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(54) **APPARATUS USED FOR EXTREME ULTRAVIOLET LITHOGRAPHY COMPRISING A FILTER FOR SUPPRESSING UNDESIRE**
D ATOMIC AND MICROSCOPIC PARTICLES FROM A RADIATION
SOURCE AND FILTER USED IN SUCH AN APPARATUS

GERÄT FÜR EXTREM-ULTRAVIOLETT-LITHOGRAPHIE MIT EINEM FILTER ZUR
UNTERDRÜCKUNG UNERWÜNSCHTER ATOMARER UND MIKROSKOPISCHER PARTIKEL
EINER STRAHLUNGSQUELLE SOWIE IN EINEM DERARTIGEN APPARAT VERWENDETES
FILTER

APPAREIL POUR LITHOGRAPHIE AUX ULTRAVIOLETS EXTREMES COMPRENANT UN FILTRE
POUR LA SUPPRESSION DE PARTICULES ATOMIQUES ET MICROSCOPIQUES INDESIRABLES
PROVENANT D'UNE SOURCE DE RADIATION AINSI QUE FILTRE UTILISE DANS UN TEL
APPAREIL

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- **"COLLIMATOR FOR X-RAY LITHOGRAPHY" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 33, no. 4, 1 September 1990, page 278/279 XP000106428**

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Description

[0001] The invention relates to an apparatus comprising a radiation source and a processing organ for processing the radiation from the radiation source, wherein a filter is placed between the radiation source and the processing organ which filter comprises a plurality of foils or plates that are positioned oblique with respect to a virtual axis connecting the radiation source to the processing organ.

[0002] Such an apparatus may be used in the production of integrated circuits, that is to say in a lithographical application. The invention may also be applied in various other fields. For a good understanding of the invention, however, a lithographical application will serve well as illustration. Continuous attempts are made to make integrated circuits smaller and smaller in order to improve the processing speed of the integrated circuits.

[0003] According to the prior art, such integrated circuits are manufactured chiefly by using lithography with visible and ultraviolet light. With these known technologies, it is possible to manufacture integrated circuits that may be as short as 120 nanometres. The ultraviolet light used with said circuits has a wavelength of 193 nanometres. The known techniques do not allow a further decrease of the dimensions of the integrated circuits, and a possible solution is the use of lithography on the basis of extreme ultraviolet light. Such light has a wavelength of 13 nanometres. The known optical elements cannot be used at this wavelength. The known mirrors and lenses absorb too large a portion of the extreme ultraviolet light. In order to allow for this, the processing organ for processing the radiation from the radiation source is a multi-layer mirror which consists of 40 or more molybdenum layers alternating with silicon layers.

[0004] In such an apparatus for extreme ultraviolet lithography a laser plasma source is used to generate a plasma by heating an object by means of a laser source of high energy density, for example of at least 10^{11} W/cm^2 . The object heated by the laser will function as source of secondary emission of mainly shortwave radiation. However, this will also release undesirable particles and atoms producing the effect of debris in the apparatus. The objective of the invention is to prevent the production of said debris.

[0005] WO 96/10324 discloses such an apparatus for the generation of radiation. This apparatus uses a fast rotating target which is heated by the laser source and which produces the secondary emission. Due to the kinetic energy of the particles formed from the plasma on the rotating target, this apparatus has a filtering effect in respect of the so-called macro-particles. However, trapping atoms and in particular the fastest micro-particles, is not possible in this known apparatus.

[0006] US-A-4,837,794 concerns a filter apparatus according to the preamble of the main claim including a series of baffles for diffusing hot gases and directing them away from a window of sight. Due to the placement of

the baffles the said window of sight is rather narrow.

[0007] It is the object of the invention to circumvent the drawbacks of the prior art. According to the invention, this is realised by the apparatus according to the preamble of the main claim, which is characterized in that each foil or plate essentially points in the radial direction when viewed from the radiation source, such that the foils or plates share a common virtual point of intersection located approximately at the radiation source. Surprisingly it has been shown that this very simple measure not only makes it possible to trap atoms and micro-particles, but also clusters of such micro-particles, respectively the smallest macro-particles.

[0008] Quite advantageous is that the apparatus according to the invention shows no limitation with respect to the effectively usable angle of sight due to the fact that the apparatus embodied with the filter according to the invention provides full optical transparency.

[0009] A first preferred embodiment of the apparatus according to the invention is characterized in that the foils or plates are positioned in a honeycomb construction.

[0010] A second preferred embodiment of the apparatus according to the invention is characterized in that the foils or plates are cone-shaped and are positioned concentrically.

[0011] Preferably, in the radial direction the foils or plates are positioned such as to be evenly distributed in relation to one another.

[0012] Such an apparatus is used with a buffer gas in which the radiation source and the processing organ are placed. Appropriately, the distance between the radiation source and the filter's proximal end in relation to the radiation source is then selected subject to the pressure and the type of buffer gas. A very suitable choice of buffer gas is krypton, whose pressure is 0.5 Torr, and the distance between the radiation source and the proximal end of the filter is 5 cm. This setting affords sufficient opportunity for the particles to be trapped in the filter to take on the temperature of the buffer gas, for example room temperature, thereby sufficiently reducing the particle's velocity before it enters the filter.

[0013] It is further desirable to select the length of the filter, which is formed by the distance between the filter's proximal end and its distal end in relation to the radiation source, subject to the pressure of the buffer gas and the form of the filter. Especially the gas pressure determines the mean free path length for the particles to be trapped; a lower gas pressure corresponds to an increased free path length. This can be partially compensated by the form of the filter. For example, using the above-mentioned honeycomb construction provides a larger surface area, affording greater opportunity for the particles to actually be trapped.

[0014] It has been shown that good results can be obtained when the length of the filter is at least 1 cm. This filter length corresponds with a usual gas pressure of, for example, 100 mTorr.

[0015] As already mentioned above, the apparatus is

operational at room temperature. The measure of maintaining the filter at a temperature which is approximately below room temperature, allows the residence time of the atoms and particles trapped on a foil or plate to be increased, and accordingly the effectiveness of the filter to be improved.

[0016] It is further desirable that the number of plates in the filter should be adjusted subject to the thickness of each plate and the desired optical transparency of the filter as determined by the formula

$$\frac{d}{d + d_f} \times 100 \%$$

in which

d = the distance between two plates of the filter at the side of the radiation source; and

d_f = the thickness of a plate of the filter.

[0017] In this way the light output of the integral apparatus can be maintained at an adequate level, while the effectiveness of the filter can still be 100%. The apparatus is then preferably characterized in that the number of plates is adjusted such that the distance between two plates is approximately 1 mm.

[0018] The effectiveness of the filter may be improved further by roughening the surface of the plates.

[0019] The invention is further embodied in a separate filter for suppressing undesirable atomic and microscopic particles emitted by a radiation source, wherein a plurality of plates are positioned substantially parallel in relation to one another, for trapping atomic and microscopic particles on their respective surfaces.

[0020] Such a separate filter is characterized in that the plates are directed radially from the radiation source.

[0021] The invention will now be explained in more detail with reference to the drawing, in which

Fig. 1 shows schematically a radiation source together with a filter according to the invention;

Fig. 2 shows a preferred embodiment of the filter according to the invention; and

Fig. 3 shows schematically two more preferred embodiments of the filter according to the invention.

[0022] In the Figs., identical reference numbers relate to similar parts.

[0023] Fig. 1 shows a radiation source indicated by reference number 1, and a filter which is generally indicated by reference number 2. The processing organ that is used in the apparatus for, for example, extreme ultraviolet lithography, is not shown. This processing organ is located at the side of the filter 2 facing away from the radiation source 1. The filter 2 comprises a number of plates 3 positioned in a radial direction from the radiation

source 1. It is possible to position said plates in a honeycomb construction, or as a plurality of concentric cones as shown in Fig. 3.

[0024] Figs. 1 and 2 show that in the direction of radiation from the source 1, the plates are positioned such as to be evenly distributed next to one another. The proximal end 4 of the filter 2 is at a distance X from the radiation source 1, which distance is selected depending on the pressure and the type of buffer gas in which the radiation source 1, the processing organ (not shown), and also the filter 2, are placed. If the apparatus is used for extreme ultraviolet lithography, the buffer gas is preferably krypton having a pressure of 0.5 Torr, and the value of X may be 5 cm. The length of the plates of the filter is indicated by L. The value of L is selected depending on the pressure of the buffer gas and the form of the filter 2. The value of L, that is to say the length of the filter, is at least 1 cm. In Fig. 1, this value is approximately 10 cm. The thickness of the plates 3 may be, for example, 0.1 mm, and the spacing between the plates at the side nearest the radiation source 1, may be approximately 1 mm. This may result in an optical transparency of the filter 2, which is determined by the formula

$$\frac{d}{d + d_f} \times 100 \%$$

in which

d = the distance between two plates of the filter at the proximal side of the filter; and

d_f = the thickness of a plate of the filter.

[0025] The effectiveness of the filter can be promoted if the surface of the plates 3 is slightly roughened.

[0026] When the apparatus is used for extreme ultraviolet lithography, radiation is used having a wavelength of 13.5 nanometres. Various inert gasses may be used as buffer gas, such as helium and krypton which, compared with other gasses have the lowest absorption coefficient at this wavelength. Krypton is better able to meet the requirements of the present application because the atomic mass of krypton is more compatible with that of the atomic- and [deletion(s)] micro-particles emitted by the radiation source, which augments the inhibition of said undesirable particles. The krypton gas used is maintained at a pressure of at least several mTorr. It should be noted that taken over a distance of 20 cm at a pressure of 0.5 Torr, the optical transparency of krypton for the desired radiation is approximately 90%. The filter used in the apparatus is comprised of copper plates (other materials are also possible) which have a length of 7 cm and are positioned at 2 cm from the radiation source. At a plate thickness of 0.2 mm and with the plates being spaced at approximately 0.8 mm at the side of the radiation source, the filter will have a geometrical transpar-

ency of approximately 80%. The effectiveness of the filter was measured at room temperature and at a temperature of approximately -90°C. At both these temperatures the effectiveness of the filter was shown to be very high, almost 100.

[0027] It will be clear to the person skilled in the art that the various dimensions of the filter forming part of the apparatus according to the invention, as well as the distance from the filter to the radiation source, has to be determined in practice on the basis of the above-mentioned inter-relating ratios. It is therefore possible to apply diverse variations to the above description, without departing from the idea of the invention as specified in the appended claims.

Claims

1. An apparatus used for extreme ultraviolet lithography, comprising a radiation source and a processing organ for processing the radiation from the radiation source, wherein a filter is placed between the radiation source and the processing organ which filter comprises a plurality of foils or plates that are positioned oblique with respect to a virtual axis connecting the radiation source with the processing organ, **characterized in that** each foil or plate essentially points in the radial direction when viewed from the radiation source, such that the foils or plates share a virtual point of intersection located approximately at the radiation source.
2. An apparatus according to claim 1, **characterized in that** the foils or plates are positioned in a honeycomb construction.
3. An apparatus according to claim 1, **characterized in that** the foils or plates are cone-shaped and are positioned concentrically.
4. An apparatus according to one of the claims 1-3, **characterized in that** in the radial direction the foils or plates are positioned such as to be evenly distributed in relation to one another.
5. An apparatus according to one of the claims 1-4, wherein the radiation source and the processing organ are placed in a buffer gas, **characterized in that** the distance between the radiation source and the filter's proximal end in relation to the radiation source is selected subject to the pressure and the type of buffer gas.
6. An apparatus according to claim 5, **characterized in that** the buffer gas is krypton, that the pressure is at least approximately 0.1 Torr, and the distance between the radiation source and the proximal end of the filter is 5 cm.

7. An apparatus according to one of the preceding claims, **characterized in that** the length of the filter, which is formed by the distance between the filter's proximal end and its distal end in relation to the radiation source, is selected subject to the pressure of the buffer gas and the form of the filter.
8. An apparatus according to claim 7, **characterized in that** the length of the filter is at least 1 cm.
9. An apparatus according to one of the preceding claims, **characterized in that** the filter is maintained at a temperature which is below room temperature.
10. An apparatus according to one of the claims 1-9, **characterized in that** the number of plates in the filter is adjusted subject to the thickness of each plate and the desired optical transparency of the filter as determined by the formula

$$\frac{d}{d + d_f} \times 100 \%$$

in which

d = the distance between two plates of the filter at the proximal side of the filter; and
d_f = the thickness of a plate of the filter.

11. An apparatus according to claim 10, **characterized in that** the number of plates is adjusted such that the distance between two plates is approximately 1 mm.
12. An apparatus according to one of the preceding claims, **characterized in that** the surface of the plates is rough.
13. A filter used in an apparatus for extreme ultraviolet lithography for suppressing undesired atomic and microscopic particles which are emitted by a radiation source, wherein a plurality of plates are positioned substantially parallel in relation to one another, for trapping atomic and microscopic particles on their respective surfaces, **characterized in that** the plates are directed radially from the radiation source.

Patentansprüche

1. Gerät, das für Extrem-Ultraviolett-Lithografie verwendet wird, umfassend eine Strahlungsquelle und ein Verarbeitungsorgan zum Verarbeiten der Strahlung von der Strahlungsquelle, wobei ein Filter zwischen der Strahlungsquelle und dem Verarbeitungs-

organ angeordnet ist, der eine Vielzahl von Folien oder Platten umfasst, die schräg in Bezug auf eine virtuelle Achse angeordnet sind, welche die Strahlungsquelle mit dem Verarbeitungsorgan verbindet, **dadurch gekennzeichnet, dass** jede Folie oder Platte von der Strahlungsquelle aus betrachtet im Wesentlichen in die radiale Richtung zeigt, sodass die Folien oder Platten einen virtuellen Überschneidungspunkt gemeinsam haben, der ungefähr bei der Strahlungsquelle angeordnet ist.

2. Gerät gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Folien oder Platten in einer Honigwaben-Anordnung aufgestellt sind.

3. Gerät gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Folien oder Platten kegelförmig sind und konzentrisch aufgestellt sind.

4. Gerät gemäß einem der Ansprüche 1 - 3, **dadurch gekennzeichnet, dass** die Folien oder Platten in der radialen Richtung so angeordnet sind, dass sie in Bezug auf einander gleich verteilt sind.

5. Gerät gemäß einem der Ansprüche 1 - 4, wobei die Strahlungsquelle und das Verarbeitungsorgan in einem Puffergas angeordnet sind, **dadurch gekennzeichnet, dass** die Entfernung zwischen der Strahlungsquelle und dem proximalen Ende des Filters in Bezug auf die Strahlungsquelle in Abhängigkeit vom Druck und der Art des Puffergases ausgewählt ist.

6. Gerät gemäß Anspruch 5, **dadurch gekennzeichnet, dass** das Puffergas Krypton ist, dass der Druck mindestens ungefähr 0,1 Torr ist und die Entfernung zwischen der Strahlungsquelle und dem proximalen Ende des Filters 5 cm ist.

7. Gerät gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Länge des Filters, die von der Distanz zwischen dem proximalen Ende des Filters und seinem distalen Ende in Bezug auf die Strahlungsquelle gebildet ist, in Abhängigkeit vom Druck des Puffergases und der Form des Filters ausgewählt ist.

8. Gerät gemäß Anspruch 7, **dadurch gekennzeichnet, dass** die Länge des Filters mindestens 1 cm ist.

9. Gerät gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Filter bei einer Temperatur, die unterhalb der Raumtemperatur ist, gehalten wird.

10. Gerät gemäß einem der Ansprüche 1 - 9, **dadurch gekennzeichnet, dass** die Zahl der Platten im Filter in Abhängigkeit von der Dicke jeder Platte und der gewünschten optischen Transparenz des Filters an-

gepasst wird, wie von der Formel

$$\frac{d}{d + d_f} \times 100 \%$$

bestimmt, wobei

d = die Distanz zwischen zwei Platten des Filters auf der proximalen Seite des Filters; und
d_f = die Dicke einer Platte des Filters sind.

11. Gerät gemäß Anspruch 10, **dadurch gekennzeichnet, dass** die Zahl der Platten so angepasst wird, dass die Entfernung zwischen zwei Platten ungefähr 1 mm ist.

12. Gerät gemäß einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Oberfläche der Platten rau ist.

13. Filter, der in einem Gerät für Extrem-Ultraviolett-Lithografie zur Unterdrückung unerwünschter atomarer und mikroskopischer Partikel verwendet wird, die von einer Strahlungsquelle emittiert werden, wobei eine Vielzahl von Platten in Wesentlichen parallel in Bezug auf einander zum Einfangen atomarer und mikroskopischer Partikel auf ihren jeweiligen Oberflächen angeordnet sind, **dadurch gekennzeichnet, dass** die Platten strahlenförmig von der Strahlungsquelle aus ausgerichtet sind.

Revendications

1. Appareil utilisé pour lithographie aux ultraviolets extrêmes, comprenant une source de rayonnement et un organe de traitement pour traiter le rayonnement de la source de rayonnement, dans lequel un filtre est placé entre la source de rayonnement et l'organe de traitement, lequel filtre comprend une pluralité de feuilles ou plaques qui sont positionnées de façon oblique par rapport à un axe virtuel reliant la source de rayonnement et l'organe de traitement, **caractérisé en ce que** chaque feuille ou plaque pointe essentiellement dans la direction radiale, vue depuis la source de rayonnement, de telle sorte que les feuilles ou plaques partagent un point d'intersection virtuel situé approximativement à la source de rayonnement.

2. Appareil selon la revendication 1, **caractérisé en ce que** les feuilles ou plaques sont positionnées selon une construction en nid d'abeille.

3. Appareil selon la revendication 1, **caractérisé en ce**

que les feuilles ou plaques sont en forme de cône et sont positionnées concentriquement.

4. Appareil selon l'une quelconque des revendications 1 à 3, **caractérisé en ce que** dans la direction radiale les feuilles ou plaques sont positionnées de manière à être réparties régulièrement les unes par rapport aux autres. 5
5. Appareil selon l'une des revendications 1 à 4, dans lequel la source de rayonnement et l'organe de traitement sont placés dans un gaz protecteur, **caractérisé en ce que** la distance entre la source de rayonnement et l'extrémité proximale du filtre par rapport à la source de rayonnement est sélectionnée en fonction de la pression et du type du gaz protecteur. 10 15
6. Appareil selon la revendication 5, **caractérisé en ce que** le gaz protecteur est du krypton, que la pression est au moins de 0,1 Torr environ et la distance entre la source de rayonnement et l'extrémité proximale du filtre est de 5 cm. 20
7. Appareil selon l'une des revendications précédentes, **caractérisé en ce que** la longueur du filtre, qui est formée par la distance entre l'extrémité proximale du filtre et son extrémité distale par rapport à la source de rayonnement, est sélectionnée en fonction de la pression du gaz protecteur et de la forme du filtre. 25 30
8. Appareil selon la revendication 7, **caractérisé en ce que** la longueur du filtre est d'au moins 1 cm.
9. Appareil selon l'une des revendications précédentes, **caractérisé en ce que** le filtre est maintenu à une température qui est inférieure à la température ambiante. 35
10. Appareil selon l'une des revendications 1 à 9, **caractérisé en ce que** le nombre de plaques dans le filtre est ajusté en fonction de l'épaisseur de chaque plaque et de la transparence optique du filtre souhaitée comme déterminé par la formule 40 45

$$\frac{d}{d + d_f} \times 100 \%$$

dans laquelle

d = la distance entre deux plaques du filtre du côté proximal du filtre ; et

d_f = l'épaisseur d'une plaque du filtre. 50 55

11. Appareil selon la revendication 10, **caractérisé en ce que** le nombre de plaques est ajusté de telle sorte

que la distance entre deux plaques est de 1 mm environ.

12. Appareil selon l'une des revendications précédentes, **caractérisé en ce que** la surface des plaques est rugueuse.
13. Filtre utilisé dans un appareil pour lithographie aux ultraviolets extrêmes pour supprimer des particules atomiques et microscopiques indésirables qui sont émises par une source de rayonnement, dans lequel une pluralité de plaques sont positionnées sensiblement parallèlement les unes par rapport aux autres, pour capturer des particules atomiques et microscopiques sur leurs surfaces respectives, **caractérisé en ce que** les plaques sont dirigées radialement à partir de la source de rayonnement.

