

- [54] **LENS AND DEFLECTION UNIT ARRANGEMENT FOR ELECTRON BEAM COLUMNS**
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- [51] Int. Cl.² **H01J 29/76; H01J 29/70**
- [58] Field of Search **250/396; 313/421, 442**

OTHER PUBLICATIONS

Richards, "An Industrial Instrument for the Observation of Very-High Speed Phenomena"; Proceedings of the Institution of Electrical Engineers, Vol. 99, #20, part 111A, pages 729-746.

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Primary Examiner—Robert Segal
 Attorney, Agent, or Firm—John J. Goodwin

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[57] **ABSTRACT**

An improved electron beam tube system is described wherein the electron beam magnetic deflection yoke is physically located the lens pole piece of the final or projection magnetic lens of the beam tube.

4 Claims, 4 Drawing Figures

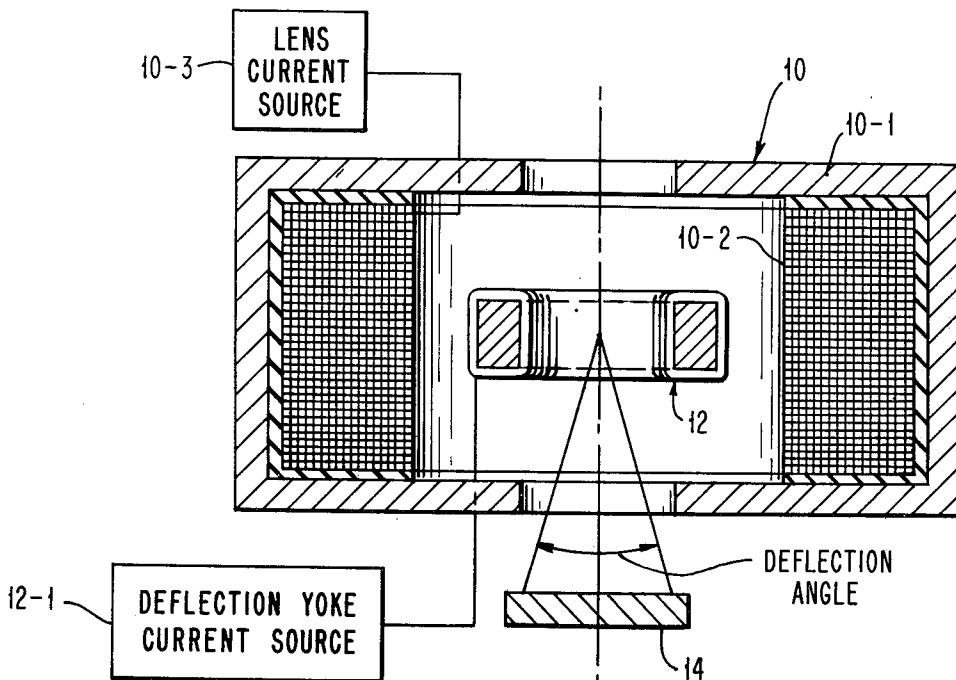


FIG. 1

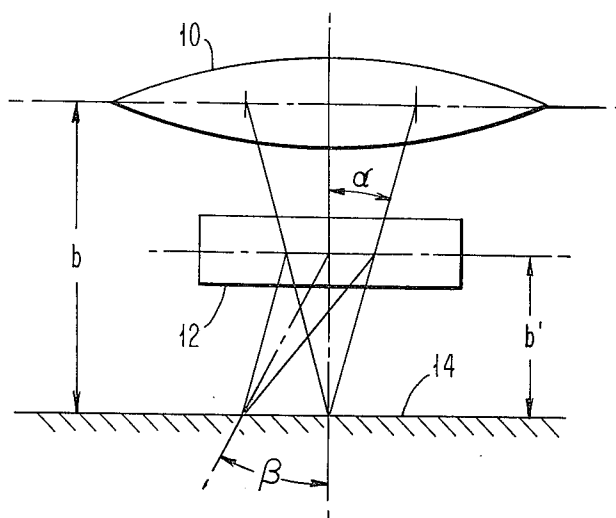


FIG. 2

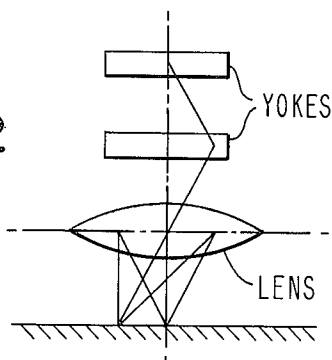


FIG. 3

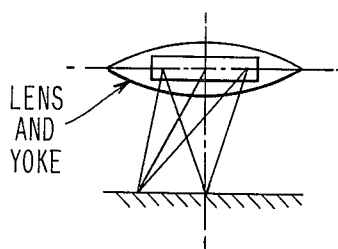
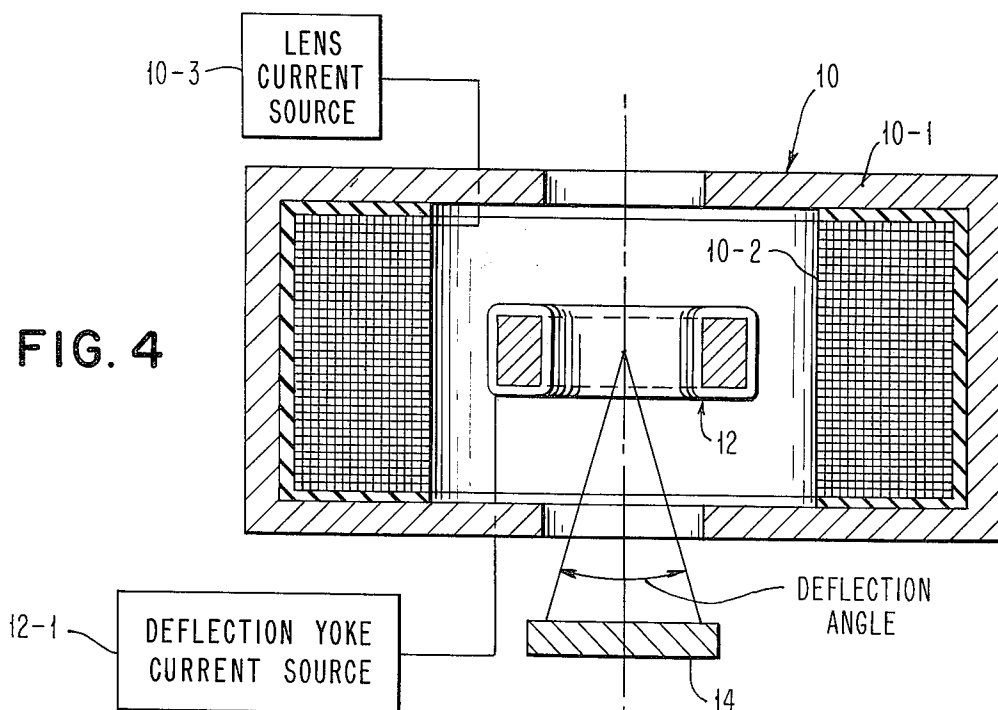


FIG. 4



LENS AND DEFLECTION UNIT ARRANGEMENT FOR ELECTRON BEAM COLUMNS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of electron beam column deflection systems, and more particularly to an arrangement of a magnetic lens relative to a deflection yoke.

2. Description of the Prior Art

Deflection units in prior art electron beam columns are known to have two basic configurations which provide deflection before the final lens or deflection after the final lens.

Deflection before the final lens results in a short focal length or working distance which reduces on-axis aberrations and provides a high resolution capability. The disadvantages are that the deflection angle and all deflection aberrations increase rapidly with increasing field coverage thereby limiting the operation of the beam column to relatively small fields of view. Deflection before the final lens requires double deflection using two deflection yokes. An example of deflection before the lens is shown in the publication "A Computer-Controlled Electron-Beam Machine for Micro-Circuit Fabrication" by T. H. P. Chang and B. A. Wallman, Record of 11th Symposium on Electron, Ion, and Laser Beam Technology, San Francisco Press, Inc., at page 471.

Deflection after the final lens eliminates off-axis aberrations of the lens and reduces the total deflection aberrations to permit a large field coverage. The disadvantage is a relatively poor resolution due to the long focal length or working distance of the final lens which results in substantial on-axis aberrations of the lens or in very small beam current.

The present invention is distinct over the prior art in that deflection is carried out inside the final lens thereby combining the advantages of the prior art configurations and minimizing the disadvantages.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an electron beam column having deflection within the final lens for reducing deflection aberrations without deteriorating resolution to provide large field coverage.

Another object of the present invention is to provide an electron beam column incorporating deflections inside the final lens to eliminate the need for double deflection.

Still another object of the present invention is to provide an electron beam column wherein all dynamic corrections for off-axis aberrations can be carried out before the beam is deflected thereby eliminating any change in field size and field rotation.

A further object of the present invention is to provide an electron beam column wherein on-axis d.c. focus can be carried out by means of a separate focus coil before the deflection yoke thereby avoiding changes in field size and field orientation.

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.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing illustrating the operation of beam deflection in an electron beam column for the conditions where the deflection is after the final lens.

FIG. 2 is a schematic drawing illustrating the operation of beam deflection in an electron beam column where the deflection is before the final lens.

FIG. 3 is a schematic drawing illustrating the operation of beam deflection in an electron beam column where the deflection is inside the final lens.

FIG. 4 is a schematic drawing illustrating the configuration of a lens pole piece and image generating coil for a final magnetic lens, and a magnetic deflection yoke located inside the magnetic lens according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to an improved deflection unit for an electron beam column of the type used for microcircuit fabrication and microscopy. Electron beam columns generally consist of a vertical arrangement of separate stages including an electron beam source, a condenser lens, alignment stages, demagnification lens stages, a projection lens, a deflection unit, a target stage and magnification lens stages.

The lenses used in electron beam columns are magnetic lenses including pole pieces and image generating coils through which an electron beam is directed. The magnetic field produces a lens effect analogous to physical lenses used in light optics. An example of a magnetic lens is given in U.S. Pat. No. 3,659,097 issued Apr. 25, 1972 to Richard Bassett et al. and assigned to National Research Development Corporation.

As previously discussed, in electron beam columns it is conventional to locate the magnetic deflection yoke before or after the final projection lens depending on the desired application. Referring to FIG. 1 a schematic drawing is provided illustrating a magnetic lens 10 and a deflection yoke 12 and the corresponding effect of these elements on the electron beam where the deflection takes place after the final lens. In FIG. 1 *b* is the distance between the lens 10 and the target 14, *b'* is the distance between the deflection yoke 12 and the target 14, β is the deflection angle produced by yoke 12 and α is the beam semi-angle produced by magnetic lens 10. Aberrations are produced by both the lens 10 and the deflection yoke 12. The lens produces chromatic aberrations which are proportional to $b\alpha^2$, astigmatism aberrations which are proportional to $b\alpha^2$ and spherical aberrations which are proportional to $b\alpha^3$. The deflection yoke produces coma which is proportional to $b'\alpha^2\beta$, astigmatism which is proportional to $b'\alpha\beta^2$ and distortion which is proportional to β^3 . For a given brightness the total beam current at the target "I target" is proportional to α^2 . Where deflection takes place after the lens as illustrated in FIG. 1, the deflection aberrations which occur are due only to the deflection yoke. This configuration produces relatively low resolution but allows relatively large field coverage.

Referring to FIG. 2, an example of the prior art technique of double deflection before the lens is illustrated. This configuration permits a relatively small field coverage but produces relatively high resolution.

FIG. 3 illustrates the effect of deflection inside the final lens as taught by the present invention and ex-

plained more fully with reference to FIG. 4. The configuration of the invention illustrated in FIG. 3 results in substantially reduced deflection aberrations, relatively high resolution and large field coverage as well as other advantages to be specified.

Referring to FIG. 4 a more detailed illustration is provided of a magnetic yoke inside a magnetic lens according to the principles of the present invention. The configuration of FIG. 4 is based on the fact that the deflection angle and therefore the deflection aberrations reach a minimum when the working distance b between the lens 10 and the target 14 is equal to the distance b' between the deflection yoke 12 and the target 14. This condition is met when the deflection yoke 12 is inside and substantially of the center of the magnetic lens 10. Thus, in FIG. 4 the magnetic lens 10 which focuses the electron beam is shown including a lens pole piece structure 10-1 and a field generating coil 10-2 which is connected to a lens current source 10-3 which provides a constant current. The deflection yoke 12 including two orthogonal sets of windings which provide lateral x and y deflection of the image at the target plane 14 is shown substantially at the center of magnetic lens 10 and is connected to a deflection yoke current source 12-1 which provides a variable current. The yoke, of course, includes electrical windings and it is to be noted that the electrical windings on the yoke for most efficient operation the windings should be arranged to provide a sinusoidal distribution. More particularly, by locating the deflection yoke inside the lens permits the pole piece gap to be larger than usual and thereby reduces the spherical and chromatic aberration of the lens.

It was previously stated that the deflection yoke 12 is located substantially at the center of the lens pole piece structure 10-1. However in practice, the actual optimum position of yoke 12 inside pole piece 10 to satisfy the condition that $b = b'$ depends on the aberrations of the lens which are proportional to the geometry of the lens pole piece, the gap and the distance of the lens to the target and also depends on the yoke aberration which are proportional to the geometry of the yoke and the distribution of the windings. Thus, the location of the yoke within the lens may not be precisely at the center of the lens but will be located at the optimum position of the aberration crossover point where the aberrations are equal. This location may be simply calculated by one skilled in the art depending on the lens and yoke aberrations in each given situation.

It has been found that in a practical working embodiment of the system for microfabrication, accurate line resolution can be obtained up to 20,000 lines per field for a field size of five millimeters square. This is an improvement over the known prior art wherein resolution over 5,000 lines per field has not been achieved. Other advantages of the invention are that deflection aberrations are reduced without lowering resolution resulting in the aforesaid field coverage, deflection inside the lens eliminates the need for double deflection as required if the deflection takes place before the lens, all dynamic corrections for off-axis aberrations such as dynamic focus can be carried out before the beam is deflected thereby eliminating any change in field size and field rotation, the on-axis d.c. focus can be carried out by means of a separate focus coil before

the yoke which avoids changes in field size orientation, and the geometry of the pole pieces can be as large as necessary to guarantee low spherical and chromatic constants of the final lens. More particularly, the electrical windings are orientated on the yoke to form a sinusoidal distribution. One way this can be accomplished is by placing one set of windings on the yoke in increasing and decreasing density following a sine function around the entire circumference of the yoke. The other set of windings are arranged in the same fashion but placed on the yoke orthogonal to the first set, that is, with a ninety degree phase shift. This is done because the sinusoidal distribution provides the most uniform deflection field distribution.

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

What is claimed is:

1. In an electron beam column deflection system of the type wherein an electron beam is generated, focussed, and deflected on a target, a focussing and deflection unit comprising:

means for producing a magnetic lens in the path of said electron beam for focussing said electron beam onto a target, said magnetic lens producing means including a field generating coil and at least two pole pieces forming an air gap for producing static magnetic field lines which form a rotationally symmetrical field distribution having a field maximum in said air gap for focussing said electron beam,

and a magnetic deflection yoke including sinusoidally distributed windings for producing a dynamic magnetic field, said magnetic deflection yoke being located inside said longitudinal magnetic field lines of said air gap of said magnetic lens means at the maximum of said symmetrical field distribution wherein said dynamic magnetic field and said static magnetic field are superimposed, for deflecting said electron beam on said target wherein the working distance between said magnetic lens and said target is designated b , the working distance between said yoke and target is designated b' , and wherein said yoke is located inside said magnetic lens at a position wherein $b = b'$ such that said yoke is located at the maximum of said symmetrical field distribution produced by said pole pieces of said magnetic lens.

2. An electron beam column deflection system according to claim 1 wherein said field generating coil is connected to a source of constant current to produce said static magnetic field lines and wherein said deflection yoke is connected to a source of varying current to produce said dynamic magnetic field.

3. An electron beam column deflection system according to claim 1 wherein said deflection yoke includes a sinusoidally arranged winding to produce a deflection field.

4. An electron beam column deflection system according to claim 1 wherein said magnetic lens is the final projection lens of said electron beam column.

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