DESCRIPTION

Lithographic Apparatus and Device Manufacturing Method

Field

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

Background

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.

It has been proposed to immerse the substrate in the lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective NA of the system and also increasing the depth of focus.) Other immersion liquids have been proposed, including water with solid particles (e.g. quartz) suspended therein.

However, submersing the substrate or substrate and substrate table in a bath of liquid (see for example US 4,509,852, hereby incorporated in its entirety by reference) means that there is a large body of liquid that must be accelerated during a scanning

exposure. This requires additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate using a liquid confinement system (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in Figures 2 and 3, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a –X direction, liquid is supplied at the +X side of the element and taken up at the –X side. Figure 2 shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of Figure 2 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in Figure 3 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

Another solution which has been proposed is to provide the liquid supply system with a seal member which extends along at least a part of a boundary of the space between the final element of the projection system and the substrate table. Such a solution is illustrated in Figure 4. The seal member is substantially stationary relative to the projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the seal member and the surface of the substrate. Preferably the seal is a contactless seal such as a gas seal. Such as system with a gas seal is disclosed in European Patent Application No. 03252955.4 hereby incorporated in its entirety by reference.

In European Patent Application No. 03257072.3 the idea of a twin or dual stage immersion lithography apparatus is disclosed. Such an apparatus is provided with two stages for supporting the substrate. Leveling measurements are carried out with a stage at a first position, without immersion liquid, and exposure is carried out with a stage at a second

position, where immersion liquid is present. Alternatively, the apparatus has only one stage.

A conventional lithographic projection apparatus requires several sensors on the substrate table so that the substrate table which carries the substrate can be correctly positioned relative to the projection beam. These sensors include a Transmission Image Sensor (TIS) which is a sensor that is used the measure the position at wafer level of a projected aerial image of a mark pattern at the reticle level (mask). Typically the projected image at wafer level is a line pattern with a line width similar to projection beam wavelength. The TIS measures these mask patterns by using a transmission pattern with a photo cell underneath. The sensor data is used to measure the position of the mask wrt the position of the wafer table in six degrees of freedom. Also the magnification and scalling of the projected mask are measured, since four points on the mask are used for the measurement. As the sensor must also be capable of measuring the pattern positions and influences of all illumination settings (Sigma, Lens NA, all masks (Binary, PSM,...)) a small line width is required. Furthermore the sensor is also used to measure/monitor the optical performance of the apparatus. Different measurements are implemented for measuring Pupil shapes, Coma, Spherical, Astigmatism and Field curvature. For these measurements, different illumination settings are used in combination with different projected images. Also such a sensor may be an Integrated Lens Interferometer At Scanner (ILIAS) which is an interferometric wavefront measurement system implemented on lithography tools. ILIAS performs (static) measurements on lens aberrations (up to Zernicke 36) as are needed for system setup and qualification. ILIAS is an on scanner integrated measurement system used for system setup and calibration. ILIAS is used for monitoring and recalibration of the scanner on a regular basis depending on the machine needs. Also such a sensor may be a dose (spot) sensor or any other type of sensor that may be used at substrate level. All of these sensors are used at substrate level and as such are positioned on the substrate table. In order to avoid the need to perform complex predications about how the immersion liquid will effect the projection beam, it is desirable to illuminate the sensors under the same conditions as the substrate is to be imaged, i.e. with immersion liquid in place between the final element of the projection system and the sensor.

Sensors of the type mentioned above used in conventional lithographic projection apparatus require the presence of an absorption layer positioned over a grating in front of

the actual photo sensor element detector. The absorbing layer is required to ensure that the sensor is a high contrast sensor so that accurate readings can be made. The absorbing layer has open and closed areas to get a high signal contrast between the light transmitted through the open patterns on the plate and the closed absorbing area. The photo sensor below the absorbing layer is normally much larger than the open patterns in order to measure the light for large angles. The ratio of the open pattern area versus the photo sensitive area in a typical sensor is roughly (1:5600). So it is critical to absorb as much light as possible using an absorbing layer on the closed areas above the photo sensor. Area patterns with a line width of the order of 200 nm are required. To implement this a multi-layer structure is used so that the required resolution can easily be achieved. Typically the absorption elements of such sensors are made of a plurality of layers of different metal types. Chromium is the most widely used because it is common on mask production, and has good absorbing properties for blocking UV and DUV light. Aluminum is also used because it has good etch selectivity wrt chromium and a good optical density. Other metals, both elemental and alloys, may be suitable. Metals are preferred because of their good electrical conductivity and optical reflectivity which is useful for substrate table height measurements.

In a prior art immersion lithographic projection apparatus disclosed in US 5,825,043 sensors are arranged above the substrate table relying on reflection of radiation off the surface of the substrate table thereby avoiding the need to make the sensors resistant to immersion liquid. This results in a loss in accuracy.

SUMMARY

It is desirable to provide accurate sensors for use in an immersion lithographic projection apparatus.

According to the invention, there is provided a lithographic projection apparatus arranged to project a pattern from a patterning device onto a substrate and having:

- a liquid supply system arranged to provide an immersion liquid to a space between the final element of said projection system and said substrate with an immersion liquid; and
- a sensor mounted on said substrate table for being exposed by radiation whilst immersed in immersion liquid from said liquid supply system, said sensor including an outer surface in contact with said immersion liquid during irradiation of said

sensor being formed of one or fewer metal types.

With the invention, the formation of a galvanic cell between two dissimilar metal types when immersed in immersion liquid can be prevented especially when the immersion liquid is water or water based. This allows the sensor to be positioned on the substrate table. Because of the required small size of the features on the absorption element, if a galvanic cell is allowed to be established, the effectiveness of that absorption element will quickly decrease as one of the metal types dissolves away. Thus, a high contrast sensor is achieved by the invention which provides a long service lifetime in the immersion environment.

The term metal type means an elemental metal or an alloy.

In one embodiment the outer surface is formed by a continuous layer of one metal type. One way of then providing the areas of different absorption characteristics is by providing the one layer so that it is not uniform in thickness. Thus, the use of two metals in the absorption element is completely avoided so that even with minor damage to the continuous layer a galvanic cell will not be established.

Alternatively the absorption element may comprise at least one layer of an isolation material. The isolation material provides a convenient way to ensure that different metal types can be electrically insulated from one another or isolated liquid from the immersion. Preferably the layer is continuous but need not be as long as two metal types are insulated from one another or isolated from the immersion liquid.

In one embodiment the absorption element comprises at least one layer of metal which is not uniform in thickness. In that embodiment the outer surface may comprise areas of said layer of isolation material and areas of one of said at least one layer of one metal type. If the at least one layer of metal is two layers of metal each of a different metal type then the layer of isolation material may be an electrical insulation material and be sandwiched between the two layers each of a different metal type.

Also when the absorption element comprises at least one layer of an isolation material, the absorption element may comprise two layers each of a different single metal type. Those two layers each of a different one metal type may be in contact if the layer of isolation material forms the outer surface.

According to a further aspect of the invention there is provided a device manufacturing method comprising the steps of:

- projecting a patterned beam of radiation onto a substrate through an immersion liquid in a space between the final element of a projection system and said substrate and;
- illuminating a sensor on said substrate table after providing an immersion liquid between said final element and said sensor; wherein said sensor includes an outer surface in contact with said immersion liquid being formed of one or fewer metal types.

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 2 and 3 depict a liquid supply system used in a prior art lithographic projection apparatus;
- Figure 4 depicts a liquid supply system according to another prior art lithographic projection apparatus;

Figure 5 illustrates another liquid supply system as well as a sensor according to the present invention;

Figure 6 illustrates a sensor according to the first embodiment of the present invention;

Figure 7 illustrates a sensor according to a second embodiment of the present invention;

Figure 8 illustrates a sensor according to a third embodiment of the present invention; and

Figure 9 illustrates a sensor according to a fourth embodiment of the invention.

DETAILED DESCRIPTION

Figure 1 schematically depicts a lithographic apparatus according to one embodiment of the invention. The apparatus comprises:

- an illumination system (illuminator) IL configured to condition a radiation beam B

(e.g. UV radiation or DUV 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.

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 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."

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.

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 (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.

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.

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.

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.

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

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.

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 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.

3. In another mode, the mask table MT is kept essentially stationary holding a programmable patterning device, 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 programmable patterning device, such as a programmable mirror array of a type as referred to above.

Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

Figure 5 shows a liquid reservoir 10 between the projection system PL and a sensor 20 which is positioned on the substrate stage WT. The liquid reservoir 10 is filled with a liquid 11 having a relatively high refractive index, e.g. water, provided via inlet/outlet ducts 13. The liquid has the effect that the radiation of the projection beam is a shorter wavelength in the liquid than in air or in a vacuum, allowing smaller features to be resolved. It is well known that the resolution limit of a projection system is determined, *inter alia*, by the wavelength of the projection beam and the numerical aperture of the system. The presence of the liquid may also be regarded as increasing the effective numerical aperture. Furthermore, at fixed numerical aperture, the liquid is effective to increase the depth of field.

The reservoir 10 forms a preferably contactless seal to the substrate W around the image field of the projection lens PL so that the liquid is confined to fill the space between the substrate's primary surface, which faces the projection system PL, and the final optical element of the projection system PL. The reservoir is formed by a seal member 12 positioned below and surrounding the final element of the projection lens PL. Thus, the liquid supply system provides liquid on only a localized area of the substrate. The seal

member 12 forms part of the liquid supply system for filling the space between the final element of the projection system and the sensor 10 (or substrate W) with a liquid. This liquid is brought into the space below the projection lens and within the seal member 12. The seal member 12 extends a little above the bottom element of the projection lens and the liquid rises above the final element so that a buffer of liquid is provided. The seal member 12 has an inner periphery that at the upper end closely conforms to the shape of the projection system or the final elements thereof and may, e.g. be round. At the bottom the inner periphery forms an aperture which closely conforms to the shape of the image field, e.g. rectangular, though this is not necessarily so. The projection beam passes through this aperture.

The liquid 11 is confined in the reservoir 10 by a seal device 16. As illustrated in Figure 2, the seal device is a contactless seal, i.e. a gas seal. The gas seal is formed by gas, e.g. air or synthetic air, provided under pressure via inlet 15 to the gap between seal member 12 and substrate W and extracted by first outlet 14. The over pressure on the gas inlet 15, vacuum level on the first outlet 14 and the geometry of the gap are arranged so that there is a high-velocity air flow inwards towards the optical axis of the apparatus that confines the liquid 11. As with any seal, some liquid is likely to escape, for example up the first outlet 14.

Figures 2 and 3 also depict a liquid reservoir defined by inlet(s) IN, outlet(s) OUT, the substrate W and the final element of projection lens PL. Like the liquid supply system of Figure 4 the liquid supply system illustrated in Figures 2 and 3, comprising inlet(s) IN and outlet(s) OUT, supplies liquid to a space between the final element of the projection system and a localized area of the primary surface of the substrate.

All of the liquid supply systems of Figures 2 to 4 and Figure 5 can be used with the sensor 20 which is illustrated in more detail in Figure 6. In Figure 6 the liquid supply system is not illustrated but the final element of the projection system 30 is depicted as is the liquid reservoir 10, filled with immersion liquid 11.

The sensor 20 is comprised of a sensor element detector 40, a transmissive sensor grating 45 and an absorption element 100. The absorption element 100 is used to enhance the sensor contrast and thus the overall sensor performance. The contrast in this sensor due to the absorption element 100 is the ratio of the light transmitted through an open area of the pattern in relation to the amount of light that is transmitted through the closed area i.e. the areas which are covered. The behaviour of the absorbing element is mainly driven by

the ratio of the open area of the transmissive sensor grating 45 and the area of the absorbing element 100 above the sensor element detector 40. For the TIS, the ratio of the open grating area vs closed absorbing area is 1:5600. In order to obtain a 0.1 % contribution of the light transmitted through the absorption element 100 an optical density of 10e-3/5600~2e-7 is required.

The transmissive sensor grating 45 is used for convolution of the projected aerial image of a corresponding pattern at reticle level (4 or 5 times larger than the pattern on the sensor). The convolution of the transmissive sensor grating 45 with the projected aerial image of the pattern at reticle level will provide an intensity profile depending on the position of the transmission sensor grating 45 at substrate level. With the intensity data at different substrate table positions the position and shape of the aerial image can be calculated.

The sensor element detector 40 transforms the light that is transmitted through the open area of the grating into an electrical signal. However, the total amount of light that is transmitted through he grating 45 and the absorption element 100 contribute to the total electrical signal. In order to get a good sensor performance the amount of light that transmits through the absorption element 100 must be minimized (less than 0.1% of the light transmitted through the open area). If the optical density of the absorption layer 100 is too large, the sensor performance will degrade.

The purpose of the absorption element 100 is thus to absorb part of the energy of the projection beam PB so that the sensor can achieve sufficient contrast by providing areas of different absorption characteristics. The absorption element 100 is preferably made of at least one metal layer such as aluminium and/or chromium (or alloys thereof) but may be made of layers of any metals. Al and Cr are particularly efficient at absorbing projection beam radiation and may be advantageous manufacturing and processing resources.

The total thickness of the metal layers is of the order of a 200 nm. In an Al/Cr multi-layer, the Al layer is typically 100 nm and the Cr layer 90 nm thick. The width of the areas not covered is of the order of 100 to 300 nm for TIS and 2-5 μm for ILIAS. The problem with using two layers each of different metal types in the absorption element is that a galvanic cell may be set up when the two metal types are in electrical contact and in contact with an electrolyte i.e. the immersion liquid. In such a galvanic cell the less noble metal (aluminium) reacts as in reaction 1:

$Al \rightarrow Al^{3+} + 3e^-$ (reaction 1)

The three electrons generated in reaction 1 move to the chromium-immersion liquid interface where reaction 2 takes place. In the case of an immersion liquid based on water, the reaction is:

$2H_2O + O_2 + 4e^- \rightarrow 4OH^-$ (reaction 2)

For immersion liquids other than water, a slightly different reaction takes place.

When these reactions are summed the following reaction takes place:

$4Al + 6H_2O + 3O_2 \rightarrow 4Al^{3+} + 12OH^-$ (reaction 3)

As a rule of thumb, the rate of the overall reaction is influenced, among others, by the metals involved. The closer their positions in the galvanic series, the lower the corrosion rate will be. Metals close to aluminum in the galvanic series, such as zinc or cadmium, have drawbacks that make them not suitable for use in this application to replace the chromium.

In the first embodiment the establishment of such a galvanic cell is prevented by the use of a continuous layer 120 of an isolation material such as SiO_2 or SiN typically between 20 and 100 nm in thickness. The layer 120 need not be continuous over areas where only layer 105 would be in contact with the immersion liquid; it need only be continuous where without it, layers 105 and 107 would together come into contact with the immersion liquid. A continuous layer using all of layer 105 is preferred as it prevents problems with the compatibility of layer 105 with the immersion liquid due to pinholes and scratches in layer 105. The isolation material may either be liquid impermeable (either electrically insulative or conductive) or an electrical insulator and must be sufficiently transparent to the radiation with which the sensor is irradiated. An electrical insulator is preferred. The continuous layer 120 covers both metal layers 105, 107 of the absorption element 100 (i.e. an outer surface of the absorption element 100 which is in contact with the immersion liquid during exposure of the sensor is formed by the continuous layer) such that a galvanic reaction between the two metal layers or even between two different metal

types in a single layer cannot proceed because the second metal layer 107 (the chromium layer) is isolated from the immersion liquid 11 so that reaction 2 cannot proceed.

With the invention, the formation of a galvanic cell between two dissimilar metal types when immersed in immersion liquid can be prevented especially when the immersion liquid is water or water based. This allows the sensor to be positioned on the substrate table. Because of the required small size of the features on the absorption element, if a galvanic cell is allowed to be established, the effectiveness of that absorption element will quickly decrease as one of the metal types dissolves away. Thus, a high contrast sensor is achieved by the invention which provides a long service lifetime in the immersion environment.

The term metal type means an elemental metal or an alloy. The isolation material provides a convenient way to ensure that different metal types can be electrically insulated from one another or isolated liquid from the immersion.

As will be appreciated, each of the two metal layers 105, 107 may be made of different types of metal and indeed this embodiment can also be used with only a single layer of metal which may be made of one or more types of metal.

Embodiment 2

The second embodiment will now be described with reference to Figure 6 and is the same as the first embodiment except as described below.

In the second embodiment the absorption layer 100 also consists of two metal layers 105, 107. However, in the second embodiment the continuous isolation layer 120 is made of an electrical insulation material and is sandwiched between the first and second layers 105, 107. Again, the isolation layer is only necessary where the stack of layers 105 and 107 would, without it, come into contact with the immersion liquid but a continuous layer is preferable to deal with imperfections in layer 105. Thus, the surface of the absorption element 100 is formed partly of the first metal layer 105 and partly of the layer of insulation material 120. In this embodiment the function of the layer of insulation material 120 is to electrically isolate the first and second metal layers 105, 107 from each other such that no galvanic couple exists. In this embodiment the first metal layer 105 must be made of a single metal type i.e. an elemental metal or an alloy but not of two elemental metals or two alloys which are not fully alloyed. The second metal layer 107 may be made of one or more metal types.

Embodiment 3

The third embodiment will now be described with reference to Figure 7 and is the same as the first embodiment save as described below.

In the third embodiment, there is no layer of insulation material 120. There are two layers 105, 108, one of which is a metal layer 105, preferably of Cr and another of which is a non-metal layer 108, such as a ceramic, for example a metal carbide or nitride, preferably TiN. The layers 105,108 may be either way around. This combination also has good resistance to galvanic corrosion and has the advantage of being easy to manufacture as each layer needs only to be about 100 nm thick.

Embodiment 4

The fourth embodiment will now be described with reference to Figure 8 and is the same as the first embodiment except as described below.

In the third embodiment the formation of a galvanic couple is prevented by the use of only one metal type in the absorption element 100. The single metal type may be deposited in a layer 105. The areas of different absorption characteristics are formed by depositing the metal layer 105 in different thicknesses so that the thickness of the layer 105 is not uniform. As only one metal type is exposed to the immersion liquid, no galvanic couple exists. Thus, the use of two metals in the absorption element is completely avoided so that even with minor damage to the continuous layer a galvanic cell will not be established.

In all of the above described embodiments, the metal layers 105, 107 may be of various thicknesses over the area of the sensor. The variation thicknesses include areas where the layer is not deposited at all (as in Figures 5, 6 and 7). The first and second embodiments have been described with the metal layers either in existence in a given area at a certain thickness, or not existent in a area at all, this need not be the case and the thicknesses of the layers may vary over the area of the sensor.

Preferably the transmissive sensor grating 45 and the substrate table WT are made of non conductive materials. This is advantageous as a galvanic couple cannot then be set

up between the metal layers 105, 107 deposited on the substrate table WT or transmissive sensor grating 45 and other metals which are also in contact with the immersion liquid.

The above described methods of avoiding the formation of galvanic cells can be applied to any parts of any sensors which are immersed in immersion liquid.

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.

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 present invention can be applied to any immersion lithography apparatus, in particular, but not exclusively, those types mentioned above.

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.

This application claims the priority of European Patent Application No. 03255228.3 filed 24 July 2003, which document is hereby incorporated by reference.

CLAIMS:

1. A lithographic projection apparatus arranged to project a pattern from a patterning device onto a substrate and having:

- a liquid supply system arranged to provide an immersion liquid to a space between the final element of said projection system and said substrate with an immersion liquid; and
- a sensor mounted on said substrate table for being exposed by radiation whilst immersed in immersion liquid from said liquid supply system, said sensor including an outer surface in contact with said immersion liquid during irradiation of said sensor said outer surface being formed of one or fewer metal types.

2. A lithographic projection apparatus according to claim 1, wherein said outer surface is formed by a continuous layer of one metal type.

3. A lithographic projection apparatus according to claim 2, wherein said continuous layer is not uniform in thickness, thereby to provide areas with different absorption characteristics.

4. A lithographic projection apparatus according to claim 1, wherein said outer surface is formed of a layer of one metal type and said sensor comprises a further layer of a ceramic material.

5. A lithographic projection apparatus according to claim 1, wherein said sensor comprises at least one layer of an isolation material.

6. A lithographic projection apparatus according to claim 5, wherein said sensor comprises at least one layer of metal and which is not of uniform thickness.

7. A lithographic projection apparatus according to claim 6, wherein said at least one layer of metal is two layers of metal each of a different metal type.

8. A lithographic projection apparatus according to claims 6 or 7, wherein said outer surface comprises areas of said layer of isolation material and areas of one of said at least one layer of metal which is of one metal type.

9. A lithographic projection apparatus according to claim 7, wherein said two layers of metal are in contact and said layer of isolation material is an electrical insulation material and forms said outer surface.

10. A lithographic projection apparatus according to claims 7 or 8, wherein said layer of isolation material is sandwiched between said two layers of metal.

11. A lithographic projection apparatus according to any one of the preceding claims, wherein said sensor further comprises an absorption element with areas of different absorption characteristics and said outer surface is formed by said absorption element.

12. A device manufacturing method comprising the steps of:

- projecting a patterned beam of radiation onto a substrate through an immersion liquid in a space between the final element of a projection system and said substrate and;
- illuminating a sensor on said substrate table after providing an immersion liquid between said final element and said sensor; wherein said sensor includes an outer surface in contact with said immersion liquid being formed of one or fewer metal types.