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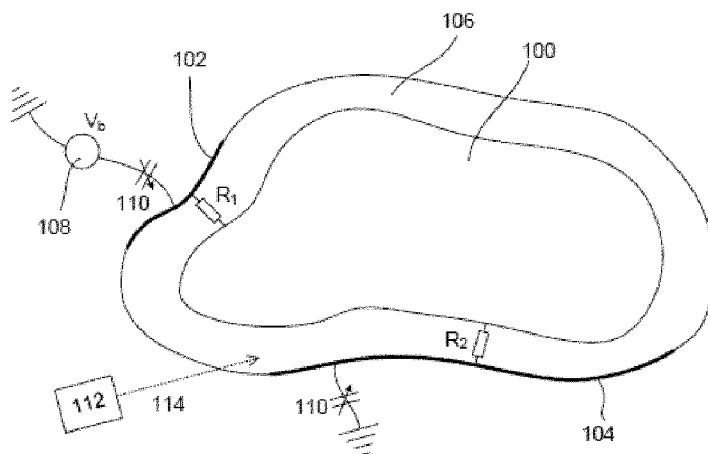


Fig. 2

(57) Abstract: A lithographic apparatus comprises: a plurality of optical elements defining an optical path; a first body; a second body; and a voltage supply. The lithographic apparatus may be an extreme ultraviolet (EUV) lithographic apparatus. The plurality of optical elements defining the optical path are arranged to receive a radiation beam, project the radiation beam onto a reticle so as to pattern the radiation beam and to form an image of the reticle on a substrate. The first body and second body are proximate to the optical path. The voltage supply is arranged to apply a potential difference across the first and second bodies. In particular, the first body, the second body and/or the voltage supply are arranged so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.



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LITHOGRAPHIC APPARATUS AND ASSOCIATED METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of EP application 22172837.1 which was filed on May 11, 2022 and EP application 22197338.1 which was filed on September 23, 2022 and which are incorporated herein in their entirety by reference.

FIELD

[0002] The present invention relates to a lithographic apparatus and associated method of operating a lithographic apparatus. In particular, it relates to extreme ultraviolet (EUV) lithographic apparatus in which hydrogen plasma may be formed. The present invention relates to apparatus and methods for controlling the flux and/or energy distribution of ions from plasma that are incident on bodies within a lithographic apparatus.

BACKGROUND

[0003] A lithographic apparatus is a machine constructed to apply a desired pattern onto a substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). A lithographic apparatus may for example project a pattern from a patterning device (e.g., a mask) onto a layer of radiation-sensitive material (resist) provided on a substrate.

[0004] The wavelength of radiation used by a lithographic apparatus to project a pattern onto a substrate determines the minimum size of features that can be formed on that substrate. A lithographic apparatus that uses EUV radiation, being electromagnetic radiation having a wavelength within the range 4-20 nm, may be used to form smaller features on a substrate than a conventional lithographic apparatus (which may for example use electromagnetic radiation with a wavelength of 193 nm).

[0005] In use, parts of an EUV lithographic apparatus through which the EUV radiation propagates may be maintained at pressures well below atmospheric pressure, for example, using vessels that are evacuated using vacuum pumps. It is known to provide hydrogen gas in such parts of an EUV lithographic apparatus (under low pressure). The EUV radiation beam is typically a pulsed radiation beam. As each pulse of radiation propagates through an optical path in the lithographic apparatus, gas molecules in the optical path tend to ionize such that a plasma is formed in the optical path. The plasma may diffuse away from the optical path such that the plasma extends slightly outside a volume through which the radiation beam propagates.

[0006] It may be desirable to provide an apparatus that obviates or mitigates one or more problems associated with the prior art.

SUMMARY

[0007] According to a first aspect of the disclosure there is provided a lithographic apparatus comprising: a plurality of optical elements defining an optical path arranged to receive a radiation beam, project the radiation beam onto a reticle so as to pattern the radiation beam and to form an image of the reticle on a substrate; a first body proximate to the optical path; a second body proximate to the optical path; and a voltage supply arranged to apply a potential difference across the first and second bodies; wherein the first body, the second body and/or the voltage supply are arranged so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.

[0008] The lithographic apparatus may be an extreme ultraviolet (EUV) lithographic apparatus. In use, the optical path may be maintained at pressures well below atmospheric pressure, for example, using vessels that are evacuated using vacuum pumps. It is known to provide hydrogen gas in the optical path (under low pressure). The radiation beam is typically a pulsed radiation beam. As each pulse of radiation propagates through the optical path, gas molecules in the optical path tend to ionize such that a plasma is formed in the optical path. The plasma may diffuse away from the optical path such that the plasma extends slightly outside a volume through which the radiation beam propagates.

[0009] The first body may be a sensitive object and therefore it may be desirable to control a flux and/or energy distribution of ions incident on the first body from the plasma. For example, the first body may be a mirror or a sensor or the like within the lithographic apparatus.

[0010] The second body may comprise one or more walls of the lithographic apparatus (which may, for example, form part of a housing for parts of the lithographic apparatus such as mirrors or the like). In general, the second body may be farther from the optical path than the first body. It will be appreciated that the second body may comprise a plurality of separate parts (for example walls of the lithographic apparatus).

[0011] It may be desirable to reduce the flux and energy of the ions that are incident on the first body. For example, ions with high energies can pose a sputter risk, leading to undesirable degradation of the first body. In addition, ions (for example hydrogen ions) can react with constituents of the first body (such as, for example, silicon from glass and stainless steel components and magnesium from aluminium components) to form volatile hydrides. Such volatile hydrides present within the lithographic apparatus may be incident on surfaces of mirrors within the lithographic apparatus, resulting on the constituents etched from the first body being deposited on the mirrors. Such deposits may absorb EUV radiation, which is undesirable. Furthermore, such deposits may be oxidized and, as a result, may absorb even more EUV radiation. Typically, hydrogen ions do not etch the outer, native oxide layer of materials (for example silicon). However, ions with sufficient kinetic energy can penetrate such oxide layers to the bulk material below, with which the ions can react to form volatile

hydrides (for example silane). Such volatile hydride formation may be stopped if the energies of the hydrogen ions are below a threshold kinetic energy such that they cannot penetrate the outer, native oxide layer of materials.

[00012] In order to control the flux and energy distribution of ions that is incident on the first body, one may naively try to apply a biasing voltage or potential to the first body. For example, if it is desirable to prevent ions from the plasma from impinging on the first body then a positive voltage may be applied to the first body to repel the ions. Similarly, if it is desirable to increase the energy or flux of ions from the plasma that impinge on the first body then a negative voltage may be applied to the first body to attract the ions. However, for an object that is proximate to the plasma, the object is in electrical contact with the plasma (via the plasma sheath). Therefore, just applying a biasing voltage to one object in the vicinity of the plasma will tend to pull the potential of the plasma up to (a fraction of) the biasing potential. The result is that the biasing potential does not result in a required or desired potential difference between the first body and the plasma and therefore has little impact on the flux and energy distribution of ions incident on the first body.

[00013] The lithographic apparatus according to the first aspect comprises two bodies (the first body and the second body) that are both proximate to the optical path and the voltage supply is arranged to apply a potential difference across the first and second bodies. Advantageously, by varying the configurations of the first and second bodies with respect to the optical path (where the plasma is formed) the lithographic apparatus according to the first aspect allows for a potential difference to be maintained between the first body and the plasma. In turn, this provides some control over the flux and energy distribution of ions incident on the first body.

[00014] It will be appreciated that as used herein an object being proximate to the optical path is intended to mean that the object is in the vicinity of the optical path such that a plasma formed in the optical path is connected to, or may be connected to, the object.

[00015] In some embodiments, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma, as now described.

[00016] The first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.

[00017] That is, an electrical resistance between the plasma and the second body is significantly less than an electrical resistance between the plasma and the first body. For example, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is less than half of the electrical conductance between the second body and the plasma. For example, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is less than a tenth of the electrical conductance between the second body and the plasma

[00018] It will be appreciated that there are several ways in which this difference in electrical conductance between the two bodies and the plasma can be achieved. In general, it is desirable to: (a) reduce surface area of first body relative to that of the second body; (b) increase the density of plasma between the second body and the optical path; and (c) reduce the distance between the second body and the optical path.

[00019] The second body may define a textured surface facing the optical path.

[00020] Providing a textured surface on the second body increases the surface area of the second body (compared to a flat surface). Advantageously, this increased surface area increases the electrical conductance (reduces the electrical resistance) between the plasma and the second body.

[00021] The textured surface may be a corrugated surface.

[00022] The lithographic apparatus may further comprise a mechanism for generating a conductive medium between the optical path and the second body.

[00023] The mechanism for generating a conductive medium between the optical path and the second body may comprise a voltage supply arranged to produce a plasma between the optical path and the second body.

[00024] The plasma may be a radiofrequency (RF) plasma.

[00025] Additionally or alternatively, the mechanism for generating a conductive medium between the optical path and the second body may comprise any source of ionizing radiation.

[00026] The mechanism for generating a conductive medium between the optical path and the second body may comprise an electron source arranged to increase a density of electrons between the optical path and the second body.

[00027] The mechanism for generating a conductive medium between the optical path and the second body may comprise a radiation source arranged to generate radiation that propagates between the optical path and the second body.

[00028] Such a radiation source may, for example, comprise an ultra violet (UV) radiation source. Alternatively, the radiation source may, for example, comprise an electron beam source.

[00029] The second body may comprise a portion which is adjacent to the optical path.

[00030] For example, rather than only comprising walls which form part of a housing for parts of the lithographic apparatus such as mirrors or the like, the second body may be further comprise an additional portion which is adjacent to the optical path. Such a portion may extend from the walls of the lithographic apparatus towards the optical path. Advantageously, this can reduce the distance between the plasma generated by the radiation beam and the second body (compared to an arrangement with no portion adjacent the optical path). Advantageously, this reduced distance from the plasma to the second body increases the electrical conductance (reduces the electrical resistance) between the plasma and the second body.

[00031] The portion which is adjacent to the optical path may extend at least partially around an optical axis of the optical path.

[00032] For example, the portion which is adjacent to the optical path may comprise a generally cylindrical or frustoconical hollow body that the radiation beam propagates through.

[00033] The voltage supply may be arranged to apply a biasing potential to the first body and the second body may be grounded.

5 [00034] For example, in order to reduce a flux and/or energy of ions from the plasma from impinging on the first body a positive biasing potential may be applied to the first body to repel the ions. Since there may be a significantly greater electrical conductance between the second body and the plasma than there is between the first body and the plasma, by grounding the second body the (local) biasing potential applied to the first body may have an insignificant effect on the potential of the plasma.

10 [00035] Alternatively, the voltage supply may be arranged to apply a biasing potential to the second body and the first body may be grounded.

[00036] For example, in order to reduce a flux and/or energy of ions from the plasma from impinging on the first body a negative biasing potential may be applied to the second body to attract ions thereto. As explained above, there may be a significantly greater electrical conductance between the second body and the plasma than there is between the first body and the plasma. Therefore, by applying a negative biasing potential to the second body, the potential of the plasma may be reduced significantly. In turn, this reduces the flux and energy of ions that impinge on the first body (which is grounded).

15 [00037] The second body may be formed from a material that is resistant to etching by the plasma.

[00038] Advantageously, this can reduce the amount of material which can be etched from the second body (and which may be subsequently deposited on sensitive surfaces within the lithographic apparatus such as, for example, surfaces of mirrors). It will be appreciated that the first body and the second body may be formed from materials which are compatible with the environment within an EUV lithographic apparatus.

20 [00039] The second body may be formed from tungsten.

[00040] Tungsten (W) is resistant to etching by hydrogen plasmas due to its mass. Furthermore, tungsten is compatible with the environment within an EUV lithographic apparatus.

[00041] In other embodiments, the second body may be formed from another heavy inert metal such as, for example, molybdenum (Mo), ruthenium (Ru), rhodium (Rh), silver (Ag), rhenium (Re), osmium (Os), iridium (Ir) or platinum (Pt). These materials may have at least some resistance to etching by hydrogen plasmas.

30 [00042] In some embodiments, the voltage supply may be arranged such that an energy distribution of ions incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which does not result in etching on a bulk material of the first body, as now described.

[00043] The voltage supply may be arranged to apply a potential difference across the first and second bodies such that an energy distribution of ions from the plasma that are incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which results in minimal etching of a bulk material of the first body.

5 [00044] The voltage supply may be arranged such that an alternating potential difference is applied across the first and second bodies.

[00045] The voltage supply may be arranged such that a rate of change of a potential across a plasma sheath of the plasma is small for the majority of the time.

10 [00046] Advantageously, by reducing the amount of time that the rate of change of the potential is above a threshold the amount of time in which a potential across the plasma sheath is varying is reduced. In some embodiments, the potential is either constant or slowly varying for the majority of the time and oscillates (abruptly) between a positive potential and a negative potential. In some embodiments, the potential oscillates (abruptly) between a positive portion of a duty cycle and a negative portion of a duty cycle and in each of the positive and negative portions of the duty cycle the potential is either constant or slowly varying.

15 [00047] Advantageously, by reducing the amount of time in which a potential across the plasma sheath is varying, a spread or width of the distribution of energies of ions impinging on the first member is reduced.

20 [00048] The potential difference may alternate between a positive portion wherein the first body is positively biased and negative portion wherein the first body is negatively biased.

[00049] An average of the potential difference applied across the first and second bodies may be non zero.

25 [00050] The non-zero average of the potential difference applied across the first and second bodies is a direct current (DC) component of the alternating potential difference. The average of the potential difference applied across the first and second bodies is dependent on the value of the potential difference applied during the positive portion and the negative portion and a duty cycle of the alternating potential difference (i.e. a ratio of the time duration of the negative portion to that of the positive portion). It will be appreciated that the average energy of ions impinging on the first body is dependent on the value of the average of the potential difference applied across the first and second bodies.

30 [00051] Although the average energy of ions impinging on the first body is dependent on the value of the average of the potential difference applied across the first and second bodies, a spread or width of the distribution of energies of ions impinging on the first member is dependent on the shape of the periodic potential difference applied across the first and second bodies.

35 [00052] A duty cycle of the potential difference applied across the first and second bodies may be such that a ratio of the time duration of the negative portion to the time duration of the positive portion is greater than 0.9.

[00053] Advantageously, this ensures that for at least 90% of the time the first body is negatively biased so as to attract ions from the plasma so as to etch contaminants from the first body. The positive portion allows time for accumulated charge on the first and second bodies to be removed.

[00054] A magnitude of the potential difference applied across the first and second bodies may increase during the negative portion.

[00055] For example, the magnitude of the potential difference applied across the first and second bodies may increase linearly during the negative portion. As discussed above, during the negative portion the first body is negatively biased so as to attract ions from the plasma so as to etch contaminants from the first body. During the negative portion positive surface charge can accumulate on the first body. Note that the first body may be connected to the voltage supply via a matching box or capacitor. By increasing the magnitude of the potential difference applied across the first and second bodies during the negative portion the effects of such surface charge can be at least partially accounted for. Again, this can reduce a spread or width of the distribution of energies of ions impinging on the first member, which is advantageous.

[00056] A frequency of the potential difference applied across the first and second bodies may be less than 400 kHz.

[00057] The first body and/or the second body may be connected to the voltage supply via a matching box or capacitor.

[00058] By connecting both the first body and the second to the voltage supply via a matching box or capacitor the net current averaged over a cycle of the alternating potential difference is zero. Advantageously, since the net current averaged over a cycle of the alternating potential difference is zero there is no net charge accumulation on surfaces within the lithographic apparatus LA over an integer number of cycles of the alternating potential difference. As such, it can be ensured that there is no net charge accumulation on surfaces within the lithographic apparatus LA due to the alternating potential difference. Such accumulation of net charge on surfaces within the lithographic apparatus LA is undesirable.

[00059] The lithographic apparatus may include a third body. The third body may be proximate to the optical path. The third body may be configured to be at ground potential or at floating potential. As such, the third body may have no active control of surface potential.

[00060] The lithographic apparatus may include a diode in electrical connection with the second body. In this way, the surface of the second body is biased relative to ground in order to influence plasma interactions with the first body. This relative potential may be established by a voltage source or a passive element, such as a diode.

[00061] The lithographic apparatus may be configured to provide the first body at a floating potential, a ground potential, or at another bias potential relative to ground.

[00062] According to a second aspect of the present disclosure, there is provided a method of controlling a flux and/or energy distribution of ions that is incident on a first body within a lithographic

apparatus, the method comprising: directing a radiation beam along an optical path in the lithographic apparatus, the first body being proximate to said optical path; and applying a potential difference across the first body and a second body that is also proximate to the optical path so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.

[00063] The lithographic apparatus may be an extreme ultraviolet (EUV) lithographic apparatus. In use, the optical path may be maintained at pressures well below atmospheric pressure, for example, using vessels that are evacuated using vacuum pumps. It is known to provide hydrogen gas in the optical path (under low pressure). The radiation beam is typically a pulsed radiation beam. As each pulse of radiation propagates through the optical path, gas molecules in the optical path tend to ionize such that a plasma is formed in the optical path. The plasma may diffuse away from the optical path such that the plasma extends slightly outside a volume through which the radiation beam propagates.

[00064] The first body may be a sensitive object and therefore it may be desirable to control a flux and/or energy distribution of ions incident on the first body from the plasma. For example, the first body may be a mirror or a sensor or the like within the lithographic apparatus.

[00065] The second body may comprise one or more walls of the lithographic apparatus (which may, for example, form part of a housing for parts of the lithographic apparatus such as mirrors or the like). In general, the second body may be farther from the optical path than the first body. It will be appreciated that the second body may comprise a plurality of separate parts (for example walls of the lithographic apparatus).

[00066] It may be desirable to reduce the flux and energy of the ions that are incident on the first body. For example, ions with high energies can pose a sputter risk, leading to undesirable degradation of the first body. In addition, ions (for example hydrogen ions) can react with constituents of the first body (such as, for example, silicon from glass and stainless steel components and magnesium from aluminium components) to form volatile hydrides. Such volatile hydrides present within the lithographic apparatus may be incident on surfaces of mirrors within the lithographic apparatus, resulting on the constituents etched from the first body being deposited on the mirrors. Such deposits may absorb EUV radiation, which is undesirable. Furthermore, such deposits may be oxidized and, as a result, may absorb even more EUV radiation. Typically, hydrogen ions do not etch the outer, native oxide layer of materials (for example silicon). However, ions with sufficient kinetic energy can penetrate such oxide layers to the bulk material below, with which the ions can react to form volatile hydrides (for example silane). Such volatile hydride formation may be stopped if the energies of the hydrogen ions are below a threshold kinetic energy such that they cannot penetrate the outer, native oxide layer of materials.

[00067] In order to control the flux and energy distribution of ions that is incident on the first body, one may naively try to apply a biasing voltage or potential to the first body. For example, if it is

desirable to prevent ions from the plasma from impinging on the first body then a positive voltage may be applied to the first body to repel the ions. Similarly, if it is desirable to increase the energy or flux of ions from the plasma that impinge on the first body then a negative voltage may be applied to the first body to attract the ions. However, for an object that is proximate to the plasma, the object is in electrical contact with the plasma (via the plasma sheath). Therefore, just applying a biasing voltage to one object in the vicinity of the plasma will tend to pull the potential of the plasma up to the biasing potential. The result is that the biasing potential does not result in a potential difference between the first body and the plasma and therefore has little impact on the flux and energy distribution of ions incident on the first body.

[00068] The method according to the second aspect uses two bodies (the first body and the second body) that are both proximate to the optical path and applies a potential difference across the first and second bodies (for example using a voltage supply). Advantageously, by controlling the potential difference applied across the first and second bodies the method according to the second aspect allows for a potential difference to be maintained between the first body and the plasma. In turn, this provides some control over the flux and energy distribution of ions incident on the first body.

[00069] It will be appreciated that as used herein an object being proximate to the optical path is intended to mean that the object is in the vicinity of the optical path such that a plasma formed in the optical path is connected to, or may be connected to, the object.

[00070] In some embodiments, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma, as now described.

[00071] The first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.

[00072] That is, an electrical resistance between the plasma and the second body is significantly less than an electrical resistance between the plasma and the first body. For example, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is less than half of the electrical conductance between the second body and the plasma. For example, the first body and the second body may be arranged such that an electrical conductance between the first body and the plasma is less than a tenth of the electrical conductance between the second body and the plasma

[00073] It will be appreciated that there are several ways in which this difference in electrical conductance between the two bodies and the plasma can be achieved. In general, it is desirable to: (a) reduce surface area of first body relative to that of the second body; (b) increase the density of plasma between the second body and the optical path; and (c) reduce the distance between the second body and the optical path.

[00074] The method may further comprise generating a conductive medium between the optical path and the second body.

[00075] Generating a conductive medium between the optical path and the second body may comprise producing a plasma between the optical path and the second body.

5 [00076] The plasma may be a radiofrequency (RF) plasma.

[00077] Additionally or alternatively, the mechanism for generating a conductive medium may comprise any source of ionizing radiation.

[00078] Generating a conductive medium between the optical path and the second body may comprise increasing a density of electrons between the optical path and the second body.

10 [00079] Generating a conductive medium between the optical path and the second body may comprise directing radiation so as to propagate between the optical path and the second body.

[00080] Such a radiation may, for example, comprise ultra violet (UV) radiation. Alternatively, the radiation may, for example, comprise an electron beam source

[00081] Applying a potential difference across the first body and a second body may comprise
15 applying a biasing potential to the first body and grounding the second body.

[00082] For example, in order to reduce a flux and/or energy of ions from the plasma from impinging on the first body a positive biasing potential may be applied to the first body to repel the ions. Since there may be a significantly greater electrical conductance between the second body and the plasma than there is between the first body and the plasma, by grounding the second body the (local)
20 biasing potential applied to the first body may have an insignificant effect on the potential of the plasma.

[00083] Applying a potential difference across the first body and a second body may comprise applying a biasing potential to the second body and grounding the first body.

[00084] For example, in order to reduce a flux and/or energy of ions from the plasma from impinging on the first body a negative biasing potential may be applied to the second body to attract
25 ions thereto. As explained above, there may be a significantly greater electrical conductance between the second body and the plasma than there is between the first body and the plasma. Therefore, by applying a negative biasing potential to the second body, the potential of the plasma may be reduced significantly. In turn, this reduces the flux and energy of ions that impinge on the first body (which is grounded).

30 [00085] The second body may be formed from a material that is resistant to etching by the plasma.

[00086] Advantageously, this can reduce the amount of material which can be etched from the second body (and which may be subsequently deposited on sensitive surfaces within the lithographic apparatus such as, for example, surfaces of mirrors). It will be appreciated that the first body and the
35 second body may be formed from materials which are compatible with the environment within an EUV lithographic apparatus.

[00087] The second body may be formed from tungsten.

[00088] Tungsten (W) is resistant to etching by hydrogen plasmas due to its mass. Furthermore, tungsten is compatible with the environment within an EUV lithographic apparatus.

[00089] In other embodiments, the second body may be formed from another heavy inert metal such as, for example, molybdenum (Mo), ruthenium (Ru), rhodium (Rh), silver (Ag), rhenium (Re),
5 osmium (Os), iridium (Ir) or platinum (Pt). These materials may have at least some resistance to etching by hydrogen plasmas.

[00090] In some embodiments, the applied voltage may be such that an energy distribution of ions incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which does not result in etching on a bulk material of the first body, as now described.

10 [00091] Applying a potential difference across the first body and a second body may be such that an energy distribution of ions from the plasma that are incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which results in minimal etching of a bulk material of the first body.

[00092] Applying a potential difference across the first body and a second body may comprise
15 applying an alternating potential difference across the first and second bodies.

[00093] Applying a potential difference across the first body and a second body may be such that a rate of change of a potential across a plasma sheath of the plasma is small for the majority of the time.

[00094] Advantageously, by reducing the amount of time that the rate of change of the potential
20 is above a threshold the amount of time in which a potential across the plasma sheath is varying is reduced. In some embodiments, the potential is either constant or slowly varying for the majority of the time and oscillates (abruptly) between a positive potential and a negative potential. In some embodiments, the potential oscillates (abruptly) between a positive portion of a duty cycle and a negative portion of a duty cycle and in each of the positive and negative portions of the duty cycle the
25 potential is either constant or slowly varying.

[00095] Advantageously, by reducing the amount of time in which a potential across the plasma sheath is varying, a spread or width of the distribution of energies of ions impinging on the first member is reduced.

[00096] The potential difference may alternate between a positive portion wherein the first body
30 is positively biased and negative potential wherein the first body is negatively biased.

[00097] An average of the potential difference applied across the first and second bodies may be non-zero.

[00098] The non-zero average of the potential difference applied across the first and second bodies is a direct current (DC) component of the alternating potential difference. The average of the
35 potential difference applied across the first and second bodies is dependent on the value of the potential difference applied during the positive portion and the negative portion and a duty cycle of the alternating potential difference (i.e. a ratio of the time duration of the negative portion to that of the positive

portion). It will be appreciated that the average energy of ions impinging on the first body is dependent on the value of the average of the potential difference applied across the first and second bodies.

[00099] Although the average energy of ions impinging on the first body is dependent on the value of the average of the potential difference applied across the first and second bodies, a spread or width of the distribution of energies of ions impinging on the first member is dependent on the shape of the periodic potential difference applied across the first and second bodies.

[000100] A duty cycle of the potential difference applied across the first and second bodies may be such that a ratio of the time duration of the negative portion to the time duration of the positive portion is greater than 0.9.

[000101] Advantageously, this ensures that for at least 90% of the time the first body is negatively biased so as to attract ions from the plasma so as to etch contaminants from the first body. The positive portion allows time for accumulated charge on the first and second bodies to be removed.

[000102] A magnitude of the potential difference applied across the first and second bodies may increase during the negative portion.

[000103] For example, the magnitude of the potential difference applied across the first and second bodies may increase linearly during the negative portion. As discussed above, during the negative portion the first body is negatively biased so as to attract ions from the plasma so as to etch contaminants from the first body. During the negative portion positive surface charge can accumulate on the first body. Note that the first body may be connected to the voltage supply via a matching box or capacitor. By increasing the magnitude of the potential difference applied across the first and second bodies during the negative portion the effects of such surface charge can be at least partially accounted for. Again, this can reduce a spread or width of the distribution of energies of ions impinging on the first member, which is advantageous.

[000104] A frequency of the potential difference applied across the first and second bodies may be less than 400 kHz.

[000105] The first body and/or the second body may be connected to the voltage supply via a matching box or capacitor.

[000106] By connecting both the first body and the second to the voltage supply via a matching box or capacitor the net current averaged over a cycle of the alternating potential difference is zero.

Advantageously, since the net current averaged over a cycle of the alternating potential difference is zero there is no net charge accumulation on surfaces within the lithographic apparatus LA over an integer number of cycles of the alternating potential difference. As such, it can be ensured that there is no net charge accumulation on surfaces within the lithographic apparatus LA due to the alternating potential difference. Such accumulation of net charge on surfaces within the lithographic apparatus LA is undesirable.

[000107] The method may further include providing a third body at ground potential or at floating potential. In other words, there is no active control of surface potential.

[000108] The method may further include providing a diode in electrical connection with the second body to thereby bias the second body relative to ground.

[000109] The method may further include providing the first body at a floating potential, a ground potential, or at another bias potential relative to ground.

5 [000110] It will be appreciated that one or more aspects or features described above or referred to in the following description may be combined with one or more other aspects or features.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [000111] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which:

- Figure 1 is a schematic illustration of a lithographic system comprising a lithographic apparatus and a radiation source;

- Figure 2 is a schematic illustration of a lithographic apparatus according to embodiments of the present disclosure comprising two bodies that are proximate to an optical path and a voltage supply;

15 - Figure 3 shows an example waveform for an alternating biasing potential that may be applied across the first and second bodies of the arrangement shown in Figure 2; and

- Figure 4 is a schematic illustration of a method according to embodiments of the present disclosure which may be carried out using the lithographic apparatus shown in Figure 2.

20 - Figure 5 is a schematic illustration of a lithographic apparatus according to embodiments of the present disclosure comprising three bodies that are proximate to an optical path and a voltage supply.

DETAILED DESCRIPTION

[000112] Figure 1 shows a lithographic system. The lithographic system comprises a radiation source SO and a lithographic apparatus LA. The radiation source SO is configured to generate an extreme ultraviolet (EUV) radiation beam B. The lithographic apparatus LA comprises an illumination system IL, a support structure MT configured to support a reticle assembly 15 including a patterning device MA (e.g., a reticle or mask), a projection system PS and a substrate table WT configured to support a substrate W. The illumination system IL is configured to condition the radiation beam B before it is incident upon the patterning device MA. The projection system is configured to project the radiation beam B (now patterned by the patterning device MA) onto the substrate W. The substrate W may include previously formed patterns. Where this is the case, the lithographic apparatus aligns the patterned radiation beam B with a pattern previously formed on the substrate W.

[000113] The radiation source SO, illumination system IL, and projection system PS may all be constructed and arranged such that they can be isolated from the external environment. A gas at a pressure below atmospheric pressure (e.g., hydrogen) may be provided in the radiation source SO. A vacuum may be provided in the illumination system IL and/or the projection system PS. A small

amount of gas (e.g., hydrogen) at a pressure well below atmospheric pressure may be provided in the illumination system IL and/or the projection system PS.

[000114] The radiation source SO shown in Figure 1 is of a type that may be referred to as a laser produced plasma (LPP) source. A laser 1, which may for example be a CO₂ laser, is arranged to deposit energy via a laser beam 2 into a fuel, such as tin (Sn) that is provided from a fuel emitter 3. Although tin is referred to in the following description, any suitable fuel may be used. The fuel may for example be in liquid form, and may for example be a metal or alloy. The fuel emitter 3 may comprise a nozzle configured to direct tin, e.g., in the form of droplets, along a trajectory towards a plasma formation region 4. The laser beam 2 is incident upon the tin at the plasma formation region 4. The deposition of laser energy into the tin creates a plasma 7 at the plasma formation region 4. Radiation, including EUV radiation, is emitted from the plasma 7 during de-excitation and recombination of ions of the plasma.

[000115] The EUV radiation is collected and focused by a near normal incidence radiation collector 5 (sometimes referred to more generally as a normal incidence radiation collector). The collector 5 may have a multilayer structure that is arranged to reflect EUV radiation (e.g., EUV radiation having a desired wavelength such as 13.5 nm). The collector 5 may have an elliptical configuration, having two ellipse focal points. A first focal point may be at the plasma formation region 4, and a second focal point may be at an intermediate focus 6, as discussed below.

[000116] In other embodiments of a laser produced plasma (LPP) source the collector 5 may be a so-called grazing incidence collector that is configured to receive EUV radiation at grazing incidence angles and focus the EUV radiation at an intermediate focus. A grazing incidence collector may, for example, be a nested collector, comprising a plurality of grazing incidence reflectors. The grazing incidence reflectors may be disposed axially symmetrically around an optical axis.

[000117] The radiation source SO may include one or more contamination traps (not shown). For example, a contamination trap may be located between the plasma formation region 4 and the radiation collector 5. The contamination trap may for example be a rotating foil trap, or may be any other suitable form of contamination trap.

[000118] The laser 1 may be separated from the radiation source SO. Where this is the case, the laser beam 2 may be passed from the laser 1 to the radiation source SO with the aid of a beam delivery system (not shown) comprising, for example, suitable directing mirrors and/or a beam expander, and/or other optics. The laser 1 and the radiation source SO may together be considered to be a radiation system.

[000119] Radiation that is reflected by the collector 5 forms a radiation beam B. The radiation beam B is focused at point 6 to form an image of the plasma formation region 4, which acts as a virtual radiation source for the illumination system IL. The point 6 at which the radiation beam B is focused may be referred to as the intermediate focus. The radiation source SO is arranged such that the intermediate focus 6 is located at or near to an opening 8 in an enclosing structure 9 of the radiation source SO.

[000120] The radiation beam B passes from the radiation source SO into the illumination system IL, which is configured to condition the radiation beam. The illumination system IL may include a faceted field mirror device 10 and a faceted pupil mirror device 11. The faceted field mirror device 10 and faceted pupil mirror device 11 together provide the radiation beam B with a desired cross-sectional shape and a desired angular distribution. The radiation beam B passes from the illumination system IL and is incident upon the reticle assembly 15 held by the support structure MT. The reticle assembly 15 includes a patterning device MA and a pellicle 19. The pellicle is mounted to the patterning device MA via a pellicle frame 17. The reticle assembly 15 may be referred to as a reticle and pellicle assembly 15. The patterning device MA reflects and patterns the radiation beam B. The illumination system IL may include other mirrors or devices in addition to or instead of the faceted field mirror device 10 and faceted pupil mirror device 11. Although this example embodiment shows a pellicle 19 (as part of a reticle assembly 15) in some other embodiments there may be no pellicle present, in which case the patterning device MA is supported by the support structure MT.

[000121] Following reflection from the patterning device MA the patterned radiation beam B enters the projection system PS. The projection system comprises a plurality of mirrors 13, 14 that are configured to project the radiation beam B onto a substrate W held by the substrate table WT. The projection system PS may apply a reduction factor to the radiation beam, forming an image with features that are smaller than corresponding features on the patterning device MA. A reduction factor of 4 may for example be applied. Although the projection system PS has two mirrors 13, 14 in Figure 1, the projection system PS may include any number of mirrors (e.g., six mirrors).

[000122] The lithographic apparatus may, for example, be used in a scan mode, wherein the support structure (e.g., mask table) MT and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a substrate W (i.e., a dynamic exposure). The velocity and direction of the substrate table WT relative to the support structure (e.g., mask table) MT may be determined by the demagnification and image reversal characteristics of the projection system PS. The patterned radiation beam that is incident upon the substrate W may comprise a band of radiation. The band of radiation may be referred to as an exposure slit. During a scanning exposure, the movement of the substrate table WT and the support structure MT may be such that the exposure slit travels over an exposure field of the substrate W.

[000123] The radiation source SO and/or the lithographic apparatus that is shown in Figure 1 may include components that are not illustrated. For example, a spectral filter may be provided in the radiation source SO. The spectral filter may be substantially transmissive for EUV radiation but substantially blocking for other wavelengths of radiation such as infrared radiation.

[000124] In other embodiments of a lithographic system the radiation source SO may take other forms. For example, in alternative embodiments the radiation source SO may comprise one or more free electron lasers. The one or more free electron lasers may be configured to emit EUV radiation that may be provided to one or more lithographic apparatus.

[000125] As was described briefly above, the reticle assembly 15 includes a pellicle 19 that is provided adjacent to the patterning device MA. The pellicle 19 is provided in the path of the radiation beam B such that radiation beam B passes through the pellicle 19 both as it approaches the patterning device MA from the illumination system IL and as it is reflected by the patterning device MA towards the projection system PS. The pellicle 19 comprises a thin film or membrane that is substantially transparent to EUV radiation (although it will absorb a small amount of EUV radiation). By EUV transparent pellicle or a film substantially transparent for EUV radiation herein is meant that the pellicle 19 is transmissive for at least 65% of the EUV radiation, preferably at least 80% and more preferably at least 90% of the EUV radiation. The pellicle 19 acts to protect the patterning device MA from particle contamination.

[000126] Whilst efforts may be made to maintain a clean environment inside the lithographic apparatus LA, particles may still be present inside the lithographic apparatus LA. In the absence of a pellicle 19, particles may be deposited onto the patterning device MA. Particles on the patterning device MA may disadvantageously affect the pattern that is imparted to the radiation beam B and therefore the pattern that is transferred to the substrate W. The pellicle 19 advantageously provides a barrier between the patterning device MA and the environment in the lithographic apparatus LA in order to prevent particles from being deposited on the patterning device MA.

[000127] The pellicle 19 is positioned at a distance from the patterning device MA that is sufficient that any particles that are incident upon the surface of the pellicle 19 are not in a field plane of the lithographic apparatus LA. This separation between the pellicle 19 and the patterning device MA acts to reduce the extent to which any particles on the surface of the pellicle 19 impart a pattern to the radiation beam B that is imaged onto the substrate W. It will be appreciated that where a particle is present in the beam of radiation B, but at a position that is not in a field plane of the beam of radiation B (for example not at the surface of the patterning device MA), then any image of the particle will not be in focus at the surface of the substrate W. In the absence of other considerations it may be desirable to position the pellicle 19 a considerable distance away from the patterning device MA. However, in practice the space which is available in the lithographic apparatus LA to accommodate the pellicle is limited due to the presence of other components. In some embodiments, the separation between the pellicle 19 and the patterning device MA may, for example, be approximately between 1 mm and 10 mm, for example between 1 mm and 5 mm, for example between 2 mm and 2.5 mm.

[000128] The lithographic apparatus LA shown in Figure 1 comprises a plurality of optical elements 10, 11, 13, 14 that define an optical path (shown schematically in Figure 1). The optical elements 10, 11, 13, 14 are arranged to receive the radiation beam B from the radiation source SO, project the radiation beam B onto a reticle MA so as to pattern the radiation beam B and to form an image of the reticle MA on a substrate W.

[000129] In use, the optical path of the lithographic apparatus LA may be maintained at pressures well below atmospheric pressure, for example, using vessels that are evacuated using vacuum pumps.

It is known to provide hydrogen gas in the optical path (under low pressure). The radiation beam B is typically a pulsed radiation beam. As each pulse of radiation propagates through the optical path, gas molecules in the optical path tend to ionize such that a plasma is formed in the optical path. The plasma may diffuse away from the optical path such that the plasma extends slightly outside a volume through which the radiation beam B propagates.

[000130] It may be desirable to reduce the flux and energy of the ions that are incident on some components within the lithographic apparatus LA. For example, ions with high energies can pose a sputter risk, leading to undesirable degradation of the body of such components. In addition, ions (for example hydrogen ions) can react with constituents of the body of a component (such as, for example, silicon from glass and stainless steel components and magnesium from aluminium components) to form volatile hydrides. Such volatile hydrides present within the lithographic apparatus LA may be incident on surfaces of mirrors 10, 11, 13, 14 within the lithographic apparatus LA, resulting in the constituents that are etched from some components being deposited on the mirrors 10, 11, 13, 14. Such deposits may absorb EUV radiation, which is undesirable. Furthermore, such deposits may be oxidized and, as a result, may absorb even more EUV radiation. Typically, hydrogen ions do not etch the outer, native oxide layer of materials (for example silicon, Si). However, ions with sufficient kinetic energy can penetrate such oxide layers to the bulk material below, with which the ions can react to form volatile hydrides (for example silane, SiH_4). Such volatile hydride formation may be stopped if the energies of the hydrogen ions are below a threshold kinetic energy such that they cannot penetrate the outer, native oxide layer of materials.

[000131] It may be desirable to provide ions in the vicinity of, or direct ions so as to be incident on, some components within the lithographic apparatus LA. For example, ions can react with contaminants which can prevent them from depositing on surfaces of mirrors 10, 11, 13, 14 within the lithographic apparatus LA. Similarly, ions that are incident on surfaces of mirrors 10, 11, 13, 14 within the lithographic apparatus LA can etch such contaminants from the mirrors 10, 11, 13, 14.

[000132] In order to control the flux and energy distribution of ions that is incident on a body, one may naively try to apply a biasing voltage or potential to that body. For example, if it is desirable to prevent ions from the plasma from impinging on the body then a positive voltage may be applied to the first body to repel the ions. Similarly, if it is desirable to increase the energy or flux of ions from the plasma that impinge on the first body then a negative voltage may be applied to the first body to attract the ions. However, the inventors have realized that for an object that is proximate to the plasma, the object is in electrical contact with the plasma (via the plasma sheath). Therefore, just applying a biasing voltage to one object in the vicinity of the plasma will tend to pull the potential of the plasma up to (a fraction of) the biasing potential. The result is that the biasing potential does not result in a required or desired potential difference between the body to which the bias is applied and the plasma and therefore has little impact on the flux and energy distribution of ions incident on the first body.

[000133] According to embodiments of the present disclosure there is provided a lithographic apparatus LA of the type shown in Figure 1, comprising a plurality of optical elements 10, 11, 13, 14 that define an optical path. The optical elements 10, 11, 13, 14 are arranged to receive the radiation beam B from the radiation source SO, project the radiation beam B onto a reticle MA so as to pattern the radiation beam B and to form an image of the reticle MA on a substrate W. The lithographic apparatus LA according to embodiments of the present disclosure comprises two bodies that are proximate to the optical path, and a voltage supply, as now discussed with reference to Figure 2.

[000134] In Figure 2, a plasma 100 that is formed in the lithographic apparatus LA as the radiation beam B propagates along the optical path is shown schematically. The lithographic apparatus LA comprises a first body 102 and a second body 104. Within the lithographic apparatus LA, the first body 102 and the second body 104 are both proximate to the optical path and therefore proximate to the plasma 100. It will be appreciated that as used herein an object being proximate to the optical path is intended to mean that the object is in the vicinity of the optical path such that a plasma 100 formed in the optical path is connected to, or may be connected to, the object. As will be appreciated by the skilled person, the bulk of the plasma 100 is surrounded by a plasma sheath 106 which extends to surrounding objects including the first body 102 and the second body 104.

[000135] The lithographic apparatus LA further comprises a voltage supply 108 arranged to apply a potential difference across the first and second bodies 102, 104. In the example shown the voltage supply 108 is arranged to apply a biasing potential V_b to the first body 102 and the second body 104 is grounded. It will be appreciated that in alternative embodiments the voltage supply 108 may be arranged to apply a biasing potential V_b to the second body 104 and the first body 102 may be grounded. In general, the voltage supply 108 is arranged to maintain the first and second bodies 102, 104 at different potentials such that there is a potential difference across the first and second bodies 102, 104.

[000136] Particularly for embodiments in which the voltage supply 108 is arranged to apply an alternating potential difference across the first and second bodies 102, 104, each of the first and second bodies 102, 104 may be connected to a biasing potential via a matching box or capacitor 110.

[000137] The first body 102, the second body 104 and/or the voltage supply 108 are arranged so as to control a flux and/or energy distribution of ions incident on the first body 102 from a plasma 100 formed in the optical path by the radiation beam B.

[000138] For example, in order to reduce a flux and/or energy of ions from the plasma 100 from impinging on the first body 102 a positive biasing potential V_b may be applied to the first body 102 to repel the ions. Since there may be a significantly greater electrical conductance between the second body 104 and the plasma 100 than there is between the first body 102 and the plasma 100, by grounding the second body 104 the (local) biasing potential applied to the first body 102 may have an insignificant effect on the potential of the plasma.

[000139] Alternatively, in other embodiments, in order to reduce a flux and/or energy of ions from the plasma 100 from impinging on the first body 102 a negative biasing potential may be applied

to the second body 104 to attract ions thereto. As explained below, there may be a significantly greater electrical conductance between the second body 104 and the plasma 100 than there is between the first body 102 and the plasma 100. Therefore, by applying a negative biasing potential to the second body 104, the potential of the plasma may be reduced significantly. In turn, this reduces the flux and energy of ions that impinge on the first body 102 (which is grounded).

[000140] The first body 102 may be a sensitive object and therefore it may be desirable to control a flux and/or energy distribution of ions incident on the first body 102 from the plasma 100. For example, the first body 102 may be a mirror or a sensor or the like within the lithographic apparatus. Alternatively, the first body 102 may be any object within the lithographic apparatus (for example formed from glass, stainless steel or aluminum) from which volatile hydrides may be released if ions with sufficient energy to penetrate to the bulk material are incident on said bodies.

[000141] The second body 104 may comprise one or more walls of the lithographic apparatus LA (which may, for example, form part of a housing for parts of the lithographic apparatus LA such as mirrors or the like). In general, the second body 104 may be farther from the optical path than the first body 102. It will be appreciated that the second body 104 may comprise a plurality of separate parts (for example walls of the lithographic apparatus LA).

[000142] The lithographic apparatus LA according to the present disclosure comprises two bodies (the first body 102 and the second body 104) that are both proximate to the optical path (and therefore, in use, a plasma 100) and the voltage supply 108 is arranged to apply a potential difference across the first and second bodies 102, 104. Advantageously, by varying the configurations of the first and second bodies 102, 104 with respect to the optical path (where the plasma 100 is formed) the lithographic apparatus LA according to the present disclosure allows for a potential difference to be maintained between the first body 102 and the plasma 100. In turn, this provides some control over the flux and energy distribution of ions incident on the first body 102.

[000143] In some embodiments, the first body 102 and the second body 104 are arranged such that an electrical conductance between the first body 102 and the plasma 100 is significantly smaller than an electrical conductance between the second body 104 and the plasma 100, as now described. A simplified electrostatic model is depicted in Figure 2, where the connection of the first body 102 to the plasma 100 via the plasma sheath 106 is schematically shown as having a first electrical resistance R_1 and the connection of the second body 104 to the plasma 100 via the plasma sheath 106 is schematically shown as having a second electrical resistance R_2 . It is proposed that the first and second bodies 102, 104 should be arranged such that $R_2 \ll R_1$.

[000144] That is, an electrical resistance R_2 between the plasma 100 and the second body 104 is significantly less than an electrical resistance R_1 between the plasma 100 and the first body 102. For example, the first body 102 and the second body 104 may be arranged such that an electrical conductance between the first body 102 and the plasma 100 is less than half of the electrical conductance between the second body 104 and the plasma 100. For example, the first body 102 and the second body

104 may be arranged such that an electrical conductance between the first body 102 and the plasma 100 is less than a tenth of the electrical conductance between the second body 104 and the plasma 100.

[000145] Note that this arrangement wherein the electrical resistance R_2 between the plasma 100 and the second body 104 is significantly less than the electrical resistance R_1 between the plasma 100 and the first body 102 is not typical in known lithographic apparatus. For example, in general, the first body 102 may be a sensitive object the flux and/or energy distribution of ions received by which it is desirable to control. Such bodies 102 may typically be very close to the plasma 100 and therefore the electrical resistance R_1 may be relatively low. It is for this reason that only biasing the first body 102 typically will not have a significant effect on the flux and energy distribution of ions (since this low electrical resistance R_1 will mean that the plasma potential can be strongly influenced by the biasing potential). The second body 104 may comprise one or more walls of the lithographic apparatus LA (which may, for example, form part of a housing for parts of the lithographic apparatus LA such as mirrors or the like). Such bodies 104 may typically be significantly further away from the plasma 100 than the first body 102 and therefore the electrical resistance R_2 may be relatively high. At least in some embodiments of the present disclosure, the lithographic apparatus LA has been modified in some way in order to ensure that the electrical resistance R_2 between the plasma 100 and the second body 104 is significantly less than the electrical resistance R_1 between the plasma 100 and the first body 102.

[000146] It will be appreciated that there are several ways in which this difference in electrical conductance between the first and second bodies 102, 104 and the plasma 100 (i.e. the condition that $R_2 \ll R_1$) can be achieved. In general, it is desirable to: (a) reduce surface area of first body 102 relative to that of the second body 104; (b) increase the density of plasma 100 between the second body 104 and the optical path; and (c) reduce the distance between the second body 104 and the optical path.

[000147] In some embodiments the second body 104 may define a textured surface facing the optical path. Providing a textured surface on the second body 104 increases the surface area of the second body 104 (compared to a flat surface). Advantageously, this increased surface area increases the electrical conductance (reduces the electrical resistance R_2) between the plasma 100 and the second body 104. For example, the textured surface of the second body 104 may be a corrugated surface.

[000148] In some embodiments, the lithographic apparatus LA may further comprise a mechanism 112 for generating a conductive medium between the optical path and the second body 104.

[000149] The mechanism 112 for generating a conductive medium between the optical path and the second body 104 may comprise a voltage supply arranged to produce a plasma between the optical path and the second body 104. The plasma may be a radiofrequency (RF) plasma.

[000150] Additionally or alternatively, the mechanism 112 for generating a conductive medium between the optical path and the second body 104 may comprise any source of ionizing radiation 114 (shown schematically in Figure 2).

[000151] For example, the mechanism 112 for generating a conductive medium between the optical path and the second body 104 may comprise an electron source arranged to increase a density of electrons between the optical path and the second body 102.

[000152] In some embodiments, the mechanism 112 for generating a conductive medium
5 between the optical path and the second body 104 may comprise a radiation source arranged to generate radiation that propagates between the optical path and the second body 104. Such a radiation source may, for example, comprise an ultra violet (UV) radiation source. Alternatively, the radiation source may, for example, comprise an electron beam source.

[000153] In some embodiments, the second body 104 may comprise a portion which is adjacent
10 to the optical path. For example, rather than only comprising walls which form part of a housing for parts of the lithographic apparatus LA such as mirrors or the like, the second body 104 may further comprise an additional portion which is adjacent to the optical path. Such a portion may extend from the walls of the lithographic apparatus towards the optical path. Advantageously, this can reduce the distance between the plasma 100 generated by the radiation beam and the second body 104 (compared
15 to an arrangement with no portion adjacent the optical path). Advantageously, this reduces a distance from the plasma 100 to the second body 104 and increases the electrical conductance (reduces the electrical resistance R_2) between the plasma 100 and the second body 104.

[000154] In some embodiments, the portion of the second body 104 which is adjacent to the optical path extends at least partially around an optical axis of the optical path. For example, the portion
20 of the second body 104 which is adjacent to the optical path may comprise a generally cylindrical or frustoconical hollow body that the radiation beam B propagates through.

[000155] In some embodiments, the second body 104 may be formed from a material that is resistant to etching by the plasma 100. Advantageously, this can reduce the amount of material which can be etched from the second body 104 (and which may be subsequently deposited on sensitive
25 surfaces within the lithographic apparatus LA such as, for example, surfaces of mirrors). It will be appreciated that the first body 102 and the second body 104 may be formed from materials which are compatible with the environment within an EUV lithographic apparatus LA.

[000156] In some embodiments, the second body 104 may be formed from tungsten. Tungsten (W) is resistant to etching by hydrogen plasmas 100 due to its mass. Furthermore, tungsten is
30 compatible with the environment within an EUV lithographic apparatus LA.

[000157] In other embodiments, the second body may be formed from another heavy inert metal such as, for example, molybdenum (Mo), ruthenium (Ru), rhodium (Rh), silver (Ag), rhenium (Re), osmium (Os), iridium (Ir) or platinum (Pt). These materials may have at least some resistance to etching by hydrogen plasmas.

[000158] In some embodiments, the voltage supply 108 is arranged such that an energy
35 distribution of ions incident on the first body 102 is in a range that results in etching of contaminants

on a surface of the first body 102 and which does not result in etching on a bulk material of the first body 102, as now described.

[000159] The voltage supply 108 may be arranged to apply a potential difference V_b across the first and second bodies 102, 104 such that an energy distribution of ions from the plasma 100 that are incident on the first body 102 is in a range that results in etching of contaminants on a surface of the first body 102 and which results in minimal etching of a bulk material of the first body 102. An example potential difference V_b to achieve this is now described with reference to Figure 3.

[000160] In some embodiments, the voltage supply 108 is arranged such that a potential difference V_b having a waveform 200 as shown in Figure 3 is applied across the first and second bodies 102, 104.

[000161] The potential difference V_b shown in Figure 3 is an alternating potential difference V_b having a particular waveform 200.

[000162] When applying potential difference V_b having the waveform 200 shown in Figure 3, a rate of change of a potential across the plasma sheath 106 of the plasma 100 is small for the majority of the time. Advantageously, by reducing the amount of time that the rate of change of the potential V_b is above a threshold the amount of time in which a potential across the plasma sheath 106 is varying is reduced. In the embodiment shown in Figure 3, the potential V_b is either constant or slowly varying for the majority of the time and oscillates (abruptly) between a positive potential and a negative potential. In the embodiment shown in Figure 3, the potential V_b oscillates (abruptly) between a positive portion 202 of a duty cycle and a negative portion 204 of the duty cycle and in each of the positive and negative portions 202, 204 of the duty cycle the potential V_b is either constant or slowly varying.

[000163] Advantageously, by reducing the amount of time in which a potential across the plasma sheath 106 is varying, a spread or width of the distribution of energies of ions impinging on the first member 102 is reduced. Such a biasing potential V_b therefore allows for accurate control of the energies of ions impinging on the first member 102.

[000164] In the embodiment shown in Figure 3, the potential difference V_b alternates between the positive portion 202 wherein the first body 102 is positively biased and negative portion 204 wherein the first body 102 is negatively biased.

[000165] When applying potential difference V_b having the waveform 200 shown in Figure 3, an average of the potential difference $\langle V_b \rangle$ applied across the first and second bodies 102, 104 is non zero. The non-zero average of the potential difference $\langle V_b \rangle$ applied across the first and second bodies 102, 104 is a direct current (DC) component of the alternating potential difference V_b . The average of the potential difference $\langle V_b \rangle$ applied across the first and second bodies 102, 104 is dependent on the value of the potential difference applied during the positive portion 202 and the negative portion 204 and a duty cycle of the alternating potential difference (i.e. a ratio of the time duration of the negative portion 204 to that of the positive portion 202). It will be appreciated that the average energy of ions

impinging on the first body 102 is dependent on the value of the average of the potential difference $\langle V_b \rangle$ applied across the first and second bodies 102, 104.

[000166] Although the average energy of ions impinging on the first body 102 is dependent on the value of the average of the potential difference $\langle V_b \rangle$ applied across the first and second bodies 102, 104, a spread or width of the distribution of energies of ions impinging on the first member 102 is dependent on the shape of the periodic potential difference V_b applied across the first and second bodies 102, 104.

[000167] If a sinusoidal waveform potential difference was applied across the first and second bodies 102, 104 then the potential across the plasma sheath 106 is continuously varying. As a result there is a wide distribution of ion energies of the ions which are incident on the first body 102. Therefore, it can be impossible to ensure that all ions which are incident on the first body 102 have an energy which is both: (a) above a threshold for etching contaminants; and (b) below the threshold for etching the bulk material of the first body 102. In contrast, when a potential difference V_b having the waveform 200 shown in Figure 3 is applied across the first and second bodies 102, 104, the potential across the plasma sheath 106 is generally constant. This results in a very narrow distribution of ion energies of the ions which are incident on the first body 102. In addition the stable potential across the plasma sheath 106 results in low electron heating. Therefore, when a potential difference V_b having the waveform 200 shown in Figure 3 is applied across the first and second bodies 102, 104, advantageously, it is possible to ensure that all ions which are incident on the first body 102 have an energy which is both: (a) above a threshold for etching contaminants; and (b) below the threshold for etching the bulk material of the first body 102.

[000168] In some embodiments, a duty cycle of the potential difference V_b applied across the first and second bodies 102, 104 is such that a ratio of the time duration of the negative portion 204 to the time duration of the positive portion 202 is greater than 0.9. Advantageously, this ensures that for at least 90% of the time the first body 102 is negatively biased so as to attract ions from the plasma 100 so as to etch contaminants from the first body 102. The positive portion 202 allows time for accumulated charge on the first and second bodies 102, 104 to be removed.

[000169] In the embodiment shown in Figure 3, a magnitude of the potential difference $|V_b|$ applied across the first and second bodies 102, 104 increases during the negative portion 204. For example, in this embodiment, the magnitude of the potential difference $|V_b|$ applied across the first and second bodies 102, 104 increases linearly during the negative portion 204. As discussed above, during the negative portion 204 the first body 102 is negatively biased so as to attract ions from the plasma 100 so as to etch contaminants from the first body 102. During the negative portion positive surface charge can accumulate on the first body 102. Note that the first body 102 may be connected to the voltage supply 108 via a matching box or capacitor 110. By increasing the magnitude of the potential difference V_b applied across the first and second bodies 102, 104 during the negative portion 204 the effects of

such surface charge can be at least partially accounted for. Again, this can reduce a spread or width of the distribution of energies of ions impinging on the first member 102, which is advantageous.

[000170] In some embodiments, a frequency of the potential difference V_b applied across the first and second bodies 102, 104 is less than 400 kHz.

5 [000171] In embodiments wherein the biasing voltage V_b shown in Figure 3 is applied to the first body 102 (or the second body 104), the first body 102 and/or the second body 104 may be connected to the voltage supply 108 via a matching box or capacitor 110. By connecting both the first body 102 and the second body 104 to the voltage supply 108 via a matching box or capacitor 110 the net current averaged over a cycle of the alternating potential difference is zero. Advantageously, since the net
10 current averaged over a cycle of the alternating potential difference is zero there is no net charge accumulation on surfaces within the lithographic apparatus LA over an integer number of cycles of the alternating potential difference. As such, it can be ensured that there is no net charge accumulation on surfaces within the lithographic apparatus LA due to the alternating potential difference. Such accumulation of net charge on surfaces within the lithographic apparatus LA is undesirable.

15 [000172] According to some embodiments of the present disclosure, there is provided a method of controlling a flux and/or energy distribution of ions that is incident on a first body 102 within a lithographic apparatus LA. As shown in Figure 4, the method 300 comprises a step 302 of directing a radiation beam B along an optical path in the lithographic apparatus LA, the first body 102 being proximate to said optical path. The method 300 further comprises a step 304 of applying a potential
20 difference across the first body 102 and a second body 104 that is also proximate to the optical path so as to control a flux and/or energy distribution of ions incident on the first body 102 from a plasma 100 formed in the optical path by the radiation beam B.

[000173] It will be appreciated that the method 300 may include any or all of the features of the lithographic apparatus LA as describe above with reference to Figures 1 to 3.

25 [000174] The method 300 uses two bodies (the first body 102 and the second body 104) that are both proximate to the optical path and applies a potential difference across the first and second bodies 102, 104 (for example using a voltage supply). Advantageously, by controlling the potential difference applied across the first and second bodies 102, 104 the method 300 allows for a potential difference to be maintained between the first body 102 and the plasma 100. In turn, this provides some control over
30 the flux and energy distribution of ions incident on the first body 102.

[000175] It will be appreciated that as used herein the flux of ions incident on a body is intended to mean the number of ions incident on the body per unit time per unit area.

[000176] According to the embodiment depicted in Figure 5, a plasma 100 that is formed in the lithographic apparatus LA as the radiation beam B propagates along the optical path is shown
35 schematically. The lithographic apparatus LA comprises a first body 102 and a second body 104, and a third body 116. Within the lithographic apparatus LA, the first body 102, the second body 104, and the third body 116 are each proximate to the optical path and therefore proximate to the plasma 100. It

will be appreciated that as used herein an object being proximate to the optical path is intended to mean that the object is in the vicinity of the optical path such that a plasma 100 formed in the optical path is connected to, or may be connected to, the object. As will be appreciated by the skilled person, the bulk of the plasma 100 is surrounded by a plasma sheath 106 which extends to surrounding objects including the first body 102, the second body 104, and the third body 116.

[000177] In the depicted embodiment, third body 116 is grounded, but may alternatively be allowed to have a floating potential. As such, there is no active control of the surface potential of third body 116. Second body 104 is electrically biased relative to ground to influence the plasma interaction with the first body 102, which may be an optical element such as a mirror. The electrical potential relative to ground may be provided by way of a voltage source 108 or via a passive component, such as a diode. First body 102 includes a critical surface that requires control of the plasma interaction and this is achieved by biasing the second body 104. The first body 102 can be at floating potential, connected to ground potential, or at another bias potential relative to ground. The voltage source 108 may be configured to operate as described herein

[000178] The first body 102 may be a sensitive object and therefore it may be desirable to control a flux and/or energy distribution of ions incident on the first body 102 from the plasma 100. For example, the first body 102 may be a mirror or a sensor or the like within the lithographic apparatus. Alternatively, the first body 102 may be any object within the lithographic apparatus (for example formed from glass, stainless steel or aluminium) from which volatile hydrides may be released if ions with sufficient energy to penetrate to the bulk material are incident on said bodies.

[000179] The second body 104 may comprise one or more walls of the lithographic apparatus LA (which may, for example, form part of a housing for parts of the lithographic apparatus LA such as mirrors or the like). In general, the second body 104 may be farther from the optical path than the first body 102. It will be appreciated that the second body 104 may comprise a plurality of separate parts (for example walls of the lithographic apparatus LA). The terms voltage and potential are synonymous in this document unless stated to the contrary and may be used interchangeably.

[000180] References to a mask or reticle in this document may be interpreted as references to a patterning device (a mask or reticle is an example of a patterning device) and the terms may be used interchangeably. In particular, the term mask assembly is synonymous with reticle assembly and patterning device assembly.

[000181] Although specific reference may be made in this text to embodiments of the invention in the context of a lithographic apparatus, embodiments of the invention may be used in other apparatus. Embodiments of the invention may form part of a mask inspection apparatus, a metrology apparatus, or any apparatus that measures or processes an object such as a wafer (or other substrate) or mask (or other patterning device). These apparatus may be generally referred to as lithographic tools.

[000182] The term "EUV radiation" may be considered to encompass electromagnetic radiation having a wavelength within the range of 4-20 nm, for example within the range of 13-14 nm. EUV

radiation may have a wavelength of less than 10 nm, for example within the range of 4-10 nm such as 6.7 nm or 6.8 nm.

[000183] Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications. Possible other applications include the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc.

[000184] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The descriptions above are intended to be illustrative, not limiting. Thus it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims and clauses set out below.

1. A lithographic apparatus comprising: a plurality of optical elements defining an optical path arranged to receive a radiation beam, project the radiation beam onto a reticle so as to pattern the radiation beam and to form an image of the reticle on a substrate; a first body proximate to the optical path; a second body proximate to the optical path; and a voltage supply arranged to apply a potential difference across the first and second bodies; wherein the first body, the second body and/or the voltage supply are arranged so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.

2. The lithographic apparatus of clause 1 wherein the first body and the second body are arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.

3. The lithographic apparatus of clause 1 or clause 2 wherein the second body defines a textured surface facing the optical path.

4. The lithographic apparatus of clause 3 wherein the textured surface is a corrugated surface.

5. The lithographic apparatus of any preceding clause further comprising a mechanism for generating a conductive medium between the optical path and the second body.

6. The lithographic apparatus of clause 5 wherein the mechanism for generating a conductive medium comprises a voltage supply arranged to produce a plasma between the optical path and the second body.

7. The lithographic apparatus of clause 5 or clause 6 wherein the mechanism for generating a conductive medium comprises an electron source arranged to increase a density of electrons between the optical path and the second body.

8. The lithographic apparatus of any one of clauses 5 to 7 wherein the mechanism for generating a conductive medium comprises a radiation source arranged to generate radiation that propagates between the optical path and the second body.

9. The lithographic apparatus of any one of clause 5 to 8 wherein the second body comprises a portion which is adjacent to the optical path.
10. The lithographic apparatus of clause 9 wherein the portion which is adjacent to the optical path extends at least partially around an optical axis of the optical path.
- 5 11. The lithographic apparatus of any preceding clause wherein the voltage supply is arranged to apply a biasing potential to the first body and the second body is grounded.
12. The lithographic apparatus of any one of clauses 1 to 10 wherein the voltage supply arranged to apply a biasing potential to the second body and the first body is grounded.
13. The lithographic apparatus of any preceding clause wherein the second body is formed from a
10 material that is resistant to etching by the plasma.
14. The lithographic apparatus of any preceding clause wherein the second body is formed from tungsten.
15. The lithographic apparatus of any preceding clause wherein the voltage supply is arranged to apply a potential difference across the first and second bodies such that an energy distribution of ions
15 from the plasma that are incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which results in minimal etching of a bulk material of the first body.
16. The lithographic apparatus of any preceding clause wherein the voltage supply is arranged such that an alternating potential difference is applied across the first and second bodies.
17. The lithographic apparatus of any preceding clause wherein the voltage supply is arranged such
20 that a rate of change of a potential across a plasma sheath of the plasma is small for the majority of the time.
18. The lithographic apparatus of any preceding clause wherein the potential difference alternates between a positive portion wherein the first body is positively biased and negative portion wherein the first body is negatively biased.
- 25 19. The lithographic apparatus of clause 16 or clause 18 wherein an average of the potential difference applied across the first and second bodies is non zero.
20. The lithographic apparatus of any preceding clause when dependent either directly or indirectly on clause 16 or clause 18 wherein a duty cycle of the potential difference applied across the first and second bodies is such that a ratio of the time duration of the negative portion to the time duration of the
30 positive portion is greater than 0.9.
21. The lithographic apparatus of any preceding clause when dependent either directly or indirectly on clause 18 wherein a magnitude of the potential difference applied across the first and second bodies increases during the negative portion.
22. The lithographic apparatus of any preceding clause when dependent either directly or indirectly
35 on clause 16 or clause 18 wherein a frequency of the potential difference applied across the first and second bodies is less than 400 kHz.

23. The lithographic apparatus of any preceding clause wherein the first body and/or the second body is connected to the voltage supply via a matching box or capacitor.

24. The lithographic apparatus of any preceding clause, wherein the apparatus includes a third body proximate the optical path, optionally wherein the third body is configured to be at ground potential or at floating potential.

25. The lithographic apparatus of any preceding clause, wherein the apparatus includes a diode in electrical connection with the second body.

26. The lithographic apparatus of any preceding clause, wherein the apparatus is configured to provide the first body at a floating potential, a ground potential, or at another bias potential relative to ground

27. A method of controlling a flux and/or energy distribution of ions that is incident on a first body within a lithographic apparatus, the method comprising: directing a radiation beam along an optical path in the lithographic apparatus, the first body being proximate to said optical path; and applying a potential difference across the first body and a second body that is also proximate to the optical path so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.

28. The method of clause 27 wherein the first body and the second body are arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.

29. The method of clause 27 or clause 28 further comprising generating a conductive medium between the optical path and the second body.

30. The method of clause 29 wherein generating a conductive medium comprises producing a plasma between the optical path and the second body.

31. The method of clause 29 or clause 30 wherein generating a conductive medium comprises increasing a density of electrons between the optical path and the second body.

32. The method of any one of clauses 29 to 31 wherein generating a conductive medium comprises directing radiation so as to propagate between the optical path and the second body.

33. The method of any one of clauses 27 to 32 wherein applying a potential difference across the first body and a second body comprises applying a biasing potential to the first body and grounding the second body.

34. The method of any one of clauses 27 to 32 wherein applying a potential difference across the first body and a second body comprises applying a biasing potential to the second body and grounding the first body.

35. The method of any one of clauses 27 to 34 wherein the second body is formed from a material that is resistant to etching by the plasma.

36. The method of any one of clauses 27 to 35 wherein the second body is formed from tungsten.

37. The method of any one of clauses 27 to 36 wherein applying a potential difference across the first body and a second body is such that an energy distribution of ions from the plasma that are incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which results in minimal etching of a bulk material of the first body.
- 5 38. The method of any one of clauses 27 to 37 wherein applying a potential difference across the first body and a second body comprises applying an alternating potential difference across the first and second bodies.
39. The method of any one of clauses 27 to 38 wherein applying a potential difference across the first body and a second body is such that a rate of change of a potential across a plasma sheath of the
- 10 plasma is small for the majority of the time.
40. The method of any one of clauses 27 to 39 wherein the potential difference alternates between a positive portion wherein the first body is positively biased and negative potential wherein the first body is negatively biased.
41. The method of clause 38 or clause 40 wherein an average of the potential difference applied
- 15 across the first and second bodies is non zero.
42. The method of any one of clauses 27 to 41 when dependent either directly or indirectly on clause 38 or clause 40 wherein a duty cycle of the potential difference applied across the first and second bodies is such that a ratio of the time duration of the negative portion to the time duration of the positive portion is greater than 0.9.
- 20 43. The method of any one of clauses 27 to 42 when dependent either directly or indirectly on clause 37 wherein a magnitude of the potential difference applied across the first and second bodies increases during the negative portion.
44. The method of any one of clauses 27 to 43 when dependent either directly or indirectly on clause 19 or clause 31 wherein a frequency of the potential difference applied across the first and second
- 25 bodies is less than 400 kHz.
45. The method of any one of clauses 27 to 44 wherein the first body and/or the second body is connected to the voltage supply via a matching box or capacitor.
46. The method of any one of clauses 27 to 45, wherein the method further includes providing a third body at ground potential or at floating potential.
- 30 47. The method of any one of clauses 27 to 46, wherein the method further includes providing a diode in electrical connection with the second body to thereby bias the second body relative to ground.
48. The method of any one of clauses 27 to 47, wherein the method includes providing the first body at a floating potential, a ground potential, or at another bias potential relative to ground.

CLAIMS

1. A lithographic apparatus comprising:
a plurality of optical elements defining an optical path arranged to receive a radiation beam, project the radiation beam onto a reticle so as to pattern the radiation beam and to form an image of the reticle on a substrate;
a first body proximate to the optical path;
a second body proximate to the optical path; and
a voltage supply arranged to apply a potential difference across the first and second bodies;
wherein the first body, the second body and/or the voltage supply are arranged so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.
2. The lithographic apparatus of claim 1 wherein the first body and the second body are arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.
3. The lithographic apparatus of any preceding claim further comprising a mechanism for generating a conductive medium between the optical path and the second body, comprising a voltage supply arranged to produce a plasma between the optical path and the second body, and/or comprising an electron source arranged to increase a density of electrons between the optical path and the second body, and/or comprising a radiation source arranged to generate radiation that propagates between the optical path and the second body.
4. The lithographic apparatus of claim 3 wherein the second body comprises a portion which is adjacent to the optical path, extending at least partially around an optical axis of the optical path.
5. The lithographic apparatus of any preceding claim wherein the voltage supply is arranged to apply a biasing potential to the first body and the second body is grounded or wherein the voltage supply arranged to apply a biasing potential to the second body and the first body is grounded.
6. The lithographic apparatus of any preceding claim wherein the second body is formed from tungsten.
7. The lithographic apparatus of any preceding claim wherein the voltage supply is arranged to apply a potential difference across the first and second bodies such that an energy distribution of ions

from the plasma that are incident on the first body is in a range that results in etching of contaminants on a surface of the first body and which results in minimal etching of a bulk material of the first body.

8. The lithographic apparatus of any preceding claim wherein the voltage supply is arranged such that an alternating potential difference is applied across the first and second bodies.

9. The lithographic apparatus of any preceding claim when dependent either directly or indirectly on claim 8 wherein a duty cycle of the potential difference applied across the first and second bodies is such that a ratio of the time duration of the negative portion to the time duration of the positive portion is greater than 0.9.

10. The lithographic apparatus of any preceding claim, wherein the apparatus includes a third body proximate the optical path, optionally wherein the third body is configured to be at ground potential or at floating potential.

11. The lithographic apparatus of any preceding claim, wherein the apparatus includes a diode in electrical connection with the second body.

12. A method of controlling a flux and/or energy distribution of ions that is incident on a first body within a lithographic apparatus, the method comprising:
directing a radiation beam along an optical path in the lithographic apparatus, the first body being proximate to said optical path; and
applying a potential difference across the first body and a second body that is also proximate to the optical path so as to control a flux and/or energy distribution of ions incident on the first body from a plasma formed in the optical path by the radiation beam.

13. The method of claim 12 wherein the first body and the second body are arranged such that an electrical conductance between the first body and the plasma is significantly smaller than an electrical conductance between the second body and the plasma.

14. The method of claim 12 or claim 13 further comprising generating a conductive medium between the optical path and the second body,
wherein generating a conductive medium comprises producing a plasma between the optical path and the second body, and/or

wherein generating a conductive medium comprises increasing a density of electrons between the optical path and the second body, and/or

wherein generating a conductive medium comprises directing radiation so as to propagate between the optical path and the second body.

15. The method of any one of claims 12 to 14 wherein applying a potential difference across the first body and a second body comprises applying a biasing potential to the first body and grounding the second body, or wherein applying a potential difference across the first body and a second body comprises applying a biasing potential to the second body and grounding the first body.

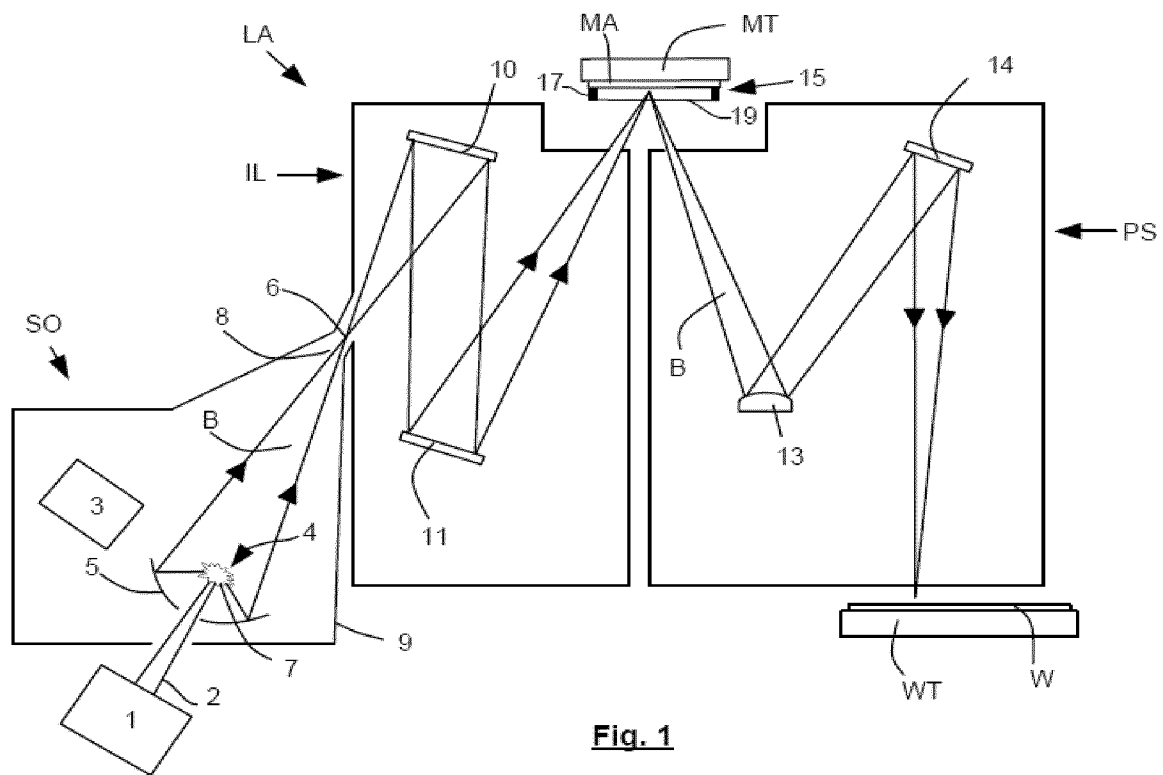
16. The method of any one of claims 12 to 15 wherein applying a potential difference across the first body and a second body comprises applying an alternating potential difference across the first and second bodies.

17. The method of any one of claims 12 to 16 wherein the potential difference alternates between a positive portion wherein the first body is positively biased and negative potential wherein the first body is negatively biased.

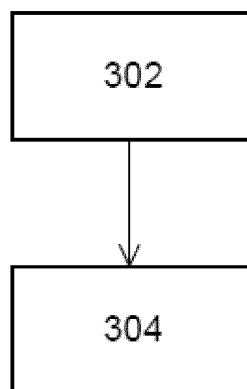
18. The method of claim 16 or claim 17 wherein an average of the potential difference applied across the first and second bodies is non zero.

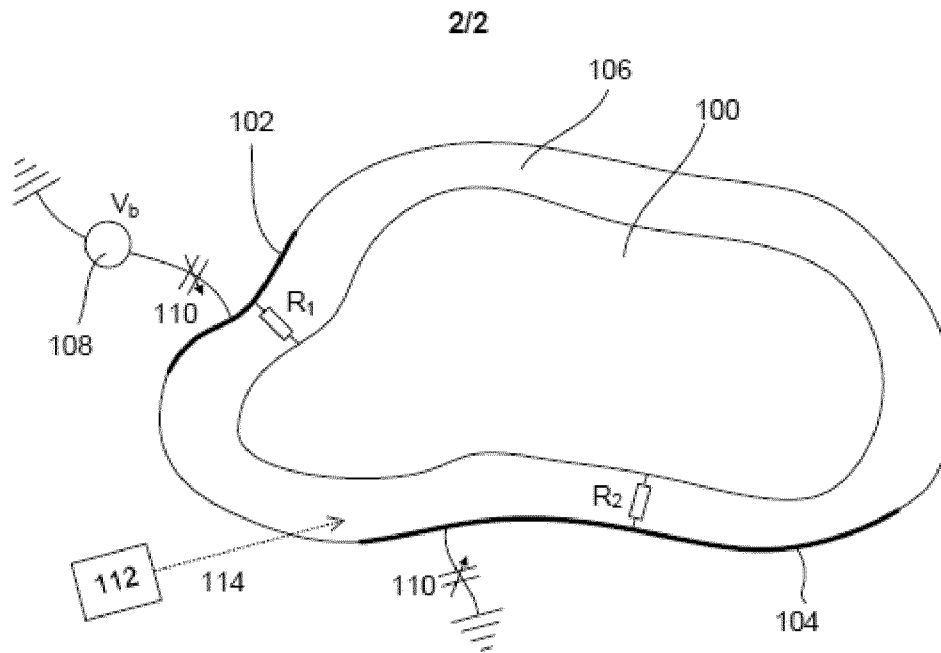
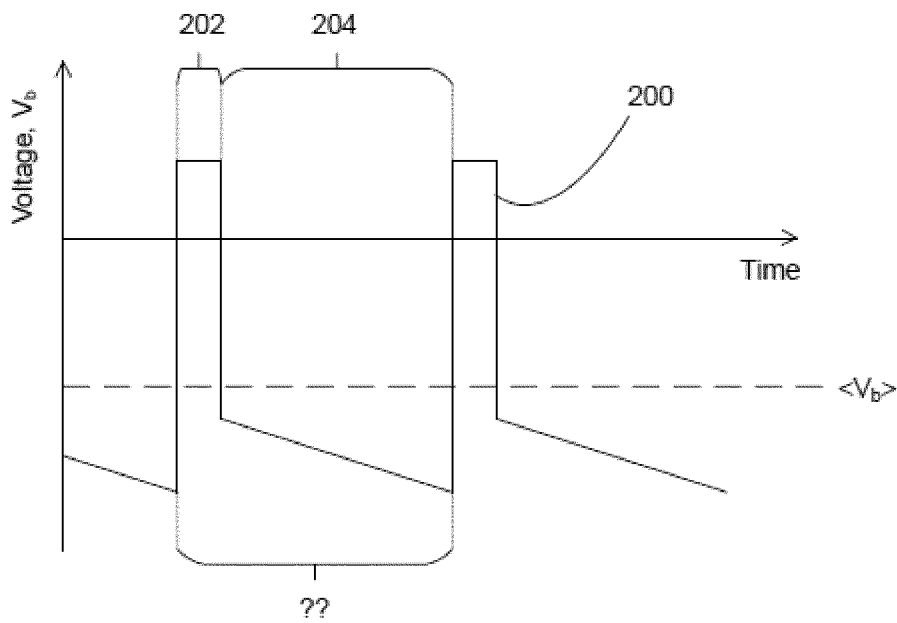
19. The method of any one of claims 12 to 18 when dependent either directly or indirectly on claim 16 or claim 17 wherein a duty cycle of the potential difference applied across the first and second bodies is such that a ratio of the time duration of the negative portion to the time duration of the positive portion is greater than 0.9.

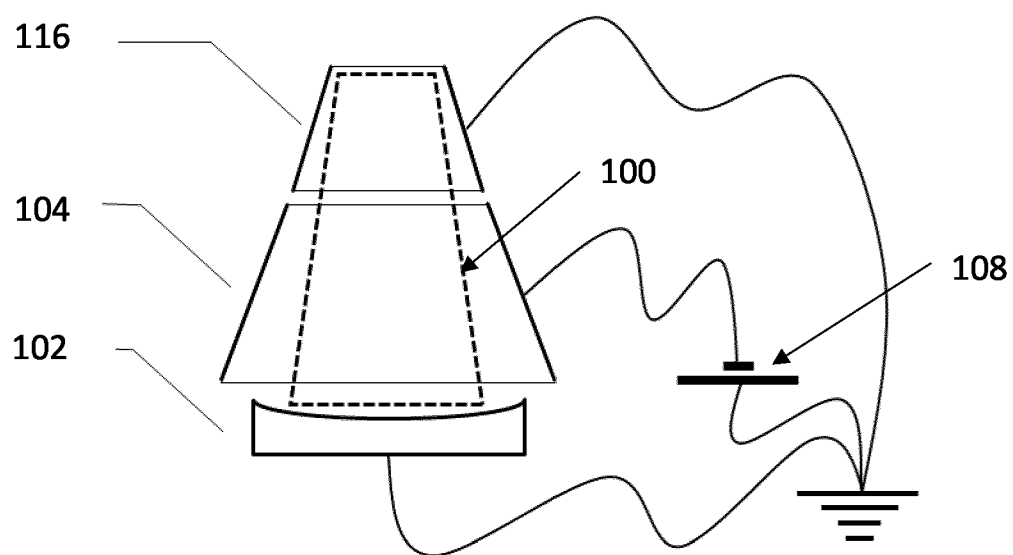
20. The method of any one of claims 12 to 19, wherein the method further includes providing a third body at ground potential or at floating potential.

**Fig. 1**

300

**Fig. 4**

**Fig. 2****Fig. 3**

**Fig. 5**

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/059979

A. CLASSIFICATION OF SUBJECT MATTER**INV. G03F7/00****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 practicable, 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 2005/120953 A1 (BANINE VADIM Y [NL] ET AL) 9 June 2005 (2005-06-09) paragraphs [0042], [0052] - [0068]; figures 1-5 -----	1, 4-8, 10-12, 15-18, 20
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

29 June 2023

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/059979

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	MARK VAN DE KERKHOF ET AL: "EUV-induced Hydrogen Plasma : Pulsed Mode Operation and Confinement in Scanner", ARXIV.ORG, CORNELL UNIVERSITY LIBRARY, 201 OLIN LIBRARY CORNELL UNIVERSITY ITHACA, NY 14853, 20 May 2021 (2021-05-20), XP081967100, the whole document -----	1-20

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Information on patent family members

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