US00RE41665E

(19) **United States**

(12) **Reissued Patent**

Hamashima et al.

(10) **Patent Number: US RE41,665 E**

(45) **Date of Reissued Patent: *Sep. 14, 2010**

(54) **OBJECT OBSERVATION APPARATUS AND OBJECT OBSERVATION**

(75) Inventors: **Muneki Hamashima**, Urayasu (JP); **Yoichi Watanabe**, Kawasaki (JP); **Yoshiaki Kohama**, Kawasaki (JP)

(73) Assignee: **Nikon Corporation**, Tokyo (JP)

(*) Notice: This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/808,916**

(22) Filed: **Jun. 13, 2007**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **6,479,819**
Issued: **Nov. 12, 2002**
Appl. No.: **09/505,280**
Filed: **Feb. 16, 2000**

U.S. Applications:

(60) Division of application No. 10/986,576, filed on Nov. 12, 2004, now Pat. No. Re. 40,221, which is a continuation-in-part of application No. PCT/JP98/03667, filed on Aug. 19, 1998.

(30) **Foreign Application Priority Data**

Aug. 19, 1997 (JP) 222187/1997
Aug. 29, 1997 (JP) 234466/1997

(51) **Int. Cl.**
H01J 37/28 (2006.01)

(52) **U.S. Cl.** **250/310**; 250/397

(58) **Field of Classification Search** 250/310, 250/397

See application file for complete search history.

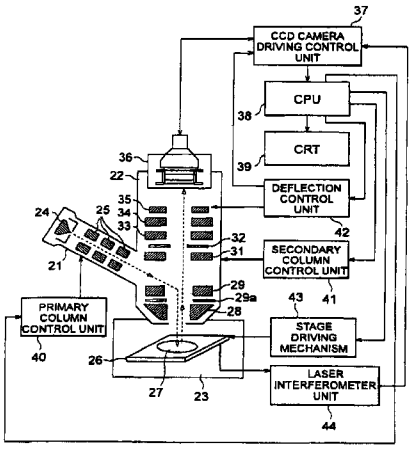
(56) **References Cited**

U.S. PATENT DOCUMENTS

2,901,627	A	8/1959	Wiskott et al.	
3,714,425	A	1/1973	Someya et al.	
4,399,360	A	8/1983	Fotino	
4,472,631	A	9/1984	Enke et al.	
4,564,758	A	1/1986	Slodzian et al.	
4,686,566	A	8/1987	Bucher	
4,877,326	A	10/1989	Chadwick et al.	
4,933,552	A	6/1990	Lee	
4,954,705	A	9/1990	Brunner et al.	
4,963,823	A	10/1990	Otto et al.	
5,144,149	A	9/1992	Frosch	
5,302,828	A	4/1994	Monahan	
5,448,064	A	9/1995	Matsuyama	
5,466,934	A	11/1995	Adams et al.	
5,483,065	A	1/1996	Sato et al.	
5,498,874	A	3/1996	Miyoshi et al.	
5,502,306	A	3/1996	Meisburger et al.	
5,576,833	A	11/1996	Miyoshi et al.	
5,578,821	A	11/1996	Meisberger et al.	
5,717,206	A	2/1998	Watanabe et al.	
5,973,323	A	10/1999	Adler et al.	
6,087,659	A	7/2000	Adler et al.	
6,184,526	B1	2/2001	Kohama et al.	
6,479,819	B1 *	11/2002	Hamashima et al.	250/310
6,713,759	B2	3/2004	Adler et al.	
RE40,221	E *	4/2008	Hamashima et al.	250/310
2003/0205669	A1	11/2003	Adler et al.	

FOREIGN PATENT DOCUMENTS

JP	48-031685		10/1973
JP	56-013723		2/1981
JP	56-016068		2/1981
JP	04-190408		7/1992
JP	04-242060		8/1992
JP	A-4242060	*	8/1992
JP	05-109381		4/1993
JP	05-258703		10/1993
JP	07-057680		3/1995
JP	07-181297		7/1995
JP	A-7-181297	*	7/1995
JP	A-7-249393	*	9/1995
JP	07-249393		9/1995
JP	A-9-270242	*	10/1997
JP	09-270242		10/1997
JP	10-197462		7/1998
JP	A-10-197462	*	7/1998
JP	10-197463		7/1998
JP	A-10-197463	*	7/1998
JP	11-064256		3/1999
JP	11-073905		3/1999



OTHER PUBLICATIONS

E. Bauer, et al., "Emission and Low Energy Reflection Electron Micrscopy," Surface and Interface Characterization by Electron Optical Methods, Series B. Psysics, vol. 191, edited by A. Howie and U. Valdre (1987).
Veneklasen, L.H., "Scanning versus direct imaging emission microscopy," Ultramicroscopy, 36, (1991) 63–75.
Veneklasen, L.H., "The continuing development of low–energy electron microscopy for characterizing surfaces," Rev. Sci. Instrum, 63(12) Dec. 1992, pp. 5513–5532.
What is EMPA? Or is it EPMA? Jun. 19, 1997.
Habliston et al., "Photoelectron Imaging of Cells: Photoconductivity Extends the Range of Applicability," Biophysical Journal, vol. 69, Oct. 1995, pp. 1615 to 1624.

* cited by examiner

Primary Examiner—Jack I Berman
(74) *Attorney, Agent, or Firm*—Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.

(57) **ABSTRACT**

This invention relates to an object observation apparatus and observation method. The object observation apparatus is characterized by including a drivable stage on which a sample is placed, an irradiation optical system which is arranged to face the sample on the stage, and emits an electron beam as a secondary beam, an electron detection device which is arranged to face the sample, causes to project, as a primary beam, at least one of a secondary electron, reflected electron, and back-scattering electron generated by the sample upon irradiation of the electron beam, and generates image information of the sample, a stage driving device which is adjacent to the stage to drive the stage, and a deflector arranged between the sample and the electron detection device to deflect the secondary beam, the electron detection device having a converter arranged on a detection surface to convert the secondary beam into light, an array image sensing unit which is adjacent to the converter, has pixels of a plurality of lines each including a plurality of pixels on the detection surface, sequentially transfers charges of pixels of each line generated upon reception of light of an optical image obtained via the converter to corresponding pixels of an adjacent line at a predetermined timing, adds, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputs charges added up to a line corresponding to an end, and a control unit connected to the array image sensing unit to output a transfer signal for sequentially transferring charges of pixels of each line to an adjacent line, and the control unit having a stage scanning mode in which the array image sensing unit is controlled in accordance with a variation in projection position of the secondary beam projected on the electron detection device that is generated by movement of the stage device, and a deflector operation mode in which the array image sensing unit is controlled in accordance with a variation in projection position of the secondary beam projected on the detection device by the deflector.

11 Claims, 11 Drawing Sheets

Fig.1

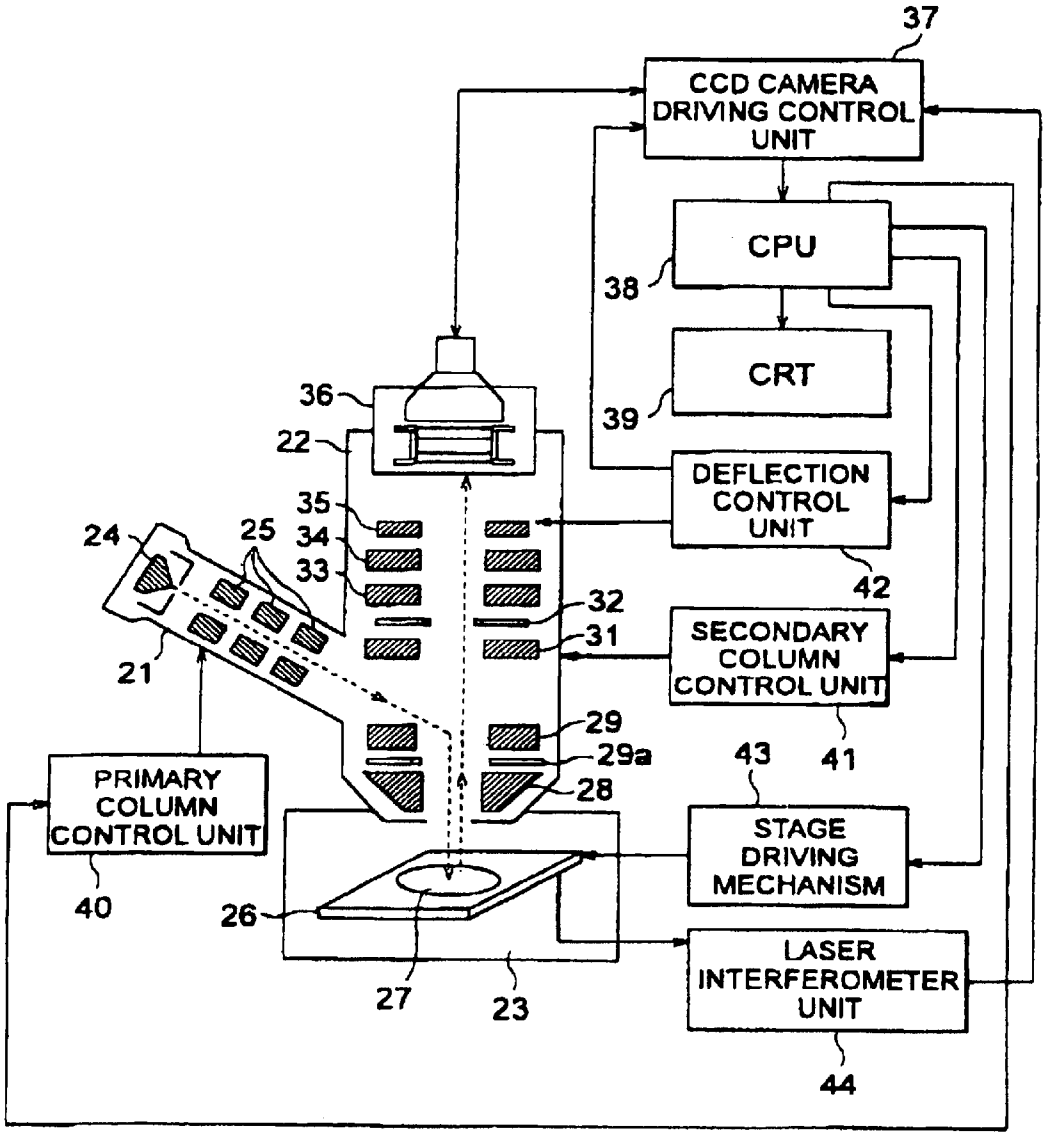

37
CCD CAMERA DRIVING CONTROL UNIT
CPU
38
CRT
39
DEFLECTION CONTROL UNIT
42
SECONDARY COLUMN CONTROL UNIT
41
43
STAGE DRIVING MECHANISM
LASER INTERFEROMETER UNIT
44
PRIMARY COLUMN CONTROL UNIT
40
36
22
35
34
33
32
31
29
29a
28
24
25
21
26
27
23

Fig.2

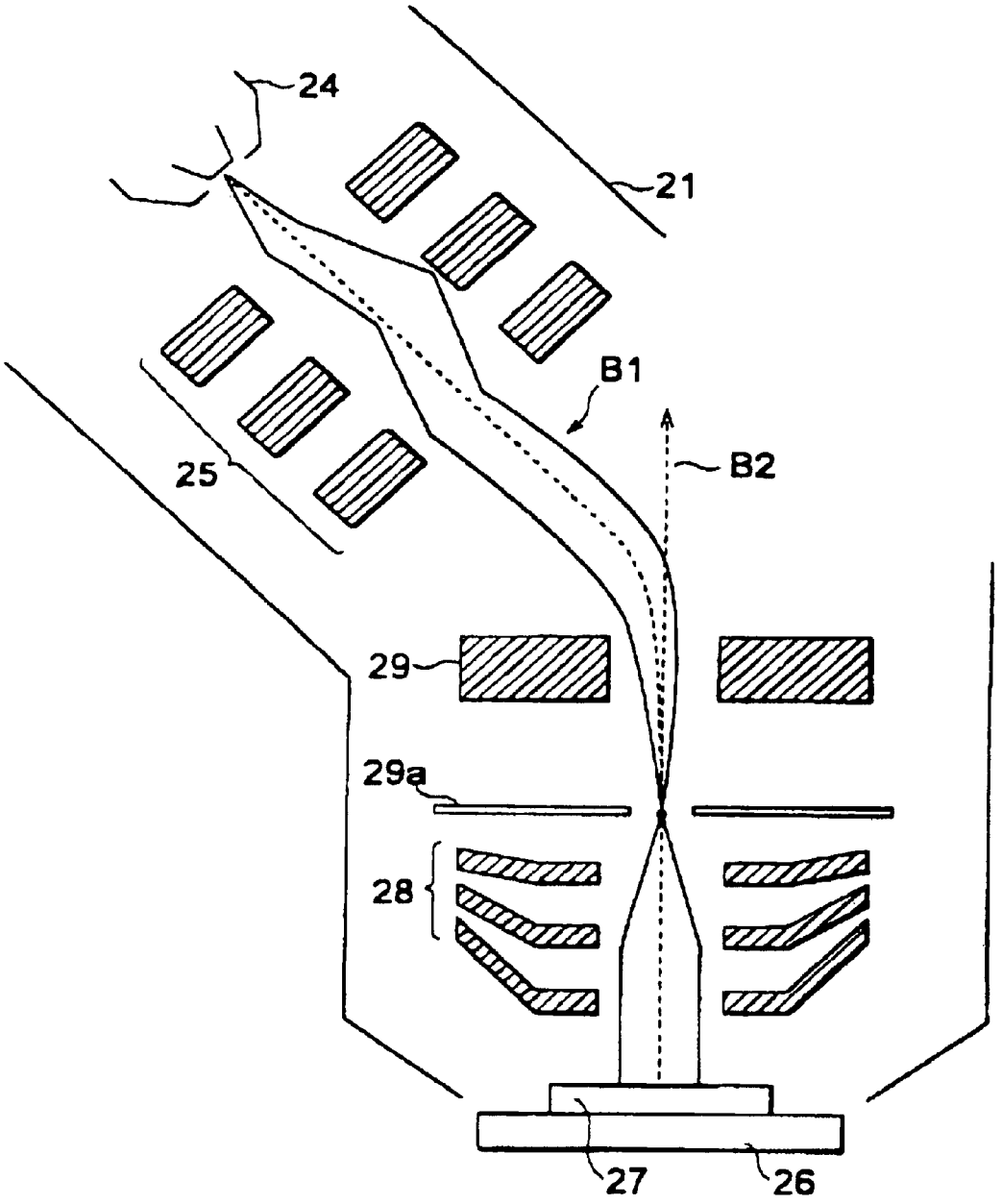


Fig.3A

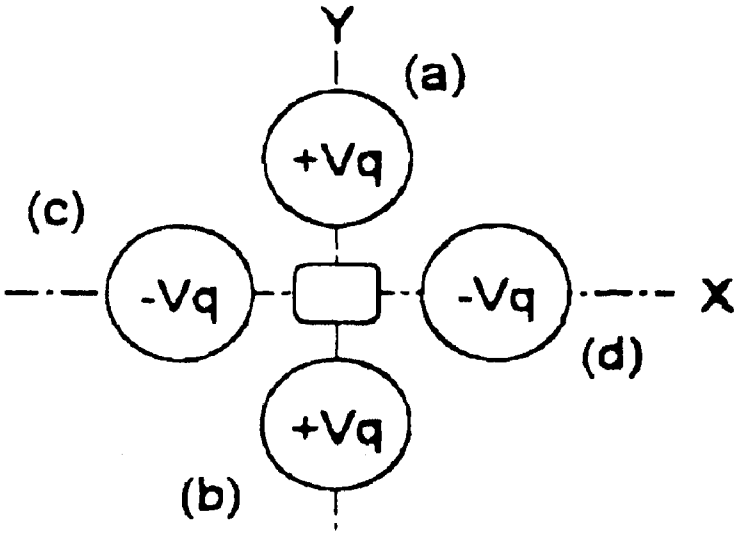


Fig.3B

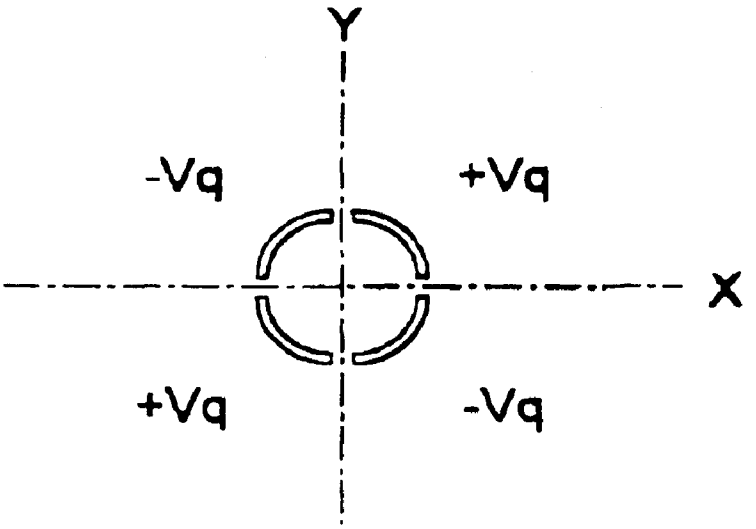


Fig.4

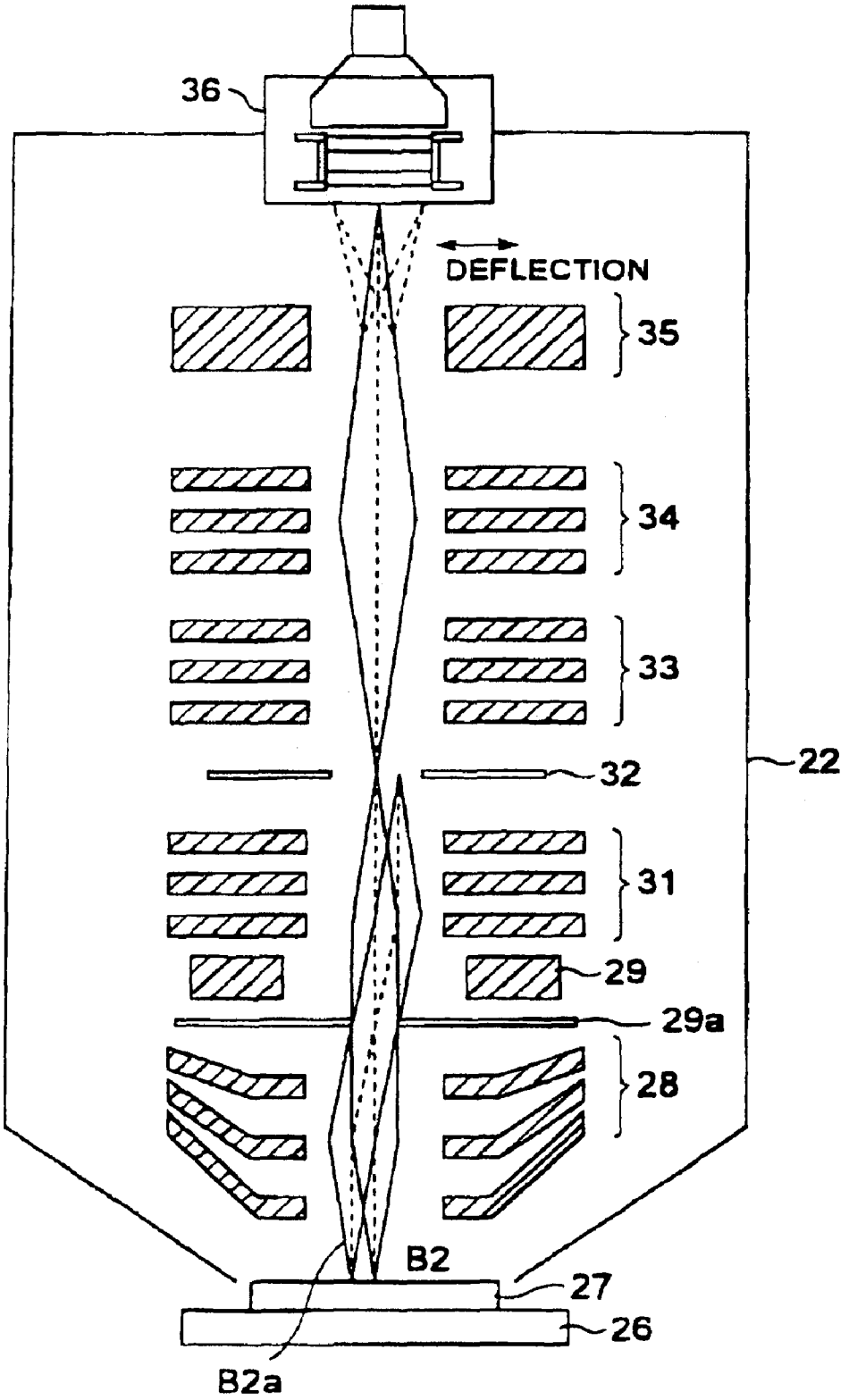


Fig.5A

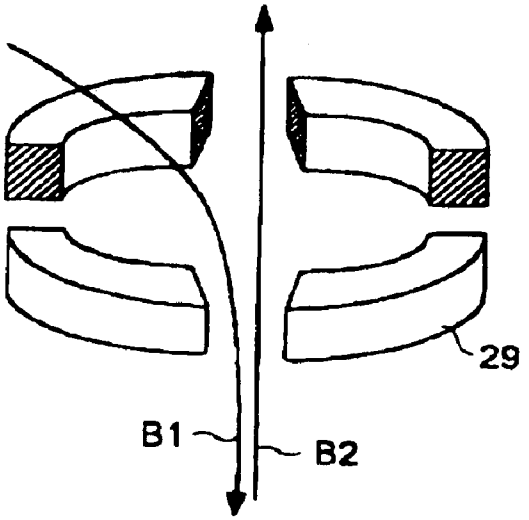


Fig.5B

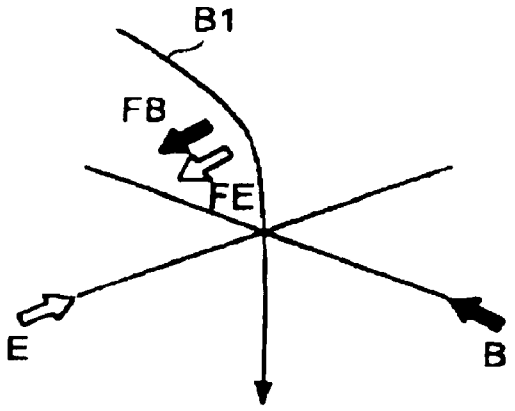


Fig.5C

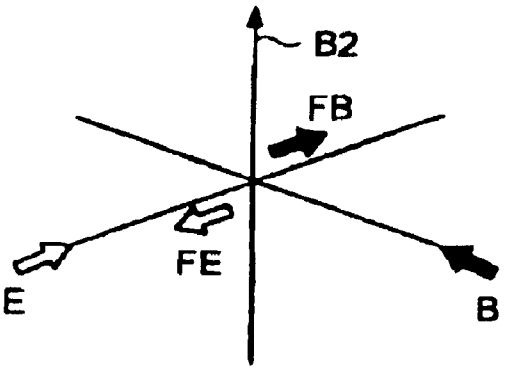
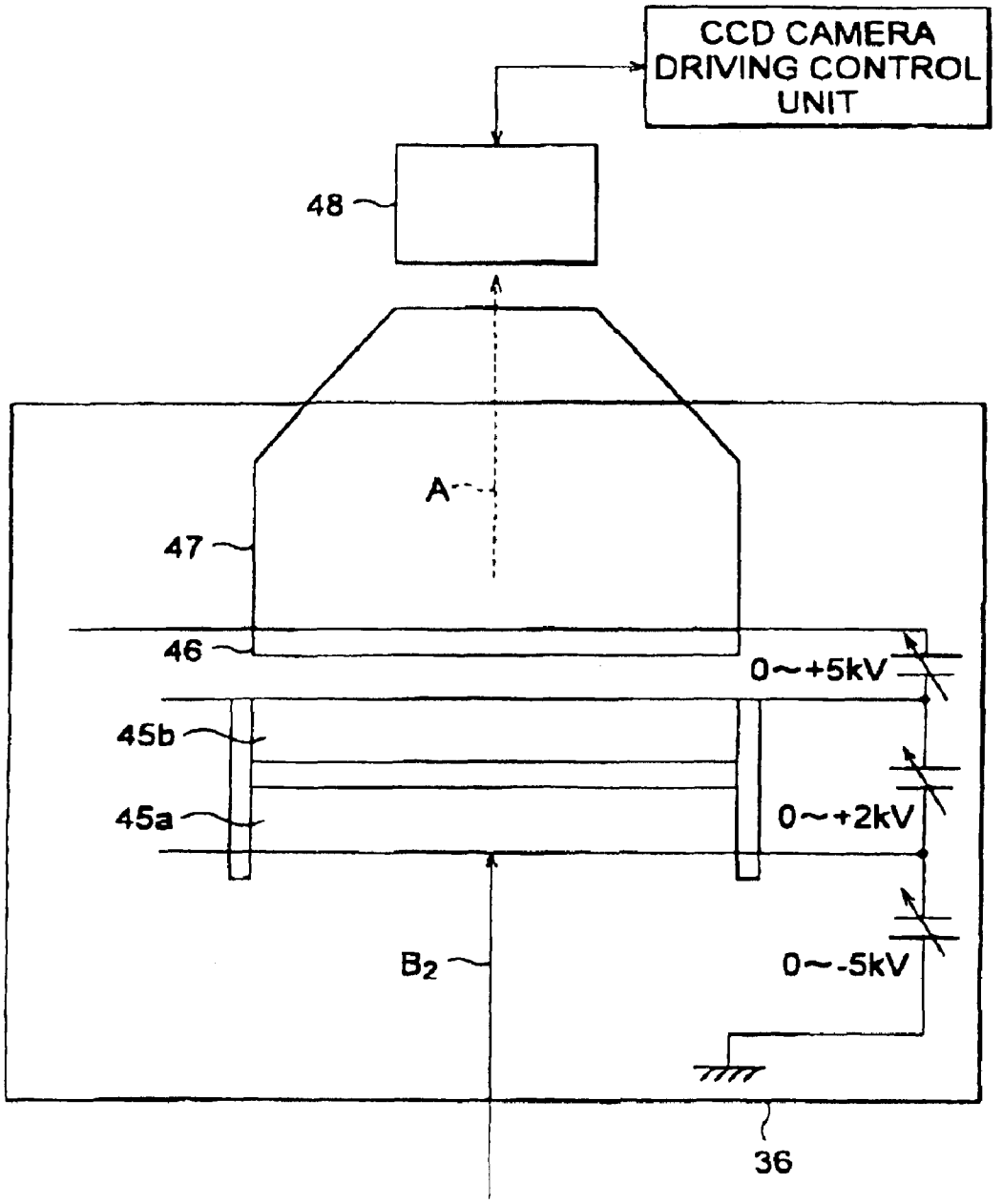


Fig.6


CCD CAMERA DRIVING CONTROL UNIT
48
A
47
46
0~+5kV
45b
45a
0~+2kV
B2
0~-5kV
36

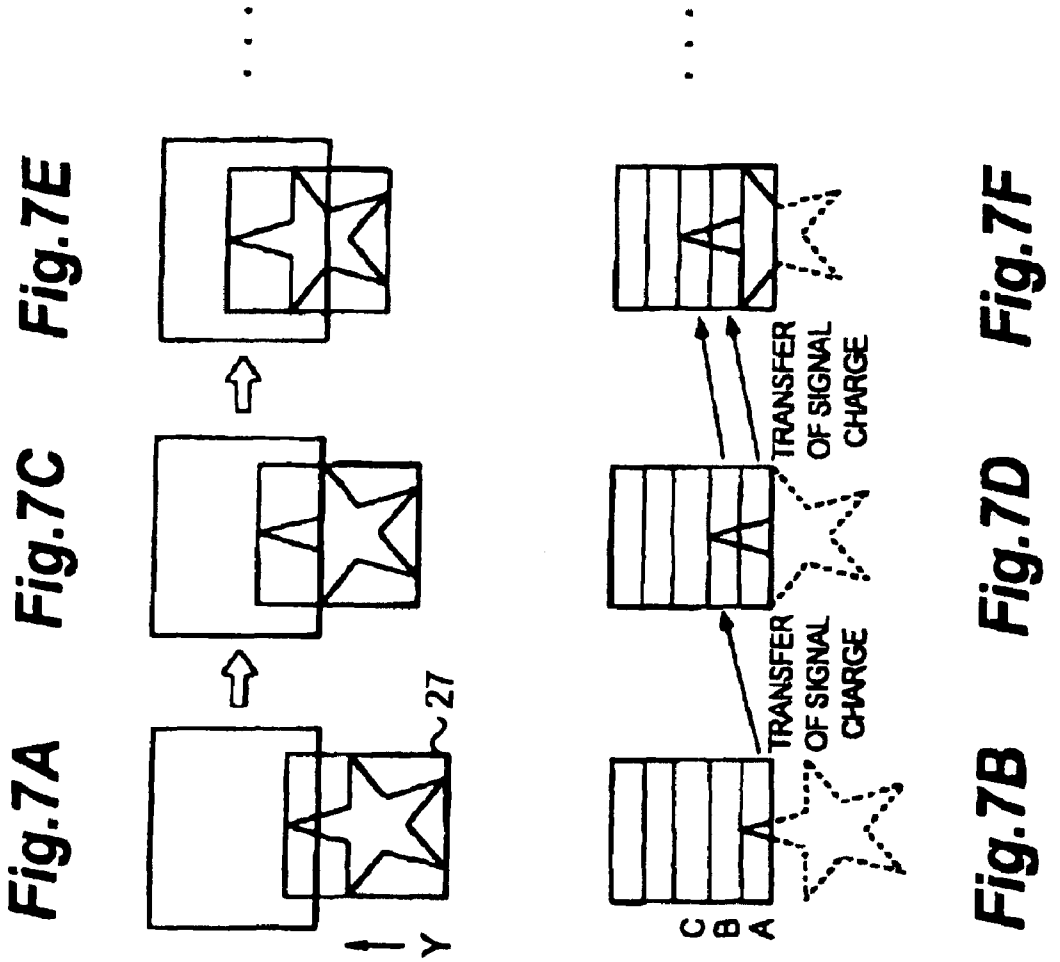


Fig.7A Fig.7C Fig.7E

Fig.7B Fig.7D Fig.7F

Fig.8

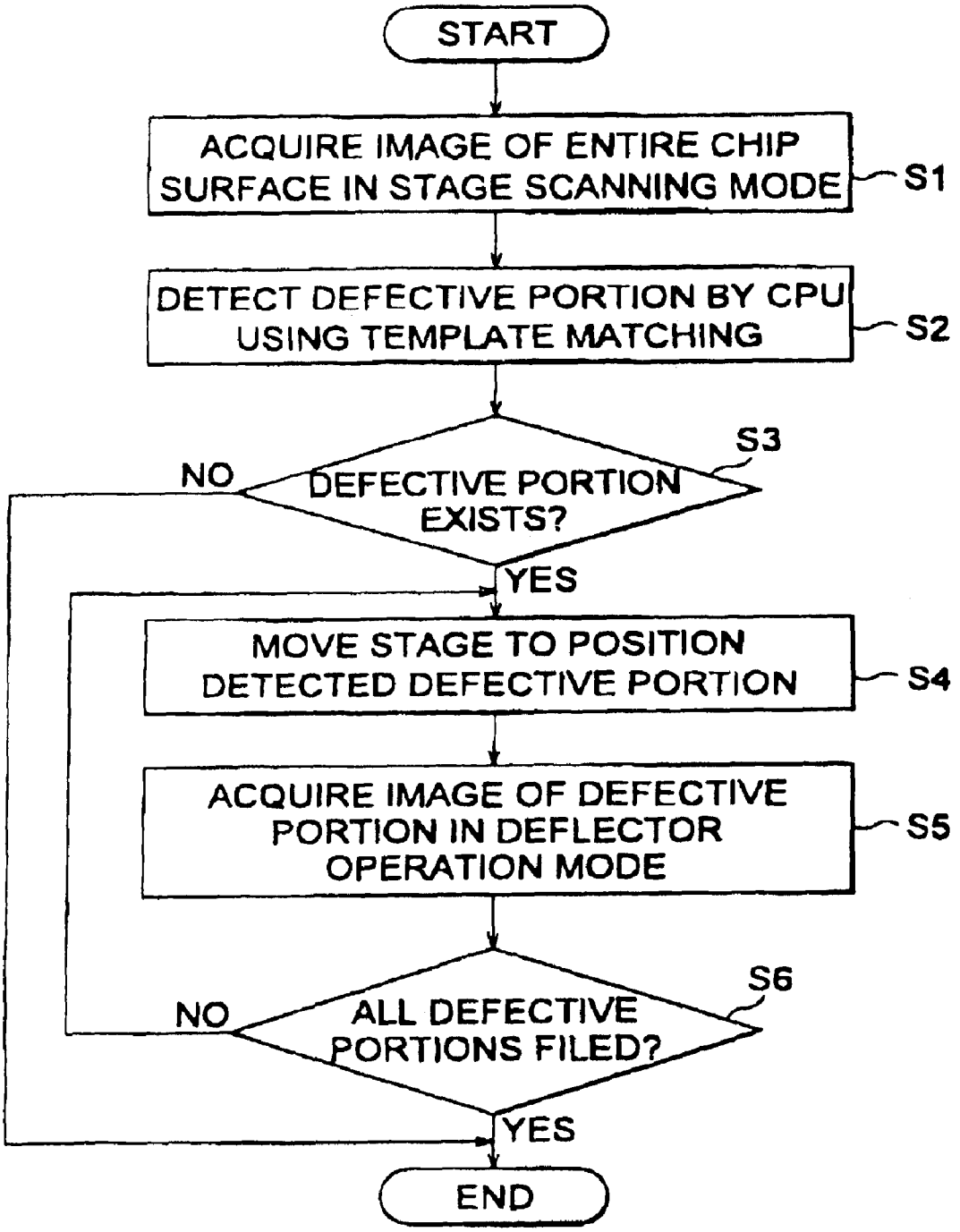

START
ACQUIRE IMAGE OF ENTIRE CHIP SURFACE IN STAGE SCANNING MODE
S1
DETECT DEFECTIVE PORTION BY CPU USING TEMPLATE MATCHING
S2
S3
NO
DEFECTIVE PORTION EXISTS?
YES
MOVE STAGE TO POSITION DETECTED DEFECTIVE PORTION
S4
ACQUIRE IMAGE OF DEFECTIVE PORTION IN DEFLECTOR OPERATION MODE
S5
S6
NO
ALL DEFECTIVE PORTIONS FILED?
YES
END

Fig.9A

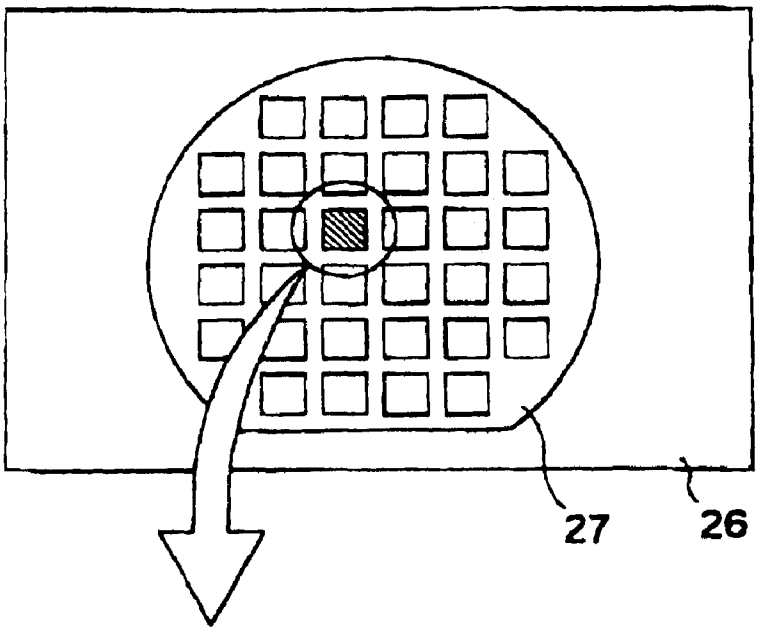

27
26

Fig.9B

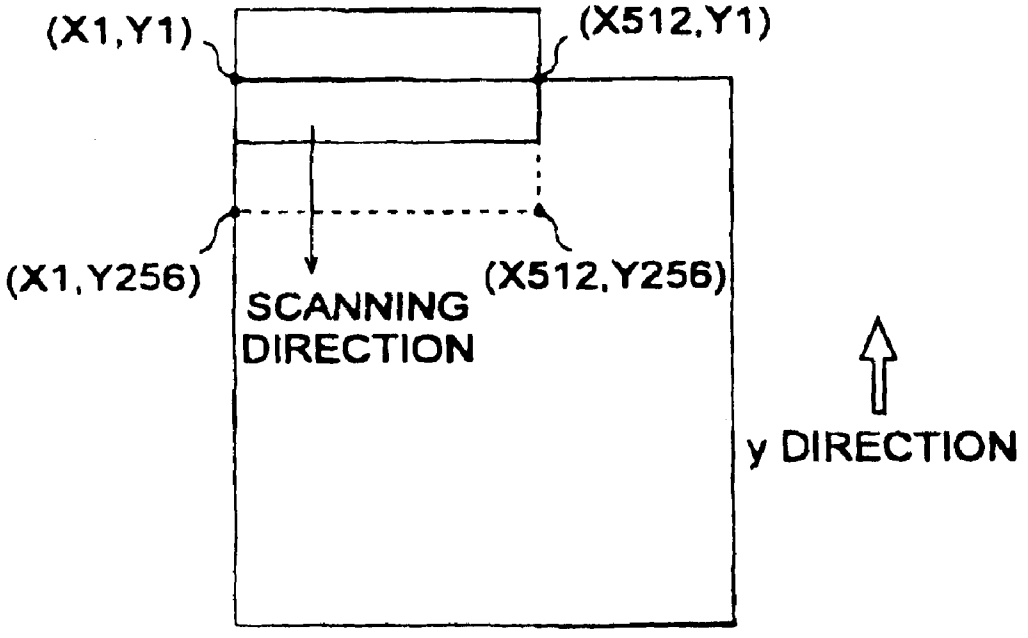

(X1,Y1)
(X512,Y1)
(X1,Y256)
(X512,Y256)
SCANNING DIRECTION
y DIRECTION

Fig.10

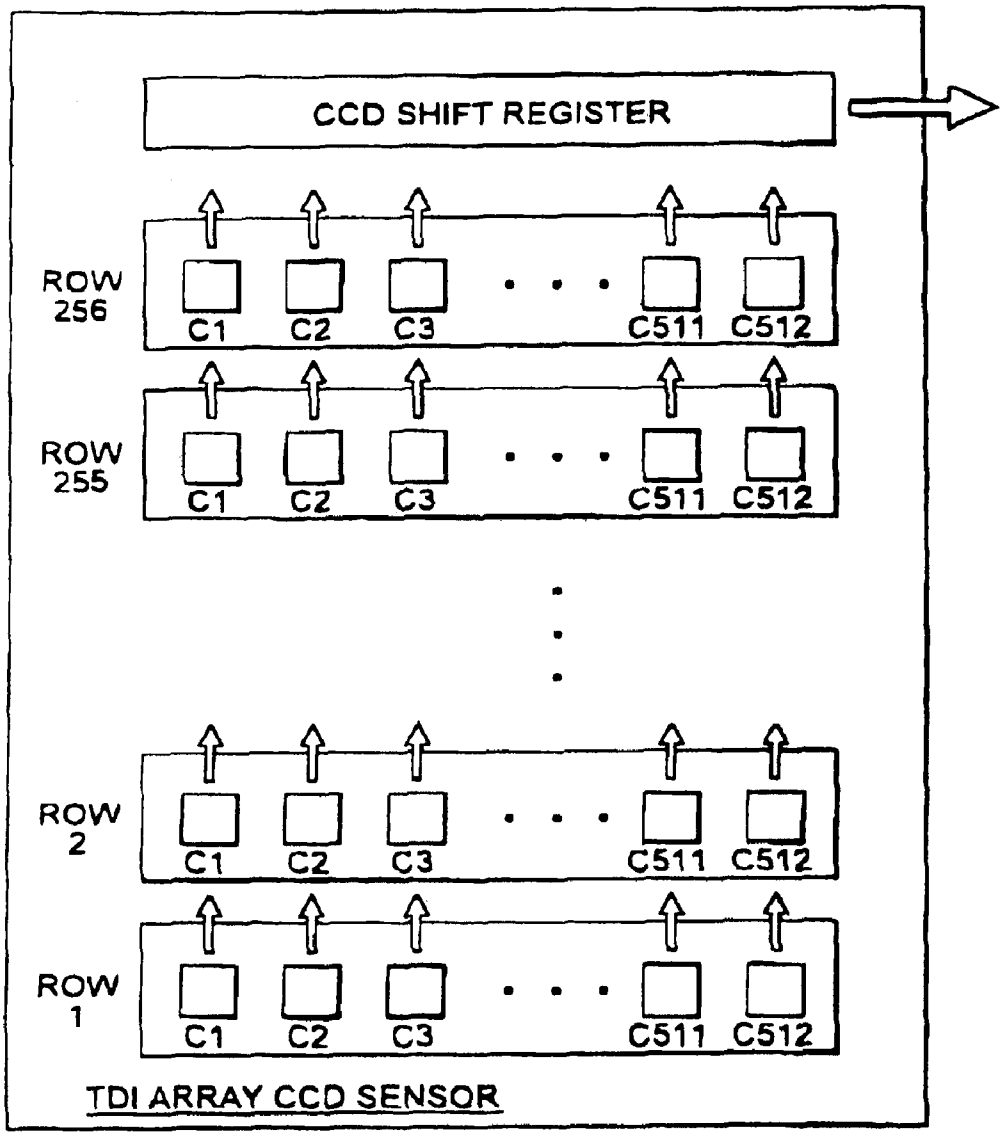

CCD SHIFT REGISTER
ROW 256
ROW 255
ROW 2
ROW 1
C1
C2
C3
C511
C512
TDI ARRAY CCD SENSOR

Fig.11A

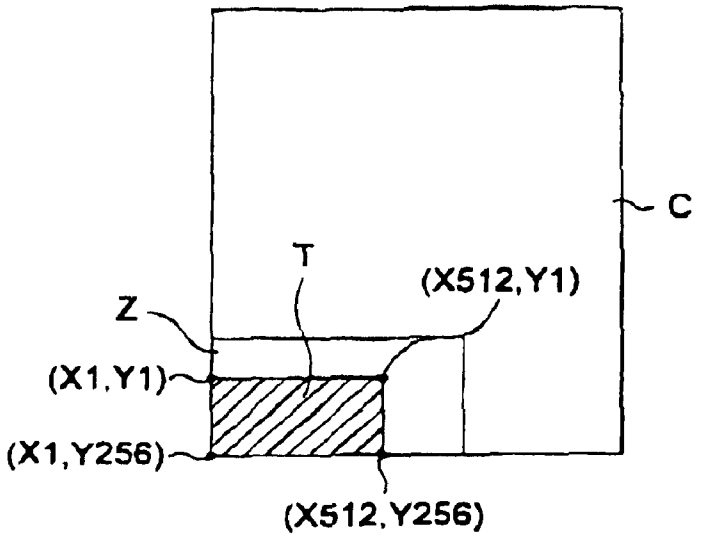
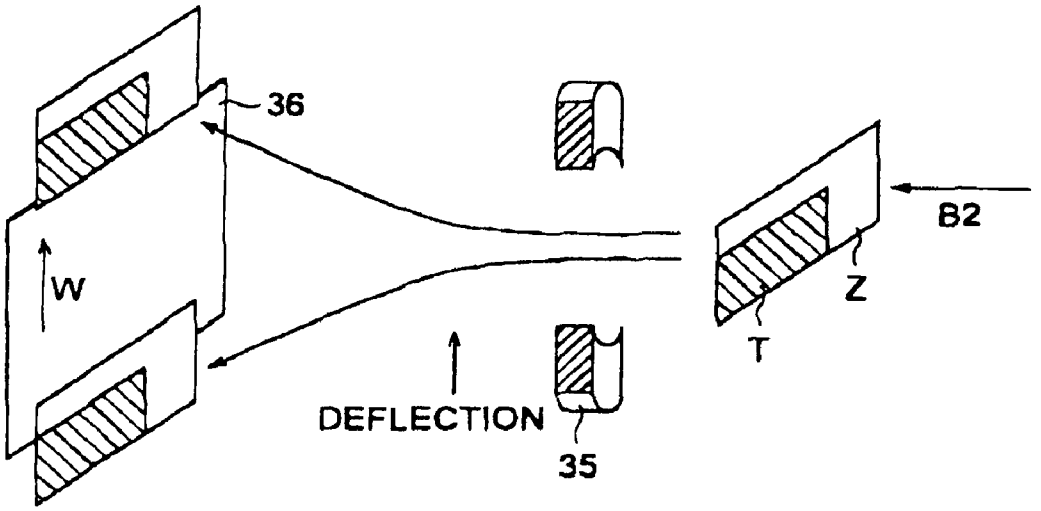


Fig.11B



OBJECT OBSERVATION APPARATUS AND OBJECT OBSERVATION

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

RELATED APPLICATIONS

This is a *divisional reissue application of U.S. Reissue application Ser. No. 10/986,576, filed on Nov. 12, 2004, now U.S. Patent RE40,221, which is a reissue application of U.S. patent application Ser. No. 09/505,280, filed on Feb. 16, 2000, now U.S. Pat. No. 6,479,819, which is a* Continuation-in-part application of International Patent Application Serial No. PCT/JP98/03667 filed on Aug. 19, 1998, [now pending] *the entire disclosures of which are incorporated herein by reference. U.S. Reissue application Ser. No. 10/986,576 and the present application are co-pending applications to reissue U.S. Pat. No. 6,479,819.*

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an object observation apparatus and, more particularly, to an apparatus and method of observing the integrated circuit pattern of a semiconductor wafer or the like using, e.g., an electron beam.

2. Related Background Art

With higher integration degrees of recent LSIs, the defect detection sensitivity required for samples such as a wafer and mask is increasing. For example, to detect defective portions on a wafer pattern 0.25 μm in DRAM pattern size, a detection sensitivity of 0.1 μm is required. In addition, demands have arisen for inspection apparatuses which satisfy both an increase in detection sensitivity and an increase in detection speed. To meet these requirements, surface inspection apparatuses using an electron beam have been developed.

A known example of an apparatus for scanning an electron beam on an object and observing secondary electrons from the object is a scanning electron microscope (SEM). A known example of an inspection apparatus for inspecting defects using an electrooptic system as a primary optical system is one disclosed in Japanese Patent Laid-Open No. 7-181297 (corresponding to U.S. Pat. No. 5,498,874). As disclosed in Japanese Patent Laid-Open No. 7-249393 (corresponding to U.S. Pat. No. 5,576,833), a pattern inspection apparatus is known which forms the sectional shape of a beam into a rectangular or elliptic shape through a rectangular cathode and quadrupole lens.

SUMMARY OF THE INVENTION

However, the conventional apparatuses are difficult to realize high-precision observation of an object using an electron beam.

It is, therefore, an object of the present invention to provide an observation apparatus and observation method capable of observing a clear image of an object to be observed at a high precision.

It is another object of the present invention to provide an object observation apparatus characterized by comprising a drivable stage on which a sample is placed, an irradiation optical system which is arranged to face the sample on the stage, and emits an electron beam as a primary beam, an electron detection device which is arranged to face the sample, has a detection surface on which at least one of a secondary electron, reflected electron, and back-scattering electron generated by the sample upon irradiation of the electron beam is projected as a secondary beam, and generates image information of the sample, a stage driving device which is adjacent to the stage to drive the stage, and a deflector arranged between the sample and the electron detection means to deflect the secondary beam, the electron detection device having a converter arranged on the detection surface to convert the secondary beam into light, an array image sensing unit which is adjacent to the converter, has pixels of a plurality of lines each including a plurality of pixels, sequentially transfers charges of pixels of each line generated upon reception of light of an optical image obtained via the converter to corresponding pixels of an adjacent line at a predetermined timing, adds, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputs charges added up to a line corresponding to an end, and a control unit connected to the array image sensing unit to output a transfer signal for sequentially transferring charges of pixels of each line to an adjacent line, and the control unit having a stage scanning mode in which the array image sensing unit is controlled in accordance with a variation in projection position of the secondary beam projected on the electron detection device that is generated by movement of the stage device, and a deflector operation mode in which the array image sensing unit is controlled in accordance with a variation in projection position of the secondary beam projected on the detection device that is generated by operation of the deflector.

It is still another object of the present invention to provide an object observation apparatus comprising an irradiation optical system which is arranged to face a sample, and irradiates the sample surface with an electron beam, an electron detection device which is arranged to face the sample, and detects as a secondary beam at least one of a secondary electron, reflected electron, and back-scattering electron generated by the sample upon irradiation of the electron beam, a deflector arranged between the irradiation optical system and electron detection device and the sample, irradiates the sample surface with the electron beam from the irradiation optical system, and guides a primary beam generated by the sample to the electron detection device, an objective electrooptic system arranged between the deflector and the sample, and a limiting member arranged at a focus position of the objective electrooptic system to limit the secondary beam amount, wherein the objective electrooptic system and limiting member constitute a telecentric electrooptic system.

It is still another object of the present invention to provide an object observation method of observing an object using an electron beam, characterized by comprising the irradiation step of irradiating the object on a stage with the electron beam, the conversion step of projecting a secondary beam from the irradiated object onto a fluorescent portion, and converting the secondary beam into light at the fluorescent portion, and the image sensing step of detecting image information of the light, converted at the fluorescent portion, with pixels of a plurality of lines each including a plurality of pixels, sequentially transferring charges generated in pixels of each line to corresponding pixels of an adjacent line at a predetermined timing, adding, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputting charges added up to a line corresponding to an end, the image sensing step having a stage scanning mode in which a

projection position of the secondary beam from the object moving with movement of the stage is varied, and a deflector operation mode in which the projection position of the secondary beam from the object is varied by operating a deflector.

It is still another object of the present invention to provide an object observation apparatus characterized by comprising a drivable stage on which a sample is placed, an irradiation optical system which is arranged to face the sample on the stage, and emits an electron beam, an electron detection device which is arranged to face the sample, has a detection surface on which at least one of a secondary electron, reflected electron, and back-scattering electron generated by the sample upon irradiation of the electron beam is projected as a secondary beam, and generates image information of the sample, an electrooptic system arranged between the sample and the electron detection device to form the secondary beam into an image on the detection surface of the electron detection device, and a position detection device which is adjacent to the stage to detect a position of the stage, the electron detection device having a converter arranged on the detection surface to convert the secondary beam into light, an array image sensing unit which is adjacent to the converter, has pixels of a plurality of lines each including a plurality of pixels, sequentially transfers charges of pixels of each line generated upon reception of light of an optical image obtained via the converter to corresponding pixels of an adjacent line at a predetermined timing, adds, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputs charges added up to a line corresponding to an end, and a control unit connected to the array image sensing unit to output a transfer signal for sequentially transferring charges of pixels of each line to an adjacent line, the control unit controlling the array image sensing unit using a detection signal from the position detection device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing the whole arrangement of an object observation apparatus according to an embodiment of the present invention;

FIG. **2** is a view for explaining the structure of a primary column and the orbit of a primary beam in the object observation apparatus shown in FIG. **1**;

FIGS. **3**A and **3**B are views each for explaining the structure of an electrostatic lens in the primary column shown in FIG. **2**;

FIG. **4** is a view for explaining the structure of a secondary column and the orbit of a secondary beam in the object observation apparatus shown in FIG. **1**;

FIGS. **5**A, **5**B, and **5**C are views for explaining the structure and operation principle of a Wien filter **29** used in the object observation apparatus shown in FIG. **1**;

FIG. **6** is a view showing the structure of a detector **36** used in the object observation apparatus of the embodiment shown in FIG. **1**;

FIGS. **7**A to **7**F are views for explaining the operation principle of a TDI array;

FIG. **8** is a flow chart for explaining defective portion detecting operation executed in the object observation apparatus of the embodiment shown in FIG. **1**;

FIGS. **9**A and **9**B are views for explaining a stage scanning mode executed in the object observation apparatus of the embodiment shown in FIG. **1**;

FIG. **10** is a block diagram showing the arrangement of a TDI array sensor used in the embodiment shown in FIG. **1**; and

FIGS. **11**A and **11**B are views for explaining a deflector operation mode executed in the object observation apparatus of the embodiment shown in FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will be described with reference to the accompanying drawings. The same reference numerals denote the same parts throughout the drawings, and a repetitive description thereof will be omitted.

FIG. **1** is a view showing the whole arrangement of the embodiment. FIG. **2** is a view showing the structure of a primary column and the orbit of a primary beam. FIG. **3** shows views of the structure of an electrostatic lens in the primary column. FIG. **4** is a view showing the orbit of a secondary beam in a secondary column.

As shown in FIG. **1**, an observation apparatus comprises a primary column **21**, secondary column **22**, and chamber **23**.

The primary column **21** is diagonally connected to the side surface of the secondary column **22**, and the chamber **23** is located below the secondary column **22**.

The primary column **21** incorporates an electron gun **24**. A primary optical system **25** is located on the optical path of an electron beam (primary beam) emitted by the electron gun **24**. A Wien filter **29** in the secondary column **22** is located diagonally to the optical axis ahead of the primary optical system **25**.

The chamber **23** incorporates a stage **26** on which a sample **27** is placed.

In the secondary column **22**, a cathode lens **28**, the Wien filter **29**, a numerical aperture **29**a, a first lens **31**, a field aperture **32**, a second lens **33**, a third lens **34**, a deflector **35**, and a detector **36** are arranged on the optical path of a secondary beam generated by the sample **27**.

Note that the numerical aperture **29**a corresponds to an aperture stop, and is made of a thin film of a metal (Mo or the like) having a circular hole. This aperture portion is positioned at the convergent position of the primary beam and a pupil position serving as the focus position of the cathode lens **28** to which a parallel beam from the sample is focused by the cathode lens **28**. Thus, the cathode lens **28** and numerical aperture **29**a constitute a telecentric electrooptic system.

A primary beam from the electron gun **24** is incident on the Wien filter **29** while being influenced by lens operation through the primary optical system **25**. The electron gun chip is made of LaB_6 from which a large current can be extracted by a rectangular cathode. The primary optical system **25** uses a quadrupole or octupole electrostatic (electromagnetic) lens asymmetrical about the axis of rotation. This lens can cause convergence and divergence on each of the x- and y-axes, similar to a so-called cylindrical lens. This lens is formed from two or three lenses, and the conditions of each lens are optimized. This makes it possible to form a beam irradiation region on the sample surface into an arbitrary rectangular or elliptic shape without losing any irradiation electrons.

More specifically, when an electrostatic lens is used, as shown in FIG. **3**A, four columnar rods are used. Facing electrodes (a-b or c-d) are set at the same potential and given opposite voltage characteristics. Instead of the columnar quadrupole lens, lenses obtained by dividing a generally used circular plate may be used in an electrostatic deflector, as shown in FIG. **3**B. In this case, the lens can be downsized.

As shown in FIG. **2**, the orbit of a primary beam B**1** having passed through the primary optical system **25** is deflected by the deflecting operation of the Wien filler **29**. Assume that the magnetic field and electric field cross at a right angle, and E, B, and v represent the electric field, magnetic field, and charged-particle speed, respectively. In this case, the Wien filter **29** allows only charged particles that satisfy the Wien condition of E=vB to travel straight, and deflects the remaining charged particles.

The function of the Wien filter will be explained. As shown in FIGS. **5**A, **5**B, and **5**C, a force FB by the magnetic field and a force FE by the electric field are generated for the primary beam B**1** to deflect its beam orbit. As for a secondary beam B**2**, the forces FB and FE act in opposite directions and cancel each other, and thus the secondary beam B**2** travels straight.

The lens voltage of the primary optical system **25** is set in advance so as to form a primary beam into an image at the aperture portion of the numerical aperture **29**a. This numerical aperture **29**a prevents a redundant electron beam scattering in the apparatus from reaching the sample surface, and prevents charge-up and contamination of the sample **27**.

The numerical aperture **29**a and cathode lens **28** constitute a telecentric optical system. Hence, as shown in FIG. **2**, a primary beam having passed through the cathode lens **28** becomes a parallel beam, which uniformly irradiates the sample **27**. That is, so-called Köhler illumination in an optical microscope is realized.

The primary beam having passed through the cathode lens **28** vertically irradiates the sample **27** to give the secondary beam a clear electronic image without any shadow.

In this embodiment, the irradiation region of the primary beam irradiating the sample **27** is rectangular. Secondary electrons, reflected electrons, or back-scattering electrons are generated as a secondary beam from the entire beam irradiation region of the sample **27**. This secondary beam has rectangular two-dimensional image information.

When the primary beam irradiates the sample, secondary electrons, reflected electrons, or back-scattering electrons are generated as a secondary beam from the beam irradiation surface of the sample.

The secondary beam passes through the lens while being influenced by the lens operation of the cathode lens **28**. The cathode lens **28** is made up of three electrodes. The lowest electrode is designed to form a positive electric field with the potential on the sample **27** side, draw electrons (especially secondary electrons weak in directivity), and efficiently guide the electrons into the lens.

The lens operation is attained by applying a voltage between the first and second electrodes of the cathode lens **28** and setting the third electrode to a potential of 0. Alternatively, the cathode lens **28** may be made up of four electrodes.

The numerical aperture **29**a is located at the focus Position of the cathode lens **28**, i.e., the back-focus position from the sample **27**.

As shown in FIG. **4**, a bundle B**2**a of electron beams generated outside the center of the field of view (outside the axis) are also changed into parallel beams, which pass through the central position of the numerical aperture **29**a without being eclipsed.

Note that the numerical aperture **29**a functions to suppress the lens aberration of the first, second, and third lenses **31**, **32**, and **34** with respect to the secondary beam.

The secondary beam B**2** having passed through the numerical aperture **29**a travels straight and passes through the Wien filter **29** without being influenced by the deflecting operation of the Wien filter **29**. By changing the electromagnetic field applied to the Wien filter **29**, only electrons (e.g., secondary electrons, reflected electrons, or back-scattering electrons) having a specific energy pass through the deflector **35** and are formed into an image on the detection surf ace of the detector **36**. At this time, electrons are free from any deflecting operation of the deflector **35**.

If the secondary beam B**2** is formed into an image by only the cathode lens **28**, the lens operation becomes strong, and aberration readily occurs. To prevent this, the cathode lens **28** forms one image in cooperation with the first lens **31**. The secondary beam is formed into an intermediate image at the field aperture **32** through the cathode lens **28** and first lens **31**.

Generally in this case, the secondary optical system is often short in necessary enlargement magnification, and thus is constituted by the second and third lenses **33** and **34** as lenses for enlarging an intermediate image. The secondary lens is enlarged and formed into an image through the second and third lenses **33** and **34**. In this case, a total of two images are formed. Note that the third and fourth lenses **33** and **34** may be combined to form one image (a total of two images).

The first to third lenses **31** to **34** are lenses symmetrical about the axis of rotation called unipotential or einzel lenses. Each lens has three electrodes. In general, the two outer electrodes are set to a potential of 0, and lens operation is attained and controlled by the voltage applied to the central electrode.

The field aperture **32** is set at the intermediate imaging point. This field aperture **32** limits the field of view to a necessary range, similar to the field stop of an optical microscope. For an electron beam, the field aperture **32** cuts off a redundant beam in cooperation with the second and third lenses **33** and **34** on the exit side to prevent chart-up and contamination of the detector **36**. The enlargement magnification is set by changing the lens conditions of the second and third lenses **33** and **34**, e.g., their focal lengths.

In this manner, in the first embodiment, the numerical aperture **29**a and cathode lens **28** constitute a telecentric electrooptic system. As for the primary beam, the beam can uniformly illuminate a sample. That is, Köhler illumination can be easily realized.

As for the secondary beam, all principal rays from the sample **27** are incident on the cathode lens **28** vertically (parallel to the optical axis of the lens), and pass through the numerical aperture **29**a. For this reason, marginal rays are not eclipsed, and the image brightness at the periphery of the sample does not decrease on the detection surface.

So-called aberration of magnification occurs in which the imaging position changes owing to variations in electron energy (in particular, secondary electrons cause a large aberration of magnification because of great variations in energy). However, this chromatic aberration of magnification can be suppressed by locating the numerical aperture **29**a at the focus position of the cathode lens **28**, i.e., making the aperture position coincide with the pupil position of the optical system.

Even if the distance between the sample **27** and cathode lens **28** varies, and focusing is executed, the enlargement magnification does not change because of the telecentric optical system. Focusing is done by changing the focal length of the cathode lens **28**. Even if the focal length is changed, the arrangement of the telecentric electrooptic system does not change because the focal offset is very small.

The enlargement magnification is changed after a beam passes through the numerical aperture **29**a. Even if set magnifications as the lens conditions of the second and third lenses **33** and **34** are changed, a uniform image can be obtained on the entire field of view on the detection side.

This embodiment can attain a uniform image. Further, the embodiment can keep the signal density of detection electrons constant to obtain an image having a constant brightness even if the enlargement magnification of the secondary optical system is increased by increasing the irradiation energy density of an electron beam.

As shown in FIG. **1**, the input/output terminal of the detector **36** is connected to the input/output terminal of a CCD camera driving control unit **37**. An output from the CCD camera driving control unit **37** is input to a CRT **39** via a CPU **38**.

The CPU **38** outputs a control signal to a primary column control unit **40**, secondary column control unit **41**, deflection control unit **42**, and stage driving mechanism **43**.

The primary column control unit **40** controls the lens voltage of the primary optical system **25**, and the secondary column control unit **41** controls the lens voltages of the cathode lens **28**, first lens **31**, second lens **33**, and third lens **34**. The deflection control unit **42** controls a voltage applied to the deflector **35**, and the stage driving mechanism **43** controls driving of the stage **26** in the x and y directions.

The CCD camera driving control unit **37** receives a control signal from a laser interferometer unit **44** and a control signal from the deflection control unit **42**.

The primary column **21**, secondary column **22**, and chamber **23** are connected to an evacuation system (not shown), and evacuated by the turbopump of the evacuation system to keep their insides vacuum.

FIG. **6** shows the structure of the detector **36**. The detector **36** is constituted by a first MCP (Micro Channel Plate) **45**a, second MCP **45**b, FOP (Fiber Optic Plate) **47** having a fluorescent surface **46**, and CCD camera **48** having a TDI array CCD sensor.

Image sensing operation of the TDI array CCD sensor used in the object observation apparatus will be explained with reference to FIGS. **7**A to **7**F.

As shown in FIG. **7**A, an electron beam irradiates a predetermined portion of the sample **27**. At this time, as shown in FIG. **7**B, the TDI array CCD sensor accumulates signal charges in a horizontal scanning line A corresponding to the portion irradiated with the electron beam. The CPU **38** moves the stage **26** and sample **27** at a predetermined timing by one horizontal scanning line in the y direction, as shown in FIG. **7**C. At the same time, the CCD camera driving control unit **37** transfers signal charges accumulated in the line A to a line B. Hence, as shown in FIG. **7**D, the sum of signal charges accumulated in previous image sensing operation and signal charges obtained in current image sensing operation is accumulated in the line B. As shown in FIG. **7**E, the CRT **39** further moves the stage **26** and sample **27** by one horizontal scanning line. At the same time, as shown in FIG. **7**F, the CCD camera driving control unit **37** transfers the signal charges of the line A to the line B and the signal charges of the line B to a line C. As a result, the sum of signal charges obtained in second previous, previous, and current image sensing operations is accumulated in the line C.

By repeating the above operation, signal charges at the same portion of the sample can be added and accumulated by the number of horizontal scanning lines. In other words, the TDI array CCD sensor can delay signal charges to repeat image sensing operation, thereby accumulating and increasing signal charges at the same portion of the sample. This can increase the current density of the sample and the S/N ratio of a detected image. As shown in FIG. **4**, the secondary beam B**2** is incident on the first MCP **45**a. While the current amount is amplified within the first MCP **45**a, the secondary beam B**2** passes through the second MCP **45**b and collides against the fluorescent surface **46**. At this time, the incident potential of the first MCP **45**a is adjusted to set the acceleration voltage of the secondary beam to a value having the highest detection efficiency of the MCP.

For example, when the acceleration voltage of the secondary beam is +5 kv, the incident potential of the first MCP **45**a is set to −4.5 kV to decelerate and set the electron energy to about 0.5 keV.

The current amplification factor of the secondary beam is defined by a voltage applied between the first and second MCPs **45**a and **45**b. For example, when a voltage of 1 kV is applied, the amplification factor is 1×104. In order to suppress spread of a secondary beam output from the second MCP **45**b as much as possible, a voltage of about 4 kV is applied between the second MCP **45**b and fluorescent surface **46**.

On the fluorescent surface **46**, electrons are converted into an optical image. The optical image passes through the FOP **47** and is sensed by the CCD camera **48**. To make the image size on the fluorescent surface **46** match the image sensing size of the CCD camera **48**, the FOP **47** reduces the optical image to about ⅓, and projects the reduced image.

The optical image is photoelectrically converted by the TDI array CCD sensor of the CCD camera **48**, and signal charges are accumulated in the TDI array CCD sensor. The CCD camera driving control unit **37** serially reads out image information from the TDI array CCD sensor, and outputs the information to the CPU **38**. The CPU **38** displays the detected image on the CRT **39**.

Next, a stage scanning mode and deflector operation mode as operations according to this embodiment will be described with reference to the accompanying drawings. FIG. **8** is a flow chart for explaining defective portion detecting operation.

Operation Mode

Stage Scanning Mode

When the sample is a semiconductor wafer, as shown in FIGS. **9**A and **9**B, raster scanning is executed to detect an image on the entire chip. FIG. **9**B is an enlarged view of one chip in FIG. **9**A. The primary beam irradiates a fixed position and scans the sample surface by driving the stage **26**.

The sample on the stage **26** moves at a constant speed in the y direction by the CPU **38** and stage driving mechanism **43**.

In this case, a region from (X**1**, Y**1**) to (X**512**, Y**256**) is set as a region to be inspected. The TDI array CCD sensor has, e.g., 512×256 pixels, and the region to be inspected is projected to match the TDI array CCD sensor.

An image from (X**1**, Y**1**) to (X**512**, Y**1**) as the region to be inspected is sensed by the TDI array CCD sensor. Signal charges are accumulated in ROW **1** of the TDI array CCD sensor shown in FIG. **10**. The stage **26** moves in the y direction in accordance with an instruction from the CPU **38**, and then the beam irradiation region moves in the scanning direction by one horizontal scanning line of the TDI array CCD sensor. At the same time, the laser interferometer unit

44 outputs a vertical clock signal to the CCD camera driving control unit 37.

Upon reception of the vertical clock signal, the CCD camera driving control unit 37 outputs a transfer pulse to transfer signal charges accumulated in ROW 1 to ROW 2. In ROW 2, signal charges obtained by sensing an image from (X1, Y1) to (X512, Y1) have been accumulated. These signal charges are added to signal charges transferred from ROW 1, and the sum is accumulated. Then, an image from (X1, Y2) to (X512, Y2) is sensed, and its signal charges are accumulated in ROW 1.

Tn this way, the primary beam scans the region to be inspected by sequentially driving the stage 26 in the y direction. Accumulated charges are sequentially transferred to an adjacent row in accordance with driving of the stage.

When an image from (X1, Y256) to (x512, Y256) as the region to be inspected is sensed and accumulated in ROW 1 of the TDI array COD sensor, an image from (X1, Y1) to (X512, Y1) is cumulated by the number of horizontal scanning lines and accumulated in ROW 256 of the TDI array CCD sensor.

If a transfer pulse is input to the TDI array CCD sensor in this state, signal charges accumulated in ROW 256 are transferred to a CCD shift register via a transfer gate (not shown), and output to the CPU 38 via the CCD camera driving control unit 37.

By sequentially driving the stage 26, the primary beam scans the sample, and the sample image is extracted from the TDI array CCD sensor in units of horizontal scanning lines.

This operation is executed for the entire chip surface to acquire an image of the entire chip surface (step S1 in FIG. 8).

After the image of the entire chip surface is acquired, the CPU 38 specifies a defective portion by template matching with a template image prepared in advance based on design data. More specifically, the CPU 38 reduces noise by smoothing processing using an edge-preserved smoothing filter, and then calculates the correlation coefficient between the template image and detected image, thereby specifying an unmatched portion, i.e., defective portion (step S2 in FIG. 8). The CPU 38 stores the address of the defective portion in an internal memory.

Deflector Operation Mode

The deflector operation mode in which a defective portion is enlarged and displayed when the defective portion is detected (step S3 in FIG. 8) will be explained.

The CPU 38 drives the stage 26 via the stage driving mechanism 43 to position the defective portion (step S4 in FIG. 8). The CPU 38 changes the focal lengths of the second and third lenses 33 and 34 to enlarge and display the defective portion.

As shown in FIG. 11A, an image from (X1, Y1) to (X512, Y1) in a region T to be inspected at the defective portion in a beam irradiation region Z on the chip C is sensed and accumulated in ROW 1 of the TDI array CCD sensor in FIG. 10.

The CPU 38 calculates a voltage value to be applied to the deflector 35 on the basis of a set enlargement magnification, and outputs a control signal to the deflection control unit 42. The deflection control unit 42 controls the voltage applied to the deflector 35 in accordance with the control signal from the CPU 38. As shown in FIG. 11B, the projection position of a secondary beam projected on the detection surface of the detector 36 is deflected and moved by one horizontal scanning line in an arrow direction W in FIG. 11B.

At the same time, the deflection control unit 42 outputs a vertical clock signal to the CCD camera driving control unit 37. The CCD camera driving control unit 37 outputs a transfer pulse to transfer signal charges accumulated in ROW 1 to ROW 2.

In ROW 2, signal charges obtained by sensing an image from (X1, Y1) to (X512, Y1) have been accumulated. These signal charges are added to signal charges transferred from ROW 1, and the sum is accumulated. Then, an image from (X1, Y2) to (X512, Y2) is sensed, and its signal charges are accumulated in ROW 1.

In this fashion, the region to be inspected is scanned by sequentially moving the projection position of the secondary beam by the deflector 35. At this time, accumulated signal charges are sequentially transferred to an adjacent row in accordance with the projection position of the secondary beam. When an image from (X1, Y256) to (X512, Y256) as the region to be inspected is sensed and accumulated in ROW 1 of the TDI array CCD sensor, an image from (X1, Y1) to (X512, Y1) is added by the number of horizontal scanning lines and accumulated in ROW 256 of the TDI array CCD sensor.

If a transfer pulse is input in this state, signal charges accumulated in ROW 256 are transferred to the CCD shift register via the transfer gate (not shown), and output to the CPU 38 via the CCD camera driving control unit 37.

By sequentially moving the projection position of the secondary beam by the deflector 35, the sample image is extracted from the TDI array CCD sensor in units of horizontal scanning lines. The CPU 38 can acquire an image at the defective portion (step S5 in FIG. 8).

This operation is executed for all the defective portions, and repeated until the images of the defective portions are sequentially acquired and stored as an image file in a recording medium (step S6 in FIG. 8).

For the entire chip surface, the object observation apparatus of the embodiment drives the stage 26 to execute beam scanning, and senses an image using the TDI array CCD sensor to detect a defective portion. For the defective portion, the apparatus moves the projection position of the secondary beam by the deflector 35 to scan the sample.

The object observation apparatus uses the stage scanning mode for detection of an image on the entire sample surface, and uses the deflector operation mode for the local region of the sample. Accordingly, the apparatus can detect the defective pattern of the sample at a high speed and high precision.

Especially in the local region, no image is sensed by driving the stage 26, so the stage 26 need not be controlled at a high precision. In addition, a decrease in S/N ratio of a detected image owing to hunting of the stage 26 poses a problem. However, the decrease in image quality can also be avoided.

As a sample scanning method, this embodiment executes raster scanning, but the present invention is not limited to this.

In the deflector operation mode, the beam irradiation region may be changed in accordance with the size of a defective portion. The shape of the beam irradiation region is not limited to a rectangular one.

The matching method in pattern matching is not limited to the method described in the embodiment, and may be another matching method such as SSDA (Sequential Similarity Detection Algorithm) or the residual sum of squares.

In the object observation apparatus of the embodiment, a defect detection device 9 detects a defective portion from image information of a sample by template matching or the like.

At this time, it is also possible to search for defective portions of the entire sample in the stage scanning mode and then finely observe each defective portion in the deflector operation mode.

This embodiment adopts the Wien filter **29** for deflecting the orbit of the primary beam and allowing the secondary beam to travel straight, but the present invention is not limited to this. The primary beam may travel straight, and secondary electrons or the like emitted by the sample may be detected. Alternatively, the orbit of the secondary beam may be deflected by the Wien filter and detected.

This embodiment forms a rectangular beam as a primary lens through the rectangular lens and quadrupole lens, but the present invention is not limited to this. A circular beam may be formed using a general electrostatic or electromagnetic lens symmetrical about the axis of rotation, and may be formed into a rectangular or elliptic beam. Instead, the circular beam may be extracted as a rectangular beam through a slit. In this case, the primary optical system can be realized with a simple arrangement. Since the primary optical system need not be made up of three lenses, this system can be electrically, mechanically downsized at a low cost.

As has been described above, the object observation apparatus according to the embodiment of the present invention has the stage scanning mode in which an electron beam scans a sample by driving the stage, and the deflector operation mode in which an image is sensed by moving the projection position of the secondary beam using the deflection means. For a large region to be inspected, the apparatus can use the stage scanning mode to detect an image at a high speed. For a small region, the apparatus can use the deflector operation mode to detect an image at a high sensitivity and high image quality. Especially in detecting an image of the local region, the stage must be stably controlled at a high precision. However, using the deflector operation mode eliminates complicated high-precision control of the stage. The apparatus can cope with detection of a very small region.

In this object observation apparatus, the stage scanning mode is suitable for detection of defects and confirmation of an image on the entire sample. The deflector operation mode is suitable for detection of defects in the local region of the sample. By using a combination of the two modes, defective portions of an image can be detected at a high speed and high precision. In this manner, the pattern inspection apparatus to which the present invention is applied can avoid a decrease in S/N ratio caused by vibrations of the stage without controlling driving of the stage at a high precision. Consequently, the inspection reliability can increase.

In this embodiment, the objective electrooptic system and beam limiting means constitute a telecentric electrooptic system. Hence, all the principal rays from a sample are vertically incident on the objective electrooptic system and pass the beam limiting means. Marginal rays are not eclipsed, and the image brightness at the periphery of the sample does not decrease. That is, a uniform, clear image can be acquired both at the periphery and center of the sample.

Even if the distance between the sample and objective electrooptic system varies, and focusing is executed, the enlargement magnification does not change because of the telecentric electrooptic system.

Since an electron beam is focused at the focus position of the objective electrooptic system, the electron beam uniformly irradiates the sample. That is, Köhler illumination can be easily realized. Even if an electron gun chip for emitting an electron beam suffers luminance irregularity, the intensity irregularity of the beam is unified by the objective electrooptic system, and the beam irradiates the sample. Thus, noise by intensity irregularity can be reduced.

Moreover, the sectional shape of the electron beam can be formed into a rectangular or elliptic shape. The beam irradiation region on the sample surface, therefore, has a predetermined rectangular or elliptic area. At this time, complicated lens control is required to uniformly irradiate the entire irradiation area with a beam. However, this embodiment can unify the electron beam to irradiate the entire area.

Since the observation apparatus to which the present invention is applied can increase the S/N ratio of an observation image, a high-reliability observation apparatus can be realized.

What is claimed is:

[1. An object observation apparatus comprising:

a drivable stage on which a sample is placed;

an irradiation optical system which is arranged to face the sample on said stage, and emits an electron beam as a primary beam;

an electron detector which is arranged to face the sample, has a detection surface on which at least one of a secondary electron, a reflected electron, and a backscattering electron generated by the sample upon irradiation of the electron beam is projected as a secondary beam, and generates image information of the sample;

a stage driver which is adjacent to said stage to drive said stage; and

a deflector arranged between the sample and said electron detector to deflect the secondary beam,

said electron detector having:

a converter arranged on the detection surface to convert the secondary beam into light;

an array image sensor which is adjacent to said converter, has pixels of a plurality of lines each including a plurality of pixels, sequentially transfers charges of pixels of each line generated upon reception of light of an optical image obtained via said converter to corresponding pixels of an adjacent line at a predetermined timing, adds, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputs charges added up to a line corresponding to an end; and

a controller connected to said array image sensor to output a transfer signal for sequentially transferring charges of pixels of each line to an adjacent line, and

said controller having:

a stage scanning mode in which said array image sensor is controlled in accordance with a variation in projection position of the secondary beam projected on said electron detector that is generated by movement of said stage device; and

a deflector operation mode in which said array image sensor is controlled in accordance with a variation in projection position of the secondary beam projected on said detector that is generated by operation of said deflector.**]**

[2. An object observation apparatus according to claim **1**, further comprising a defect detector that detects a defective portion from the image information of the sample generated by said electron detector.**]**

[3. An object observation apparatus according to claim **1**, wherein the electron beam has a rectangular or elliptic sectional shape.**]**

[4. An object observation method of observing an object using an electron beam, comprising:

an irradiation step of irradiating the object on a stage with the electron beam;

a conversion step of projecting a secondary beam from the irradiated object onto a fluorescent portion, and converting the secondary beam into light at the fluorescent portion; and

an image sensing step of detecting image information of the light, converted at the fluorescent portion, with pixels of a plurality of lines each including a plurality of pixels, sequentially transferring charges generated in pixels of each line to corresponding pixels of an adjacent line at a predetermined timing, adding, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputting charges added up to a line corresponding to an end,

the image sensing step having:

a stage scanning mode in which a projection position of the secondary beam from the object moving with movement of the stage is varied; and

a deflector operation mode in which the projection position of the secondary beam from the object is varied by operating a deflector.]

[5. An object observation apparatus comprising:

a drivable stage on which a sample is placed;

an irradiation optical system which is arranged to face the sample on said stage, and emits an electron beam;

an electron detector which is arranged to face the sample, has a detection surface on which at least one of a secondary electron, a reflected electron, and a backscattering electron generated by the sample upon irradiation of the electron beam is projected as a secondary beam, and generates image information of the sample;

an electrooptic system arranged between the sample and said electron detector to form the secondary beam into an image on the detection surface of said electron detector; and

a position detector which is adjacent to said stage to detect a position of said stage,

said electron detector having:

a converter arranged on the detection surface to convert the secondary beam into light;

an array image sensor which is adjacent to said converter, has pixels of a plurality of lines each including a plurality of pixels, sequentially transfers charges of pixels of each line generated upon reception of light of an optical image obtained via said converter to corresponding pixels of an adjacent line at a predetermined timing, adds, every transfer, charges generated upon reception of light after the transfer at the pixels which received the charges, and sequentially outputs charges added up to a line corresponding to an end; and

a controller connected to said array image sensor to output a transfer signal for sequentially transferring charges of pixels of each line to an adjacent line,

said controller controlling said array image sensor using a detection signal from said position detector.]

[6. An object observation apparatus according to claim 5, further comprising:

a deflector arranged between the sample and said electron detector to deflect the secondary beam; and

a deflector driver connected to said deflector to drive said deflector, and

said controller controls said array image sensor by selectively using the detection signal and a control signal from said deflector driver.]

7. A method of observing an object using an electron beam, comprising:

irradiating a region of an object with a primary electron beam, wherein a secondary beam is generated from the region of the object, the region of the object comprising a plurality of pixels;

detecting image information of the secondary beam using a time delay integration array charge coupled device sensor, the sensor having a plurality of lines each of which contains a plurality of pixels; and

transferring signal charges accumulated in one of the lines to an adjacent line in correspondence with driving a stage or a voltage applied to a deflector which deflects the secondary beam.

8. The method of claim 7, wherein the number of pixels in the region of the object corresponds to the number of pixels in the sensor.

9. A method of observing an object using an electron beam, comprising:

irradiating a region of an object with a primary electron beam, wherein a secondary beam is generated from the region of the object, the region of the object comprising a plurality of pixels;

detecting image information of the secondary beam to acquire an image of an entire surface of the object using a time delay integration array charge coupled device sensor, the sensor having a plurality of lines each of which contains a plurality of pixels, wherein signal charges accumulated in one of the lines are transferred to an adjacent line in correspondence with driving a stage;

specifying a defective region of the object by template matching with a template image;

detecting image information of the secondary beam to acquire an enlarged image of the defective region using the time delay integration array charge coupled device sensor, wherein signal charges accumulated in one of the lines are transferred to an adjacent line in correspondence with driving a voltage applied to a deflector which deflects the secondary beam.

10. The method of claim 9, wherein the number of pixels in the region of the object corresponds to the number of pixels in the sensor.

11. A method of observing an object using an electron beam, comprising:

irradiating a region of an object with a primary electron beam, wherein a secondary beam is generated from the region of the object, the region of the object comprising a plurality of pixels;

converting electrons emitted from the region of the object into light;

detecting image information of the light using a time delay integration array charge coupled device sensor, the sensor having a plurality of lines each of which contains a plurality of pixels; and

transferring signal charges accumulated in one of the lines to an adjacent line in correspondence with driving a stage or a voltage applied to a deflector which deflects the secondary beam.

12. The method of claim 11, wherein the number of pixels in the region of the object corresponds to the number of pixels in the sensor.

13. A method of observing an object using an electron beam, comprising:

irradiating a region of an object with a primary electron beam, wherein a secondary beam is generated from the region of the object, the region of the object comprising a plurality of pixels;

converting electrons emitted from the region of the object into light;

detecting image information of the light to acquire an image of an entire surface of the object using a time delay integration array charge coupled device sensor, the sensor having a plurality of lines each of which contains a plurality of pixels, wherein signal charges accumulated in one of the lines are transferred to an adjacent line corresponding to a driving of a stage;

specifying a defective region of the object by template matching with a template image;

detecting image information of the light to acquire an enlarged image of the defective region using the time delay integration array charge coupled device sensor, wherein signal charges accumulated in one of the lines are transferred to an adjacent line in correspondence with driving a voltage applied to a deflector which deflects the secondary beam.

14. The method of claim 13, wherein the number of pixels in the region of the object corresponds to the number of pixels in the sensor.

15. An object observation apparatus, comprising:

a stage for placing an object;

a stage driver;

an irradiation optical system for irradiating a region of the object with a primary electron beam;

an electron detector for detecting image information of a secondary beam generated from the region of the object, the region of the object comprising a plurality of pixels; and

a deflector arranged between the object and the electron detector for deflecting the secondary beam;

wherein the electron detector comprises:

a time delay integration array charge coupled device sensor having a plurality of lines, each line containing a plurality of pixels; and

a controller connected to the time delay integration array image charge coupled device sensor for transferring signal charges accumulated in one of the lines to an adjacent line in accordance with driving the stage by the stage driver or a voltage applied to the deflector for deflecting the secondary beam.

16. An object observation apparatus, comprising:

a stage for placing an object;

a stage driver;

an irradiation optical system for irradiating a region of the object with a primary electron beam;

an electron detector for detecting image information of a secondary beam generated from the region of the object, and the electron detector comprising a time delay integration array charge coupled device sensor having a plurality of lines, each line containing a plurality of pixels, and a controller connected to the time delay integration array charge coupled device sensor for transferring signal charges accumulated in one of the lines to an adjacent line;

a deflector arranged between the object and the electron detector for deflecting the secondary beam; and

a specifying unit for receiving image information of an entire surface of the object and specifying a defective region of the object by template matching with a template image;

wherein the controller transfers the signal charges in accordance with driving the stage by the stage driver to acquire the image information of the entire surface of the object and a voltage applied to the deflector for deflecting the secondary beam to acquire an enlarged image of the defective region of the object.

17. An object observation apparatus, comprising:

a stage for placing an object;

a stage driver;

an irradiation optical system for irradiating a region of the object with a primary electron beam;

an electron detector for detecting image information of a secondary beam generated from the region of the object, and the electron detector comprising a fluorescent unit for converting the secondary beam into light, a time delay integration array charge coupled device sensor having a plurality of lines, each line containing a plurality of pixels, and a controller connected to the time delay integration array charge coupled device sensor for transferring signal charges accumulated in one of the lines to an adjacent line;

a deflector arranged between the object and the electron detector for deflecting the secondary beam; and

a specifying unit for receiving image information of an entire surface of the object and specifying a defective region of the object by template matching with a template image;

wherein the controller transfers the signal charges in accordance with driving the stage by the stage driver to acquire the image information of the entire surface of the object and a voltage applied to the deflector for deflecting the secondary beam to acquire an enlarged image of the defective region of the object.

* * * * *