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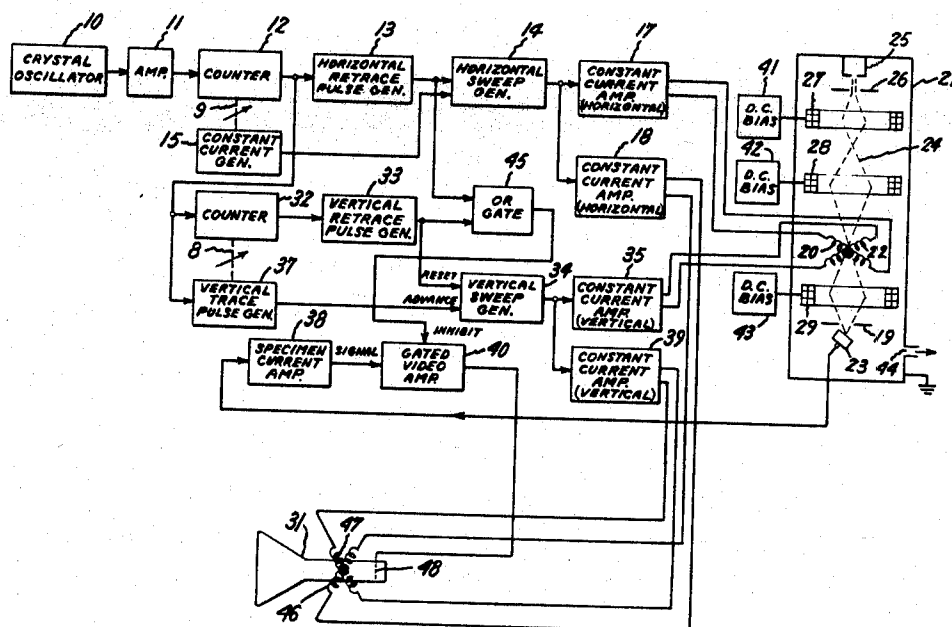
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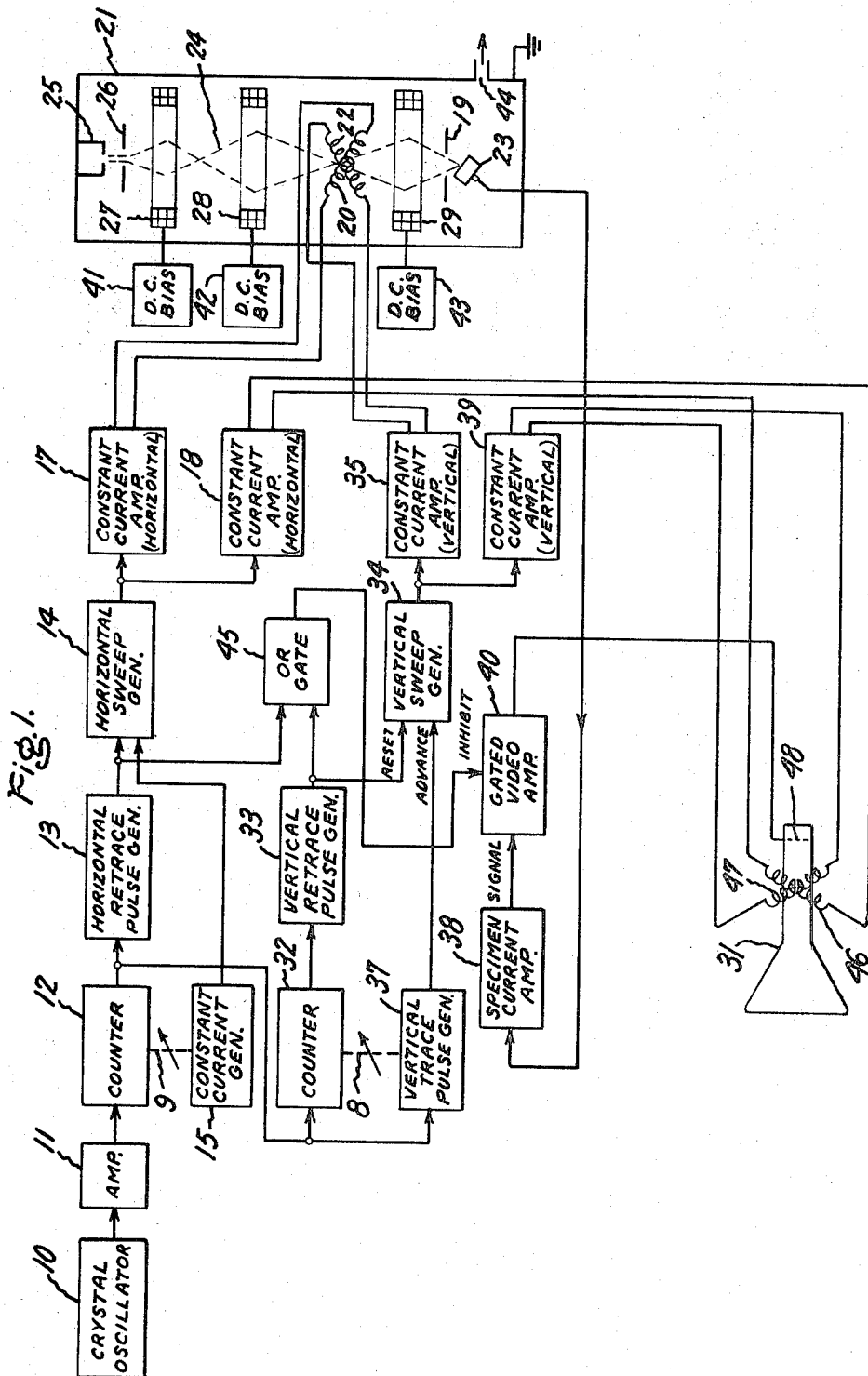
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**[54] SCANNING ELECTRON MICROSCOPE WHEREIN
AN IMAGE IS FORMED AS A FUNCTION OF
SPECIMEN CURRENT
9 Claims, 12 Drawing Figs.**

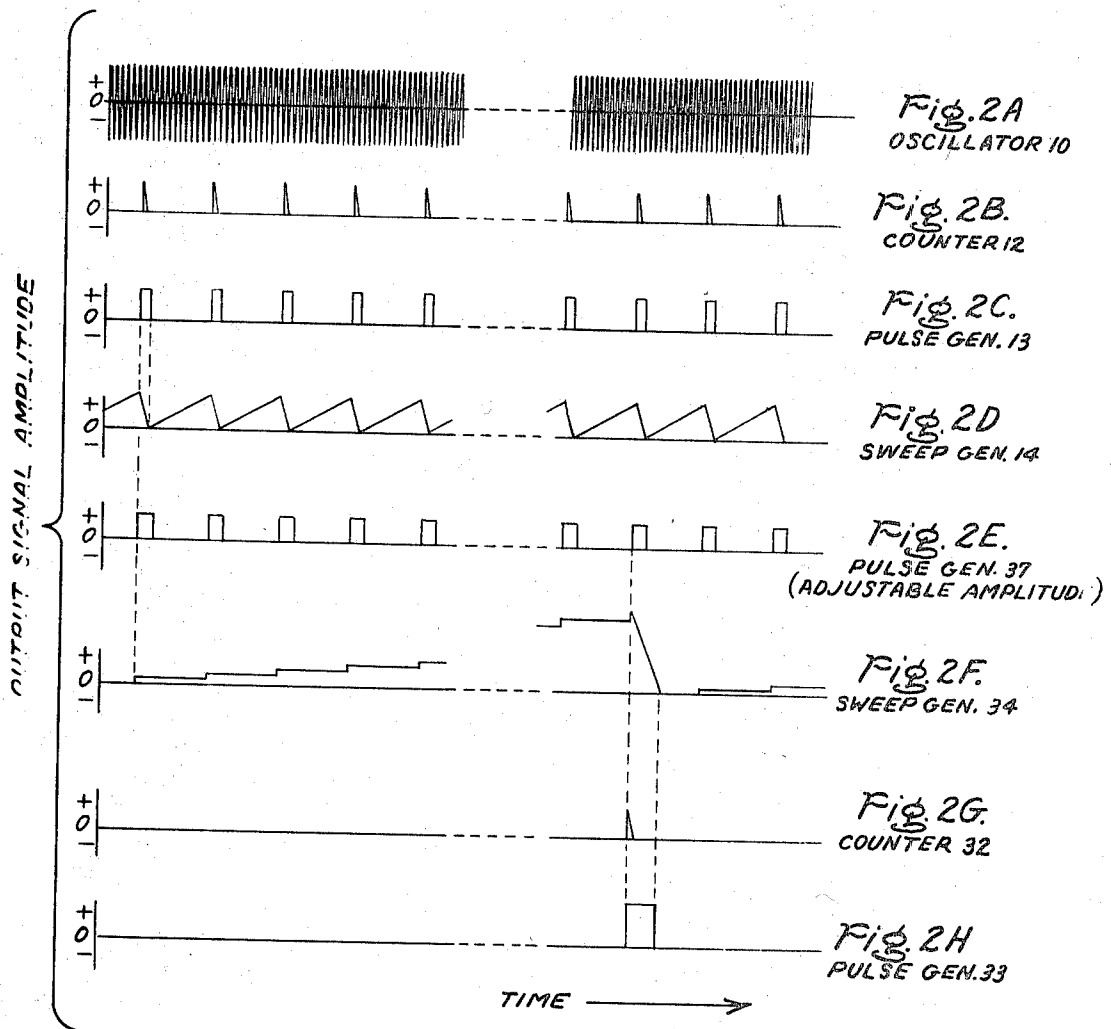
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ABSTRACT: A system for producing high resolution magnified images of a specimen includes an electron beam scanning in a two-dimensional pattern over the surface of the specimen, and modulates brightness of an electromagnetically deflected cathode ray tube according to a signal proportional to instantaneous specimen current. The voltage drop across a resistor connected to the specimen comprises the specimen signal. A crystal oscillator synchronizes scanning of the electron beam to scanning of the cathode ray tube.





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Fig. 3.

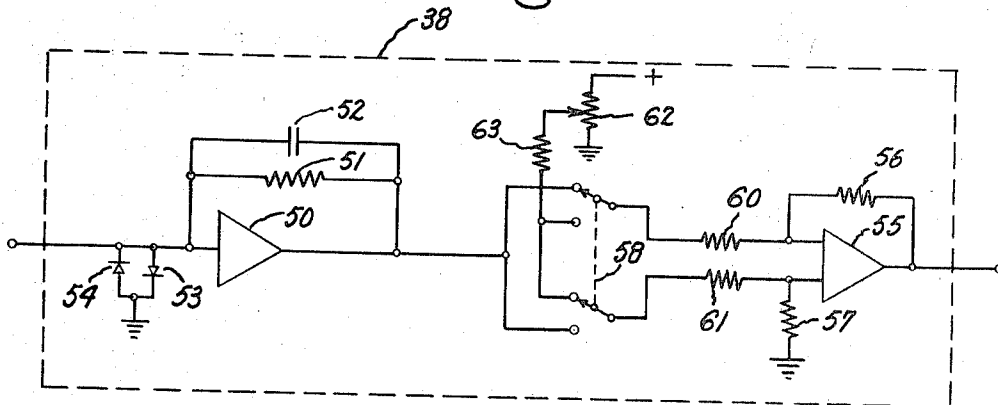


Fig. 4.

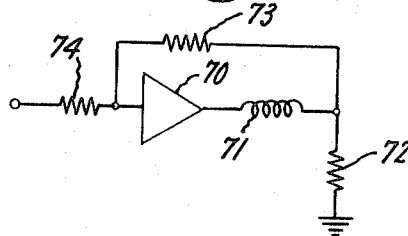
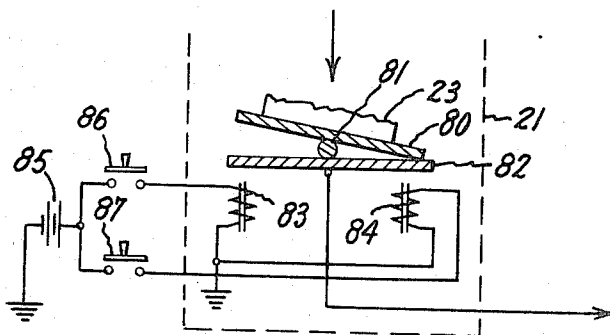


Fig. 5.



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SCANNING ELECTRON MICROSCOPE WHEREIN AN IMAGE IS FORMED AS A FUNCTION OF SPECIMEN CURRENT

INTRODUCTION

This invention relates to electron microscopy, and more particularly to a system in which an electron beam scans a specimen so as to generate magnified images thereof.

Scanning electron microscopes have proven to be a valuable aid in examining specimens microscopically. Typically, a scanning electron microscope employs a finely focused beam of electrons which is scanned over the surface of the specimen. Electrons which are either backscattered from the primary beam by the specimen or given off by the specimen as secondary emission electrons are detected, generating a signal proportional to the rate at which the electrons are detected. This signal is then used to modulate brightness on a cathode ray tube which scans in synchronism with the primary electron beam, so that a magnified image of the specimen is formed on the face of the cathode ray tube. The magnification thus obtained is a ratio of any linear distance scanned on the specimen to the corresponding linear distance scanned on the face of the cathode ray tube.

Heretofore, scanning electron microscopes have been relatively complex. This complexity has been due, in large measure, to need for proper placement and orientation of electron detectors to detect either the relatively high energy primary backscattered electrons or the relatively low energy secondary emission electrons with high efficiency and without introduction of appreciable noise in the detector output signal. These prior scanning electron microscopes have also been subject to image aberrations due to power line frequency magnetic fields. Moreover, brightness, spot size and contrast on the cathode ray tube face, which depend on cathode ray tube anode voltage amplitude, have been less than satisfactory since the electrostatic deflection and focusing employed in the cathode ray tube to achieve precise and linear deflection of the cathode ray or electron beam therein, impose relatively low maximum limitations on cathode ray tube anode voltage amplitude.

The present invention concerns a scanning electron microscope which has been simplified by avoiding any need for electron detectors and their associated placement and orientation requirements. Instead of detecting primary backscattered electrons or secondary emission electrons, the apparatus of the instant invention responds to specimen current, or electron flow through the specimen, by sensing current flow through a circuit connected in series with the specimen. Moreover, by employing electromagnetic deflection and focusing in the cathode ray tube, cathode ray tube anode voltage is increased, resulting in improved brightness, spot size and contrast in the displayed image. Aberrations in the displayed image due to interference from the power line frequency magnetic fields are minimized by employing a crystal oscillator to generate the basic timing signals for the system.

Accordingly, one object of the invention is to provide a simplified scanning electron microscope wherein the image of an observed specimen is determined in accordance with sensed specimen current.

Another object is to provide a scanning electron microscope with improved brightness, spot size and contrast in the displayed image.

Another object is to provide a scanning electron microscope wherein aberrations due to power line frequency magnetic fields are minimized.

Briefly, in accordance with a preferred embodiment of the invention, a system for producing high resolution magnified images of a specimen with a scanning electron beam comprises magnetic field generating means for sweeping the electron beam in a predetermined two-dimensional pattern over the surface of the specimen undergoing observation and means controlling the rate at which the electron beam is swept

in each direction over the surface of the specimen. High gain amplifier means are connected to the specimen. Additional magnetic field generating means are connected to optical display means having an image display surface in order to sweep the predetermined pattern over the surface of the display means in synchronism with the pattern swept by the electron beam. The output of the high gain amplifier means is connected to the optical display means in order to modulate intensity of the pattern as the pattern is traced out over the surface of the display means.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the invention believed to be novel are set forth with particularity in the appended claims. The invention itself, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram of a system embodying the instant invention;

FIGS. 2A—2H are waveforms of output signals produced by designated apparatus in the system shown in FIG. 1;

FIG. 3 is a schematic diagram of a high-gain low-noise specimen current amplifier which may be employed in the system shown in FIG. 1;

FIG. 4 is a schematic diagram of a constant current amplifier for driving magnetic deflection coils which may be employed in the system shown in FIG. 1; and

FIG. 5 is a schematic diagram of a tiltable specimen holder which may be employed in the system shown in FIG. 1.

DESCRIPTION OF TYPICAL EMBODIMENTS

In FIG. 1, a crystal oscillator 10 is shown driving a decimal counter 12 through an amplifier 11. Oscillator 10 may be operated at any convenient frequency, such as 31,500 Hz., for example, and counter 12 may be set to count to any predetermined multiple or submultiple of the power line frequency. Typical submultiples and multiples of the power line frequency to which counter 12 may be set are 10, 30 and 300, for example. Each time counter 12 has counted to a selected predetermined multiple or submultiple of the power line frequency, a horizontal retrace pulse generator 13 is actuated to furnish a resetting pulse jointly to a horizontal sweep generator 14 and the first input of a 2-input OR gate 45. Horizontal sweep generator 14 comprises an integrating circuit which integrates a constant current supplied for a constant current generator 15, and hence provides a ramp type voltage; that is, a voltage of substantially constant slope is generated upon occurrence of each horizontal retrace pulse from pulse generator 13. The amplitude of current supplied by constant current generator 15 is adjusted each time the preset count of counter 12 is changed by virtue of a mechanical interconnection 9. Thus, constant current generator 15 provides facility for adjusting the slope of output voltage from horizontal sweep generator 14. This sloping voltage causes the electron beam in both an electron optical column 21 and a cathode ray tube 31 to sweep horizontally in a smooth manner.

Output signals from horizontal sweep generator 14 are furnished jointly to a pair of constant current amplifiers 17 and 18. Constant current amplifier 17 drives horizontal scanning coils 20 in column 21, while constant current amplifier 18 furnishes input signals to horizontal scanning coils 46 of cathode ray tube 31.

Output signals from counter 12 are also furnished to a digital counter 32, which functions as a frequency divider so as to produce a single output pulse each time a predetermined number of input pulses have been counted. Counter 32 may conveniently be set to count 128, 256, 512 or 1,024 input pulses. Each time counter 32 has counted to its predetermined number of input pulses, a vertical retrace pulse generator 33 is

actuated to furnish a resetting pulse jointly to a vertical sweep generator 34 and the second input of 2-input OR gate 45.

Vertical sweep generator 34 provides a staircase type voltage; that is, each pulse produced by a vertical trace pulse generator 37 is integrated by vertical sweep generator 34 in typical staircase counter fashion, causing the electron beam in electron optical column 21 and the cathode ray in cathode ray tube 31 to step, or advance vertically by a predetermined increment, during each horizontal retrace. Vertical trace pulse generator 37 is driven by counter 12, and produces pulses of uniform amplitude which is adjusted each time the preset count of counter 32 is changed, by virtue of a mechanical interconnection 8. The vertical trace pulses are produced in synchronism with the output pulses of counter 12. After a predetermined number of vertical trace pulses have been integrated by vertical sweep generator 34, counter 32 furnishes an output signal to vertical retrace pulse generator 33 which thereupon resets itself to its initial output amplitude. This returns the electron beam and the cathode ray to their initial vertical positions preliminary to resuming another cycle of vertical stepwise advancement.

For operation in which the electron beam in electron optical column 21 is to sweep across a predetermined horizontal distance, the setting of constant current generator 15 adjusts the slope of output voltage produced by horizontal sweep generator 14 so that the requisite amplitude for completing each horizontal sweep is reached simultaneously with initiation of the next vertical trace pulse. Thus, each horizontal retrace pulse returns the beam in a generally horizontal direction to its initial horizontal starting point. Simultaneously, the staircase signal from vertical sweep generator 34 is furnished to the input of each one of a pair of constant current amplifiers 35 and 39. Constant current amplifier 35 drives magnetic deflection coils 22 in electron optical column 21 so as to move the electron beam in a vertical direction, while constant current amplifier 39 drives magnetic deflection coils 47 so as to move the trace on cathode ray tube 31 in a vertical direction.

When the electron beam in electron optical column 21 impinges upon a specimen 23 in the electron optical column, a signal made up of electrons leaving specimen 23 is furnished to a high gain, low noise, specimen current amplifier 38 directly from specimen 23. Output signals from specimen current amplifier 38 are furnished to the signal input of a gated video amplifier 40. Energization of the gating or control input of amplifier 40, which thereupon prevents or inhibits any output signal from amplifier 40, is furnished by OR gate 45. Input signals to the intensity control input or grid 48 of cathode ray tube 31 are supplied by gated video amplifier 40 in absence of an output signal from OR gate 45. However, when either the first or second input to OR gate 45 is fulfilled, gated video amplifier 40 is switched to its nonconductive or blocking condition, preventing the output signal of specimen current amplifier 38 from reaching the intensity control input of cathode ray tube 31. Thus, gated video amplifier 40 facilitates blanking, herein defined as interrupting the cathode ray (or electron beam) in cathode ray tube 31 during those times in which the cathode ray is not forming a part of the image being displayed on the face of the cathode ray tube.

Within electron optical column 21, the electron beam 24 (which assumes the outline indicated by dotted lines) is furnished from an electron gun 25 through a beam-defining apertured anode 26. The beam is focused by means of first and second magnetic condenser lenses 27 and 28, comprising electromagnetic coils energized with constant voltage from DC bias sources 41 and 42 respectively. Bias sources 41 and 42 may be adjusted independently to desired amplitude values for focusing the electron beam within electron optical column 21. In addition, a magnetic objective lens 29 is likewise situated in electron optical column 21, and comprises a coil energized with a constant voltage from a DC bias source 43. DC bias source 43 may be adjusted to provide to coils 29 the amplitude of voltage required to focus the electron beam on specimen

23. The electron beam in electron optical column 21 finally passes through a beam defining apertured plate 19 before impinging upon specimen 23. A vacuum is maintained within electron optical column 21 by pumps (not shown) which exhaust the column through a port 44 in the electrically grounded walls of the column.

In considering operation of the system of FIG. 1, assume that horizontal sweep generator 14 and vertical sweep generator 34 are each in their initial output conditions, and that the electron beam in electron optical column 21 is finely focused by virtue of proper amplitude settings on DC bias means 41, 42 and 43. Pulses produced by crystal oscillator 10 and illustrated in FIG. 2A, are counted by counter 12. Counter 12 produces an output pulse each time a preset number of input pulses have been counted, thereby acting as a frequency divider. Each pulse supplied by counter 12, such as illustrated in FIG. 2B, drives horizontal retrace pulse generator 13 which produces horizontal retrace pulses such as illustrated in FIG. 2C. Each horizontal retrace pulse resets horizontal sweep generator 14 to its initial condition and, by fulfilling the first input to OR gate 45, gates video amplifier 40 into its nonconductive condition throughout the horizontal retrace pulse duration so as to prevent energization of grid 48 of cathode ray tube 31 with signals from specimen current amplifier 38. Blanking of cathode ray tube 31 is thus achieved, preventing distortion of the image on the face of cathode ray tube 31 from occurring while the horizontal retrace pulse endures.

Upon completion of each horizontal retrace pulse, a ramp voltage is produced by horizontal sweep generator 14 which integrates charge supplied by constant current generator 15. The amplitude of current supplied by constant current generator 15 is selected through linkage 9 whenever a count is preset in counter 12. Horizontal sweep generator 14 continues to integrate charge until the next horizontal retrace pulse occurs returning the horizontal sweep generator output voltage to zero. The resulting output voltage waveform produced by horizontal sweep generator 14 is illustrated in FIG. 2D.

Each pulse from counter 12 which actuates horizontal retrace pulse generator 13 to reset horizontal sweep generator 14 to its initial condition also actuates vertical trace pulse generator 37 to advance the output voltage amplitude of vertical sweep generator 34 by a single uniform increment. The size of this increment is determined by the vertical trace pulse amplitude which is selected through linkage 8 when the number of horizontal lines to be generated in each raster is selected. This selection is made by setting counter 32 to produce an output pulse after counting a predetermined number of input pulses. The output signal of vertical trace pulse generator 37 is illustrated in FIG. 2E, while the incrementally increasing amplitude voltage produced by vertical sweep generator 34 is illustrated in FIG. 2F.

When counter 32 has counted to its preset count, an output pulse, such as illustrated in FIG. 2G, is supplied to vertical retrace pulse generator 33, resulting in a vertical retrace pulse such as illustrated in FIG. 2H. This vertical retrace pulse resets vertical sweep generator 34 to its initial output voltage amplitude and simultaneously fulfills the second input to OR gate 45, thereby blanking cathode ray tube 31 while the cathode ray is being returned to its initial vertical position.

In the foregoing manner, a horizontal signal is generated which smoothly deflects the electron beams in both electron optical column 21 and cathode ray tube 31 in horizontal directions and rapidly returns the beams to their initial horizontal positions. Similarly, a vertical signal is generated which moves both electron beams stepwise in vertical directions during the rapid return of the beams to their initial horizontal positions and also returns the beams rapidly to their initial vertical positions after the beams have been swept horizontally in their final vertical positions. A high degree of linearity in the resulting raster is achieved because the horizontal and vertical signals are coupled to electron beam deflection means through constant current amplifiers 17 and 18, and 35 and 39, respectively.

As the electron beam in electron optical column 21 is scanned across the surface of specimen 23, current leaving the specimen flows to low input impedance specimen current amplifier 38. The low input impedance of amplifier 38 helps prevent deleterious electric fields from forming on specimen 23. The amplified specimen current is furnished by amplifier 38 through gated video amplifier 40 to grid 48 of cathode ray tube 31. Thus, the image on the face of cathode ray tube 31 is modulated in accordance with amplitude of specimen current from specimen 23. For a constant electron beam current in electron optical column 21, the specimen current depends on surface topography, average atomic number of the specimen in the path of the electron beam, and the presence of magnetic or electric fields near the surface of the specimen. The effect of surface topography, in turn, depends upon the surface structure and orientation of the specimen.

With the apparatus of the instant invention, a large depth of focus is obtained, providing high quality images of surfaces too irregular to be observed in a conventional light microscope. The scanning electron microscope of the instant invention is also superior to conventional electron microscopes in the study of very fragile surface structures which cannot be replicated; in fact, no specimen preparation is ordinarily required, except for cutting to a convenient size and mounting on the specimen holder. If the material to be examined exceeds 10^6 ohm-centimeters in resistivity, a thin layer of carbon or aluminum evaporated over the surface of the specimen usually overcomes any static voltage built up on the specimen which might otherwise result in dielectric breakdown. This also avoids degradation in image resolution due to the varying surface potential which would otherwise result on a specimen of this type.

The resolution obtainable in a scanned image is equal to the size of the electron beam striking the specimen, to a first approximation. As the beam size is reduced by the electron lenses in the electron optical column, the current in the beam is also reduced, as well as the ratio of signal to noise. Therefore, it is highly desirable to employ a low noise preamplifier in the first stage of the video signal amplifying apparatus system. A preamplifier of this type is illustrated in FIG. 3.

Thus, in FIG. 3, specimen current amplifier 38 is illustrated to comprise an operational amplifier 50 which permits amplification of intensity or video signals as small as 10^{-9} amperes without introducing objectionable noise. A feedback resistance 51 determines the gain obtained from operational amplifier 50 while a capacitance 52 in shunt with resistance 51 is used to reduce the high frequency gain of the circuit and prevent oscillation. A pair of low leakage diodes 53 and 54, connected in opposed parallel relationship, protect amplifier 50 by preventing voltages at its input from deviating more than about 1 volt from ground potential. Since the specimen signal is derived from a high voltage electron beam which can have large voltage transients, diodes 53 and 54 prevent damage to the sensitive field effect transistor input of operational amplifier 50 which might otherwise result. The low impedance input to operational amplifier 50, which results from the use of negative feedback through resistance 51, permits employment of several feet of coaxial cable between the specimen and amplifier 50 without any adverse effect upon frequency response of the apparatus.

The second stage of specimen current amplifier 38 comprises a differential input operational amplifier 55 having a feedback resistance 56 coupling a first input of operational amplifier 55 to the output thereof. An additional resistance 57 is connected between a second input to operational amplifier 55 and ground. A double-pole-double-throw image polarity switch 58 is used for reversing output signal polarity of specimen current amplifier 38 so that positive or negative images may be displayed. Switch 58 is connected to the first and second inputs of operational amplifier 55 through input resistances 60 and 61, respectively. A potentiometer 62 and a resistance 63 connected in series with the moveable tap of potentiometer 62 comprise a bias level control. Thus, depend-

ing upon the position of switch 58, either the output of amplifier 50 is coupled to the first input of amplifier 55 and a positive bias is coupled to the second input of amplifier 55, as shown in FIG. 3, or the positive bias is coupled to the first input of operational amplifier 55 and the output of amplifier 50 is coupled to the second input of operational amplifier 55. Therefore, by changing position of switch 58, the polarity of output signal from amplifier 38 is reversed, permitting display of either positive or negative images. The bias level control comprising potentiometer 62 and resistance 63 permits the steady background of the specimen current to be subtracted out of the signal, so that only the useful video signal is amplified by the second stage of specimen current amplifier 38.

By employing magnetic focusing and deflection of the cathode ray in the cathode ray tube, the quality of display is further improved. Brightness, spot size and contrast improve with higher anode voltages on the cathode ray tube, but electrostatic deflection and focusing of the beam become more difficult under these circumstances. Therefore, in order to make the magnetic deflection system precise and linear over a wide range of sweep frequencies, magnetic deflection of the electron beam in both the cathode ray tube and the electron optical column is employed. The same type of circuit is employed in both cases, and is illustrated in FIG. 4. An operational amplifier 70 receiving input signals through a current-limiting resistance 74 drives magnetic deflection coils 71, with feedback voltage obtained across a resistance 72 and furnished to the input of amplifier 70 through a feedback resistance 73 in order to realize a constant current mode of operation. Hence, the current flowing through windings 71 is proportional to the voltage applied to the input of amplifier 70 within the frequency response limits of the amplifier. Magnification achieved in the image can be increased by reducing current in the deflection coils of the electron optical column. This is accomplished by increasing the value of resistance 72, thereby reducing the gain in this amplifier stage.

Many specimen structures have deep relief and hence are best studied stereoscopically. The present invention facilitates making stereoscopic pairs of micrographs, or images of microscopic regions, by employing a tilting specimen holder 80 within electron column 21, as illustrated schematically in FIG. 5. Specimen holder 80 comprises a bistable platform, such as of nickel, to which is spot-welded a wire rod fulcrum 81 for the platform. The diameter of rod 81 is chosen in order to provide a particular desired stereo angle. Wire rod 81 rotates atop a nonmagnetic, electrically conductive support 82 to which the specimen current amplifier input is connected. The electron beam impinging on specimen 23 is indicated by the vertical arrow.

A pair of electromagnets 83 and 84 are situated beneath either end of support 82, so as to exert a magnetic influence on bistable platform 80. Electromagnets 83 and 84 are energized from a power supply 85 through a pair of pushbuttons 86 and 87 respectively. Thus, during viewing, either of the two bistable positions of platform 80 can be selected by momentarily depressing the appropriate one of pushbuttons 86 and 87, momentarily activating the appropriate electromagnet. This selects one or the other of two possible angles of incidence for the electron beam. Upon deenergization of the previously energized electromagnet, the platform remains in its selected position. Stereoscopic pairs of micrographs may then be made by photographing the displayed image of a particular area or feature twice on specimen 23, once during each of the two bistable positions assumed by the platform.

The foregoing describes a simplified scanning electron microscope wherein the image of an observed specimen is determined in accordance with sensed specimen current. The microscope provides improved brightness, spot size and contrast in the displayed image. In addition, image aberrations due to interference from power line frequency magnetic fields are minimized.

While only certain preferred features of the invention have been shown by way of illustration, many modifications and

changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

We claim:

1. In a system for producing high resolution magnified images of a specimen undergoing observation with a scanning electron beam, the combination comprising:

magnetic field generating means for sweeping the electron beam in a predetermined two-dimensional pattern over the surface of the specimen undergoing observation;

means coupled to said magnetic field generating means for controlling the rate at which said electron beam is swept in each direction over the surface of said specimen; said rate controlling means including crystal oscillator means; counter means coupled to said oscillator means for producing an output pulse after a predetermined number of oscillator pulses have transpired; sweep generating means coupling said counter means to said magnetic field generating means so as to drive the electron beam smoothly in one of the two dimensions; and circuit means coupling said counter means to said magnetic field generating means so as to drive the electron beam incrementally in the other of the two dimensions after said predetermined number of oscillator pulses have transpired;

high gain amplifier means;

conductive means connecting said specimen to said amplifier means, said amplifier means being responsive to electrons leaving said specimen through said conductive means; optical display means having an image display surface;

means coupling said magnetic field generating means to said optical display means for sweeping said pattern over the surface of said display means in synchronism with the pattern swept by said electron beam; and

means coupling said amplifier means to said optical display means for modulating the intensity of said pattern as said pattern is traced out over the surface of said display means.

2. The system of claim 1 wherein said magnetic field generating means includes an operational amplifier, an electron beam deflection coil having one of two terminals coupled to the output of said operational amplifier, and feedback resistance means coupling the other of said two terminals to the input of said operational amplifier.

3. The system of claim 2 wherein said optical display means comprises a cathode ray tube and wherein said means coupling said magnetic field generating means to said optical display means includes an additional operational amplifier, an additional electron beam deflection coil positioned to deflect the cathode ray tube electron beam and having one end thereof connected to the output of said additional operational amplifier, and an operational amplifier feedback resistor connecting the input of said additional operational amplifier to the other end of said additional electron beam deflection coil.

4. The system of claim 1 wherein said conductive means includes a specimen holder and means connecting said specimen holder directly to the input of said high gain amplifier means so as to furnish the electrons leaving said specimen to the input of said high gain amplifier means.

5. In a system for producing high resolution magnified images of a specimen undergoing observation with a scanning electron beam, the combination comprising:

magnetic field generating means for sweeping the electron beam in a predetermined two-dimensional pattern over the surface of the specimen undergoing observation;

means coupled to said magnetic field generating means for controlling the rate at which said electron beam is swept in each direction over the surface of said specimen;

high gain amplifier means including first and second operational amplifiers, said second operational amplifier having first and second input means for accepting signals of

positive and negative polarity respectively, and switching means coupling the output of said first operational amplifier selectively to the first or second input of said second operational amplifier in accordance with the polarity of image to be displayed on said optical display means;

conductive means connecting said specimen to said amplifier means, said amplifier means being responsive to electrons leaving said specimen through said conductive means;

optical display means having an image display surface;

means coupling said magnetic field generating means to said optical display means for sweeping said pattern over the surface of said display means in synchronism with the pattern swept by said electron beam; and

means coupling said amplifier means to said optical display means for modulating the intensity of said pattern as said pattern is traced out over the surface of said display means.

6. A high resolution scanning electron microscope comprising:

means supporting a specimen to be examined within an evacuated chamber;

electron beam generating means situated within said evacuated chamber and positioned to direct a beam of electrons toward said means for supporting said specimen;

magnetic field generating means for sweeping said beam of electrons in a raster pattern over said means for supporting said specimen; said magnetic field generating means including an operational amplifier, an electron beam deflection coil having one of two terminals coupled to the output of said operational amplifier, and feedback resistance means coupling the other of said two terminals to the input of said operational amplifier;

means coupled to said magnetic field generating means for controlling the rate at which said electron beams is swept over the surface of said specimen;

high gain amplifier means;

conductive means connecting said means supporting said specimen to the input of said high gain amplifier means;

cathode ray tube display means;

means coupling said magnetic field generating means to said cathode ray tube display means for sweeping said raster pattern over the face of said cathode ray tube in synchronism with the raster pattern swept by said beam of electrons; and

means coupling said amplifier means to said cathode ray tube display means for modulating the intensity of the raster pattern being traced out over the face of said cathode ray tube display means.

7. The high resolution scanning electron microscope of claim 6 wherein said amplifier means includes first and second operational amplifiers, said second operational amplifier having first and second input means for accepting signals of positive and negative polarity respectively, and switching means coupling the output of said first operational amplifier selectively to one of the inputs of said second operational amplifier so as to selectively produce a positive or negative image on the face of said cathode ray tube display means.

8. The high resolution scanning electron microscope of claim 6 wherein said means coupling said magnetic field generating means to said cathode ray tube display means includes an additional operational amplifier, an additional electron beam deflection coil positioned to deflect the cathode ray tube electron beam and having one end thereof connected to the output of said additional operational amplifier, and an additional operational amplifier feedback resistor connecting the input of said additional operational amplifier to the other end of said additional electron beam deflection coil.

9. The high resolution scanning electron microscope of claim 8 including means for controllably tilting the means supporting said specimen so as to permit said beam of electrons to impinge upon said specimen at either of two predetermined angles of incidence.