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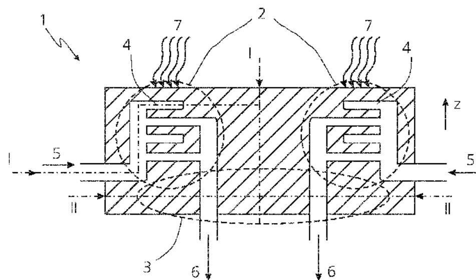
(54) Title: OPTICAL ELEMENT

(57) Abstract: The invention relates to an optical element for a projection exposure apparatus for semiconductor lithography comprising an optically active surface (9) and at least one cooling component for cooling the optical element, wherein the cooling component is connected to at least two separate cooling circuits and embodied in such a way that the optically active surface (9) can be cooled to a greater extent in at least one partial region than in a further partial region. The invention furthermore relates to a projection exposure apparatus comprising an optical element according to the invention.



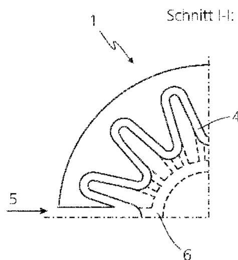


Fig. 1

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Optical Element

Description:

5 The invention relates to optical elements having at least one optically active surface. An optical element can in this case be, in particular, an optical individual component such as e.g. a deflection mirror in an EUV illumination system for semiconductor lithography. 10 Likewise, an optical element can also be constructed from one or from a plurality of optical individual components. By way of example, a facet mirror composed of a mirror carrying body and many individual mirror facets is hereinafter likewise designated as optical ele- 15 ment.

The optical elements mentioned are often mounted in a larger unit, such as an EUV illumination system, for example. In this case, the optical element is a three- 20 dimensional geometrical body which is generally delimited by a plurality of surfaces, and is used for fulfilling one or a plurality of optical functions, such as e.g. deflection or other manipulation of electromagnetic radiation. In accordance with the optical beam 25 path, the electromagnetic radiation impinges at least on one surface of the optical elements, wherein said surface is designated here as optically active surface. The optically active surface can be subdivided into a plurality of partial surfaces, can be convexly or con- 30 cavely curved in partial sections and can also contain topography jumps, as customary e.g. in the case of a diffractive optical structure. The optically active surface can always be found at a surface of the optical element, wherein the optically active surface can, in- 35 ter alia, also consist of a multilayer and/or can comprise other coatings, such as e.g. also an absorber layer. The individual optical elements can be con-

structured from different materials and/or generally also have different component geometries. During the operation of the illumination system it is possible, moreover, to set different illumination settings, such as e.g. an annular setting, a dipole, quadrupole or some other multipole setting or else a quasar or Cquad setting. This has the consequence that, depending on the illumination setting, electromagnetic radiation impinges with locally different intensity on the optical elements. Furthermore, locally different absorber layers are applied in some optical elements under consideration here. Said absorber layers are used to obtain a defined spatially resolved intensity distribution of the reflected radiation after the reflection of the EUV radiation at these optical elements. Depending on the magnitude of the absorption of EUV radiation, the energy input at the optical elements can be locally different. During the operation of the illumination system, IR radiation from other optical elements or from mechanical components can furthermore also impinge on the optical element under consideration and can be wholly or partly absorbed there. The IR radiation can, for example, also originate from a heated component – such as e.g. a so-called sigma diaphragm – which has previously absorbed EUV radiation. Overall, therefore, a locally different heat distribution can be present at the optically active surface of the optical elements. In particular, even in the case of a homogeneous or a symmetrical energy input, asymmetrical local heat distributions can also occur if e.g. the absorption properties for electromagnetic radiation differ in a spatially resolved fashion at the component. During the operation of the illumination systems, temperatures of from 100°C to 200°C or higher can occur in some instances in the uncooled case at the optical elements. The spatially resolved heat distribution can result in undesired deformations of the optical elements. Particularly when

an illumination setting changes and in the case of a thermal loading which is constant over a specific period of time, deformations of the optical elements can occur in a temporal consideration relative to the thermally unloaded basic state at ambient temperature or some other steady-state or quasi-steady-state condition set previously.

The present invention is based on the object of specifying an optical element and a projection exposure apparatus in which the thermally induced deformations mentioned are reduced during operation.

This object is achieved by means of the optical element and the projection exposure apparatus comprising the features presented in the independent claims. The dependent claims relate to advantageous variants and embodiments of the invention.

For cooling the optical elements having an optically active surface, use is made of at least one cooling component which is connected to at least two separate cooling circuits. Said cooling component is therefore embodied in such a way that the optically active surface can be cooled to a greater extent in at least one partial region than in a further partial region. The cooling thus counteracts the locally different radiation-induced energy input, such that deformations at the optically active surface as far as possible do not form or are otherwise at least reduced. The advantage afforded by the cooling is the avoidance of disturbing effects on the further course of the electromagnetic radiation after impinging on the optical element under consideration. The thermal loading and, in particular, the heat distribution in the components can also change over time, e.g. if the illumination setting is changed. The cooling used here, alongside the local adaptation,

can now also be embodied in temporally adaptive fashion.

For analysing the local heat distributions and the local deformations of the optical elements, an FEM analysis can also be used. The results of the FEM calculations can be used, in particular, for designing the cooling systems and also for controlling the cooling system by closed-loop control and open-loop control.

The locally and temporally adaptive cooling can – e.g. depending on the set illumination setting – be effected in a locally and temporally adapted fashion at an optical element. Furthermore, the optical elements of a module can also be cooled to different extents. Thirdly, it is also possible to fit cooling bodies to the optical elements, wherein the cooling bodies have individual or a plurality of locally adapted cooling zones.

The optical element can, for example, also be a multilayer mirror for EUV lithography. In this case, the multilayer mirror can be provided with a cooling body or have a mirror carrier embodied as a cooling body. The cooling body, which here constitutes the cooling component, can be divided into different partial regions and be cooled to different extents there. Besides the option of applying the optical element to the separate cooling body, it is also possible to use the mirror carrier itself for the spatially resolved cooling of the optically active surface. In these cases, the mirror carrier is embodied as a cooling component.

The cooling body used for cooling the optical element can have one or a plurality of cooling channels arranged in different cooling zones. The optically active surface is cooled by, for example, a cooling medium flowing through the cooling channels of the different

cooling zones. The cooling zones having the introduced cooling channels correspond here to the partial regions which can be cooled to different extents.

5 The different cooling zones can also be arranged in different planes with respect to a z-direction. The z-direction typically corresponds to the normal direction which can be assigned to the optical element on the side of the optically active surface as a whole.

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The cooling channels can be connected to separate cooling circuits. This affords advantages, in particular, if the cooling in the different partial regions is performed by a locally adapted choice of the parameters 15 which define the cooling rate. When separate cooling circuits are used, said parameters, such as the flow rate, for example, can thus be set independently of one another and be temporally changed separately for each cooling circuit.

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The cooling channels can be formed by casting methods, moulding methods, eroding, etching or machining production methods.

25 The cooling channels can furthermore also be embodied as cooling lines connected to the cooling body. The cooling lines are thus separate components fitted to the cooling body.

30 The cooling lines can be connected to the cooling body for example by welding, bonding or soldering.

The cooling channels can be embodied in meandering fashion and can also have different geometries for dif-35 ferent cooling zones. If a plurality of cooling zones are present in an optical element, the cooling zones differ with regard to the frequency of the cooling

channels if the sum of the cooling channel surfaces in an imaginary volume unit is different in comparison with a further cooling zone. A different frequency is also present, for example, if a geometry section of the cooling channel within one cooling zone is repeated for example multiply periodically, wherein the number of repetitions is greater than in another cooling zone.

The optical element can also be cooled by means of a cooling body by virtue of the fact that the latter is in thermal contact with the optical element via connecting elements and greater cooling is achieved in one partial region by virtue of the fact that the contact area between connecting element and optical element is larger than in the further partial region. The formation of connecting elements which are adapted to the desired local cooling rate thus constitutes a further alternative with respect to cooling the optical element in different partial regions. In this case, by exchanging the connecting elements it is possible to adapt the overall configuration of the system to new conditions in a simple manner.

The optical elements can be provided with an EUV absorber layer on the optically active surface, said EUV absorber layer having different thicknesses in different regions of the optically active surface. By applying the EUV absorber layer it is possible to obtain, in particular, a location-adapted intensity modulation of the electromagnetic radiation that impinges on the optical element. At the partial regions having a high thickness of the absorber layer, on account of the greater energy input there in comparison with the partial regions having a smaller thickness of the EUV absorber layer, it is necessary to effect cooling to different extents.

The optical element can also be a facet mirror having a plurality of individual mirror facets. In this case, a micro cooler having cooling channels can be integrated in at least one individual mirror facet. In this case, 5 the desired spatially resolved cooling is achieved by individual or groups of individual mirror facets being cooled to different extents.

The micro cooler can be integrated below a mirroring 10 surface of the individual mirror facet and generally has the function of counteracting the thermal energy input as much as possible at the originating location.

The mirror carrier of an individual mirror facet, that 15 is to say that part of the individual mirror facet which carries the mirroring surface, can contain the feed and discharge lines for coolant.

The feed line can open, for example, in the region of 20 the centre of the individual mirror facet and the discharge line can be connected to a circularly embodied edge channel.

It is possible to produce the cooling channels by etch- 25 ing or micro milling.

The mirror carrying body of the facet mirror, that is to say that body into which the individual mirror facets are integrated, can also be connected to further 30 cooling components.

In this case, the cooling components of the mirror carrying body can likewise be configured in such a way that the mirror carrying body can be cooled to a great- 35 er extent in at least one partial region than in a further partial region. The spatially resolved cooling can be improved further by this measure.

In addition, temperature sensors can also be integrated in the optical elements, as a result of which it is possible to achieve, for example, an open-loop/closed-loop control of the temperature distribution over the optical element.

In the case of a planned thermal load change in association with a change in the illumination setting, the occurring deformations to be expected in this case can also be prevented by a cooling flow. This is effected e.g. by means of a suitable temporal parameter selection for the open-loop and closed-loop control of the relatively sluggish cooling circuit.

An exemplary embodiment of the invention is explained in greater detail below with reference to the drawing, in which:

Figure 1 shows a cooling body with a first cooling zone for an annular thermal load,

Figure 2 shows said cooling body with a second cooling zone for a dipole-type thermal load,

Figure 3a shows an optical individual mirror facet into which a micro cooler is integrated,

Figure 3b shows a mirror carrying body of a facet mirror with three cooling zones and six implemented individual mirror facets,

Figure 4 shows an optical multilayer mirror with a locally different EUV absorptivity and with three cooling zones, wherein the parameters of the individual partial cooling circuits can be adapted,

Figure 5 shows an optical multilayer mirror with a locally different EUV absorptivity and with three cooling zones, wherein the contact areas with respect to the optical multilayer mirror are fashioned locally differently,

Figure 6 shows an optical multilayer mirror with a locally different EUV absorptivity and with three cooling zones, wherein the geometries of the cooling channels are fashioned locally differently.

For the spatially resolved cooling of these heat distributions at the optical elements, a cooling body 1, 23 (Figures 1, 2 and 5) is used here. The cooling body 1 shown can, for example, be fitted to a facet mirror or to a deflection mirror or be embodied as a mirror carrier of an EUV deflection mirror (figures 4 and 6). The possibility of integrating a micro cooler 10 into an individual mirror facet 8 is shown in figure 3a.

Figure 1 and Figure 2 show the cooling body 1 with cooling channels 4 introduced in the two cooling zones 2 and 3, wherein the first cooling zone 2 is designed for an annular thermal load and the second cooling zone 3 is designed for a dipole-type thermal load. Figure 1 does not illustrate the optically active surface of the optical element; in the example shown, said optically active surface is situated in the region indicated by the arrow 7. The cooling zone 3 is situated along the depicted z-direction in a plane situated at a deeper level in comparison with the cooling zone 2. In the cooling body 1, it is additionally possible also to implement cooling channels such as are used in accordance with the prior art for homogeneous cooling and which do not serve for locally adapted cooling. Figure 1 shows a cooling body 1 wherein only the cooling channels 4 provided for the locally adapted cooling are depicted. Ad-

vantageous materials of the cooling body 1 can be, for example, steel, aluminium, ceramic and copper. The cooling channels 4 shown here are embodied substantially in meandering fashion, but can also have, for example, straight or circular sections. Machining production methods as well as eroding and/or etching methods and also casting and moulding methods can be used for producing the cooling channels 4. A further possibility (not shown here) consists of the connection of cooling lines, which then correspond to the cooling channels 4, to the cooling body 1, e.g. in the region of an optically non-active surface of the associated optical element. The connection of the cooling liens (not illustrated here) to the cooling body 1 can be effected e.g. by welding, soldering, bonding or else by other connection techniques. Embodiments are possible in which the cooling is performed by means of cooling lines implemented exclusively into the cooling body 1, by means of cooling channels 4 implemented exclusively into the cooling body 1, or by means of a combination of implemented cooling lines and cooling channels 4. The cooling channels 4 illustrated in figure 1 and figure 2 or else the cooling lines (not illustrated) are in each case connected via an inlet 5 and an outlet 6 to a cooling circuit (not depicted in the drawing), such that a cooling medium can flow from the inlet 5 to the outlet 6 through the cooling channels 4. The cooling medium can be, for example, water, glycol or liquid metal. The tube diameter can be in the range of approximately 5 mm to 9 mm and the volumetric flow rate of the cooling medium can be 3 litres per minute, for example. The pressure losses are intended not to exceed a value of approximately 1 bar for each cooling circuit.

By way of example, in figure 1 the cooling body 1 is subjected to an annular thermal load, which is indicated by the curved arrows 7 in figure 1. For cooling pur-

poses it is possible to use here, in particular, the first cooling zone 2, wherein a cooling medium flows through the cooling channels 4 of said cooling zone 2. For cooling heat distributions caused by a different annular illumination setting with a plurality of ring-shaped illuminated regions, further cooling zones can also be introduced into the cooling body 1, which then run in addition to the ring-shaped cooling zone 2 along a ring having a smaller or a larger diameter. Merely by way of example, one ring-shaped cooling zone 2 is provided in the cooling body 1 in figure 1.

The sectional illustration I-I in Figure 1 shows, in a plan view, the meandering course of the cooling channel 4 in the ring-shaped cooling zone 2.

It can be helpful to design the cooling body 1 at the same time with differently configured cooling zones. This is advantageous particularly when the thermal loading of the optical element changes over time.

Figure 2 shows, as section II-II, the cooling body 1 illustrated in figure 1 in a plane situated at a deeper level along the depicted z-direction with the second cooling zone 3. Said cooling zone 3 consists of the partial cooling zones 3.1 and 3.2, which together form a dipole-type arrangement. In the case of a dipole-type thermal load, the cooling zone 3 can be used to compensate for the asymmetrical heat distribution in the cooling body in a location-adapted manner. The cooling zone 3 likewise has an inlet 5 and an outlet 6, into and out of which the cooling medium can respectively flow. The cooling channels 4 of said cooling zone 3 are connected to the cooling circuit (not illustrated in the drawing).

For the purpose of cooling the locally different heat distribution, alongside the separate use of the different cooling zones 2 and 3, there is, in particular, also the possibility of combined use of the cooling channels 4 in said cooling zones 2 and 3 in order also to be able to react to other illumination settings. The individual cooling zones 2 and 3 and also the individual cooling channels 4 are designed for rapid changeover. In other words, in the case of this embodiment, the individual cooling channels 4 and, if appropriate, the cooling lines of the cooling zones 2 and 3 can be disconnected from the cooling circuit or connected thereto in a short time. The cooling system established by the cooling body 1 and by the cooling circuit is generally temporally sluggish. When a planned change in illumination setting is carried out, therefore, in this case the second cooling zone 3 is supplementarily connected during a temporally limited cooling flow with respect to the first cooling zone 2.

In order to determine the temperature in the individual cooling zones 2 and 3, temperature sensors can additionally also be implemented there, which can also be used by the open-loop and closed-loop control of the cooling system.

The flow in the cooling channels 4 can either be laminar or turbulent or assume intermediate states. In this case, a turbulent flow has the advantage of more efficient cooling relative to a laminar flow. However, care must be taken to ensure that the flow of the cooling medium does not induce any mechanical oscillations which are undesirable in the optical exposure process. For the purpose of homogeneously cooling an areal region of the cooling body 1, cooling channels 4 operating according to the countercurrent principle can also be implemented, in particular.

The heat distribution at the individual optical elements is generally also dependent on the material thereof and the component geometry thereof. The use of empirical values, experimental measurements and also FEM calculations are advantageous for determining the spatially resolved heat distribution and the local deformations that occur, and for designing the cooling body 1 with the cooling channels 4 and for designing the open-loop and closed-loop control.

Figure 3a shows a variant of the invention in which the principle according to the invention is applied to an individual mirror facet of a facet mirror. Such facet mirrors, which can be contained in an EUV illumination system, for example, can consist of 500 to 600 individual mirror facets 8 and are generally implemented in the holes of a mirror carrying body (not illustrated in the figure). The incident EUV radiation heats the individual mirror facet 8 and the mirror carrying body during the operation of the associated projection exposure apparatus, wherein, in particular, deformations at the optically active surfaces 9 of the individual mirror facets 8 also prove to be unfavourable for the optical illumination process. Furthermore, the entire module, consisting of mirror carrying body and many individual mirror facets, can also be deformed on account of the thermal load.

Figure 3a illustrates an individual mirror facet 8, into which a micro cooler 10 with cooling channels 4' is integrated directly below the optically active surface 9. The cooling is thus effected substantially in very close proximity to the energy input induced by the EUV radiation, and thus counteracts the deformations at the optically active surface 9. The micro cooler 10 in the individual mirror facet 8 shown is embodied in ring-

shaped fashion and has meandering cooling channels 4'. A mirror carrier 11 of the individual mirror facet 8 contains the feed line 12 and the discharge lines 13, which can be produced by etching, for example. The mirror carrier 11 is embodied here in such a way that the cooling medium flows through a central middle channel, serving as feed line 12, to the centre of the mirror. From there, the cooling medium is fed radially into the micro channels of the individual mirror facet and then via a circularly embodied edge channel to the discharge lines 13 of the mirror carrier 11. Via an inlet 5, cooling medium can thus flow through the feedline 12 to the cooling channels 4. Via the discharge lines 13, which are likewise integrated into the mirror carrier 11, the cooling medium passes from the cooling channels 4 to the two outlets 6. The inlet 5 and the two outlets 6 are connected to a cooling circuit (not illustrated more specifically here). The cooling channels 4 can be produced e.g. by etching using hydrofluoric acid and using a photomask. However, the use of the photomask for applying the structure to be etched in does not constitute a necessary step in this case. Further possibilities for introducing the structure include micro milling and embossing into a layer previously applied to the rear side of the mirror, which layer can be composed of nickel, for example. However, the preferred methods for introducing the structure are etching and micro milling, since the heat transfer can thus be effected through a homogeneous material without additional other layers. The connection of the mirror rear side 14 to the mirror carrier 11 can preferably be carried out by means of diffusion welding or laser bonding.

In the exemplary embodiment shown in Figure 3b, a basic cooling of the facet mirror can also be effected via the mirror carrying body 1', wherein the latter can then be embodied as a cooling body e.g. with three in-

dividual cooling zones 16, 17 and 18 for spatially resolved cooling. By way of example, the mirror carrying body 1' here contains different cooling channels 4'' in which a coolant flows. It is thus possible firstly to counteract the deformation of the entire module. The avoidance and reduction of the deformations at the optically active surfaces 9 of the individual mirror facets 8 are effected, by contrast, substantially with the integrated micro coolers 10.

Figure 4, Figure 5 and Figure 6 in each case show a multilayer mirror 15 for EUV lithography with different possibilities of the spatially resolved cooling in the three cooling zones 16, 17 and 18. The multilayer mirrors 15 situated in a vacuum consist of a substrate 19, an MoSi layer 20 for reflecting EUV radiation, and an EUV absorber layer 21 having a locally different thickness. The EUV absorber layer 21 can be composed, for example, of ruthenium, molybdenum or silicon and has in the cases shown here, for example, a linear thickness gradient, such that during operation the EUV radiation is absorbed to different extents locally at the EUV absorber layer 21. The reflected radiation has, relative to the incident radiation, inter alia, an intensity modulation resulting from the absorption at the multilayer mirror 15 with EUV absorber layer 21. The thermal input as a result of the EUV radiation is thus locally different, such that temperature gradients can arise in the multilayer mirror 15, which temperature gradients, if appropriate, also lead to a strain and deformation of the multilayer mirror 15. Imaging aberrations and wavefront aberrations can thus occur in particular as a result of deformations at the optically active surface 9 of the multilayer mirrors 15.

Figure 4 illustrates a multilayer mirror 15 with an EUV absorber layer 21 having a locally different thickness,

wherein the spatially resolved cooling is effected by means of a suitable choice of parameters of the cooling circuit. For this purpose, the cooling circuit is divided into three partial cooling circuits, to each of
5 which a separate cooling channel 4'' is connected. This therefore results in the three cooling zones 16, 17 and 18 in this example. During operation, it is possible, in particular, to set the cooling medium, the initial temperature, the throughflow rate, and the type of dis-
10 tinct flow state for each cooling zone and to vary them over time. The flow state can be laminar or turbulent or assume an intermediate state. By way of example, the flow state can be influenced via adjustable valves. During operation, in particular the following two spe-
15 cial states can also be effected, wherein, in the first case, a constant input temperature is maintained and the throughflow rates are individually adapted to the energy rate generated by the absorbed EUV radiation. In the second special state, a constant flow velocity is
20 provided, but the input temperature of the cooling medium can be adapted differently locally. Overall, the cooling rate in the cooling zones has to counteract the spatially resolved energy input - induced by the EUV radiation. In the example shown in Figure 4, the sub-
25 strate 19 simultaneously fulfils the function of a cooling body.

Figure 5 shows a multilayer mirror 15 with a locally different EUV absorber layer 21 and the three cooling
30 zones 16, 17 and 18. Three connecting elements 22 each provided with a contact area of different sizes are fitted to the substrate 19. The contact areas touch the substrate 19 of the multilayer mirror 15. The substrate 19 is not provided with cooling channels 4 in this ex-
35 ample; rather, a separate cooling body 23 is present, in which the cooling channel 4'' runs. The thermal transfer coefficients are set individually in the three

cooling zones 16, 17 and 18 for example by means of the size of the contact area between substrate 19 and cooling body 23, in order to be able to counteract the spatially resolved energy input as a result of the UV radiation.

Figure 6 illustrates a multilayer mirror 15 with a locally different EUV absorber layer 21, wherein the cooling channels 4 in the three cooling zones 16, 17 and 18 illustrated here have a different geometry. The cooling channels 4 are embodied here in meandering fashion and have a different frequency over the gradient of the EUV absorber layer 21.

As an alternative to the illustration in Figures 5 and 6, in each case or else in part separate cooling circuits can also be used instead of a common cooling circuit for the cooling zones.

Patent Claims:

1. Optical element for a projection exposure apparatus for semiconductor lithography comprising an optically active surface (9) and at least one cooling component for cooling the optical element, whereby the cooling component is connected to at least two separate cooling circuits and embodied in such a way that the optically active surface (9) can be cooled to a greater extent in at least one partial region than in a further partial region, characterized in that the optical element is a facet mirror having a plurality of individual mirror facets (8), and in that a micro cooler (10) having cooling channels (4') is integrated into at least one individual mirror facet (8) and that a mirror carrier (11) of the individual mirror facet (8) contains feed (12) and discharge lines (13) for coolant.

2. Optical element according to Claim 1, characterized in that the micro cooler (10) is integrated below a mirroring surface of the individual mirror facet (8).

3. Optical element according to any of Claims 1 to 2, characterized in that a feed line (12) opens in the region of the centre of the individual mirror facet (8) and a discharge line (13) is connected to a circularly embodied edge channel.

4. Optical element according to any of Claims 1 to 3, characterized in that the cooling channels (4') are produced by etching or micro milling.

5. Optical element according to any of Claims 1 to 4, characterized in that a mirror carrying body (1') of the facet mirror is connected to further cooling components.

6. Optical element according to Claim 5, characterized in that the cooling components of the mirror carrying body (1') are configured in such a way that the mirror carrying body (1') can be cooled to a greater extent in at least one partial region than in a further partial region.

7. Optical element for a projection exposure apparatus for semiconductor lithography comprising an optically active surface (9) and at least one cooling component for cooling the optical element, characterized in that the cooling component is connected to at least two separate cooling circuits and embodied in such a way that the optically active surface (9) can be cooled to a greater extent in at least one partial region than in a further partial region.

8. Optical element according to Claim 7, characterized in that the optical element is a multilayer mirror for EUV lithography, wherein the multilayer mirror has a mirror carrier (11, 19) provided with a cooling body (1, 23) or embodied as a cooling body (1, 19).

9. Optical element according to Claim 8, characterized in that the cooling body (1) has cooling channels (4) arranged in different cooling zones (2, 3, 16, 17, 18) for cooling individual partial regions.

10. Optical element according to Claim 9, characterized in that the different cooling zones (2, 3) are arranged in different planes with respect to a z-direction.

11. Optical element according to Claim 9 or 10, characterized in that the cooling channels (4) are connected to separate cooling circuits.

12. Optical element according to any of Claims 9 to 11, characterized in that the cooling channels (4) are formed by casting methods, moulding methods, eroding, etching or machining production methods.

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13. Optical element according to any of Claims 9 to 11, characterized in that the cooling channels (4) are embodied as cooling lines connected to the cooling body.

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14. Optical element according to Claim 13, characterized in that the cooling lines are connected to the cooling body by welding, bonding or soldering.

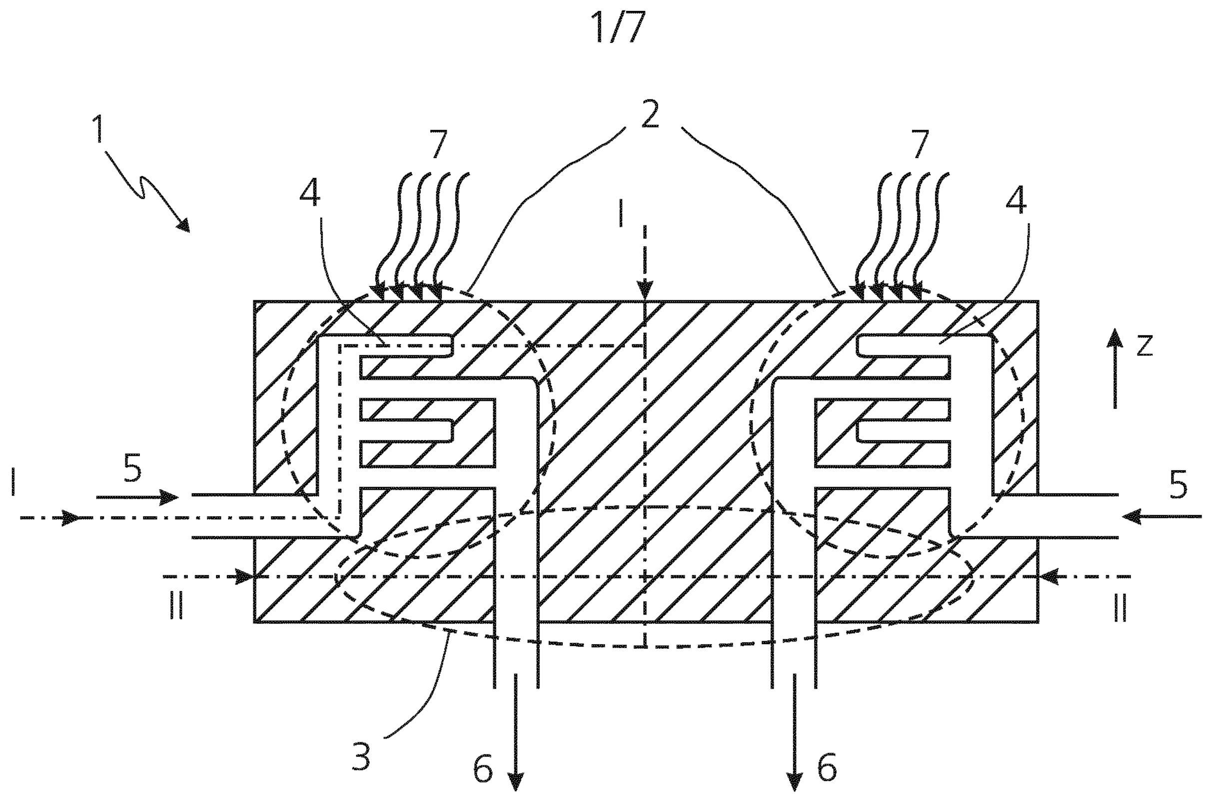
15 15. Optical element according to Claim 9, characterized in that the cooling channels (4) are embodied in meandering fashion and have different geometries for different cooling zones (2, 3, 16, 17, 18).

20 16. Optical element according to Claim 8, characterized in that the cooling body (23) is in thermal contact with the optical element via connecting elements (22) and the greater cooling in one partial region is achieved by virtue of the fact that the contact area
25 between connecting element (22) and optical element is larger than in the further partial region.

17. Optical element according to any of the preceding claims, characterized in that an EUV absorber layer
30 (21) is arranged on the optically active surface (9), said EUV absorber layer having different thicknesses in different regions of the optically active surface (9).

18. Optical element according to any of the preceding
35 claims, characterized in that temperature sensors are present.

19. Projection exposure apparatus for semiconductor lithography, in particular for EUV lithography, comprising an optical element according to any of Claims 1 to 18.



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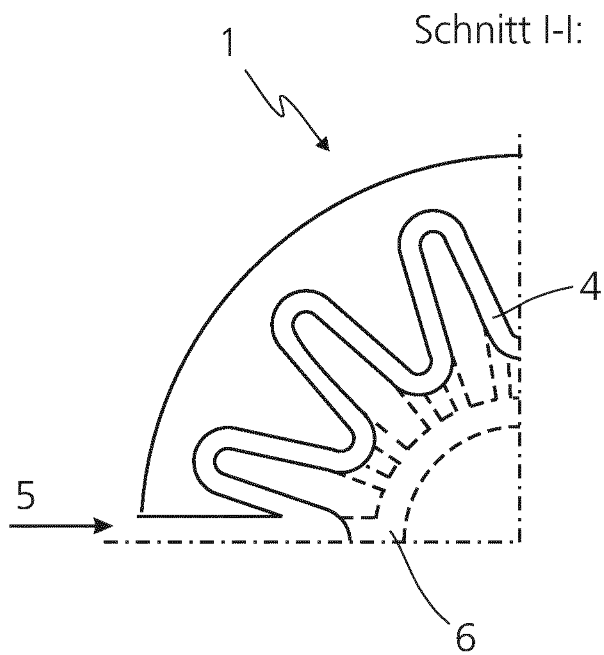

Fig. 1

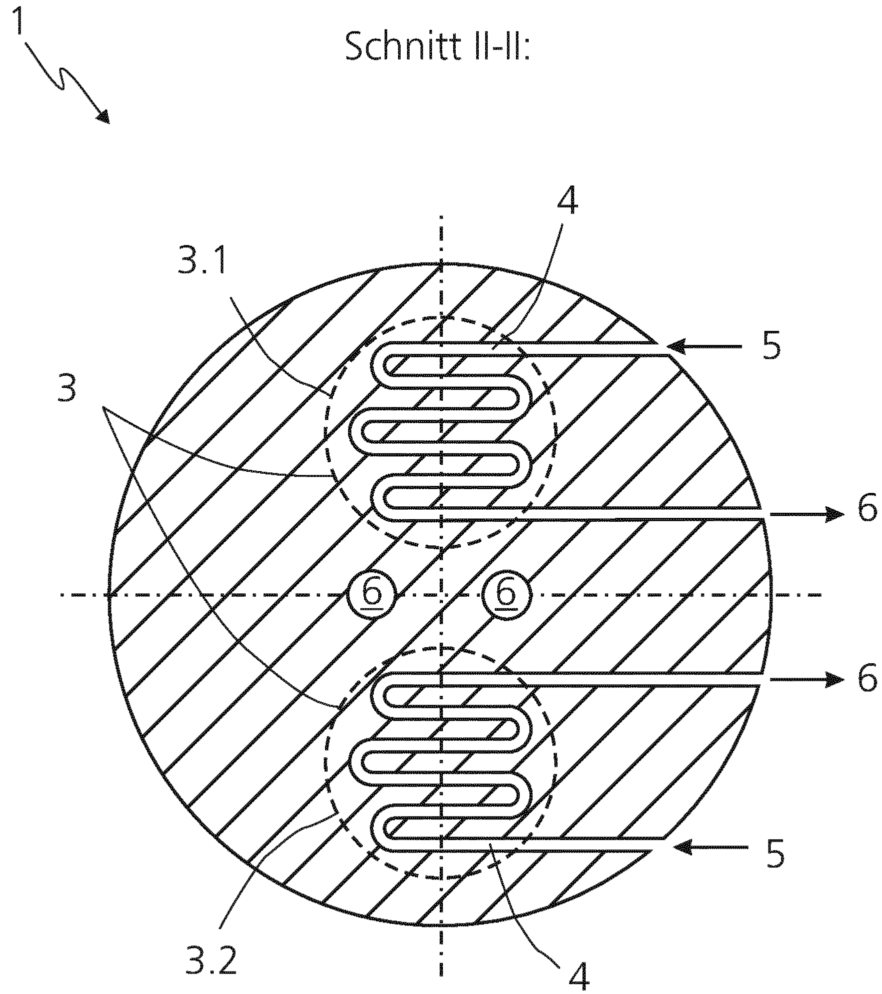

Fig. 2

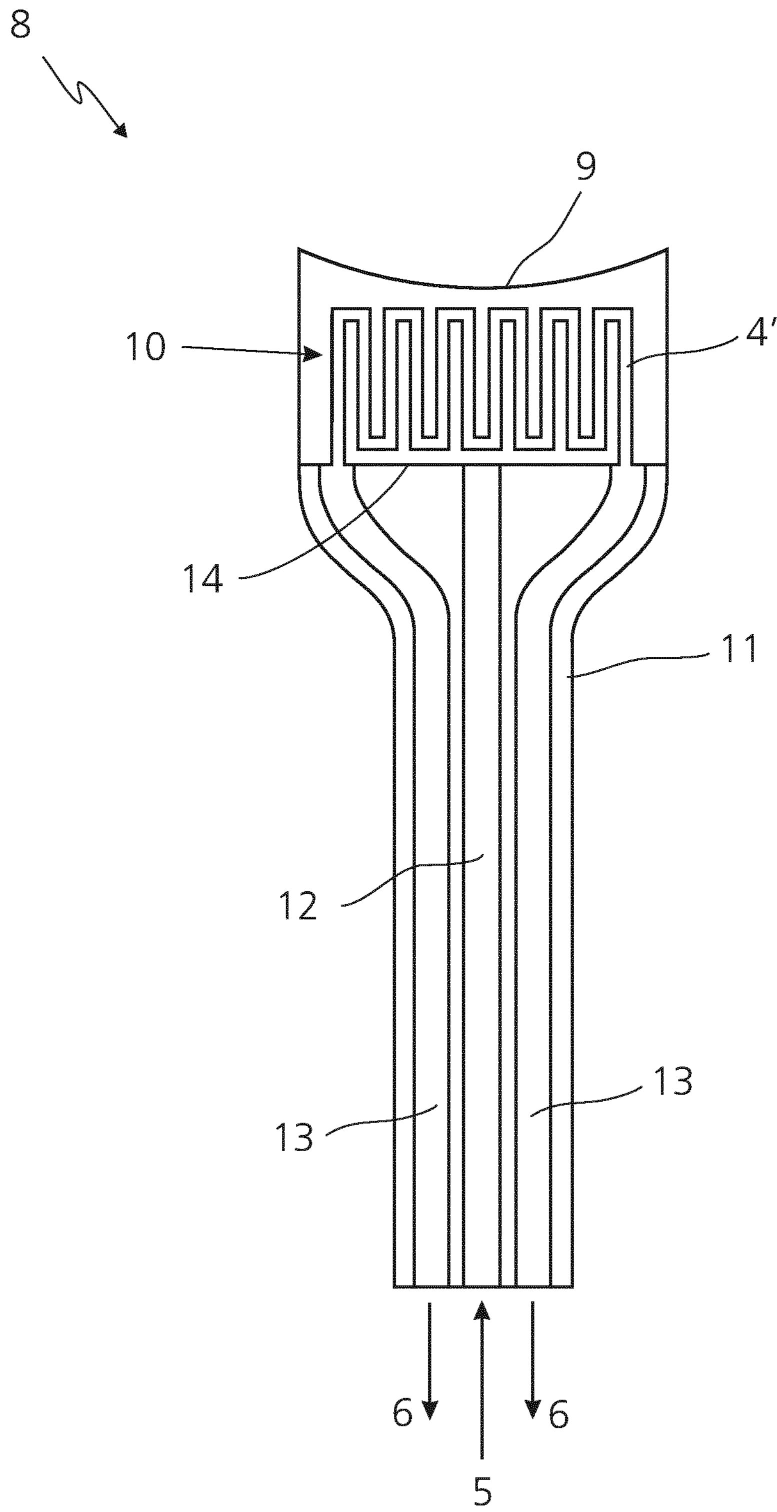

Fig. 3a

9 8 9 8 9

10 10

18

4'' 4'' 1'

16 17

6

5

Fig. 3b

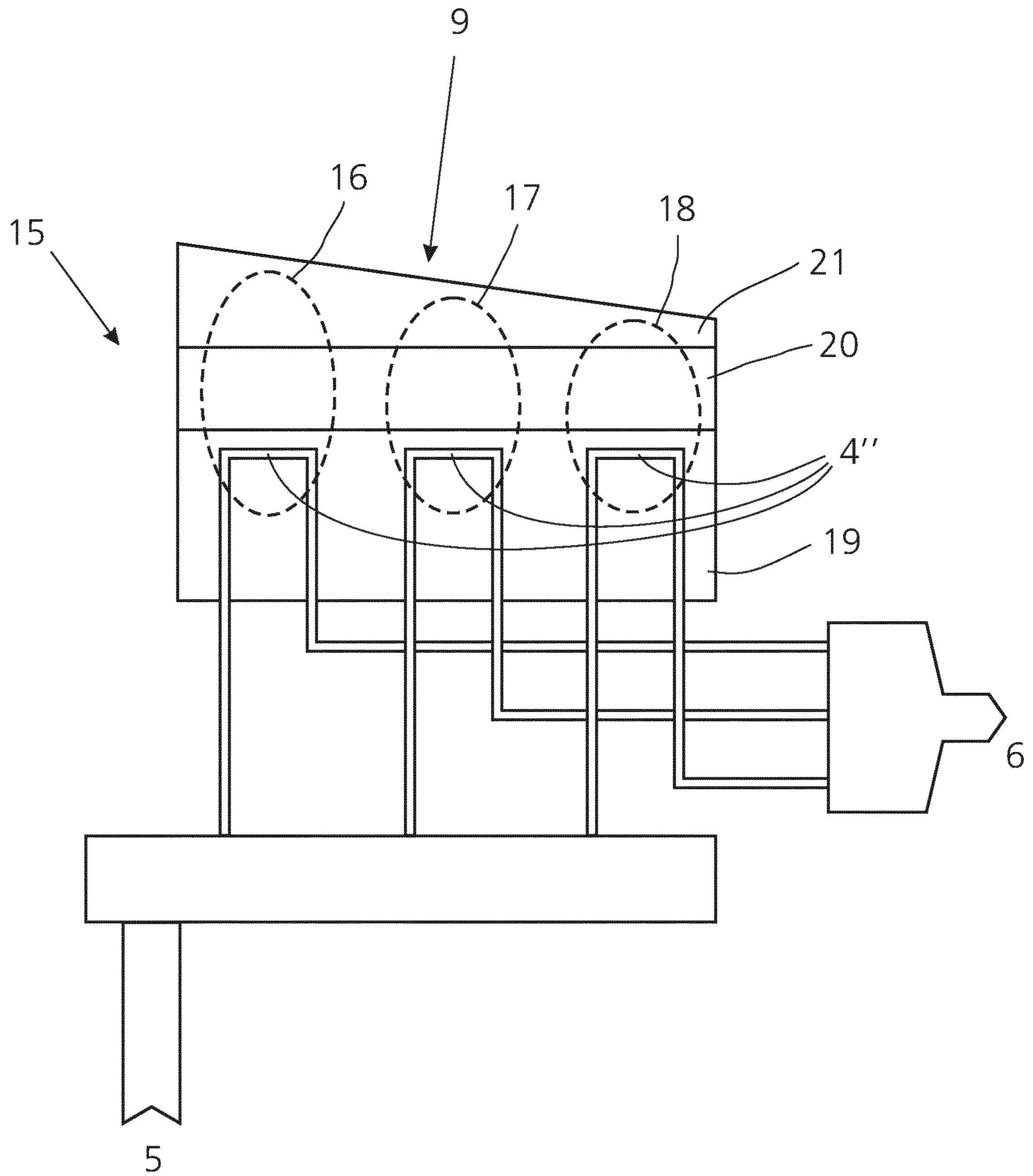

Fig. 4

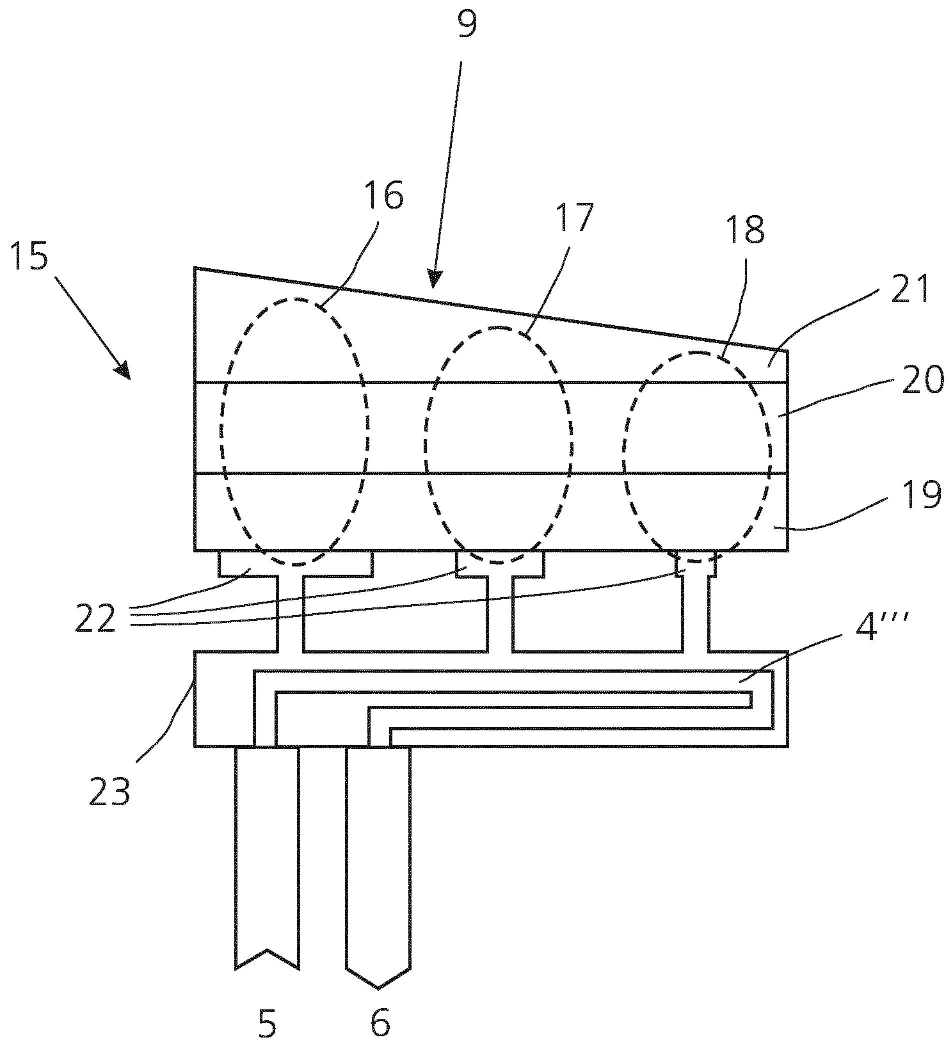

Fig. 5

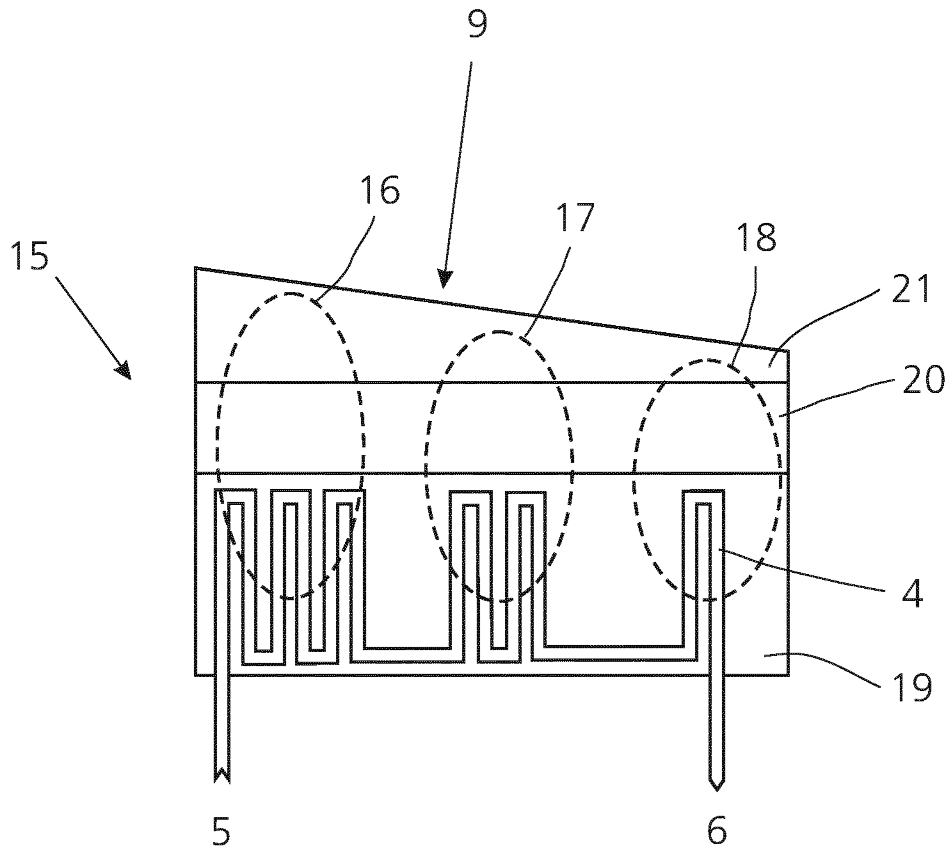

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/054664

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20 G02B7/195
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03F G02B

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

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

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0 532 236 A1 (CANON KK [JP]) 17 March 1993 (1993-03-17) column 4, line 38 - column 8, line 10; figure 1 -----	7-19 1-6
X Y	EP 1 376 239 A2 (NIPPON KOGAKU KK [JP]) 2 January 2004 (2004-01-02) paragraphs [0076] - [0088]; figures 3, 4, -----	7,19 1
Y	US 2010/007866 A1 (WARM BERNDT [DE] ET AL) 14 January 2010 (2010-01-14) paragraphs [0005], [0065]; figure 6 -----	1-6

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2012	14/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Eisner, Klaus

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/054664

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0532236 A1	17-03-1993	CA 2077572 A1	08-03-1993
		DE 69220868 D1	21-08-1997
		DE 69220868 T2	06-11-1997
		EP 0532236 A1	17-03-1993
		US 5390228 A	14-02-1995
EP 1376239 A2	02-01-2004	EP 1376239 A2	02-01-2004
		US 2004051984 A1	18-03-2004
US 2010007866 A1	14-01-2010	DE 102007008448 A1	21-08-2008
		EP 2122393 A2	25-11-2009
		JP 2010519725 A	03-06-2010
		US 2010007866 A1	14-01-2010
		WO 2008101656 A2	28-08-2008