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(54) Title: MIRROR FOR AN ILLUMINATION OPTICAL UNIT OF A PROJECTION EXPOSURE APPARATUS COMPRISING A SPECTRAL FILTER IN THE FORM OF A GRATING STRUCTURE AND METHOD FOR PRODUCING A SPECTRAL FILTER IN THE FORM OF A GRATING STRUCTURE ON A MIRROR

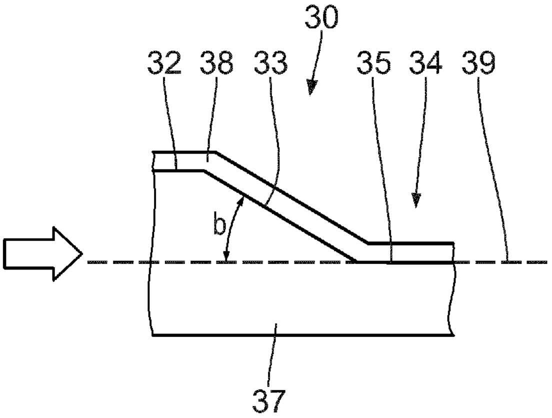

Fig. 3

(57) Abstract: A mirror for an illumination optical unit (4) of a projection exposure apparatus (1) comprises a spectral filter in the form of a grating structure (30), wherein the grating structure (30) has a maximum edge steepness (b) in the range of 15° to 60°.

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Mirror for an illumination optical unit of a projection exposure apparatus comprising a spectral filter in the form of a grating structure and method for producing a spectral filter in the form of a grating structure on a mirror

The present patent application claims the priority of the German patent application DE 10 2018 220 629.5, the content of which is incorporated by reference herein.

The invention relates to a mirror for an illumination optical unit of a projection exposure apparatus. The invention furthermore relates to a method for producing a spectral filter in the form of a grating structure on a mirror for an illumination optical unit. Moreover, the invention relates to an illumination optical unit and an illumination system for a projection exposure apparatus, and a projection exposure apparatus. Finally, the invention relates to a method for producing a microstructured or nanostructured component and to a component produced according to the method.

The use of a grating structure as spectral filter is known for example from DE 10 2012 010 093 A1. There is a need to improve such a grating structure, in particular a mirror for an illumination optical unit comprising such a grating structure.

This object is achieved by means of the features of Claim 1.

The heart of the invention consists in forming the grating structure with a defined edge steepness. The edge steepness, in particular the maximum edge steepness, of the grating structure, is in particular in the range of 15° to 60°, in particular in the range of 30° to 45°.

In this case, the edge steepness is measured relative to a surface of the mirror, in particular to a tangent to the respective local surface of the mirror in the region between two grating ridges.

The edges of the grating structure are formed in particular without undercuts. The grating structure has no etched undercut, in particular.

According to the invention, it has been recognized that the grating structure can be better protected as a result. It is possible, in particular, in this way to form a mirror comprising a spectral filter in the form of a grating structure having a better durability.

For performance reasons, grating structures on a mirror for an illumination optical unit of a projection exposure apparatus are usually formed as steeply as possible, in particular as far as possible perpendicularly, with respect to the mirror surface. Surprisingly, it has been found that for the issue of the durability of the grating structures, in particular with regard to the hydrogen stability thereof, it can be advantageous to form the grating structures with a reduced edge steepness.

In accordance with a further aspect of the invention, the grating structure is covered by a closed protective layer. The grating structure is in particular completely covered by a closed protective layer.

Penetration of harmful hydrogen into the grating structure can be prevented by means of the protective layer. It is thereby possible to prevent stresses in the material that may result in undesired layer detachments. In the case of a mirror substrate composed of a material which is attacked in a harmful hydrogen atmosphere, this material can be protected. Such materials can be for example tin, silicon or the compounds thereof.

In accordance with a further aspect of the invention, the protective layer is composed of one or more plies comprising a constituent of molybdenum and/or silicon. The protective layer can also comprise constituents of copper, silver, platinum, gold, rhodium, a metal, an oxide or a combination of such substances or consist of corresponding substances. The protective layer is composed, in particular, of a hydrogen-stable material. In particular, a plurality of molybdenum-silicon double plies can serve as the protective layer. In particular, a layer stack composed of a plurality of such plies, in particular a plurality of such molybdenum-silicon double plies, can serve as the protective layer. The number of double plies can be in the range of 10 to 100, in particular in the range of 30 to 80, in particular in the range of 40 to 60.

Molybdenum-silicon double plies are suitable in particular for applications in the EUV range. The mirror can be, in particular, a component of an EUV exposure apparatus.

According to the invention, it has been recognized that the molybdenum-silicon double plies on account of the defined edge steepness, can be applied on the grating structure without interruptions, that is to say in a closed layer, in particular in a completely closed layer.

In accordance with a further aspect of the invention, the grating structure is applied on a substrate or is introduced into a substrate, wherein the substrate is composed of one or more of the following materials or their compounds: amorphous silicon (a-Si), silicon dioxide (SiO_2), titanium (Ti), platinum (Pt), gold (Au), aluminium (Al), titanium oxide (TiOx, i.e. TiO or Ti_2O_3), nickel (Ni), copper (Cu), nickel-phosphorus (NiP), silver (Ag), tantalum (Ta), aluminium oxide (Al_2O_3).

Such materials have proved worthwhile in particular for components of an EUV projection exposure apparatus.

In accordance with a further aspect of the invention, the grating ridges each have a cross section having a trapezium-shaped smallest convex envelope. The grating ridges can in particular each have a trapezium-shaped cross section. This should be understood to mean, in particular, that the part of the grating ridges which projects above a local tangential plane through a bottom of the adjacent grooves has a trapezium-shaped cross section. This can involve an isosceles trapezium or a non-isosceles trapezium. In particular, a non-right-angled trapezium is involved. In other words, the grating ridges have in particular a non-rectangular cross section having more than three vertices.

The trapezium is, in particular, a proper, non-degenerate trapezium. The grating ridges have in particular an at least quadrilateral cross section. They each have in particular a cross section having more than three vertices.

In principle, it is also possible to form the grating ridges with a cross section of a general quadrilateral. The front side of the grating ridges in particular need not necessarily be parallel to the bottom of the grooves adjacent to the respective grating ridge.

In accordance with a further aspect of the invention, the front side of the grating ridges and/or the bottom of the grooves between adjacent grating ridges are/is embodied in each case in planar fashion. The front side of the grating ridges can be oriented in particular parallel to the bottom of the grooves.

In accordance with a further aspect of the invention, the total area proportion constituted by the sidewalls of the grating ridges in a plan view, in particular in a direction perpendicular to the front side of the grating ridges and/or in a direction perpendicular to the bottom of the grooves between adjacent grating ridges, is at most 10%, in particular at most 5%, in particular at most 3%, in particular at most 2%, in particular at most 1%, in particular at most 0.5%, in particular at most 0.3%. The total area proportion should be understood here to mean, in particular, that area proportion of the total reflection surface area of the mirror which is constituted by the sidewalls.

The proportion of the surface areas of the mirror which are oriented substantially perpendicular to a normal to the mirror, in particular are inclined by less than 15°, in particular less than 10°, in particular less than 5°, in particular less than 3°, in particular less than 2°, in particular less than 1°, with respect to a normal to a smallest convex envelope of all the grating ridges or with respect to a normal through a plane extending through the bottoms of the grooves between adjacent grating ridges, is in particular at least 90%, in particular at least 95%, in particular at least 97%, in particular at least 98%, in particular at least 99%, in particular at least 99.5%, in particular at least 99.7%, of the total reflection surface area of the mirror.

In accordance with a further aspect of the invention, the mirror is a collector mirror or a condenser mirror.

A further object of the invention is to improve a method for producing a spectral filter in the form of a grating structure on a mirror for an illumination optical unit of a projection exposure apparatus. This object is achieved by means of a method comprising the following steps:

- providing a substrate for a mirror body,

- applying a structuring layer on the substrate,

- structuring the structuring layer,

- structuring the substrate, wherein one or more of the following method alternatives or combinations thereof is/are used for structuring the substrate:

    -- etching with a predefined etching angle in the range of 0° to 60°, in particular in the range of 0° to 20°, wherein the etching angle in this case is the angle of incidence of the ions during etching, in particular the deviation thereof from the normal direction,

    -- etching, wherein structuring layer and substrate have different etching rates,

    -- etching, wherein the structuring layer was provided with a sidewall steepness in the range of 10° to 90° during the structuring, wherein these angles are measured relative to the surface of the substrate,

- applying a closed protective layer on the substrate.

The heart of the invention consists in producing a grating structure having a defined edge steepness, in particular having an edge steepness in the range of 15° to 60°, by means of a targeted process implementation during the structuring of the substrate or a combination of a plurality of aspects thereof.

The advantages are evident from those described above.

The protective layer can in particular grow on the substrate. In general, the substrate is coated with the protective layer.

For details of the protective layer reference should be made to the description above.

In particular, a photoresist (PR) layer can serve as the structuring layer. In accordance with a further aspect of the invention, one or more of the following method alternatives or combinations thereof is/are used for structuring the substrate:

- an inert dry etching method with an etching angle in the range of 0° to 60°, in particular in the range of 0° to 20°, wherein the etching angle in this case is the angle of incidence of the ions during etching, in particular the deviation thereof from the normal direction,

- an inert dry etching method, wherein the structuring layer and the substrate have different etching rates,

- an inert dry etching method, wherein the structuring layer was provided with a sidewall steepness in the range of 10° to 90° during the structuring, wherein these angles are measured relative to the surface of the substrate,

- an inert dry etching method, wherein a ratio of the etching rates of substrate and structuring layer is set by means of various parameters such as e.g. etching angle or ion energy,

- a reactive dry etching method, wherein a ratio of the etching rates of substrate and structuring layer is set by controlling the composition of an etching gas,

- a wet-chemical etching method, wherein a ratio of the etching rates of substrate and structuring layer is set by controlling the composition of an etching medium.

The different method alternatives can also be combined with one another. By way of example, the structured structuring layer having a sidewall steepness in the range of 10° to 90° can also be provided in the case of a reactive dry etching method or in the case of a wet-chemical etching method.

In the case of a reactive dry etching method, the oxygen content of the etching gas can be controlled, in particular. In particular, a defined etching of the structuring layer is readily possible as a result.
In accordance with a further aspect of the invention, a combination of an inert etching method and a reactive etching method is used for structuring the substrate.

In the case of such combined etching, the etching yield is achieved simultaneously by chemical and physical yield. The influencing possibilities described above can be combined as a result.

In accordance with a further aspect of the invention, an etching method with a predefined longitudinal etching angle in the range of 0° to 60° is used for structuring the substrate

In accordance with a further aspect of the invention, an etching method with a predefined transverse etching angle in the range of 0° to 60° is used for structuring the substrate.

In this case, a longitudinal etching angle should be understood to mean the etching angle in a plane which extends perpendicularly to the substrate and which is defined by the groove direction of the grating structure.

In this case, a transverse etching angle should be understood to mean an etching angle in a plane which extends perpendicularly to the substrate, perpendicular to the groove direction of the grating structure.

In accordance with a further aspect of the invention, an ion beam for etching, in particular for structuring the substrate, can be tilted about an axis extending perpendicularly to the local surface of the substrate and, during the etching process, can be rotated about the axis extending perpendicularly to the surface of the substrate. By this means, too, it is possible to structure the substrate in order to produce a grating structure having a defined edge steepness.

In accordance with a further aspect of the invention, at least one of the following parameters is controlled in a targeted manner for setting the sidewall steepness of the structuring layer:

- focusing of a laser beam, exposure time of a contact lithography method, distance of a proximity exposure, design of a mask, in particular of a holographic mask, wavelength of an exposure method,

- intensity of the exposure in a lithography process for structuring the structuring layer,

- duration of the development of a lithography process for structuring the structuring layer,

- hard bake and/or reflow.

As a result, the sidewall steepness of the structuring layer can be influenced, in particular set flexibly and precisely.

Further objects of the invention are to improve an illumination optical unit and an illumination system for a projection exposure apparatus, and also a projection exposure apparatus.

These objects are achieved by means of an illumination optical unit and an illumination apparatus and respectively a projection exposure apparatus comprising a mirror in accordance with the description above. The advantages are evident from those described above.

Further objects of the invention are to improve a method for producing a microstructured or nanostructured component, and such a component.

These objects are achieved by providing a projection exposure apparatus in accordance with the description above. With regard to the advantages, reference should again be made to the description above.

Further advantages, features and details of the invention are evident from the description of a plurality of exemplary embodiments with reference to the figures. In the figures:

Fig. 1	schematically shows a meridional section through a projection exposure apparatus for EUV projection lithography,
Fig. 2	shows a schematic illustration of a mirror comprising a spectral filter in the form of a grating structure,
Fig. 3	schematically shows an excerpt from a grating structure in the region of the edge of a grating ridge,
Fig. 4A	schematically shows a first variant of a method for structuring a substrate,
Fig. 4B	shows by way of example a schematic illustration of the substrate structured by means of the method in accordance with Figure 4A with a structuring layer applied thereon,

Figs 5A to 5C	schematically show an alternative variant of a method for structuring a substrate with an initial state (Figure 5A), an intermediate product (Figure 5B) and the finished structured substrate (Figure 5C),
Figs 6A to 6C	show a further variant of a method for structuring a substrate with an initial state (Figure 6A), an intermediate product (Figure 6B) and the finished structured substrate (Figure 6C) for the case where the etching rate is lower in the structuring layer than in the substrate,
Figs 7A to 7C	show a further variant of a method for structuring a substrate with an initial state (Figure 7A), an intermediate product (Figure 7B) and the finished structured substrate (Figure 7C) for the case where the etching rate is higher in the structuring layer than in the substrate,
Figs 8A and 8B	show by way of example schematic illustrations for elucidating the influence of the focusing of a laser beam on the structuring of the structuring layer,
Fig. 9	schematically shows an illustration for elucidating the effect of a lengthened development duration on the sidewall steepness of a structuring layer,
Fig. 10A	schematically shows an excerpt from a substrate with structuring layer without hard bake,

Fig. 10B	shows an illustration in accordance with Fig. 10A after a hard bake,
Fig. 11	schematically shows an illustration of an excerpt from a substrate with applied structuring layer after isotropic, wet-chemical etching.

Firstly, the general construction of a microlithographic projection exposure apparatus 1 will be described.

Fig. 1 schematically shows a microlithographic projection exposure apparatus 1 in a meridional section. An illumination system 2 of the projection exposure apparatus 1 has, besides a radiation source 3, an illumination optical unit 4 for the exposure of an object field 5 in an object plane 6. In this case, a reticle arranged in the object field 5 and not illustrated in the drawing, said reticle being held by a reticle holder (likewise not illustrated), is exposed. A projection optical unit 7 serves for imaging the object field 5 into an image field 8 in an image plane 9. A structure on the reticle is imaged onto a light-sensitive layer of a wafer arranged in the region of the image field 8 in the image plane 9, said wafer likewise not being illustrated in the drawing and being held by a wafer holder (likewise not illustrated).

The radiation source 3 is an EUV radiation source having an emitted used radiation in the range of between 5 nm and 30 nm. This may be a plasma source, for example a GDPP (gas discharge-produced plasma) source or an LPP (laser-produced plasma) source. By way of example, tin can be excited to form a plasma by means of a carbon dioxide laser operating at a wavelength of 10.6 μm, that is to say in the infrared range. A radiation source based on a synchrotron can also be used for the radiation source 3. Information about such a radiation source can be found by the person skilled in the art for example in US 6,859,515 B2. EUV radiation 10 emerging from the radiation source 3 is focused by a collector 11. A corresponding collector is known from EP 1 225 481 A. Downstream of the collector 11, the EUV radiation 10 propagates through an intermediate focal plane 12 before being incident on a field facet mirror 13 with a multiplicity of field facets 13a. The field facet mirror 13 is arranged in a plane of the illumination optical unit 4 which is optically conjugate with respect to the object plane 6.

The EUV radiation 10 is also referred to hereinafter as illumination light or as imaging light.

Downstream of the field facet mirror 13, the EUV radiation 10 is reflected by a pupil facet mirror 14 with a multiplicity of pupil facets 14a. The pupil facet mirror 14 is arranged in a pupil plane of the illumination optical unit 4, which is optically conjugate with respect to a pupil plane of the projection optical unit 7. With the aid of the pupil facet mirror 14 and an imaging optical assembly in the form of a transfer optical unit 15 comprising mirrors 16, 17 and 18 designated in the order of the beam path, field individual facets 19 of the field facet mirror 13, which are also referred to as subfields or as individual-mirror groups and are described in even greater detail below, are imaged into the object field 5. The last mirror 18 of the transfer optical unit 15 is a mirror for grazing incidence (“grazing incidence mirror”).

Figure 2 illustrates by way of example and schematically the reflection surface of a mirror comprising a spectral filter in the form of a grating structure 30. The grating structure 30 serves as a spectral filter for masking out radiation having wavelengths in a predefined range, in particular for masking out wavelengths in the infrared range.

The grating structure 30 comprises a plurality of grating ridges 31. The grating ridges 31 each have a front side 32 and sidewalls 33. Grooves 34 are in each case formed between the grating ridges 31. The grooves 34 each have a bottom 35.

The grating ridges 31 each have in particular a trapezium-shaped cross section. The cross section can correspond to an isosceles trapezium or a non-isosceles trapezium. It is non-rectangular, in particular. It is non-triangular, in particular.

That area proportion of the total reflection surface area of the mirror, in particular of the total area of the grating structure 30, which is constituted by the sidewalls 33, in plan view, in particular in perpendicular projection, is at most 10%, in particular at most 5%, in particular at most 3%, in particular at most 2%, in particular at most 1%, in particular at most 0.5%, in particular at most 0.3%.

Instead of a trapezium-shaped cross section, the grating ridges 31 can generally also have a cross section having a trapezium-shaped smallest convex envelope. In principle, the front side 32 of the grating ridges 31 need not be oriented parallel to the bottom 35 of the adjacent grooves 34.

Between the front side 32 of the grating ridges 31 and the bottom 35 of the grooves 34, there is an offset V in the direction of a surface normal 36 with respect to the substrate 37. The offset V is, in particular, in the region of one quarter wavelength in the infrared range. The offset V is, in particular, in the range of 1 micrometer to 10 micrometers. Other values are likewise possible.

The offset V is also referred to as the groove depth of the grating structure 30. For further details, reference should be made to DE 10 2012 010 093 A1.

According to the invention, it has been recognized that an embodiment of the grating ridges 31 with steep or even negative sidewalls has the effect that after a protective layer 38 has been applied, the substrate is not completely enclosed by the protective layer 38. This can have the effect that the substrate is attacked in an aggressive atmosphere, in particular in an atmosphere comprising ionized hydrogen. The hydrogen can lead, in particular, to the substrate 37 breaking up or to stresses that can cause layer detachments.

According to the invention, it has therefore been recognized that it is advantageous if the sidewalls 33 each have a sidewall steepness b in the range of 15° to 60°. In this case, the sidewall steepness b, also referred to as edge steepness, is measured in relation to a local tangential plane 39 in the region of the bottom 35 of the groove 34 adjacent to the sidewall 33 (see Figure 3).

Such a defined sidewall steepness b has the effect that it is possible to ensure that the protective layer 38 is closed, in particular covers the substrate 37 completely and without gaps.

A description is given below of various variants regarding how sidewalls 33 having a defined sidewall steepness b can be produced by means of suitable process implementation, in particular during the structuring of a structuring layer 40, in particular with the aid of a lithography process, and/or during the etching of the structuring layer 40 and of the substrate 37, in particular.

In particular, a layer composed of photoresist (PR) serves as the structuring layer 40. Said layer can be structured flexibly and precisely by means of a structuring step, in particular by means of a lithographic method.

Figure 4A schematically illustrates an inert dry etching method for structuring the substrate 37. In a method of this type, etching is carried out in a vacuum using accelerated directional ions, wherein the material removal is produced purely physically by means of corrosions. In this case, there are in principle two possibilities for setting the sidewall steepness b. In the variant illustrated in Figure 4A, the sidewall steepness b is influenced by an angle ew of incidence of the ions. The angle ew of incidence is also referred to as the etching angle. In this case, the ion beam 41 can be tilted parallel to the orientation of the grooves 34. This is also referred to as longitudinal tilting. The ion beam 41 can also be tilted transversely with respect to the orientation of the grooves 34. This is referred to as transverse tilting. It is also possible to tilt the ion beam 41 in relation to a surface normal 42 with respect to the substrate 37 and to rotate the tilted ion beam 41 about said surface normal 42.

On account of the shading by the structuring layer 40, a sidewall 33 having a sidewall steepness b of less than 90° is formed (see Fig. 4B). The sidewall steepness b can be influenced, in particular set, by the choice of the angle ew of incidence.

In the case of inert dry etching, the sidewall steepness b can also be influenced by virtue of the structuring layer 40 and the substrate 37 having different etching rates. This is illustrated by way of example in Figures 5A to 5C. As is evident in particular from the intermediate product (see Figure 5B), differences in the etching rates lead to an influencing of the sidewall steepness b. In this figure and the subsequent figures, the etched region is illustrated in a hatched manner in each case.

Different etching rates can be achieved, in particular, by the selection of different resists for the structuring layer 40.

In addition to the influence of different etching rates, the sidewall steepness b can be influenced, in particular set, here by the steepness c of a sidewall 43 of the structuring layer 40. The steepness c is also referred to as the resist steepness. It can be chosen flexibly and precisely in the lithography step for structuring the structuring layer 40.

Moreover, in this variant, too, the sidewall steepness b can be influenced, in particular set, by the choice of etching angle.

In the case of a reactive dry etching method, etching is carried out in a vacuum using accelerated directional ions, wherein the material removal takes place to the greatest possible extent by way of chemical reactions of the ions with the materials of the surface. In this case, the sidewall steepness b can be set by targeted selection of the chemical components. Possible etching gases here are O_2 (C_{12}, Sf_6, CF_4, CHF_3, O_2, C_2F_6, CF_6, SIC_{14}, BC_{13}) and a mixture thereof.

By way of example, a defined etching of the structuring layer 40 is settable by means of a targeted selection of the composition of the etching gas, for example by changing the oxygen content thereof. The etching rate of the structuring layer 40 can be lower (Figures 6A to 6C), or higher (Figures 7A to 7C), than the etching rate of the substrate 37.

A given sidewall steepness c of the sidewalls 43 of the structuring layer 40 can thus lead to a flatter or steeper sidewall steepness in the substrate 37.

Combined etching is also possible. In the case of combined etching, the etching removal is achieved simultaneously with chemical and physical removal. This can be achieved for example by using reactive etching gases and applying them directionally and in an accelerated manner onto the surface of the substrate 37 with the structuring layer 40 applied thereon. It is thereby possible to combine the variants described above, in particular the influencing possibilities for setting the sidewall steepness b.

The sidewall steepness c of the sidewalls 43 of the structuring layer 40 can be influenced by various factors in the lithography process. It can be influenced, in particular, by the intensity of the exposure in the lithography process. It can be influenced by targeted focusing of a laser beam 44 (see Figure 8A).

By using a collimated laser beam 44, it is possible to achieve a higher sidewall steepness c in the structuring layer 40 (see Figure 8B).

The development operation of the lithography process for structuring the structuring layer 40 also influences the sidewall steepness c of the resist structure. A dark removal of the resist also always takes place during the development of the exposed structuring layer 40. Said dark removal results in edge rounding. Figure 9 illustrates by way of example pronounced edge rounding as a consequence of a lengthened development duration.

Hard bake and reflow can also be used in a targeted manner for influencing the sidewall steepness c of the structuring layer 40. Thermal reflow of developed photoresist structures can be used in a targeted manner for structuring the structuring layer 40 and thus for influencing the sidewall steepness b of the grating ridges 31 that is produced by means of a dry etching method, for example. A hard bake results, in particular, in spherical or cylindrical rounding of the resist edges. Figure 10A illustrates by way of example a substrate 37 with a structured structuring layer 40 applied thereon without or before a hard bake. Figure 10B illustrates the corresponding structure having been thermally rounded after a hard bake.

Different etching rates of the structuring layer 40 and of the substrate 37 can be achieved in the case of a wet-chemical etching method as well. A corresponding influencing of the sidewall steepness b as in the case of the inert dry etching method in accordance with Figure 5B is thus customary.

In the case, too, of isotropic, diffusion-limited etching of the substrate 37, the sidewall steepness b can be influenced in a targeted manner. In the case of a method of this type, the extent of an undercut region 45 is dependent, in particular, on the intermixing of the etching solution.

After the structuring of the substrate 37, the grating structure 30 is provided with the closed protective layer 38. The protective layer 38 is applied in particular on the substrate 37. It can be deposited in particular on the substrate 37. It is also possible to allow the protective layer 38 to grow on the substrate 37.

In particular, a molybdenum-silicon double-ply structure can serve as the protective layer. Details of such a layer stack are known from the prior art.

With the aid of the projection exposure apparatus 1, at least one part of the reticle in the object field 5 is imaged onto a region of a light-sensitive layer on the wafer in the image field 8 for the lithographic production of a microstructured or nanostructured component, in particular of a semiconductor component, for example of a microchip. Depending on the embodiment of the projection exposure apparatus 1 as a scanner or as a stepper, the reticle and the wafer are moved in a temporally synchronized manner in the y-direction continuously in scanner operation or step by step in stepper operation.

Patent claims:

1. Mirror for an illumination optical unit (4) of a projection exposure apparatus (1)
   1.1. comprising a spectral filter in the form of a grating structure (30),
   1.2. wherein the grating structure (30) has a plurality of grating ridges (31),
      1.2.1. wherein the grating ridges (31) each have a front side (32) and sidewalls (33), and
      1.2.2. wherein a groove (34) having a bottom (35) is in each case formed between two grating ridges (31),
   1.3. wherein the grating structure (30) has a maximum edge steepness (b) in the range of 15° to 60°.

2. Mirror according to Claim 1, **characterized in that** the grating structure (30) is covered by a closed protective layer (38).

3. Mirror according to Claim 2, **characterized in that** the protective layer (38) is composed of one or more plies comprising a constituent of molybdenum and/or silicon.

4. Mirror according to any of the preceding claims, **characterized in that** the grating structure (30) is applied on a substrate (37) or is introduced into a substrate (37), wherein the substrate (37) is composed of one or more of the following materials or their compounds: amorphous silicon (a-Si), nickel-phosphorus (NiP), silicon dioxide (SiO_2), titanium (Ti), platinum (Pt), gold (Au), aluminium (Al), titanium oxide (TiOx), nickel (Ni), copper (Cu), silver (Ag), tantalum (Ta), aluminium oxide (AlOx).

5. Mirror according to any of the preceding claims, characterized in that the grating ridges (31) each have a cross section having a trapezium-shaped smallest convex envelope.

6. Method for producing a spectral filter in the form of a grating structure (30) on a mirror for an illumination optical unit (4) of a projection exposure apparatus (1) comprising the following steps:
   - 6.1. providing a substrate (37) for a mirror body,
   - 6.2. applying a structuring layer (40) on the substrate (37),
   - 6.3. structuring the structuring layer (40),
   - 6.4. structuring the substrate (37),
   - 6.5. wherein one or more of the following method alternatives or combinations thereof is/are used for structuring the substrate (37):
     - 6.5.1. etching with a predefined etching angle in the range of 0° to 60°.
     - 6.5.2. etching, wherein structuring layer (40) and substrate (37) have different etching rates,
     - 6.5.3. etching, wherein the structuring layer (40) was provided with a sidewall steepness in the range of 10° to 90° during the structuring,
   - 6.6. applying a closed protective layer (38) on the substrate (37).

7. Method according to Claim 6, **characterized in that** one or more of the following method alternatives or combinations thereof is/are used for structuring the substrate (37):
   - 7.1. an inert dry etching method with an etching angle in the range of 0° to 60°,

7.2. an inert dry etching method, wherein the structuring layer (40) and the substrate (37) have different etching rates,

7.3. an inert dry etching method, wherein the structuring layer (40) was provided with a sidewall steepness (b) in the range of 0° to 60° during the structuring,

7.4. a reactive dry etching method, wherein a ratio of the etching rates of substrate (37) and structuring layer (40) is set by controlling the composition of an etching gas,

7.5. a wet-chemical etching method, wherein a ratio of the etching rates of substrate (37) and structuring layer (40) is set by controlling the composition of an etching medium.

8. Method according to either of Claims 6 and 7, **characterized in that** a combination of an inert etching method and a reactive etching method is used for structuring the substrate (37).

9. Method according to any of Claims 6 to 8, **characterized in that** an etching method with a predefined longitudinal etching angle in the range of 0° to 60° is used for structuring the substrate (37).

10. Method according to any of Claims 6 to 9, **characterized in that** an etching method with a predefined transverse etching angle in the range of 0° to 60° is used for structuring the substrate (37).

11. Method according to any of Claims 6 to 10, **characterized in that** at least one of the following parameters is controlled in a targeted manner for setting the sidewall steepness of the structuring layer (40): focusing of a laser beam for structuring the structuring layer (40), intensity of the exposure in a lithography process for structuring the structuring

layer (40), duration of the development of a lithography process for structuring the structuring layer (40), hard bake and/or reflow, temperature of the structuring layer (40) after a structuring thereof.

12. Illumination optical unit (4) for a projection exposure apparatus (1), comprising at least one mirror according to any of Claims 1 to 5.

13. Illumination system (2) for a projection exposure apparatus (1), comprising
    13.1. an illumination optical unit (4) according to Claim 12, and
    13.2. a radiation source (3) for generating illumination radiation.

14. Microlithographic projection exposure apparatus (1), comprising:
    14.1. an illumination optical unit (4) according to Claim 12 for transferring illumination radiation (10) from a radiation source (3) onto a reticle having structures to be imaged, and
    14.2. a projection optical unit (7) for imaging the structures of the reticle onto a wafer.

15. Method for producing a microstructured or nanostructured component, comprising the following steps:
    - providing a substrate, on which a layer composed of a light-sensitive material is at least partly applied,
    - providing a reticle having structures to be imaged,
    - providing a projection exposure apparatus (1) according to Claim 14,
    - projecting at least one part of the reticle onto a region of the light-sensitive layer of the substrate with the aid of the projection exposure apparatus (1).

16. Component produced by a method according to Claim 15.

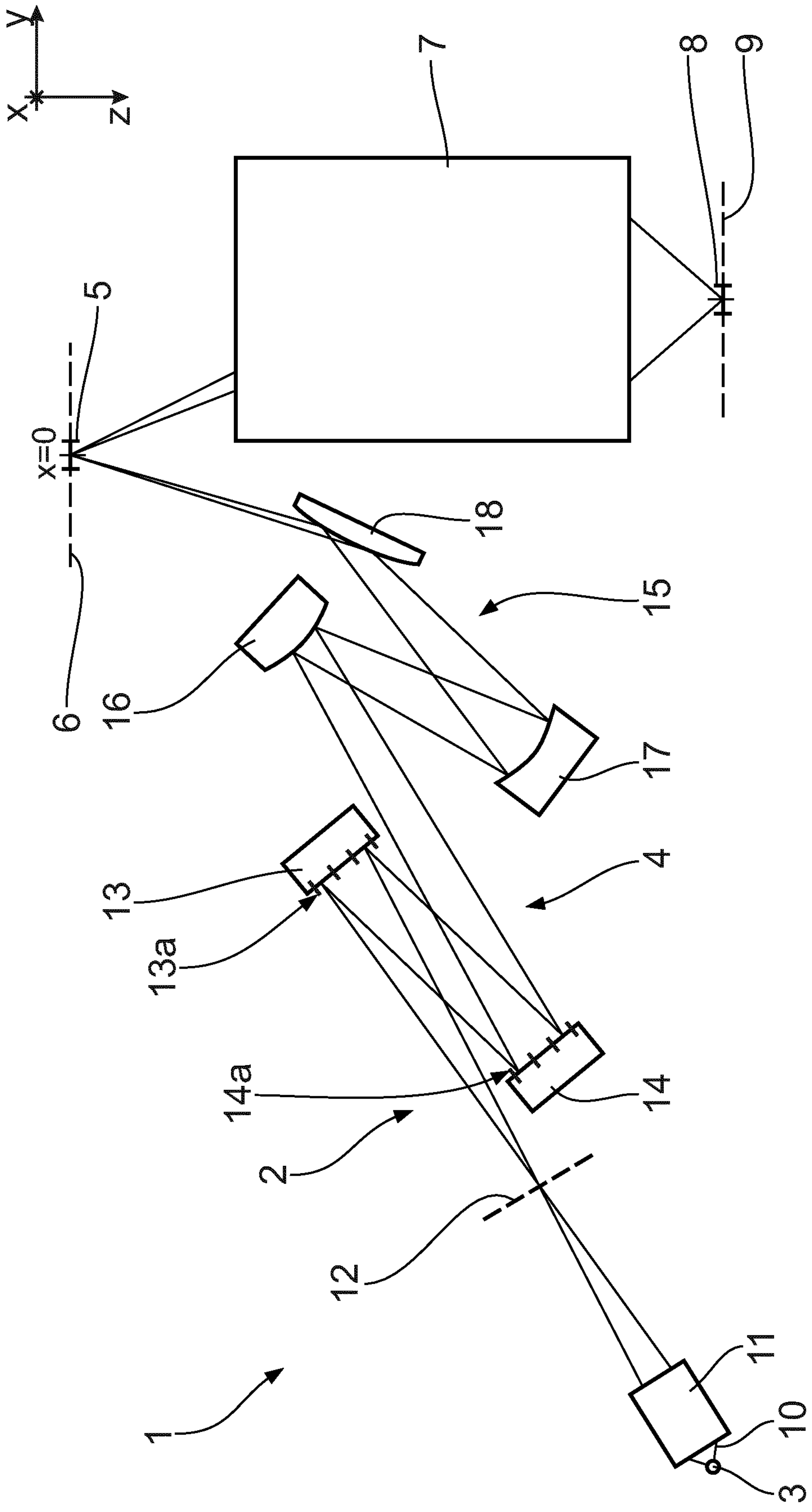

Fig. 1

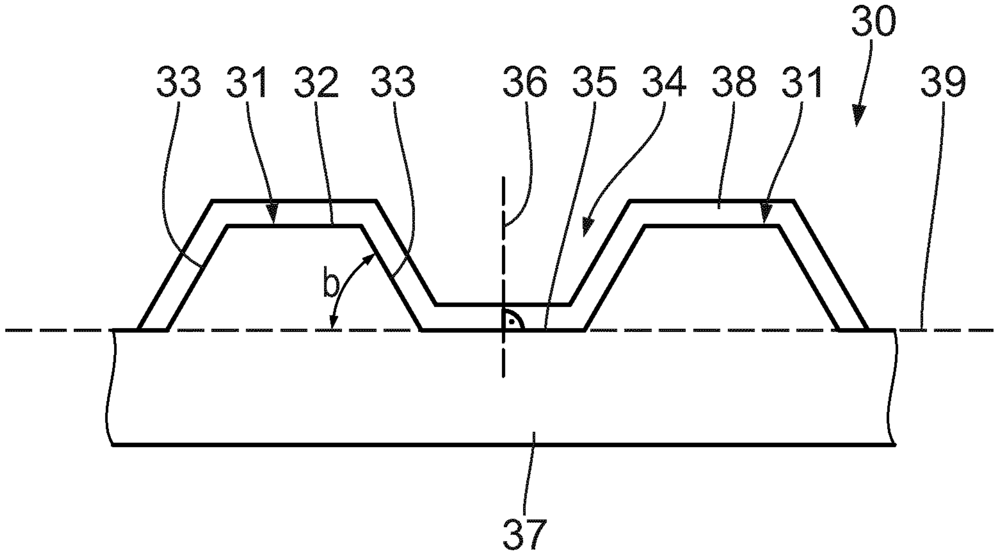

Fig. 2

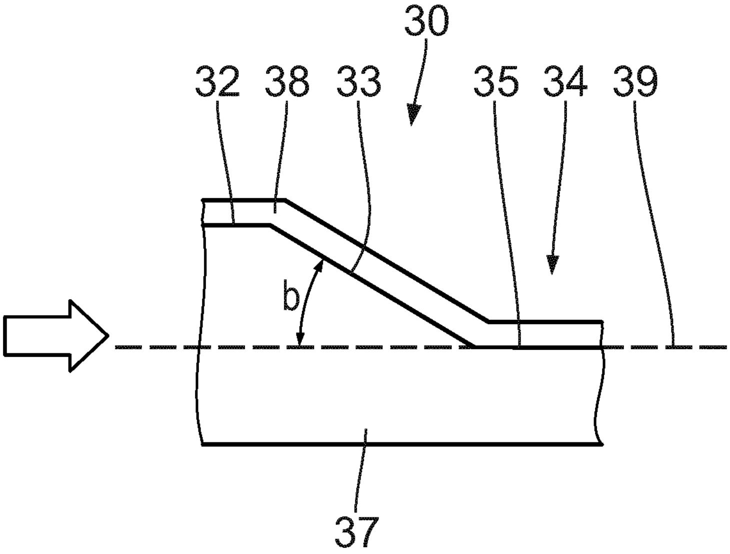

Fig. 3

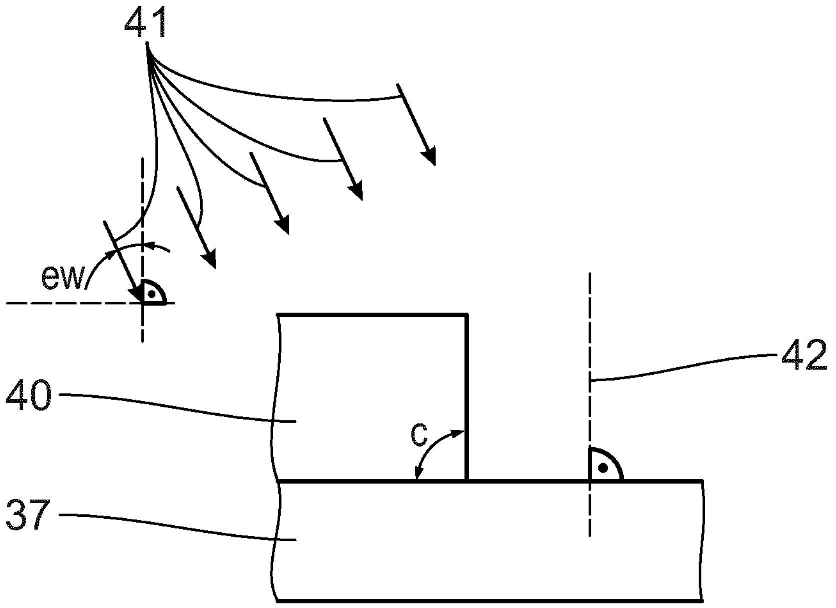

Fig. 4A

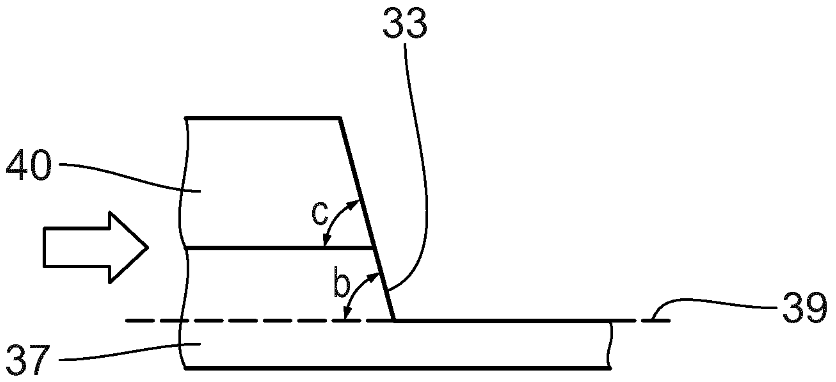

Fig. 4B

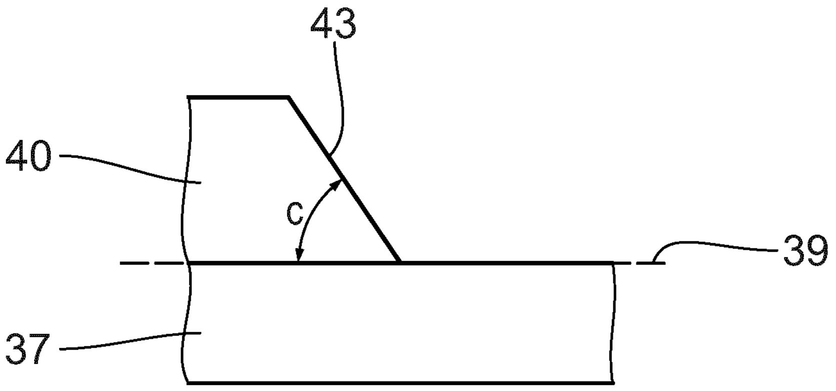

Fig. 5A

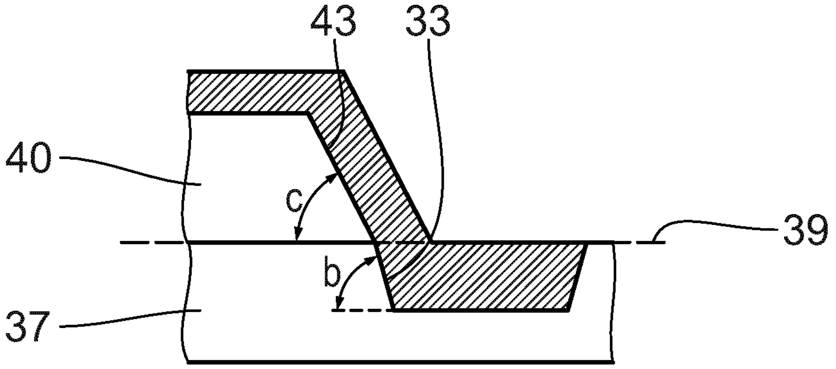

Fig. 5B

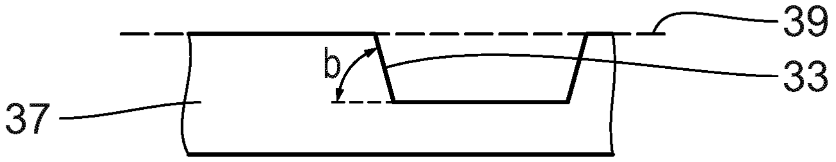

Fig. 5C

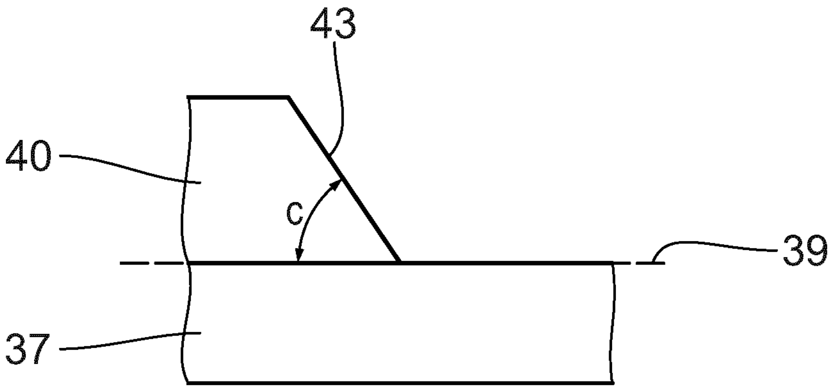

Fig. 6A

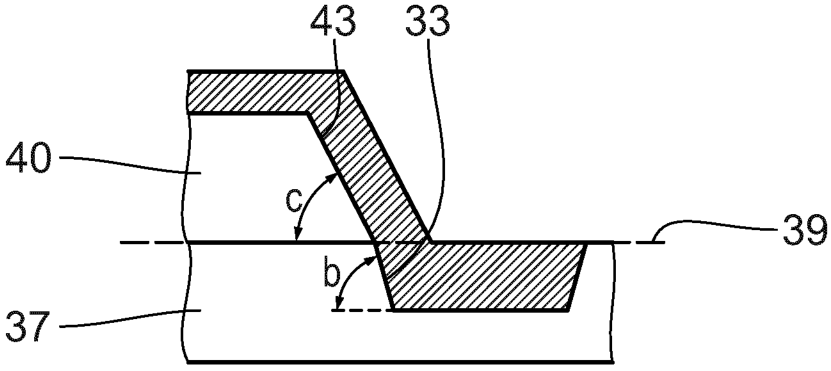

Fig. 6B

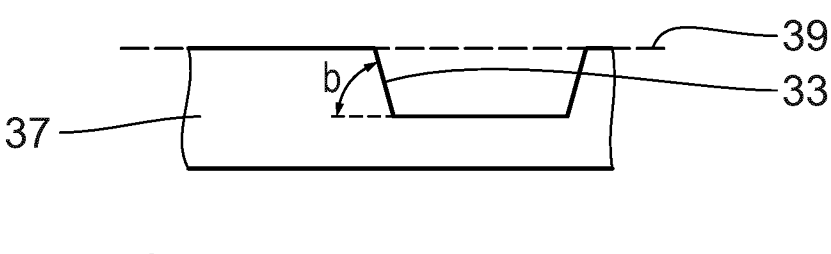

Fig. 6C

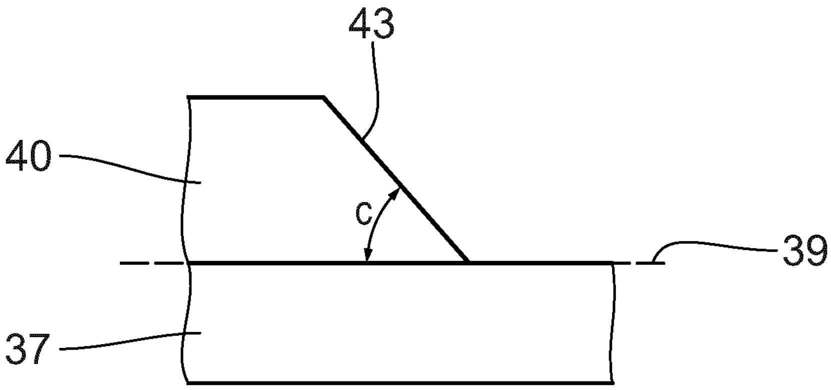

Fig. 7A

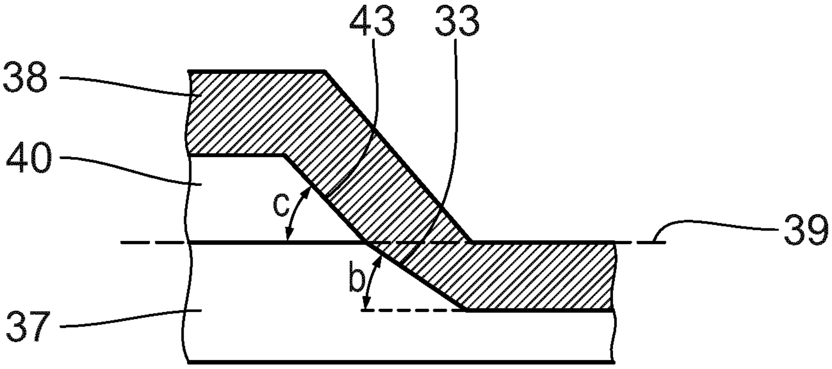

Fig. 7B

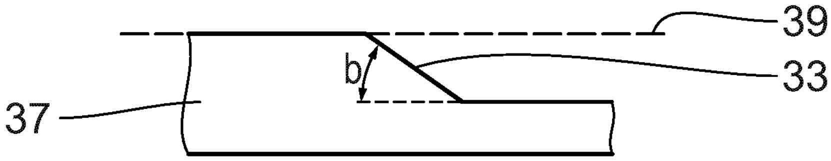

Fig. 7C

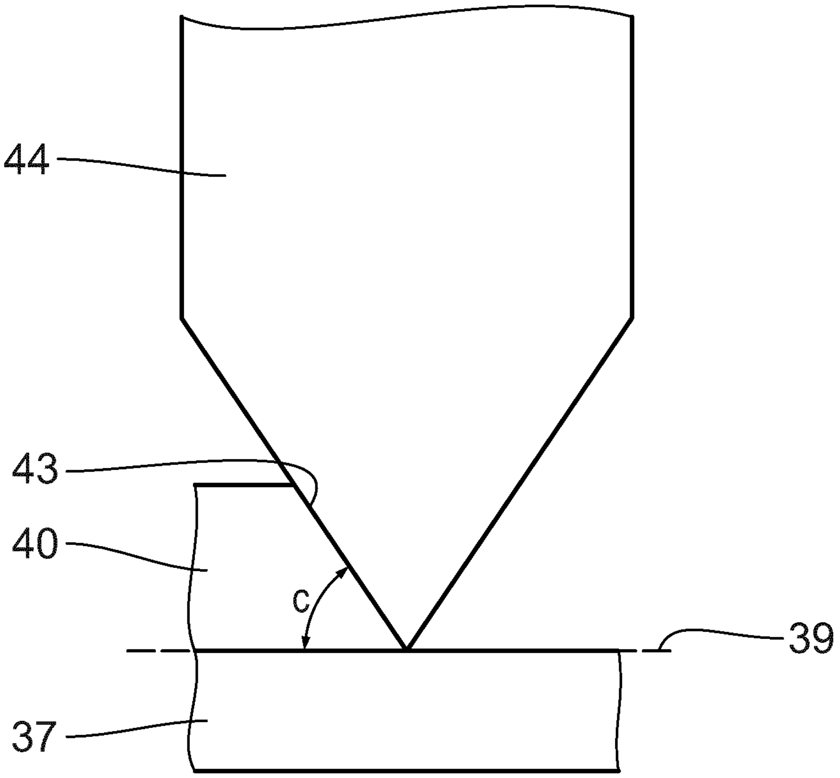

Fig. 8A

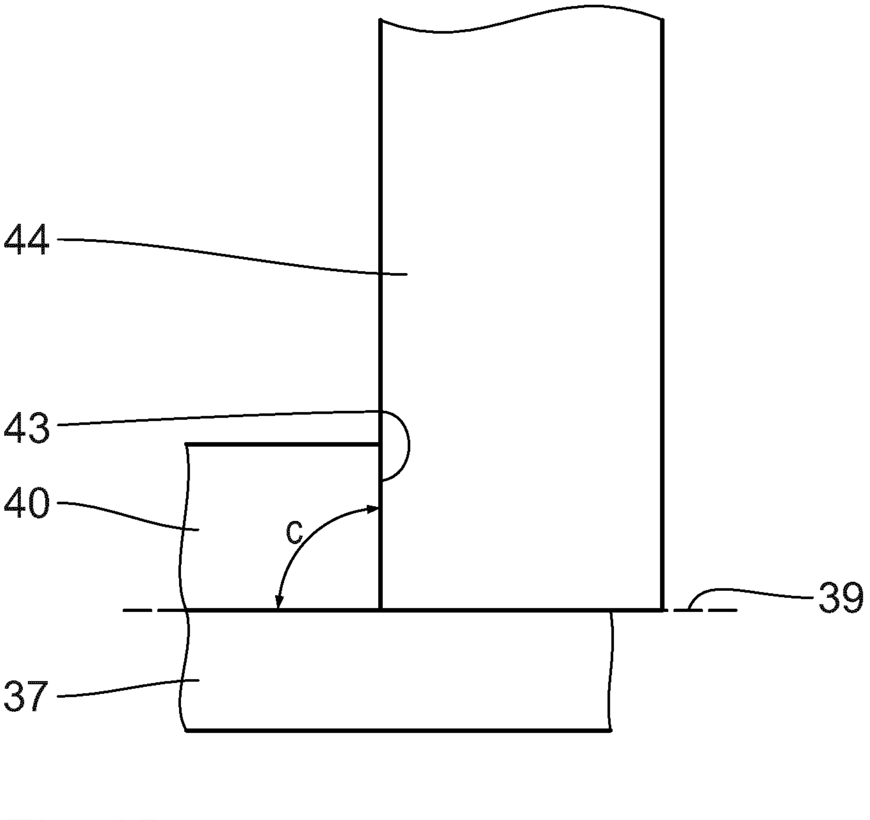

Fig. 8B

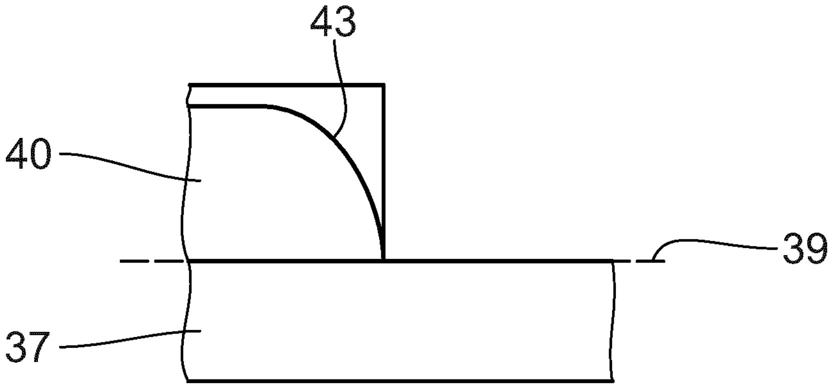

Fig. 9

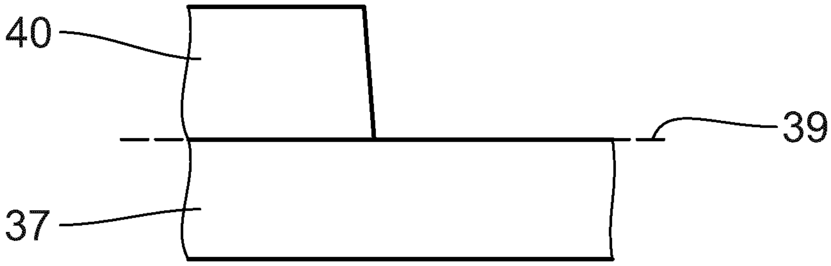

Fig. 10A

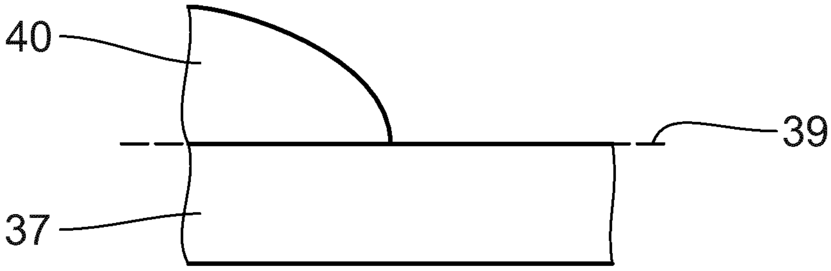

Fig. 10B

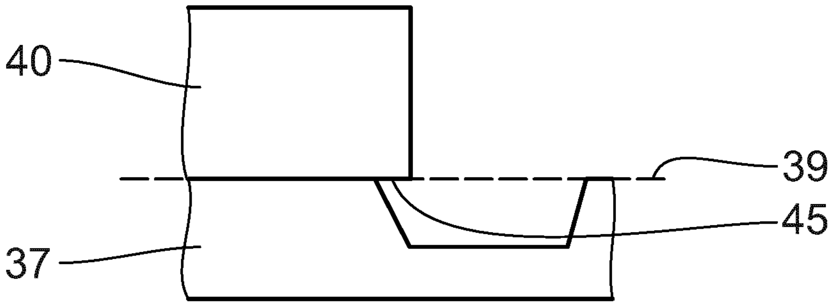

Fig. 11