

LOW-ENERGY SCANNING ELECTRON MICROSCOPE SYSTEM, SCANNING ELECTRON MICROSCOPE SYSTEM, AND SPECIMEN DETECTION METHOD

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TECHNICAL FIELD

The disclosure relates to scanning electron microscope technologies, and in particular, to a low-energy scanning electron microscope system, a scanning electron microscope system, and a specimen detection method.

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BACKGROUND

A scanning electron microscope is widely used to observe characteristics of a specimen in a size range of microns or nanometers. During observation of a nonmetal specimen such as a biological specimen or a semiconductor specimen, a low-droppoint-energy (less than 3 keV) scanning electron microscope is widely used due to its reduced damage and charge effect to the specimen.

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On one hand, in a low-droppoint energy condition, most specimens to be detected are non-conductive materials. To prevent a charge effect and damage to the specimen, an incident scanning beam is usually set to be very small, e.g., several hundreds of picoamperes (pAs) or even several pAs, causing very few signal electrons to be excited from the specimen. To ensure imaging quality, a detector needs to collect as many signal electrons as possible. Moreover, an imaging speed is constrained by signal electron collection efficiency, that is, the signal electron collection efficiency affects a flux of a scanning electron microscope. Therefore, it is very important to improve the signal electron collection efficiency.

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On the other hand, among signal electrons excited by an incident electron beam on the specimen, electrons with energy less than 50 eV are secondary electrons (SE), and electrons with energy close to that of incident electrons are back-scatter electrons (BSE). The secondary electrons can represent morphological characteristics of the specimen. Since the back-scatter electrons are related to an atomic number of an observed material, the back-scatter electrons represent more material information of the specimen. Back-scatter electrons emitted at small angles relative to a specimen surface are influenced by fluctuation of the specimen surface, and can also reflect the morphology information of the specimen surface. Therefore, different types of signal electrons and back-scatter electrons emitted at different angles reflect different specimen information. Especially, for a biological specimen, if being stained by heavy metals, a pure back-scatter electron image is more helpful to characterize the structure of the specimen. Therefore, an image with a better contrast can be formed by detecting secondary electrons and back-scatter electrons, so as to facilitate identifying the structure of the specimen.

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At present, in a low-droptpoint energy condition, there is no scanning electron microscope that can meet requirements such as a high resolution, signal electron collection efficiency reaching 100% or close to 100%, flexible detection of back-scatter electrons emitted at different angles, and flexible control of types of received signal electrons.

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SUMMARY

In view of this, embodiments of the disclosure provide a low-energy scanning electron microscope system, a scanning electron microscope system, and a specimen detection method, so as to improve signal electron collection efficiency and control types of received signal electrons flexibly while maintaining a high resolution of the low-energy scanning electron microscope system.

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An embodiment of the disclosure provides a low-energy scanning electron microscope system, including a first electron source, an electron acceleration structure, a first deflection device, a first detection device, and a composite objective lens composed of a magnetic lens and an electro lens. The first electron source is configured to generate an electron beam. The electron acceleration structure is configured to increase a motion velocity of the electron beam. The composite objective lens is configured to converge the electron beam accelerated by the electron acceleration structure. The first deflection device is located between an inner wall of the magnetic lens and an optical axis of the electron beam, and is configured to change a motion direction of the electron beam accelerated by the electron acceleration structure. The first detection device includes a first sub-detection device configured to receive secondary electrons and back-scatter electrons generated when the electron beam acts on a specimen, a second sub-detection device configured to receive the back-scatter electrons, and a control device configured to change motion directions of the secondary electrons and the back-scatter electrons. The electro lens includes the second sub-detection device, a specimen stage, and a control electrode, and is configured to reduce the motion velocity of the electron beam and change the motion directions of the secondary electrons and the back-scatter electrons.

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In the foregoing solution, the electron acceleration structure is an anode.

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In the foregoing solution, the electron acceleration structure includes the anode and a high-voltage tube, where the high-voltage tube is connected to both the anode and the second sub-detection device.

In the foregoing solution, an electron beam adjustment device is further included, and is configured to change a characteristic of the electron beam having passed through the electron acceleration structure.

In the foregoing solution, the electron beam adjustment device includes a convergence device and/or an aperture, where the convergence device is configured to converge the electron beam

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accelerated by the electron acceleration structure; and the aperture is configured to filter the electron beam, where a center of the aperture is at the optical axis.

In the foregoing solution, the first sub-detection device is located between the anode and the magnetic lens, and is close to the magnetic lens; and the second sub-detection device is located
5 below the magnetic lens, and is close to a pole shoe of the magnetic lens.

In the foregoing solution, the first sub-detection device is located between the anode and the magnetic lens, and is close to the magnetic lens; and the second sub-detection device is located below the magnetic lens, and is connected to a lower end surface of the high-voltage tube.

In the foregoing solution, the control device includes a multipole electric deflector and a
10 multipole magnetic deflector.

In the foregoing solution, the magnetic lens is an immersion magnetic lens excited by a current coil, and a pole shoe of the magnetic lens opens towards the specimen.

In the foregoing solution, a diameter of a center hole of the first sub-detection device is not greater than 1 millimeter.

15 In the foregoing solution, a diameter of a center hole of the second sub-detection device is less than a diameter of a center hole of the control electrode.

In the foregoing solution, a voltage value V_1 of the first electron source is less than -5 kV, and a voltage value of the anode is zero.

20 In the foregoing solution, the second sub-detection device is at a ground voltage, the specimen stage has a voltage value V_2 , V_1 is less than V_2 , and V_2 is less than -5 kilo volts, the control electrode has an adjustable voltage value V_3 , and V_3 is less than or equal to 0 kilo volt.

In the foregoing solution, a voltage value V_1 of the first electron source is less than 0 kV, both a voltage value of the anode and a voltage value of the high-voltage tube are V_4 , and V_4 is greater than $+5$ kilo volts.

25 In the foregoing solution, a voltage value of the second sub-detection device is V_4 , the specimen stage has a voltage value V_2 , V_1 is less than V_2 , and V_2 is less than 0 kilo volt, the control electrode has an adjustable voltage value V_3 , and V_3 is less than or equal to V_4 .

In the foregoing solution, when a voltage value V_3 of the control electrode is greater than a voltage value of the second sub-detection device constituting the electro lens, and is less than a
30 voltage value V_2 of the specimen stage constituting the electro lens. The first sub-detection device is specifically configured to receive secondary electrons, and back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, greater than a first threshold. The second sub-detection device is specifically configured to receive back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, less than the first threshold.

35 In the foregoing solution, when a voltage value V_3 of the control electrode in the control

electro lens is less than a voltage value V_2 of the specimen stage by at least 50 volts, the first sub-detection device is specifically configured to receive only back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, greater than a first threshold; and the second sub-detection device is specifically configured to receive only back-scatter electrons in
5 emergent directions at angles, with respect to a surface of the specimen, less than the first threshold.

In the foregoing solution, the low-energy scanning electron microscope system further includes: a signal processing device, connected to the first sub-detection device and/or the second sub-detection device, and configured to process a first signal generated by the first sub-detection
10 device based on the secondary electrons and/or the back-scatter electrons received by the first sub-detection device, and/or configured to process a second signal generated by the second sub-detection device based on the back-scatter electrons received by the second sub-detection device.

In the foregoing solution, the signal processing device includes: a signal amplification
15 sub-device, configured to amplify the first signal and/or the second signal; and a signal processing sub-device, configured to process the amplified first signal and/or second signal.

In the foregoing solution, the signal processing device further includes a signal synthesis sub-device, configured to conduct synthesis processing on the first signal and the second signal that have been processed by the signal processing sub-device, to form a composite image.

20 An embodiment of the disclosure further provides a specimen detection method, including: causing an electron beam generated by a first electron source to pass through an electron acceleration structure, to increase a motion velocity of the electron beam; converging, through a composite objective lens, the electron beam accelerated by the electron acceleration structure, retarding the electron beam through an electro lens, changing a motion direction of the electron
25 beam through a first deflection device, and causing the electron beam to act on a specimen to generate secondary electrons and back-scatter electrons, where the composite objective lens includes a magnetic lens and the electro lens; and changing motion directions of the secondary electrons and the back-scatter electrons under action of the electro lens and a control device, to receive the secondary electrons and the back-scatter electrons by a first detection device.

30 In the foregoing solution, the changing motion directions of the secondary electrons and the back-scatter electrons under action of the electro lens and a control device, to receive the secondary electrons and the back-scatter electrons by a first detection device includes: controlling a voltage value V_3 of a control electrode in the control electro lens to be greater than a voltage value of a second sub-detection device constituting the electro lens, and to be less than a voltage
35 value V_2 of a specimen stage constituting the electro lens; under action of an electric field and a

magnetic field generated by the control device, receiving, by a first sub-detection device in the first detection device, the secondary electrons and back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, greater than a first threshold; and receiving, by the second sub-detection device in the first detection device, back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, less than the first threshold.

In the foregoing solution, when a voltage value V_3 of the control electrode in the control electro lens is less than a voltage value V_2 of the specimen stage by at least 50 volts, under action of the electric field and the magnetic field generated by the control device, all the back-scatter electrons in emergent directions at angles, greater than the first threshold, relative to the surface of the specimen are received by the first sub-detection device in the first detection device; all the back-scatter electrons in emergent directions at angles, less than the first threshold, relative to the surface of the specimen are received by the second sub-detection device in the first detection device; and the secondary electrons move to the surface of the specimen, and are not received by the first sub-detection device and the second sub-detection device.

In the foregoing solution, the method further includes: processing a first signal generated by the first sub-detection device based on the secondary electrons and/or the back-scatter electrons received by the first sub-detection device; and/or processing a second signal generated by the second sub-detection device based on the back-scatter electrons received by the second sub-detection device.

In the foregoing solution, the method further includes: amplifying the first signal and/or the second signal, processing the amplified first signal and/or second signal, and outputting processed first signal and/or second signal to form a first image and/or a second image.

In the foregoing solution, synthesis processing is conducted on the first image and the second image to form a composite image.

In the embodiments of the disclosure, voltages of the first electron source, the electron acceleration structure, the second sub-detection device, the control electrode, and the specimen stage are controlled, such that droppoint energy when an electron beam reaches a specimen is less than 5 keV; the composite objective lens composed of the electro lens and the magnetic lens increases a resolution of the scanning electron microscope system; through a synergistic effect of the electro lens and the control device, signal electron collection efficiency is close to or reaches 100%; and types of received signal electrons and back-scatter electrons emitted at a specific angle can be flexibly controlled by adjusting a voltage value of the control electrode.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram of a low-energy scanning electron microscope system according to embodiment one of the disclosure;

FIG. 2 is a schematic diagram of receiving a signal electron by a detector according to embodiment one of the disclosure;

FIG. 3a is a first schematic diagram of an electrical lens field according to embodiment one of the disclosure;

5 FIG. 3b is a second schematic diagram of the electrical lens field according to embodiment one of the disclosure;

FIG. 4 is a block diagram of a low-energy scanning electron microscope system according to embodiment two of the disclosure;

10 FIG. 5a is a first block diagram of a low-energy scanning electron microscope system according to embodiment three of the disclosure;

FIG. 5b is a second block diagram of the low-energy scanning electron microscope system according to embodiment three of the disclosure;

FIG. 6 is a block diagram of a low-energy scanning electron microscope system according to embodiment four of the disclosure;

15 FIG. 7 is a schematic diagram of receiving a signal electron by a detector according to embodiment four of the disclosure;

FIG. 8a is a first schematic diagram of an electrical lens field according to embodiment four of the disclosure;

20 FIG. 8b is a second schematic diagram of an electrical lens field according to embodiment four of the disclosure;

FIG. 9 is a block diagram of a low-energy scanning electron microscope system according to embodiment five of the disclosure;

FIG. 10a is a first block diagram of a low-energy scanning electron microscope system according to embodiment six of the disclosure;

25 FIG. 10b is a second block diagram of the low-energy scanning electron microscope system according to embodiment six of the disclosure;

FIG. 11 is a block diagram of a low-energy scanning electron microscope system according to embodiment seven of the disclosure;

30 FIG. 12 is a schematic diagram of a processing procedure of a specimen detection method according to embodiment eight of the disclosure;

FIG. 13 is a schematic diagram of a processing procedure of a specimen detection method according to embodiment nine of the disclosure;

FIG. 14 is a block diagram of a scanning electron microscope objective lens system according to embodiment ten of the disclosure;

35 FIG. 15a is a schematic structural diagram of a deflection control electrode according to an

embodiment of the disclosure;

FIG. 15b is another schematic structural diagram of a deflection control electrode according to an embodiment of the disclosure;

FIG. 16a is schematic diagram of a structure and a detection area of a first subdetector
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FIG. 16b is schematic diagram of a structure and a detection area of another first subdetector according to an embodiment of the disclosure;

FIG. 16c is a schematic diagram of a structure and a detection area of yet another first subdetector according to an embodiment of the disclosure;

10 FIG. 17 is a block diagram of a scanning electron microscope objective lens system according to embodiment eleven of the disclosure;

FIG. 18 is a block diagram of a scanning electron microscope objective lens system according to embodiment twelve of the disclosure;

FIG. 19 is a block diagram of a scanning electron microscope objective lens system
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FIG. 20 is a block diagram of a scanning electron microscope objective lens system according to embodiment fourteen of the disclosure;

FIG. 21 is a schematic diagram of a processing procedure of a specimen detection method according to an embodiment of the disclosure;

20 FIG. 22a is a first schematic scanning diagram of an MORRIL according to an embodiment of the disclosure;

FIG. 22b is a first schematic scanning diagram of an SORRIL according to an embodiment of the disclosure;

FIG. 23a is a second schematic scanning diagram of an MORRIL according to an
25 embodiment of the disclosure;

FIG. 23b is a second schematic scanning diagram of an SORRIL according to an embodiment of the disclosure;

FIG. 24a is a schematic diagram of detecting signal electrons generated in a central position of a large scanning field according to an embodiment of the disclosure; and

30 FIG. 24b is a schematic diagram of detecting signal electrons generated at an edge of a large scanning field according to an embodiment of the disclosure.

DETAILED DESCRIPTION

The following further describes the disclosure in detail with reference to accompanying
35 drawings and embodiments. It should be understood that specific embodiments described herein

are used only to explain the disclosure, but are not intended to limit the disclosure.

Before the disclosure is further described in detail, nouns and terms in the embodiments of the disclosure are described, and the nouns and the terms in the embodiments of the disclosure are applicable to the following explanation.

5 (1) A space-charge effect: in an electro-optical system, an electron beam "expands" due to Coulomb force between electrons, increasing aberration of an electron beam imaging system; especially when the electron beam forms a cross beam spot, electron density at the cross beam spot is extremely high and a distance between the electrons is very short; and relatively large Coulomb force leads to expansion of a focused beam spot of the electron beam because Coulomb force is
10 inversely proportional to the square of the distance between the electrons.

(2) An initial electron beam: an electron beam generated by a first electron source and reaching a specimen is an initial electron beam.

(3) Signal electrons, which are generated when an electron beam acts on a specimen and include secondary electrons and back-scatter electrons.

15 (4) An optical axis, which is an optical center axis of an electron beam.

(5) An emission angle, which is an included angle between an emergent direction of a signal electron and a surface of a specimen.

It should be noted that, in the accompanying drawings of the disclosure, a motion track when signal electrons rotate along an optical axis under action of a magnetic field is not marked,
20 only a track of the signal electrons on a meridian plane of the optical axis is marked.

In the related technology, aberration of a single magnetic lens or a single electro lens increases significantly in a low-droppoint energy condition. The electro lens can partially compensate for aberration of the magnetic lens. Therefore, a scanning electron microscope is provided, and a composite objective lens composed of an electro lens and a magnetic lens is used,
25 to reduce aberration, thereby improving a resolution of the scanning electron microscope. In an optional embodiment, the scanning electron microscope is provided with a high-voltage tube structure. A high-voltage tube in an objective lens is used as an electrode of the electro lens. An initial electron beam emitted from a first electron source can maintain a relatively high velocity in the high-voltage tube, and when the initial electron beam approaches a specimen, the velocity of
30 the initial electron beam decreases due to impact of the electro lens composed of the high-voltage tube and the specimen. Another optional electrode between the high-voltage tube and the specimen is used as an intermediate stage of the electro lens, an electric field generated by the electro lens and a magnetic field generated by the magnetic lens overlap or are connected to each other. Therefore, in a low-droppoint-energy condition, the composite objective lens composed of the
35 electro lens and the magnetic lens can increase the resolution of the scanning electron microscope,

and improve the performance of the scanning electron microscope.

In the related technology, to increase resolution of a scanning electron microscope, a scanning electron microscope is provided. A pole shoe of a magnetic lens is used as an electrode of an electro lens, and a negative voltage is applied on a specimen, to form a retarding electric field
5 between the specimen and the magnetic lens, so as to decelerate an initial electron beam emitted from a first electron source between the magnetic lens and the specimen. Another optional electrode between the magnetic lens and the specimen is used as an intermediate stage of the electro lens. In the scanning electron microscope, an in-lens detector is placed above an objective lens. The in-lens detector is also referred to as an in-column detector. Compared with conventional
10 out-of-lens detectors, the in-lens detector does not occupy space between the objective lens and the specimen, and therefore a working distance of the objective lens can be as small as possible, so that the scanning electron microscope can maintain a high resolution.

In addition, secondary electrons excited from the specimen are attracted by an electrostatic field in the composite objective lens, to form a cross spot, and the secondary electrons are collected
15 by the in-lens detector in the objective lens. Energy of the secondary electrons is very low, i.e., less than 50 eV or even 5 eV. Therefore, almost all secondary electrons can be collected by the in-lens detector, only a few electrons pass through a center hole of the in-lens detector and are not collected, and therefore, collection efficiency of the secondary electrons is improved. However, because energy of back-scatter electrons is relatively high, the back-scatter electrons are not easily
20 attracted by the electro lens, and back-scatter electrons in emergent directions at small angles relative to a surface of the specimen cannot be collected by the in-lens detector, and are incident on an inner surface of the objective lens or outside the objective lens. Therefore, efficiency of detecting back-scatter electrons by the in-lens detector is very low.

In the related technology, to improve detection efficiency of back-scatter electrons, an optional embodiment is further provided, including: a back-scatter electron detector configured to collect back-scatter electrons emitted at small angles is placed at one end of a high-voltage tube near a specimen, and serves as an electrode of an electro lens; the back-scatter electron detector collects a pure back-scatter electron signal emitted at small angles; and all secondary electrons and back-scatter electrons emitted at a large angle pass through a center hole of the back-scatter
30 electron detector and are detected by an in-lens detector placed above an objective lens. In the related technology, another optional embodiment is further provided, including: a back-scatter electron detector is placed in a high-voltage tube to collect back-scatter electrons emitted at small angles, and secondary electrons are attracted to pass through a center hole of the back-scatter electron detector and are detected by a secondary electron detector placed above an objective lens;
35 or a back-scatter electron detector is placed in a magnetic lens, and is located below a secondary

electron detector. The angle in the foregoing embodiments is an angle between an emergent direction of back-scatter electrons and a surface of a specimen.

However, at least the following relatively apparent technical problem exists in the foregoing implementations. In a low-droppoint energy condition, a scanning electron microscope is required to have a relatively high flux and relatively high detection efficiency of secondary electrons and back-scatter electrons. In the foregoing implementations, a back-scatter electron beam is excited by an initial electron beam on a surface of a specimen, and is directly incident to a back-scatter electron detector outside an objective lens. Due to low-droppoint energy, energy of back-scatter electrons is as low as less than 3 keV, so that signals excited by the back-scatter electrons incident on the back-scatter electron detector is relatively weak, and a gain of back-scatter electron detector is relatively small. Alternatively, when back-scatter electrons are incident to a back-scatter electron detector after being accelerated by an electric field, because some secondary electrons and back-scatter electrons escape from a center hole of the uppermost detector, detection efficiency of secondary electrons and back-scatter electrons is reduced. In addition, back-scatter electrons at different emission angles can represent specimen information of different dimensions; back-scatter electrons at small emergent angles relative to a surface of a specimen can represent morphological information of the specimen; and back-scatter electrons at a large emergent angle relative to the surface of the specimen can represent material information of the specimen. For given droppoint energy, because intensity of an electric field, intensity of a magnetic field, and a position of a back-scatter electron detector are fixed, back-scatter electrons at specific emission angles cannot be detected by the back-scatter electron detector by changing a motion path of the back-scatter electrons.

In another optional implementation, a back-scatter electron detector is provided with several annular detection channels used to identify back-scatter electrons at different emission angles. However, the back-scatter electron detector of this structure is relatively complex, and has poor flexibility in terms of selectively collecting back-scatter electrons with different droppoint energy and at different emission angles.

Embodiment one

In view of the foregoing problem, embodiment one of the disclosure provides a low-energy scanning electron microscope system. A structure of the low-energy scanning electron microscope system is shown in FIG. 1, and includes a first electron source 101, an electron acceleration structure, a composite objective lens 11 composed of a magnetic lens 107 and an electro lens 10, a first deflection device 106, and a first detection device 105. The first electron source is configured to generate an electron beam. In an optional implementation, the first electron source is a first electron source for field emission, such as a first electron source for thermal field emission or a

first electron source for cold field emission. Compared with a thermal emission source prepared from a tungsten wire and a lanthanum hexaboride material, the first electron source has better electric current density and brightness, has a less virtual source, and can reduce a size of a beam spot generated when the electron beam focuses on a specimen, and improve the specimen detection resolution of the scanning electron microscopy system.

The electron acceleration structure is an anode 102, is located below the first electron source 101 along an emission direction of an electron beam, and is configured to form an electric field and increase a motion velocity of the electron beam. In the related technology, at least one suction electrode is usually included between the anode and the first electron source of the scanning electron microscope. In this embodiment of the disclosure, the electron beam generated by the first electron source 101 is directly field emitted after passing through the anode, and a distance between the anode 102 and an emission tip of the first electron source 101 is controlled to be as short as possible, which facilitates reducing energy dispersion of the electron beam, thereby reducing impact of a space-charge effect on the electron beam emitted by the first electron source 101. In this embodiment of the disclosure, after being accelerated through the anode, the electron beam can maintain relatively high energy near a focusing field formed by the composite objective lens 11. This also reduces the impact of the space-charge effect on the electron beam emitted by the first electron source 101.

In this embodiment of the disclosure, a voltage value V_1 of the first electron source 101 is less than -5 kV, and a typical value of V_1 is -10 kV. The node 102 is grounded, and a voltage value of the node 102 is zero. After the electron beam emitted by the first electron source 101 passes through the node 102, the motion velocity of the electron beam increases.

The composite objective lens 11 includes the magnetic lens 107 and the electro lens 10, and is configured to converge the electron beam accelerated by the electron acceleration structure.

The first deflection device 106 is located between an inner wall of the magnetic lens 107 and an optical axis 110 of the electron beam, and is configured to change a motion direction of the electron beam before being incident to the specimen. The first deflection device 106 includes at least a first deflector 106a and a second deflector 106b, or more deflectors may participate in scanning of initial electrons. Both the first deflector 106a and the second deflector 106b may be magnetic deflectors or electric deflectors, and the first deflector 106a and the second deflector 106b are located inside the magnetic lens. The first deflector 106a and the second deflector 106b coordinate with each other and are close to a magnetic lens field, which facilitates reducing aberration at an edge of a large scanning field when the scanning field is used. The first deflector 106a and the second deflector 106b are usually multipole magnetic deflectors or electric deflectors, for example, a 4-pole deflector, an 8-pole deflector, a 12-pole deflector, and a 16-pole deflector,

and can generate a scanning field of any deflection direction. In this embodiment of the disclosure, because all components on an electron beam path from the anode 102 to a back-scatter electron detector 105b are grounded, an electrostatic deflector is preferably used. Compared with the magnetic deflector, the electrostatic deflector has a higher speed, and is more advantageous to implement high-speed electron beam scanning and increase an imaging speed of an electron beam microscope. The first detection device 105 includes a first sub-detection device 105a configured to receive secondary electrons and back-scatter electrons generated when an initial electron beam acts on a specimen, a second sub-detection device 105b configured to receive the back-scatter electrons, and a control device 105c configured to change motion directions of the secondary electrons and the back-scatter electrons.

In an optional embodiment, the first sub-detection device 105a is a center detector located above the magnetic lens 107. The second sub-detection device 105b is a back-scatter electron detector, is located below the magnetic lens 107, and is closely attached to a pole shoe of the magnetic lens 107.

The center detector 105a and the back-scatter electron detector 105b are circular detectors with center holes, and each may be a semiconductor detector, an avalanche detector, or a detector composed of a scintillant and a light guide pipe. A thickness of the back-scatter electron detector 105b is relatively small and is controlled to be 2 mm or even less than 1 mm, so as to avoid occupation of too much space between the magnetic lens 107 and a specimen stage 109, thereby ensuring a relatively short working distance between an objective lens and a specimen and thus ensuring a relatively high resolution. A diameter $\Phi 2$ of a center hole of the center detector 105a is less than or equal to 1 mm, to improve reception efficiency of signal electrons.

In an optional embodiment, the control device 105c is located below the first sub-detection device 105a and above the second sub-detection device 105b. The control device 105c is composed of an electric deflector and a magnetic deflector, and the electric deflector and the magnetic deflector generate a composite electromagnetic field, where a magnitude and a direction of electric field intensity and a magnitude and a direction of magnetic field intensity are all related to a velocity of the initial electron beam. In a preferred implementation, the function of the control device 105c can be implemented by a Wayne analyzer.

The electric deflector in the control device 105c generates an electric field, and electric field force to which initial electrons are subjected is as follows:

$$F_e = qE \quad (1)$$

where q is an electric quantity of a charged particle, and E is electric field intensity.

Meanwhile, the magnetic deflector in the control device 105c generates a magnetic field perpendicular to the electric field intensity, and the lorentz force to which the initial electrons are

subjected is as follows:

$$F_m = qv \times B \quad (2)$$

where B is magnetic induction intensity, and v is a velocity of a charged particle.

For the initial electron beam, the electron beam is subjected to electric field force F_e and is also subjected to magnetic field force F_m in a direction opposite to that of the electric field force F_e . The electric field force and the magnetic field force are balanced, so that the initial electrons are not deflected.

When signal electrons generated when the initial electron beam acts on the specimen pass through a Wayne analyzer, an incidence direction of the signal electrons is reversed because Lorentz force is associated with a moving direction of electrons and electric field force is not associated with the moving direction of the electrons. In this case, a direction of the Lorentz force F_m is changed to be the same as a direction of the electric field force F_e , and the signal electrons are deflected to the direction of the electric field force because the signal electrons are subject to resultant force of the Lorentz force and the electric field force.

In an optional implementation, an electric deflector in a Wayne analyzer has a multi-electrode structure including multiple static electrodes, and a magnetic deflector in the Wayne analyzer has a multipole structure including multiple magnetic poles, for example, 4 poles, 8 poles, 12 poles, and 16 poles. In this case, balanced electric and magnetic fields in any direction of 360-degree rotational distribution along an optical axis can be generated, so as to control signal electrons to be deflected in any direction of 360-degree rotation along the optical axis.

In this embodiment of the disclosure, the composite objective lens 11 includes the magnetic lens 107 and the electro lens 10, where the magnetic lens 107 is preferably an immersion magnetic lens excited by a current coil, and a housing made of a magnetic material is disposed outside an exciting coil formed by winding wires; a pole shoe of the magnetic lens is located at an opening of the magnetic lens 107, the pole shoe opens towards the specimen, and the surface of the specimen is located near a strongest part of a Z-direction magnetic field of the magnetic lens 107. In the related technology, a pole shoe of a non-immersion magnetic lens pole opens towards the optical axis 110 of the electron beam, and a focusing field of the magnetic lens is relatively far from a surface of the specimen. Therefore, imaging aberration of the immersion magnetic lens 107 in this embodiment of the disclosure is less than that of the non-immersion magnetic lens in the related technology, and a resolution of the scanning electron microscope system is improved.

In this embodiment of the disclosure, the electro lens 10 is composed of the second sub-detection device 105b, the specimen stage 109, and a control electrode 108.

In an optional implementation, the second sub-detection device 105b is a back-scatter electron detector, is located below the magnetic lens 107, and is closely attached to a pole shoe of

the magnetic lens 107. The control electrode 108 is provided with a center hole, and the control electrode 108 is located between the second sub-detection device 105b and the specimen stage 109.

In an optional implementation, the electro lens 10 is a retarding cathode lens, and is
5 configured to reduce a motion velocity of an electron beam accelerated by an anode and control a motion path of signal electrons. The second sub-detection device 105b is at a ground voltage, that is, a voltage value of the second sub-detection device 105b is zero; and voltage values of the electron beam on a path from the anode 102 to the second sub-detection device 105b are all the ground voltage. A voltage value V_2 of the specimen stage 109 meets that V_1 is less than V_2 , and V_2
10 is less than -5 kilo volts. After a specimen is placed on the specimen stage 109, the specimen has a voltage value that is the same as or similar to that of the specimen stage 109. A voltage value V_3 of the control electrode 108 can be adjusted, and the voltage value V_3 of the control electrode 108 is less than or equal to 0 kV. Distribution of a retarding electro lens field is adjusted by adjusting the
15 voltage value of the control electrode 108, thereby influencing a focusing status of the initial electron beam and a track of signal electrons generated when the initial electron beam acts on the specimen. Therefore, after being accelerated through the anode 102, the electron beam generated by the first electron source 101 is retarded and focused on the specimen by the electro lens 10, where the specimen is placed on the specimen stage. The specimen is a semiconductor specimen, a conductor specimen, a non-conductive specimen, or the like. In addition, the electro lens 10 can
20 compensate partial aberration of the magnetic lens 107, and improve a resolution of the scanning electron microscope.

In this embodiment of the disclosure, the signal electrons generated by the initial electron beam by exciting the specimen include secondary electrons and back-scatter electrons. Under action of a magnetic field of the magnetic lens 107 and an electric field of the electro lens 10,
25 tracks of the secondary electrons and the back-scatter electrons are all influenced. Under combined action of the magnetic field and an electric field of the magnetic lens 107, the back-scatter electrons originally emitted along a straight line are subjected to an acting force along a direction pointing to the optical axis 110 (r direction), and a motion track of the back-scatter electrons is gradually close to the optical axis 110 after the back-scatter electrons are emitted from a surface of
30 the specimen.

In a specific droppoint energy condition, that is, the voltage V_3 of the control electrode is set to a specific value if a potential V_2 of a specimen is determinate, there is no cross point on a motion path of back-scatter electrons from a time when the back-scatter electrons are emitted from a surface of the specimen to a time when the back-scatter electrons are received by the first
35 detection device. Unless in a very low ((less than 50 eV) droppoint energy condition, energy of the

back-scatter electrons is particularly close to energy of secondary electrons. Due to action of an electromagnetic field, tracks of the back-scatter electrons form an intersection point, and the back-scatter electrons pass through a center hole of a back-scatter electron detector. Under strong action of the electromagnetic field, because the energy of the secondary electrons is excessively low (less than 50 eV), when the secondary electrons are just sent from the surface of the specimen, motion tracks of the secondary electrons form an intersection point between the specimen and the back-scatter electron detector or near a hole of the back-scatter electron detector. When a value of a diameter $\Phi 1$ of the center hole of the back-scatter electron detector is within a specific range, the secondary electrons can all pass through the center hole of the back-scatter electron detector without being detected, or even secondary electrons emitted near the surface of the specimen in parallel pass through a center hole of back-scatter electrons due to action of an electromagnetic field, and then are detected. In this case, back-scatter electrons at a small emission angle converge towards a center of the optical axis 110 due to action of force towards the optical axis 110. In an appropriate objective lens field condition, even back-scatter electrons at an emission angle close to zero can be detected by the back-scatter electron detector 105b. In addition, back-scatter electrons at large emergent angles, namely, back-scatter electrons emitted near the optical axis 110, pass through the center hole of the back-scatter electron detector 105b and are detected by the center detector 105a. $\Phi 1$ of the center hole of the back-scatter electron detector 105b is set in an order of magnitude of several mm. The signal electrons generated when the initial electron beam acts on the surface of the specimen are detected by the detector 105 after being accelerated by the electro lens 10 and deflected by the Wayne analyzer 105c. One part of the signal electrons is directly detected by the back-scatter electron detector 105b, and the other part thereof is detected by the center detector 105a. The secondary electrons can completely pass through the center hole of the back-scatter electron detector 105b.

That the control device 105c is a Wayne analyzer is taken as an example. When the Wayne analyzer 105c is turned off, as shown in FIG. 2, after signal electrons are accelerated by the electro lens 10, back-scatter electrons at a small emission angle are completely detected by the back-scatter electron detector 105b. When a center hole of the center detector 105a is very small, almost all secondary electrons and back-scatter electrons at large emission angles can be detected by the center detector 105a, and only a few secondary electrons pass through the center hole of the center detector 105a and cannot be received by the detector 105.

In this embodiment of the disclosure, when the Wayne analyzer 105c is turned on, as shown in FIG. 1, when the Wayne analyzer 105c generates an appropriate electric field and magnetic field, after signal electrons are accelerated by the electro lens 10, back-scatter electrons at a small emission angle are completely detected by the back-scatter electron detector 105b, and all

secondary electrons and back-scatter electrons at large emergent angles can be detected by the center detector 105a. In this case, with the aid of the Wayne analyzer 105c, detection efficiency of the first detection device 105 is increased to approximately 100%. On one hand, in the low-droppoint-energy scanning electron microscope system, collection efficiency of signal electrons directly determines a speed of the scanning electron microscope system. On another hand, a specimen observed by a low-droppoint-energy scanning electron beam microscope is usually a poor conductor such as a semiconductor or an organic material, and a signal electron yield of the poor conductor is quite different from that of a good conductor. Therefore, collecting as many signal electrons as possible is conducive to increasing an imaging speed of the electron microscope.

On another hand, secondary electrons and back-scatter electrons are all subjected to action of an extra acceleration field generated by the electro lens 10. This increases energy of the secondary electrons and the back-scatter electrons by approximately V_2 electron volts, thereby generating a higher signal gain on the detector, and facilitating increasing an imaging speed of the electron beam in a low-droppoint energy condition.

The voltage value V_3 of the control electrode 108 is adjustable, that is, a value of the voltage value V_3 of the control electrode 108 can be flexibly adjusted as required. Therefore, a field of the electro lens 10 can be flexibly adjusted by adjusting the voltage of the control electrode 108, so as to control motion tracks of back-scatter electrons and secondary electrons. As shown in FIG. 3a, when the voltage value V_3 of the control electrode 108 is adjusted between a voltage value of the back-scatter electron detector and the voltage value V_2 of the specimen stage 109, an electrostatic lens field is formed between the specimen stage 109 and the back-scatter electron detector 105b. Equipotential lines of an electro lens field in this embodiment is shown by reference sign 13 in FIG. 3a, the electrostatic field and a magnetic field of the objective lens together act on the signal electrons. In this case, secondary electrons form a cross spot and completely pass through the center hole of the back-scatter electron detector 105b, and back-scatter electrons at a large emergent angle also pass through the center hole of the back-scatter electron detector 105b, and are detected by the center detector 105a under action of the Wayne analyzer 105c. Back-scatter electrons at small emergent angles are detected by the back-scatter electron detector 105b under action of the electro lens 10. In addition, the voltage of the control electrode 108 may be continuously changed. Therefore, back-scatter electrons emitted within a specific angle range may be precisely controlled to be detected by the detector 105b, so as to make back-scatter electrons whose emergent angle greater than a specific value pass through the center hole of the detector 105b and be captured by the detector 105a.

Because back-scatter electrons emitted at different angles carry different material information, back-scatter electrons at small emission angles are influenced by fluctuation of the

surface of the specimen and can represent morphology information of the surface of the specimen, and back-scatter electrons at large emergent angles (close to 90°), that is, back-scatter electrons close to the optical axis 110, can represent material information of the specimen. Therefore, by adjusting the voltage value of the control electrode 108, back-scatter electrons whose emission

5 angle is within a specific value can be controlled to be detected by the detector 105b, so as to determine whether a back-scatter electron image obtained by the back-scatter electron detector 105b can better represent the material information of the specimen or can better represent the morphology information of the surface of the specimen. In addition, due to a difference of specimens, emission angles of back-scatter electrons generated when the initial electron beam acts

10 on the specimens are also different, and an optimal back-scatter electron contrast image can be obtained by flexibly selecting back-scatter electrons to be detected. Therefore, the control electrode 108 may be used to flexibly control an electric field of the electro lens in the composite objective lens 11, and may also be used to flexibly select a type and a distribution angle of signal electrons to be detected; and a back-scatter electron detector 105b may be used to select and capture

15 back-scatter electrons emitted within a specific angle range. This can more adapt to a requirement of selecting and capturing back-scatter electrons within different angle ranges compared with a case in which a back-scatter electron detector is divided into annular bands with several detection channels in the related technology, thereby reducing complexity of the detector.

In this embodiment of the disclosure, when the voltage value V_3 of the control electrode

20 108 is less than the voltage value V_2 of the specimen stage 109 by at least 50 V, electrostatic field distribution changes, as shown in FIG. 3b, to form an electric field acting downward on electrons between the control electrode 108 and the specimen stage 109, where reference sign 14 represents electric field equipotential lines in this embodiment; secondary electrons are suppressed by the electric field providing downward force, cannot move up, and thus return to the specimen; and

25 back-scatter electrons are subject to an outward force in an r direction. Therefore, back-scatter electrons at a small emission angle can also be detected by the back-scatter electron detector 105b, while back-scatter electrons at a larger emission angle are detected by the center detector 105a. The center detector 105a and the back-scatter electron detector 105b obtain pure back-scatter electrons at different emergent angles, without any secondary electrons.

Therefore, the control electrode 108 is used to flexibly control an electric field of the electro lens 10, and may also be used to flexibly select a type of electrons to be detected by the center detector 105a, so as to detect single back-scatter electrons or detect signal electrons including back-scatter electrons and secondary electrons. Compared with a case in the related technology in which an adjustable filter screen is added before a center detector to obtain pure

30 back-scatter electrons, this embodiment of the disclosure reduces complexity of the first detection

35

device.

In conclusion, the control electrode 108 can be adjusted to detect back-scatter electrons at different emergent angles, pure back-scatter electrons, a mixture of back-scatter electrons and secondary electrons, or pure secondary electrons, thereby improving the flexibility of detecting signal electrons in the low-droppoint energy condition.

It can be learned that in this embodiment of the disclosure, the electron beam generated by the first electron source 101 focuses on the specimen to form a focus point or a cross beam spot, and no other focus point or cross beam spot is generated on a path between the first electron source 101 and the specimen 109; the electron beam maintains relatively high energy from a time when the electron beam passes through the anode 102 to a time when the electron beam approaches a lens field of the composite objective; if the voltage V_1 of the first electron source 101 is -10 kV, initial electrons always maintain energy of 10 keV on an optical path close to the field of the composite objective lens, and no other focus point or cross spot is formed. Therefore, a space charge effect on the optical system is effectively reduced.

Embodiment two

A low-energy scanning electron microscope system provided in embodiment two of the disclosure is similar to the scanning electron microscope system provided in embodiment one of the disclosure, a difference thereof lies in that: a composition structure of the scanning electron microscope system provided in embodiment two of the disclosure further includes an electron beam adjustment device, disposed below the anode 102 along a direction of the optical axis 110 and configured to change characteristics of an electron beam having passed through the anode 102; and the characteristics of the electron beam include at least of beam current density of the electron beam and a diameter of the electron beam.

In an optional implementation, as shown in FIG. 4, the electron beam adjustment device is a convergence device 103, is disposed below the anode 102 along an emergent direction of an initial electron beam, and is configured to converge the electron beam accelerated by the anode, that is, change an emission field angle of the electron beam, to control the electron beam to reach the beam density of the specimen and control the electron beam not to form a cross spot after the electron beam passes through the convergence device 103.

In a preferred implementation, the convergence device 103 is an electric-excited magnetic lens, and a focusing magnetic field of the convergence device 103 can be continuously adjusted.

Embodiment three

A low-energy scanning electron microscope system provided in embodiment three of the disclosure is similar to the low-energy scanning electron microscope systems provided in embodiment one and embodiment two of the disclosure. A difference thereof lies in that: A

composition structure of the low-energy scanning electron microscope system provided in embodiment three of the disclosure is shown in FIG. 5a, and compared with the low-energy scanning electron microscope systems provided in embodiment one of the disclosure, an electron beam adjustment device is an aperture 104, where the aperture 104 is located below the anode along a direction of the optical axis and configured to filter an electron beam having passed through the anode 102.

Alternatively, a composition structure of the low-energy scanning electron microscope system provided in embodiment three of the disclosure is shown in FIG. 5b, and compared with the low-energy scanning electron microscope system provided in embodiment two of the disclosure, the electron beam adjustment device further includes an aperture 104, located below the convergence device 103 along a direction of the optical axis and configured to filter an electron beam having passed through the convergence device 103. The electron beam generated by the first electron source 101 moves downwards along the optical axis 110 after passing through the anode 102, the convergence device 103, and the aperture 104.

Embodiment four

A low-energy scanning electron microscope system provided in embodiment four of the disclosure is similar to the low-energy scanning electron microscope system provided in embodiment one of the disclosure. As shown in FIG. 6, a difference thereof lies in that: an electron acceleration structure of the low-energy scanning electron microscope system provided in embodiment four of the disclosure includes an anode 102 and a high-voltage tube 401.

In this embodiment of the disclosure, on a path from the anode 102 to the back-scatter electron detector 105b, an electron beam maintains a high velocity in the high-voltage tube, and a high voltage with a voltage value V_4 is applied on the high-voltage tube. Therefore, the first deflection device 106 is preferably a magnetic deflector.

In this embodiment of the disclosure, the electron acceleration structure is composed of the anode 102 and the high-voltage tube 401, the high-voltage tube 401 is connected to both the anode 102 and the second sub-detection device 105b, a voltage value V_1 of the first electron source 101 is less than 0 kV, both a voltage value of the anode 102 and a voltage value of the high-voltage tube 401 are V_4 , and V_4 is greater than +5 kilo volts. The electro lens 10 is a retarding cathode lens, and is configured to reduce a motion velocity of an electron beam accelerated by the anode and control a motion path of signal electrons. A voltage value of the second sub-detection device 105b is V_4 , and voltage values of the electron beam on a path from the anode 102 to the second sub-detection device 105b are all V_4 . A voltage value V_2 of the specimen stage 109 meets that V_2 is greater than V_1 , and less than or equal to 0 kV. After a specimen is placed on the specimen stage 109, the specimen has a voltage value that is the same as or similar to that of the specimen stage

109. A voltage value V_3 of the control electrode 108 can be adjusted, and the voltage value V_3 of the control electrode 108 is less than or equal to V_4 . Distribution of a retarding electro lens field is adjusted by adjusting the voltage value of the control electrode 108, so as to affect a focusing status of the initial electron beam and a track of signal electrons generated when the initial electron beam acts on the specimen.

That the control device 105c is a Wayne analyzer is taken as an example. When the Wayne analyzer 105c is turned off, as shown in FIG. 7, after signal electrons are accelerated by the electro lens 10, back-scatter electrons at small emergent angles are completely detected by the back-scatter electron detector 105b. When a center hole of the center detector 105a is very small, almost all secondary electrons and back-scatter electrons with large emergent angled are detected by the center detector 105a, and only a few secondary electrons pass through the center hole of the center detector 105a without being detected. When the Wayne analyzer 105c is turned on, as shown in FIG. 6, when the Wayne analyzer 105 generates an appropriate electric field and magnetic field, after signal electrons are accelerated by the electro lens 10, back-scatter electrons at small emergent angles are completely detected by the back-scatter electron detector 105b, and all secondary electrons and back-scatter electrons at large emergent angles are detected by the center detector 105a. Therefore, the analyzer 105c improves efficiency to approximately 100%. In the low-energy scanning electron microscope, collection efficiency of signal electrons directly determines a speed of the scanning electron microscope; a specimen observed by a low-energy scanning electron beam microscope is usually a poor conductor such as a semiconductor or an organic material, and a signal electron yield of the poor conductor is quite different from that of a good conductor. Therefore, collecting as many signal electrons as possible is conducive to increasing an imaging speed of the electron microscope. In addition, secondary electrons and back-scatter electrons are all subjected to action of an extra acceleration field of a cathode electro lens. This accelerating field increases energy of the secondary electrons and the back-scatter electrons by approximately V_2 electron volts, thereby generating a higher signal gain on the detector, and facilitating increasing an imaging speed of the electron beam in a low-energy condition.

The voltage value V_3 of the control electrode 108 is adjustable, that is, the voltage value V_3 of the control electrode 108 can be adjusted. Therefore, a field of the electro lens 10 can be flexibly adjusted by adjusting the voltage of the control electrode 108, so as to control motion tracks of back-scatter electrons and secondary electrons. As shown in FIG. 8a, when the voltage value V_3 of the control electrode 108 is adjusted between the voltage value V_4 of the back-scatter electron detector and the voltage value V_2 of the specimen stage 109, an electrostatic lens field can be formed between the specimen stage 109 and the back-scatter electron detector 105b. Equipotential

lines of an electro lens field in this embodiment are shown by 21 in FIG. 8a, the electrostatic field and a magnetic field of the objective lens together act on the signal electrons. In this case, secondary electrons form a cross spot and completely pass through the center hole of the back-scatter electron detector 105b, and back-scatter electrons at large emergent angles also pass through the center hole of the back-scatter electron detector 105b, and are detected by the center detector 105a under action of the Wayne analyzer 105c. Back-scatter electrons at small emergent angles are detected by the back-scatter electron detector 105b under action of the electro lens 10. In addition, the voltage of the control electrode 108 may be continuously changed. Therefore, back-scatter electrons emitted within a specific angle range may be precisely controlled to be detected by the detector 105b, so as to make back-scatter electrons whose emergent angle is greater than a specific value pass through the center hole of the detector 105b and be captured by the detector 105a.

Because back-scatter electrons emitted at different angles carry different material information, back-scatter electrons at a small emission angle are influenced by fluctuation of a surface of the specimen and can represent morphology information of the surface of the specimen, and back-scatter electrons at large emergent angles (close to 90°), that is, back-scatter electrons close to the optical axis, can represent material information of the specimen. Therefore, by adjusting the voltage value of the control electrode 108, back-scatter electrons whose emission angle is within a specific value can be controlled to be detected by the detector 105b, so as to determine whether a back-scatter electron image obtained by the back-scatter electron detector 105b can better represent the material information of the specimen or can better represent the morphology information of the surface of the specimen. In addition, for different specimens, emission angles of back-scatter electrons generated when the initial electron beam acts on the specimens are also different, and an optimal back-scatter electron contrast image can be obtained by flexibly selecting to-be-detected back-scatter electrons to be detected. Therefore, the control electrode 108 may be used to flexibly control an electric field of the electro lens in the composite objective lens 11, and may also be used to flexibly select a type and a distribution angle of signal electrons to be detected; and a back-scatter electron detector 105b may be used to select and capture back-scatter electrons emitted within a selected angle range. This can be more adapted to the requirement of selecting and capturing back-scatter electrons within different angle ranges compared with a case in which a back-scatter electron detector is divided into annular bands with several detection channels in the related technology, thereby reducing complexity of the detector.

In this embodiment of the disclosure, when the voltage value V_3 of the control electrode 108 is less than the voltage value V_2 of the specimen stage 109 by at least 50 V, electrostatic field distribution changes, as shown in FIG. 8b, to form an electric field acting downward on electrons

between the control electrode 108 and the specimen stage 109, where reference sign 22 represents electric field equipotential lines in this embodiment; secondary electrons are suppressed by the electric field providing a downward force, cannot move up, and return to a specimen; and back-scatter electrons are subject to an outward force in an r direction. Therefore, back-scatter electrons at small emission angles can also be detected by the back-scatter electron detector 105b, while back-scatter electrons at larger emission angles are detected by the center detector 105a. The center detector 105a and the back-scatter electron detector 105b obtain pure back-scatter electrons at different emergent angles, without secondary electrons.

Therefore, the control electrode 108 is used to flexibly control an electric field of the electro lens 10, and may also be used to flexibly select a type of electrons to be detected by the center detector 105a, so as to detect pure back-scatter electrons or detect signal electrons including back-scatter electrons and secondary electrons. Compared with a case in the related technology in which an adjustable filter screen is added before a center detector to obtain pure back-scatter electrons, this embodiment of the disclosure reduces complexity of the first detection device.

In conclusion, the electrode 108 can be adjusted and controlled to detect back-scatter electrons at different emergent angles, pure back-scatter electrons, a mixture of back-scatter electrons and secondary electrons, or pure secondary electrons, thereby improving flexibility of detecting signal electrons at low-droppoint energy condition.

Embodiment five

A low-energy scanning electron microscope system provided in embodiment five of the disclosure is similar to the low-energy scanning electron microscope system provided in embodiment four of the disclosure. A difference thereof lies in that: the low-energy scanning electron microscope system provided in embodiment five of the disclosure further includes an electron beam adjustment device, disposed below the anode 102 along a direction of the optical axis, and configured to change characteristics of an electron beam having passed through the anode 102; and the characteristics of the electron beam include at least of beam current density of the electron beam and a diameter of the electron beam.

In an optional implementation, as shown in FIG. 9, the electron beam adjustment device is a convergence device 103, is disposed below the anode 102 along an emergent direction of an initial electron beam, and is configured to converge the electron beam accelerated by the anode, that is, change an emission field angle of the electron beam, to control the electron beam to reach beam density of a specimen and control the electron beam not to form a cross spot after the electron beam passes through the convergence device 103.

In a preferred implementation, the convergence device 103 is an electric-excited magnetic lens, and a focusing magnetic field of the convergence device 103 can be continuously adjusted.

Embodiment six

A low-energy scanning electron microscope system provided in embodiment six of the disclosure is similar to the low-energy scanning electron microscope systems provided in embodiment four and embodiment five of the disclosure. A difference thereof lies in that: the low-energy scanning electron microscope system provided in embodiment six of the disclosure is shown in FIG. 10a, and compared with the low-energy scanning electron microscope system provided in embodiment four of the disclosure, an electron beam adjustment device is an aperture 104, where the aperture 104 is located below the anode along a direction of the optical axis and configured to filter an electron beam having passed through the anode 102.

Alternatively, a structure of the low-energy scanning electron microscope system provided in embodiment six of the disclosure is shown in FIG. 10b, and compared with the low-energy scanning electron microscope systems provided in embodiment five of the disclosure, the electron beam adjustment device further includes an aperture 104, located below the convergence lens 103 along a direction of the optical axis and configured to filter an electron beam having passed through the convergence lens 103, and the electron beam generated by the first electron source 101 moves downward along the optical axis 110 after passing through the anode 102, the convergence lens 103, and the aperture 104.

Embodiment seven

Based on embodiment one to embodiment six, a low-energy scanning electron microscope system provided in embodiment seven of the disclosure is shown in FIG. 11, and further includes a signal processing device 30, connected to the first sub-detection device and/or the second sub-detection device, and configured to process a first signal generated by the first sub-detection device based on secondary electrons and/or back-scatter electrons received by the first sub-detection device; and/or configured to process a second signal generated by the second sub-detection device based on back-scatter electrons received by the second sub-detection device.

In an optional implementation, the signal processing device includes a signal amplification sub-device and a signal processing sub-device, where

the signal amplification sub-device includes a first signal amplification sub-device 300a, configured to amplify the first signal; and/or a second signal amplification sub-device 300b, configured to amplify the second signal; and

the signal processing sub-device includes a first signal processing sub-device 301a, configured to process the amplified first signal, and output a processed first signal to form a first image; and/or a second signal processing sub-device 301b, configured to process the amplified second signal and output a processed second signal to form a second image.

In an optional implementation, the signal processing device further includes a signal

synthesis sub-device, configured to conduct synthesis processing on the first signal and the second signal that have been processed by the signal processing sub-device, to form a composite image.

In this embodiment of the disclosure, the signal output by the first sub-detection device and the signal output by the second sub-detection device may be amplified and processed to
5 respectively generate a secondary electron image or a back-scatter electron image for targeted detection. Alternatively, the signal synthesis sub-device 302 may be used to synthesize the first signal that is output by the first sub-detection device and that has been processed and the second signal that is output by the second sub-detection device and that has been processed, to obtain a composite image with collection efficiency of 100% or close to 100%.

10 Embodiment eight

Based on the low-energy scanning electron microscope systems in embodiment one to embodiment seven, embodiment eight of the disclosure further provides a specimen detection method. A processing procedure of the specimen detection method is shown in FIG. 12, and includes the following steps.

15 In step S101, an electron beam generated by a first electron source is caused to pass through an electron acceleration structure, to increase a motion velocity of the electron beam.

In an optional implementation, the electron acceleration structure is an anode, a voltage value V_1 of the first electron source is less than -5 kV, and the anode is grounded.

20 In another optional implementation, the electron acceleration structure includes an anode and a high-voltage tube, a voltage value V_1 of the first electron source is less than 0 kV, a voltage value V_4 meets V_4 is greater than $+5$ kilo volts, and a voltage value of the high-voltage tube is V_4 .

After the electron beam generated by the first electron source is accelerated by the electron acceleration structure, energy of the electron beam is kept larger than 5 keV, and a typical value is 10 keV. The electron beam moves downward along an optical axis. The high-energy electron beam
25 moving downward is converged through a convergence lens without forming a cross spot, and passes through an aperture, and the convergence lens and the aperture adjust a beam size and a beam spot diameter of the electron beam.

In step S102, the electron beam accelerated by the electron acceleration structure is converged through a composite objective lens, the electron beam is retarded through an electro lens,
30 a motion direction of the electron beam is changed through a first deflection device, and the electron beam is caused to act on a specimen to generate secondary electrons and back-scatter electrons, where the composite objective lens comprises a magnetic lens and the electro lens.

In a preferred implementation, after the electron beam with an increased motion velocity is converged through the composite objective lens, retarded through the electro lens, and deflected
35 through the first deflection device, the electron beam scans a surface of the specimen, to generate

secondary electrons and back-scatter electrons. The composite objective lens includes: a magnetic lens and an electro lens, where the magnetic lens is preferably an immersion magnetic lens excited by a current coil, and a housing made of a magnetic material is disposed outside an exciting coil formed by winding wires; a pole shoe of the magnetic lens is located at an opening of the magnetic lens, the pole shoe opens towards the specimen, and the surface of the specimen is located near a strongest part of a Z-direction magnetic field of the magnetic lens. In the related technology, a pole shoe of a non-immersion magnetic lens pole opens towards a direction of the optical axis of the electron beam, and a focusing field of the magnetic lens is relatively far from a surface of a specimen. Therefore, imaging aberration of the immersion magnetic lens in this embodiment of the disclosure is less than that of the non-immersion magnetic lens in the related technology, and a resolution of the scanning electron microscope system is improved.

In an optional implementation, a back-scatter electron detector in the electro lens is at a ground voltage, a voltage value of a specimen stage is V_2 , V_1 is less than V_2 , and V_2 is less than -5 kilo volts, a voltage value V_3 of a control electrode is adjustable, and the value meets V_3 is less than or equal to 0 kilo volt; and all potentials on a path from the anode to the back-scatter electron detector are at the ground voltage.

In another optional implementation, a back-scatter electron detector in the electro lens is at a potential of V_4 , a voltage value of a specimen stage meets $V_1 < V_2 \leq 0$ kV, and a voltage value V_3 of a control electrode is adjustable and meets that V_3 is less than or equal to V_4 .

A focusing magnetic field generated by the magnetic lens in the composite objective lens and a retarding electric field generated by the electro lens in the composite objective lens form a composite focusing field. The high-energy electron beam moving downward along the optical axis is converged through the composite focusing field, and a converged electron beam is decelerated by the deceleration electric field until energy is less than or equal to 5 keV, and is focused and irradiates the specimen to be detected. A low-energy focused electron beam scans the specimen under action of a deflection field generated by a deflector, to generate signal electrons including secondary electrons and back-scatter electrons.

In step S103, motion directions of the secondary electrons and the back-scatter electrons are changed under action of the electro lens and a control device, to receive the secondary electrons and the back-scatter electrons by a first detection device.

In an optional implementation, the first detection device includes a back-scatter electron detector and a center detector, and the signal electrons returned from the specimen are accelerated by the electric field of the electro lens. A voltage value V_3 of the control device may continuously change. When the voltage value V_3 of the control device is adjusted between a voltage value of the back-scatter electron detector and the voltage value V_2 of the specimen stage, secondary electrons

and back-scatter electrons whose emergent angles are greater than a first threshold are detected by the center detector, and back-scatter electrons whose emergent angles are less than the first threshold are detected by the back-scatter electron detector; and when the voltage value V_3 of the control electrode is less than the voltage value V_2 of the specimen stage by at least 50 V, secondary
5 electrons are suppressed to return to the specimen, back-scatter electrons whose emergent angles are greater than the first threshold are detected by the center detector, and back-scatter electrons whose emergent angles are less than the first threshold are detected by the back-scatter electron detector. Herein, the first threshold is related to a position or another attribute of the back-scatter electron detector.

10 In an optional implementation, when the control device is a Wayne analyzer, efficiency of collecting secondary electrons and/or back-scatter electrons by the center detector is improved by adjusting intensity of an electric field and a magnetic field generated by the Wayne analyzer.

In conclusion, the voltage value of the control device can be adjusted to detect information about back-scatter electrons at different emergent angles, pure back-scatter electrons, a mixture of
15 back-scatter electrons and secondary electrons, or pure secondary electrons.

Embodiment nine

A specimen detection method provided in embodiment nine of the disclosure is shown in FIG. 13, and is similar to the specimen detection method provided in embodiment eight. A difference from the specimen detection method provided in embodiment eight lies in that: after
20 step S103 is conducted, the following step is further included.

In step S104, a signal generated from signal electrons received by a center detector and/or a back-scatter electron detector is processed.

In this embodiment of the disclosure, a signal generated from signal electrons received by the center detector and a signal generated from signal electrons received by the back-scatter
25 electron detector may be amplified and processed respectively, to generate a secondary electron image or a back-scatter electron image for targeted detection. Alternatively, signals in the back-scatter electron detector and the center detector are processed and synthesized to obtain an image with collection efficiency of 100% or close to 100%.

Embodiment ten

30 Embodiment ten of the disclosure provides a scanning electron microscope objective lens system. A structure of the scanning electron microscope objective lens system is shown in FIG. 14, and includes a magnetic lens 401, a second deflection device 402, a deflection control electrode 403, a specimen to be detected 407, and a second detection device composed of a first subdetector 404 and a second subdetector 405.

35 In this embodiment of the disclosure, the magnetic lens 401 is an immersion

current-excited magnetic lens, and an annular pole shoe of the magnetic lens 401 opens towards the specimen to be detected 407. A strongest part of a magnetic field on a central axis of the magnetic lens 401 is near a surface of the specimen to be detected, to form an immersion magnetic lens.

5 In this embodiment of the disclosure, the second deflection device 402 is located inside the magnetic lens 401, and the second deflection device 402 includes at least one sub-deflector.

When the second deflection device 402 includes multiple sub-deflectors, the multiple sub-deflectors may be all electric deflectors, all magnetic deflectors, or a combination of electric deflectors and magnetic deflectors.

10 When the multiple sub-deflectors included in the second deflection device 402 are a combination of electric deflectors and magnetic deflectors, the number of electric deflectors and the number of magnetic deflectors are not limited. For example, when the second deflection device 402 includes four sub-deflectors, in one embodiment, there is one electric deflector and three magnetic deflectors; in another embodiment, there are two electric deflectors and two magnetic
15 deflectors; in yet another embodiment, there are three electric deflectors and one magnetic deflector; and in yet another embodiment, there is no electric deflector and four magnetic deflectors; or there are four electric deflectors and no magnetic deflector.

 In this embodiment of the disclosure, the second deflection device 402 is cylindrical. When the second deflection device 402 includes multiple sub-deflectors, the multiple sub-deflectors are
20 arranged sequentially from top to bottom along an axis direction of the magnetic lens 401. In addition, when the multiple sub-deflectors are a combination of electric deflectors and magnetic deflectors, positions of the electric deflectors and the magnetic deflectors are not limited. For example, when the second deflection device 402 includes four sub-deflectors, in an embodiment, an electric deflector, an electric deflector, a magnetic deflector, and a magnetic deflector are
25 disposed sequentially from top to bottom along the axis direction of the magnetic lens 401; in another embodiment, an electric deflector, a magnetic deflector, an electric deflector, and a magnetic deflector are disposed sequentially from top to bottom along the axis direction of the magnetic lens 401; and in yet another embodiment, a magnetic deflector, a magnetic deflector, an electric deflector, and an electric deflector are disposed sequentially from top to bottom along the
30 axis direction of the magnetic lens 401. Certainly, there are multiple combination manners of types and positions of the multiple sub-deflectors, and details are not described herein by using examples.

 In this embodiment of the disclosure, the deflection control electrode 403 is made of a nonmagnetic good-conductor material, and the deflection control electrode 403 is located below
35 the magnetic lens 401 and above the specimen to be detected 407.

In this embodiment of the disclosure, the deflection control electrode 403 includes a first center hole and multiple deflection control sub-electrodes, where the multiple deflection control sub-electrodes are distributed around the first center hole with the first center hole as a center. Therefore, the deflection control electrode 403 is of a petaline structure

5 The deflection control electrode 403 of an eight-petaline structure is taken as an example. A schematic structural diagram of the deflection control electrode 403 is shown in FIG. 15a. Electric potentials corresponding to eight deflection control sub-electrodes are $V_y + aV_x$, $aV_y + V_x$, $-aV_y + V_x$, $-V_y + aV_x$, $-V_y - aV_x$, $-aV_y - V_x$, $aV_y - V_x$, and $V_y - aV_x$ respectively, where a is a voltage scale factor, V_y is a y-direction component of a voltage, and V_x is an x-direction component of the voltage.

10 The deflection control electrode 403 of a twelve-petaline structure is taken as an example. Another schematic structural diagram of the deflection control electrode 403 is shown in FIG. 15b. Electric potentials corresponding to twelve deflection control sub-electrodes are V_y , V_x , V_y , V_x , $-V_y$, $-V_x$, $-V_y$, $-V_x$, $-V_y$, $-V_x$, V_y , and $-V_x$ respectively. V_y is a y-direction component of a voltage, and V_x is an x-direction component of the voltage. In this embodiment of the disclosure, a constant voltage V_3 is applied by a power supply system to the deflection control electrode 403, to form a fixed electric potential. In addition, an alternating voltage V_4 is also applied by the power supply system to the deflection control electrode 403, so that the deflection control electrode 403 as a sub-deflector deflects an initial electron beam incident to the specimen to be detected, and deflects signal electrons formed when the initial electron beam is incident into the specimen to be detected.

20 In this embodiment of the disclosure, a function of the first subdetector 404 may be implemented by a back-scatter electron detector, and a function of the second subdetector 405 may be implemented by a center detector. Herein, the first subdetector 404 and the second subdetector 405 each are a circular semiconductor detector with a center hole, an avalanche detector, or a detector composed of a scintillant and a light guide pipe.

25 In this embodiment of the disclosure, the first subdetector 404 has a second center hole, and a diameter of the second center hole is less than a diameter of the first center hole of the deflection control electrode 403. In a preferred embodiment, the diameter of the second center hole of the first subdetector 404 is at a millimeter order. For example, the diameter of the second center hole is less than or equal to 5 mm.

30 In this embodiment of the disclosure, the first subdetector 404 includes at least one first subdetector component, and each first subdetector component is configured to send a signal corresponding to obtained signal electrons of a corresponding area to an image processing device outside the scanning electron microscope objective lens system, to implement imaging of the signal of the corresponding area. The first subdetector 404 is made of a semiconductor material, and when the first subdetector 404 has multiple first subdetector components, the multiple first

subdetector components are distributed around the second center hole with the second center hole as a center; and the multiple first subdetector components are electrically insulated from each other, and each first subdetector component is configured to receive signal electrons from an area corresponding to the first subdetector component. Based on a structure of the first subdetector 404, it can be understood that, a detection area of the first subdetector 404 is divided into multiple detection subareas according to distribution of the multiple first subdetector components.

In an embodiment, a structure and a detection area of a first subdetector 404 are shown in FIG. 16a, and the detection area of the first subdetector 404 is composed of four sectorial detection subareas: B1, B2, B3, and B4 with the second center hole as a center. Electron signals received in the four detection subareas are recorded as S1, S2, S3, and S4 respectively, the four electron signals represent back-scatter electron signals generated in different orientations; the four electron signals each are connected to a single image processing device or image processing channel to form four independent images; mutual operation processing may be conducted on the four electron signals to form an integrated signal, then the integrated signal is output to the image processing device for output, where the operation processing includes but is not limited to operations such as addition and subtraction.

In another embodiment, a schematic diagram of a structure and a detection area of another first subdetector 404 is FIG. 15b. The detection area of the first subdetector 404 is composed of two annular detection subareas A and B with the second center hole as a center. Electron signals received in the two detection subareas are respectively recorded as S1 and S2; and the two electron signals represent back-scatter electron signals generated at different angles.

In another embodiment, a schematic diagram of a structure and a detection area of yet another first subdetector 404 is FIG. 16c. The detection area of the first subdetector 404 is composed of an annular detection subarea and a sectorial detection subarea that are with the second center hole as a center. It can be understood that the two annular detection subareas shown in FIG. 16b are divided to four sectorial areas to form eight detection subareas: A₁, A₂, A₃, A₄, B₁, B₂, B₃, and B₄. Electron signals received in the eight detection subareas are recorded as S1, S2, S3, S4, S5, S6, S7, and S8 respectively, the foregoing eight electron signals represent back-scatter electron signals generated in different orientations; the foregoing eight electronic signals each are connected to a single image processing device or image processing channel to form eight independent images; mutual operation processing may be conducted on the eight electron signals to form a synthesized signal, then the synthesized signal is output to the image processing device for output, where the operation processing includes but is not limited to operations such as addition and subtraction.

In this embodiment of the disclosure, a voltage is applied by a power supply system to the

magnetic lens 401, that is, the power supply system supplies power to an exciting coil of the magnetic lens 401, so that the magnetic lens 401 generates a steady-state magnetic field. All electric potentials of the first subdetector 404, the deflection control electrode 403, and the specimen to be detected 407 are provided by the power supply system, where the specimen to be detected 407 may be placed on a specimen stage, and the power supply system supplies power to the specimen to be detected 407 by supplying power to the specimen stage.

In an embodiment, a voltage value of the first subdetector 404 is 0 V. A range of a voltage value V_2 of the specimen to be detected 407 is $[-30 \text{ kV}, -5 \text{ kV}]$. Voltages of the deflection control electrode 403 include a constant voltage V_3 and a variable voltage V_4 , and V_2 is less than or equal to V_3 , and V_3 is less than or equal to 0 kV.

Based on control of the electric potentials of the first subdetector 404, the deflection control electrode 403, and the specimen to be detected 407, the first subdetector 404, the deflection control electrode 403, and the specimen to be detected 407 jointly form a retarding electrostatic lens field, and electric potential distribution of the retarding electrostatic lens field on an optical axis is shown by $U(z)$ of 408 in FIG. 14; magnetic field distribution of the magnetic lens 401 on an optical axis is shown by $B(z)$ of 408 in FIG. 14, and a maximum value of $B(z)$ is near a surface of the specimen to be detected 407. The deflection control electrode 403 forms a scanning electric field under control of the variable voltage V_4 , and the scanning electric field is shown by $D(z)$ of 408 in FIG. 14.

Herein, the retarding electrostatic lens field and an immersion magnetic field generated by the magnetic lens 401 jointly form a composite retarding receiving immersion lens field, where functions of the composite retarding receiving immersion lens field mainly include three aspects. In a first aspect, it can focus an initial electron beam incident to the specimen to be detected 407 to make the initial electron beam focused on a surface of the specimen to be detected 407; in a second aspect, it can retard the initial electron beam incident to the specimen to be detected 407, so that the initial electron beam falls onto the specimen to be detected at lower energy, so as to reduce a charge effect of a non-conductive specimen; and in a third aspect, it accelerates signal electrons (including back-scatter electrons and secondary electrons) generated on the surface of the specimen to be detected 407, to improve signal electron collection efficiency of the first subdetector 404 and the second subdetector 405.

The composite retarding receiving immersion lens field and scanning fields formed by the second deflection device 402 and the deflection control electrode 403 are coupled mutually, to jointly form a swing objective retarding receiving immersion lens scanning manner or a shift objective retarding receiving immersion lens scanning manner. The foregoing two scanning manners can reduce off-axis aberration and deflection aberration of large field scanning, so as to

implement high resolution scanning and imaging in a large field in an order of 100 microns.

Embodiment eleven

A scanning electron microscope objective lens system provided in embodiment eleven of the disclosure is similar to the scanning electron microscope objective lens system provided in
5 embodiment ten of the disclosure, a difference thereof lies in that: a structure of the scanning electron microscope objective lens system provided in embodiment eleven of the disclosure is shown in FIG. 17, and further includes a second electron source 201 and an anode 202, the second electron source 201 is a second electron source for thermal emission or a second electron source for field emission; and the second electron source 201 emits an initial electron beam, and the initial
10 electron beam moves downward along an optical axis 203, and is focused and imaged on a surface of the specimen to be detected 407 after passing through the scanning electron microscope objective lens system in embodiment eleven of the disclosure.

In this embodiment of the disclosure, the second deflection device includes a sub-deflector 402a and a sub-deflector 402d.

15 In this embodiment of the disclosure, a power supply system 406 supplies power to the scanning electron microscope objective lens system, so that a voltage value of the second electron source 201 is V_1 , and a range of V_1 is $[-30 \text{ kV}, -5 \text{ kV}]$. The anode 202, the second subdetector 405 and the first subdetector 404 are all at the ground voltage, that is, voltage values thereof are 0 V. A range of a voltage value V_2 of the specimen to be detected 407 is $[-30 \text{ kV}, -5 \text{ kV}]$. Voltages of the
20 deflection control electrode 403 include a constant voltage V_3 and a variable voltage V_4 , where V_2 is less than or equal to V_3 , and V_3 is less than or equal to 0 kilo volt.

Embodiment twelve

A scanning electron microscope objective lens system provided in embodiment twelve of the disclosure is similar to the scanning electron microscope objective lens system provided in
25 embodiment eleven of the disclosure. A difference thereof lies in that: a structure of the scanning electron microscope objective lens system provided in embodiment twelve of the disclosure is shown in FIG. 18, and compared with the scanning electron microscope objective lens system provided in embodiment eleven, the second deflection device 402 includes a sub-deflector 402a, a sub-deflector 402b, a sub-deflector 402c, and a sub-deflector 402d from top to bottom sequentially
30 along a direction of an optical axis 203.

Embodiment thirteen

A scanning electron microscope objective lens system provided in embodiment thirteen of the disclosure is similar to the scanning electron microscope objective lens system provided in
embodiment eleven of the disclosure, a difference thereof lies in that: a structure of the scanning
35 electron microscope objective lens system provided in embodiment thirteen of the disclosure is

shown in FIG. 19, and further includes a high-voltage tube 503, where one constituent part of the high-voltage tube 503 is an anode 503a, and a lower end 503b of the high-voltage tube 503 is electrically insulated from the first subdetector 404.

In this embodiment of the disclosure, the second deflection device includes a sub-deflector 502a and a sub-deflector 502d, and both the sub-deflector 502a and the sub-deflector 502d are magnetic deflectors.

In this embodiment of the disclosure, a power supply system 406 supplies power to the scanning electron microscope objective lens system, so that a voltage value of the second electron source 201 is V_1 , and a range of V_1 is $[-15 \text{ kV}, 0 \text{ kV}]$. Voltage values of the anode 502a, the second subdetector 405 and the first subdetector 404 are all V_5 , and a range of V_5 is $[5 \text{ kV}, 30 \text{ kV}]$. The specimen to be detected 407 is at a ground voltage, that is, a voltage value of the specimen to be detected is 0 V. Voltages of the deflection control electrode 403 include a constant voltage V_3 and a variable voltage V_4 , and $0 \leq V_3 \leq V_5$.

Embodiment fourteen

A scanning electron microscope objective lens system provided in embodiment five of the disclosure is similar to the scanning electron microscope objective lens system provided in embodiment thirteen of the disclosure. A difference thereof lies in that: a structure of the scanning electron microscope objective lens system provided in embodiment fourteen of the disclosure is shown in FIG. 20, and compared with the scanning electron microscope objective lens system provided in embodiment fourteen, the second deflection device includes a sub-deflector 502a, a sub-deflector 502b, a sub-deflector 502c, and a sub-deflector 502d from top to bottom sequentially along a direction of an optical axis 203; and all the sub-deflector 502a, the sub-deflector 502b, the sub-deflector 502c, and the sub-deflector 502d are magnetic deflectors.

Embodiment fifteen

Based on the scanning electron microscope objective lens systems in embodiment ten to embodiment fourteen, embodiment fifteen of the disclosure further provides a specimen detection method. A processing procedure of the specimen detection method is shown in FIG. 21, and includes the following steps.

In step 201, a composite retarding immersion lens field acts on an initial electron beam, the electron beam is deflected through a second deflection device and a deflection control electrode in the scanning electron microscope objective lens system, and the electron beam is caused to be incident to the specimen to be detected to generate signal electrons.

In an embodiment, a first subdetector configured to receive back-scatter electrons, the deflection control electrode, and the specimen to be detected that are in the scanning electron microscope objective lens system form a retarding electrostatic lens field, the retarding

electrostatic lens field overlaps, at an area near the specimen to be detected, with a magnetic field generated by a magnetic lens in the scanning electron microscope objective lens system, to form a composite retarding receiving immersion lens field 605.

The second deflection device including a sub-deflector 602a and a sub-deflector 602d is taken as an example. As shown in FIG. 22a and FIG. 22b, an initial electron beam emitted from a second electron source 401 is firstly deflected by the sub-deflector 602a to move far way from an optical axis 410, as shown by 603 in FIG. 22a and FIG. 22b; and then the electron beam passes through the sub-deflector 602d.

In an embodiment, as shown in FIG. 22a, a scanning electric field is generated after a scanning voltage is applied by a power supply system to the deflection control electrode 403, the scanning electric field and a scanning electric field generated by the sub-deflector 602d are jointly coupled to the composite retarding immersion lens field 605, so that a central axis 606 of the composite retarding immersion lens field moves and does not coincide with the central axis 410 of the scanning electron microscope objective lens system any longer, to form a Moving Objective Retarding Receiving Immersion Lens (MORRIL). Because the central axis 606 of the composite retarding immersion lens field moves, the scanning electron microscope objective lens system has small off-axis aberration and deflection aberration when conducting large field scanning, so that there are relatively high resolutions at an edge and a center of a large field. 607 in FIG. 22a shows grating-type large field scanning conducted by the initial electron beam under joint control of the sub-deflector 602a, the sub-deflector 602d, and the deflection control electrode 403, where 607a is a central point of a scanning field, and 607b is any point at an edge of the scanning field.

In an embodiment, as shown in FIG. 22b, A scanning electric field is generated after a scanning voltage is applied by a power supply system to the deflection control electrode 403, the scanning electric field and a scanning electric field generated by the sub-deflector 602d are jointly coupled to the composite retarding immersion lens field 605 in a coupling manner different from that in FIG. 22a, so that a central axis 606 of the composite retarding immersion lens field swings and is not parallel to the central axis 410 of the scanning electron microscope objective lens system any longer, to form a Swing Objective Retarding Receiving Immersion Lens (SORRIL). Because the central axis 606 of the composite retarding immersion lens field swings, the scanning electron microscope objective lens system has small off-axis aberration and deflection aberration when conducting large field scanning, so that there are relatively high resolutions at an edge and a center of a large field. 607 in FIG. 22a shows grating-type large field scanning conducted by the initial electron beam under joint control of the sub-deflector 602a, the sub-deflector 602d, and the deflection control electrode 403, where 607a is a central point of a scanning field, and 607b is any point at an edge of the scanning field.

That the second deflection device includes a sub-deflector 602a, a sub-deflector 602b, a sub-deflector 602c, and a sub-deflector 602d is taken as an example. As shown in FIG. 23a and FIG. 23b, an initial electron beam emitted from a second electron source 401 is first deflected by the sub-deflector 602a, the sub-deflector 602b, and the sub-deflector 602c to move far way from an optical axis 410, as shown by 603 in FIG. 23a and FIG. 23b; and then the electron beam passes through the sub-deflector 602d.

In an embodiment, as shown in FIG. 23a, a scanning electric field is generated after a scanning voltage is applied by a power supply system to the deflection control electrode 403, the scanning electric field and a scanning electric field generated by the sub-deflector 602d are jointly coupled to the composite retarding immersion lens field 605, so that a central axis 606 of the composite retarding immersion lens field moves and does not coincide with the central axis 410 of the scanning electron microscope objective lens system any longer, to form an MORRIL. Because the central axis 606 of the composite retarding immersion lens field moves, the scanning electron microscope objective lens system has small off-axis aberration and deflection aberration when conducting large field scanning, so that there are relatively high resolutions at an edge and a center of a large field. 507 in FIG. 23a shows grating-type large field scanning conducted by the initial electron beam under joint control of the sub-deflectors 602a, 602b, 602c, and 602d and the deflection control electrode 403, where 507a is a central point of a scanning field, and 507b is any point at an edge of the scanning field.

In an embodiment, as shown in FIG. 23b, a scanning electric field is generated after a scanning voltage is applied by a power supply system to the deflection control electrode 403, the scanning electric field and a scanning electric field generated by the sub-deflector 602d are jointly coupled to the composite retarding immersion lens field 605 in a coupling manner different from that in FIG. 23a, so that a central axis 606 of the composite retarding immersion lens field swings and does not coincide with the central axis 410 of the scanning electron microscope objective lens system any longer, to form an SORRIL. Because the central axis 406 of the composite retarding immersion lens field swings, the scanning electron microscope objective lens system has small off-axis aberration and deflection aberration when conducting large field scanning, so that there are relatively high resolutions at an edge and a center of a large field. 507 in FIG. 23b shows grating-type large field scanning conducted by the initial electron beam under joint control of the sub-deflectors 602a, 602b, 602c, and 602d and the deflection control electrode 403, where 507a is a central point of a scanning field, and 507b is any point at an edge of the scanning field.

It should be noted that compared with a case in which the second deflection device includes two sub-deflectors, when the second deflection device includes four sub-deflectors, a large field scanning method is conducting area scanning on a scanning field. First, an initial electron beam is

deflected to a starting position of a small area (for example, a small area 507b at an upper left corner of 507) through a deflection field formed by the sub-deflectors 602a and 602d and the deflection control electrode 403; the sub-deflectors 602b and 602c conduct fast scanning on each area; the initial electron beam is deflected to a starting position of a next small area through a deflection field formed by the sub-deflectors 602b and 602c and the deflection control electrode 403; and then the sub-deflectors 602b and 602c conduct fast scanning on the area, and so on, and eventually forming a large scanning field 507.

In step S202: a voltage value of the deflection control electrode is controlled, such that the signal electrons are received by a first subdetector and a second subdetector.

In an embodiment of the disclosure, in an implementation, a voltage of the specimen is controlled to be V_2 , and $0 \leq V_2 \leq -5$ kV; a voltage of the first subdetector is controlled to be 0 V; and a voltage value V_3 of the third voltage is controlled to be a constant voltage, and $V_2 \leq V_3 \leq 0$.

In another implementation, a voltage of the specimen is controlled to be V_2 equal to 0; a voltage of the first subdetector is controlled to be V_5 , and $5 \text{ kV} < V_5 \leq 30 \text{ kV}$; and a voltage value V_3 of the third voltage is controlled to be a constant voltage, and $0 < V_3 \leq V_5$.

A schematic diagram of detecting signal electrons (secondary electrons and back-scatter electrons) generated in a central position of a large scanning field is FIG. 24a. This case is corresponding to a detection scenario in which signal electrons are generated in and near the central position of the scanning field 607a in FIG. 22a and FIG. 22b, and is also corresponding to a detection scenario in which signal electrons are generated during scanning of the central area 507a in FIG. 23a and FIG. 23b. As shown in FIG. 24a, back-scatter electrons 801 emitted by the specimen are not converged and are received by a first subdetector 404 in a divergent manner, while secondary electrons 802 are converged by a composite retarding receiving immersion lens field, continue to move upward through a center hole 803 of the first subdetector 404, and are finally received by a second subdetector 405. In this embodiment of the disclosure, tracks of the back-scatter electrons 801 and the secondary electrons 802 are adjusted by adjusting electric potentials V_3 and V_4 applied on the deflection control electrode 403 and an electric potential V_2 on the specimen, so that all the back-scatter electrons 801 and the secondary electrons 802 can be well received by corresponding detectors in different conditions.

A schematic diagram of detecting signal electrons generated at an edge of a large scanning field is FIG. 24b. This case is corresponding to a detection scenario in which signal electrons are generated in and near the position 607b at the edge of the scanning field in FIG. 22a and FIG. 22b, and is also corresponding to a detection scenario in which signal electrons are generated during scanning of the small area 507b at the edge of the scanning field in FIG. 23a and FIG. 23b. In this embodiment of the disclosure, tracks of the back-scatter electrons 801 and the secondary electrons

802 are adjusted by adjusting electric potentials V_3 and V_4 applied on the deflection control electrode 403 and an electric potential V_2 on the specimen, so that back-scatter electrons and secondary electrons generated at the edge of the scanning field can also be well received by corresponding detectors.

5 In conclusion, signal electrons generated at a center and edges of a large scanning field can be detected efficiently by adjusting a voltage value of a control device.

The foregoing descriptions are merely specific implementation modes of the disclosure, but the protection scope of the disclosure is not limited thereto. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in the disclosure shall
10 fall within the protection scope of the disclosure. Therefore, the protection scope of the disclosure shall be subject to the protection scope of the claims.

CLAIMS

1. A low-energy scanning electron microscope system, comprising a first electron source, an electron acceleration structure, a first deflection device, a first detection device, and a composite objective lens composed of a magnetic lens and an electro lens, wherein
- 5 the first electron source is configured to generate an electron beam;
the electron acceleration structure is configured to increase a motion velocity of the electron beam;
the composite objective lens is configured to converge the electron beam accelerated by the electron acceleration structure;
the first deflection device is located between an inner wall of the magnetic lens and an optical axis
10 of the electron beam, and is configured to change a motion direction of the electron beam accelerated by the electron acceleration structure;
the first detection device comprises a first sub-detection device configured to receive secondary electrons and back-scatter electrons generated when the electron beam acts on a specimen, a second sub-detection device configured to receive the back-scatter electrons, and a control device
15 configured to change motion directions of the secondary electrons and the back-scatter electrons;
and
the electro lens comprises the second sub-detection device, a specimen stage, and a control electrode, and is configured to reduce the motion velocity of the electron beam and change the motion directions of the secondary electrons and the back-scatter electrons.
- 20 2. The low-energy scanning electron microscope system of claim 1, wherein the second sub-detection device is at a ground voltage V_1 , the specimen stage has a voltage value V_2 , V_1 is less than V_2 , and V_2 is less than -5 kilo volts, the control electrode has an adjustable voltage value V_3 , and V_3 is less than or equal to 0 kilo volt.
3. The low-energy scanning electron microscope system of claim 1, wherein the second
25 sub-detection device has a voltage value V_4 , the specimen stage has a voltage value V_2 , V_1 is less than V_2 , and V_2 is less than 0 kilo volt, the control electrode has an adjustable voltage value V_3 , and V_3 is less than or equal to V_4 .
4. A specimen detection method, wherein the method comprises:
causing an electron beam generated by a first electron source to pass through an electron
30 acceleration structure, to increase a motion velocity of the electron beam;
converging, through a composite objective lens, the electron beam accelerated by the electron acceleration structure, retarding the electron beam through an electro lens, and changing a motion direction of the electron beam through a first deflection device, to cause the electron beam to act on a specimen to generate secondary electrons and back-scatter electrons, wherein the composite
35 objective lens comprises a magnetic lens and the electro lens; and

changing motion directions of the secondary electrons and the back-scatter electrons under action of the electro lens and a control device, to receive the secondary electrons and the back-scatter electrons by a first detection device.

5. The method of claim 4, wherein the changing motion directions of the secondary electrons and the back-scatter electrons under action of the electro lens and the control device, to receive the secondary electrons and the back-scatter electrons by the first detection device comprises:
controlling a voltage value V_3 of a control electrode in the control electro lens to be greater than a voltage value of a second sub-detection device constituting the electro lens, and to be less than a voltage value V_2 of a specimen stage constituting the electro lens;
under action of an electric field and a magnetic field generated by the control device, receiving, by a first sub-detection device in the first detection device, the secondary electrons, and back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, greater than a first threshold; and
receiving, by the second sub-detection device in the first detection device, back-scatter electrons in emergent directions at angles, with respect to a surface of the specimen, less than the first threshold.

6. A scanning electron microscope objective lens system, comprising a magnetic lens, a second deflection device, a deflection control electrode, a specimen to be detected, and a second detection device, wherein
a pole-shoe direction of the magnetic lens is towards the specimen to be detected;
the second deflection device is located inside the magnetic lens, and comprises at least one sub-deflector;
the deflection control electrode is located between the second detection device and the specimen to be detected, and the deflection control electrode is configured to change a direction of an initial electron beam acting on the specimen to be detected, and change a direction of signal electrons generated when the initial electron beam acts on the specimen to be detected; and
the second detection device comprises a first subdetector configured to receive back-scatter electrons in the signal electrons, and a second subdetector configured to receive secondary electrons in the signal electrons.

7. The scanning electron microscope objective lens system of claim 6, wherein the deflection control electrode comprises a first center hole and multiple deflection control sub-electrodes, wherein
the multiple deflection control sub-electrodes are distributed around the first center hole with the first center hole as a center.

8. The scanning electron microscope objective lens system of claim 6, wherein

The scanning electron microscope objective lens system further comprises a specimen stage having a second voltage value V_2 , where V_2 is greater than or equal to -30 kilo volts and less than or equal to -5 kilo volts;

the first subdetector has a voltage value 0 V, and the deflection control electrode has a third voltage and a fourth voltage, wherein

a voltage value V_3 of the third voltage is a constant voltage, and V_2 is less than or equal to V_3 , and V_3 is less than or equal to 0 kilo volt; and

a voltage value V_4 of the fourth voltage is an alternating voltage.

9. A specimen detection method, applied to a scanning electron microscope objective lens system, wherein a first subdetector configured to receive back-scatter electrons, a deflection control electrode, and a specimen to be detected in the scanning electron microscope objective lens system form a retarding electrostatic lens field, the retarding electrostatic lens field overlaps, at an area near the specimen to be detected, with a magnetic field generated by a magnetic lens in the scanning electron microscope objective lens system, to form a composite retarding immersion lens field; and the method comprises:

acting on an initial electron beam through the composite retarding immersion lens field, deflecting the electron beam through a second deflection device and the deflection control electrode in the scanning electron microscope objective lens system, and causing the electron beam to be incident to the specimen to be detected to generate signal electrons; and

controlling a voltage value of the deflection control electrode, such that the signal electrons are received by the first subdetector and a second subdetector in the scanning electron microscope objective lens system.

10. The method of claim 9, wherein the method further comprises:

controlling a voltage of the second deflection device and a voltage of the deflection control

electrode to couple a deflection field formed by the second deflection device and the deflection control electrode to the composite retarding immersion lens field, to implement shift objective retarding receiving immersion lens scanning on the specimen to be detected or swing objective retarding receiving immersion lens scanning on the specimen to be detected.