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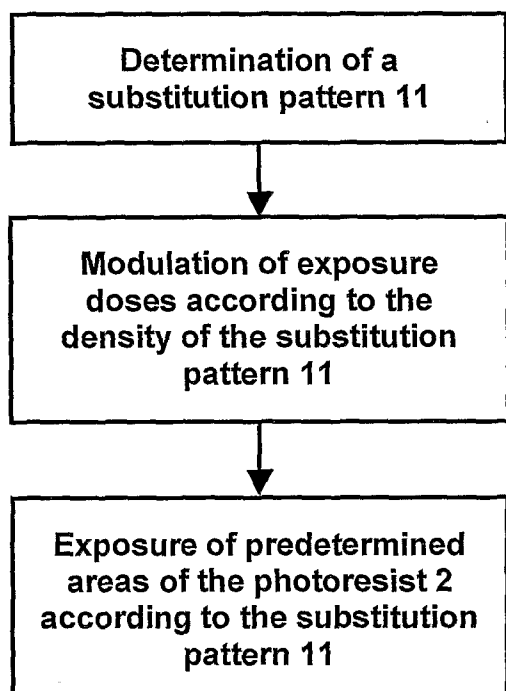
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(54) Title: METHOD FOR TRANSFERRING A PREDETERMINED PATTERN REDUCING PROXIMITY EFFECTS



(57) Abstract: A method for transferring a predetermined pattern onto a flat support performed by direct writing by means of a particle beam comprises at least: deposition of a photoresist layer on a free surface of the support, application of the beam on exposed areas of the photoresist layer, performing correction by modulation of exposure doses received by each exposed area, developing of the photoresist layer so as to form said pattern. Correction further comprises determination of a substitution pattern (11) comprising at least one subresolution feature and use of the substitution pattern (11) for determining the areas to be exposed when the electron beam is applied. In addition, modulation takes account of the density of the substitution pattern (11) near to each exposed area.

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Method for transferring a predetermined pattern reducing proximity effects.

Background of the invention

The invention relates to a method for transferring a predetermined pattern onto a flat support by direct writing by means of a particle or photon beam, and comprising at least:

- deposition of a photoresist layer on a free surface of the support,
- application of the beam on exposed areas of the photoresist layer,
- performing correction by modulation of exposure doses received by each exposed area,
- developing of the photoresist layer so as to form said pattern.

State of the art

Electron Beam Lithography (EBL) is a lithography technique for direct writing on a flat support, i.e. a writing technique not requiring a mask. The flat support 1 is more often than not an optical lithography mask (or reticle) or a semi-conducting substrate, for example made of silicon or silicon on insulator (SOI).

Thus, as represented in figure 1, transferring a pattern by E-beam lithography onto a flat support 1 is generally performed by means of a photoresist layer 2 arranged on a free surface of said support 1. An electron beam emitter 3 then produces an electron beam 4 (also noted E-beam 4) designed to be applied to predetermined areas of the photoresist layer 2. Said predetermined areas are also called the exposed areas of the photoresist layer 2 and they are determined by the pattern to be transferred 5. Thus, as represented by the block 6 in figure 1, the electron beam emitter 3 is controlled such that application of the electron beam 4 onto the photoresist layer 2 corresponds

either to the pattern to be transferred 5 or to the complementary part thereof. For example, a pattern to be transferred 5 is represented in figure 3 and the hatched parts in figures 4 and 7 represent the exposed areas of the photoresist layer 2 after application of the electron beam 4 to obtain the pattern to be transferred 5 in the support 1. In figure 4, the hatched parts correspond to the elements of the pattern to be transferred 5 whereas in figure 7 the hatched parts correspond to the complementary part of said pattern to be transferred 5.

Once exposure has been completed, the photoresist layer 2 is developed so as to free parts of the surface of the support 1. If the photoresist is a positive photoresist, the exposed areas of the photoresist layer are then eliminated in the developing step whereas, for a negative photoresist, the eliminated parts correspond to the non-exposed areas of the photoresist. The free parts of the flat support 1, i.e. the parts not covered by the photoresist after the developing step, are then etched so as to obtain a pattern corresponding to the pattern to be transferred 5 in the flat support.

E-beam lithography presents the advantage of being inexpensive and of obtaining a pattern presenting small dimensions, for example less than 10nm. It is today extensively used in research laboratories, in particular for producing magnetic heads or, in the semi-conductor field, for producing the masks to be used in an optical lithography process.

This technique is however hardly used for producing integrated circuits directly on a semi-conducting wafer. It does in fact present a slow writing speed compared with the writing speed of an optical lithography.

Moreover, in this field of application and in a more general manner, the size of the pattern produced must be perfectly well controlled. Dimensional control of a pattern does however require very precise control of the proximity

phenomena liable to occur when the electron beam is applied to the photoresist layer.

The proximity effects in an electron beam lithography process can at present be reduced by modulating the exposure dose received by the photoresist layer according to the writing density, i.e. according to the density of the pattern to be produced, near the area to be exposed.

In the article "Performance Improvement in E-beam Reticle Writer HL-800M", Hidetoshi Satoh et al. (SPIE Vol. 3096, pages 72-83) propose using proximity effect correction (PEC) hardware to obtain a pattern presenting sufficiently linear edges. Correction is performed directly during application of the electron beam on the photoresist layer. The exposed area of the photoresist layer is thus broken down into a grid of predetermined mesh. The writing density in each mesh is then calculated to then determine the value of the exposure dose to be applied for a given mesh during application of the electron beam.

As indicated by Laurent Pain et al. in the article "65 nm Device Manufacture Using Shaped E-Beam Lithography" (Japanese Journal of Applied Physics, Vol 43. N°6B, 2004), proximity effect correction can also be performed, on the same principle, by a proximity effect correction software such as the PROXECCO® software marketed by PDF solution.

Thus, as illustrated in figure 2, control 6 of the electron beam emitter 3 is more particularly achieved by previously entering the pattern to be transferred 5 into a control device and then performing correction by modulating the exposure dose according to the density of the pattern to be transferred 5, for example by means of the PROXECCO® software. The electron beam 4 is then applied to the photoresist layer 2 so as to expose

predetermined areas of the photoresist layer before the latter is developed and the support 1 is etched.

The Patent US6649452 proposes means for compensating the proximity effects liable to occur when a reticle, designed to transfer an integrated circuit pattern onto a semi-conductor wafer by optical lithography, is produced by E-beam lithography. These means consist in particular in adding additional features (subresolution design features) to the pattern to be transferred, to determine the areas of the photoresist layer to be exposed. These additional features are not resolved on the reticle and they can be of any type of shape and in any type of arrangement. However, the integrated circuit patterns produced on reticles according to the teachings of the Patent US6649452 present dimensions four times larger than those of the final pattern transferred onto the semi-conducting wafer.

To produce a pattern presenting a size smaller than 70nm on masks and integrated circuits, proximity effect correction does however remain difficult to achieve with these tools. Indeed, it does not enable a good dimensional control of said pattern to be obtained, i.e. within $\pm 10\%$ of the required size.

Object of the invention

The object of the invention is to provide a method for transferring a predetermined pattern onto a flat support, by E-beam lithography, remedying the shortcomings of the prior art. More particularly, it is the object of the invention to reduce the proximity effects in simple and efficient manner for any type of pattern to be transferred.

According to the invention, this object is achieved by the appended claims.

Brief description of the drawings

Other advantages and features will become more clearly apparent from the following description of particular embodiments of the invention given as non-restrictive examples only and represented in the accompanying drawings, in which:

Figure 1 schematically represents a particular embodiment of transfer of a pattern onto a support by E-beam lithography, according to the prior art, in block diagram form.

Figure 2 schematically represents a particular mode of control of the electron beam according to the prior art, in block diagram form.

Figure 4 schematically illustrates a top view of a first mode of exposure according to the prior art of a pattern to be transferred represented in top view in figure 3.

Figures 5 and 6 represent the distribution of forward electrons exposing the photoresist (curve α) and the variation of the backscattering electron ratio (curve β) for two portions, respectively dense and isolated, exposed according to figure 4.

Figure 7 schematically illustrates a top view of a second method of exposure according to the prior art of a pattern to be transferred according to figure 3.

Figure 8 schematically represents a particular method of control of an electron beam according to the invention in block diagram form.

Figure 9 schematically represents a top view of a first embodiment of a substitution pattern according to the invention.

Figure 10 represent the resultant curves α and β of a set of features of the substitution pattern according to figure 9.

Figures 11 and 12 schematically represent top views of a second embodiment of a substitution pattern according to the invention, respectively at the end of a first exposure and of a second exposition to electronic irradiation.

Figures 13 and 14 represent the curves (α_1 and β_1) and (α_2 and β_2 and α_3 and β_3) respectively for a dense portion and a set of features of a substitution pattern according to figures 11 and 12, and figure 15 corresponds to superposition of the curves (α_1 , α_2 and α_3) and (β_1 , β_2 and β_3).

Figure 16 schematically represents a top view of an alternative embodiment of a substitution pattern at the end of a second application period.

Figures 17 and 18 illustrate the curves (α_1 and β_1) and (α'_2 and β'_2) respectively for a dense portion and a subresolution feature of a substitution pattern according to figures 13 and 16, and figure 19 corresponds to superposition of the curves (α_1 and α'_2) and (β_1 and β'_2).

Figure 20 schematically represents a top view of a third embodiment of a substitution pattern according to the invention.

Description of particular embodiments

Generally speaking, the proximity effects observed are caused by a high backscattering electron ratio at the interface between the support 1 and the photoresist layer 2. It has however been observed that, whatever the type of photoresist used, whether it be negative or positive, the backscattering electron ratio depended essentially on the surface exposed. Thus, the larger the surface of the exposed area, the higher the backscattering electron ratio and therefore the greater the noise, which gives rise to detrimental proximity effects, poor pattern resolution and large dimensional variations.

For example and as illustrated in figures 4 to 6, a pattern to be transferred 5 such as the one represented in figure 3 is transferred according to the prior art onto a negative or positive photoresist layer 2. As represented in figure 4, exposure is performed in such a way that the exposed areas of the layer 2 correspond to said pattern 5. In figure 4, four exposed areas 7 are situated in a dense area, i.e. an area comprising a high density of elements to be transferred, and two exposed areas 8 are situated in an isolated area, i.e.

comprising a low density of elements to be transferred. In a more general manner, it can be considered that the exposed areas 7 and 8 correspond respectively to dense portions 9 and to isolated portions 10 of the pattern to be transferred 5. Each dense portion 9 comprises a longitudinal axis S_1 and each isolated portion 10 comprises a longitudinal axis S_2 .

The proximity effects can be evaluated by means of two curves α and β . Curve α represents the Gaussian distribution of the incident electron beam (forward electrons) produced by the emitter 3 and exposing the photoresist layer 2, centred on the axis of symmetry of the portion of the pattern to be transferred. Curve β represents the intensity of the ratio of backscattering electrons diffused by the support 1. Curve α enables a threshold C_d , called the photoresist threshold, to be determined corresponding to the size required for the portion of the pattern once the latter has been transferred, and the gradient of the curve α , at the level of said threshold, gives indications on the contrast. The width and height of the curve β represent the noise which could impact the resolution of possible transferred neighboring features and therefore cause proximity effects, but also roughness of the photoresist edges after transfer. Thus, the width and height of curve β must be minimal, which can not be obtained in one shot exposure, as present-day proximity effect correction solutions propose to do. In addition, the maximum height D of the curve β and the difference d between the threshold C_d and said maximum can be very small, which indicates that the elements of the transferred pattern are poorly resolved or not resolved due to process window reduction and/or that they are rough, which is caused by the proximity effects.

The curves α and β have thus been represented in figures 5 and 6 respectively for a dense portion 9 and for an isolated portion 10 of the pattern to be transferred 5, for the same threshold C_d , i.e. for transferred portions 9 and 10 having the same width L . It can thus be observed in figures 5 and 6 that the difference d_9 is smaller than the difference d_{10} and that the maximum

D_9 is greater than the maximum D_{10} . Thus, in this case, the isolated portions 10 of the pattern to be transferred are better resolved on the support 1 than the dense portions 9 of said pattern and they will be subject to less proximity effects.

It can be shown that the reverse phenomenon occurs if the pattern represented in figure 3 is transferred according to the prior art onto a positive photoresist layer 2, performing an exposure as illustrated in figure 7, i.e. exposing areas corresponding to the complementary part of the pattern 5. Proximity effects and poor resolution of the patterns will occur for the isolated portions 10 of said pattern 5 whereas the dense portions 9 will be protected. It can in fact be shown that, in this case, for the isolated portions 10, the energy level β is in the same order of magnitude as the threshold C_d , corresponding to the energy necessary to obtain the required size L of said portion. The noise energy level is such that the isolated portions 10 are totally exposed, which prevents their resolution.

The backscattering electron ratio and therefore the proximity effects thereby depend strongly on the width of the exposed area and on the density of features to be transferred. Thus, the backscattering electron ratio is high if the width of the exposed surface is large and vice-versa.

The method for transferring according to the invention proposes to reduce the proximity effects in simple and efficient manner, whatever the shape of the pattern to be transferred 5. Thus, as represented in figure 8, control 6 of the electron beam used to perform transfer of a predetermined pattern 5 onto the flat support 1 is achieved, according to the invention, by replacing entry of the pattern to be transferred 5 by determination and entry of a substitution pattern 11 comprising at least one subresolution feature (also called fine element).

In this way, instead of determining the areas to be exposed when the electron beam 4 is applied according to the pattern to be transferred 5, as in the prior art, the method for transferring according to the invention uses a predetermined substitution pattern 11 comprising at least one subresolution feature.

Correction by modulating the exposure doses received by each exposed area thus takes account of the density of the substitution pattern 11, in proximity to each exposed area. Correction by modulating exposure doses can for example be performed using the PROXECCO® software.

The electron beam 4 is then applied on the photoresist layer 2 so as to expose predetermined areas of said layer in accordance with the substitution pattern 11. The photoresist layer 2 then undergoes a revelation step to free parts of the free surface of the support 1.

Determination of the substitution pattern 11 and determination of the subresolution feature or features depends in particular on the outline of the pattern to be transferred and on the exposure mode and/or the type of photoresist used.

According to a first embodiment, at least one portion of the pattern to be transferred 5 is replaced, in the substitution pattern 11, by a set of at least two subresolution features parallel to a longitudinal axis of said portion. Moreover, the exposed areas of the photoresist layer are formed by the substitution pattern 11. This first embodiment is more particularly suited to the case where the density of the pattern to be transferred 5 is high at the level of the portion to be replaced by a set of at least two subresolution features.

As an example illustrated in figure 9, the substitution pattern 11 comprises four features 12. The features 12 replace the dense portions 9 in the pattern to be transferred 5 represented in figure 3. Each feature 12 thus has a longitudinal axis that coincides with the longitudinal axis S_1 of a corresponding dense portion 9. It is formed by three distinct, parallel and equidistant subresolution features 13. In addition, in figure 9, one of the subresolution features 13 is superposed on the corresponding axis S_1 . The substitution pattern 11 comprises elements corresponding to the rest of the pattern to be transferred 5, and in particular the exposed areas 8 corresponding to the isolated portions 10. The subresolution features 13 of each set of features 12 present an identical length equal to the length of the associated dense portion 9. Furthermore, the width of each set of features 12 is equal to that of said the associated portion, after transfer. In some cases, the width of each set of features 12 can also be equal to that of said the associated portion of the pattern to be transferred.

The number of subresolution features 13 forming a set 12 is not limited to three. It is determined according to the width of the portion to be replaced. Moreover, determination of the width of each subresolution feature 13 can be performed empirically. For example, the number of subresolution features 13 constituting a set 12 is determined beforehand, then, for a constant pitch p between different dense portions 9 of fixed width L' , the width L actually obtained on the support 1 is measured for different width values of the subresolution features 13 and distance values between two subresolution features 13. The width of the subresolution features and the distance between two subresolution features are then determined as soon as the value of the width L coincides substantially with that of the fixed width L' .

For example, dense portions 9 having a width L' of 60nm and a pitch p between two dense portions 9 of 60nm can each be replaced by a set 12 of three subresolution features 13 each having a width of 15nm with a 7.5nm spacing between two adjacent subresolution features 13 of said set 12.

Electron beam exposure is performed following a grid the pitch of which grid corresponds to a minimum unit proper to each application device or emitter used. Thus, if the emitter used presents a grid pitch having a fineness of 1nm, such as for example the exposure device marketed under the name of LEICA, SB 350 DW, the 7.5nm spacing can be obtained by performing two successive exposure steps, with spacings of respectively 7nm and 8nm between the adjacent subresolution features 13 of the sets 12, so as to obtain a mean spacing of 7.5nm.

Dense portions 9 having a width L' of 60nm and a pitch p between two dense portions 9 of 120nm can each be replaced by a set 12 of three subresolution features 13 each having a width of 16nm, with a 6nm spacing between two subresolution features 13.

The first embodiment is particularly well suited for portions of patterns located in a dense environment and having a high backscattering electron ratio. The subresolution features are in fact of smaller sizes than the dense portion 9 and they present a low backscattering electron ratio compared with a dense portion 9. Moreover the set formed by the subresolution features 13 provides the energy necessary for formation of the pattern, at the required size.

In figure 10, the curves α and β represented correspond to superposition of the respective curves α_1 , α_2 , α_3 , and β_1 , β_2 and β_3 of each subresolution feature 13 of a set 12 as represented in figure 9 and designed to replace a dense portion 9. However, the curve α of the set 12 is finer than the curve α of a dense portion 9, as represented in figure 5. In addition, the gradient of the curve α of the set 12, at the level of the threshold C_d , is steeper than that of the dense portion 9, which indicates an improvement of the contrast of the transferred pattern. Furthermore, compared to the height and width of the curve β of a dense portion 9 (figure 5), the height and width of the curve β of the set 12 are very small, which indicates that the impact of the

backscattering electrons has considerably decreased on account of the substitution pattern 11. Thus, the sum of the curves α of each subresolution feature 13 of a set 12 reproduces the replaced dense portion 9, while improving the lithographical performances. Correction by exposure dose modulation, performed in accordance with the substitution pattern 11 as represented in figure 9, is moreover facilitated due to the fact that the ruggedness range of the control device is increased.

According to a second embodiment, the substitution pattern 11 can be formed by the pattern to be transferred during a first electron beam application period, then by at least one subresolution feature during a second electron beam application period. The subresolution feature is parallel to a longitudinal axis of a portion of the pattern to be transferred and it presents a length equal to the length of said portion. The density of the pattern to be transferred is preferably high at the level of said portion and the exposed areas of the photoresist layer 2 are formed by the substitution pattern 11.

More particularly and as represented in figures 11 and 12, the substitution pattern 11 is formed by the pattern to be transferred 5 during the first application period of the electron beam 4 and by a plurality of sets 12 respectively formed by two subresolution features 13 during the second application period. Each set 12 corresponds to a dense portion 9 of the pattern to be transferred 5. The two subresolution features 13 of each set 12 are then symmetrical with respect to the longitudinal axis S_1 of said corresponding portion 9 and the width of each set 12 is equal to that of said associated portion 9, after transfer. More particularly, the width of each set 12 can also be equal to that of said associated portion 9 of the pattern to be transferred. As represented in figures 13 and 14, the exposure dose applied during the first application period is preferably lower than the exposure dose applied during the second application period. In this case, particular care must be taken over control 6 of the electron beam. Indeed, the areas of the photoresist layer 2, exposed during the first application period, have to be

exposed again during the second application period, according to the set 12 associated with said portion 9. Thus, the two exposures must be perfectly superposed at the level of the dense portions 9, in order not to affect the final resolution of the pattern. It can also be observed in figure 15 that the gradient of the curve α is much steeper than that of the curve α according to figure 5, which indicates an improvement of the contrast. Furthermore, the width and height of the curve β are smaller than those of the curve β in figure 5. The second embodiment of the substitution pattern therefore provides an improvement of the contrast and a reduction of the noise and therefore of the proximity effects compared with a transfer method not comprising proximity effect correction.

Determination of the width of the subresolution features is preferably obtained empirically, for example by successively varying the exposure dose, the size of the subresolution features and the size of the space between said subresolution features. For example, for a dense portion 9 with a width of 45nm separated from another dense portion 9 by a pitch of 90nm, the set 12 can be formed by two subresolution features 13 with a width of 15nm separated from one another by 30nm.

In an alternative embodiment represented by figure 16, the substitution pattern 11, during the second application period, can be formed by a plurality of sets 12 each comprising a single subresolution feature 13 superposed on the longitudinal axis S1 of said portion 9. For example, for a dense portion 9 with a width of 45nm separated from another dense portion 9 by a pitch of 90nm, a subresolution feature 13 can be used with a width of 9nm the longitudinal axis whereof is superposed on that of the corresponding portion 9. For a portion 9 with a width of 60nm separated from another portion 9 by a pitch of 120nm, a subresolution feature 13 can be used with a width of 32nm whereas for the same portion separated from another portion 7 by a pitch of 60nm, the width of the subresolution feature can be 48nm.

As for figures 13 to 15, figures 17 to 19 enable it to be observed that the exposure dose applied during the first application period is lower than that applied during the second application period. The gradient of the curve α in figure 19 is much steeper than that of the curve α in figure 5. Moreover, the width and height of the curve β in figure 19 are smaller than those of the curve β in figure 5. Thus, the alternative to the second embodiment of the substitution pattern also provides an improvement of the contrast and a reduction of noise and therefore of the proximity effects.

In a third embodiment, the substitution pattern 11 is formed by the pattern to be transferred 5, completed by subresolution features 13 arranged outside at least one portion of the pattern to be transferred. More particularly and as represented in figure 20, the exposed areas of the photoresist layer are formed by the areas complementary to the substitution pattern 11. The portion completed by subresolution features 13 is an isolated portion 10, i.e. the density of the pattern to be transferred is low at the level of said portion. More particularly, the isolated portions 10 are surrounded by large exposure surfaces 14. Thus, the subresolution features 13 are arranged outside at least one isolated portion 10, in parallel manner to a longitudinal axis S_2 of said portion 10, in said exposure surfaces 14. They are situated near to said portion 10, for example at a distance less than 10 times the width of said portion.

The subresolution features 13 present a length smaller than or equal to the length of said portion. In addition, the number and/or width of each subresolution feature 13 and/or the distance between a subresolution feature and the corresponding portion and/or the width of said portion are determined according to the width of a complementary area of the pattern to be transferred adjacent to said portion. More particularly, these parameters are determined empirically. For a fixed value L' of a portion 10 of the pattern to be transferred 5, the result of the width L actually obtained on the support 1 as a function of the value W of the exposed surface can for example be

noted. This makes it possible to determine the critical dimension from which the proximity effects begin for each value L' , i.e. the size W from which a decrease of the actual value L is observed with respect to the fixed value L' . The size of the subresolution features and the distance between each subresolution feature and the portion 10 is then determined empirically. For each portion impacted by proximity effects, subresolution features are added having a width varying from 5nm to 20nm and/or a distance between each subresolution feature and the portion 10 that also varies. The required width and distance are obtained when the actual width L is equal to or close to the required value L .

For example, to obtain a portion 10 with a width of 40nm achieved in a positive photoresist, two subresolution features with a width of 40 nm can be used arranged on each side of a longitudinal portion with a width of 80nm, respectively at a distance of 40nm from said longitudinal portion. The portion 10 obtained then presents a width of 40nm and the subresolution features are not resolved when the photoresist layer is developed.

Unlike the embodiments described in the Patent US6649452, the subresolution features of the third embodiment of the substitution pattern 11 are arranged close to isolated portions 10 in a large exposure surface and they have a length smaller than or equal to that of the portion 10. The arrangement of the subresolution features 13 enables the background noise to be locally reduced, whatever the size of the isolated portion, thus reducing the proximity effects and writing time while improving the contrast and resolution, in particular compared with the embodiment as represented in figure 7. In the Patent US6649452, an isolated portion of the pattern to be transferred is arranged in a lattice of equidistant parallel lines. Certain lines are interrupted by the isolated portion so as to free a space around the whole periphery of the isolated portion. The presence of said lines enables the backscattering electron energy level to be homogenized.

According to the invention, it is possible to obtain a portion presenting a minimum size that can be less than 70nm, whereas with the embodiments described in the Patent US6649452 the portion obtained would have a minimum size of 130 to 140nm.

The invention is not limited to the embodiments described above.

Thus, in the first and second embodiments, when the substitution pattern 11 comprises several subresolution features 13, the latter can have different widths. The set formed by the set of subresolution features 13 replacing a predetermined portion of the pattern to be transferred (1st embodiment) or the set formed by said portion during a first application period and by at least one subresolution feature formed during a second application period (2nd embodiment) can for example have a larger width, preferably larger by a maximum of 10%, than the width of the predetermined portion of the pattern to be transferred. Determination of this width is more particularly a function of the size of the pattern to be transferred and not of the grid of the emitter device. The chosen width is considered to be satisfactory when the transferred pattern has the required size, with a minimum line roughness of 3% with respect to said required size.

Furthermore, the lithography process can be replaced by any type of direct writing method and the electron beam can be replaced by a particle beam such as an ion beam or by a photon beam.

Claims

1. Method for transferring a predetermined pattern (5) onto a flat support (1) by direct writing by means of a particle or photon beam (4), and comprising at least:

- deposition of a photoresist layer (2) on a free surface of the support (1),
- application of the beam (4) on exposed areas (7, 8, 14) of the photoresist layer (2),
- performing correction by modulation of exposure doses received by each exposed area (7, 8, 14),
- developing of the photoresist layer (2) so as to form said pattern,

method characterized in that said correction in addition comprises:

- determination of a substitution pattern (11) comprising at least one subresolution feature (13),
- using the substitution pattern (11) to determine the areas to be exposed (7, 8, 14) when the beam (4) is applied,

the modulation taking account of the density of the substitution pattern (11) near each exposed area (7, 8, 14).

2. Method according to claim 1, characterized in that the exposed areas (7, 8) of the photoresist layer are formed by the substitution pattern (11).

3. Method according to claim 2, characterized in that at least one portion (9) of the pattern to be transferred (5) is replaced, in the substitution pattern (11), by a set (12) of at least two subresolution features (13), parallel to a longitudinal axis (S_1) of said portion (9) and presenting a length equal to the length of said portion (9), the width of said set being equal to that of said portion (9), after transfer.

4. Method according to claim 3, characterized in that the density of the pattern to be transferred (5) is high at the level of said portion (9).

5. Method according to claim 2, characterized in that the substitution pattern (11) is formed by the pattern to be transferred (5) during a first application period of the beam (4), then, during a second application period of the beam (4), by at least one subresolution feature (13), parallel to a longitudinal axis (S_1) of a portion (9) of the pattern to be transferred (5) and having a length equal to the length of said portion (9).
6. Method according to claim 5, characterized in that the density of the pattern to be transferred (5) is high at the level of said portion (9).
7. Method according to claims 5 and 6, characterized in that the subresolution feature (13) is superposed on longitudinal axis (S_1) of said portion (9).
8. Method according to claims 5 and 6, characterized in that, during the second period, the substitution pattern (11) associated with said portion (9) is formed by a set (12) formed by two subresolution features (13), symmetrical with respect to the longitudinal axis (S_1) of said portion (9), the width of said set (12) being equal to that of said portion (9), after transfer.
9. Method according to claim 1, characterized in that the exposed areas (14) of the photoresist layer (2) are formed by the complementary areas to the substitution pattern (11).
10. Method according to claim 9, characterized in that the substitution pattern (11) is formed by the pattern to be transferred (5), completed by subresolution features (13) arranged outside at least one portion (10) of the pattern to be transferred (5), parallel to a longitudinal axis (S_2) of said portion (10) and having a length smaller than or equal to the length of said portion (10).

11.Method according to claim 10, characterized in that the number and/or width of each subresolution feature (13) and/or the distance between a subresolution feature (13) and the corresponding portion (10) and/or the width of the portion (10) are determined according to the width of a complementary area of the pattern to be transferred (5) adjacent to said portion (10).

12.Method according to one of the claims 10 and 11, characterized in that the density of the pattern to be transferred (5) is low at the level of said portion (10).

13.Method according to any one of the claims 1 to 12, characterized in that direct writing is performed by lithography.

14. Method according to any one of the claims 1 to 13, characterized in that the particle beam (4) is selected from the group consisting in an electron beam and an ion beam.

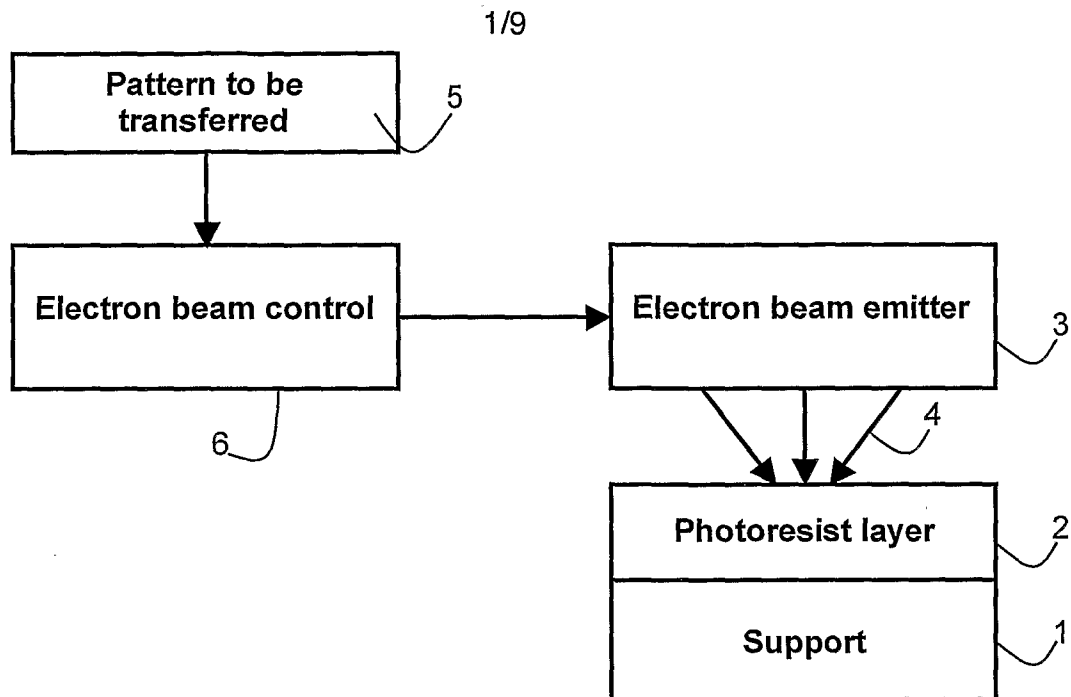


Fig. 1 (Prior art)

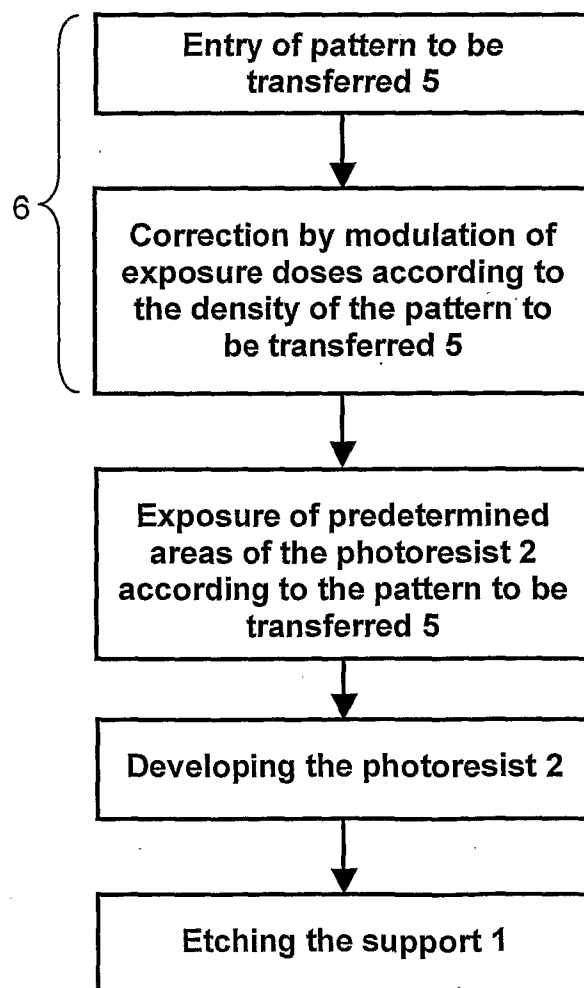


Fig. 2 (Prior art)

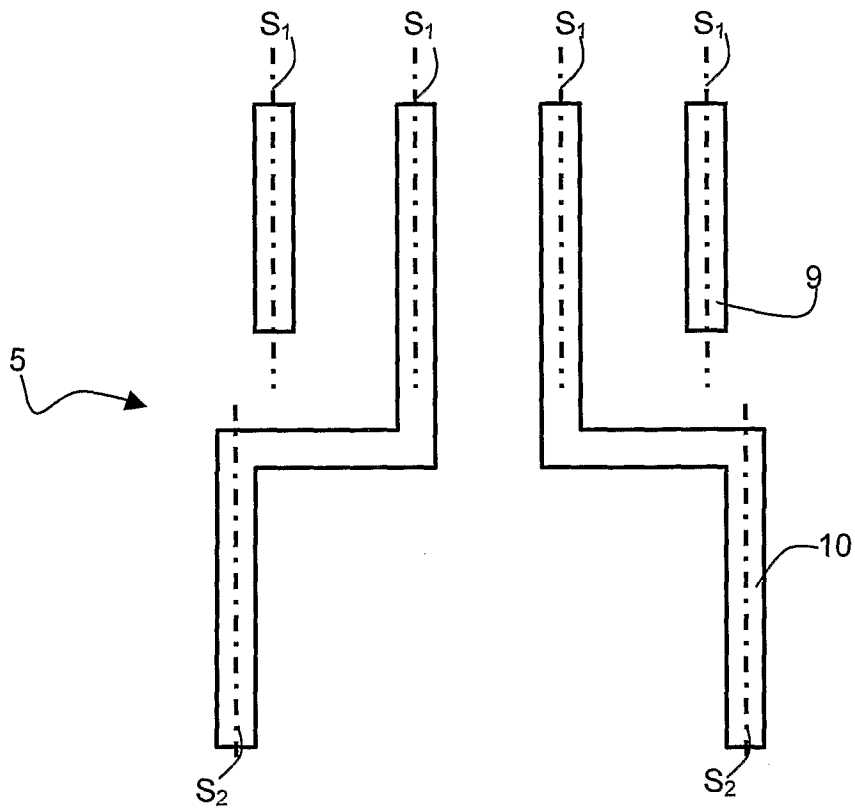


Fig. 3

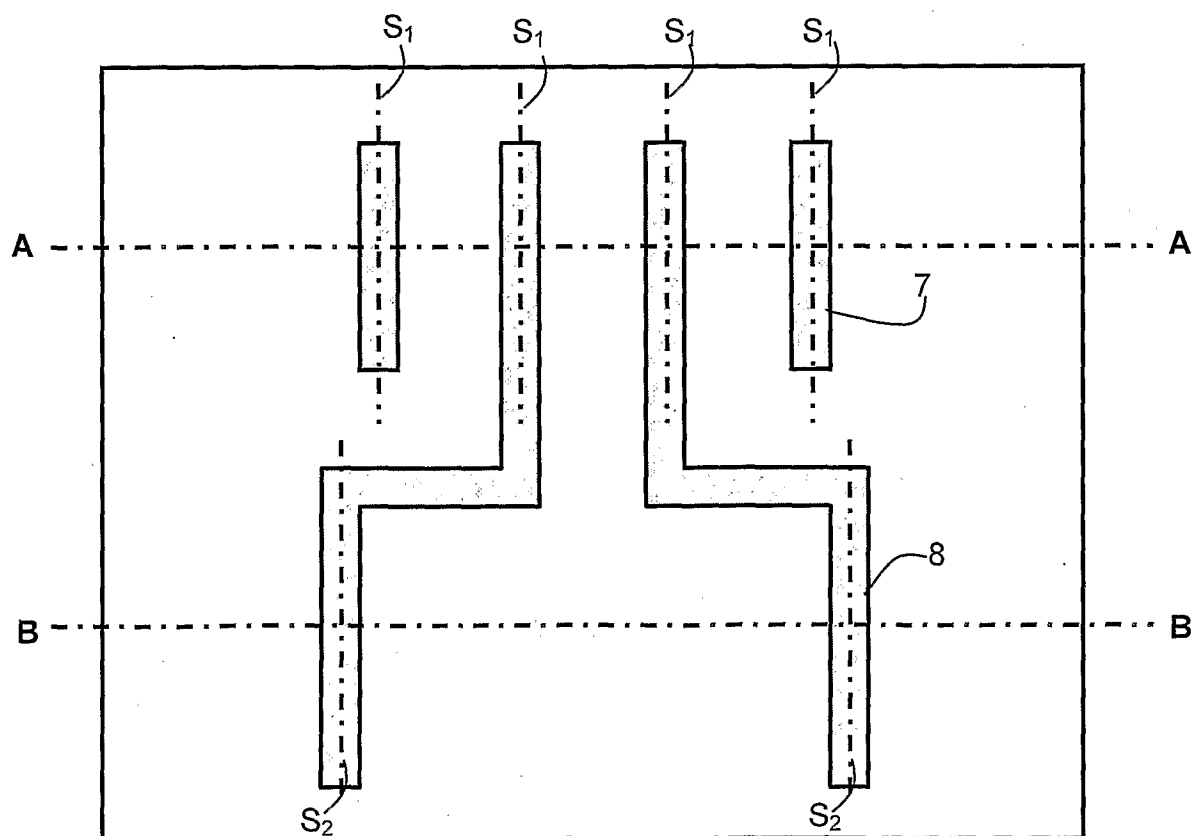


Fig. 4 (Prior art)

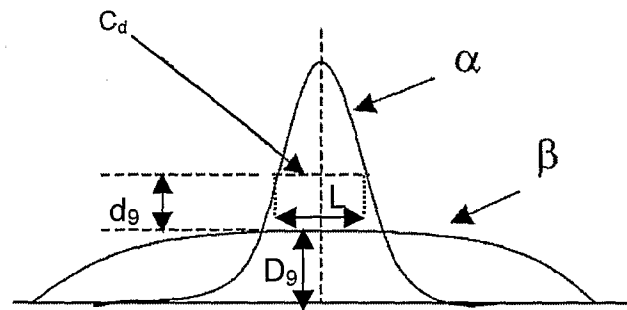


Fig. 5, (Prior art)

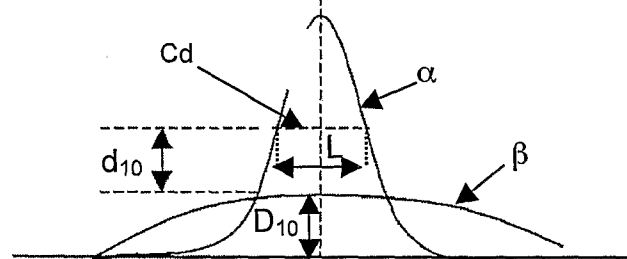


Fig. 6 (Prior art)

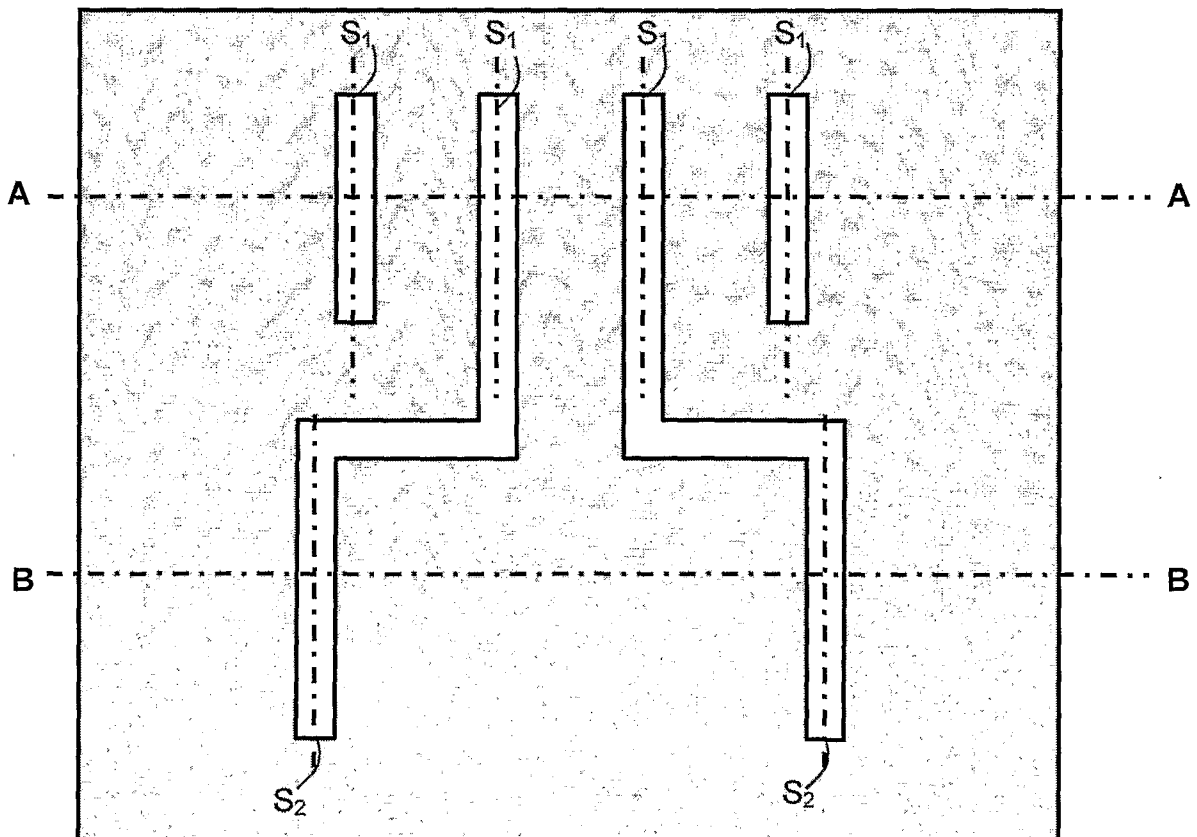


Fig. 7 (Prior art)

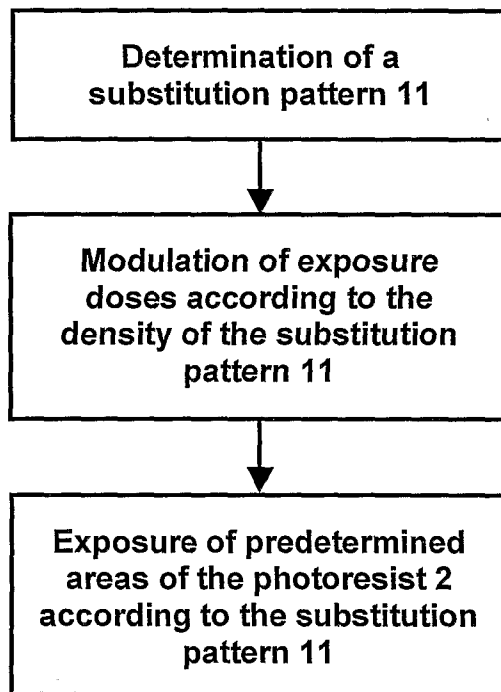


Fig. 8

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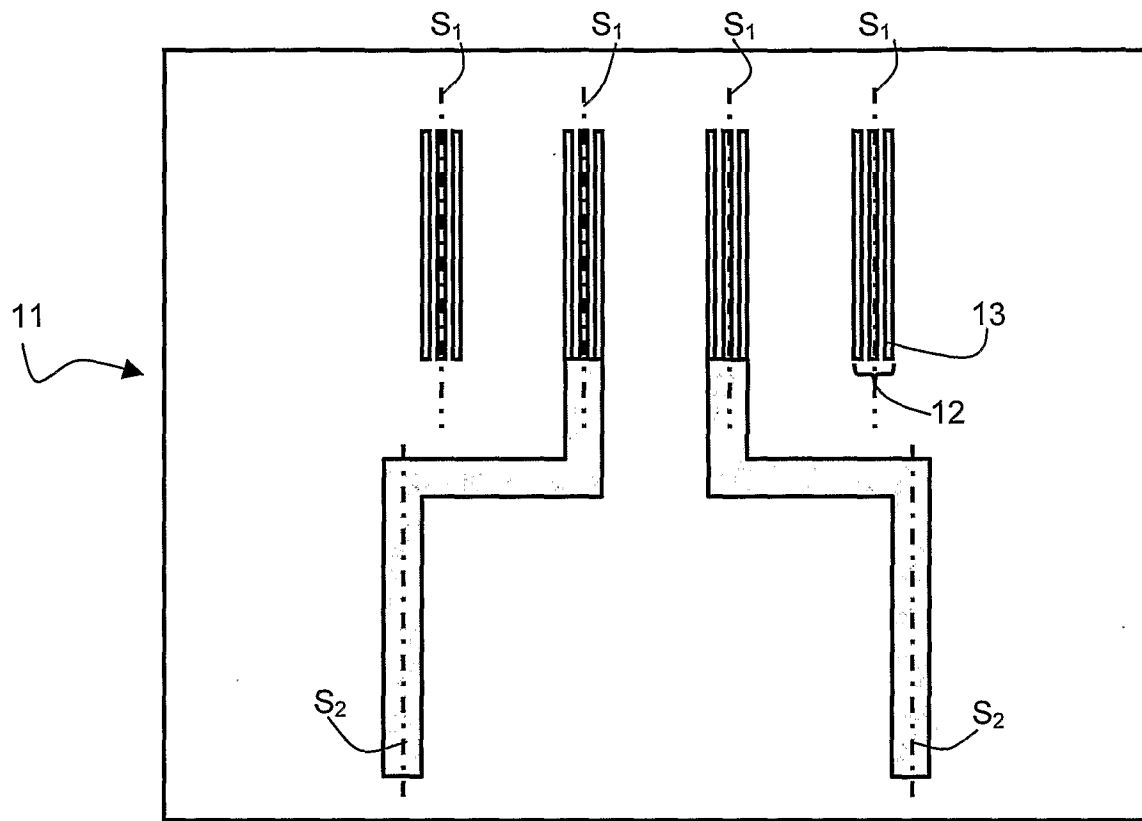


Fig. 9

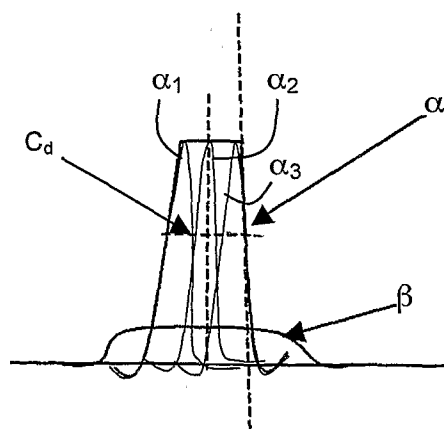


Fig. 10

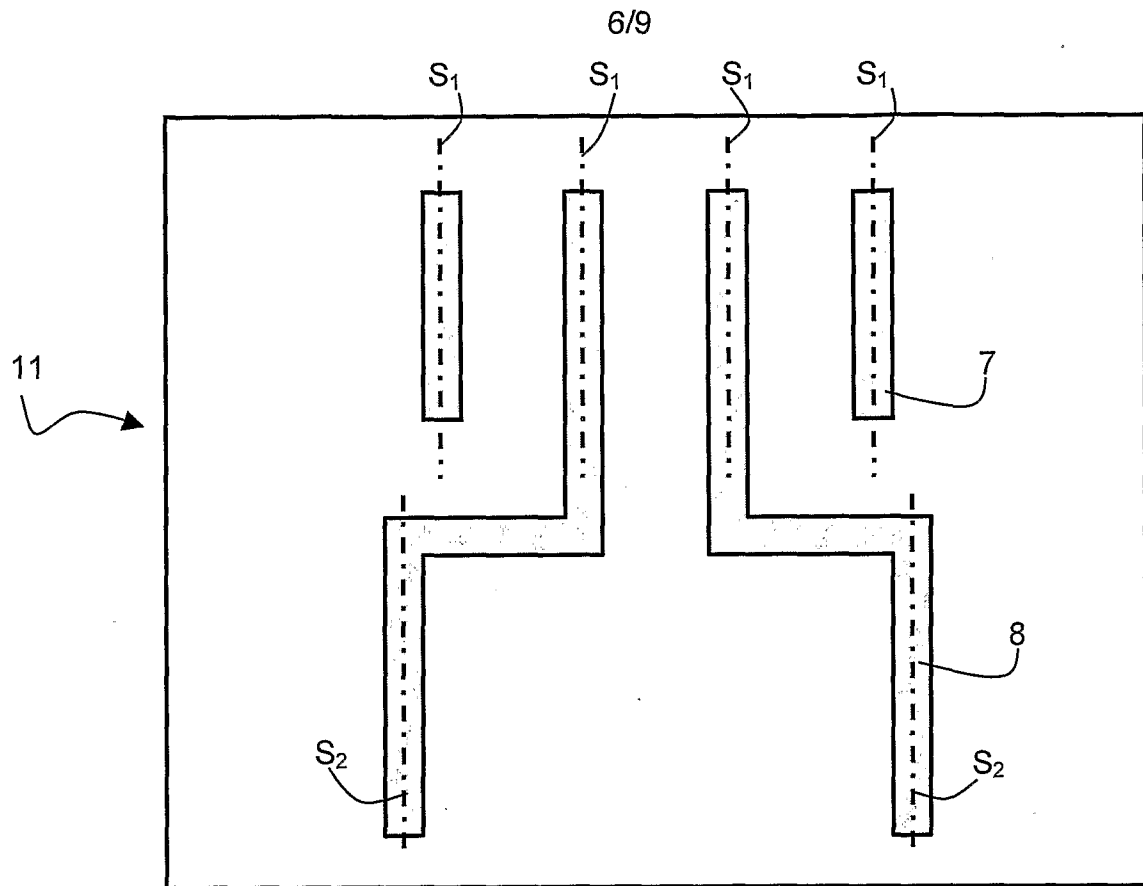


Fig. 11

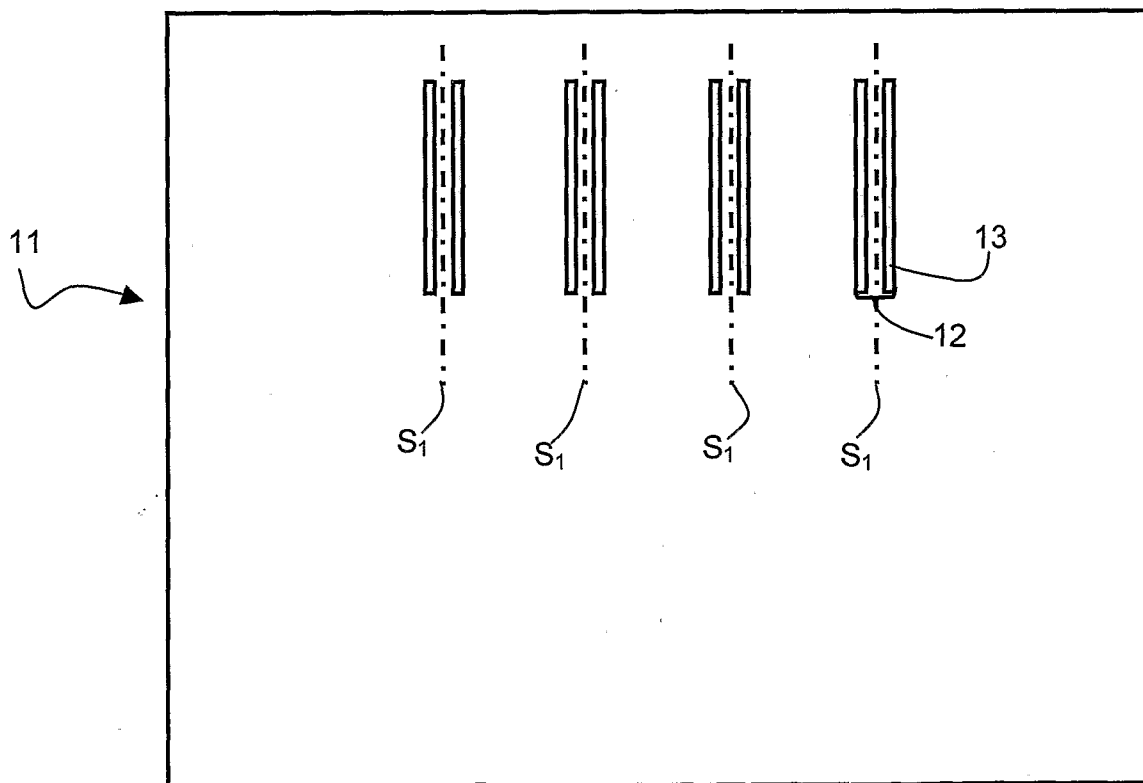


Fig. 12

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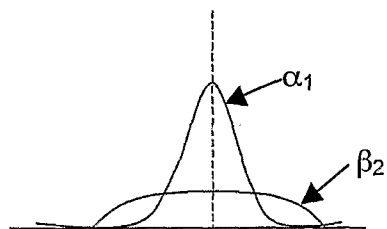


Fig. 13

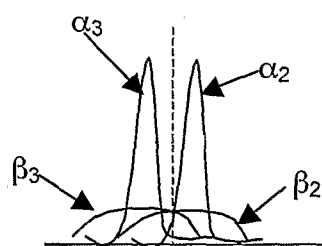


Fig. 14

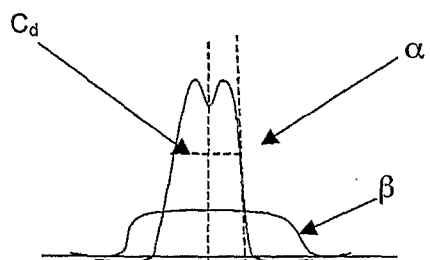


Fig. 15

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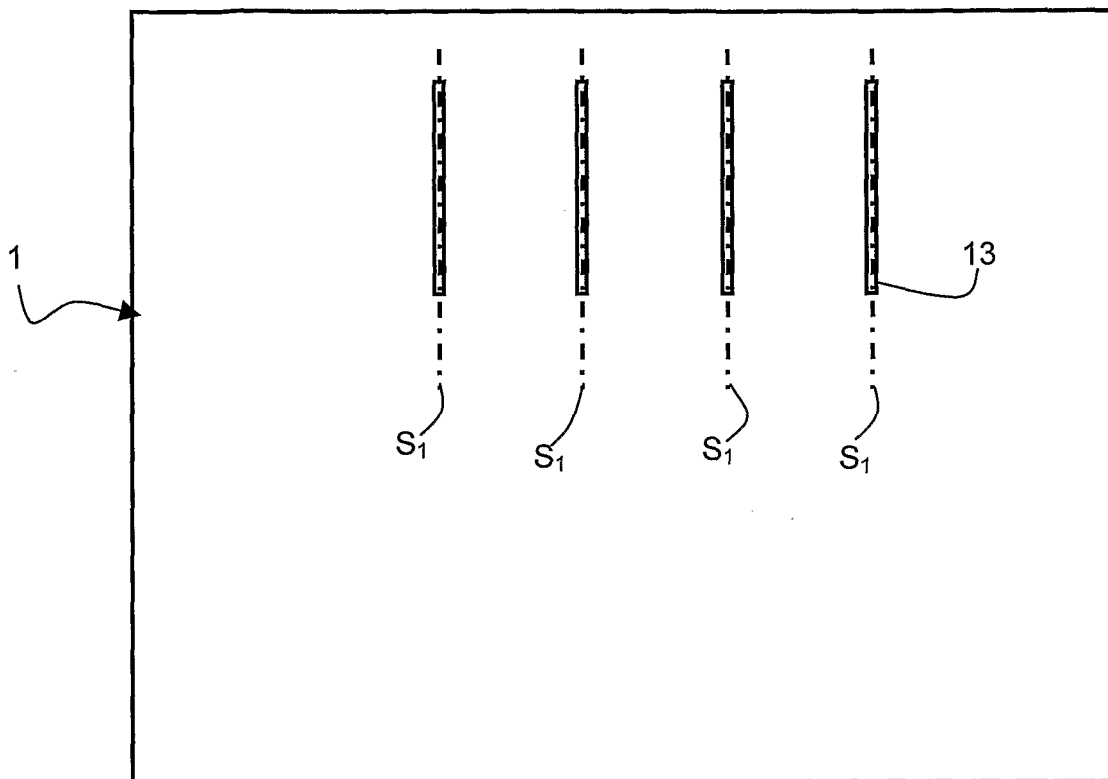


Fig. 16

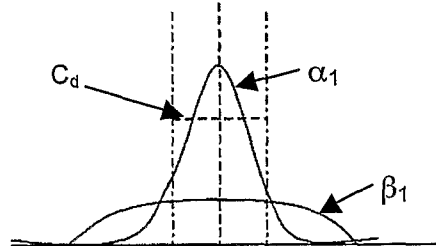


Fig. 17

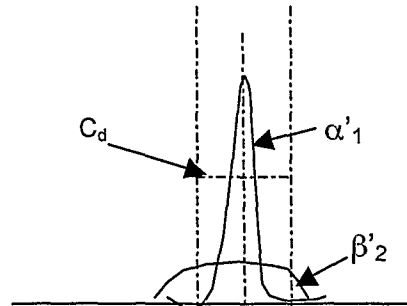


Fig. 18

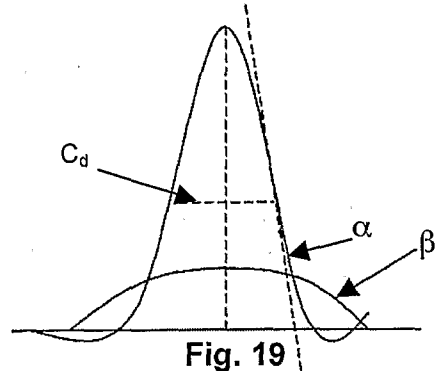


Fig. 19

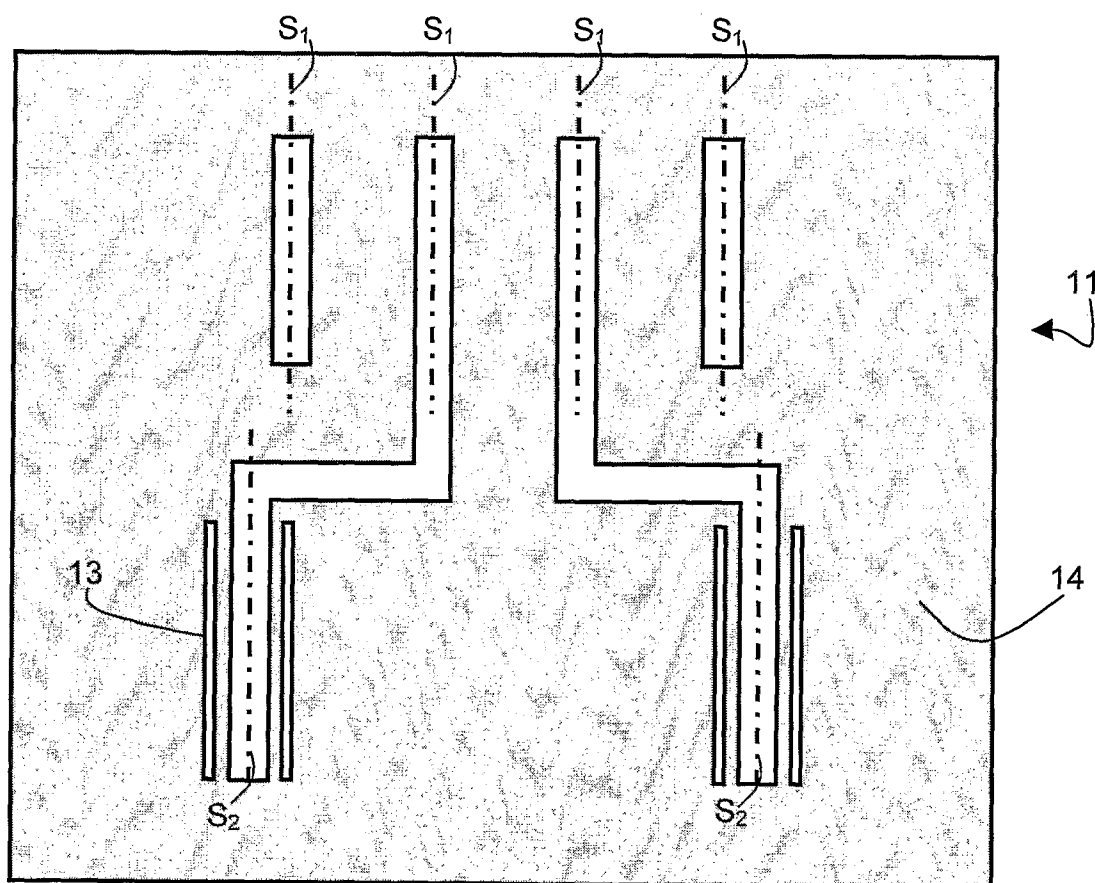


Fig. 20

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2006/001670

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
G03F H01J H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 180 784 A (HITACHI LTD [JP]) 20 February 2002 (2002-02-20)	1-4,13, 14
Y	paragraphs [0006] - [0009], [0012] - [0015], [0019] - [0026], [0048] figures 1-3,15	5,6,8
Y	----- US 2006/057471 A1 (SCHENAU KOEN V I [NL] ET AL) 16 March 2006 (2006-03-16) paragraphs [0002], [0061], [0067], [0089], [0090], [0100] figures 4,6	5,6,8
A	----- WO 2004/090979 A (AOTI OPERATING COMPANY INC [US]; SMITH NIGEL PETER [GB]; HAMMOND MICHA) 21 October 2004 (2004-10-21) page 23, line 25 - line 30 figure 6 ----- -/--	1-3

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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.

"Z" document member of the same patent family

Date of the actual completion of the international search

4 April 2007

Date of mailing of the international search report

02.07.07

Name and mailing address of the ISA/

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Authorized officer

Breccia, Luca

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2006/001670

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 139 994 A (BROEKE DOUG VAN DEN [US] ET AL) 31 October 2000 (2000-10-31) page 2, line 36 - line 60 page 5, line 55 - line 61 -----	1
A	SATOH, SOMEDA, SAITOU, KAWASAKI, MIZUNO, KADOWAKI, HOGA, SOGA: "Performance improvement in e-beam reticle writer HL-800M" PROCEEDINGS OF SPIE, vol. 3096, August 1997 (1997-08), pages 72-83, XP002427771 cited in the application abstract -----	1
A	PAIN ET AL.: "65nm device manufacture using shaped E-Beam Lithography" JAPANESE JOURNAL OF APPLIED PHYSICS, vol. 43, no. 6b, 29 June 2004 (2004-06-29), pages 3755-3761, XP002427772 cited in the application abstract -----	1
A	US 6 649 452 B2 (LUCAS KEVIN D [US] ET AL) 18 November 2003 (2003-11-18) cited in the application abstract -----	1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2006/001670

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-8, 13, 14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 13, 14

Method for transferring a predetermined pattern onto a flat support by direct writing by means of a particle or photon beam wherein the pattern is transferred during a first application period of the beam and at least one subresolution feature is transferred during a second application period of the beam.

2. claims: 9-12

Method for transferring a predetermined pattern onto a flat support wherein the exposed areas of the photoresist layer are formed by the complementary areas to the pattern.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2006/001670

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1180784	A	20-02-2002	JP 3394237 B2	07-04-2003
			JP 2002057090 A	22-02-2002
			US 2002027198 A1	07-03-2002

US 2006057471	A1	16-03-2006	JP 2006085174 A	30-03-2006

WO 2004090979	A	21-10-2004	EP 1614154 A2	11-01-2006
			KR 20060009248 A	31-01-2006

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US 6649452	B2	18-11-2003	US 2003162329 A1	28-08-2003
