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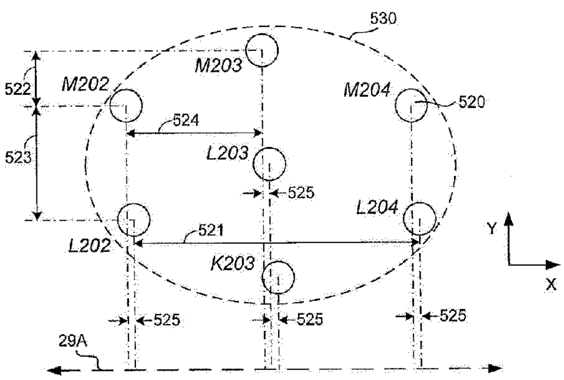
(54) **Beam grid layout.**

(57) A sub-beam aperture array for forming a plurality of sub-beams from one or more charged particle beams. The sub-beam aperture array comprises one or more beam areas, each beam area comprising a plurality of sub-beam apertures arranged in a non-regular hexagonal pattern, the sub-beam apertures arranged so that, when projected in a first direction onto a line parallel to a second direction, the sub-beam apertures are uniformly spaced along the line, and wherein the first direction is different from the second direction.



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BEAM GRID LAYOUT

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an aperture array and a charged particle lithography system using an aperture array.

2. Description of the Related Art

[0002] In the charged particle lithography field, various aperture pattern schemes for a multi-beam pattern definition device are known. For example, U.S. Pat. No. 5,369,282 to Arai discloses an electron-beam lithography system using a blanking aperture array (BAA) as the pattern definition device. The BAA has a number of rows of apertures, and the images of the apertures are scanned over a stripe of the substrate in a controlled, continuous motion.

[0003] Arai teaches to group aperture rows of the BAA by exposure order. The substrate stripe is first exposed using a full dosage, as delivered by a first group, and then subsequently exposed to compensate for proximity effects exhibited by the substrate stripe, as delivered by a second group. In some embodiments, corresponding apertures of the first and second groups are offset from each other in relation to an electron scanning direction and/or to a mechanical scanning direction. Further, within each group, apertures on every other row align in the electron-scan direction and all rows align in the mechanical-scan direction.

[0004] U.S. Patent Application No. 2011-0073782 to Wieland discloses an electron-beam lithography system with a beamlet blanker array with apertures for generating 16 sub-beams arranged in a square 4x4 array, where each sub-beam is divided into 9 beamlets arranged in a square 3 x 3 array. Wieland teaches various writing strategies using such beamlet arrangements to achieve exposure of a wafer surface when the wafer is moved with respect to the beamlet blanker array and the beamlets are deflected over the surface of the wafer.

[0005] Among other deficiencies, the system of Arai lacks sufficient throughput for commercial viability and neither system provides an optimum arrangement of sub-beams or beamlets for uniform exposure of the wafer. Thus there is a need for alternative aperture pattern schemes that improve throughput and distribution of the writing beams on the wafer surface.

BRIEF SUMMARY OF THE INVENTION

[0006] The invention aims to address these problems. In one aspect the invention provides a sub-beam aperture array for forming a plurality of sub-beams from one or more charged particle beams. The sub-beam aperture array comprises one or more beam areas, each beam area comprising a plurality of sub-beam apertures arranged in a non-regular hexagonal pattern, the sub-beam apertures arranged so that, when projected in a first direction onto a line parallel to a second direction, the sub-beam apertures are uniformly spaced along the line, and wherein the first direction is different from the second direction.

[0007] In the non-regular hexagonal pattern of the sub-beam apertures of each beam area, each aperture has six neighbouring apertures, but these six neighbours are not arranged in the shape of a regular hexagon. The hexagonal pattern is non-regular in the sense that an aperture is not equi-distant from all of its six neighbouring apertures, but the aperture array preferably repeats the same non-regular hexagonal pattern uniformly within each beam area so that every aperture within a beam area is arranged in the same non-regular hexagonal pattern. The uniform spacing of sub-beam apertures when they are projected onto a line parallel to the second direction, results in evenly spaced writing paths when a plurality of sub-beams are formed using the sub-beam aperture array, and a target such as a wafer is moved perpendicular to the second direction relative to the sub-beam aperture array. The uniform spacing of projected apertures preferably applies for all of the sub-beam apertures in all of the beam areas. The preferred arrangement enables each sub-beam to form a separate writing path which does not coincide with the writing path of any other sub-beam and is equidistant from the writing paths of adjacent sub-beams.

[0008] Within each of the one or more beam areas of the sub-beam aperture array, the sub-beam apertures may be arranged in a plurality of columns regularly spaced in the second direction, with the sub-beam apertures in each column offset by a same amount, in the second direction, from each adjacent sub-beam aperture in the same column. Furthermore, the columns of sub-beam apertures may extend generally in the first direction, the columns being spaced apart with uniform spacing in the second direction. Within each column, adjacent apertures may be offset from each other in the second direction by a uniform offset. This uniform offset results in the sub-beam apertures being uniformly spaced, when projected in the first direction onto a line parallel to the second direction. This offset also results in the columns of apertures not extending exactly in the first direction but at a slight angle to the first direction.

[0009] The offset between sub-beam apertures within each column may be the same as an offset between a sub-beam aperture in one beam area and an adjacent sub-beam aperture in a corresponding column of another beam area. The offset of adjacent sub-beam apertures in a single column may be equal to a fraction of a diameter of the sub-beam apertures. Also, within each of the one or more beam areas, the sub-beam apertures in each column may be staggered, in the first direction, with respect to the sub-beam apertures of a neighbouring column. This stagger of apertures of adjacent columns results in the apertures being not aligned in the second direction. In one arrangement, the sub-beam apertures of neighbouring columns are not aligned in the second direction but the sub-beam apertures of every other column are be aligned in the second direction.

[0010] In the sub-beam aperture array, the second direction may be substantially perpendicular to the first direction. The first and second directions may be exactly perpendicular, but also may be close to perpendicular but not exactly perpendicular. This may be done, for example, to compensate for movement of the target in the first direction while the sub-beams are being scanned across the surface of the target in the second direction.

[0011] In a second aspect the invention provides a beamlet aperture array for forming a plurality of beamlets from one or more charged particle sub-beams. The beamlet aperture array comprises a plurality of beamlet apertures arranged in one or more groups, wherein the beamlet apertures are arranged so that, when projected in a fourth direction onto a line parallel to a third direction, the sub-beam apertures of each group are uniformly spaced along the line, and wherein the third direction is different from the fourth direction. The beamlets may be formed from a single charged particle sub-beam, or from multiple separate sub-beams, where each group of beamlet apertures corresponds with a separate charged particle sub-beam projected onto the beamlet aperture array. The sub-beams may be formed by a separate sub-beam array as described above and herein.

[0012] The uniform spacing of beamlet apertures when they are projected onto a line parallel to the third direction, results in evenly spaced writing paths when a plurality of beamlets are formed using the beamlet aperture array, and the beamlets are scanned across a target such as a wafer perpendicular to the third direction. The uniform spacing of projected apertures preferably applies for all of the beamlet apertures in each group. The preferred arrangement enables each beamlet to form a separate writing path which does not coincide with the writing path of any other beamlet and is equidistant from the writing paths of adjacent beamlets.

[0013] The beamlet apertures may be arranged in rows and columns, each beamlet aperture within a row of the beamlet aperture array being uniformly offset in the third direction from adjacent beamlet apertures in the row. In the beamlet aperture array, the fourth direction may be substantially perpendicular to the third direction. The third and fourth directions may be exactly perpendicular, but also may be close to perpendicular but not exactly perpendicular. This may be done, for example, to compensate for movement of the target in the third direction while the sub-beams are being scanned across the surface of the target in the fourth direction. The beamlet aperture apertures within a column of each group may be aligned in the fourth direction.

[0014] In another aspect the invention provides a beamlet aperture array for forming a plurality of beamlets from one or more charged particle sub-beams, the beamlet aperture array comprising a plurality of beamlet apertures arranged in one or more groups, each group corresponding to a sub-beam, wherein the positions of the beamlet apertures within each group form an unbalanced array.

[0015] The beamlet apertures neighboring within a row of the beamlet aperture array may be offset from each other by a uniform amount with respect to the third direction. The offset may be equal to a fraction of the pitch between the neighboring beamlet apertures. This fraction may be equal to the pitch between the neighboring beamlet apertures divided by the number of beamlet apertures within the row. The beamlet apertures in each group of the beamlet aperture array may be arranged in the form of a skewed square array.

[0016] The beamlet apertures in each group may be all offset from the center of a beam spot formed by the group of beamlet apertures. In a beamlet aperture array with forty-nine beamlet apertures arranged within the beam spot, each beamlet aperture may be associated with an aperture number, and the offset in an X direction of each beamlet aperture from the center of the beam spot is defined by the formula: appxoffset = (int[(aperture number – 1)/7)] – 3) * pitch, where int is a floor function. The offset in a Y direction of each beamlet aperture from the center of the beam spot may be defined by the formula: appyoffset = (-pitch/2) + [(6 –

[(aperture number – 1) mod 7] + int(aperture number/29)- 3) * pitch] – [(pitch/7) * (int[(aperture number – 1)/7)]- 3)] , where int is a floor function.

[0017] In yet another aspect, the invention provides a charged particle lithography system for exposing a target using a plurality of charged particle sub-beams. The system comprises a charged particle generator for generating a charged particle beam, a sub-beam aperture array as described above and herein arranged to receive the charged particle beam and form a plurality of sub-beams at the locations of the apertures of the sub-beam array, and a projection lens system configured to project the sub-beams onto the surface of the target.

[0018] The charged particle lithography system may further comprise a deflector arranged to deflect the sub-beams in the first direction, and may further comprise a moveable stage for moving the target in the second direction. The first direction may correspond to a scanning direction of the plurality of sub-beams and the second direction to a mechanical-scan direction of the target.

[0019] The charged particle lithography system may also comprise a beamlet aperture array as described above and herein, the beamlet aperture array arranged to receive the sub-beams and form a plurality of beamlets at the locations of the beamlet apertures of the beamlet array. The first direction (for the sub-beam array) may be the same as the third direction (for the beamlet array), and the second direction (for the sub-beam array) may be the same as the fourth direction (for the beamlet array).

[0020] In yet another aspect, the invention provides a method for exposing a field of a target using a plurality of charged particle beamlets, the field having a length in a first direction and a width in a second direction. The method comprises forming the charged particle beamlets into a plurality of discrete groups, the groups being equally spaced across the width of the field, and moving the target in the first direction and simultaneously scanning each group of beamlets across a width of a corresponding stripe of the field so that each beamlet follows a writing path on the surface of the target, wherein the writing paths of the beamlets of each group are evenly spaced in the first direction. Each group of beamlets is assigned to a single stripe of the field, and is deflected across the width of the field as the target is moved. The writing paths of separate groups of beamlets do not substantially overlap (there may be some small overlap of the writing paths where stitching is performed at the boundary between two stripes). Similarly, the writing paths of the individual beamlets with each group are evenly spaced in the first direction.

[0021] The first direction may be substantially perpendicular to the second direction. The first and second directions may be exactly perpendicular, but also may be close to perpendicular but not exactly perpendicular. This may be done, for example, to compensate for movement of the target in the first direction while the beamlets are being scanned across the field.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Various aspects of the invention will be further explained with reference to embodiments shown in the drawings wherein:

[0023] FIG. 1 is a simplified schematic overview of an example of a charged particle multi beamlet lithography system;

[0024] FIG. 2 is a simplified schematic overview, in side view, of an end module of the lithography system of FIG. 1;

[0025] FIG. 3 is a conceptual diagrams illustrating the concept of multiple beamlets per projection lens;

[0026] FIG. 4 is a diagram of an example of a wafer divided in to fields;

[0027] FIG. 5 is a diagram of an arrangement of sub-beam writing paths for writing a field of a wafer;

[0028] FIG. 6 is a diagram of an arrangement of sub-beams to form an electron-optical slit;

[0029] FIG. 7 is a diagram of a portion of a tilted hexagonal arrangement of sub-beams for an electron-optical slit;

[0030] FIGS. 8A-C are diagrams showing the sub-beam aperture array at different levels of detail;

[0031] FIGs. 9A and 9B show the relationship between sub-beams and beamlets;

[0032] FIGs. 10A and 10B are diagrams showing a beamlet aperture group;

[0033] FIG. 11A is a diagram of an arrangement of beamlet writing paths for writing stripes of a field of a wafer;

[0034] FIG. 11B is a diagram of an arrangement of beamlets for writing a stripe of a field;

[0035] FIGs. 12A and 12B are diagrams showing a beamlet aperture group and the beamlets projected on a wafer substrate;

[0036] FIGs. 13A and 13B are diagrams showing the beamlets projected on a wafer substrate;

[0037] FIG. 14 is a schematic diagram showing a beamlet scan line; and

[0038] FIGs. 15A and 15B show the difference in overscan between two aperture patterning schemes.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0039] The following is a description of various embodiments of the invention, given by way of example only and with reference to the drawings. Further, unless noted otherwise, the drawings are not drawn to scale.

[0040] In this description the following definitions are used:

[0041] Unbalanced array: an array or matrix with at least one row and/or column that has a different number of elements than another row or column of the array or matrix; a sub-set of unbalanced arrays include arrays with "shifted" columns, wherein the patterning scheme shifts one or more columns in relation to the other columns of the array.

[0042] Offset: the distance between one feature of an aperture, beam spot, or other object with respect to a corresponding feature of another object or other reference point. The distance may be with respect to (e.g. perpendicular to) a mechanical scan direction and/or an electron scan direction. For example, features of an aperture include the midpoint and centerline of an aperture.

[0043] Stagger: objects arranged in a zig-zag or other misalignment pattern.

[0044] Column: a sub-group of elements that align with the least deviation from the Y-axis or mechanical scan direction compared with alternative alignments of the elements of a group.

[0045] Row: a sub-group of elements that align with the least deviation from the X-axis or an electron scan direction compared with alternative alignments of the elements of a group.

[0046] Corresponding beam: A beam or group of beams arranged to pass through an aperture, projection lens, or deflector. Corresponding beams may have a one-to-one, one-to-many, or many-to-one relationship with an aperture, projection lens, or deflector.

[0047] Sub-beam: a charged particle beam projected by an aperture array that will be further divided into a plurality of beams known as beamlets.

[0048] FIG. 1 shows a simplified schematic drawing of an embodiment of a charged particle multi-beamlet lithography system based upon an electron beam optical system without a common cross-over of all the electron beamlets. Such lithography systems are described for example in U.S. Patent Nos. 6,897,458; 6,958,804; 7,019,908; 7,084,414; 7,129,502; 7,709,815; and 7,842,936, which are all assigned to the owner of the present invention and are all hereby incorporated by reference in their entirety.

[0049] FIG. 1 further illustrates an embodiment of a charged particle multi-beamlet lithography system that forms beamlets from sub-beams. An electron source 1 produces a homogeneous, expanding electron beam 20. Beam energy is preferably maintained relatively low in the range of about 1 to 10 keV.

[0050] The electron beam 20 from the electron source 1 passes a collimator lens 3 to produce a collimated electron beam 21, which impinges on sub-beam aperture array 4. The aperture array 4 blocks part of the beam and emits a plurality of sub-beams 22. The system generates a large number of sub-beams 22, e.g. about 10,000 to 1,000,000 beamlets.

[0051] The sub-beams pass through a condenser lens array 5, which focuses the sub-beams approximately in the plane of beam stop array 8 and towards a corresponding opening in beam stop array 8. In principle each sub-beam can be focused either at the corresponding opening in beam stop array 8, or at the effective lens plane of the corresponding projection lens system. In practice it is preferred to focus the sub-beams somewhere between these two points. This results in the aperture array 4 being imaged onto the target 11.

[0052] The condenser lens array may comprise a single condenser lens array or a set of condenser lens arrays, as would be known to a person of skill in the field of electron-optics.

[0053] The sub-beams 22 are intercepted by multiple aperture array 6 which includes a number of apertures in the path of (i.e., corresponding to) each sub-beam, producing a group of beamlets 23 from each sub-beam 22. The groups of beamlets, formed from the sub-beams, are also focused approximately in the plane of beam stop array 8 and each group of beamlets is directed towards a corresponding opening in beam stop array 8.

[0054] These beamlets 23 then pass through beamlet blanker array 7. Blanked beamlets are blocked by beam stop array 8, while unblanked beamlets in each group pass through a corresponding opening in beam stop array 8 and are subsequently projected onto the target by projection lens arrangement 10. In the example shown in FIG. 1, the aperture array 6 produces a group of three beamlets 23 from each sub-beam 22. The group of beamlets, if undeflected by beam blanker array 7, strike the beam stop array 8 at a corresponding opening so that the three beamlets are projected onto the target by the projection lens system 10. In practice, a much larger number of beamlets may be produced for each projection lens system 10. In a practical embodiment, as many as 50 beamlets may be directed through a single projection lens system, and this may be increased to 200 or more.

[0055] The beamlet blanker array 7 may deflect individual beamlets 23 in a group of beamlets at certain times in order to blank them. This is illustrated in FIG. 1 by the left-hand sub-beam 22, in which the middle beamlet 23 has been deflected to a location on the beam stop array 8 near to but not at an opening so that the beamlet is blanked. In the middle sub-beam 22 the right-hand beamlet 23 has been deflected and is blanked, and in the right-hand sub-beam 22 no beamlets are deflected and blanked.

[0056] Subsequently, the electron beamlets 23 enter the end module. The end module may be constructed as an insertable, replaceable unit which comprises various components or a discreet combination of individual components. The end module includes a beam stop array 8, a beam deflector array 9, and a projection lens arrangement 10. The end module will, amongst other functions, provide a demagnification of about 25 to 500 times. Additionally, the end module may be configured to deflect the beamlets 23. After leaving the end module, the beamlets 23 impinge on a surface of a target 11 positioned at a target plane. For lithography applications, the target usually comprises a wafer provided with a charged-particle sensitive layer or resist layer.

[0057] In the end module, the electron beamlets 23 first pass beam stop array 8. This beam stop array 8 largely determines the opening angle of the beamlets. In an embodiment, the apertures in beam stop array 8 are round, resulting in beamlets with a generally uniform opening angle.

[0058] The passages of the beam stop array 8 may be aligned with the elements of the beamlet blanker array 7. The beamlet blanker array 7 and beam stop array 8 then operate together to block or let pass the beamlets 23 in the following way. If beamlet blanker array 7 deflects a beamlet, it will not pass through the corresponding aperture in beam stop array 8.

Instead, it will be blocked by the substrate of beam stop array 8. However, if beamlet blanker array 7 does not deflect a beamlet, it will pass through the corresponding aperture in beam stop array 8, and will then be projected as a spot on the surface of target 11. In this way the individual beamlets 23 may be effectively switched on and off.

[0059] Next, the beamlets 23 pass through a beam deflector array 9 which provides for deflection of each beamlet 23 in a direction substantially perpendicular to the direction of the undeflected beamlets 23. Next, the beamlets 23 pass through projection lens arrangement 10 and are projected onto a target 11 to be exposed, typically a wafer, located in a target plane.

[0060] FIG. 2 shows an embodiment of the end module in more detail, showing the beam stop array 8, the deflection array 9, and the projection lens arrangement 10, projecting an electron beamlet onto a target 11. The beamlets 23 are projected onto target 11, preferably resulting in a geometric spot size of about 10 to 30 nanometers in diameter. The projection lens arrangement 10 in such a design may provide a demagnification of about 100 to 500 times. In the embodiment of FIG. 2, a central part of a beamlet 23 first passes through beam stop array 8 (assuming it has not been deflected by beamlet blanker array 7). Then, the beamlet passes through a deflector or set of deflectors arranged in a sequence forming a deflection system, of beam deflection array 9, for scanning the beamlet across the surface of the target 11. The beamlet 23 subsequently passes through an electro-optical system of projection lens arrangement 10 and finally impinges on a target 11 in the target plane.

[0061] The projection lens arrangement 10 in the embodiment of the end module shown in FIG. 2, has three plates 12, 13 and 14 arranged in sequence, used to form an array of electrostatic lenses. The plates 12, 13, and 14 preferably comprise plates or substrates with apertures formed in them. The apertures are preferably formed as round holes though the plate, although other shapes can also be used. In an embodiment, the plates are formed of silicon or other semiconductor processed using process steps well-known in the semiconductor chip industry. The apertures can be conveniently formed in the plates using lithography and etching techniques known in the art.

[0062] The plates may be coated with an electrically conductive coating to form electrodes. A metal with a conductive native oxide may be used for the electrode, such as molybdenum, deposited onto the plate using techniques well known in the art. An electrical voltage is applied to each electrode to control the shape of the electrostatic lenses formed at the location of each aperture. Each electrode is controlled by a single control voltage for the complete array. Thus, in the embodiment shown in FIG. 2 with three electrodes, there will be only three voltages for all lenses.

[0063] The three control voltages V1, V2, and V3 create an array of uniform electrostatic lenses which focus and demagnify the large number of electron beamlets 23. The characteristics of the electrostatic lenses are controlled by the three control voltages, so that the amount of focusing and demagnification of all of the beamlets can be controlled by controlling these three voltages. In this way, a single common control signal can be used to control a whole array of electrostatic lenses for demagnifying and focusing a very large number of electron beamlets. A common control signal may be provided for each plate or as a voltage difference between two or more plates. The number of plates used in different projection lens arrangements may vary, and the number of common control signals may also vary.

[0064] The voltages V1, V2, and V3 may be set so that the difference in voltage between the second and third plates (13 and 14) is greater than the difference in voltage between first and second plates (12 and 13). This results in stronger lenses being formed between plates 13 and 14 so that the effective lens plane of each projection lens system is located between plates 13 and 14, as indicated in FIG. 2 by the curved hatched lines between plates 13 and 14 in the lens opening. This places the effective lens plane closer to the target and enables the projection lens systems to have a shorter focal length. It is further noted that while, for simplicity, the beamlet in FIG. 2 is shown focused as from the deflector 9, a more accurate representation of the focusing of beamlet 23, e.g. as in a traced ray illustration, would indicate that the actual lens plane of lens system 10 is between plates 13 and 14.

[0065] FIG. 2 also illustrates deflection of a beamlet 23 by deflection array 9 in the Y-direction, illustrated in FIG. 2 as a deflection of the beamlet from left to right. In the embodiment of FIG. 2, an aperture in deflection array 9 is shown for one or more beamlets to pass through, and electrodes are provided on opposite sides of the aperture, the electrodes provided with a voltage +V and –V. Providing a potential difference over the electrodes causes a deflection of the beamlet or beamlets passing though the aperture. Dynamically changing the voltages (or the sign of the voltages) will allow the beamlet(s) to be swept in a scanning fashion. Similarly, deflection may also be performed in a different direction perpendicular to the direction of propagation of the beamlets, e.g. in a direction into and out of the paper.

[0066] FIG. 3 is a schematic diagram of the path of beamlets in the end module, to illustrate the aforementioned insight underlying using multiple beamlets per projection lens.

[0067] FIG. 3 shows a system having three beamlets per projection lens system, each beamlet originating from a separate point and passing though a projection lens system at different angles. The application of multiple beamlets through a single projection lens system appears to be possible without disturbing the amount of aberration. This is especially the case where all beamlets present in the lithography system are distributed over a multiplicity of projection lens systems.

[0068] The multiple aperture plate 6 above the deflector array 9 may comprise a multiplicity of apertures 24 as depicted, i.e. may have a patterned opening to accommodate the multiple beamlets 23 that correspond to a single lens system associated with on opening in beam stop array 8. Note that in a real design, the beam angle is much smaller than shown in FIG. 3. The relatively large beam angle shown in FIG. 3 is merely present to clarify the invention.

[0069] Because part or all of the plurality of beamlets directed through to a each projection lens system may be blanked at any point in time during operation, a system encompassing aforementioned principle may in this description be referred to as a patterned beamlet system. Such a patterned beamlet system may also be regarded as a multiplicity of miniaturized imaging systems arranged side by side.

[0070] Referring back to FIG. 1, a control unit 140 is configured to actuate movement of a substrate support member or (wafer) stage 16 arranged for supporting the target 11 to be exposed, e.g. a wafer. This movement is referred to variously in this description as a movement in a first direction or the Y-direction or the mechanical scan direction. The movement in the Y-direction is usually achieved by mechanical movement of the substrate support member, but could also be achieved by movement of the rest of the system, deflection of the beamlets, or any combination of the above techniques.

[0071] Further, the patterned beamlets are scanned across the surface of the target 11 by the deflector array 9. This movement of the beamlets is performed in a second direction, the second direction being different than the first direction. This second direction is referred to variously in this description as a second direction or X-direction or deflection scan direction. In one embodiment of the invention, the first direction is substantially perpendicular to the second direction, i.e. nearly perpendicular but not exactly perpendicular, as explained below. Please note that the movement of the beamlets in the second direction is generally a repetitive movement, i.e. a beamlet is scanned from a starting position over a certain distance until an end position and then moved back again to the starting position. Hence, the movement of the beamlets in the second direction may be performed with a certain predetermined frequency.

[0072] As mentioned previously, for lithography applications, the target usually comprises a wafer provided with a charged-particle sensitive layer or resist layer. The current industry standard is a 300mm wafer, although new systems accommodating 450mm wafers are already being designed. Wafers are typically divided into fixed size fields with a maximum dimension of 26mm x 33mm, although other sized fields may also be used. Each field may be processed to produce multiple integrated circuits (i.e. the layout for multiple chips may be written into a single field) but the ICs usually do not cross a field border. With a maximum size of 26mm x 33mm there are 63 fields available on a single standard 300mm wafer. Smaller fields are possible and will result in a higher number of fields per wafer.

[0073] FIG. 4 shows a wafer 26 divided into a number of fields 27, and the direction of writing the fields 30. It is possible to write partial (incomplete) fields, for example by writing full fields into the partial fields and crossing the wafer boundary at the edges of the wafer. Note that FIG. 4 is not drawn exactly to scale.

[0074] In one embodiment of the lithography machine, the machine generates 13,260 sub-beams and each sub-beam is split into 49 beamlets arranged in a 7x7 unbalanced array, resulting in 649,740 beamlets (i.e. 13,260 x 49). Of the 13,260 sub-beams, 260 sub-beams may be used for a redundancy scan, i.e. for use during a second scan of each field to take the place of faulty beamlets. Other embodiments are also possible using a subset of sub-beams for a first scan and another (different) sub-set of sub-beams for a second scan of the same area of the wafer, in order to divide the total heat loading of the beamlets striking the wafer across two scans and to reduce the data path capacity needed for each scan by reducing the number of active sub-beams per scan. In a similar way, the sub-beams can be used in three or more subsets over three or more scans of the same area of the wafer.

[0075] When this arrangement is applied in the machine of FIG. 1, the aperture array 4 contains 13,260 holes and the aperture array 6 and beamlet blanker array 7 contain 649,740 holes, which form the electron-optical (EO) slit in an area of 26 x 26mm (i.e. the size of the complete array of beamlets as projected onto the wafer). Each sub-beam comprising 49 beamlets may be used to write a single stripe in each field in the Y-direction.

[0076] FIG. 5 illustrates an example of an arrangement of sub-beams for writing a field 27 of a wafer 26. In this arrangement, a single sub-beam 510 (e.g sub-beam 22 formed by sub-beam aperture array 4 of FIG. 1) is used for writing one stripe 28 of the field 27. In this embodiment, each sub-beam is scanned in an X-direction across the width of a stripe while the wafer 26 is moved in the Y-direction, resulting in each stripe 28 being exposed along a writing path 511 along the length 27B of the field 27. In this example, the sub-beams (e.g. 13,000 sub-beams out of a total 13,260 sub-beams) are arranged with writing paths 511 evenly distributed over the width 27A of the field (e.g. over 26mm) in the X-direction resulting in stripes of width 28A (e.g. 2μm) in the X-direction (substantially perpendicular to the Y-direction) and a stripe length as long as the field in the Y-direction (e.g. 33 mm in the example of FIG. 4).

[0077] FIG. 6 shows an arrangement of sub-beams 510 to form an EO slit 29, arranged to form equally spaced writing paths which are distributed evenly across the width 27A of the field 27. As the wafer 26 is moved in the Y-direction, each sub-beam 510 of the array traces a writing path 511 along the length of a stripe 28 on the surface of the wafer. This results in the EO slit 29 having a writing width 29A, equal to the field width 27A (e.g. 26mm). Note that FIG. 6 shows a square array of 225 sub-beams for convenience of illustration, although in a preferred embodiment a much larger number of sub-beams is used in a non-square arrangement, as will be described below. The arrangement of the sub-beams in the EO slit, and the arrangement of the multiple beamlets within each sub-beam, are important elements of the invention and are discussed in detail below.

[0078] The wafer is preferably written on (exposed) by the lithography machine in both a backward and forward Y-direction, as shown in FIG. 4. For convenience the drawings show the X- and Y-directions as being perpendicular. However, in some embodiments the two directions are substantially (but not exactly) perpendicular. In this embodiment, the X-direction is slightly tilted so that movement (scanning) of the sub-beams for writing in the X-direction is coordinated with the simultaneous relative movement of the target in the Y-direction, resulting in the end of an exposure scan line for a sub-beam being at approximately the same Y-direction position on the wafer as the beginning of the scan line for that sub-beam. The amount of tilt depends on the amount of movement in the Y-direction during the deflection scan of sub-beams in the X-direction, i.e. during exposure of a single scan line in the X-direction. Alternatively, the relative movement of the target in the Y-direction during the deflection scan may be taken into account by arranging the deflection scan of the sub-beam (e.g. by beam deflection array 9) to include a small component in the Y-direction. In this case, the X- and Y-directions may be (exactly) perpendicular to each other.

[0079] When the width of a field 27 is chosen to be smaller than the width 29A of the electron-optical (EO) slit 29 (i.e. the size of the complete array of sub-beams as projected onto the wafer) (e.g. smaller than the maximum size of 26mm), then more fields can be placed on the wafer, but not all of the sub-beams will be used to write on the wafer. The EO slit will need to cross the wafer more often to write all fields and the overall throughput will decrease. Therefore, the EO slit 29 preferably has a writing width 29A that coincides with the width of a field 27.

[0080] The arrangement of sub-beams 510 in the EO slit 29 is determined by the pattern of apertures in the aperture array (e.g. aperture array 4 in the system of FIG. 1) that creates the sub-beams (although deflections and other manipulations of the sub-beams will also affect the arrangement of the sub-beams at the surface of the target 11). When designing an aperture array pattern, two relevant considerations are aperture density and mutual beam influence. Arranging the apertures in a regular hexagonal grid pattern (each aperture at an equal distance from six adjacent apertures) enables a high aperture density with relatively low and consistent mutual beam influence, due to every aperture being equi-distant from all the neighbouring apertures. However, a regular hexagonal arrangement results in writing paths that are not uniformly spaced.

[0081] FIG. 7 is a diagram of a portion of a hexagonal arrangement of apertures of an aperture array to form a corresponding arrangement of sub-beams 510 of an electron-optical slit 29. The sub-beams 510 and apertures are arranged in a regular hexagonal pattern (one regular hexagon indicated by reference number 512) with each aperture equi-distant from six neighbouring apertures, and the pattern is tilted by a shallow angle 513 with respect to the Y-direction. The resulting aperture pattern results in the sub-beams along one column forming parallel writing paths on a wafer when, for example, the wafer is moved in the Y-direction. For example, writing paths 511 formed by the sub-beams 510 positioned along columns 515A and 515B of the aperture array are shown in FIG. 7.

[0082] The aperture array may be tilted by an angle 513 selected so that the writing paths 511 of adjacent sub-beams in each column are separated by a desired distance, e.g. by the stripe width 28A. For example, all of the sub-beams 510 positioned along column 514A of the aperture array will have writing paths 511A separated by equal distances, and all of the sub-beams 510 along column 514B will have writing paths 511B separated by equal distances. The desired result is that all of the writing paths 511 of all of the sub-beams 501 are evenly distributed across the width 29A of the EO-slit 29, i.e. each writing path is equi-distant from adjacent writing paths.

[0083] However, due to the geometry of a regular hexagonal pattern, the distance separating adjacent writing paths of sub-beams on adjacent columns will not be uniform for all of the sub-beams. For example, in FIG. 7, the writing path of sub-beam 510A of column 514A and the writing path of sub-beam 510B of column 514B may be separated by a distance 515A different from the separation between the writing paths of the sub-beams of column 514A. The tilt angle 513 of the array could be adjusted to make the distance 515A the same as the writing path separation of the sub-beams of column 514A, but then the distance 515B between the writing path of sub-beam 510B' of column 514B and the writing path of sub-beam 510C of column 514C will be different from the writing path separation of the sub-beams of column 514A. Furthermore, for aperture arrangements having multiple beam areas separated by non-beam areas, e.g. as shown in the embodiment in FIGs. 8A-8C, the writing paths of sub-beams from adjacent beam areas may have a different separation distance than for sub-beams on the same column within a single beam area.

[0084] These uneven distances between adjacent writing paths results in a non-uniform distribution of sub-beams across the width 29A of the EO slit 29. This will result in uneven exposure of the wafer fields unless corrected, but correcting the uneven distribution of sub-beams will result in a more complex and difficult to control lithography system. Alternative arrangements of apertures are described below to overcome this problem.

[0085] FIGS. 8A-C are diagrams showing an arrangement of apertures in the sub-beam aperture array at different levels of detail. FIG. 8A is a simplified diagram showing five beam areas 500 of an entire sub-beam aperture array 4. In this embodiment, the beam areas 500 are separated by non-beam areas 501 in which there are no apertures, so that the separate beam areas form distinct groups of apertures, each beam area 500 having a regular pattern of apertures which is interrupted by the non-beam areas 501. FIG. 8B is an enlarged diagram showing a single beam area 500. FIG. 8C is also an enlarged diagram showing the spatial relationships between two beam areas 500.

[0086] Beam areas may be designated by the letters *P*, *Q*, *R*, *S*, *T*. Although this embodiment includes five beam areas it may include fewer or more than five beam areas, and may comprise only a single beam area. In some embodiments, each beam area 500 includes an array of 204 columns by 13 rows of apertures, as shown in FIG. 8B with apertures 520 of beam area 500. Within each beam area, rows may be designated by the letters *A* through *M*, and each column may be designated by the numbers *1* through *204*. Thus, each sub-beam aperture may be identified by beam area letter, row letter, and column number. For example, <T>-<M><1> is the top, left most sub-beam aperture of FIGs. 8A and 8C.

[0087] The apertures in all of the beam areas 500 are preferably distributed so that they are all spaced evenly when projected onto a line parallel with the X-direction, i.e. there is an equal distance between all adjacent apertures when projected onto this line. This arrangement results in forming sub-beams 510 (one sub-beam generated by each aperture 520) with equally spaced writing paths which are distributed evenly across the surface of a wafer when it is moved in the Y-direction (or more generally, when the wafer and sub-beams move relatively to each other). In one embodiment, the apertures 520 in the set of beams areas 500 are arranged to form an array of sub-beams 510, thus forming an EO slit 29 with equally spaced writing paths 511 which are distributed evenly across the width 27A of the field 27 of wafer 26. As the wafer 26 is moved in the Y-direction, each sub-beam 510 of the array traces a writing path 511 along the length of a stripe 28 on the surface of the wafer. This results in the EO slit 29 having a writing width 29A, equal to the field width 27A (e.g. 26mm).

[0088] In some embodiments, the centerlines of row A apertures and row M apertures in the same numbered columns of neighboring beam areas have the same spacing 506, e.g. 4.225 mm, in the Y-direction, as shown in FIG. 8C. For example, the Y-direction distance between the T-A204 and S-M204 X-direction centerlines is 4.225 mm. Further, in some embodiments, neighboring beam area apertures that are in the same numbered column are offset by the same amount 505, e.g. 2μm, with respect to direction Y'. For example, S-M1 may be offset by 2μm from T-A1. Other offset values besides 4.225 mm and 2μm are within the scope of the present invention. For example, the offset 505 of apertures within the same numbered column may be any fraction of the aperture diameter.

[0089] In some embodiments, the diameter of apertures 520 varies and in others it is constant. In some embodiments, the smallest diameter is approximately 2.7μm. Equally-sized apertures and other diameter sizes are within the scope of the invention.

[0090] FIG. 9A is an enlarged view, with respect to FIG. 8B, of apertures 520, shown for illustrative purposes enclosed within circular or elliptic area 530 from one of the beams areas 500. The apertures 520 are arranged in a non-regular hexagonal pattern, and distributed so that the apertures are spaced evenly when projected onto a line 29A parallel with the X-direction. This arrangement results in forming sub-beams 510 (one sub-beam generated by each aperture 520) with equally spaced writing paths which are distributed evenly on the surface of a wafer when it is moved in the Y-direction (or more generally, when the wafer and sub-beams move relatively to each other). Only a small portion of the apertures of one beam area 500 are shown, but this arrangement is preferably reproduced across all of the apertures of each beam area.

[0091] In some embodiments, the apertures 520 are arranged in a plurality of columns oriented in the Y-direction, and adjacent columns are regularly spaced with a fixed pitch in the X-direction. The apertures 520 of every other column of the aperture array may be aligned in the X-direction and have a fixed pitch (e.g. distance 521 between apertures L202 and L204, equal to 260μm in some embodiments). In some embodiments, apertures in adjacent columns of the aperture array are staggered by a fixed amount in the Y-direction (e.g. distance 522 between apertures M202 and M203, equal to 75μm in some embodiments) and have a uniform aperture column pitch (e.g. pitch 523 between apertures M202 and L202, equal to 150μm in some embodiments). Thus, in the embodiment shown in FIG. 9A, aperture L203 is located at the X-direction midpoint (e.g. 130μm) between apertures L202 and L204 and the Y-direction midpoint (e.g. 75μm) between apertures M202 and L202.

[0092] Further still, in some embodiments, neighboring apertures within the same numbered column of a beam area are offset in the X-direction by a uniform amount (e.g. offset 525, equal to 2μm in some embodiments). That is, in the embodiment shown in FIG. 9A, apertures K203 and L203 are offset by 2μm and apertures K203 and M203 are offset by 4μm in the X-direction. Other pitch and offset values are within the scope of the present invention. In some embodiments, the uniform offset 525 in the X-direction between neighboring apertures within the same column of a beam area 500 is the same as the offset 505 between neighbouring apertures of different beam areas on either side of a non-beam area. For example, in the embodiment shown in FIG. 8C, aperture S-M1 may be offset from aperture T-A1 in the X-direction by the same amount as the offset between aperture T-A1 and T-B1 in the X-direction (e.g. offset by 2μm).

[0093] As can be seen in FIG 9A, the aperture pattern is a hexagonal pattern; however, the pattern is not a regular hexagon but has an offset or skew between apertures in each column. Rather, as explained above, apertures are staggered in the Y-direction and, in this embodiment, align in the X-direction in every other column. Although a regular hexagonal grid pattern has desirable properties, as explained above it involves significant tradeoffs.

[0094] One aspect of the invention is based on the insight that a skewed or offset hexagonal pattern e.g. as described above obtains most of the benefits of a regular hexagonal pattern regarding aperture density and mutual beam influence, but maintains uniform spacing of writing paths and avoids or minimizes other disadvantages of a tilted regular hexagonal pattern.

[0095] FIG. 9B is a diagram showing a portion of the multiple aperture array 6. Circle/ellipse 620 encompasses an area of the aperture array 6 where a group of sub-beams 510 generated by the apertures 520 shown in FIG, 9A are projected onto the multiple aperture array 6. Each sub-beam 510 is projected onto a beam spot 621 which includes a group of beamlet apertures 620 residing on the multiple aperture array 6. In some embodiments, the beam spots 621 formed by sub-beams 510 maintain similar spacing as the sub-beam apertures 520.

[0096] FIG. 10A is an enlarged diagram, relative to FIG. 9B, showing one group of beamlet apertures 620 which are formed from one sub-beam 510. Each group of beamlet apertures 620 forms a beam spot 621. Cross 710 shows the center point of beam spot 621. In some embodiments, beamlet apertures 620 are numbered 1 through 49. Thus, each beamlet aperture 620 may be identified by its aperture number and the corresponding beam area letter, row letter, and column number, as discussed above. In some embodiments, beamlet apertures may have a diameter of approximately 2.7µm.

[0097] In the embodiment shown in FIG. 10A, the beamlet apertures 620 are arranged in a square array, with apertures arranged in rows and columns with an equal number of apertures in the rows and columns. Other arrangements may also be used, but it is preferred to arrange the apertures 620 compactly within the circular beam spot 621. One aspect of the embodiment shown is arranging apertures in an unbalanced array pattern. As can be seen in FIG. 10A, not every row of the array contains the same number of apertures. Thus, it is an example of an unbalanced array. The unbalanced array may also be characterized as having one or more “shifted” columns, wherein the patterning scheme shifts one or more columns in relation to the other columns of the array. For example, in FIG. 10A the three columns on the right side have been shifted upwards by one row with respect to the four columns on the left side. The apertures 620 may be aligned in columns that follow the Y–direction (as shown in FIG. 10A), or the X-direction, or another direction.

[0098] A further aspect of the invention includes offsetting apertures within a column of apertures to skew the array and provide slanting rows (at an angle with respect to the X-direction in FIG. 10A, e.g. the row made by apertures 1, 8, 15, 22, 30, 37, 44). In particular, an intra-row offset 625 between neighbouring apertures 620 in the Y-direction may be equal to a fraction of the pitch 624 between neighboring apertures within a row in the X-direction, as shown in FIG. 10B. FIG. 10B is an enlarged diagram, relative to FIG. 10A, showing a sub-group of four neighboring beamlet apertures 620.

[0099] In some embodiments, the intra-row offset 625 is equal to the pitch 624 between beamlet apertures 620 of neighboring columns divided by the number of apertures within the row. This results in all of the apertures 620 within a group/beam spot 621 being equally spaced when projected onto a line parallel to the Y-direction. This arrangement results in forming beamlets (e.g. one beamlet 610 generated by each aperture 620) with equally spaced writing paths 611 which are distributed evenly on the surface of a wafer when the group of beamlets 621 is moved in the X-direction (e.g. by the deflection scan of the beamlets). For example, the beamlet apertures 620 in FIG. 10A mostly form slanted rows of seven apertures.

Thus, the offset 625 between apertures neighboring within a row is approximately 1.143μm with a row pitch 624 of 8μm, i.e., 8μm/7 apertures per row ≈ 1.143μm.

[00100] Another aspect of the arrangement includes patterning an array such that the group of beamlet apertures 620 are offset from center point 710 of beam spot 621. In embodiments including forty-nine apertures that are arranged within each beam spot, each aperture may be associated with an aperture number, and the offset of each aperture from the center of the beam spot may be defined by the following formulas:

$$app_{xoffset} = (\mathrm{int}[(num - 1)/7)] - 3) * pitch;$$

$$app_{yoffset} = (-pitch/2) + [(6 - [(num - 1) \bmod 7] + \mathrm{int}(num/29) - 3) * pitch] - [(pitch/7) * (\mathrm{int}[(num - 1)/7)] - 3)];$$

where $app_{xoffset}$ and $app_{yoffset}$ express the X and Y-axis offset from center point 710, num = aperture number, and int[] is a floor function that maps a real number to the largest previous integer, including 0.

[00101] FIGs. 10A and 10B illustrate only one embodiment. Alternative arrangements of unbalanced arrays, number of apertures, row and column pitches, and intra-row offset values are within the scope of the invention.

[00102] FIG. 11A is a diagram showing beamlet writing paths 611 for writing stripes 28 of a field 27 of a wafer. In this embodiment, multiple groups 621 of beamlets 610 are generated, each group of beamlets assigned to writing one stripe 28 of the field 27. In one embodiment, each beamlet group 621 is formed from a single sub-beam 510, and the sub-beams are arranged with writing paths 511 as shown in FIG. 5. Thus, in this arrangement, multiple sub-beams 510 are arranged with writing paths 511 evenly spaced and distributed in one direction (e.g. in the X-direction across the width of the field 27), and multiple beamlets 610 formed from each one of the sub-beams 510 are arranged with writing paths 611 evenly spaced and distributed in a different direction (e.g. in the Y-direction along the length of the field 27). The two directions are preferably exactly or nearly perpendicular to each other.

[00103] It should be noted that this arrangement may be used without actually forming any sub-beams. The groups of beamlets 610 may be formed in a single aperture array, in which the groups form beam spots 621 which are evenly spaced and distributed in one direction (e.g. in the X-direction across the width of the field 27). The multiple beamlets 610 in each group/beam spot 621 are arranged with writing paths 611 evenly spaced and distributed in a

different direction (e.g. in the Y-direction along the length of the field 27), where the two directions are preferably exactly or nearly perpendicular to each other.

[00104] FIG. 11B is a diagram of an arrangement of beamlets 610 which may be generated by the aperture arrangement shown in FIG. 10A suitable for the writing scheme shown in FIG, 11A. The beamlets 610 are arranged to form writing paths 611 with uniform spacing 625 when the group of beamlets is scanned in the X-direction across the wafer. The writing paths 611 are evenly distributed across a beam spot width 610A in the Y-direction.

[00105] FIG. 12A is a simplified schematic diagram showing a beamlet crossover at the beam stop array 8. In particular, FIG. 12A shows a portion 6a of the multiple aperture array 6, a portion 8a of the beam stop array 8, and a portion 11a of the wafer. In each case, the portions 6a, 8a, and 11a correspond to a beamlet group, as shown in FIG 10A.

[00106] To explain further, a beamlet group is projected from the multiple aperture array potion 6a and towards beam stop array portion 8a. The beamlet group crosses over at or near beam stop array portion. This crossover results in a translated image being projected on wafer portion 11a.

[00107] FIG. 12B shows in more detail the beamlet group translation. On the left, a group of beamlets 610 are shown, as exiting multiple aperture array portion 6a. The beamlets 610 are numbered in the same fashion as in FIG. 10A, but only the numbers 1, 7, 43, and 49 are shown for clarity. Further beamlet number 1 is shaded to clearly show the translation.

[00108] On the right, a group of beamlets 610' are shown, as projected on wafer portion 11a. The two groups of beamlets 610 and 610' show, for example, that beamlet numbers 1, 7, 43, and 49 are translated into a different position, along with the other beamlets not numbered in FIG. 12B.

[00109] FIG. 13A is an enlarged diagram, relative to FIG. 12B, showing the group of beamlets 610', as projected on a wafer. FIG. 13B is a further enlarged diagram, showing a sub-group of four neighboring beamlets 610'. Because of focusing and demagnification, the column and row pitch may be much smaller in relation to the column and row pitch of the multiple aperture array portion shown in FIG. 10A. For example, in some embodiments the offset between beamlets neighboring within a row is 10.5nm with a row and column pitch of 73.5nm.

[00110] As further exampled below, one advantage of the present invention is minimizing overscan. FIG. 14 shows a schematic diagram of a scan line of a beam or beamlet, including the sub-beam or beamlet's overscan section. A beam deflector array (e.g., beam deflector array 9 of FIG. 1) generates a deflection signal, which includes a scan phase (from A to B) and a fly-back phase (from B to C). During the scan phase, the deflection signal moves a group of beamlets (corresponding to a sub-beam), each beam having its own scan line and scan area. After the scan phase, the fly-back phase starts, in which the beamlets are switched off and the deflection signal quickly moves the beamlets back to the position where the next scan phase will start.

[00111] A scan line is the path of a sub-beam or beamlet on the surface of the wafer during the scan phase. A scan line (see FIG. 14 at the right) is divided into three sections: a start overscan section, a pattern section, and an end overscan section. In the overscan sections, the beamlets are typically switched off. In the pattern section, the beamlets are switched on according to the features required to be written in the wafer field. The bits in the scan-line bit frame for both the overscan section and pattern section represent data to be transferred to the beam blanker array. The bits/pixels in the overscan section consume bandwidth of the data path and increase wafer processing time.

[00112] It is therefore desirable to arrange the apertures of the aperture plate to minimize overscanning. Embodiments of the present invention minimize this problem, as can be seen in FIGs. 15A and 15B.

[00113] FIG. 15A and 15B are diagrams showing two groups of beamlets and their respective overscan length. Beamlet group 1100 is projected by an multiple aperture array in an embodiment of the present invention. Beamlet group 1120 is projected by an alternative multiple aperture array having a rotated balanced array. Both beamlet groups 1100 and 1120 are shown as projected on a section of a wafer. Both beamlet groups have the same number of beamlets and are projected by multiple aperture arrays that have the same fill factor and a column and row pitch of 8μm.

[00114] As explained in FIG. 14, a scanline bit frame includes two overscan sections, a start overscan section and end overscan section. For some writing schemes, the bit length of these sections are in proportion to the X-axis width of a beamlet group. Beamlet group 1120 is 63nm wider than beamlet group 1100. The overscan per scan line for beamlet group 1120 is

1.104μm compared to 1.041 μm for beamlet group 1100. Further, the throughput performance of beamlet group 1100 is at least 2% higher than beamlet group 1120.

[00115] Although the figures show a particular lithography system, sub-beam array 4 and multiple aperture array 6 are beneficial in a number of different configurations upstream and downstream of the arrays, including the use of either array 4 or 6 individually and with other arrays not within the scope of the invention. Arrays 4 and 6 may be implemented in either parallel or perpendicular writing strategies. Further, the beamlets may be focused individually or in groups.

[00116] Thus, it will be recognized that these embodiments are susceptible to various modifications and alternative forms well known to those of skill in the art without departing from the spirit and scope of the invention. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the invention, which is defined in the accompanying claims.

CONCLUSIES

1. Een lithografiesysteem op basis van geladen deeltjes voor het belichten van een doel met behulp van een veelheid van geladen deeltjes deelbundels, waarbij het systeem omvat:

een geladen deeltjesgenerator voor het genereren van een bundel van geladen deeltjes;

een deelbundelapertuurarray omvattende één of meer bundelgebieden, waarbij elk bundelgebied een veelheid van deelbundelaperturen omvat, waarbij de deelbundelapertuurarray is verschaft om de bundel geladen deeltjes te ontvangen en een veelheid van deelbundels te vormen op de locaties van de deelbundelaperturen; en

een projectielenssysteem, geconfigureerd om de deelbundels te projecteren op het oppervlak van het doel;

waarbij de deelbundelaperturen zijn gerangschikt in een niet-regelmatig hexagonaal patroon, zodanig dat, wanneer geprojecteerd in een eerste richting op een lijn parallel aan een tweede richting, de deelbundelaperturen op gelijkmatige afstand van elkaar zijn gelegen langs de lijn, en waarbij de eerste richting verschillend is van de tweede richting; en

waarin het systeem verder een beamletapertuurarray omvat omvattende meerdere beamletaperturen, gerangschikt in één of meer groepen, waarbij de beamletapertuurarray is verschaft om de deelbundels te ontvangen en een veelheid van beamlets te vormen op de locaties van de beamletaperturen van de beamletarray.

2. Het systeem volgens conclusie 1, waarbij, in elk van de één of meer bundelgebieden, de deelbundelaperturen zijn gerangschikt in een veelheid van kolommen die op een regelmatige afstand van elkaar zijn gelegen in de tweede richting, en de deelbundelaperturen in elke kolom zijn verschoven met eenzelfde hoeveelheid, in de tweede richting, van elke aangrenzende deelbundelapertuur in dezelfde kolom.

3. Het systeem volgens conclusie 2, waarbij de verschuiving tussen deelbundelaperturen in elke kolom gelijk is aan een verschuiving tussen een deelbundelapertuur in één

bundelgebied en een aangrenzende deelbundelapertuur in een overeenkomstige kolom van een andere bundelgebied.

4. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de verschuiving van aangrenzende deelbundelaperturen in een enkele kolom gelijk is aan een fractie van een diameter van de deelbundelaperturen.

5. Het systeem volgens eenieder van de voorgaande conclusies, waarbij, in elk van de één of meer bundelgebieden, de deelbundelaperturen in elke kolom zijn versprongen, in de eerste richting, ten opzichte van de deelbundelaperturen van een aangrenzende kolom.

6. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de deelbundelaperturen van elke kolom zijn uitgelijnd in de tweede richting.

7. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de tweede richting in hoofdzaak loodrecht staat op de eerste richting.

8. Het systeem volgens eenieder van de voorgaande conclusies, waarin elke groep beamletaperturen overeenkomt met een aparte deelbundel van geladen deeltjes, geprojecteerd op de beamletapertuurarray.

9. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de beamletaperturen zo zijn gerangschikt dat, indien geprojecteerd in een vierde richting op een lijn evenwijdig aan een derde richting, de deelbundelaperturen van elke groep op gelijkmatige afstand van elkaar gelegen zijn langs de lijn, en waarbij de derde richting verschillend is van de vierde richting.

10. Het systeem volgens conclusie 9, waarbij de eerste richting dezelfde is als de derde richting, en de tweede richting dezelfde is als de vierde richting.

11. Het systeem volgens eenieder van de conclusies 9 of 10, waarbij de beamletaperturen zijn gerangschikt in rijen en kolommen, en elke beamletapertuur binnenin een rij van de beamletapertuurarray gelijkmatig is verschoven in de derde richting van aangrenzende beamletaperturen in de rij.

12. Het systeem volgens eenieder van de conclusies 9-11, waarbij de vierde richting in hoofdzaak loodrecht staat op de derde richting.

13. Het systeem volgens eenieder of conclusies 9-12, waarbij de beamletaperturen binnenin een kolom van elke groep uitlijnen in de vierde richting.

14. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de beamletaperturen zijn gerangschikt in meerdere groepen, waarbij elke groep overeenkomt met een deelbundel, waarbij de posities van de beamletaperturen binnenin elke groep een ongebalanceerde reeks vormen.

15. Het systeem volgens conclusie 14, waarbij naburige beamletaperturen binnenin een rij van de beamletapertuurarray zijn verschoven ten opzichte van elkaar met een uniforme hoeveelheid ten opzichte van de derde richting.

16. Het systeem volgens conclusie 15, waarbij de verschuiving gelijk is aan een fractie van de steek tussen naburige beamletaperturen.

17. Het systeem volgens conclusie 16, waarbij de fractie gelijk is aan de steek tussen de naburige beamletaperturen gedeeld door het aantal beamletaperturen in de rij.

18. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de beamletaperturen in elke groep een scheve vierkante array vormen.

19. Het systeem volgens eenieder van de voorgaande conclusies, waarbij de beamletaperturen in elke groep alle zijn verschoven uit het midden van een bundelvlek, gevormd door de groep beamletaperturen.

20. Het systeem volgens conclusie 19, waarbij negenenveertig beamletaperturen zijn gerangschikt binnenin de bundelvlek, waarbij elk beamletapertuur is geassocieerd met een apertuurnummer, en de verschuiving in een X-richting van elk beamletapertuur uit het centrum van de bundelvlek gedefinieerd wordt de formule: appxoffset = (int [(apertuurnummer - 1) / 7)] - 3) * steek, waar int een trapfunctie is.

21. Het systeem volgens conclusie 19 of 20, waarbij de verschuiving in een Y-richting van elke beamletapertuur uit het centrum van de bundelvlek is gedefinieerd door de formule: appyoffset = (-steek/2) + [(6 - [(apertuurnummer - 1) mod 7] + int (apertuurnummer/29) - 3) * steek] - [(steek / 7) * (int [(apertuurnummer - 1) / 7)] - 3)], waarbij int een trapfunctie is.

22. Het systeem volgens eenieder van de voorgaande conclusies, verder omvattende een deflector ingericht om de deelbundels af te buigen in de eerste richting.

23. Het systeem volgens eenieder van de voorgaande conclusies, verder omvattende een beweegbare tafel voor het bewegen van het doel in de tweede richting.

24. Een deelbundelapertuurarray voor het vormen van meerdere deelbundels uit één of meer bundels geladen deeltjes, waarbij de deelbundelapertuurarray één of meer bundelgebieden omvat, waarbij elk bundelgebied een veelheid van deelbundelaperturen omvat gerangschikt in een niet-regelmatig hexagonaal patroon, waarbij de deelbundelaperturen zo zijn gerangschikt dat, wanneer geprojecteerd in een eerste richting op een lijn parallel aan een tweede richting, de deelbundelaperturen op gelijkmatige afstand van elkaar gelegen langs de lijn zijn, en waarbij de eerste richting verschillend is van de tweede richting.

25. De deelbundelapertuurarray volgens conclusie 24, waarbij, in elk van de één of meer bundelgebieden, de deelbundelaperturen gerangschikt zijn in een veelheid van kolommen op een regelmatige afstand in de tweede richting, en de deelbundelaperturen in elke kolom zijn verschoven met eenzelfde hoeveelheid, in de tweede richting, van elke aangrenzende deelbundelapertuur in dezelfde kolom.

26. De deelbundelapertuurarray volgens conclusie 25, waarbij de verschuiving tussen deelbundelaperturen in elke kolom gelijk is aan een verschuiving tussen een deelbundelapertuur in één bundelgebied en een aangrenzende deelbundelapertuur in een overeenkomstige kolom van een andere bundelgebied.

27. De deelbundelapertuurarray volgens eenieder van de conclusies 24-26, waarbij de verschuiving van aangrenzende deelbundelaperturen in een enkele kolom gelijk is aan een fractie van een diameter van de deelbundelaperturen.

28. De deelbundelapertuurarray volgens eenieder van de conclusies 24-27, waarbij, in elk van de één of meer bundelgebieden, de deelbundelaperturen in elke kolom zijn versprongen, in de eerste richting, ten opzichte van de deelbundelaperturen van een aangrenzende kolom.

29. De deelbundelapertuurarray volgens eenieder van de conclusies 24-28, waarbij de deelbundelaperturen van elke kolom zijn uitgelijnd in de tweede richting.

30. De deelbundelapertuurarray volgens eenieder van de conclusies 24-29, waarbij de tweede richting in hoofdzaak loodrecht staat op de eerste richting.

31. Een beamletapertuurarray voor het vormen van meerdere beamlets uit één of meer deelbundels van geladen deeltjes, waarbij de beamletapertuurarray meerdere beamletaperturen omvat, gerangschikt in één of meer groepen, waarbij de beamletaperturen zo gerangschikt zijn dat, wanneer geprojecteerd in een vierde richting op een lijn evenwijdig aan een derde richting, de deelbundelaperturen van elke groep op gelijk-

matige afstand van elkaar gelegen zijn langs de lijn, en waarbij de derde richting verschillend is van de vierde richting.

32. De beamletapertuurarray volgens conclusie 31, waarbij elke groep beamletaperturen overeenkomt met een aparte deelbundel van geladen deeltjes, geprojecteerd op de beamletapertuurarray.

33. De beamletapertuurarray volgens conclusie 31 of 32, waarbij de beamletaperturen gerangschikt zijn in rijen en kolommen, en elke beamletapertuur binnenin een rij van de beamletapertuurarray gelijkmatig verschoven is in de derde richting van aangrenzende beamletaperturen in de rij.

34. De beamletapertuurarray volgens eenieder van de conclusies 31-33, waarbij de vierde richting in hoofdzaak loodrecht staat op de derde richting.

35. De beamletapertuurarray volgens eenieder van de conclusies 31-34, waarbij de beamletaperturen binnenin een kolom van elke groep uitlijnen in de vierde richting.

36. Een beamletapertuurarray voor het vormen van meerdere beamlets uit één of meer deelbundels van geladen deeltjes, waarbij de beamletapertuurarray meerdere beamletaperturen omvat, gerangschikt in één of meer groepen, waarbij elke groep overeenkomt met een deelbundel, waarbij de posities van de beamletaperturen binnenin elke groep een ongebalanceerde reeks vormen.

37. De beamletapertuurarray volgens conclusie 36, waarbij naburige beamletaperturen binnenin een rij van de beamletapertuurarray zijn verschoven ten opzichte van elkaar met een uniforme hoeveelheid ten opzichte van de derde richting.

38. De beamletapertuurarray van conclusie 37, waarbij de verschuiving gelijk is aan een fractie van de steek tussen naburige beamletaperturen.

39. De beamletapertuurarray volgens conclusie 38, waarbij de fractie gelijk is aan de steek tussen naburige beamletaperturen gedeeld door het aantal beamletaperturen in de rij.

40. De beamletapertuurarray volgens eenieder van de conclusies 31-39, waarbij de beamletaperturen in elke groep een scheve vierkante reeks vormen.

41. De beamletapertuurarray volgens eenieder van de conclusies 31-40, waarbij de beamletaperturen in elke groep alle verschoven zijn uit het midden van een bundelvlek, gevormd door de groep beamletaperturen.

42. De beamletapertuurarray volgens conclusie 41, waarbij negenenveertig beamletaperturen zijn gerangschikt binnenin de bundelvlek, waarbij elke beamletapertuur is geassocieerd met een apertuurnummer, en de verschuiving in een X-richting van elke beamletapertuur uit het centrum van de bundelvlek is gedefinieerd door de formule: appxoffset = (int [(apertuurnummer - 1) / 7)] - 3) * steek, waar int een trapfunctie is.

43. De beamletapertuurarray volgens conclusie 41 of 42, waarbij de verschuiving in een Y-richting van elk beamletapertuur uit het centrum van de bundelvlek is gedefinieerd door de formule: appyoffset = (-steek/2) + [(6 - [(apertuurnummer - 1) mod 7] + int (apertuurnummer/29) - 3) * steek] - [(steek / 7) * (int [(apertuurnummer - 1) / 7)] - 3)], waarbij int een trapfunctie is.

44. Een werkwijze voor het belichten van een gebied van een doel met behulp van meerdere beamlets van geladen deeltjes, waarbij het gebied een lengte in een eerste richting en een breedte in een tweede richting heeft, waarbij de werkwijze omvat:

het vormen van de beamlets van geladen deeltjes in meerdere afzonderlijke groepen, waarbij de groepen op gelijkmatige afstand van elkaar gelegen zijn over de breedte van het gebied; en

het bewegen van het doel in de eerste richting en het gelijktijdig scannen van elke groep beamlets over een breedte van een overeenkomstige strook van het veld zodat elke beamlet een schrijfpad volgt op het oppervlak van het doel;

waarbij de schrijfpaden van de beamlets van elke groep op een gelijkmatige afstand van elkaar zijn gelegen in de eerste richting.

45. De werkwijze volgens conclusie 44, waarbij de eerste richting in hoofdzaak loodrecht staat op de tweede richting.

* * * * * *

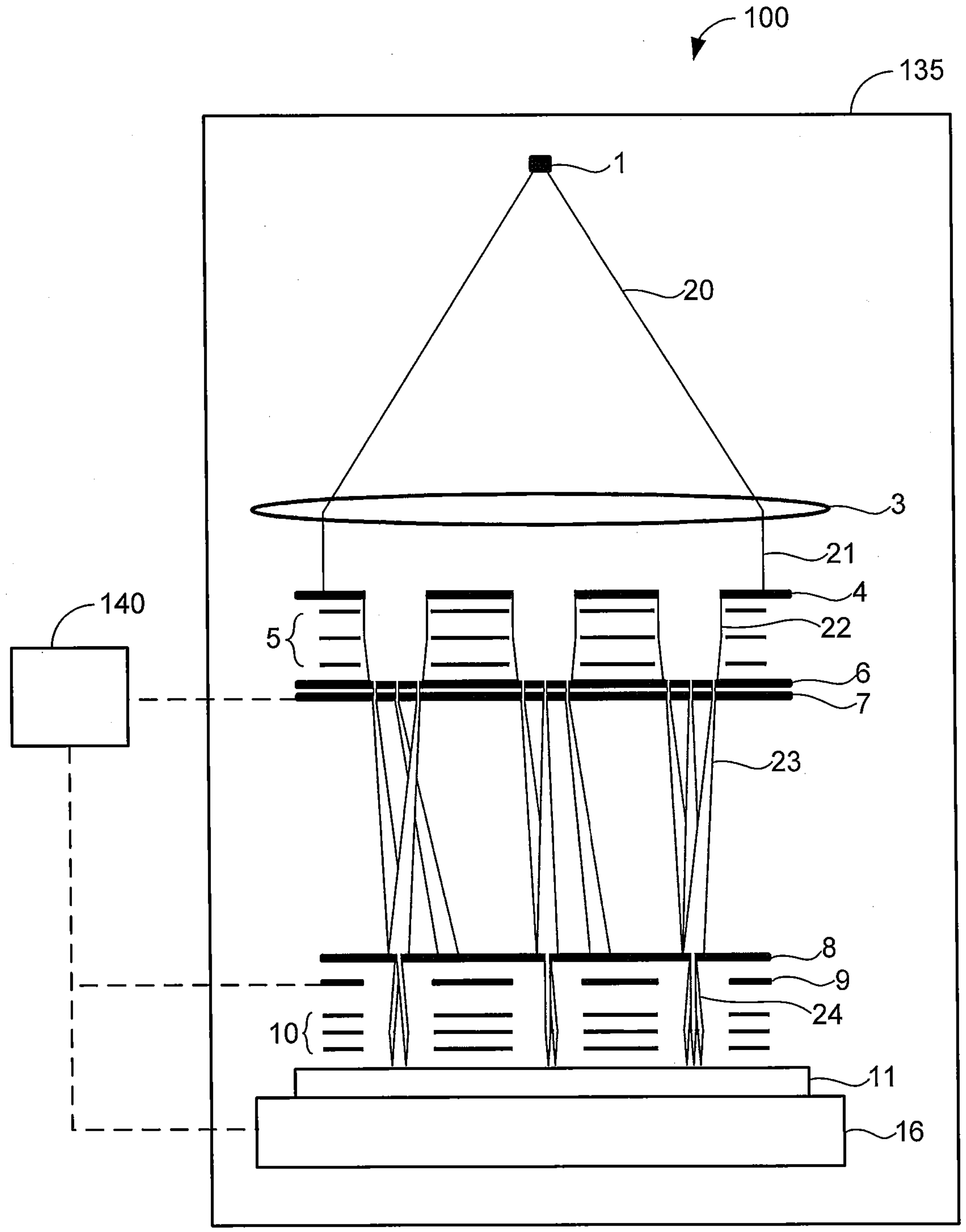


FIG. 1

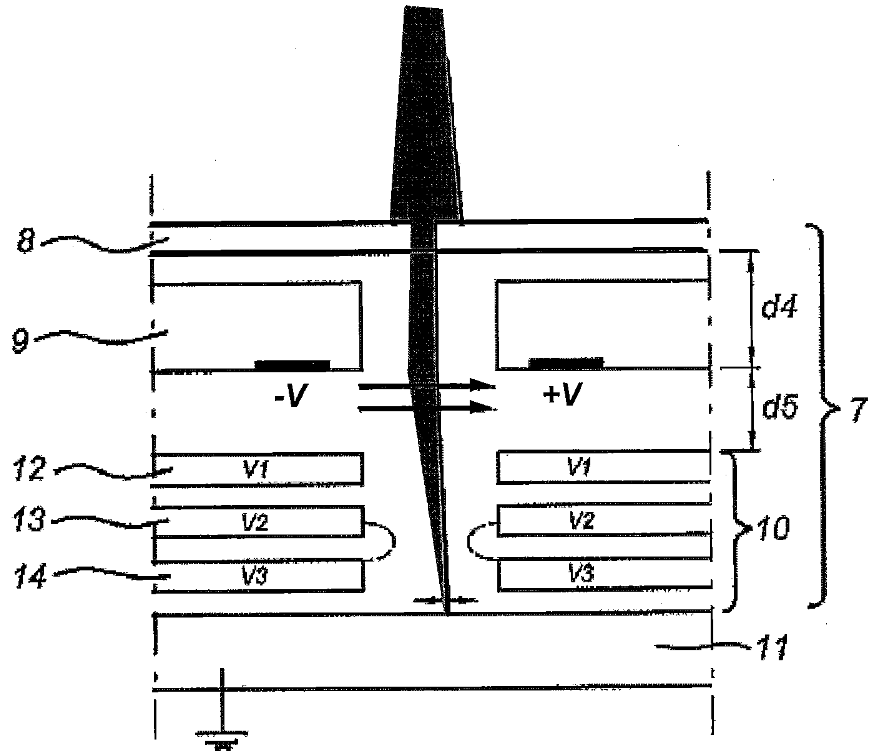


FIG. 2

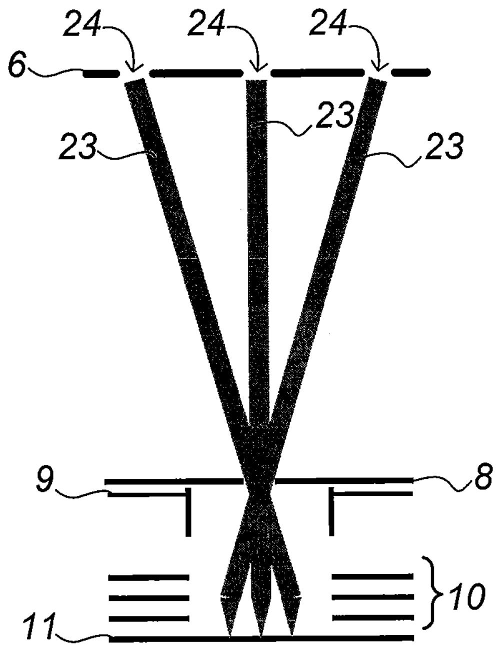


FIG. 3

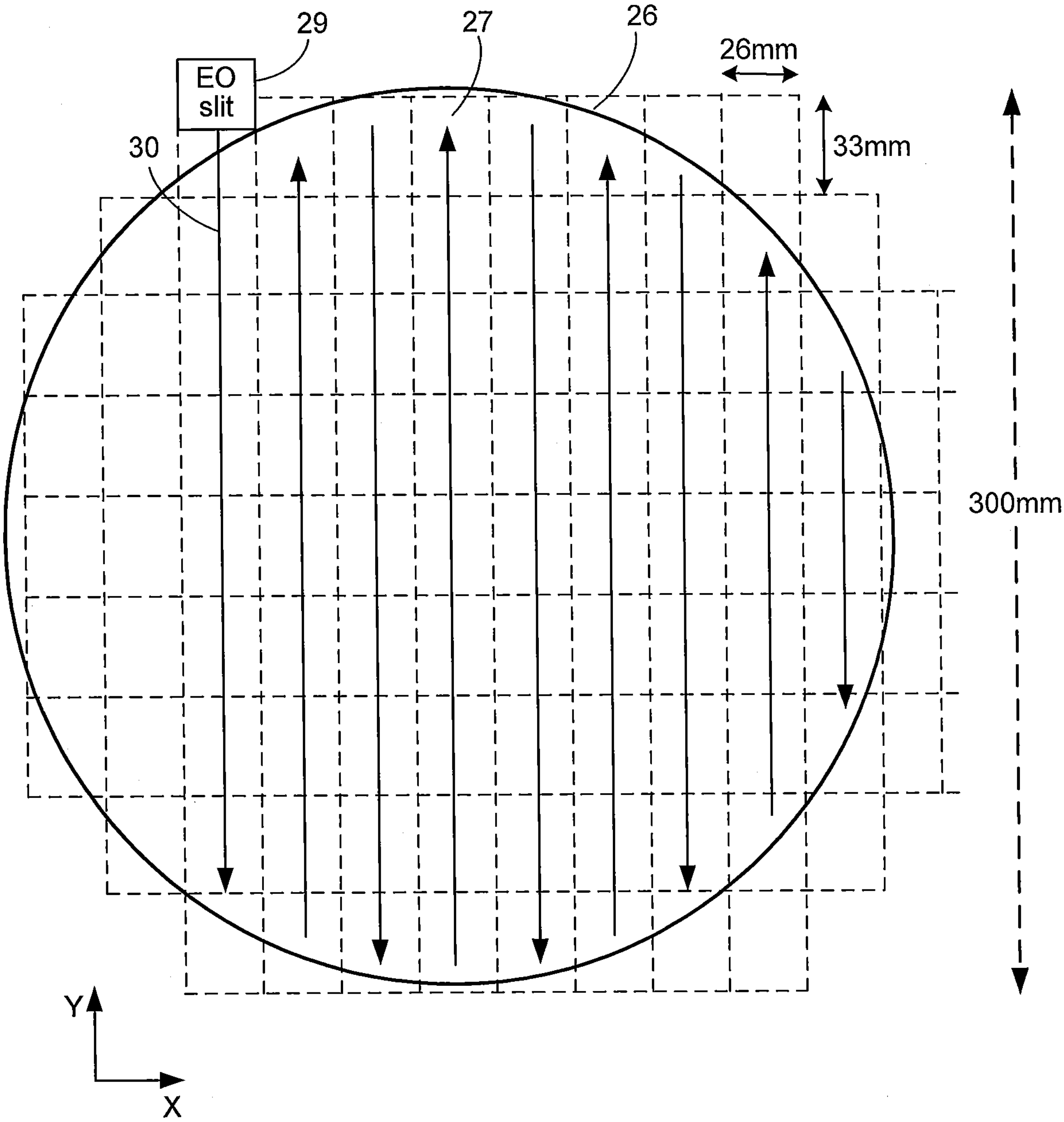


FIG. 4

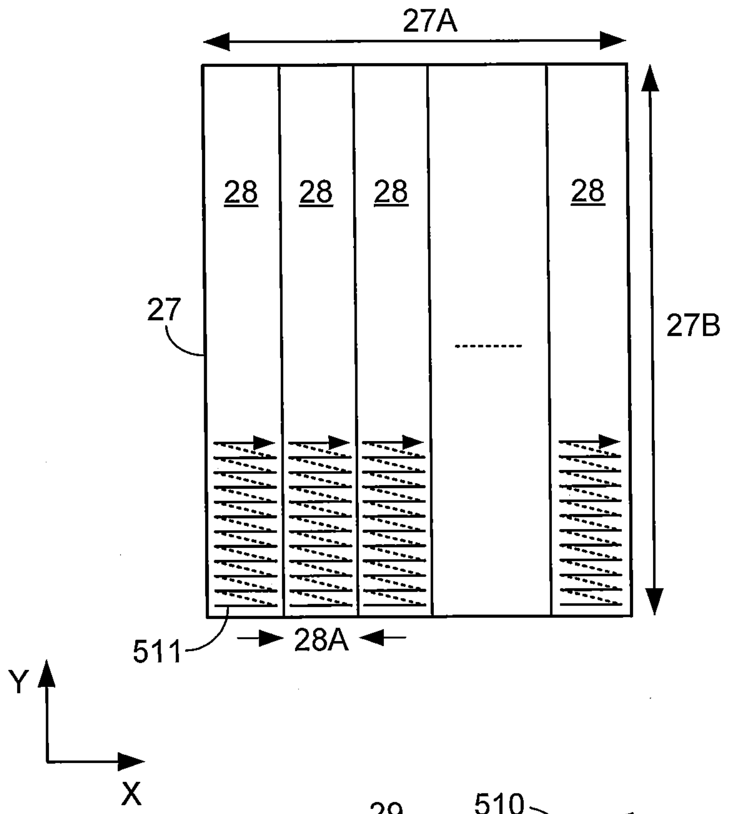


FIG. 5

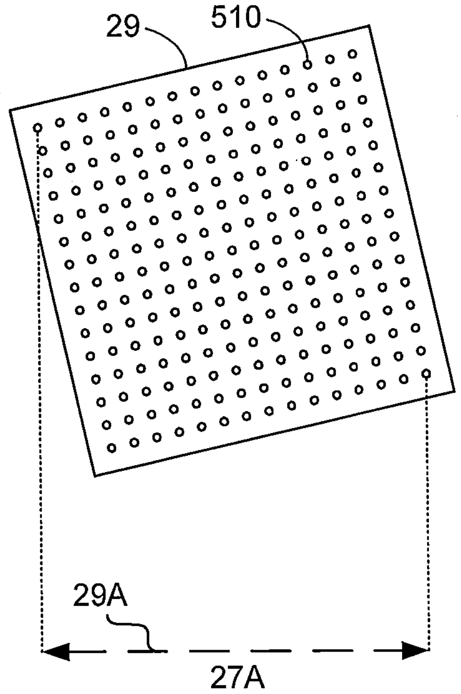


FIG. 6

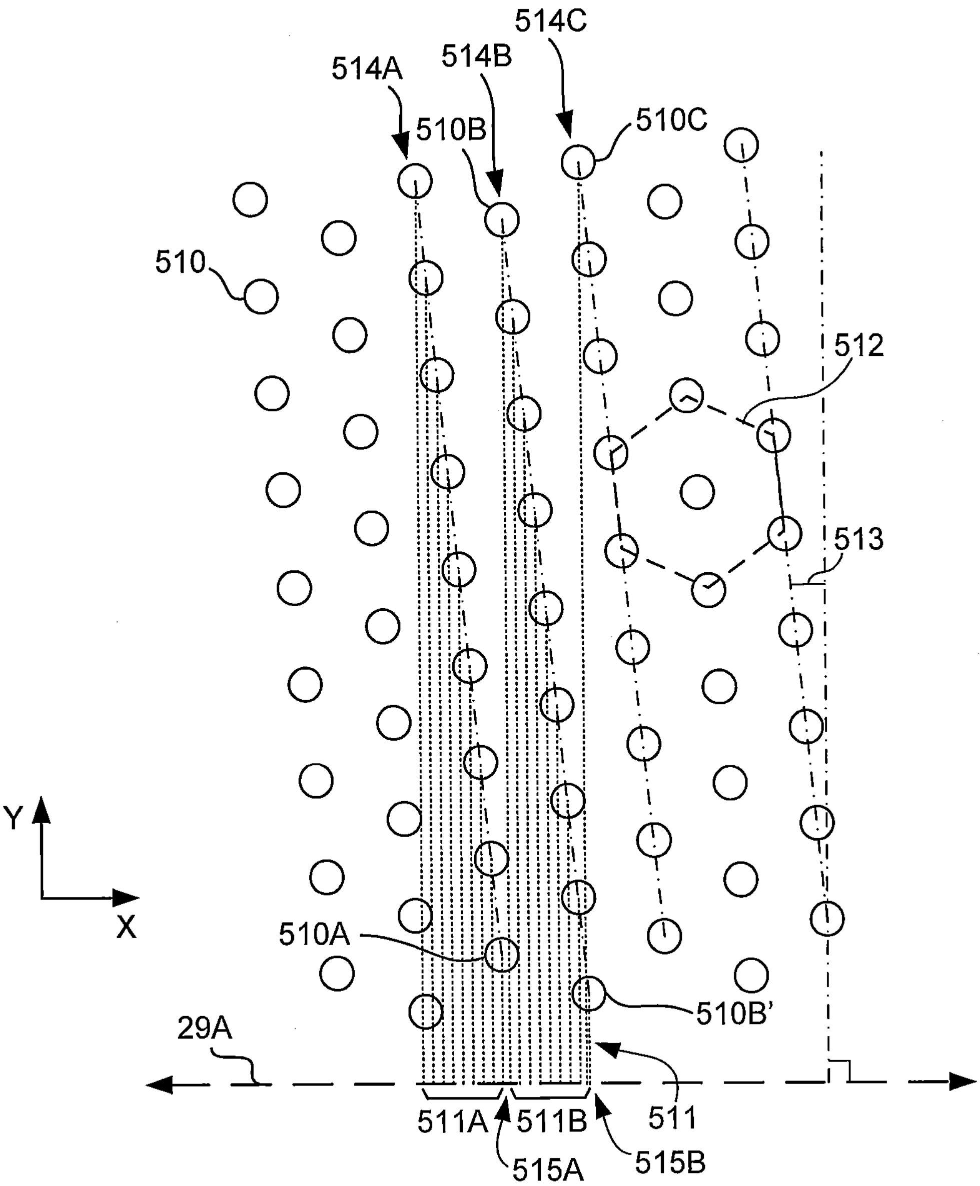

514C
514A
514B
510B
510C
510
512
513
Y
X
510A
510B'
29A
511
511A
511B
515A
515B

FIG. 7

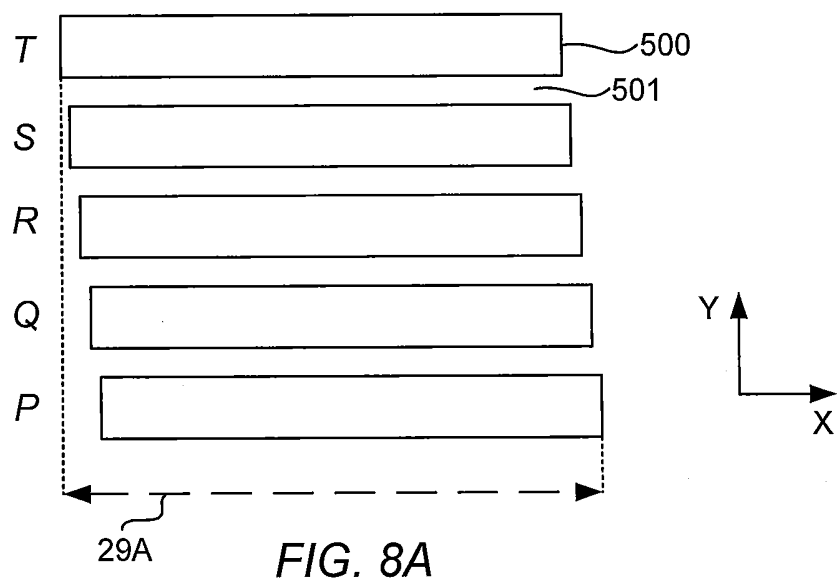


FIG. 8A

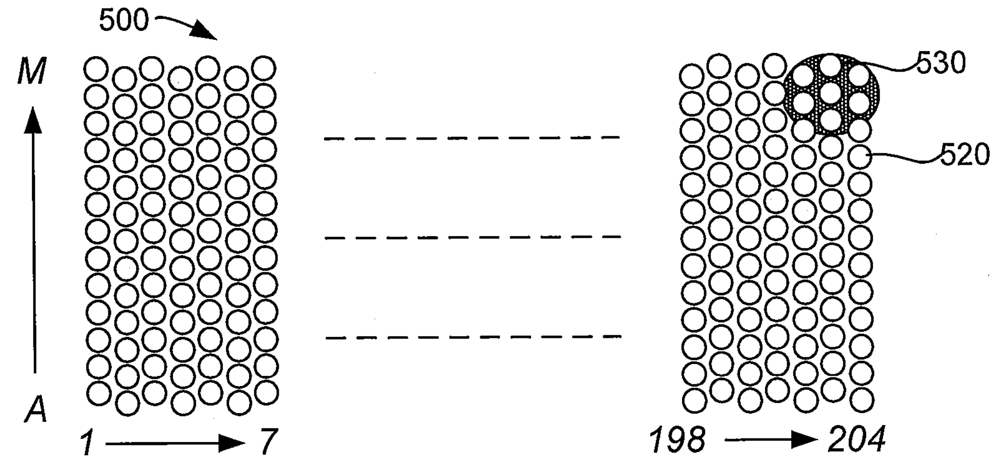


FIG. 8B

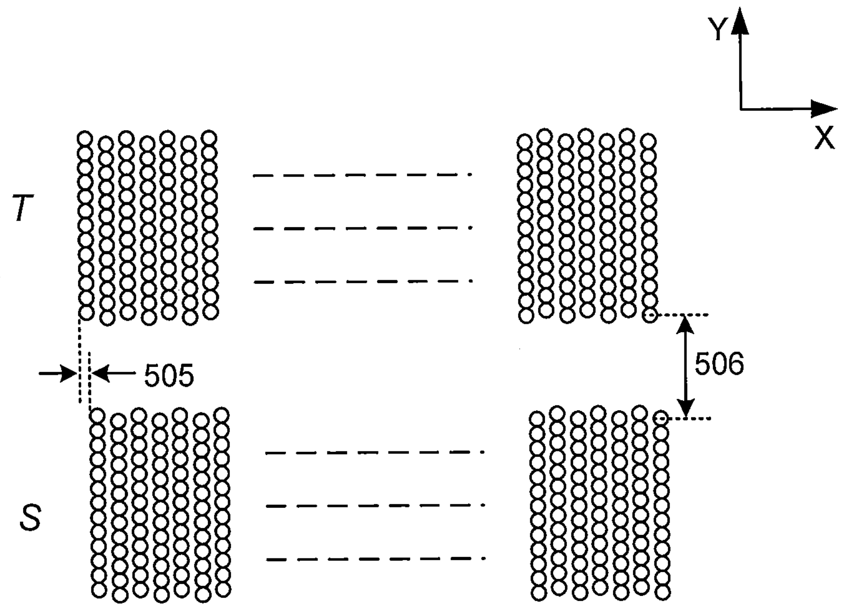


FIG. 8C

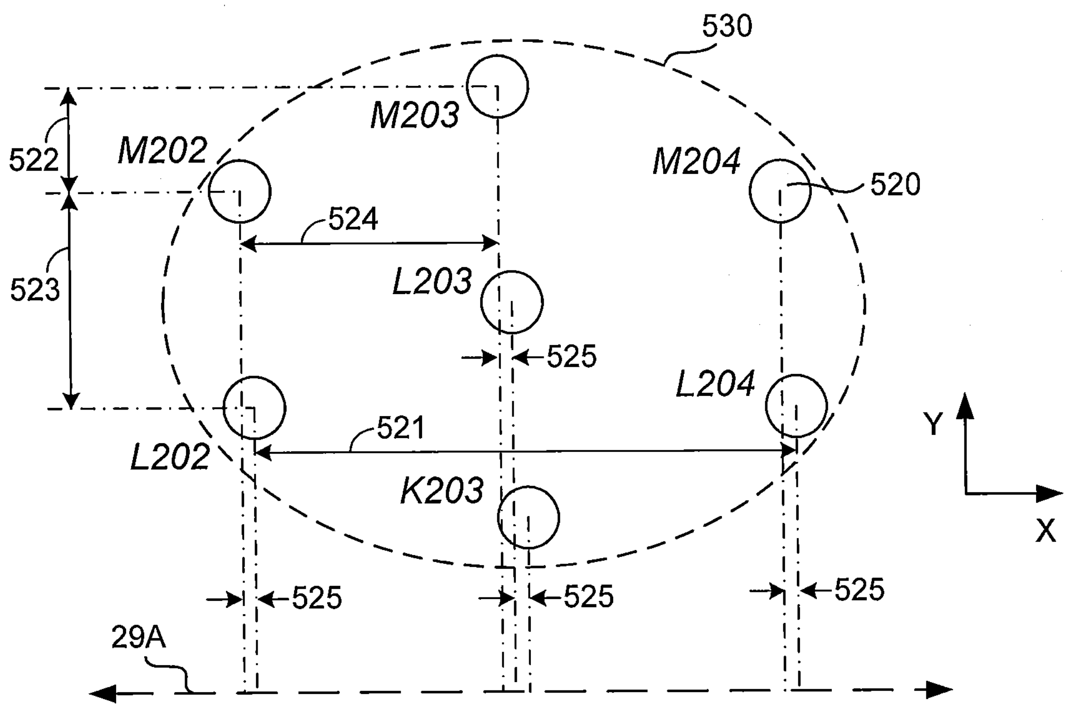

530
M203
M202
M204
520
522
524
523
L203
525
L204
L202
521
K203
Y
X
525
525
525
29A

FIG. 9A

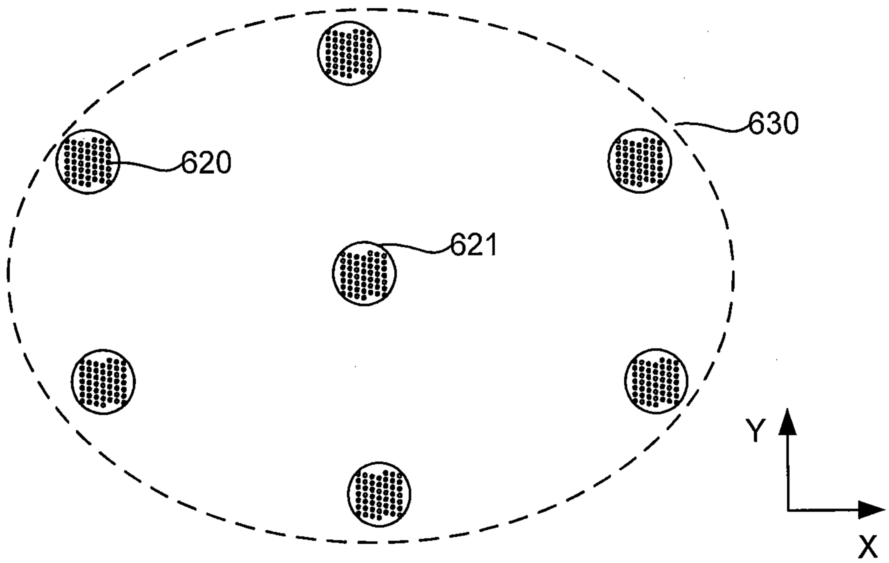

630
620
621
Y
X

FIG. 9B

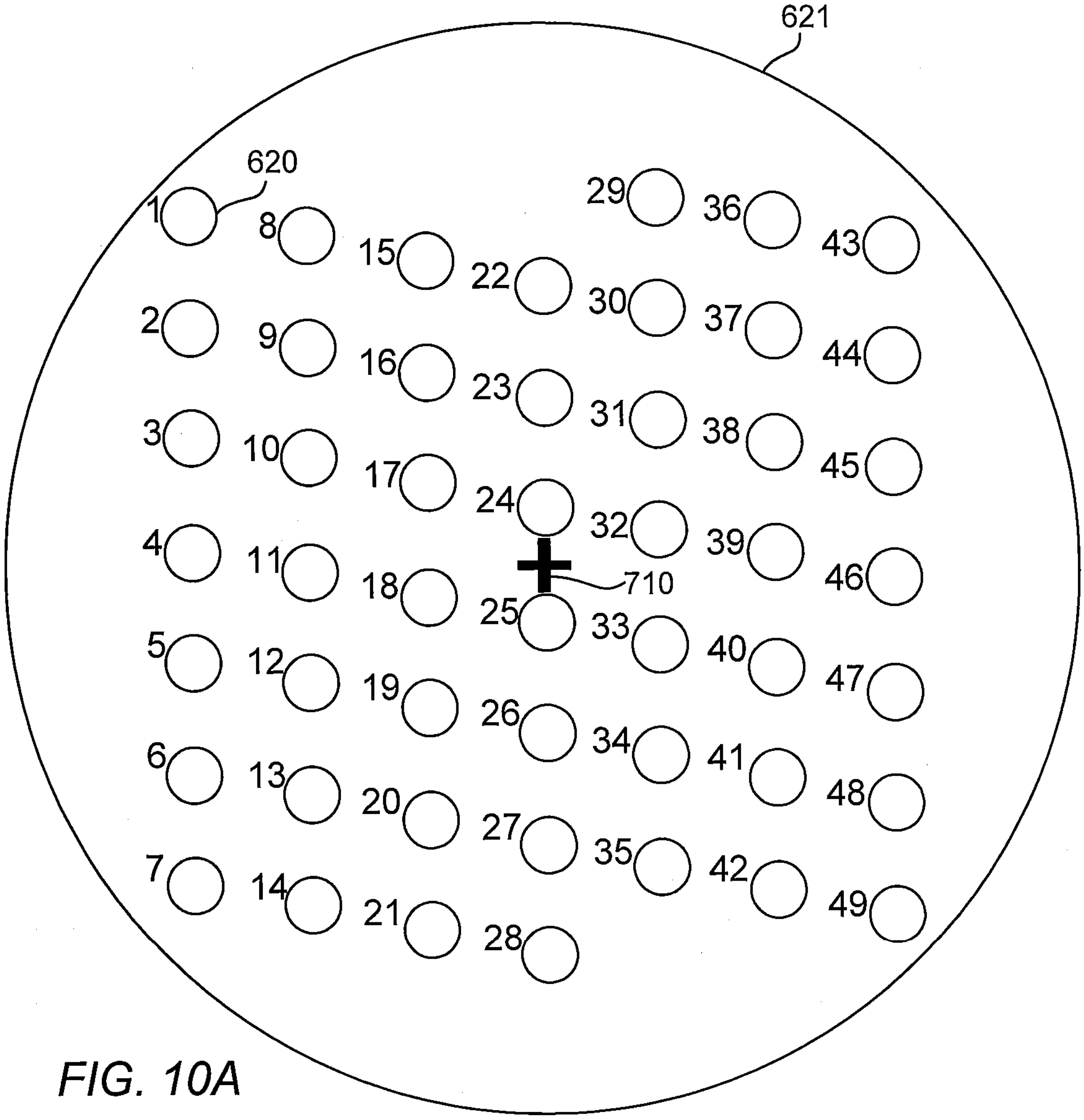


FIG. 10A

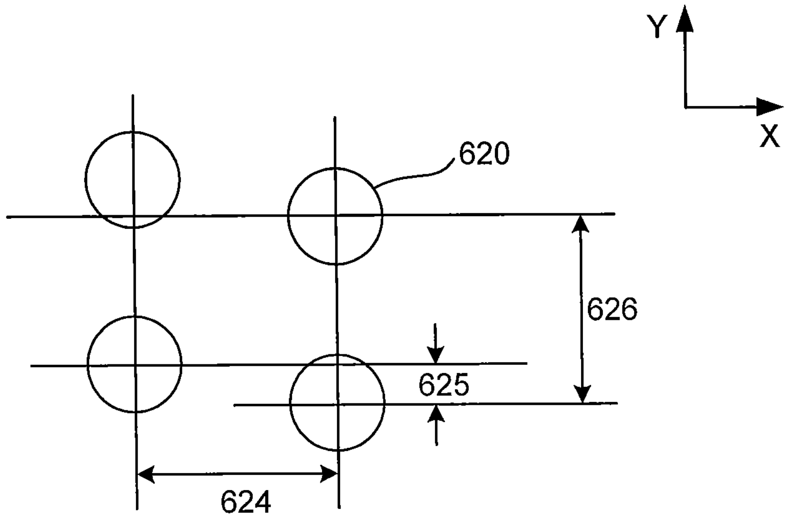


FIG. 10B

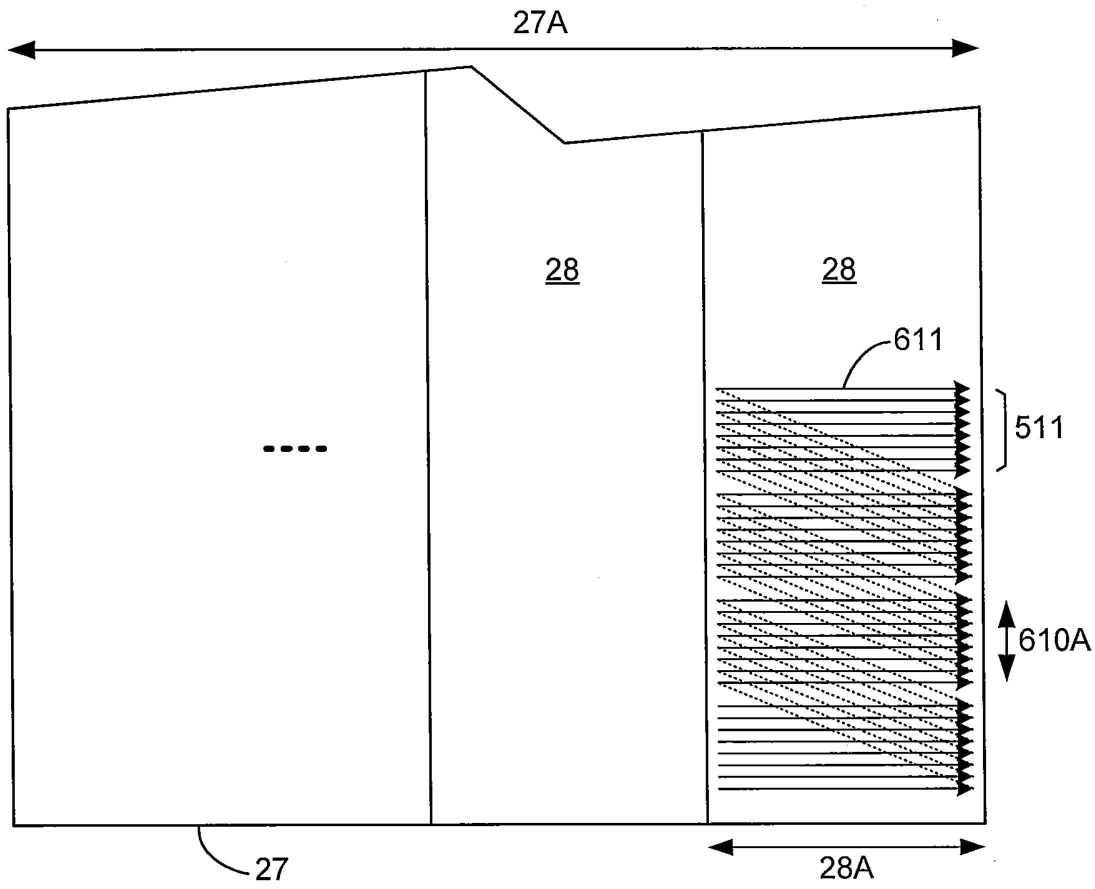


FIG.11A

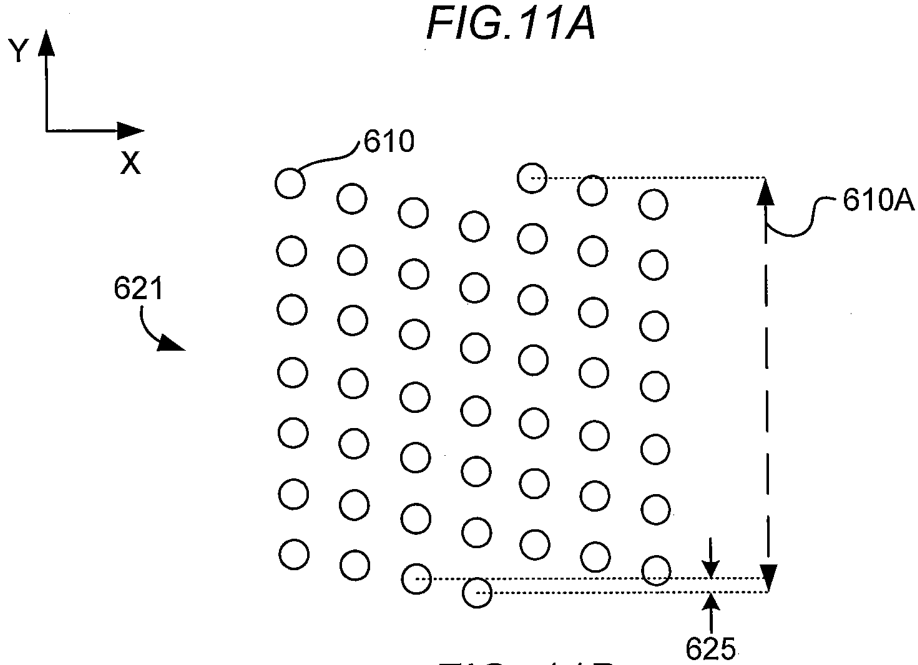
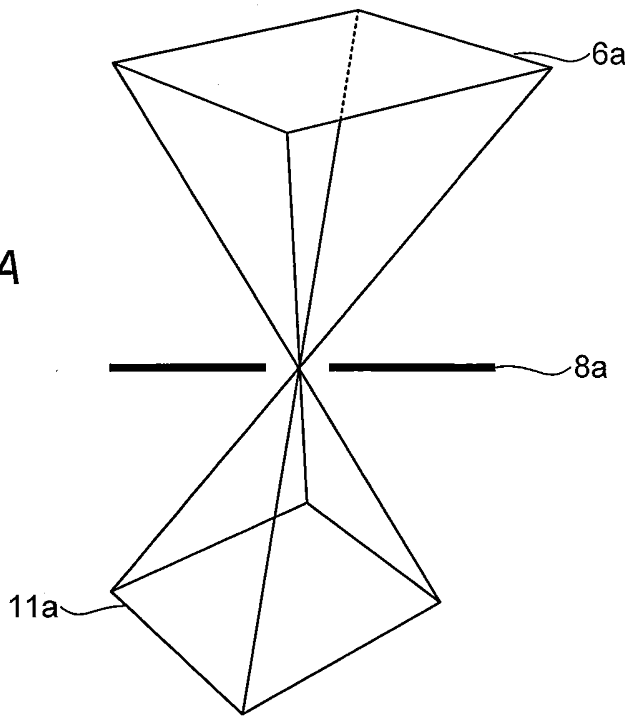


FIG. 11B

FIG.12A



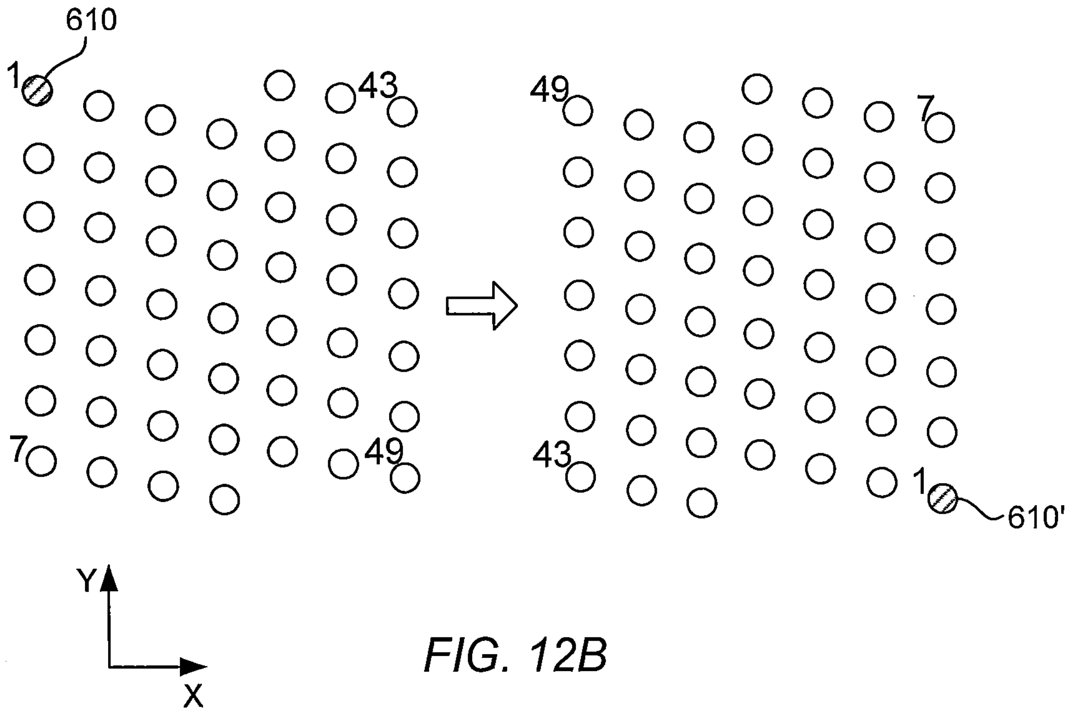


FIG. 12B

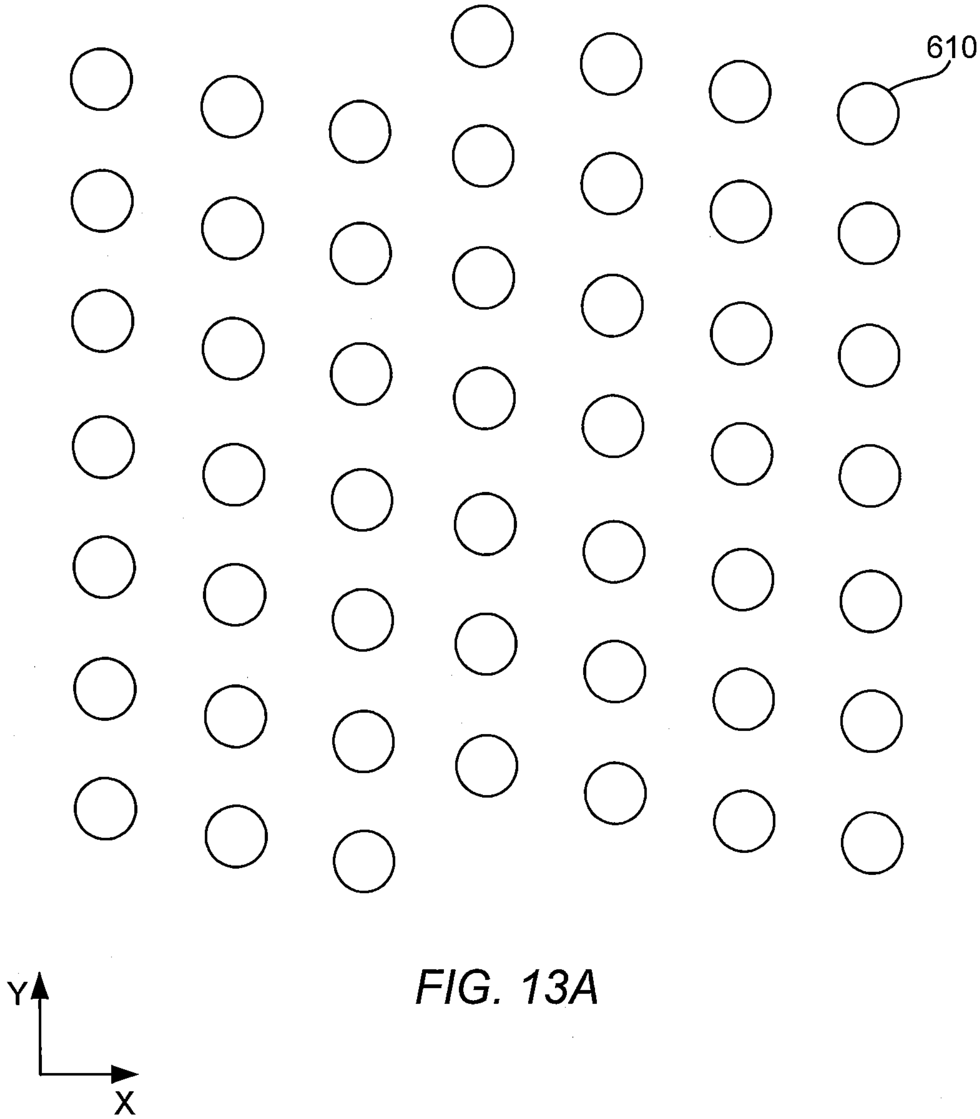
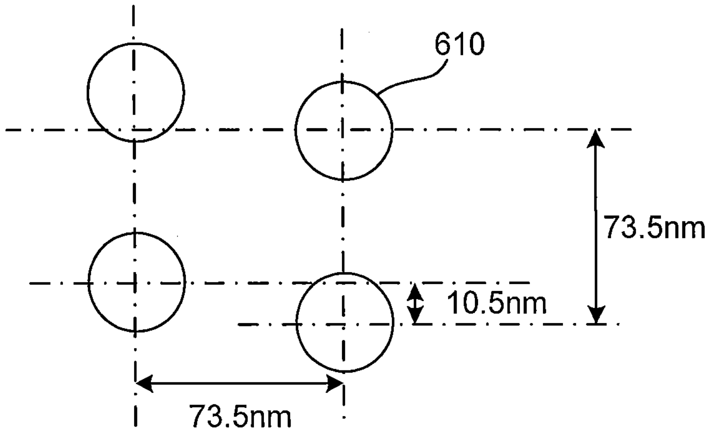
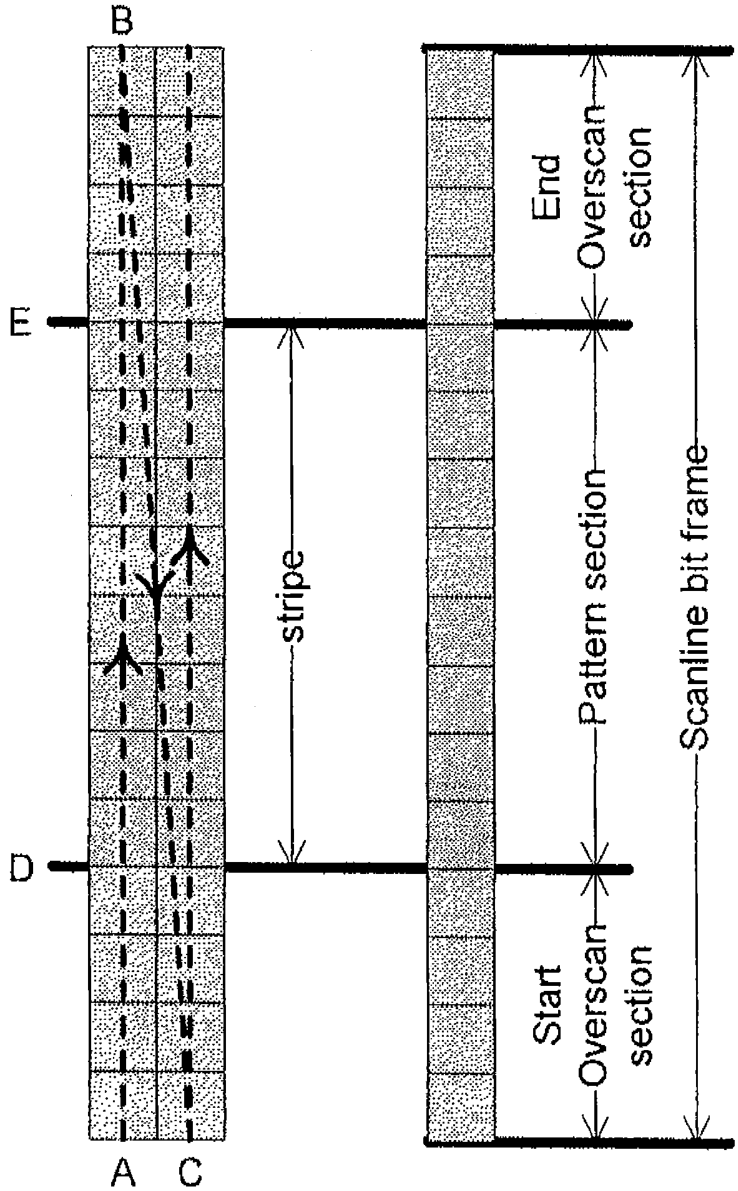


FIG. 13A

FIG. 13B





B
E
D
A
C
stripe
End
Overscan
section
Pattern section
Start
Overscan
section
Scanline bit frame

FIG. 14

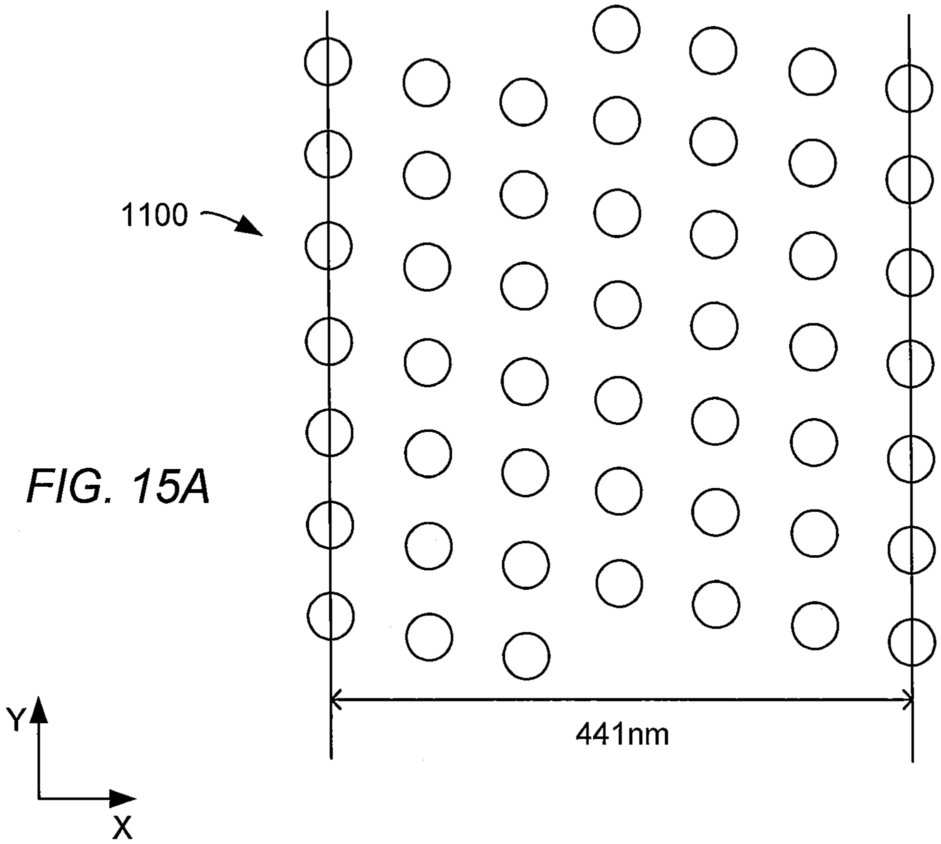


FIG. 15A

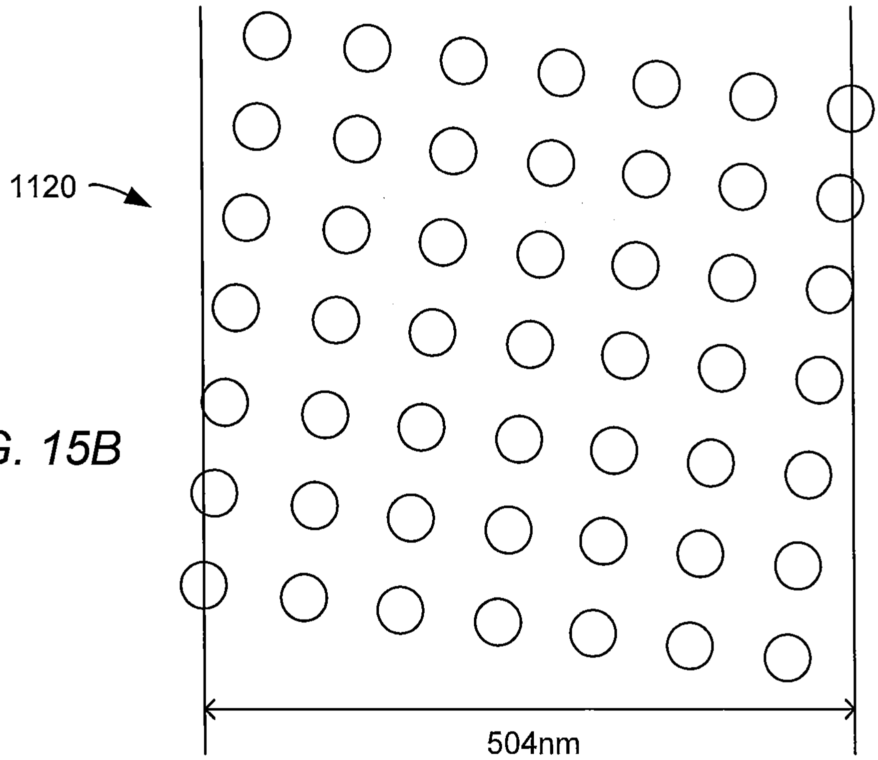


FIG. 15B

Agentschap NL
Ministerie van Economische Zaken

OCTROOIAANVRAAG NR.:
NO 138683
NL 2010760

ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR

Categorie[1]	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie (IPC)
	EENHEID VAN UITVINDING ONTBREEKT zie aanvullingsblad B -----		INV. H01J37/317
X	WO 2007/048433 A1 (ZEISS CARL SMS GMBH [DE]; PLATZGUMMER ELMAR [AT]; KNIPPELMEYER RAINER) 3 mei 2007 (2007-05-03) * bladzijde 9, regels 9-10; figuur 3 * * bladzijde 12, regels 17-20 * -----	1-7, 23-36	
X	US 5 369 282 A (ARAI SOICHIRO [JP] ET AL) 29 november 1994 (1994-11-29) * figuur 13 * -----	1-7, 23-36	

Onderzochte gebieden van de techniek: H01J

Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:

Plaats van onderzoek:	Datum waarop het onderzoek werd voltooid:	Bevoegd ambtenaar:
München	29 januari 2014	Oestreich, Sebastian

[1] CATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur
T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvrage vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

1

EOB FORM 02.83 (P0414B)

GEBREK AAN EENHEID VAN UITVINDING

Octrooiaanvrage Nr.:

NO 138683
NL 2010760

AANVULLINGSBLAD B

De Instantie belast met het uitvoeren van het onderzoek naar de stand van de techniek heeft vastgesteld dat deze aanvrage meerdere uitvindingen bevat, te weten:

1. conclusies: 1-36

   Multi-beam array with hexagonal arrangement of apertures

   ---

2. conclusies: 37-46

   Multi-beam array with unbalanced array arrangement of apertures; Method of exposing a target

   ---

Het vooronderzoek werd tot het eerste onderwerp beperkt.

AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK, UITGEVOERD IN DE OCTROOIAANVRAGE NR.

NO 138683
NL 2010760

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.
De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per
De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

29-01-2014

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
WO 2007048433 A1	03-05-2007	AT 424621 T	15-03-2009
		EP 1943660 A1	16-07-2008
		JP 4843679 B2	21-12-2011
		JP 2009514200 A	02-04-2009
		US 2009212240 A1	27-08-2009
		WO 2007048433 A1	03-05-2007
US 5369282 A	29-11-1994	GEEN	

OCTROOICENTRUM NEDERLAND

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER	INDIENINGSDATUM	VOORRANGSDATUM	AANVRAAGNUMMER
NO138683	06.05.2013		NL2010760
CLASSIFICATIE INV. H01J37/317			
AANVRAGER Mapper Lithography IP B.V.			

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☒ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☒ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☐ Onderdeel VII Overige gebreken
- ☐ Onderdeel VIII Overige opmerkingen

	DE BEVOEGDE AMBTENAAR
	Oestreich, Sebastian

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2010760

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.

2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:

   a. type materiaal:

   - ☐ sequentie opsomming
   - ☐ tabel met betrekking tot de sequentie lijst

   b. vorm van het materiaal:

   - ☐ op papier
   - ☐ in elektronische vorm

   c. moment van indiening/aanlevering:

   - ☐ opgenomen in de aanvraag zoals ingediend
   - ☐ samen met de aanvraag elektronisch ingediend
   - ☐ later aangeleverd voor het onderzoek

3. ☐ In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.

4. Overige opmerkingen:

SCHRIFTELIJKE OPINIE

Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk

De vraag of de uitvinding in de aanvraag nieuw, inventief en industrieel toepasbaar is, wordt niet behandeld in deze schriftelijke opinie met betrekking tot:

☐ de gehele aanvraag

☒ conclusies 37-46

omdat:

☐ deze aanvraag of deze conclusies , betrekking hebben op materie waarvoor het niet zinvol is een schriftelijke opinie op te stellen.

☐ de beschrijving, figuren of deze conclusies , , zo onduidelijk zijn dat het niet zinvol is een schriftelijke opinie op te stellen.

☐ deze conclusies , onvoldoende steun vinden in de beschrijving waardoor het niet zinvol is een schriftelijke opinie op te stellen.

☒ geen onderzoek naar de stand van de techniek is uitgevoerd voor deze conclusies 37-46.

☐ een zinvolle schriftelijke opinie niet opgesteld kon worden omdat de sequentie opsomming niet beschikbaar was in het juiste formaat, of in het geheel niet beschikbaar was (WIPO ST25).

☐ een zinvolle schriftelijke opinie niet opgesteld kon worden zonder de tabellen met betrekking tot de sequentie opsommingen; of deze tabellen waren niet beschikbaar in elektronische vorm.

☐ Zie aparte bladzijde

Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding

1. Vastgesteld is dat de octrooiaanvraag betrekking heeft op meer dan één uitvinding.

   Zie aparte bladzijde

2. Het onderzoek naar de stand van de techniek is beperkt tot de eerstgenoemde uitvinding in de conclusies en betreft:

   ☐ alle conclusies

   ☒ conclusies: (zie nieuwheidsrapport)

SCHRIFTELIJKE OPINIE

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja:	Conclusies	4, 8-22, 28
	Nee:	Conclusies	1-3, 5-7, 23-27, 29-36
Inventiviteit	Ja:	Conclusies	8-22
	Nee:	Conclusies	1-7, 23-36
Industriële toepasbaarheid	Ja:	Conclusies	1-36
	Nee:	Conclusies	

2. Citaties en toelichting:

Zie aparte bladzijde

Reference is made to the following documents:

D1 WO 2007/048433 A1 (ZEISS CARL SMS GMBH [DE]; PLATZGUMMER ELMAR [AT]; KNIPPELMEYER RAINER) 3 mei 2007 (2007-05-03)

D2 US 5 369 282 A (ARAI SOICHIRO [JP] ET AL) 29 november 1994 (1994-11-29)

Re Item IV

Lack of unity of invention

Document D1 discloses

Een lithografiesysteem op basis van geladen deeltjes voor het belichten van een doel (*wafer* 25) met behulp van een veelheid van geladen deeltjes deelbundels, waarbij het systeem omvat:
een geladen deeltjesgenerator (*electron beam source* 3) voor het genereren van een bundel van geladen deeltjes;
een deelbundelapertuurarray (*plate defining a plurality of apertures* / part of *beam manipulation arrangement* 11) omvattende één of meer bundelgebieden, waarbij elk bundelgebied een veelheid van deelbundelaperturen omvat, waarbij de deelbundelapertuurarray is verschaft om de bundel geladen deeltjes te ontvangen en een veelheid van deelbundels (*electron beamlets* 13) te vormen op de locaties van de deelbundelaperturen; en
een projectielenssysteem (*objective lens arrangement* 21), geconfigureerd om de deelbundels te projecteren op het oppervlak van het doel (page 9, line 9-10);
waarbij de deelbundelaperturen zijn gerangschikt in een niet-regelmatig hexagonaal patroon, zodanig dat, wanneer geprojecteerd in een eerste richting op een lijn parallel aan een tweede richting, de deelbundelaperturen op gelijkmatige afstand van elkaar zijn gelegen langs de lijn, en waarbij de eerste richting verschillend is van de tweede richting (see Figure 3, lines 73 are said to be equally distanced on page 12, lines 17 and following; the irregular hexagonal arrangement can be obtained from the figure).

Thus, claim 1 is not new, and the first claim contributing over the prior art is claim 4. Claim 4 is however not considered to be inventive, and thus claim 8 is be considered as the first claim contributing substantially over the prior art, without affecting the outcome of the following assessment.

As a preliminary remark, claim 1 requires a hexagonal pattern for the apertures, which is not present in claims 37 to 46.

In a more formal way, the difference between the subject matter of claim 8 and the disclosure of document D1 is that it additionally comprises a beamlet aperture array which receives the partial beams and shapes them into multiple beamlets.

This is the special technical feature of claim 8.

This special technical feature is not present in any of claims 37 to 46, nor is any technical feature which could solve the technical task of creating multiple beamlets from the partial beams (corresponding technical feature) present in these claims.

Thus the first invention is defined by claim 8, wherein administratively claims 1- 36, which either depend on claim 8, or lack novelty or inventive step, have been covered in this opinion.

A second invention, and possibly further inventions are defined by claims 37 to 46.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Independent claims

The present application does not meet the criteria of patentability, because the subject-matter of **claim 1** is not new.

Document D1 discloses

Een lithografiesysteem op basis van geladen deeltjes voor het belichten van een doel (*wafer* 25) met behulp van een veelheid van geladen deeltjes deelbundels, waarbij het systeem omvat:
een geladen deeltjesgenerator (*electron beam source* 3) voor het genereren van een bundel van geladen deeltjes;
een deelbundelapertuurarray (*plate defining a plurality of apertures* / part of *beam manipulation arrangement* 11) omvattende één of meer bundelgebieden, waarbij elk bundelgebied een veelheid van deelbundelaperturen omvat, waarbij de deelbundelapertuurarray is verschaft om de bundel geladen deeltjes te ontvangen en een veelheid van deelbundels (*electron beamlets* 13) te vormen op de locaties van de deelbundelaperturen; en
een projectielenssysteem (*objective lens arrangement* 21), geconfigureerd om de deelbundels te projecteren op het oppervlak van het doel (page 9, line 9-10);
waarbij de deelbundelaperturen zijn gerangschikt in een niet-regelmatig hexagonaal patroon, zodanig dat, wanneer geprojecteerd in een eerste richting op een lijn parallel aan een tweede richting, de deelbundelaperturen op gelijkmatige afstand van elkaar zijn gelegen langs de lijn, en waarbij de eerste richting verschillend is van de tweede richting (see Figure 3, lines 73 are said to be equally distanced on page 12, lines 17 and following; the irregular hexagonal arrangement can be obtained from the figure).

Similarly, Document D2 discloses on Figure 13, a irregular hexagonal pattern (consider the aperture indicated as IB2, Ib1 and IB3 have the distance 2S, whereas the apertures 1A2, 1A3, 2A2 and 2A3 have a slightly larger distance from IB2). When projecting the columns along y on the x-direction, the distance is equal for neighboring columns.

The additional subject matter of dependent claims 2, 3, 5 to 7, 23 and 24 is already disclosed in documents D1 and D2, see the passages cited.

The subject matter of **claim 25** is broader than that of claim 1, in that it only addresses the aperture array, and it does not contain any further technical detail, not already present in claim 1.

The reasoning above thus applies as well for claim 25.

For claims 26,27, 29-31 the same applies as for claims 2, 3, 5 to 7, 23 and 24 mentioned above.

Claim 32 is even less specific than claim 25, as it does not comprise the requirement of hexagonal arrangement. The features present in claim 32 are all present in claim 25, with the difference of naming the directions for projecting (third and fourth direction in claim 32 versus first and second direction in claim 25), which however are meaningless without any further details on these directions.

The reasoning above thus applies as well for claim 32.

Claim 33 refers to an entity not defined in the claim or any claim it refers to (*aparte deelbundel van geladen deeltjes, geprojecteerd op de beamletapertuurarray*), and can thus not establish novelty.

The additional subject matter of dependent claims 34 - 36 is already disclosed in documents D1 and D2.

It is believed, that the additional subject matter of dependent claims 4 and 28 is a design option well within the reach of a person skilled in the art.

The subject matter of claim 8 is presently not known from the available prior art. It solves the technical problem of creating multiple beamlets from the partial beams created from the aperture array with the hexagonal pattern, which is not suggested by the prior art considered so far in the procedure.