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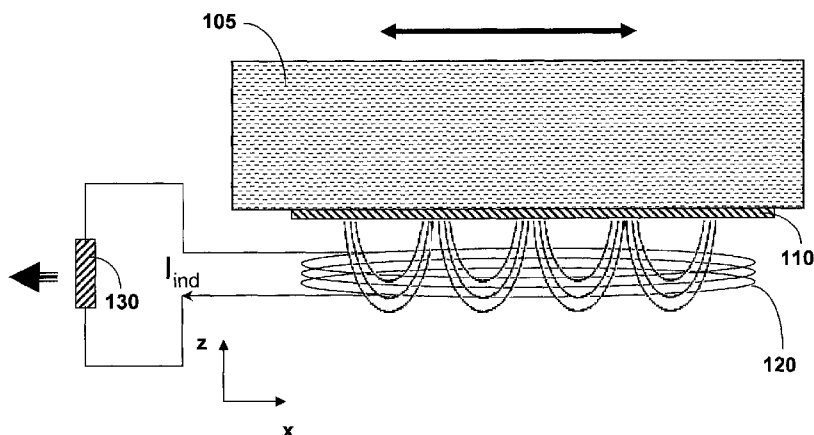
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(54) Title: ARRANGEMENT FOR AND METHOD OF DAMPING A SHOCK LOADING OF AN OPTICAL SYSTEM

Fig. 3



(57) Abstract: The invention concerns an arrangement for and a method of damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, wherein the optical system has at least one optical element (105), comprises an abutment arrangement (541 -546) for limiting a displacement travel of the optical element (105) in the case of a shock loading, and an energy dissipation path which does not include the abutment arrangement (541 -546) and on which kinetic energy of the optical element is converted during a deflection of the optical element (105) in a non-operational phase of the optical element and is given off to the environment of the optical system.

5 Arrangement for and method of
damping a shock loading of an optical system

BACKGROUND OF THE INVENTION

10 Field of the invention

The invention concerns an arrangement for and a method of damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus.

15 State of the art

20 Microlithography is used for the production of microstructured components such as for example integrated circuits or LCDs. The microlithography process is carried out in what is referred to as a projection exposure apparatus having an illumination system and a projection objective. In that case the image of a mask (=reticle) illuminated by means of the illumination system is projected by means of the projection objective on to a substrate (for example a silicon wafer) which is coated with a light-sensitive layer (photoresist) and arranged in the image plane of the projection objective in order to transfer the mask structure on to the light-sensitive coating on the substrate.

Mirrors are used as optical components for the imaging process in projection objectives designed for the EUV range, that is to say at wavelengths of for example about 13 nm or about 7 nm, due to the lack of availability of suitable translucent refractive materials.

It is known inter alia from WO 2005/026801 A2 to use three actuator devices in a projection objective of an EUV projection exposure apparatus for the manipulation of optical elements such as mirrors, in up to six degrees of freedom, the actuator devices each having at least two Lorentz actuators or two
5 actively actuable axes of motion. In addition there is provided a weight force compensation device (or gravity compensation device) in the form for example of a spring element to minimise the power consumption of the Lorentz actuators as the weight compensation device substantially carries the mass of the optical element or mirror so that in that respect there is no need for a permanent flow of
10 current, with the generation of heat that this entails.

A problem occurring in spite of the use of such weight compensation devices lies in sagging or flexing which is caused by the actual weight of the mirror (which in an EUV system can certainly be 50 kg or more) and which is not prevented
15 solely by the weight compensation effect provided at the mirror assembly. That problem occurs in particular in high-aperture projection objectives (for example with values of the numerical aperture of greater than 0.4) as it is in such systems that it is generally necessary for the mirrors to be comparatively thin (in which respect for example the ratio of maximum diameter to maximum thickness, with
20 respect to the area which is optically used or acted upon by light, can be 10 or more) so that the width-to-thickness ratio becomes more and more disadvantageous in regard to the unwanted gravitationally induced flexing.

Approaches for resolving the problems linked to the application of mechanical
25 stresses to optical elements such as mirror or lenses are known for example from WO 2005/054953 A1 or US 2009/0122428 A1.

SUMMARY OF THE INVENTION

According to a first aspect, an object of the present invention is to provide an arrangement for and a method of damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, wherein negative effects of shock loadings, which e.g. can occur outside operation of the optical system such as during transport, can be reduced.

That object is attained by the features of the independent claims.

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An arrangement for damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, wherein the optical system has at least one optical element, comprises:

- an abutment arrangement for limiting a displacement travel of the optical element in the case of a shock loading; and
- an energy dissipation path which does not include the abutment arrangement and on which kinetic energy of the optical element is converted during a deflection of the optical element in a non-operational phase of the optical element and is given off to the environment of the optical system.

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In accordance with an embodiment, energy transmitted to the abutment arrangement by the optical element is reduced in comparison with a similar system without the energy dissipation path.

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In accordance with an embodiment, the arrangement has a first component suitable for producing a magnetic field and a second component, the first and second components being so arranged that said deflection of the optical element produces an electric induction current in the second component.

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In accordance with an embodiment, the second component is a coil.

In accordance with an embodiment, the arrangement further has an electric resistor through which the induction current produced in the second component flows in the case of said deflection.

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In accordance with an embodiment, the first component suitable for producing a magnetic field is a permanent magnet.

10 In accordance with an embodiment, the permanent magnet is mounted to the optical element.

15 In accordance with an embodiment, provided between the permanent magnet and the optical element is at least one mechanical decoupling means which reduces an application of mechanical stresses to the optical element, that is caused by the mounting of the permanent magnet to the optical element, in comparison with a corresponding arrangement without the mechanical decoupling.

20 In accordance with an embodiment, the mechanical decoupling means has at least one peripherally extending incision on the permanent magnet.

In accordance with an embodiment, the arrangement further has a controllable voltage source for acting on the at least one coil with a controllable electric current.

25

In accordance with an embodiment, the arrangement further has a device for bridging over the controllable voltage source in a non-operational phase of the optical system.

In accordance with an embodiment, the arrangement has at least two coils which can be acted upon with electric currents different from each other in their magnitude and/or their direction.

- 5 The invention also concerns a method of damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, during a non-operational phase of the optical system,

- wherein the optical system has at least one optical element and an abutment arrangement for limiting a displacement travel of the optical
10 element in the case of a shock loading, and
- wherein in the case of a shock loading kinetic energy of the optical element is given off to the environment of the optical system on an energy dissipation path which does not include the abutment arrangement.

- 15 In accordance with an embodiment, in the case of a shock loading an electric current is induced in at least one coil, wherein heat dissipation is effected in an electric resistor through which said electric current flows.

- According to a further aspect, the disclosure also relates to a method of and an
20 arrangement for actuating an optical element in an optical system, in particular a microlithographic projection exposure apparatus, which even in the case of higher numerical apertures reduces or avoids adverse effects in respect of imaging properties due to parasitic forces or moments occurring at the optical elements.

- 25 In this aspect the disclosure concerns a method of actuating an optical element in an optical system, in particular a microlithographic projection exposure apparatus, wherein a magnetic force is exerted on the optical element by changing a magnetic field in which the optical element is disposed, and wherein
30 the method comprises the following steps:

- determining a disturbance in the imaging properties of the optical system;
and
- changing the magnetic field in such a way that deformation of the optical
element which at least partially compensates for said disturbance in the
5 imaging properties is achieved.

Thus the disclosure also involves the concept, by means of a change in a
magnetic field in which an optical element is disposed, of producing an actively
adjustable deformation of said optical element, which in turn is used to
10 compensate for unwanted disturbances.

In that respect in accordance with the present disclosure the deformation of the
optical element preferably corresponds to a deformation relative to the ideal or
nominal optical active surface of the optical element by at least 2 picometers
15 (pm), in particular at least 5 pm, further in particular at least 10 pm.

It is possible in that way to achieve in particular compensation for the above-
described gravitationally induced flexing. In that respect active adjustability of
that deformation also affords the possibility, depending on the intended place of
20 delivery or use of the optical system, of taking account of the definitely significant
fluctuations in gravitational force and thus specifically and targetedly
compensating for the gravitationally induced flexing phenomena which are
possibly different depending on the respective location of use.

25 The optical element can be in particular a mirror. The disclosure however is not
limited thereto. Rather it can involve for example a (in particular cylindrical or
spherical) lens or also another transmissive element such as for example a
prism, depending on the respective specific configuration of the optical system
(for example a projection objective of a microlithographic projection exposure
30 apparatus for wavelengths in the DUV or EUV range) or the position in the
optical system.

In an embodiment the change in the magnetic field is effected by varying the actuation of at least one coil with an electric current. In that respect, in particular to alter the magnetic field, a plurality of coils can each be acted upon with an electric current. Furthermore the electric currents in at least two of those coils can be different from each other in magnitude and/or direction. According to the disclosure in that case homogeneous magnetic fields or magnetic field changes are not necessarily produced, but they can also have a local variation in order to specifically and targetedly introduce forces for deformation purposes depending on the respective position, at the optical element.

In accordance with an embodiment a first coil is acted upon with a first electric current which causes a change in the magnetic field which substantially compensates for a gravitationally induced flexing of the optical element, and at least one second coil is acted upon with a second electric current which causes a change in the magnetic field which produces an additional deformation of the mirror. By means of the disclosure therefore, using a plurality of coils, it is possible on the one hand to compensate for gravity, to avoid flexing, while on the other hand it is possible to produce a specifically targeted deformation effect in order to compensate for any unwanted disturbances in operation of the optical system.

The deformation phenomena to be compensated according to the disclosure can be for example in the range of between 50 and 100 nm, without the invention being restricted thereto. In that respect the deformation which is set according to the invention, as already described hereinbefore, can also cause only partial compensation in respect of that deformation. Preferably according to the disclosure at least substantial compensation for the gravitationally induced flexing is achieved. As a quantitative criterion for compensation for gravitationally induced flexing, which can be implemented by the disclosure, it can be specified for example that the deformation is below a given deformation limit as a

consequence of the compensation effect according to the disclosure. In particular a uniform optical active surface of the optical element or mirror is preferably adjusted by means of the compensation effect according to the disclosure insofar as that optical active surface after the compensation effect
5 according to the disclosure has a maximum deformation of less than 10 picometers (pm), in particular less than 5 pm, further particularly less than 2 pm.

The force required to achieve a desired deformation is dependent on the geometry of the mirror and also the position frequency of the deformation, in
10 which respect the forces required can be correspondingly less, the thinner the mirrors and the lower the position frequency of the deformation in each case. Typical values can be in the range of between 0.5 N and 10 N, without the invention being restricted thereto.

15 In further embodiments active compensation of disturbances occurring in operation of the optical system can also be achieved by suitable regulation, insofar as for example firstly a shock acting on the optical element is detected in terms of strength or magnitude and direction, for example with an acceleration sensor, and then the acceleration in question of the optical element is
20 counteracted by way of a suitable voltage pulse at the coil.

In a further aspect the disclosure concerns an arrangement for actuating an optical element, for use in a method as set forth in one of the preceding claims, comprising

- 25
- a component suitable for producing a magnetic field;
 - at least one coil; and
 - a controllable voltage source for acting on the at least one coil with a controllable electric current.

In an embodiment the arrangement has at least two coils which can be acted upon with electric currents different from each other in their magnitude and/or their direction.

- 5 The component suitable for producing a magnetic field can be in particular a permanent magnet which can be mounted at the optical element.

10 In an embodiment provided between the permanent magnet and the optical element is at least one mechanical decoupling means which reduces an application of mechanical stresses to the optical element, that is caused by the mounting of the permanent magnet to the optical element, in comparison with a corresponding arrangement without the mechanical decoupling. The mechanical decoupling means can have at least one peripherally extending incision on the permanent magnet.

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In an embodiment the arrangement further has a device for bridging over the controllable voltage source in a non-operational phase of the optical system.

20 In an embodiment the arrangement has at least one abutment for limiting a displacement travel of the optical element in the case of a shock loading of the optical element.

25 In an embodiment the arrangement has at least one electric resistor for dissipating the heat to the environment of the optical system having the optical element, wherein said heat is generated by an electric current induced in the at least one coil in the case of a shock loading.

Further configurations of the invention are to be found in the description and the appendant claims.

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The invention is described in greater detail hereinafter by means of embodiments by way of example illustrated in the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 shows a diagrammatic view to illustrate an arrangement for actuating an optical element in accordance with an embodiment of the invention,

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Figure 2 shows a diagrammatic view to illustrate a further embodiment of an arrangement according to the invention, and

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Figures 3-6 show diagrammatic views to illustrate further embodiments of the invention, in which unwanted effects of shock loadings occurring in an optical system are reduced.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 shows a diagrammatic view of an optical element in the form of a mirror 105 to which a magnet 110 is mounted in this embodiment on its rear side or surface opposite to the optical active surface. In addition the arrangement of Figure 1 has an induction coil 120 in a circuit with an electric resistor 130 spaced from the mirror 105 and a controllable voltage source 140.

25

As is also shown in exaggerated form in Figure 1 the mirror 105, as a consequence of its own weight, has a gravitationally induced flexure which leads

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to the mirror 105 sagging down in its central region in the direction of the negative z-axis (in the illustrated co-ordinate system).

The controllable voltage source 140 serves to produce a compensating force on the mirror 105 by regulation of the voltage generated by the voltage source 140 and thus the electric current flowing through the induction coil, by means of which force the above-described mirror flexure, as a consequence of the force of gravity, can be at least partially compensated. The current induced by the controllable voltage source 140 is identified by I_{Komp} in Figure 1. Active control of the compensating force on the mirror 105, that is possible by way of the controllable voltage source 140, also affords the possibility of taking account of the certainly significant differences in terms of force of gravity and thus different deformation states at a respective location, depending on the respective intended location of delivery or use of the optical system.

The compensation force can be produced as shown in Figure 1 in opposite relationship to the direction of the force of gravity (that is to say in the direction of the positive z-axis in the illustrated co-ordinate system), but alternatively it can also be produced in the direction of the force of gravity (that is to say in the direction of the negative z-axis in the illustrated co-ordinate system) for example to still further increase the deformation depending on the respective specific desired conditions of use or to put the mirror into a desired deformation state. In further embodiments the effect of gravity can also be overcompensated, whereby deformation of the mirror 105 can also be achieved.

In further embodiments, as only diagrammatically indicated in Figure 2, it is also possible to use a plurality of induction coils 120 (that is to say two or more) and to supply them with an electric current in parallel by way of the controllable voltage source 140. In that case, the direction of the respectively exerted force can be varied by a suitable design configuration in respect of the geometry of the induction coils and/or forces of differing magnitudes can act on the underside of

the mirror. Figure 2 involves for example a first induction coil 220 (provided similarly to Figure 1) while references 221 and 222 denote second and third induction coils which produce different forces acting at the underside of the mirror 105, wherein those forces, as indicated, by virtue of the differing directions of the electric current flowing through the induction coil, also go in opposite directions.

Figure 2 also diagrammatically indicates three actuator units 331 – 333 in the form of Lorentz actuators which in per se known manner can each have a weight force compensating device in the form for example of a spring element, wherein the weight force compensating devices substantially carry the mass of the mirror 105 to minimise the power consumption of the Lorentz actuators so that in that respect there is no need for a permanent flow of current through the Lorentz actuators. Admittedly the above-mentioned weight force compensating devices compensate for the respectively occurring weight force at the mirror connection assemblies, but the above-described problem of gravitationally induced mirror flexing is still not eliminated therewith, the induction coils 120 and 220 being provided for that purpose.

Basically any movement of the mirror 105 leads to a change in the magnetic flux through the induction coil 120 and thus also induction of an electric current in the induction coil 120. That electric current I_{ind} induced by the movement of the mirror 105 is identified by I_{ind} in Figure 1.

As regards the mirror movements which occur in usual operation of a projection objective, having the mirror 105, of an EUV projection exposure apparatus, they are typically of the order of magnitude of μm and are thus comparatively slight so that induction currents I_{ind} caused thereby in the induction coil 120 are comparatively negligible. The effect of induction of an electric current in the induction coil 120 solely by virtue of the movement of the mirror 105 however can also be specifically utilised in accordance with a further aspect of the

invention to compensate for unwanted effects which occur outside operation of the optical system having the mirror 105 (for example shock loadings during transport) or which can also be caused by unusual events (for example earthquakes).

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Thus for example shock loads occurring during assembly or adjustment and also during transport of a projection objective can accelerate the mirrors which are supported in a substantially freely flying relationship by way of Lorentz actuators, wherein the speed or kinetic energy of the mirrors increases with increasing

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mass and increasing travel distances of the mirrors.

Firstly the problem involved herewith will be described with reference to Figures 5 and 6.

15 As shown in Figures 5 and 6 abutments (end stops) 541 – 546 – which are only diagrammatically illustrated – are usually provided, which ensure, while mechanically limiting the freedom of movement of the mirror 105, that the air gap between the movable and the stationary actuator portions 531a, b and 532a, b in the respective Lorentz actuator 531, 532 does not fall below a minimum size

20 even in the event of shock loads occurring during transport or in operation, to avoid damage to the Lorentz actuators 531, 532. The abutments or end stops 541 – 546 are thus used to limit the uncontrolled movement of a mirror 105 and to brake the mirror 105 over the shortest possible distances in non-destructive fashion. The abutments or end stops 541 – 546 typically have spring elements

25 which are acted upon with a force which is correspondingly greater, the higher the level of kinetic energy transmitted by the mirror 105. As indicated in Figure 6 however, the loading of the contact locations increases with increasing kinetic energy of the mirror 105, in which respect increasing mechanical stresses are applied to the mirror 105.

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Referring again to Figure 1 energy can now be effectively dissipated out of the system if required, that is to say in a load situation, by virtue of the fact that the movements occurring in the region of the abutments or end stops 541 - 546 in a load situation, typically occur over a distance of some millimeters and thus induce significant induction currents. That energy dissipation is based on the fact that the electric current I_{ind} induced by the movement of the mirror 105, as shown in Figure 1, is passed by way of the electric resistor 130, the heat generated in the electric resistor 130 being discharged from the system.

Because of the above-mentioned energy dissipation the abutments or end stops 541 - 546 of Figures 5 and 6 can absorb substantially less energy as a part of the energy has been removed from the system prior to the mirror encountering the respective abutment or end stop, as a consequence of generation of the induction current or conversion into heat at the electric resistor. In other words therefore according to the invention there is provided an additional energy dissipation path which dissipates energy from the system by the kinetic energy involved in unwanted deflection of the mirror 105 being ultimately converted into heat energy. The dissipation of that heat energy is by way of the electric resistor 130 (which is preferably arranged away from the optical system) so that the optical properties of the system are not impaired by the dissipated heat.

The controllable voltage source 140 can also be bridged over during transport, in order to achieve the above-described effect only as diagrammatically indicated in Figures 3 and 4.

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The unwanted movement of the mirror 105 can include both a shock loading with a braking effect that entails at an abutment element, and also oscillating movements of relatively small amplitude that occur during operation. In a further embodiment there is also the possibility of damping or terminating unwanted oscillating movements of the mirror 105. For example, an acceleration detector or sensor (not shown) can also be arranged at the mirror 105, which detects a

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respective currently prevailing acceleration of the mirror 105. The corresponding signal can be fed to the system again in a regulating loop in order to apply a signal which has a precisely counteracting effect and thus produces a compensation action in order as a result to embody an active damping device.

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The fitment of the magnet 110 (and not the induction coil 120) on the mirror 105, adopted in the embodiment of Figures 1 – 4, has the advantage that there is no need to provide necessary feed lines or possibly the voltage source 140 are not to be provided on the movable mirror 105 and same can thus be arranged more easily. The invention however is not restricted thereto but also embraces
10 embodiments in which the induction coil 120 is arranged on the mirror 105.

In further embodiments, as diagrammatically shown in Figure 4, the induction coil 120 can also be replaced by a metal plate 150 in which eddy currents are induced by virtue of the above-described change in the magnetic field, that is
15 involved with the movement of the mirror 105, the eddy currents also at least partially being converted into heat and dissipated from the system.

A substantial advantage of the approach according to the invention is that no
20 external sources whatsoever (such as batteries or the like) are required, but the desired effect is achieved solely by the combination of a magnet 110 and an induction coil 120 or metal plate. Consequently feed lines which cause a problem in particular for example during transport or even possibly components which are prohibited for safety reasons, for example during air transportation, can also be
25 dispensable. Accordingly therefore in a load situation (either upon transport or in the event of unusual events such as for example earthquakes during operation) the kinetic energy of the mirror 105 is reduced in accordance with the eddy current principle, without 'normal operation' of the system being disturbed.

30 In the above-described embodiments the magnet 110 can be a permanent magnet or also another component suitable for producing a magnetic field or for

changing the magnetic flux at the location of the induction coil 120. For example, instead of a permanent magnet, it is also possible to use a further induction coil with associated current source, or the material of the optical element or mirror 105 itself can be provided with magnetic additives. In addition the magnet 105
5 can in principle also be mounted at the top side or the side surface of the mirror.

When the magnet 110 is mounted to the mirror 105 the different coefficients of thermal expansion of the mirror 105 on the one hand and the magnet 110 on the other hand are to be taken into account, for which reason care is to be taken to
10 provide for adequate mechanical decoupling. To implement such decoupling for example incisions or recesses which extend in peripheral relationship in the region of the mounting of the magnet 110 can be provided for example on the part of the mirror 105. In that way it is possible at least substantially to ensure that deformation phenomena occurring due to different thermal expansion effects
15 are not transmitted to the optically active region of the mirror 105. In that respect, it is also possible to take account of the different coefficients of thermal expansion in particular upon hardening of adhesive materials used during the joining process. In accordance with further embodiments other mechanical decoupling elements such as for example suitable spring elements can also be
20 used for mechanical decoupling purposes. By means of such decoupling elements, any troublesome deformation phenomena can be kept away from the optically active region of the mirror not only during the joining process but also in operation.

25 In the above-described embodiments moreover suitable magnetic or magnetisable materials can also be used as the optical element (for example by introducing iron particles into optical glasses), in which case mounting a separate magnet on the optical element or mirror (mechanically 'decoupled' as described hereinbefore) is dispensable.

In a further aspect the invention concerns a method of actuating an optical element in an optical system, in particular a microlithographic projection exposure apparatus, as well as an arrangement for actuating an optical element as defined in the following clauses.

5

1. A method of actuating an optical element in an optical system, in particular a microlithographic projection exposure apparatus, wherein a magnetic force is exerted on the optical element by changing a magnetic field in which the optical element is disposed, and wherein the method comprises the following steps:

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- determining a disturbance in the imaging properties of the optical system; and

- changing the magnetic field in such a way that deformation of the optical element which at least partially compensates for said disturbance in the imaging properties is achieved.

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2. A method as set forth in clause 1, characterised in that the change in the magnetic field is effected in such a way that the deformation achieved thereby of the optical element at least partially compensates for a gravitationally induced flexing of the optical element.

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3. A method as set forth in clause 1 or clause 2, characterised in that the change in the magnetic field is effected by a variation in the actuation of at least one coil with an electric current.

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4. A method as set forth in clause 3, characterised in that a plurality of coils are respectively acted upon with an electric current to change the magnetic field.

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5. A method as set forth in clause 4, characterised in that the electric currents in at least two of said coils are different in magnitude from each other.

6. A method as set forth in clause 4 or clause 5, characterised in that the electric currents in at least two of said coils are different in direction from each other.

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7. A method as set forth in anyone of clauses 4 through 6, characterised in that

- a first coil is acted upon with a first electric current which causes a change in the magnetic field which substantially compensates for a gravitationally induced flexing of the optical element; and

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- at least one second coil is acted upon with a second electric current which causes a change in the magnetic field which produces an additional deformation of the mirror.

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8. An arrangement for actuating an optical element, for use in a method as set forth in one of the preceding clauses, comprising

- a component suitable for producing a magnetic field;

- at least one coil; and

- a controllable voltage source for acting on the at least one coil with a

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controllable electric current.

9. An arrangement as set forth in clause 8, characterised in that it has at least two coils which can be acted upon with electric currents different from each other in their magnitude and/or their direction.

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10. An arrangement as set forth in clause 8 or clause 9, characterised in that the component suitable for producing a magnetic field is a permanent magnet.

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11. An arrangement as set forth in clause 10, characterised in that the permanent magnet is mounted to the optical element.

12. An arrangement as set forth in clause 11, characterised in that provided between the permanent magnet and the optical element is at least one mechanical decoupling means which reduces an application of mechanical stresses to the optical element, that is caused by the mounting of the permanent magnet to the optical element, in comparison with a corresponding arrangement without the mechanical decoupling.

13. An arrangement as set forth in clause 12, characterised in that the mechanical decoupling means has at least one peripherally extending incision on the permanent magnet.

14. An arrangement as set forth in anyone of clauses 8 through 13, characterised in that it further has a device for bridging over the controllable voltage source in a non-operational phase of the optical system.

15. An arrangement as set forth in anyone of clauses 8 through 14, characterised in that the arrangement has at least one abutment for limiting a displacement travel of the optical element in the case of a shock loading of the optical element.

16. An arrangement as set forth in clause 15, characterised in that it has at least one electric resistor for dissipating heat to the environment of the optical system having the optical element, wherein said heat is generated by an electric current induced in the at least one coil in the case of a shock loading.

Even if the invention has been described by reference to specific embodiments numerous variations and alternative embodiments will be apparent to the man skilled in the art, for example by combination and/or exchange of features of individual embodiments. Accordingly it will be appreciated by the man skilled in the art that such variations and alternative embodiments are also embraced by

the present invention and the scope of the invention is limited only in the sense of the accompanying claims and equivalents thereof.

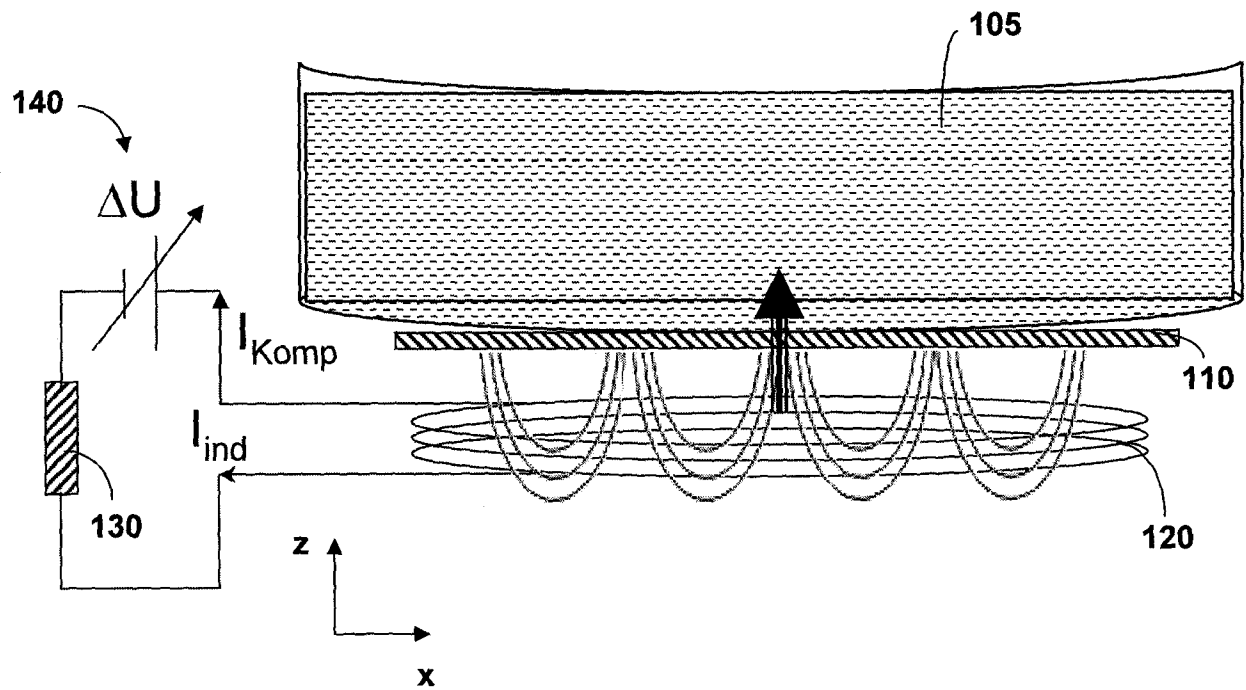
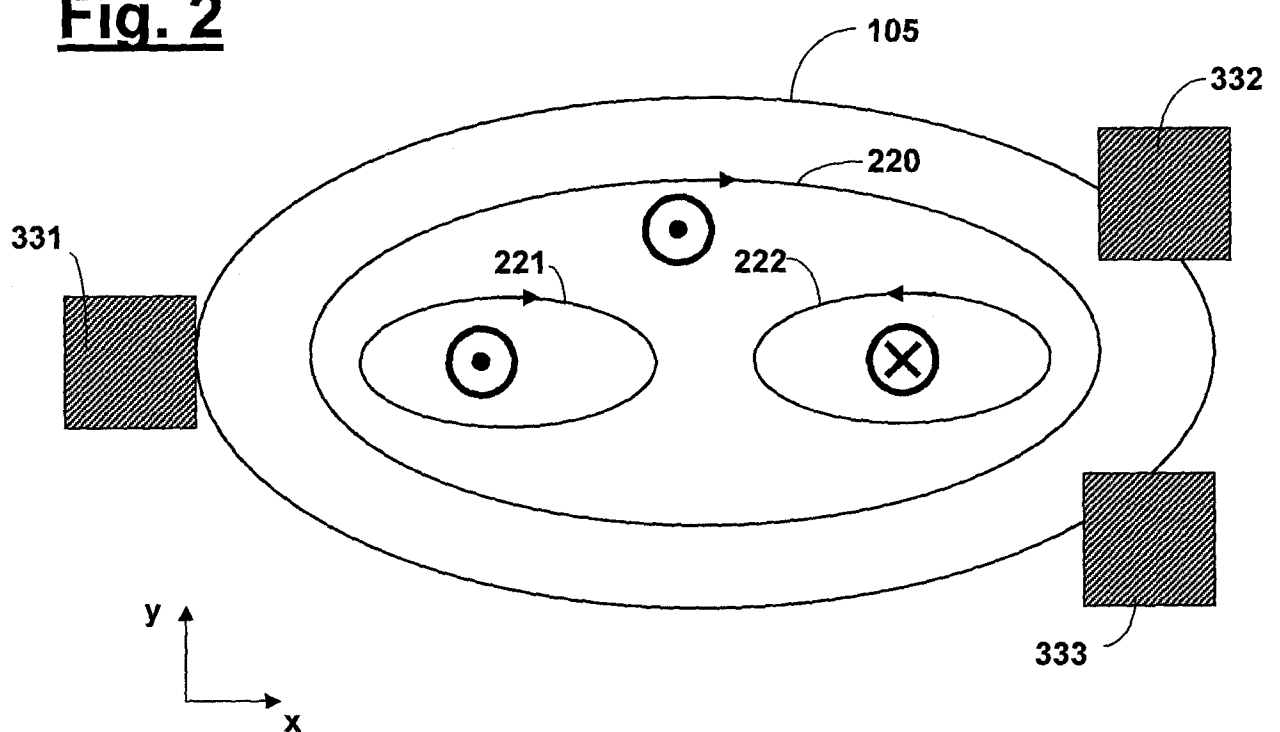
Claims

1. An arrangement for damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, wherein the optical system has at least one optical element, comprising
 - an abutment arrangement (541-546) for limiting a displacement travel of the optical element (105) in the case of a shock loading; and
 - an energy dissipation path which does not include the abutment arrangement and on which kinetic energy of the optical element (105) is converted during a deflection of the optical element (105) in a non-operational phase of the optical element (105) and is given off to the environment of the optical system.
2. An arrangement as set forth in claim 1, characterised in that energy transmitted to the abutment arrangement (541-546) by the optical element (105) is reduced in comparison with a similar system without the energy dissipation path.
3. An arrangement as set forth in claim 1 or claim 2, characterised in that it has a first component suitable for producing a magnetic field and a second component, the first and second components being so arranged that said deflection of the optical element (105) produces an electric induction current in the second component.
4. An arrangement as set forth in claim 3, characterised in that the second component is a coil (120, 220, 221, 222).
5. An arrangement as set forth in claim 3 or 4, characterised in that it further has an electric resistor (130) through which the induction current produced in the second component flows in the case of said deflection.

6. An arrangement as set forth in anyone of the claims 3 through 5, characterised in that the first component suitable for producing a magnetic field is a permanent magnet (110).
- 5
7. An arrangement as set forth in claim 6, characterised in that the permanent magnet (110) is mounted to the optical element (105).
8. An arrangement as set forth in claim 7, characterised in that provided
10 between the permanent magnet (110) and the optical element (105) is at least one mechanical decoupling means which reduces an application of mechanical stresses to the optical element (105), that is caused by the mounting of the permanent magnet (110) to the optical element (105), in comparison with a corresponding arrangement without the mechanical
15 decoupling.
9. An arrangement as set forth in claim 8, characterised in that the mechanical decoupling means has at least one peripherally extending incision on the permanent magnet.
- 20
10. An arrangement as set forth in anyone of the claims 4 through 9, characterised in that it further has a controllable voltage source (140) for acting on the at least one coil (120, 220, 221, 222) with a controllable electric current (I_{Komp}).
- 25
11. An arrangement as set forth in claim 10, characterized in that it further has a device for bridging over the controllable voltage source (140) in a non-operational phase of the optical system.

12. An arrangement as set forth in claim 10 or 11, characterised in that it has at least two coils (220, 221, 222) which can be acted upon with electric currents different from each other in their magnitude and/or their direction.
- 5 13. A method of damping a shock loading of an optical system, in particular a microlithographic projection exposure apparatus, during a non-operational phase of the optical system,
- wherein the optical system has at least one optical element (105) and an abutment arrangement (541-546) for limiting a
10 displacement travel of the optical element (105) in the case of a shock loading, and
 - wherein in the case of a shock loading kinetic energy of the optical element (105) is given off to the environment of the optical system on an energy dissipation path which does not include the abutment
15 arrangement (541-546).
14. A method as set forth in claim 13, characterised in that in the case of a shock loading an electric current is induced in at least one coil (120, 220, 221, 222), wherein heat dissipation is effected in an electric resistor (130)
20 through which said electric current flows.

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Fig. 1**Fig. 2**

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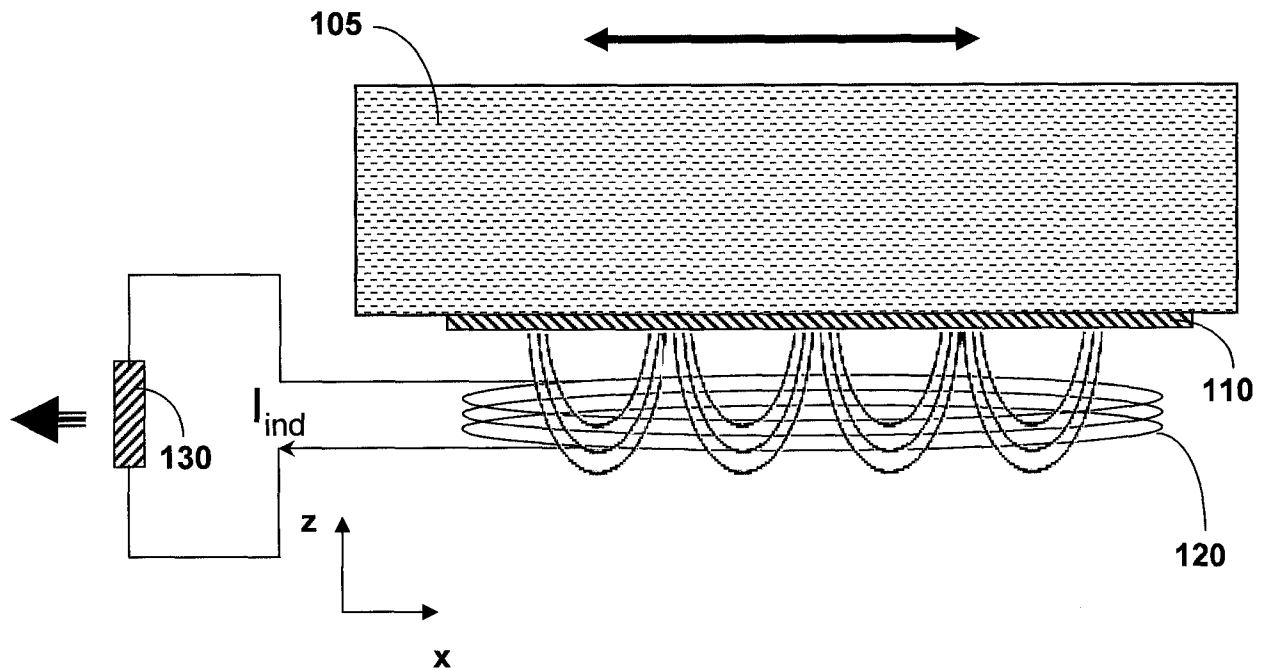
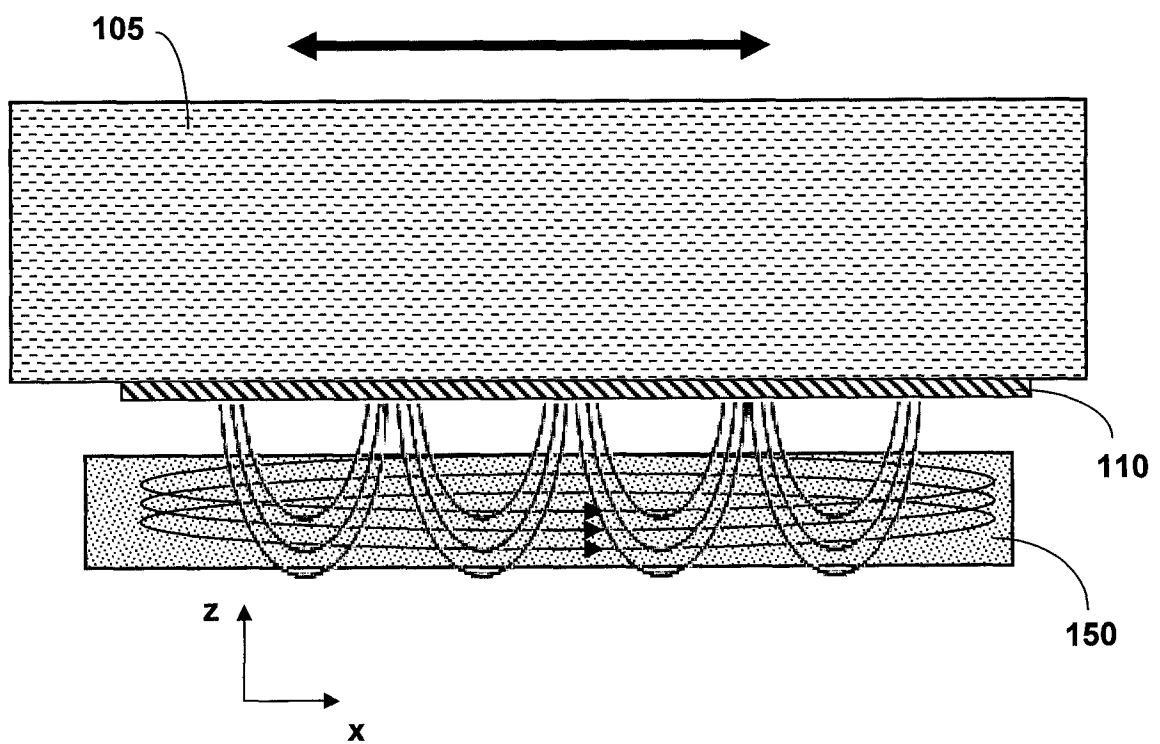
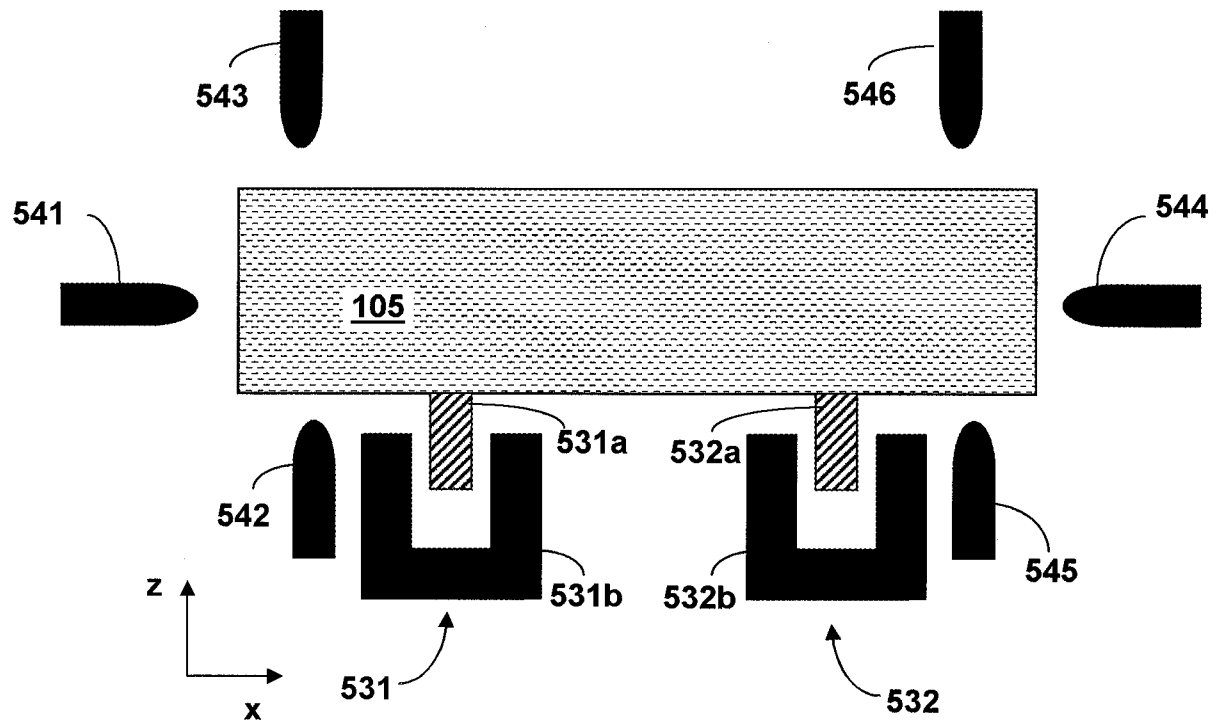
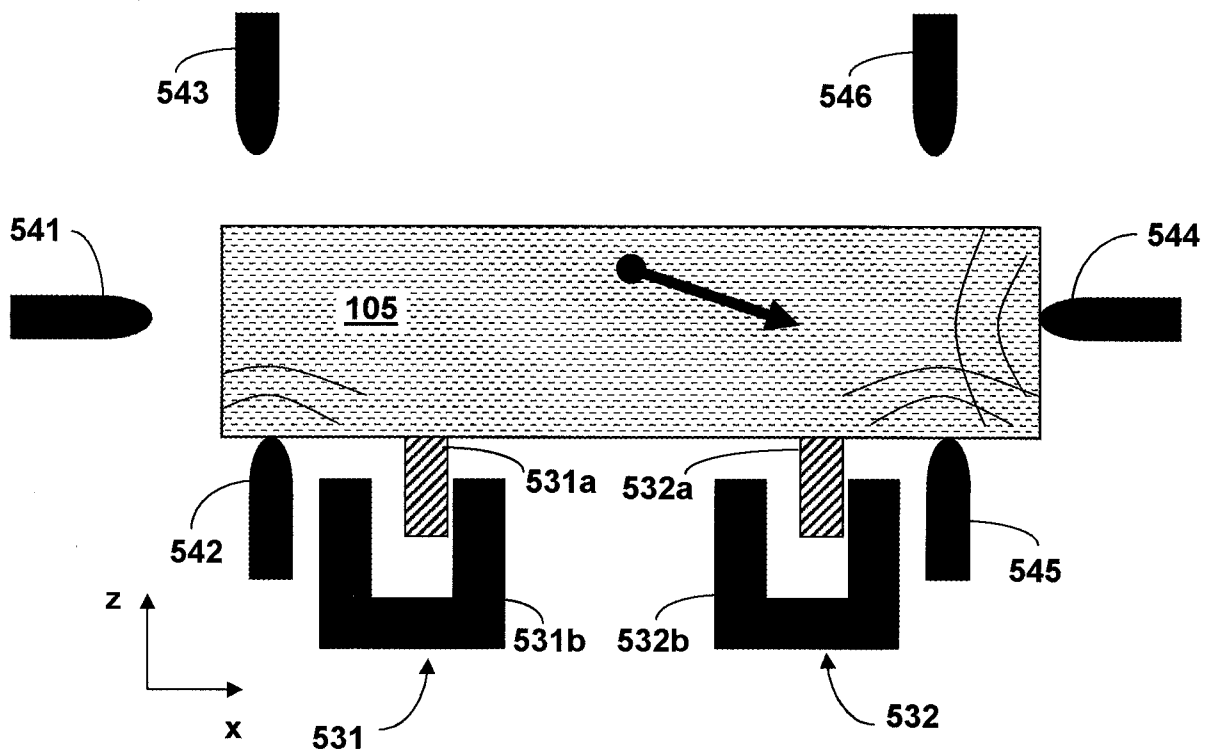
Fig. 3**Fig. 4**

Fig. 5**Fig. 6**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/062468

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20
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

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/153348 A1 (ROUX STEPHEN [US] ET AL) 5 July 2007 (2007-07-05)	1-3,13
Y	paragraphs [0070], [0071], [0083] - [0090]; figures 1,5A,5B,6	1-14
Y	US 2004/179192 A1 (MIZUNO MAKOTO [JP] ET AL) 16 September 2004 (2004-09-16) figures 17,18	1-14



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

28 October 2011

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/062468

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007153348	A1	05-07-2007	NONE
US 2004179192	A1	16-09-2004	EP 1457834 A2 15-09-2004