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[11] 3,900,736

Michail et al.

[45] Aug. 19, 1975

[54] METHOD AND APPARATUS FOR POSITIONING A BEAM OF CHARGED PARTICLES

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[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

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[21] Appl. No.: **437,585**

[52] **U.S. Cl.** .... **250/492 A**; 219/121 EB

[51] **Int. Cl.**² **H01J 37/00**

[58] **Field of Search** .... 250/492 A, 398; 219/121 EB; 148/1.5

[56] **References Cited**

UNITED STATES PATENTS

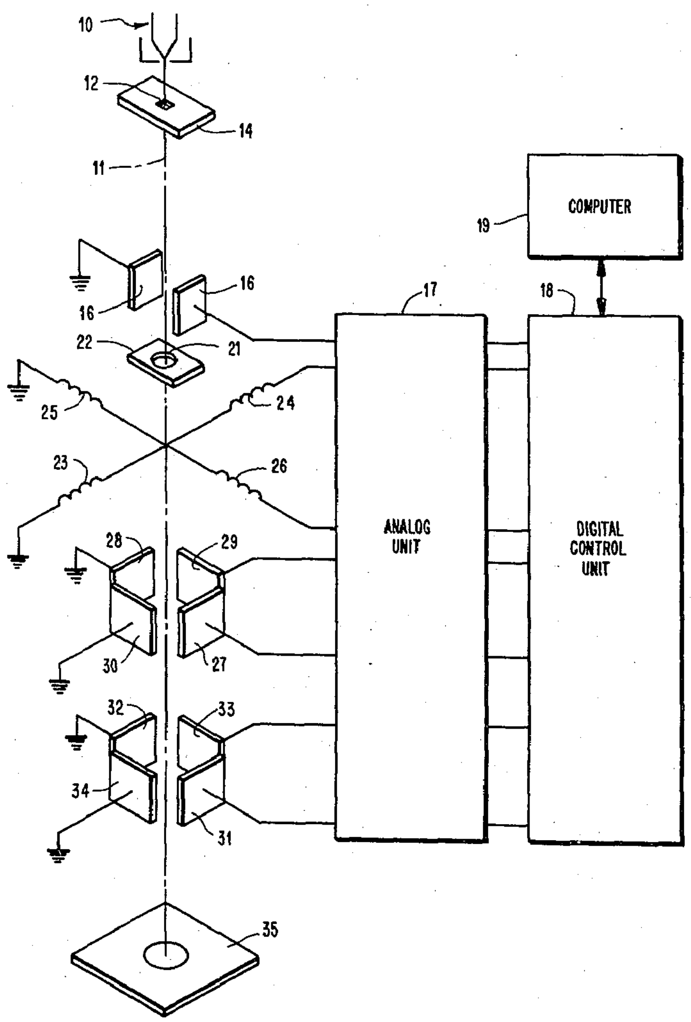
3,644,700	2/1972	Kruppa	250/492 A
3,651,303	3/1972	Rehme	250/492 A

Primary Examiner—Craig E. Church
Attorney, Agent, or Firm—Frank C. Leach, Jr.; Theodore E. Galanthay

[57] **ABSTRACT**

A beam of charged particles is stepped from one predetermined position to another to form a desired pattern on a semiconductor wafer to which the beam is applied in accordance with a predetermined pattern. Instead of the beam being stepped to each of the predetermined positions, there is a dynamic correction for the deviation of the actual position from its predetermined position so that the beam is applied to the deviated position rather than the predetermined position whereby the pattern is written within the boundaries of the writing field as determined by the location of four registration marks, which are in four separate positions or points in the field. Through location of each of the four registration marks, the writing field is precisely defined. Writing fields may be interconnected by the sharing of registration marks enabling the construction of chips which are larger than a single writing field.

27 Claims, 7 Drawing Figures



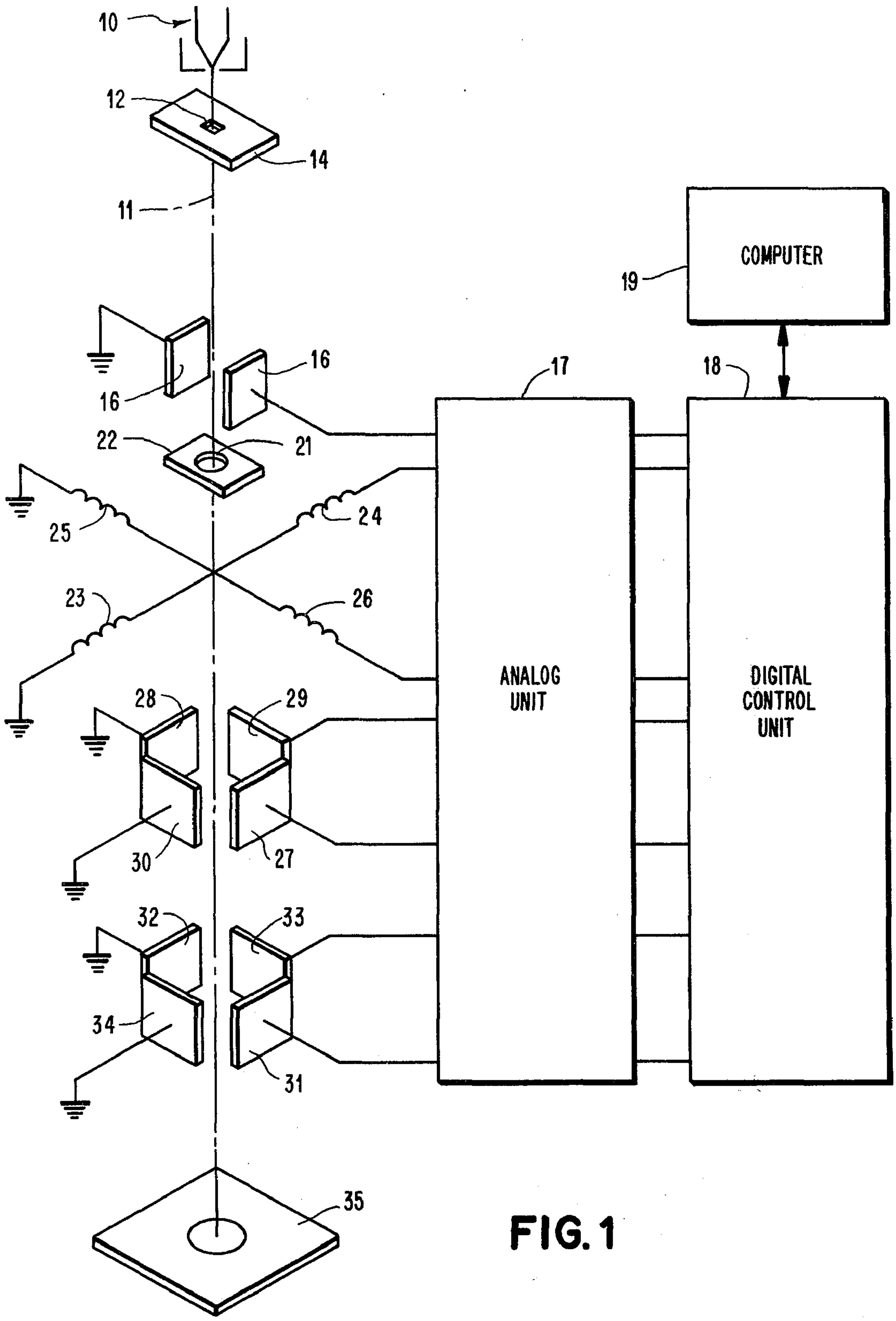

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FIG. 1

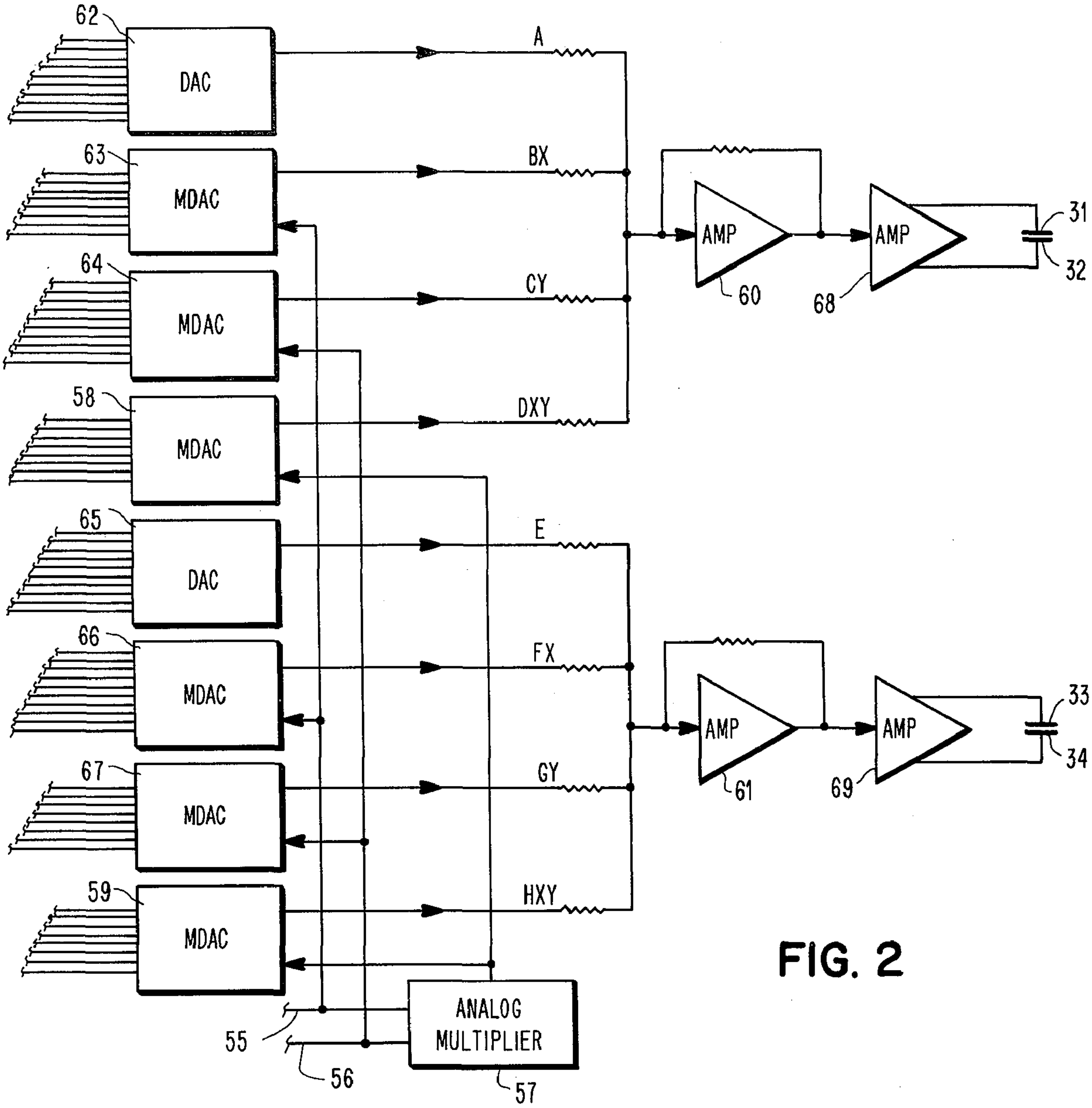

FIG. 2

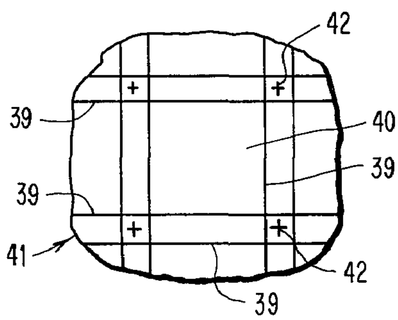

FIG. 4

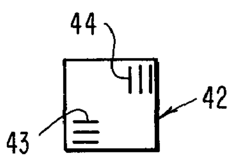

FIG. 5

FIG. 7

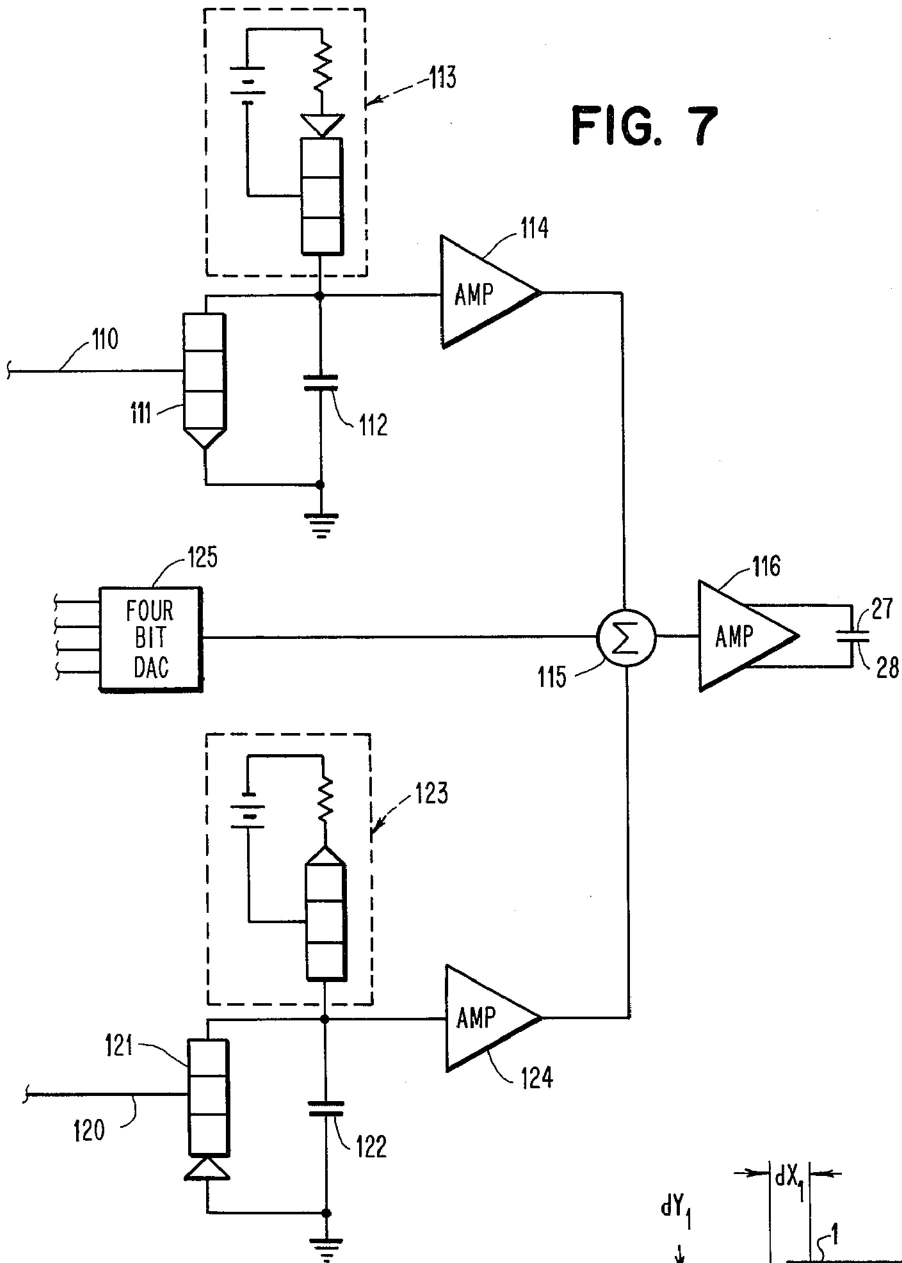
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FIG. 3

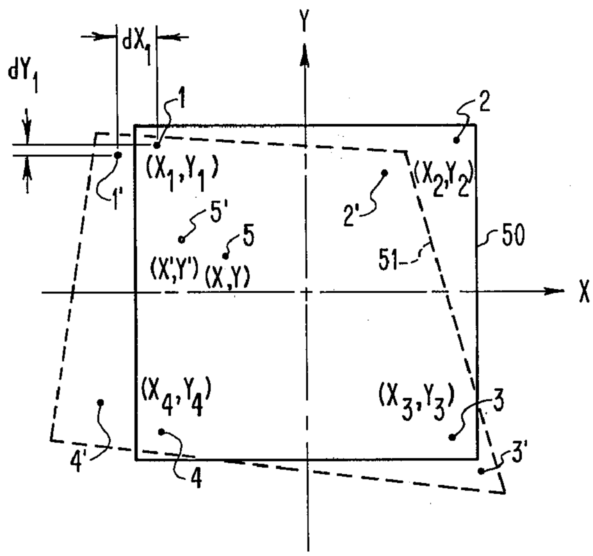
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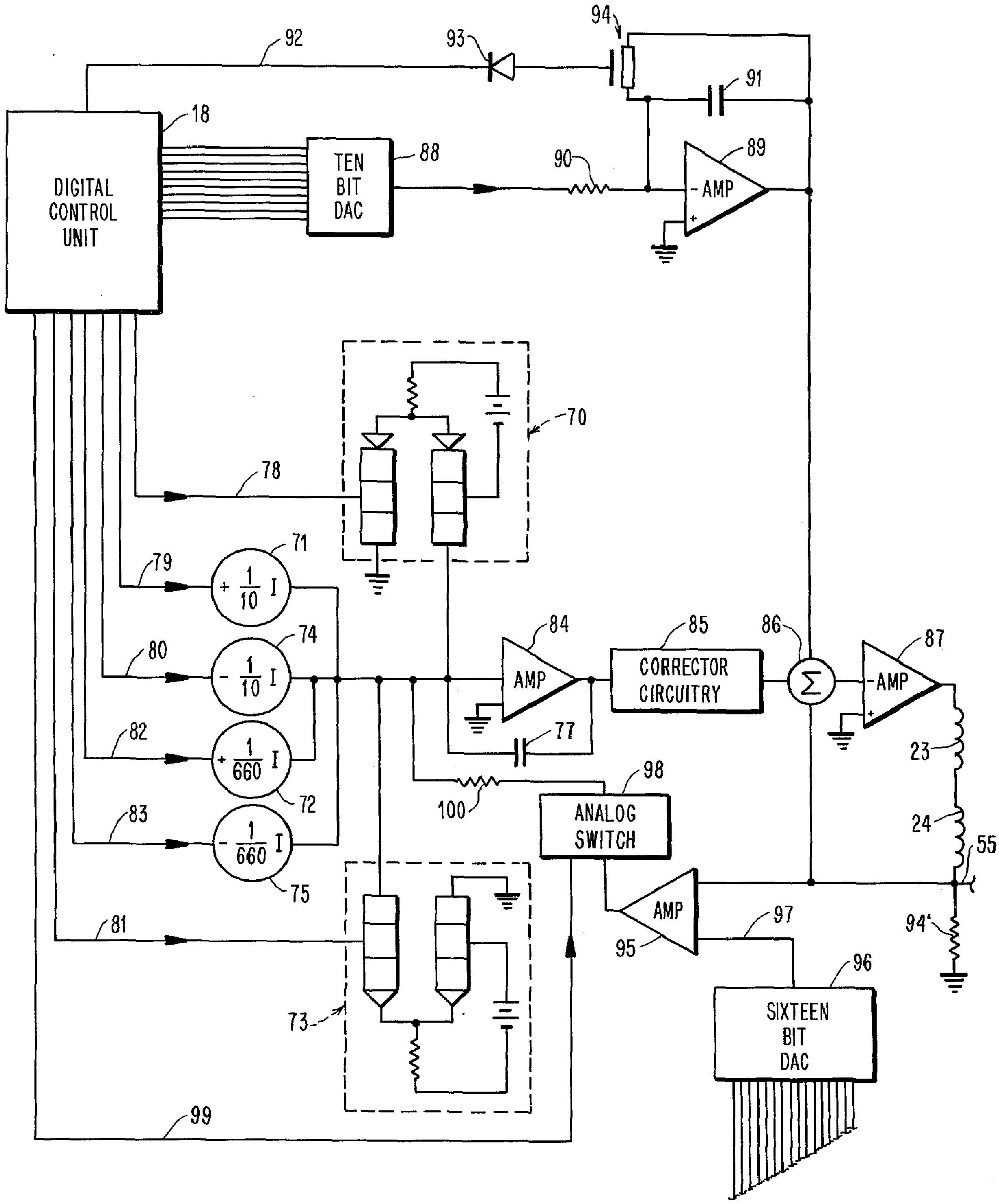
FIG. 6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METHOD AND APPARATUS FOR POSITIONING A BEAM OF CHARGED PARTICLES

In U.S. Pat. No. 3,644,700 to Kruppa et al., there is shown a method and apparatus for controlling a square-shaped beam. The beam is employed to both write desired patterns on chips of a semiconductor wafer and to locate each chip relative to a predetermined position through determining the positions of a pair of registration marks for each chip by utilization of the beam. In the aforesaid Kruppa et al patent, the location of the two registration marks insures that the pattern can be written within the chip.

Because of the accuracy required in applying the beam to a field, the size of each chip site must be limited to that of the writing field so that any beam error therein is within a certain range. Accordingly, the size of the writing fields cannot be enlarged to enable a single pattern to be written within a single writing field, which defines the maximum size of a chip site in the aforesaid Kruppa et al patent, when the pattern size exceeds the maximum field size within which the beam can be written and still have the beam error within the desired range.

The present invention is an improvement of the method and apparatus of the aforesaid Kruppa et al patent in that a single pattern can be written in more than one writing field rather than being limited to one writing field. Thus, the method and apparatus of the present invention permit a semiconductor wafer to have continuous patterns larger than the field to which the beam can be applied accurately to be written therein.

The present invention accomplishes this through utilizing a plurality of square or rectangular shaped fields with each field overlying each of the adjacent fields. Thus, each field, which is not on the periphery of the fields of the wafer, has an overlying relation with four other adjacent fields. In each of the four corners of the field, a registration mark is disposed in the overlying area of the adjacent fields.

While it is desired for each of these registration marks to be at a design position so that the registration marks would define a four sided rectangular or square shaped field having the registration marks at their corners, there is usually some slight deviation of each of the registration marks from its design position since the registration marks are written on the wafer within a certain tolerance. Therefore, the registration marks are normally not at their design positions but at some deviation therefrom. By ascertaining the deviation of each of the four registration marks for a particular field from the design locations for the registration marks, the boundaries of the writing field are located.

Since the beam is being applied in accordance with a predetermined pattern in which the field was deemed to be a perfect square or rectangle, these deviations of the registration marks for the particular field result in the field not being a perfect square or rectangle. Therefore, if the beam were to be applied in accordance with the predetermined pattern, the beam may be applied beyond the boundaries defined by the registration marks and into another field if correction is not made.

While the patterns for writing within a specific field would be such as to insure that the beam is not applied beyond the field even with the deviations of the marks, this cannot be employed when writing a single pattern in more than one field. This is because the beam must

be applied to each field separately because of the required accuracy of the beam with respect to field size. Thus, each line of the beam must stop at a specific boundary so that when the beam is applied to the next adjacent field it will be applied as a continuation of the prior location of the beam at the boundary between the two adjacent field.

Accordingly, to insure that the beam is applied within the boundaries of the field as defined by the actual locations of the registration marks relative to the beam, it is necessary to dynamically correct the position of the beam when it is stepped from one predetermined position to the next within the field so that the beam is applied to an actual position, which is a deviation from the predetermined position, in accordance with the actual site of the field as defined by the four registration marks of the field. By this dynamic correction at each of the predetermined positions, the beam writes the pattern within the field boundaries as defined by the actual locations of the registration marks.

When the fields are written by moving the beam from one field to the next adjacent field in the X direction and to the right, the registration marks in the upper and lower right hand corners of the first field will be the registration marks in the upper and lower left hand corners for the next field. Therefore, these two registration marks define the common boundary between the two fields and function as reference points to which the beam is applied at the next of the adjacent fields. The other boundaries of the field are similarly defined with respect to the registration marks of the other adjacent fields.

It should be understood that reference points could be ascertained relative to the actual locations of the registration marks and used to define the boundaries of the field rather than the registration marks per se. This shift would be accomplished within the computer, but it would not have any effect on the concept of the pattern being written within the field as defined by the four registration marks at the corners of the field.

Through ascertaining the actual location of each of the registration marks of a field, various digital constants can be determined and applied throughout writing of the pattern within the particular field. The digital constants are utilized to correct for translation, magnification, rotation, and distortion of the beam in the X and Y directions. By using the magnetic deflection voltages for each of the X and Y directions at each of the predetermined positions to which the beam is to be applied and then modifying these voltages by the appropriate digital constants for the particular field, correction voltages are applied for both the X and Y directions to a set of electrostatic field plates to shift the beam from the predetermined position to the actual deviated position in accordance with the actual field as defined by the actual location of the registration marks.

As a result of applying the correction voltage to shift the beam, the beam is written within the boundaries of the field since the beam would either be compressed or extended, for example, in each line to compensate for the difference between the predetermined position and the actual position.

The method and apparatus of the present invention is particularly useful when it is desired to write a plurality of patterns at different levels of a chip with each level being written at a different time. Thus, the present invention enables overlay accuracy between the written fields at various levels on a chip.

The present invention accomplishes this through ascertaining the actual location of each of the four registration marks of a field, as previously mentioned, and retaining these actual locations for reference throughout the various levels of pattern writing. If it should be necessary to use a new set of registration marks, these would be written with their actual locations determined with respect to the actual locations of the prior registration marks, which define the field. Thus, by using the digital constants to correct the translation, magnification, rotation, and distortion of the beam in the X and Y directions, the beam can always be shifted from its predetermined position to its actual deviated position irrespective of the level at which the pattern is being written to insure that the pattern at each level has an accurate overlay with the patterns at other levels of the field.

An object of this invention is to dynamically position a beam of charged particles at each of the positions to which it is moved within a field on a semiconductor wafer in accordance with the boundaries of the field.

Another object of this invention is to provide a method and apparatus for writing a continuous pattern with a beam of charged particles in more than one field on a semiconductor wafer with each field having a separate portion of the pattern written therein at various times.

A further object of this invention is to dynamically position a beam of charged particles at each of the positions to which it is moved within an area on a target in accordance with the actual boundaries of the area.

Still another object of this invention is to provide a method and apparatus for writing a continuous pattern with a beam of charged particles in more than one area of a target with each area having a separate portion of the pattern written therein at different times.

A still further object of this invention is to provide a method and apparatus for automatically overlaying two separate patterns written within an area on a target or within a field on a semiconductor wafer with each pattern written therein at various times.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a schematic view showing an electron beam and the apparatus for controlling the beam.

FIG. 2 is a schematic block diagram of a circuit arrangement for dynamically supplying signals to shift the beam from each of its predetermined positions to the actual deviated position in accordance with the location of the registration marks of the field to which the beam is being applied.

FIG. 3 is a schematic diagram showing the relation between an actual field to which the beam is to be applied in conjunction with the learn corrected field to which the beam would be applied without dynamic correction for the location of the registration marks.

FIG. 4 is a top plan view of a portion of a semiconductor wafer having fields to which the beam is to be applied and showing the relation of the overlapping fields.

FIG. 5 is an enlarged top plan view of a registration mark that identifies one corner of a field within which an electron beam can write.

FIG. 6 is a schematic wiring diagram showing the magnetic deflection circuit for controlling the X magnetic deflection coils.

FIG. 7 is a schematic wiring diagram showing the electrostatic deflection circuit for controlling the X electrostatic deflection plates.

Referring to the drawings and particularly FIG. 1, there is shown an electron gun **10** for producing a beam **11** of charged particles in the well-known manner. The electron beam **11** is passed through an aperture **12** in a plate **14** to shape the beam **11.** The beam **11** is preferably square shaped and has a size equal to the minimum line width of the pattern that is to be formed.

The beam **11** passes between a pair of blanking plates **16**, which determine when the beam **11** is applied to the material and when the beam **11** is blanked. The blanking plates **16** are controlled by circuits of an analog unit **17**. The analog unit **17** is controlled by a digital control unit **18** in the manner more particularly shown and described in the copending patent application of Philip M. Ryan for "Method And Apparatus For Controlling Movable Means Such As An Electron Beam," Ser. No. 398,734, filed Sept. 19, 1973, and assigned to the same assignee as the assignee of this application. The digital control unit **18** is connected to a computer **19**, which is preferably an IBM 370 computer.

The beam **11** then passes through a circular aperture **21** in a plate **22**. This controls the beam **11** so that only the charged particles passing through the centers of the lenses (not shown) are used so that a square-shaped spot without any distortion is produced.

The beam **11** is next directed through magnetic deflection coils **23, 24, 25,** and **26.** The magnetic deflection coils **23** and **24** control the deflection of the beam **11** in a horizontal or X direction while the magnetic deflection coils **25** and **26** control the deflection of the beam **11** in a vertical or Y direction. Accordingly, the coils **23–26** cooperate to move the beam **11** in a horizontal scan by appropriately deflecting the beam **11.**

While the beam **11** could be moved in a substantially raster fashion as shown and described in the aforesaid Kruppa et al patent, it is preferably moved in a back and forth scan so that the beam **11** moves in opposite directions along adjacent lines as shown and described in the aforesaid Ryan application. Thus, the negative bucking sawtooth of the type shown in FIG. 3b of the aforesaid Kruppa et al patent is supplied to the coils **23** and **24** during forward scan while a positive bucking sawtooth, which is of opposite polarity to the sawtooth shown in FIG. 3b of the aforesaid Kruppa et al patent, is supplied to the coils **23** and **24** during the backward scan.

The beam **11** then passes between a first set of electrostatic deflection plates **27, 28, 29,** and **30.** The electrostatic deflection plates **27** and **28** cooperate to deflect the beam in a horizontal or X direction while the electrostatic deflection plates **29** and **30** cooperate to move the beam **11** in the vertical or Y direction. The plates **27-30** are employed to provide any desired offset of the beam **11** at each of the predetermined positions or spots to which it is moved. In the aforesaid Kruppa et al patent, the plates **27–30** corrected for linearity, but these correction signals are supplied to the coils **23–26** in this application.

After passing between the electrostatic deflection plates 27–30, the beam 11 then passes between a second set of electrostatic deflection plates 31, 32, 33, and 34. The electrostatic deflection plates 31 and 32 cooperate to deflect the beam 11 in the horizontal or X direction while the electrostatic deflection plates 33 and 34 cooperate to deflect the beam 11 in the vertical or Y direction. The plates 31 and 32 deflect the beam 11 in the X direction and the plates 33 and 34 deflect the beam 11 in the Y direction from each of the predetermined positions to which it is moved in accordance with its predetermined pattern so that the beam 11 is applied to its actual position based on the deviation of the area from its designed position, both shape and location, in which the beam 11 is to write.

The beam 11 is then applied to a target, which is supported on a table 35. The table 35 is movable in the X and Y directions as more particularly shown and described in the aforesaid Kruppa et al patent.

The beam 11 is moved through A, B, and C cycles as shown and described in the aforesaid Kruppa et al patent. The present invention is concerned with supplying signals to shift the beam 11 from each of the predetermined positions to which it is stepped to a deviated actual position, which is determined by the location of an actual field in comparison with the design field, during the B cycle when the pattern is being written.

As shown in FIG. 4, the target may comprise a plurality of fields 39 which overlap each other. A chip 40 may be formed within each of the fields 39 so that there is a plurality of the chips 40 on a semiconductor wafer 41 with each of the chips 40 having resist to be exposed by the beam 11.

It should be understood that the chip 40 may comprise a plurality of the fields 39 or one of the fields 39 may have a plurality of the chips 40. The following description will be with one of the chips 40 formed within each of the fields 39.

There is a registration mark 42 (schematically shown as a cross in FIG. 4) at each of the four corners of each of the fields 39. As shown in FIG. 4, the overlapping of the adjacent fields 39 results in the same registration mark 42 being utilized for each of four different adjacent fields 39. Thus, the registration mark 42 in the lower right corner of the only complete field 39 shown in FIG. 4 also is the registration mark in the lower left corner for the field 39 to the right of the complete field 39, the upper right corner of the field below the complete field 39, and the upper left corner of the field 39 which is diagonally to the right of the completed field 39.

Each of the registration marks 42 is preferably formed of a plurality of horizontally extending bars 43, preferably three in number as shown in FIG. 5, and a plurality of vertically extending bars 44, preferably equal in number to the number of the bars 43. Any other suitable arrangement of registration marks can be employed in which there can be scan of vertical edges of the mark in the X direction and of horizontal edges of the mark in the Y direction.

The overlapping of the fields 39 enables writing to occur between the adjacent fields. The boundary of each of the chips 40 is within the overlapping area of the field 39 of the chip 40 and is normally defined by the lines extending between the registration marks 42.

As explained in the copending patent application of Ollie C. Woodard for "Method And Apparatus For Detecting The Registration Mark On A Target Such As A Semiconductor Wafer," Ser. No. 437,434, filed Jan. 28, 1974, and assigned to the same assignee as the assignee of this application, the exact location of each of the registration marks 42 is obtained through passing the electron beam 11 over the vertical edges of the vertically disposed bars 44 of the mark 42 during scans in the X direction and over the horizontal edges of the horizontally disposed bars 43 of the mark 42 during scans in the Y direction. Thus, as described in the aforesaid Woodard application, the actual location of each of the registration marks 42 is obtained.

If the registration marks 42 were located at their design positions, then the design field, as defined by the registration marks 42 being located at design positions 1, 2, 3, and 4 in FIG. 3, would exist, and the beam 11 would be applied thereto. The design field 50 would be a perfect square or rectangle and is the learn corrected field.

However, because of various factors such as the condition of the surface of the wafer 41, the material of the wafer 41 at the particular level, the tilt of the wafer 41, rotational error due to location of the wafer 41, positional errors of the beam 11, and the errors in putting down the registration marks 42, the registration marks 42 are not located at the design positions 1, 2, 3, and 4 as shown in FIG. 3. Instead, because of these various factors, the registration marks 42 are located at positions such as positions 1', 2', 3', and 4', for example, as shown in FIG. 3. As a result, an actual field 51, which is not necessarily a perfect square or rectangle but is four sided, in which the beam 11 can write is produced by the registration marks 42 being at the positions 1', 2', 3', and 4' rather than the design positions 1, 2, 3, and 4.

If it is desired to write the pattern in both the chip 40 within the field 51 and the chip 40 within the field to the right of the field 51, for example, then the line between the positions 2' and 3' must be accurately defined so that the beam 11 will form a continuation of the same lines within the field 51 when writing in the field to the right of the field 51. The line defined between the positions 2' and 3' is the boundary between the chip 40 within the field 51 and the chip 40 within the field to the right of the field 51 so that this is a common boundary between the two chips 40. It should be understood that the area of the chip 40 within which the beam 11 writes need not be the entire field as defined by the positions of the registration marks 42 but can be smaller and use the registration marks 42 as reference points.

The difference between the design and actual positions of each of the registration marks 42 can be defined by setting forth the difference between the design and actual positions of the mark 42 in both the X and Y directions. The equations for any specific mark position are:

$$dX = A + BX + CY + DXY \quad (1)$$

and

$$dY = E + FX + GY + HXY. \quad (2)$$

In equations (1) and (2), X represents the design position of the mark in the X direction and Y represents the design position in the Y direction with dX being the distance between the design position and the actual position in the X direction and dY being the distance between the actual position and the design position in the Y direction. Each of A, B, C, D, E, F, G, and H is a digital constant which can be ascertained for the particular field within which the beam **11** is to be applied.

The digital constant A represents the translation of the beam in the X direction while the digital constant E represents the translation of the beam **11** in the Y direction. The digital constant B represents the magnification error in the X direction, and the digital constant G represents the magnification error in the Y direction. The digital constant C represents the rotation error of the beam **11** in the X direction, and the digital constant F represents the rotation error of the beam **11** in the Y direction. The digital constant D represents the distortion of the beam **11** in the X direction, and the digital constant H represents the distortion of the beam **11** in the Y direction.

Thus, to determine the distance between the four positions **1**, **2**, **3**, and **4** of the design registration marks for the design field **50** and the four positions **1'**, **2'**, **3'**, and **4'** for the actual registration marks defining the actual field **51**, the following equations would be employed for determining the distances in the X direction with each subscript corresponding to the particular position **1**, **2**, **3**, and **4**:

$$dX_1 = A + BX_1 + CY_1 + DX_1Y_1 \quad (3)$$

$$dX_2 = A + BX_2 + CY_2 + DX_2Y_2 \quad (4)$$

$$dX_3 = A + BX_3 + CY_3 + DX_3Y_3 \quad (5)$$

and

$$dX_4 = A + BX_4 + CY_4 + DX_4Y_4. \quad (6)$$

Similarly, each of the distances between the actual positions **1'**, **2'**, **3'**, and **4'** of the registration marks **42** with respect to the design positions **1**, **2**, **3**, and **4**, respectively, in the Y direction with the subscripts corresponding to the four positions **1**, **2**, **3**, and **4** are defined by the following equations:

$$dY_1 = E + FX_1 + GY_1 + HX_1Y_1 \quad (7)$$

$$dY_2 = E + FX_2 + GY_2 + HX_2Y_2 \quad (8)$$

$$dY_3 = E + FX_3 + GY_3 + HX_3Y_3 \quad (9)$$

and

$$dY_4 = E + FX_4 + GY_4 + HX_4Y_4. \quad (10)$$

As an example, the design field **50** is shown as being a square. With this example, the distance between the marks **42** at positions **1** and **2** in the design field **50** or positions **3** and **4** in the field **50** is the same and may be defined by W. Similarly, the height of the field **50** between the positions **1** and **4** or positions **2** and **3** is the same and may be defined as h.

With this special case of symmetry between the four positions **1**, **2**, **3**, and **4** and X being positive to the right and Y being positive downwardly in FIG. **3**, then the X and Y locations of each of the four positions can be determined relative to h and W. These are:

$$X_1 = \frac{-W}{2}, \qquad Y_1 = \frac{-h}{2}$$
$$X_2 = \frac{W}{2}, \qquad Y_2 = \frac{-h}{2}$$
$$X_3 = \frac{W}{2}, \qquad Y_3 = \frac{h}{2}$$

and

$$X_4 = \frac{-W}{2}, \qquad Y_4 = \frac{h}{2}.$$

With these values substituted in equations (3) to (6) for dX_1 to dX_4 and equations (7) to (10) for dY_1 to dY_4 and solving for the digital constants A to H, the following equations result:

$$A = \frac{dX_1 + dX_2 + dX_3 + dX_4}{4} \quad (11)$$

$$B = \frac{dX_2 - dX_1 + dX_3 - dX_4}{2W} \quad (12)$$

$$C = \frac{dX_4 - dX_1 + dX_2 - dX_3}{2h} \quad (13)$$

$$D = \frac{dX_3 - dX_4 + dX_1 - dX_2}{hw} \quad (14)$$

$$E = \frac{dY_1 + dY_2 + dY_3 + dY_4}{4} \quad (15)$$

$$F = \frac{dY_2 - dY_1 + dY_3 - dY_4}{2W} \quad (16)$$

$$G = \frac{dY_4 - dY_1 + dY_3 - dY_2}{2h} \quad (17)$$

and

$$H = \frac{dY_3 - dY_4 + dY_1 - dY_2}{hW} \quad (17)$$

Accordingly, since the distance of each of the actual positions **1'**, **2'**, **3'**, and **4'** from the design positions **1**, 2, 3, and **4**, respectively, in each of the X and Y directions can be ascertained with the method and apparatus shown and described in the aforesaid Woodard application, the digital constants A through H for the field **51**, as defined by the positions **1'**, **2'**, **3'**, and **4'** of the registration marks **42**, can be calculated in the computer **19**.

Although equations (**11**) to (**18**) are for the special case of symmetry between the four mark positions, similar equations could be generated for the general case of non-symmetry between the four positions **1**, **2**, **3**, and **4** of the design registration marks **42** so that dX_1, dX_2, dX_3, dX_4, dY_1, dY_2, dY_3, and dY_4 can be obtained. Thus, equations (**3**) to (**6**) could be written as

$$\begin{bmatrix} dX_1 \\ dX_2 \\ dX_3 \\ dX_4 \end{bmatrix} = \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} \cdot \begin{bmatrix} 1 & X_1 & Y_1 & X_1Y_1 \\ 1 & X_2 & Y_2 & X_2Y_2 \\ 1 & X_3 & Y_3 & X_3Y_3 \\ 1 & X_4 & Y_4 & X_4Y_4 \end{bmatrix} \quad (19)$$

and equations (7) to (10) could be written as

$$\begin{bmatrix} dY_1 \\ dY_2 \\ dY_3 \\ dY_4 \end{bmatrix} = \begin{bmatrix} E \\ F \\ G \\ H \end{bmatrix} \cdot \begin{bmatrix} 1 & X_1 & Y_1 & X_1Y_1 \\ 1 & X_2 & Y_2 & X_2Y_2 \\ 1 & X_3 & Y_3 & X_3Y_3 \\ 1 & X_4 & Y_4 & X_4Y_4 \end{bmatrix} \quad (20)$$

where each of the single column matrices in each of equations (19) and (20) is a vector matrix and the four column matrix in each of equations (19) and (20) is the system matrix.

By transposing the four column matrix, equation (19) can be written as

$$\begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = \begin{bmatrix} 1 & X_1 & Y_1 & X_1Y_1 \\ 1 & X_2 & Y_2 & X_2Y_2 \\ 1 & X_3 & Y_3 & X_3Y_3 \\ 1 & X_4 & Y_4 & X_4Y_4 \end{bmatrix}^{-1} \cdot \begin{bmatrix} dX_1 \\ dX_2 \\ dX_3 \\ dX_4 \end{bmatrix} \quad (21)$$

and replace equations (11) to (14). Similarly, by transposing the four column matrix, equation (20) can be written as

$$\begin{bmatrix} E \\ F \\ G \\ H \end{bmatrix} = \begin{bmatrix} 1 & X_1 & Y_1 & X_1Y_1 \\ 1 & X_2 & Y_2 & X_2Y_2 \\ 1 & X_3 & Y_3 & X_3Y_3 \\ 1 & X_4 & Y_4 & X_4Y_4 \end{bmatrix}^{-1} \cdot \begin{bmatrix} dY_1 \\ dY_2 \\ dY_3 \\ dY_4 \end{bmatrix} \quad (22)$$

and replace equations (15) to (18). In each of equations (21) and (22), the four column matrix is the inverse matrix of the system matrix and is calculated by the computer **19**.

From equation (21), A, B, C, and D can be obtained. From equation (22), E, F, G, and H can be obtained.

The digital constants A, B, C, D, E, F, G, and H are ascertained through using the design locations of the positions **1, 2, 3,** and **4** in the X and Y directions, which are known for the design field **50**, along with the actual distances, as defined by dX_1 to dX_4 and dY_1 to dY_4, between the positions **1, 2, 3,** and **4** and the positions **1', 2', 3',** and **4'**, respectively, in the X and Y directions. Each of the positions of the beam **11** in the field **50** also is defined by the magnetic deflection voltage of the beam **11** at the particular position.

Thus, after the digital constants A, B, C, D, E, F, G, and H for the actual field **51** have been solved, the magnetic voltages for X and Y can be substituted in equation (1) for dX and equation (2) for dY to ascertain the deflection voltage that must be applied to the beam **11** when it is at any predetermined position (X, Y) such as position **5**, for example, to shift the beam **11** to its corresponding actual position (X', Y') such as position **5'**, for example. Thus, dX is the deflection voltage to be applied for the X direction to shift the beam **11** from its predetermined position X to its actual position X', and dY is the deflection voltage to be applied to shift the beam **11** in the Y direction from its predetermined position Y to its actual position Y'.

Accordingly, with the magnetic deflection voltage at each of the predetermined positions to which the beam **11** is stepped during the writing of the pattern being different, the substitution of the X and Y magnetic deflection voltages in equations (1) and (2) enables determination of dX and dY for any position in the writing pattern. This enables the corrections to be correlated to the magnetic deflection voltages.

The voltage, which is obtained by solving equation (1) for dX, is the deflection voltage applied to the electrostatic deflection plates **31** and **32**, and the deflection voltage, which is obtained by solving equation (2) for dY, is supplied to the electrostatic deflection plates **33** and **34**. Thus, the deflection voltages at each of the predetermined positions causes a shift of the beam **11** to dynamically correct the deflection of the beam **11** at each of the predetermined positions to which it is stepped so that the beam **11** is moved to the actual deviated position whereby the predetermined pattern is written within the actual field **51** rather than the design field **50** for which the pattern was programmed in the computer **19**.

Therefore, to write the predetermined pattern within the actual field **51** rather than the design field **50**, it is necessary to continuously determine the X and Y magnetic deflection voltages at any position in the field. After determining the appropriate correction voltages (dX and dY) with the X and Y magnetic deflection voltages substituted in equations (1) and (2), the correction voltage (dX) is supplied to the electrostatic deflection plates **31** and **32** for the X direction and the correction voltage dY is supplied to the electrostatic deflection plates **33** and **34** for the Y direction.

Accordingly, to continuously apply the correction to the beam **11**, the circuit of FIG. **2** is employed. This enables dynamic correction of the beam **11** as it is stepped to each of the predetermined positions in accordance with the pattern to be written so that the beam **11** is not applied to the predetermined position to which it is stepped by the magnetic coils **23–26** but is shifted to the actual deviated position. As shown and described in the aforesaid Ryan application, it should be understood that the beam **11** can be on or off for the entire time that it is at a position or on for only a portion of the time.

As shown in FIG. **2**, the X deflection voltage is supplied from the analog unit **17** through a line **55** while the Y deflection voltage is supplied from the analog unit **17** through a line **56**. The X deflection voltage on the line **55** is correlated to the deflection current applied to the magnetic deflection coils **23** and **24** for the X direction at the predetermined position, and the Y deflection voltage on the line **56** is correlated to the deflection current applied to the magnetic deflection coils **25** and **26** for the Y direction at the predetermined position. The lines **55** and **56** are connected to an analog multiplier **57**, which has the product of the X and Y deflection voltages as its output and supplied to each of a pair of multiplying digital to analog converters (MDAC) **58** and **59**.

In addition to the input from the analog multiplier **57**, the multiplying digital to analog converter **58** also has an input from the digital control unit **18** with this input being the digital constant D as defined by an eight bit word supplied from the digital control unit **18** to the multiplying digital to analog converter **58**. The output of the multiplying digital to analog converter **58** is DXY, which corrects for distortion and trapezoidal errors in the X direction and is supplied as one of the inputs to an operational amplifier **60**. The operational amplifier **60** is a summing amplifier for all of its four inputs.

In addition to the input from the analog multiplier **57**, the multiplying digital to analog converter **59** also has an input from the digital control unit **18**. This input is the digital constant H and is defined by an eight bit word from the digital control unit **18**. The output of the multiplying digital to analog converter **59** is the product of its inputs of H and XY. The output of HXY, which corrects for distortion and trapezoidal error in the Y direction, is supplied as one of the four inputs to an operational amplifier **61** in which all of its four inputs are summed.

The other inputs to the amplifier **60** are from a digital to analog converter (DAC) **62**, and multiplying digital to analog converters (MDAC) **63** and **64**. Similarly, the other inputs to the amplifier **61** are from a digital to analog converter (DAC) 65 and multiplying digital to analog converters (MDAC) 66 and 67.

The input to the digital to analog converter 62 is the digital constant A. This input is a 10 bit word from the digital control unit 18. Thus, the output of the digital to analog converter 62 to the amplifier 60 is A, which corrects for translation in the X direction.

The multiplying digital to analog converter 63 has a first input of the X deflection voltage from the line 55. A second input to the multiplying digital to analog converter 63 is the digital constant B, which is supplied from the digital control unit 18 as an eight bit word. The output of the multiplying digital to analog converter 63 to the amplifier 60 is the product of the two inputs so that its output is BX, which corrects for magnification in the X direction.

The multiplying digital to analog converter 64 has a first input of the Y deflection voltage from the line 56. The multiplying digital to analog converter 64 has the digital constant C as its second input, which is supplied as a ten bit word from the digital control unit 18 to the multiplying digital to analog converter 64. Accordingly, the output of the multiplying digital to analog converter 64 to the amplifier 60 is CY, which corrects for rotation in the X direction.

Accordingly, the four inputs, which are summed by the amplifier 60 to which they are supplied, comprise A, BX, CY, and DXY. These inputs are what define dX in equation (1) so that the output of the amplifier 60 is the deflection voltage required to be supplied to the electrostatic deflection plates 31 and 32 to shift the beam 11 from its predetermined position to the actual deviated position in the X direction. The output of the summing amplifier 60 is amplified by an amplifier 68 prior to being supplied to the electrostatic deflection plates 31 and 32 as a balanced differential signal.

The digital to analog converter 65 has only the digital constant E as its input, which is supplied from the digital control unit 18 as a ten bit word. Thus, the output of the digital to analog converter 65 to the summing amplifier 61 is E, which corrects for translation in the Y direction.

The multiplying digital to analog converter 66 has a first input of the X deflection voltage from the line 55. The other input to the multiplying digital to analog converter 66 is the digital constant F, which is supplied from the digital control unit 18 as a 10 bit word. The output of the multiplying digital to analog converter 66 to the amplifier 61 is the product of its inputs so that its output is FX, which corrects for rotation in the Y direction.

The multiplying digital to analog converter 67 has a first input of the Y deflection voltage from the line 56. The multiplying digital to analog converter 67 has the digital constant G as its second input, which is supplied from the digital control unit 18 as an eight bit word. The output of the multiplying digital to analog converter 67 to the amplifier 61 is GY, which is the product of its inputs and corrects for magnification in the Y direction.

Accordingly, the inputs to the amplifier 61 are E, FX, GY, and HXY. When added, these inputs produce dY, which is the output from the summing amplifier 61. This output is supplied from the summing amplifier 61 through an amplifier 69 to the electrostatic deflection plates 33 and 34 to shift the beam 11 in the Y direction from its predetermined position to the actual position.

Since the X and Y deflection voltages on the lines 55 and 56 are continuously changing as the beam 11 is stepped from one predetermined position to another, there is a continuous correction of the signals to the electrostatic deflection plates 31–34. Accordingly, the beam 11 is applied to the actual deviated position rather than the predetermined position as it is stepped from one position to another in accordance with its predetermined pattern, which it is writing within the chip 40 located within the boundaries of the actual field 51.

Because of the shifting of the beam 11 as it writes within the actual field 51, a single, continuous pattern can be written in more than one field. This is because the pattern being written within the actual field 51 can be written up to the boundary. Then, when the beam is to be applied to the next adjacent field, it is again applied to the actual field through using the circuit of FIG. 2. Of course, the digital constants A, B, C, D, E, F, G, and H will be different than they were for the previous field. However, they will be the same throughout the field for which they were determined. Of course, in this arrangement, the chip 40 would comprise all of the fields in which the single pattern is written.

Accordingly, once the wafer 41 has been disposed beneath the beam 11 and the beam 11 determines the location of the registration marks 42 for the initial field, then the patterns can be written continuously throughout the remainder of the wafer 41 without any mechanical corrections with respect to the actual location of each of the fields as all corrections will be made through the circuit of FIG. 2. Of course, the location of the registration marks 42 for each of the actual fields 51 must be made before any writing of the pattern in this field occurs.

It should be understood that the beam 11 attempts to locate the registration marks 42 at the design positions, but these do not occur because of the various factors previously mentioned.

It should be understood that the beam 11 requires the use of a focus grid and a calibration grid in the same manner as described in the aforesaid Kruppa et al patent. One suitable example of these grids is the focus and calibration grids of the aforesaid Kruppa et al patent.

While each of the registration marks 42 has been described as having the bars 43 and 44 formed as depressions, it should be understood that the bars 43 and 44 could be formed otherwise as long as they produced a signal when the beam 11 passed thereover. For example, each of the bars 43 and 44 could be a raised portion.

As previously mentioned, the magnetic deflection coils 23–26 cooperate to move the beam in a horizontal or X scan by appropriately deflecting the beam 11. The circuit for controlling the X magnetic deflection coils 23 and 24 is shown in FIG. 6.

This circuit includes both positive constant current sources 70, 71, and 72 and negative constant current sources 73, 74, and 75. The constant current sources 70–75, controlled by logic control signals from the digital control unit 18 and derived from an X counter, which is part of the digital control unit 18, charge a capacitor 77.

Each of the positive and negative constant current sources is not the same value so that the charge of the capacitor 77 may be different depending on which of the current sources 70–75 is used. Thus, the charge for the capacitor 77 for the different constant current sources 70–75 produces different voltage ramps, which have slopes depending upon the value of the turned on current source. The length of the ramp is dependent upon the time that the current source is activated. It should be understood that more than one of the current sources 70–75 can be turned on simultaneously to produce a variety of slopes.

The positive current source 70 is turned on by a signal on a line 78 from the digital control unit 18 in accordance with the X counter only during the B cycle. The positive current source 71 is turned on by a signal on a line 79 from the digital control unit 18 in accordance with the X counter only during the A cycle.

The negative constant current source 74 is also turned on only during the A cycle by a signal on a line 80 from the digital control unit 18 in accordance with the X counter. The negative constant current source 73 is turned on by a signal on a line 81 from the digital control unit 18 in accordance with the X counter only during the B cycle.

The digital control unit 18, in accordance with the X counter, may turn on the positive current source 72 by a signal on a line 82 or the negative current source 75 by a signal on a line 83. Only one of the current sources 72 and 75 is turned on at one time.

The current sources 72 and 75 are used primarily during the C cycle to move the beam left or right as required for focusing. They may be used at other times to probe the beam movement as desired.

The positive constant current source 70 is used to move the beam 11 in the X scans in one direction. The negative current source 73 is used to move the beam 11 in the X scans in the other direction.

The capacitor 77 is connected to the magnetic deflection coils 23 and 24 through an operational amplifier 84, corrector circuitry 85, a summing point 86, and a driver amplifier 87. The driver amplifier 87 and the summing point 86 function as a summing amplifier. The amplifier 84 forms an integrator along with the capacitor 77 and isolates the current sources 70–75 from the driver amplifier 87, which converts the voltage to current, and from the corrector circuitry 85.

The corrector circuitry 85 compensates for non-linearity of the beam 11 to a degree. Thus, the corrector circuitry 85 modifies the voltage ramps so that the beam deflection approaches linearity.

The remainder of the correction for non-linearity of the beam 11 is made through a ten bit digital to analog converter (DAC) 88, which is connected to an amplifier 89. One suitable example of the 10 bit digital to analog converter 88 is sold as model No. DAC-HI 10B by Datel Systems Inc.

The 10 bit digital to analog converter 88 is connected to the digital control unit 18 to receive correction words therefrom, and its output is supplied to the negative input of the amplifier 89 through a resistor 90. A capacitor 91 cooperates with the resistor 90 to integrate the output of the 10 bit digital to analog converter 88. The output of the amplifier 89 is supplied as one of the inputs to the summing point 86 to complete the correction for non-linearity.

The digital control unit 18 is connected through a line 92 and a diode 93 to an FET 94. The diode 93 and the FET 94 together form an analog switch. When a retrace gate signal is supplied from the digital control unit 18 in accordance with the X counter to the line 92, the FET 94 is turned on to cause a reset of the correction for non-linearity from the output of the amplifier 89 since the beam 11 moves in the opposite direction after the retrace gate.

During retrace time, the voltage developed across a sense resistor 94' by the current returning from the deflection coils 23 and 24 is fed to a comparing amplifier 95 and compared with a reference signal supplied from a 16 bit digital to analog converter (DAC) 96, which is controlled by a 16 bit word from the digital control unit 18, through a line 97.

The comparing amplifier 95 amplifies the difference between the voltage across the sense resistor 94' and the reference voltage and supplies it as an error voltage to an analog switch 98. During retrace time, a signal through a line 99 from the digital control unit 18 in accordance with the X counter closes the analog switch 98 causing the error voltage to supply current to the integrator, which comprises the capacitor 77 and the amplifier 84, through a resistor 100. This charges the capacitor 77 in the proper direction to cause the deflection voltage across the sense resistor 94' to approach the reference voltage. Current is supplied until the error voltage is reduced to zero at which time the deflection voltage is equal to the reference voltage. This insures that the beam 11 is ready for scanning in the opposite X direction. It should be understood that the signal on the line 99 is removed at the end of retrace time.

By properly selecting the values of the positive constant current sources 70, 71, and 72 and the negative constant current sources 73, 74, and 75, the speed at which the beam 11 scans in each of the X directions during the various cycles is controlled. If the positive constant current source 70 is considered to be +I and the negative constant current source 73 is considered to be −I, then the source 71 is + 1/10 I, the source 72 is + 1/660 I, the source 74 is − 1/10 I, and the source 75 is − 1/660 I.

As shown in FIG. 6, the line 55, which is connected to the analog multiplier 57 in FIG. 2, is connected between the coil 24 and the sense resistor 94'. This enables the deflection voltage to be obtained as the beam 11 moves in the X direction.

A similar type of magnetic deflection circuit is utilized with the Y deflection coils 25 and 26. This will not be described in detail.

Referring to FIG. 7, there is shown an electrostatic deflection circuit for controlling the X electrostatic deflection plates 27 and 28. The Y electrostatic deflection plates 29 and 30 would be controlled by a similar type of circuit.

The electrostatic circuit has an input from the digital control unit 18 in accordance with the X counter through a line 110 to a clamping NPN transistor 111, which resets the charge on a capacitor 112. The capacitor 112 is connected to a positive constant current source 113. The capacitor 112 and the constant current source 113 produce a positive bucking sawtooth as an output.

The capacitor 112 is connected through a high impedance amplifier 114 to a summing point 115. The summing point 115 is connected to a push-pull amplifier 116, which is connected to the X electrostatic deflection plates 27 and 28. The push-pull amplifier 116 inverts the signal from the amplifier 114 so that the signal, which is produced by the amplifier 114, is a negative sawtooth at the output of the push-pull amplifier **116.** Thus, this steps the beam **11** from left to right as discussed in the aforesaid Kruppa et al patent.

A second circuit produces a positive bucking sawtooth at the output of the push-pull amplifier **116** to cause the beam **11** to step from right to left in the X direction. This circuit includes an input from the digital control unit **18** in accordance with the X counter through a line **120** to a clamping PNP transistor **121,** which resets the charge on a capacitor **122.** The capacitor **122** is connected to a negative constant current source **123.** The capacitor **122** and the constant current source **123** produce a negative sawtooth as an output.

The capacitor **122** is connected through a high impedance amplifier **124** to the summing point **115** from which the negative sawtooth is supplied to the push-pull amplifier **116,** which inverts the input to produce a positive bucking sawtooth as its output. It should be understood that the amplifiers **114** and **124** isolate the capacitors **112** and **122,** respectively, from the push-pull amplifier **116.**

The electrostatic deflection circuit also is utilized to produce offset of the beam in the X direction in either the direction in which the beam **11** is moving or the opposite direction. The offset signal is supplied to the summing point **115** from a four bit digital to analog converter **125,** which receives its input from the digital control unit **18** (see FIG. **1**) in the manner more particularly shown and described in the aforesaid Ryan application.

When the beam **11** is being calibrated in the B cycle during the calibration operation in the manner more particularly shown and described in the aforesaid Kruppa et al patent to determine the deflection of the beam **11** in the vertical or Y direction, the line **110** or the line **120** receives a signal to cause the bucking sawtooth to be applied for a period of four lines to the push-pull amplifier **116.** This bucking sawtooth is supplied due to signals from the digital control unit **18** on the line **110** or **120.** During writing, the line **110** or **120** is activated by the digital control unit **18** in accordance with the X counter such that the negative and positive bucking sawtooths are operative for a period of every other line of scan in accordance with the direction in which the beam **11** is moving.

While the present invention has been described with respect to only a single level in which patterns are written, it should be understood that it has particular utility in the writing of patterns at different levels and at separate times for the same field location. With the present invention, accurate overlay of the pattern at each of the different levels is obtained with respect to the patterns at the other levels which are written at various separate times.

While the present invention has been described as exposing a resist, it should be understood that exposure may be made of any other phenomenon. For example, there could be exposure of silicon dioxide that is to have its etch rating enhanced.

While the present invention has described the apparatus as being employed to expose the resist on the chips of a semi-conductor wafer, it should be understood that the present invention may be employed anywhere it is desired to correct or change the position of a beam, which moves in any deflection fashion, without affecting the history of the beam in its deflection movement. Thus, for example, the present invention could be readily employed to produce engineer drawings on a cathode-ray tube or to control an electron beam welder or cutter.

While the present invention has described the detection of the electrons as being by PIN diodes, it should be understood that any suitable electron detector could be used. For example, a scintilator-photomultiplier or a direct electron multiplier could be employed.

While the target has been described as being a semiconductor wafer, for example, it should be understood that the target could be other materials. For example, the target could be a material in which a mask could be formed by the beam, for example.

While the beam has been described as being moved in a line by line scan, it should be understood that such is not a requisite for satisfactory operation. Thus, the beam can be moved in any fashion from one position to another within the field in which the pattern is written. For example, the beam could be continuously moved with continous dynamic correction occurring.

An advantage of this invention is that a single pattern can be written in more than one field. Another advantage of this invention is that it improves overlay accuracy. A further advantage of this invention is that it eliminates the need for mechanical correction for variations due to placing the wafer under the beam.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of positioning a beam of charged particles comprising:

ascertaining the actual location and shape of a four-sided area of a target in which the beam is to be applied relative to the location and shape of a design four-sided area;

directing the beam over the target after ascertaining the actual location of the area of the target and its shape relative to the location and shape of the design area;

and moving the beam in a predetermined path ot each of a plurality of predetermined positions within the design area in accordance with a predetermined pattern while dynamically electronically compensating at each of the predetermined positions for the deviation of the actual position within the actual area from the predetermined position due to the actual area having a different location and shape relative to the location and shape of the design area to cause the beam to be shifted from the predetermined position and applied at the deviated actual position so that a pattern is written within the actual area in accordance with the predetermined pattern.

2. The method according to claim **1** in which compensation at each of the predetermined positions for the deviation of the actual position from the predetermined position is obtained by simultaneously deflecting the beam in orthogonal directions.

3. The method according to claim **2** in which the location and shape of the area of the target is ascertained by scanning each of the four corners of the area of the target separately with the beam.

4. The method according to claim 3 in which the target is a semiconductor wafer.

5. The method according to claim 2 in which:

the beam is moved in the predetermined path by simultaneously deflecting the beam in orthogonal directions through the use of a separate deflection voltage for each of the orthogonal directions;

and obtaining the dynamic electronic compensation at each of the predetermined positions for the deviation of the actual position from the predetermined position by modifying the orthogonal deflection voltages for deflecting the beam to the predetermined position in each of the orthogonal directions in accordance with the location and shape of the actual area relative to the location and shape of the design area to obtain the compensating deflection of the beam in each of the orthogonal directions.

6. The method according to claim 1 in which the location and shape of the area of the target is ascertained by scanning each of the four corners of the area of the target separately with the beam.

7. The method according to claim 6 in which the target is a semiconductor wafer.

8. The method according to claim 1 in which the target is a semiconductor wafer.

9. The method according to claim 8 including:

writing a different predetermined pattern at different levels of the wafer at different times through directing the beam over the design area after each level of the wafer is formed;

and moving the beam in a predetermined path to each of a plurality of predetermined positions within the design area in accordance with the predetermined pattern at each of the levels while dynamically electronically compensating at each of the predetermined positions for the deviation of the actual position within the actual area from the predetermined position due to the actual area having a different location and shape relative to the location and shape of the design area to cause the beam to be shifted from the predetermined position and applied at the deviated actual position so that a pattern is written within the actual area in accordance with the predetermined pattern at each of the levels.

10. A method of writing a continuous pattern in more than one contiguous four-sided area of a target with a beam of charged particles including:

ascertaining the actual location and shape of a first foursided area of the target relative to the location and shape of a first design four-sided area;

applying the beam to the first actual area to write the portion of the continuous pattern therein in accordance with the actual location and shape of the first actual area relative to the location and shape of the first design area;

ascertaining the actual location and shape of a second foursided area of the target having a boundary common with the first actual area of the target relative to the location and shape of a second design four-sided area;

and applying the beam to the second actual area to write the portion of the continuous pattern therein in accordance with the actual location and shape of the second actual area relative to the location and shape of the second design area so that the pattern forms a continuation across the common boundary between the first and second actual areas.

11. The method according to claim 10 in which the location and shape of each of the areas of the target is ascertained by scanning each of the four corners of the area of the target with the beam.

12. The method according to claim 11 in which the target is a semiconductor wafer.

13. The method according to claim 10 in which the target is a semiconductor wafer.

14. The method according to claim 13 including applying the beam to each of the first and second actual areas after formation of another level of the wafer to form another continuous pattern at the another level.

15. An apparatus for controlling the movement of a beam of charged particles comprising:

means to ascertain the actual location and shape of an area of a target relative to the location and shape of a design area of the target;

means to move the beam over the design area in a predetermined path to each of a plurality of predetermined positions within the design area in accordance with a predetermined pattern;

and means to shift the beam from the predetermined position within the design area in accordance with the deviation of the actual position within the actual area from the corresponding predetermined position due to the actual area having a different location and shape relative to the location and shape of the design area to cause the beam to be applied at the actual position rather than the corresponding predetermined position when the beam is moved by said beam moving means for positioning at the corresponding predetermined position.

16. The apparatus according to claim 15 in which:

said shifting means includes:

means to produce a signal in accordance with the deviation of each of the actual positions from the corresponding predetermined position;

means to deflect the beam from the predetermined position to the actual position;

and means to supply the signal from said producing means to said deflection means.

17. The apparatus according to claim 16 in which:

said producing means includes:

first means to produce a first signal in accordance with the deviation of the actual position from the corresponding predetermined position in a first direction;

and second means to produce a second signal in accordance with the deviation of the actual position from the corresponding predetermined position in a second direction that is perpendicular to the first direction.

18. The apparatus according to claim 17 in which:

said first means of said producing means produces the first signal dependent on the deflection signals supplied to said beam moving means to move the beam in each of the first and second directions to the predetermined position;

and said second means of said producing means produces the second signal dependent on the deflection signals supplied to said beam moving means to move the beam in each of the first and second directions to the predetermined position.

19. The apparatus according to claim 15 including:

means to store information containing each of a plurality of patterns for different levels of a semiconductor wafer forming the design area;

said beam moving means moving the beam to a plurality of predetermined positions within the design area at each of the different levels of the wafer in accordance with the pattern for the particular level after each level is formed;

said storing means supplying the stored information to said beam moving means for the plurality of predetermined positions within the design area to which the beam is to be moved in accordance with the pattern for the particular level;

and said shifting means shifting the beam to each of the actual positions within the actual area from the corresponding predetermined position within the design area.

20. The apparatus according to claim **15** in which said shifting means is separate from said beam moving means.

21. The apparatus according to claim **15** in which said deflection means is separate from said beam moving means.

22. An apparatus for writing a continuous pattern with a beam of charged particles in more than one contiguous four-sided area of a target including:

means to move the beam over the target;

first means to control said moving means to move the beam to ascertain the actual location and shape of a first four-sided area relative to the location and shape of a first design four-sided area;

said first means including means to control said moving means to move the beam over the first design area in accordance with a predetermined pattern;

second means to shift the beam from a predetermined position within the first design area in accordance with the predetermined pattern to its actual deviated position within the first actual area to write a portion of the pattern, as defined by the predetermined pattern, in the first actual area in accordance with the actual location and shape of the first actual area relative to the location and shape of the first design area;

said first means controlling said moving means to move the beam to ascertain the actual location and shape of a second area relative to the location and shape of a second design area with the second actual area having a common boundary with the first actual area;

said control means of said first means controlling said moving means to move the beam over the second design area in accordance with the predetermined pattern;

and said second means shifting the beam from a predetermined position within the second design area to its actual deviated position with the second actual area to write a portion of the pattern within the second actual area in accordance with the actual location and shape of the second actual area relative to the location and shape of the second design area so that the pattern forms a continuation across the common boundary between the first and second actual areas.

23. The apparatus according to claim **22** in which the target is a semiconductor wafer.

24. The apparatus according to claim **22** in which said first means includes means to scan each of the four corners of each of the areas of the target to be located with the beam so as to ascertain the location and shape of each of the areas of the target to be located in accordance with the location of the four corners of the area of the target to be located.

25. A method of positioning a beam of charged particles comprising:

ascertaining the actual location and shape of an area of a target in which the beam is to be applied relative to the location and shape of a design area;

directing the beam over the target after locating the actual area of the target and its shape relative to the location and shape of the design area;

and moving the beam in a predetermined path to each of a plurality of predetermined positions within the design area in accordance with a predetermined pattern while dynamically electronically compensating at each of the predetermined positions for the deviation of the actual position within the actual area from the predetermined position due to the actual area having a different location and shape relative to the location and shape of the design area to cause the beam to be shifted from the predetermined position and applied at the deviated actual position so that a pattern is written within the actual area in accordance with the predetermined pattern.

26. The method according to claim **25** in which compensation at each of the predetermined positions for the deviation of the actual position from the predetermined position is obtained by simultaneously deflecting the beam in orthogonal directions.

27. The method according to claim **25** including:

writing a different predetermined pattern at different levels of the wafer at different times through directing the beam over the design area after each level of the wafer is formed;

and moving the beam in a predetermined path to each of a plurality of predetermined positions within the design area in accordance with the predetermined pattern at each of the levels while dynamically electronically compensating at each of the predetermined positions for the deviation of the actual position within the actual area from the predetermined position due to the actual area having a different location and shape relative to the location and shape of the design area to cause the beam to be shifted from the predetermined position and applied at the deviated actual position so that a pattern is written within the actual area in accordance with the predetermined pattern at each of the levels.

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