LITHOGRAPHY APPARATUS USING EXTREME UV RADIATION AND HAVING A VOLATILE ORGANIC COMPOUNDS SORBING MEMBER COMPRISING A GETTER MATERIAL

The present invention refers to a lithography apparatus using extreme UV radiation and having a Volatile Organic Compounds (VOCs) sorbing member comprising a getter material.

Lithography is a technique used in the manufacturing of integrated circuits to define the geometry of the parts that form these circuits; the technique is also used in other similar manufacturing processes, such as those of micromechanical systems (known in the field as MEMs). In order to illustrate the invention, reference will be made in the text to the manufacturing of integrated circuits (known as ICs,), but the invention can be employed in all the manufacturing processes using the lithography technique.

In the manufacturing of ICs, a film of a polymeric material, that shows the characteristic of being able to change its chemical behaviour (for example its solubility in a given solvent) upon the exposure to a radiation at a given wavelength, is positioned, or formed starting from liquid precursors, onto a slice of a supporting material, typically silicon or other semiconductor materials. By selectively illuminating with the suitable radiation only portions of the polymeric film, this is locally sensitized in such a way to make it subsequently attackable by a solvent (also the contrary is possible, i.e. that the film as such is attackable by the solvent and the radiation treatment makes it instead resistant thereto). After the selective illumination treatment, the portions rendered sensitive to the chemical attack of the solvent (or remained sensitive) are removed by a treatment with the latter, exposing only the desired portions of the supporting surface; on these portions it is then possible to form localized deposits of materials having desired characteristics, such as for example conducting or insulating materials, by techniques such as physical vapour deposition (PVD, a technique more commonly known in the field as "sputtering"), chemical vapour deposition (CVD), Molecular Beam Epitaxy (MBE) or the like; alternatively, the exposed portions of the supporting surface may undergo an erosive treatment in order to form recesses of suitable geometry

in the surface of the support itself, for example by chemical attacks. By alternating subsequent cycles of positioning or depositing of the polymeric film, selectively removing of its portions and depositing "traces" of desired materials on the exposed portions of the support or erosion thereof, the desired structures of the integrated circuit are finally manufactured.

In order to reduce the manufacturing costs and to follow the demand of the market for more and more compact electronic products, the typical dimensions of the parts that form integrated circuits undergo a constant reduction over time; at present the smallest dimension of IC parts that are obtained through lithographic techniques are about 100 nanometers (nm), but a transition to the next generation of ICs is already in progress, in which the smallest dimensions of IC parts will be around 30 nm.

In order to be able to define smaller and smaller geometries and structures, during the lithographic operations it is necessary to use radiations of smaller wavelengths, comparable to the dimensions of these geometries. The main manufacturers of ICs have defined a new wavelength standard to be used for the manufacturing of ICs of the next generation, which is around 13.5 nm. This value is in the range of UV radiations of shorter wavelength, defined in the field as extreme UV (or EUV): Lithography that uses these radiations is consequently known in the field under the definition "Extreme UV Lithography", or under its abbreviation EUVL.

The lithographic techniques employed up to now used wavelengths to which some gases, liquids or solids were transparent; it was thus possible, by suitably choosing the materials that formed the lithographic system, to obtain that the optical path of the UV radiation from the source to the polymeric film occurred in a gaseous medium (for example, purified air) and that the deviation and focusing of the radiation occurred essentially only by refraction through suitable lenses. By employing EUVL this is no longer possible, because the EUV wavelengths are almost completely sorbed by all materials. Consequently, in EUVL the optical path of the radiation can be defined only inside evacuated chambers and by using reflecting elements (mirrors, monochromators, ...).

EUVL apparatuses currently under development are comprised of various main chambers, connected to each other only through small openings for the passage of the

radiation from one chamber to another. Normally, the EUV radiation source (in general a plasma generated by a laser or an electric discharge) and a collector, that collects a portion of the radiation emitted by the source and directs the radiation along a preferred direction, are arranged in a first chamber. In an intermediate chamber there is a part of the elements for focusing and directing the beam exiting from the first chamber (for example, a monochromator and system of reflecting elements to direct the radiation from the monochromator). Finally, in a last chamber, defined "process chamber" in the following, there are the final reflecting elements for focusing the radiation onto the support, preferably made of semiconductor material that holds the polymeric film to be treated by the radiation, and a sample holder on which said support is fixed, being able to move freely and in a controlled manner in a plane perpendicular to the incident direction of the radiation (sample holders known as "X-Y tables"). Pumping systems are connected to the apparatus in order to maintain the required vacuum degree inside it, generally comprising turbo-molecular or cryogenic pumps. The required vacuum degree is different in the various chambers, and is less severe in the first chamber, up to requiring values of residual pressure lower than 10^{-7} Pa in the process chamber. An example of an EUVL apparatus is disclosed in the patent application US 2006/0175558 A1, which is referred to for a more detailed explanation of the various parts of a similar apparatus and of their functions.

A problem with EUVL apparatuses is the presence of volatile organic molecules in the process chamber. These molecules, when irradiated by the highly energetic UV radiation, can mutually react or react with the surface of the support, preferably made of semiconductor material, thus resulting in new species or in carbon residuals, resistant to the subsequent chemical treatments, that may remain incorporated in the structures under formation and cause defects thereof, thus resulting in manufacturing waste. Decomposition of the organic molecules and deposition of carbon-based layers can also take place on the optical lenses present in the process chamber which have the task to reflect the radiation coming from the EUV source. The presence of carbon layers on the surface of the lenses reduces their optical reflectivity, thus decreasing the radiation intensity reaching the substrate. This in turn decreases the photolithographic efficiency and the overall process yield.

Hydrocarbons are among the most common VOCs contaminants that may be present within the EUVL apparatuses.

EUVL apparatuses are normally equipped with various pumping units in order to maintain the chambers under high vacuum, but the scanning of the radiation across the surface of the polymeric film on the support is a source of organic molecules, both coming from the decomposition of the polymer and from solvent molecules trapped therein. These molecules are thus formed and released in the most critical zone of the system.

The pumping systems normally provided for maintaining the vacuum in EUVL apparatuses can not remove these species in a fast and effective way, before these can result in undesired reactions on or with the support, because these systems are normally positioned at far away from the support, which is also the zone wherein organic molecules are generated. In EUVL apparatuses it is not possible to bring the already present pumps closer to this zone, because the turbomolecular pumps would transmit vibrations to the reflecting elements or to the X-Y table, thus jeopardizing the scanning precision, whereas the cryogenic pumps would cause mechanical deformations in the system due to the high thermal gradients they generate, thus also resulting in this case in scanning imprecisions.

Object of the present invention is thus to provide a lithography apparatus using extreme UV radiation capable of solving or anyway minimizing the problem of the presence of inorganic volatile molecules in the process chamber.

According to the present invention, this object is obtained by means of a lithography apparatus using extreme UV radiation, characterized by having a VOC sorbing member comprising a getter element inside the process chamber or in a suitable space connected thereto.

The inventors have found that getter materials, normally used in vacuum technology at operating temperatures of 200-300°C for sorbing simple gaseous species as H_2, O_2, H_2O, CO and CO_2, can effectively sorb VOCs, with particular and non-exclusive reference to hydrocarbons at room temperature. This makes the elements containing getter materials (these being bodies either formed of getter materials only or being deposits of these materials on surfaces, or real structured getter pumps)

particularly suitable for the use proximate to the support in the process chamber of an EUVL system. As it is known in fact getter materials enable to manufacture gas sorbing members that have no moving parts and thus are free from vibrations, and the finding of the VOCs sorbing capacity at room temperature leads to the fact that these materials can be positioned very close to the support on which the polymeric film is arranged, i.e. the source of the volatile organic molecules, without altering the thermal balance of the system and thus without introducing scanning imprecisions of the UV radiation across the polymeric film.

The invention will be illustrated in the following with reference to the annexed drawings, wherein:

- figure 1 shows the general geometry of an EUVL apparatus;

- figure 2 shows a first possibility of positioning a getter member in the process chamber of an EUVL apparatus;

- figure 3 shows another possibility of positioning a getter member in the process chamber of an EUVL apparatus; and

- figure 4 shows a further possibility of positioning a getter member in the process chamber of an EUVL apparatus.

The dimensions of the elements and members shown in the drawings are not in scale, and in particular the thicknesses of some of those, such as the support, preferably made of semiconductor material, the polymeric film or the getter deposit shown in figure 4, have been largely increased to help to understand the drawings.

Moreover in the following reference will be made to the support as made of a semiconductor material, but this is only the preferred embodiment for carrying out the invention, and there may be cases in which devices may require a different type of material for the support, for example an insulating or non conducing material.

Figure 1 shows an EUVL apparatus in a schematic and extremely simplified way. The apparatus 10 comprises a first chamber 11, in which the EUV radiation source 110 and a collector 111 are present, the latter collecting parts of the radiation emitted from the source in all directions and directs the radiation to the subsequent chamber; a second chamber 12, containing a monochromator 120 that selects the desired wavelength from the band of frequencies emitted from the source and directs the monochromatic

radiation to the subsequent chamber; and a process chamber 13, containing a sample holder 130 that holds a mask 131 with the design to be reproduced on the polymeric film arranged on the support made of semiconductor material, at least one reflecting element 132 (but, in general a plurality of reflecting elements are provided, see for example figure 2 of patent application US 2006/0175558 A1), and an "X-Y" table 133 moved by a motorized member 134. On table 133 a support 135 made of a semiconductor material is arranged, on which a polymeric film 136 to be sensitized by the radiation is present; letter R in figure 1 indicates the path of the EUV radiation.

According to the invention, a getter member is arranged in the process chamber, in the area closest to the source of organic molecules.

Figure 2 shows a first possible way to introduce a getter member in the process chamber. In this case the member is a true getter pump. The drawing shows in a broken view and schematically a part of the process chamber 13, defined by a wall 20. In the wall an opening 21 for connecting a getter pump 22 to the chamber is provided, the pump being e.g. comprised of a central support 23 on which a plurality of discs 24 made of a porous getter material are fixed. The support 23 is fixed to a flange 25 that closes opening 21 and also fixes the position of the pump. The getter pump may have also other structures, e.g. of the type shown in patents EP 650639 B1, EP 650640 B1 or EP 910106 B1. In figure 2 the pump is shown mounted on wall 20 and having the getter structure facing the inside of the chamber, but it is also possible to use an opposite arrangement, i.e. to arrange the getter pump is a small side chamber external to chamber 13 but communicating therewith through opening 21. In this second way it is also possible to provide for the use of a valve for closing aperture 21 and insulating the side chamber from the process chamber when needed, e.g. in order to change the getter pump or to carry out the reactivation treatment thereof.

Figure 3 shows a second possible way to introduce a getter member in the process chamber. Also in this case the getter material is introduced into chamber 13 (defined by a wall 30) in the form of a pump 31. The pump has the shape of a hollow cylinder and is arranged coaxially to radiation R and proximate to the "X-Y" table 133. The pump 31 is comprised of a frame 32 (generally made of metal) and of a plurality of perforated discs 33 made of a porous getter material. The discs are shown simply fixed to frame 32, but

it is obviously possible to resort to more elaborated solutions, in which the discs are fixed by means of metal members in order to form a self standing structure inserted in frame 32. In addition the geometry of the getter material members could be different from the one shown and there could be used e.g. a geometry based on radially arranged planar getter members as disclosed in patent EP 650639 B1, a sinusoidal getter member as disclosed in patent EP 918934 B1 or any other suitable geometry for this purpose. Preferably, the lower portion of the frame is so shaped to form a volume 34 adapted to contain possible getter material particles that could detach from the above-standing getter members, in order to avoid that these particles fall onto table 133 or film 136.

The hollow cylinder configuration is a preferred one, although any suitable hollow container may fulfill the same purpose and function.

Finally, figure 4 shows a further possible way to introduce a getter member into the process chamber. In this case the sorbing member is comprised of a deposit of getter material on a generally metal surface. Figure 4 shows a member 41 comprised of a getter material deposit 42 arranged on an inner wall of a hollow body 43, preferably cylindrical-shaped, that is coaxial to radiation R and arranged proximate to the "X-Y" table 133. Also in this case it is possible to provide for shaping the lower portion of body 43 in such a way to form a "drawer" (case not shown in the drawing) in order to retain particles possibly detached from deposit 42, in order to avoid that these particles fall onto table 133 or film 136. However, when deposit 42 is obtained by sputtering it is not necessary to resort to this solution, because the deposits obtained through this technique are generally compact and do not generate particulate.

During the manufacturing steps carried out in the process chamber, getter members and pumps work at room temperature. However, in these conditions only the surface of the getter material is used, the surface being thereby saturated after a certain number of hours of operation and being no longer able to carry out its task. It is thus possible to foresee the presence of heating elements for the getter member or pump (not shown in the drawings) for periodically reactivating the sorbing ability of the getter material, which reactivation may be carried out during the interruptions of the manufacturing process needed for servicing the apparatus.

When such a heating element is present, it may also be used to fix the getter

elements of the getter pump, even though advantageous configurations envision the getter elements being disposed around the heating elements without being fixed thereto. A type of these getter pumps is sold by the applicant as CapaciTorr® D2000 MK5 getter pumps.

Suitable getter materials for the invention may be comprised of one single metal chosen among titanium, zirconium, vanadium, niobium or hafnium or may have a composition formed of a number of metals. In the case of a single metal, this is preferably titanium or zirconium. In the case of multi-metal materials, these are generally titanium- and/or zirconium-based alloys comprising at least another element chosen among transition elements, rare earths and aluminum, such as Zr-Fe, Zr-Ni, Zr-Al, Zr-V-Fe, Zr-Co-A alloys (where A indicates one or a number of elements chosen among yttrium, lanthanum and rare earths) or Zr-Ti-V alloys.

In order to increase the sorption speed (rate) of the getter material, this is preferably in a form having a high specific surface area (i.e. the surface area of the material for each gram of the same). This condition may be achieved by manufacturing highly porous getter material bodies, e.g. according to the techniques described in patent EP 719609 B1 or in patent application EP 1600232 A1. Alternatively, it is possible to employ getter material deposits formed on suitably shaped surfaces, according to the technique described in patent application EP 1821328 A1 or by sputtering as described in patent EP 906635 B1. When resorting to the deposition of getter material by sputtering, it is possible to increase the surface area of the deposit by forming the deposit on an uneven or rough surface and/or by operating according to the teachings of patent application WO 2006/109343 A2, i.e. under a pressure of noble gas (normally argon) in the sputtering chamber that is higher than the values normally used for the deposition of metal layers, and employing a power applied to the target that is lower than the values normally used in the technique.

CLAIMS

1. A lithography apparatus (10) using extreme UV radiation, characterized by having a Volatile Organic Compounds (VOCs) sorbing member (22; 31; 41) comprising a getter material arranged in the process chamber (13) or in a suitable space connected thereto by means of a suitable opening.

2. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump (22) comprising a getter pump support (23), said getter pump being inserted in the process chamber (13) through an opening (21) formed in a wall (20) thereof and connected to said wall by means of a flange (25) carrying said getter pump support (23).

3. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump arranged in a side chamber external to the process chamber but communicating therewith through said opening.

4. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump (22) comprised of a plurality of discs (24) made of a getter material and fixed to a central getter pump support (23).

5. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump (22) comprised of a plurality of discs (24) made of a getter material and an heating element, wherein said getter discs are fixed to said heating element.

6. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump comprised of a plurality of discs made of a getter material and a heating element, wherein said getter discs are disposed around said heating element without being fixed thereto.

7. An apparatus according to claim 1, wherein said VOCs sorbing member is a getter pump (31) having the shape of a hollow container arranged in the process chamber coaxially to the UV radiation and proximate to a supporting member of a support on which a polymeric film to be sensitized by the radiation is present.

8. An apparatus according to claim 7, wherein said hollow container is cylindrical-shaped.

9. An apparatus according to claim 8, wherein said getter pump is comprised

of a cylindrical frame (32) inside which a plurality of perforated discs (33) made of a getter material are present.

10. An apparatus according to claim 8, wherein said getter pump is comprised of a cylindrical frame inside which a plurality of radially arranged planar members made of a getter material are present.

11. An apparatus according to claim 1, wherein said VOCs sorbing member is a deposit of getter material on a metal surface.

12. An apparatus according to claim 11, wherein said VOCs sorbing member (41) is comprised of a getter material deposit (42) on an inner wall of a hollow body (43) arranged coaxially to the UV radiation and proximate to a supporting member of a support on which a polymeric film to be sensitized by the radiation is present.

13. An apparatus according to claim 1, wherein the getter material is chosen among titanium, zirconium, vanadium, niobium or hafnium, or alloys based on titanium and/or zirconium with at least another element chosen among transition elements, rare earths and aluminum.