than the first pattern.

7 Process of any of claims 1 to 6, wherein the process is a lithographic process.

8 Process of claim 7, comprising

- patterning a radiation beam by a patterning device, and
- creating the first part and the second part of the one of the overlapping patterns by illuminating the target by the patterned radiation beam.

9 Process of claim 8, comprising

- estimating the overlay errors using measurements of features of the patterning device.

10 Process of claim 8 or 9 comprising

- scanning the patterning device with respect to a projection system;
- creating a first image of a first section of the patterning device at a first moment in time, the image being created in a slit;
- creating a second image of a second section of the patterning device at a second moment in time, the image being created in a slit and whereby the second moment differs from the first moment and whereby the first section of the patterning device differs from the second section of the patterning device;
- scanning the target field with respect to the slit thereby illuminating the first section of the target field with the first image and illuminating the second section of the target field with the second image;

whereby the first image and the second image are shrunk with respect to the first section and the second section respectively of the patterning device with an image shrink factor.

11 Process of claim 10, wherein the each of at least one process parameters comprise the image shrink factor.

12 Process of any of claims 10 to 11, wherein one of the each of at least one process parameters corresponds to a third order aberration of the projection system.

13 Process of any of claims 10 to 12, wherein the patterning device is scanned with respect to the projection system and wherein the target field and the slit are scanned with respect to each other according to at least one scan parameter comprising trajectory and velocity and wherein at least one of the each of at least one process parameters corresponds to one of the at least one scan parameters.

14 Process of claim 13, wherein one of the at least one scan parameters corresponds to a velocity of the target field with respect to the slit or corresponds to a velocity of the patterning device with respect to the projection system.

15 Process of any of claims 13 to 14, wherein the patterning device is scanned with respect to the projection system in a first direction and the target field is scanned with respect to the slit in a second direction;
wherein one of the at least one scan parameters corresponds to a component of the second direction, the component being perpendicular to the first direction.

16 Process of claims 13, wherein one of the at least one scan parameters corresponds to the rotation of the patterning device with respect to the target field.

17 Apparatus arranged to determine a value of a process parameter of a process for creating overlapping patterns on a substrate by fitting a model of the process to data comprising a suggested value of the process parameter and estimated overlay errors between the overlapping patterns, the estimated overlay errors corresponding to the control of the process according to the suggested value of the process parameter, whereby the determined value of the process parameter corresponds to minimal overlay errors; characterized by:
the apparatus being arranged to determine a first value of the process parameter for creating a first part of one of the overlapping patterns in a first section of the target field and a second value of the process parameter for creating a second part of the one of the overlapping patterns, wherein the first value differs from the second value.

18 Apparatus according to claim 17 arranged to estimate the overlay errors using measurements of overlay errors on a test substrate processed according to the suggested value of the process parameter.

19 Apparatus according to claim 18 arranged to perform the measurements of the overlay errors.

20 Apparatus according to any of claims 17 to 19 for use in a process comprising patterning a radiation beam with a patterning device and creating a first part and the second part of the one of the overlapping patterns on the target field using the patterned radiation beam, arranged to estimate the overlay errors using measurements of features of a patterning device.

21 Apparatus according to any of claims 17 to 20 for use in a process comprising patterning a radiation beam with a patterning device and creating a first part and the second part of the one of the overlapping patterns on the target field using the patterned radiation beam, arranged to estimate the overlay errors using information on the creation of the patterning device.

22 Apparatus for creating a first pattern of several overlapping patterns on a substrate comprising a substrate table to hold the substrate and comprising

- creation means to create a first part of a first pattern in a first section of a target field and to create a second part of the first pattern in a second section of the target field, wherein the first part differs from the second part and the first section differs from the second section;
- controller connected to the creation means and the substrate table and arranged to control the overlay between the first pattern and a second pattern of the several overlapping patterns by controlling the substrate table and the creation means based on values of a group of process parameters;

characterized by

the apparatus being arranged to create the first part according to a first value of a first process parameter of the group of process parameters and to create the second part according to a second value of the first process parameter.

23 Apparatus according to claim 22 comprising the apparatus of any of the claims 17 to 20.

24 Apparatus according to any of claims 22 to 23, wherein the creation means comprise a projection system arranged to image a patterning device supported by the apparatus wherein the image is smaller than the patterning device by an image shrink factor, the creation means further comprising a projection system manipulator to control the shrink factor based on the first and second value of the first process parameter.

25 Device manufactured by the process of any of claims 1 to 16.