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(54) **Optical element, lithographic apparatus including such an optical element, device manufacturing method, and device manufactured thereby.**

(57) The invention may improve the spectral purity by providing an optical element that includes a structure comprising at least first layer comprising a first material, which structure is configured to be substantially reflective for a radiation of a first wavelength and substantially transparent or absorptive for a radiation of a second wavelength, a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for the radiation of the second wavelength, and vacuum between the first layer and the second layer, wherein the first layer is located upstream in the optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the radiation of the first wavelength.

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# OPTICAL ELEMENT, LITHOGRAPHIC APPARATUS INCLUDING SUCH AN OPTICAL ELEMENT, DEVICE MANUFACTURING METHOD, AND DEVICE MANUFACTURED THEREBY

5 FIELD

**[0001]** The present invention relates to an optical element and lithographic apparatus including such an optical element, a method for manufacturing a device, and device manufactured thereby. More specifically, the optical element may be used as a reflective grazing-incidence spectral purity filter for Laser Produced Plasma (LPP) Extreme Ultraviolet (EUV) sources.

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BACKGROUND

**[0002]** 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
15 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
20 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
25 patterning device to the substrate by imprinting the pattern onto the substrate.

**[0003]** When using an LPP source, the laser radiation itself represents a significant amount of unwanted radiation that is emitted into the EUV lithography tool by scattering and reflection at the plasma. Typically, a $CO_2$ laser having a wavelength of around 10.6 μm is used. Since the optics of the EUV lithographic system have a high reflectivity at 10.6 μm, the laser radiation propagates
30 into the lithography tool with significant power. Part of this power is eventually absorbed by the wafer causing unwanted heating of the wafer.

**[0004]** United States Patent No. 7,196,343 B2 discloses a reflective grazing-incidence spectral purity filter (SPF) for filtering deep ultraviolet (DUV) radiation. This SPF comprises two perpendicular mirrors with an antireflection (AR) coating for DUV radiation of one polarization.
35 By using two perpendicular reflections, the (mostly unpolarized) DUV radiation is effectively

suppressed by absorption in the substrate. Furthermore, the AR coating is characterized in that it has a high reflectivity for EUV, so that EUV radiation is mostly reflected.

**[0005]** This spectral purity filter is not suited for suppressing 10.6 μm radiation in an LPP source for mainly two reasons: AR coatings for 10.6 μm generally have a very low reflectivity for 5 EUV; and conventional mirror substrates reflect rather than absorb 10.6 μm radiation.

SUMMARY

**[0006]** Embodiments of the invention may improve the spectral purity by providing an optical element that includes a structure comprising at least first layer comprising a first material, which 10 structure is configured to be substantially reflective for EUV radiation and substantially transparent or absorptive for a $CO_2$ or yttrium aluminum garnet (YAG) laser radiation, a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for the radiation of the $CO_2$ or the YAG laser radiation, and vacuum between the first layer and the second layer, wherein the first layer is located upstream in 15 the optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the EUV radiation.

**[0007]** According to an aspect of the invention, there is provided a lithographic apparatus comprising: an illumination system configured to condition a radiation beam; a patterning device 20 configured to pattern the radiation beam; a support configured to hold a substrate; and a projection system configured to project the patterned radiation beam onto a target portion of the substrate, wherein the illumination system and/or the projection system comprises an optical element that includes a structure comprising at least a first layer comprising a first material, which structure is configured to be substantially reflective for EUV radiation and substantially transparent or 25 absorptive for a $CO_2$ or yttrium aluminum garnet (YAG) laser radiation, a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for the radiation of the $CO_2$ or the YAG laser radiation, and vacuum between the first layer and the second layer, wherein the first layer is located upstream in the optical path of incoming radiation with respect to the second layer in order to improve spectral 30 purity of the EUV radiation.

**[0008]** According to an aspect of the invention, there is provided a device manufacturing method comprising: patterning a radiation beam to form a patterned radiation beam; projecting the patterned radiation beam onto a substrate; and reflecting the radiation beam with at least one optical element that includes a structure comprising at least a first layer comprising a first material, 35 which structure is configured to be substantially reflective for EUV radiation and substantially

transparent or absorptive for a $CO_2$ or yttrium aluminum garnet (YAG) laser radiation, a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for the radiation of the $CO_2$ or the YAG laser radiation, and vacuum between the first layer and the second layer, wherein the first layer is located upstream in
5 the optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the EUV radiation.

**[0009]** According to an aspect of the invention, there is provided a device manufactured according to the method of: patterning a radiation beam to form a patterned radiation beam; projecting the patterned radiation beam onto a substrate; and reflecting the radiation beam with at
10 least one optical element that includes a structure comprising at least a first layer comprising a first material, which structure is configured to be substantially reflective for EUV radiation and substantially transparent or absorptive for a $CO_2$ or yttrium aluminum garnet (YAG) laser radiation, a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for the radiation of the $CO_2$ or the YAG laser
15 radiation, and vacuum between the first layer and the second layer, wherein the first layer is located upstream in the optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the EUV radiation.

BRIEF DESCRIPTION OF THE DRAWINGS

20 **[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 embodiment of an optical element according to the invention;

25 **[0013]** Figure 3 depicts an embodiment of the optical element according to the invention;

**[0014]** Figure 4 depicts reflectivity of the optical element of Figure 3 for radiation;

**[0015]** Figure 5 depicts reflectivity of the optical element of Figure 3;

**[0016]** Figure 6 depicts an embodiment of the optical element according to the invention;

**[0017]** Figure 7 depicts an embodiment of the optical element according to the invention;

30 **[0018]** Figure 8 depicts an embodiment of the optical element according to the invention;

DETAILED DESCRIPTION

**[0019]** Figure 1 schematically depicts a lithographic apparatus according to one embodiment of the invention. The apparatus comprises: an illumination system (illuminator) IL configured to
35 condition a radiation beam B (e.g. UV radiation, DUV radiation, EUV radiation or radiation with

even smaller wavelength than 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)
5 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.

**[0020]** The illumination system may include various types of optical components, such as
10 refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

**[0021]** 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
15 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 desired. 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
20 considered synonymous with the more general term “patterning device.”

**[0022]** 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
25 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.

**[0023]** The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are
30 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”
35 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".

**[0024]** As here depicted, the apparatus is of a reflective type (e.g. employing a reflective mask). Alternatively, the apparatus may be of a transmissive type (e.g. employing a transmissive mask).

**[0025]** 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.

**[0026]** 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.

**[0027]** 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 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 if desired, may be referred to as a radiation system.

**[0028]** The illuminator IL may comprise an adjuster 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 and a condenser. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

**[0029]** 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 IF2 (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 IF1 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.

**[0030]** The depicted apparatus could be used in at least one of the following modes:

**[0031]** 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.

**[0032]** 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.

**[0033]** 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 desired 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
5 programmable patterning device, such as a programmable mirror array of a type as referred to above.

**[0034]** Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

**[0035]** Figure 2 shows an embodiment of an optical element according to the invention,
10 comprising a first layer 1 with an EUV reflective cap layer 3, and an infrared receiving second layer 2.

**[0036]** The first layer 1 may be made of a material that is transparent to 10.6 μm radiation, for example ZnSe, ZnS, GaAs or Ge. The first layer may form a layer or a structure of so-called etalon, which is a transparent plate with two reflecting parallel surfaces. It should be noted that the
15 word etalon is sometimes used to describe a Fabry-Perot interferometer, which may comprises two closely spaced partially silvered surfaces.

**[0037]** The complex amplitude reflectivity of an etalon may be given by;

**[0038]**

$$r = -\frac{r_1 - e^{-i\delta}}{1 - r_1 e^{-i\delta}}$$

**[0039]** where r1 is the complex amplitude reflectivity of the first surface,

20 **[0040]**

$$\delta = \frac{4\pi}{\lambda} nt \cos\theta_t$$

**[0041]** where n is the index of refraction of the plate, t is the thickness of the plate, θt is the angle of refraction the light makes within the plate, and λ is the wavelength of the light in vacuum.

**[0042]** The cap layer 3 has a high reflectivity for EUV, for which typically a thickness of the order of 10 nm is required. Since metals will generally reflect 10.6 μm radiation even when
25 applied as a very thin layer, the cap layer 3 is preferably made of a non-metallic material, for example diamond-like carbon (DLC) or TiO2. The thickness of this layer may be tuned for EUV reflectivity and optimum DUV suppression in the desired wavelength range. The total thickness of the first layer 1 and the cap layer 3 may be tuned such that p-polarized infrared radiation is minimally reflected and maximally transmitted throughout the range of incidence angles. Because
30 of the polarization dependence, two perpendicular reflections are needed; this is preferably implemented at intermediate focus as shown in Figure 3.

**[0043]** The first layer 1 may be configured to be transparent to radiation of a wavelength of

10.6 μm, and the third layer 3 (EUV reflective capping layer) may have a thickness such that it functions as an antireflection coating for DUV radiation. Thus, the optical element may combine suppression of two kinds of radiation, namely radiation with a wavelength of 10.6 μm and DUV radiation: radiation with a wavelength of 10.6 μm incident on the optical element may propagate through the third layer 3 and the first layer 1, and be absorbed by the second layer 2; and DUV radiation may be suppressed by the third layer 3, which acts as an antireflection coating for the DUV radiation.

**[0044]** The infrared receiving second layer 2 may be designed to absorb the infrared radiation, reflect it outside an etendue or scatter it outside the etendue, or reflect and scatter it outside the etendue. In either case, the surface of the second layer may be inclined from the first layer. The etendue is associated with the optical path traversed by the radiation beam B in Figure 1. In the case of absorption, an inclined surface may be preferred because even infrared-absorbing materials such as glasses (e.g. fused silica) or ceramics (e.g. $TiO2$) become substantially reflective for the very small incidence angles used. In the case of reflection, an inclined surface is needed to reflect the infrared radiation in a different direction than the EUV radiation.

**[0045]** As an example, an embodiment includes a Ge etalon of 50566 nm thickness with a DLC cap layer of 20 nm thickness. Here, the thickness of the etalon has been chosen to be around 50 μm to give reasonable mechanical stability to the etalon. However, since the behavior of the etalon is periodic with a period of about 1.35 μm, the thickness can be made much smaller or larger by changing it by an integral number of periods. Figure 4 shows the reflectivity for p-polarized 10.6 μm radiation in this embodiment. The reflectivity is less than 1% for all angles between 0.04° and 10°. This is a substantial improvement compared to the prior art SPF with an antireflection coating (see Figure 5), which has a low reflectivity for only a small range of angles (less than 1% between 3.8° and 5.5°). The horizontal axis in figure 5 shows the incidence angle. Along the vertical axis is plotted the reflectivity.

**[0046]** In another embodiment, the invention is implemented as two mirrors laid out in a cross shape at intermediate focus, or another focus point in the lithography tool as shown in Figure 3. The structure shown in Figure 4 is applied on both sides of each mirror. The advantage of this embodiment is that the range of incidence angles is smaller and therefore the average reflectivity is higher. The total reflectivity of the two mirrors is obtained by integrating the average reflectivity $[Rp(\theta)Rs(\varphi) + Rs(\theta)Rp(\varphi)] / 2$ over the appropriate range of incidence angles. Under a certain condition, the total reflectivity is 85.1% at 13.5 nm and 0.06% at 10.6 μm, i.e. the total spectral purity is increased by a factor of >1000. The reflectivity in the DUV range varies between 10% and 40% and can be tuned by changing the thickness of the DLC layer.

**[0047]** It should be noted that the infrared reflectivity of the etalon is very sensitive to changes

in its thickness, and to changes in the infrared wavelength to be suppressed. This is illustrated in Figure 4 by the reflectivity of embodiments in which the etalon thickness is 50572 nm, 50578 nm and 50600 nm, respectively, instead of 50566 nm. This reflectivity is plotted along the vertical axis. In the horizontal axis is plotted the incidence angle. When the thickness of the etalon is
5 50600 nm instead of 50566 nm, the total reflectivity at 10.6 μm becomes 3.0%, i.e. the spectral purity is still increased by a factor of 28.5. Thus, the thickness must be controlled within +/- 30-40 nm to achieve good infrared suppression. Likewise, the infrared wavelength may be kept within a similar bandwidth to achieve good suppression.

**[0048]** Note that contamination (for example carbon) on the SPF will change the thickness of
10 the etalon. Therefore, cleaning strategies similar to those for EUV mirrors may be needed. However, since the contamination tolerance for the etalon is relatively large, this is not expected to be a problem.

**[0049]** In a further embodiment, the first layer 1 may not be implemented as a single slab of material with highly parallel surfaces (i.e. an etalon), but as a Fabry-Pérot interferometer
15 comprising two slabs of material that can be moved relative to one another. This embodiment is shown in Figure 6 and comprises two plates 1a and 1b and at least one actuator 4 for moving these slabs relative to one another, for example, piezo actuators for changing the distance and/or angle between the plates, or rotation means to rotate one plate relative to the other.

**[0050]** In this embodiment, imperfections in the plate thickness may be compensated by the
20 actuators. For example, if the reflective surfaces of the plates are not exactly parallel (preferably the plates are wedged in order to prevent extra unwanted etalon effects), the plates may be rotated or tilted such that a surface of one plate is aligned with a surface of the other plate. Moreover, if the thickness of the plates is not optimal (for example due to contamination build-up), this may be compensated by changing the distance between the plates.

25 **[0051]** In another embodiment, the first layer 1 may not be separated from the infrared receiving second layer 2 by vacuum, but by another material that has a refractive index close to 1 for 10.6 μm radiation. This makes the SPF more robust since there are no freestanding layers that are easily damaged.

**[0052]** In a further embodiment, the thickness of the first layer 1 is controlled by compressing
30 it with piezo elements, as shown in Figure 7. By compressing the first layer 1 from its sides, the thickness of the first layer 1 will increase slightly. Since the thickness only needs to be adjusted with a few nanometers, this slight increase suffices.

**[0053]** In another embodiment the surface of the second layer 2 is patterned to scatter the infrared radiation, as schematically shown in Figure 8.

35 **[0054]** In this embodiment scattered infrared radiation is directed outside the EUV beam after

transmission through the mirror.

**[0055]** In yet a further embodiment, the surface of second layer 2 is not patterned or rough, but continuously inclined with respect to the EUV reflective surface. This is not the preferred embodiment, as a substantial inclination angle (e.g. 5°) is needed to diffract the radiation outside
5 the EUV beam. This will produce a relatively thick mirror, which results in an undesirable increase of etendue if the mirrors are double-sided and placed at IF as shown in Figure 3. Therefore, it is preferred to break up the inclined surface in several steps, resulting in a sawtooth pattern as described in Figure 2.

**[0056]** Although specific reference may be made in this text to the use of lithographic
10 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
15 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
20 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.

**[0057]** 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
25 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.

30 **[0058]** 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 (having a wavelength in the range of 5-20 nm), as well as particle beams, such as ion beams or electron beams.

**[0059]** 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.

**[0060]** 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.

**[0061]** 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 clauses set out below. Other aspects of the invention are set out as in the following numbered clauses:

1. An optical element comprising:

a structure comprising at least a first layer comprising a first material, which structure is configured to be substantially reflective for radiation of a first wavelength and at least partially transparent for radiation of a second wavelength;

a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for a radiation of the second wavelength;

a vacuum or gas between the first layer and the second layer;

the first layer being located upstream in an optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the radiation of the first wavelength.

2. An optical element according to clause 1, wherein the structure is configured to reflect the radiation of the first wavelength to a first direction, the second layer is configured to reflect the radiation of the second wavelength to a second direction, the first direction and the second direction being substantially different from each other.

3. An optical element according to clause 1 or 2, wherein the second layer has a surface roughness with a length scale of about the order of the second wavelength.

4. An optical element according to clause 1, 2 or 3, wherein a thickness of the structure is adaptable.

5. An optical element according to any one of preceding clauses, wherein the first material comprises at least one material selected from the group consisting of ZnSe, ZnS, GaAs, Ge, diamond or diamond-like carbon.

6. An optical element according to any one of preceding clauses, wherein the second material comprises at least one material selected from the group consisting of fused silica, $TiO_2$ or any other glass or ceramic material.

7. An optical element according to any one of the preceding clauses, wherein the structure further comprises a third layer on top of the first layer, which third layer comprises a third material and is configured to be substantially reflective for radiation of the first wavelength and at least partially transparent for radiation of the second wavelength.

8. An optical element according to clause 7, wherein the third material comprises at least one material selected from the group consisting of diamond-like carbon or TiO2.

9. An optical element according to clause 7 or 8, wherein a thickness of the third layer is between 1 and 20 nm.

10. An optical element according to any one of the preceding clauses, wherein the radiation of the first wavelength is EUV radiation.

11. An optical element according to any one of the preceding clauses, wherein the radiation of the second wavelength is infrared radiation.

12. An optical device comprising at least two optical elements according to any one of the preceding clauses.

13. An optical device according to clause 12, wherein the reflecting surfaces of at least two of the optical elements are oriented transversely with respect to each other.

14. An optical device according to clause 13, wherein the reflecting surfaces are oriented at least substantially perpendicularly with respect to each other.

15. An optical device according to clause 13 or 14, wherein the optical elements have a substrate made of Si or Cu.

16. A lithographic apparatus comprising at least one optical element according to any one of the preceding clauses.

17. A lithographic apparatus comprising at least two optical elements according to any one of the preceding clauses, wherein the reflecting surfaces of the respective optical elements are oriented substantially perpendicular with respect to each other.

18. A lithographic apparatus according to clause 16 or 17, wherein the lithographic apparatus further comprises:

- an illumination system configured to condition a radiation beam;
- a patterning device configured to pattern the radiation beam;
- a support configured to hold a substrate; and
- a projection system configured to project the patterned radiation beam onto a target portion of the substrate.

19. A device manufacturing method comprising:

- patterning a radiation beam to form a patterned radiation beam;
- projecting the patterned radiation beam onto a substrate; and
- reflecting the radiation beam with at least one optical element comprising

a structure comprising at least a first layer comprising a first material, which structure is configured to be substantially reflective for radiation of a first wavelength and at least partially transparent for radiation of a second wavelength;

a second layer comprising a second material, the second layer being configured to be substantially reflective, absorptive or scattering for a radiation of the second wavelength;

a vacuum or gas between the first layer and the second layer;

the first layer being located upstream in an optical path of incoming radiation with respect to the second layer in order to improve spectral purity of the radiation of the first wavelength.

.

20. A device manufacturing method according to clause 19, wherein the structure is configured to reflect the radiation of the first wavelength to a first direction, the second layer is configured to reflect the radiation of the second wavelength to a second direction, and the first direction and the second direction being substantially different from each other.

CONCLUSIE

1. Een lithografieinrichting omvattende:
een belichtinginrichting ingericht voor het leveren van een stralingsbundel;
5 een drager geconstrueerd voor het dragen van een patroneerinrichting, welke patroneerinrichting in staat is een patroon aan te brengen in een doorsnede van de stralingsbundel ter vorming van een gepatroneerde stralingsbundel;
een substraattafel geconstrueerd om een substraat te dragen; en
een projectieinrichting ingericht voor het projecteren van de gepatroneerde stralingsbundel op een
10 doelgebied van het substraat, met het kenmerk, dat de substraattafel is ingericht voor het positioneren van het doelgebied van het substraat in een brandpuntsvlak van de projectieinrichting.

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# FIG 1

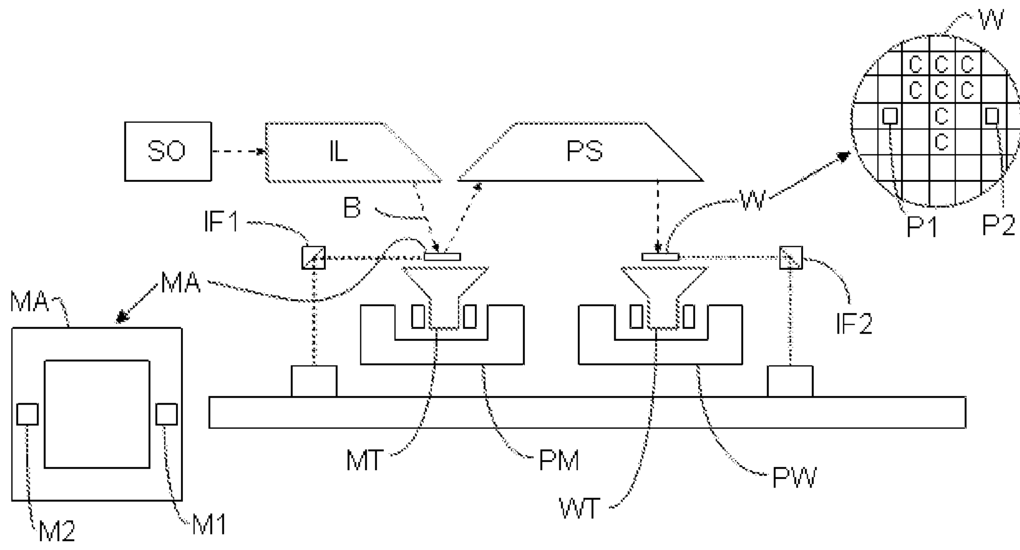


FIG 2

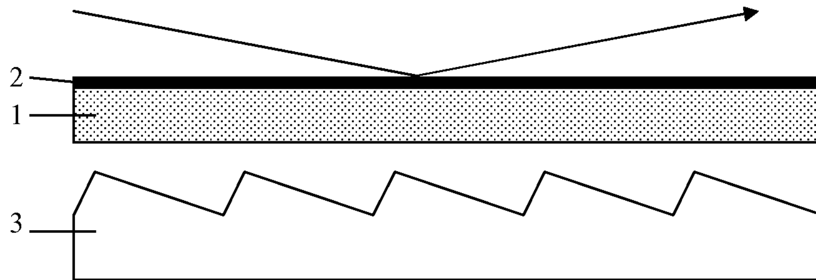
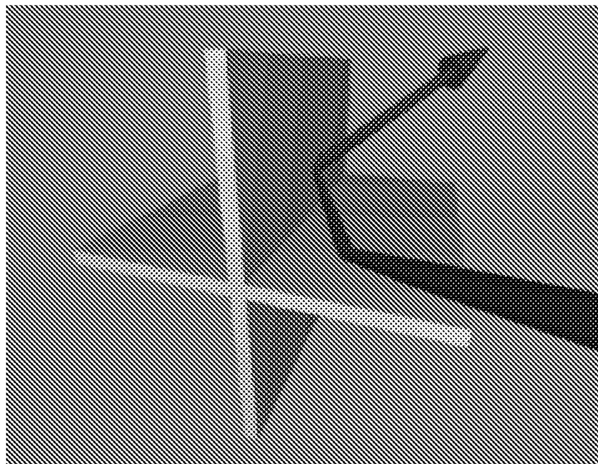
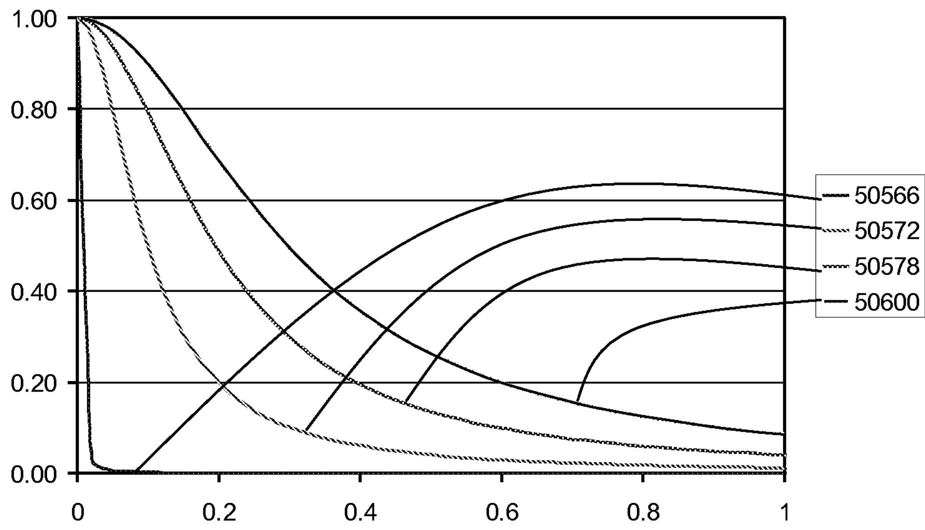



FIG 3



# FIG 4



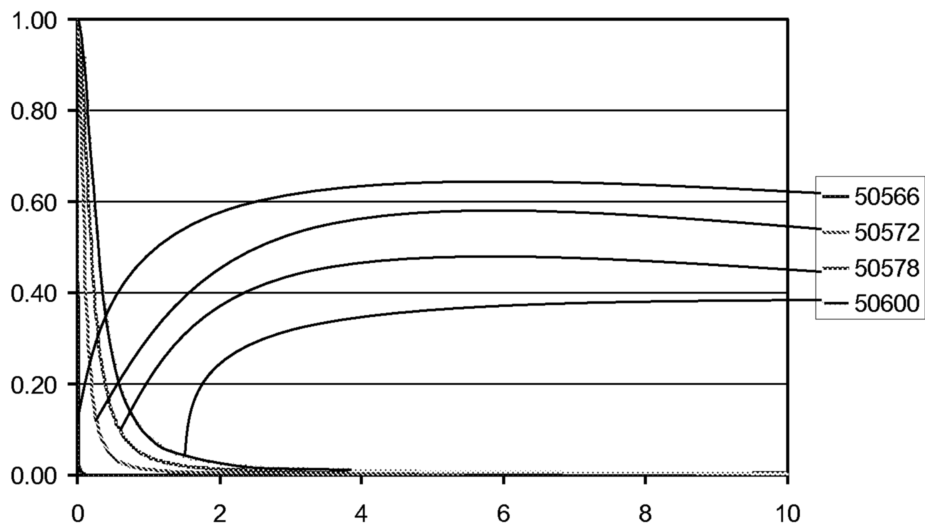



**FIG 5**

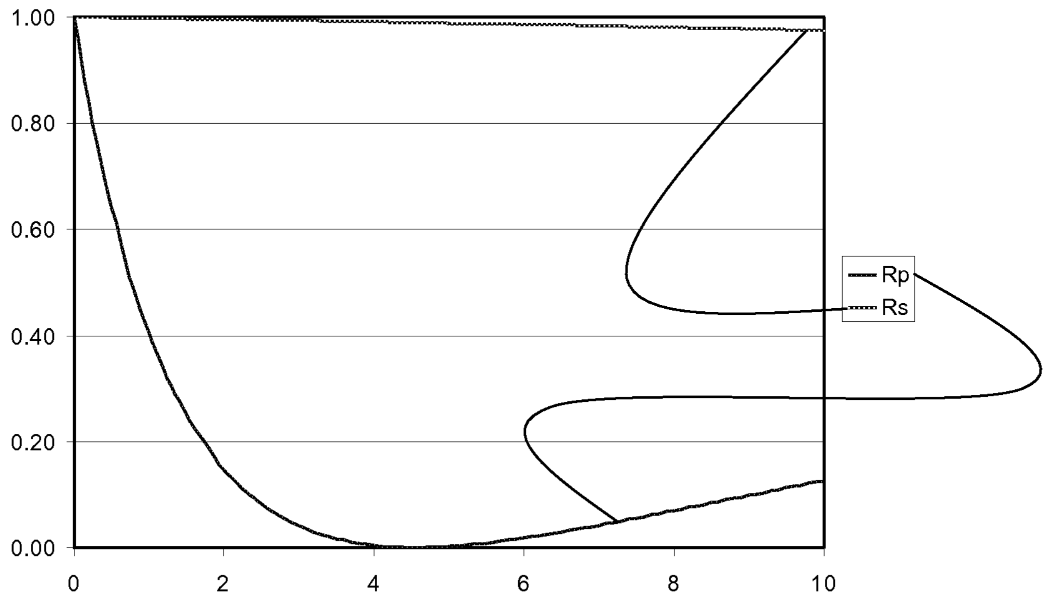


**FIG 6**

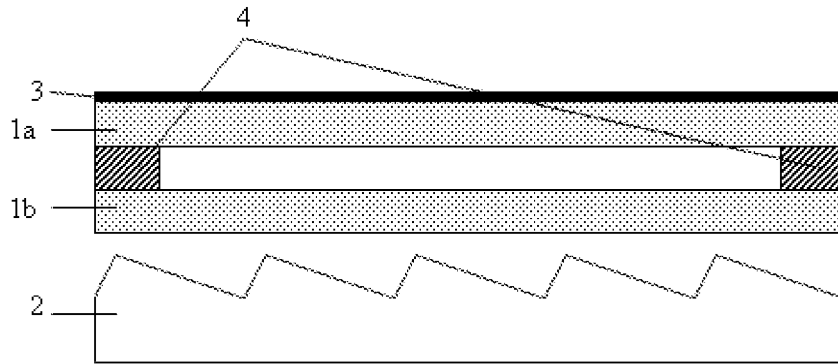



**FIG 7**

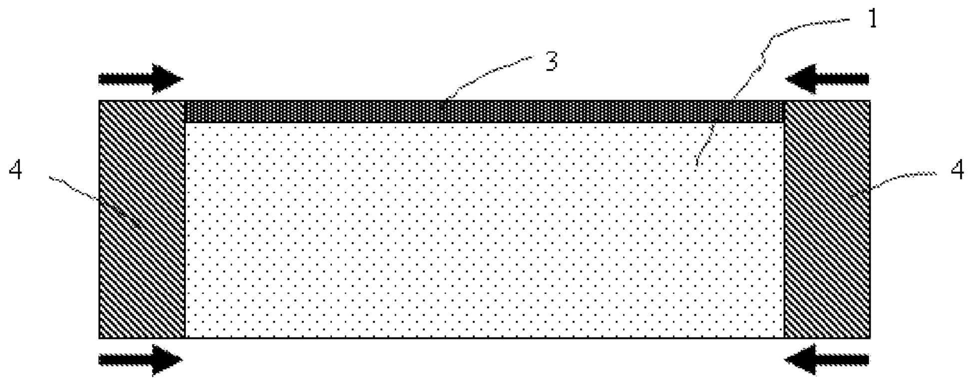


**FIG 8**