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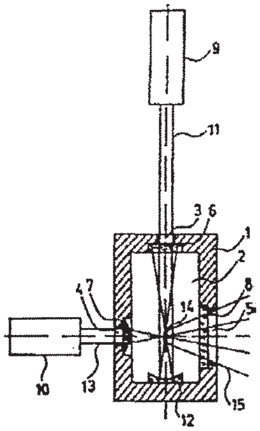
(54) Radiation source for optical devices, notably for photolithographic reproduction systems.

(57) Radiation source for optical devices, notably for photolithographic reproduction systems, characterised in that a gas-tight chamber 1 filled with a discharge medium 2 comprises at least one entry aperture 3 and 4 which allows laser radiation to pass and at least one exit aperture 5 which allows plasma radiation to pass and in that the production and maintenance of a radiation-emitting plasma in the discharge medium are ensured, in a known manner, by at least one laser situated outside the chamber 1, whereby optical means ensuring the focussing of the laser radiation in the discharge medium are mounted at an entry aperture, such that the plasma is situated at a certain distance from the wall of the chamber 1 and that the plasma radiation exits the chamber via exit aperture 5.



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The present invention relates to a radiation source for optical devices, in particular for photolithographic reproduction systems. It is preferably applied in cases where a radiated power is required which is greater than that from pressurised mercury vapour lamps, such as in photolithographic appliances for illuminating a photoresist layer on a semiconductor wafer.

Currently, numerous radiation source systems are known which are used in scientific devices and of which the properties have been widely adapted to the conditions in the field of use. These properties relate to the spectral distribution of the emission and to the obtainable radiation density, as well as to the spatial and angular distribution of the produced radiation. Requirements relating to spectral radiated powers which exceed the spectral radiated power of a black body above the melting point of solid bodies can only be satisfied through plasma. Plasmas are obtained by heating an active medium, preferably by passing an electric current through it or by the action of high-frequency electromagnetic fields. The achievable spectral radiation densities are upwardly limited by the maximum value of the harnessable electrical power per volume unit which can be thermally withstood by the constitutent materials of the electrodes and walls. In the case of high-frequency heating, limitation due to electrode loading no longer occurs, but the problem of the spatial concentration of the high-frequency energy does arise.

If the stationary operation of the radiation source is dispensed with, an increase, by a fairly large order of magnitude, in the power harnessed can be obtained for a short time, since the conversion of the fed-in power into radiation proceeds significantly faster than its transmission to the walls and, if there are any, to the electrodes of the discharge cavity. However, even with this mode of operation, alongside mechanical stresses due to the shock waves which, however, have sufficient action only in unfavourable cases, the evaporation and erosion of the materials which form the walls and electrodes contistute, when the radiation source must have a certain lifespan, an impediment to the production of intense radiant flux. In this regard, it should be noted that in the case of sources which operate in a stationary manner and in the case of sources which operate by pulses, above a power level which is type-dependent and which is achieved practically universally in the technical applications, any further increase in the radiated power is obtained at the expense of a reduction in the lifespan.

However, these short-lived radiation sources cannot be used for many applications because they unreasonably increase the maintenance costs for the devices into which they are incorporated, since changing a lamp generally entails complicated adjustment and long adaptation operations of the optical transmission system to the specific radiant flux of the lamp in question. Within certain limits, it is possible to increase the radiated power whilst retaining the overall charge of the electrical energy invested in the radiation, for the desired wavelength and the preferred spread width. This can be achieved by giving the active medium an optimal composition and by creating optimal pressure and temperature conditions for the plasma during the production of the radiation. However, consideration should be given to the limitations which arise from the existing incompatibility, at working temperature, between various active media and the consituent materials of the electrodes and the walls, such that, taking into account the withstand time of these materials, discharge conditions which are far from optimal frequently have to be selected. In the case of non-stationary operation, further limitations result from the fact that the radiation source simultaneously has to fulfil the functions of an electrical heavy-duty switch and of a converter of electrical energy into radiation. In this case too, the scope for optimising the radiation production is restricted, because the safety of ignition and switching is linked to certain plasma states.

In the case of the stationary operation and in the case of pulsed operation, there are, in electrode radiation devices, dead solid angles in which the radiation cannot be used, although the insertion of suitable optical components, such as ellipsoidal reflectors and/or light-conducting fibres theoretically make it possible to also use the areas formed by these angles and, as a result, to provide the maximum amount of radiation energy to the optical system. To illuminate optical systems used in photolithography microinstallations, lasers are also used as radiation sources (SPIE Vol. 174 [1979], p.28...36, “Coherent illumination improves step-and-repeat printing on wafers” *[Un éclairage cohérent améliore l’impression “graduelle et répétée” sur les galettes”]*, by Michel Lacombat et al.) The main limitations of these light sources result from their high spatial coherence and the structural distortions which result therefrom, their high monochromy and the effects of the resulting standing waves in photosensitive materials. Furthermore, generally, lasers with high radiated power or favourable efficiency are generally not present in advantageous spectral areas. The use of “excimer” lasers which emit the necessary energy in the desired wavelength region (UV region) are limited to contact-lithographic methods (SPIE Vol. 334 [1982], p.259...262, “Ultrafast high resolution contact lithography using excimer laser" *[“Lithographie par contact é forte résolution ultrarapide au moyen de laser excimer”*], by K. Jain et al.), because the partial spatial coherence necessary for the illumination of projection-lithography systems cannot be achieved to a degree as justified by its technical use.

The aim of the invention is to achieve a highly powerful radiation source which has a long lifespan and which makes it possible to include a substantial area of solid angles and precise and fast illumination of photosensitive areas and which, as a result, ensures a high productivity in photolithographic installations. Therefore the invention is intended to make it possible to achieve a radiation source for optical devices, in particular for photolithographic reproduction systems, which uses plasma radiation. By a spatial separation between the plasma and the wall or other installations associated with a cavity and without use of electrodes mounted in the cavity nor high-frequency fields for spatial concentration of the energy, it must make it possible to obtain a long lifespan and high power density. Furthermore, there is a reduction of stresses on the cavity though shock waves when the radiation source is in pulsed operation, and there are no dead solid angles due to electrodes or other installations in the cavity. The radiation source according to the invention is intended to possess a wide scope for optimisation of the radiation production in the desired wavelength region, because the active media and pressure and temperature conditions must be selected regardless of the compatibility with the materials which the electrodes are made of. With regard to the laser radiation, the radiation source has the advantage that, especially in the case of photolithographic reproduction systems, it has a significant partial spatial coherence and that its spectral structure is such that the effects of standing waves in the photosensitive material are attenuated.

This aim is achieved, according to the invention, by the fact that a gas-tight chamber filled with a discharge medium contains at least one entry aperture which allows laser radiation to pass and at least one exit aperture which allows plasma radiation to pass, and that the production and maintenance of a radiation-emitting plasma in the discharge medium are ensured, in a known manner, by at least one laser situated outside the chamber, whereby optical means for focussing the laser radiation in the discharge medium are mounted at an entry aperture, such that the plasma is at a certain distance from the wall of the chamber and that the plasma radiation exits the chamber via the exit aperture.

When the radiated power of a laser as supplied is not sufficient for a discharge in the discharge medium, it is advantageous that the device includes, to ignite the discharge medium, outside the chamber, at least one further pulse-operated laser which is directed by optical means to ensure focussing of the same volume at an entry aperture.

An advantageous variant, with regard to changing of position of the radiation-emitting plasma, consists in placing the optical means which ensure the focussing of the laser radiation outside the chamber. It is then possible to advantageously arrange installations which make it possible to adjust the optical means which ensure the focussing of the laser radiation.

It is possible to advantageously simplify the realisation of the radiation source by placing optical means which ensure the focussing of the laser radiation inside and/or on the surface of the chamber. In these conditions, the inner wall of the chamber constitutes an optical means for focussing the radiation coming from outside. To include as large an area of dead solid angles as possible, it is advantageous to give the inner wall of the chamber a shape such that it constitutes an optical means for ensuring the reflection of the radiation coming from the plasma. It is therefore advantageous for the inner wall of the chamber to have the shape of a convex mirror or an ellipsoidal mirror.

To obtain high power densities and to increase the lifespan, it is advantageous to provide the chamber with an external cooling system.

Various other characteristics of the invention further emerge from the following detailed description.

Embodiments of the subject of the invention are shown, by way of non-limiting examples, in the attached drawings.

Fig. 1 schematically shows an embodiment of the radiation source according to the invention.

Fig. 2 shows an exemplary embodiment in which the inner wall of the chamber has a shape such that it constitutes an optical element.

Fig. 3 and 4 show embodiments wherein the discharge chamber has the shape of an ellipsoidal reflector.

Fig. 1 schematically shows an embodiment of the radiation source according to the invention in which a gas-tight chamber 1 contains the discharge medium 2. The chamber 1 includes two entry apertures 3 and 4 which allows laser radiation to pass and an exit aperture 5 which allows plasma radiation to pass. The entry aperture 3 is sealed by the window 6 which allows infrared

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