United States Patent [19]

Engel

[11] **3,774,042**

[45] **Nov. 20, 1973**

[54] **PARTICLE BEAM APPARATUS HAVING A DATA STORAGE CONTROL SYSTEM**

[75] Inventor: **Albrecht Engel**, Berlin, Germany

[73] Assignee: **Siemens Aktiengesellschaft**, Berlin, Germany

[22] Filed: **Jan. 3, 1972**

[21] Appl. No.: **215,074**

Related U.S. Application Data

[63] Continuation of Ser. No. 30,908, April 22, 1970, abandoned.

[30] **Foreign Application Priority Data**

May 16, 1969 Germany ..... P 19 25 330.6

[52] **U.S. Cl.** ..... **250/311,** 250/327, 250/397, 250/469, 250/514, 346/74 P, 346/110 V

[51] **Int. Cl.** **H01j 37/26,** G01n 23/04

[58] **Field of Search** ..... 250/49.5 R, 49.5 A, 250/49.5 E; 346/73 CR, 74 EB, 74 P, 110 V

[56] **References Cited**

UNITED STATES PATENTS

3,137,791	6/1964	Gutter	250/49.5
3,449,759	6/1969	Warren	346/110

Primary Examiner—William F. Lindquist
Attorney—Arthur E. Wilfond et al.

[57] **ABSTRACT**

A discriminator coupled to the storage control of a storage device for storing data provided by a particle optical system determines inconstancies in operational magnitudes of the particle beam apparatus which adversely affect the quality of the data stored by the storage device and transmits the inconstancy determinations to the storage control to prevent the operation of the storage device.

7 Claims, 2 Drawing Figures

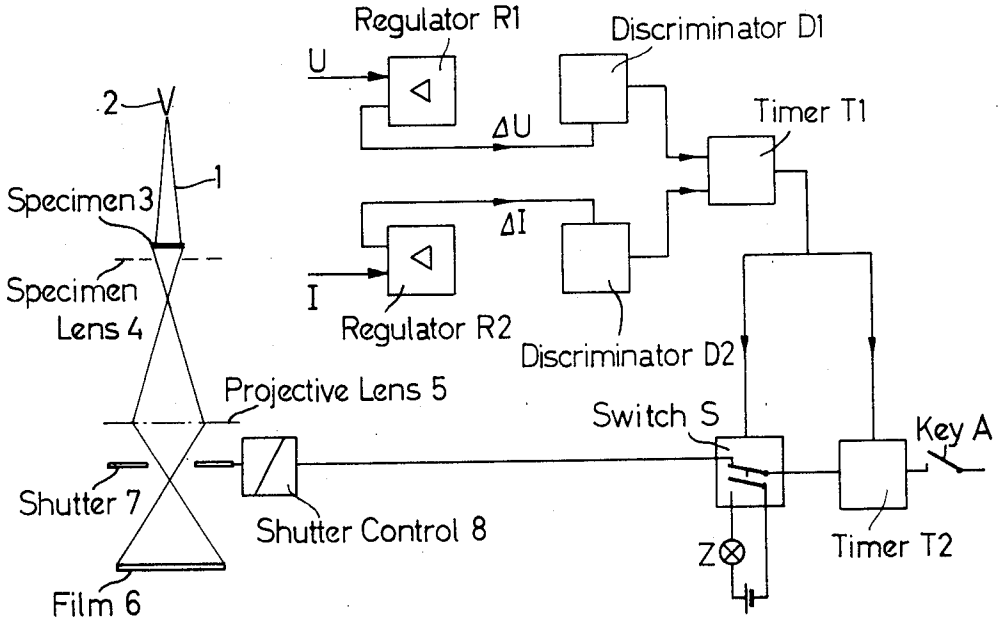


FIG. 1

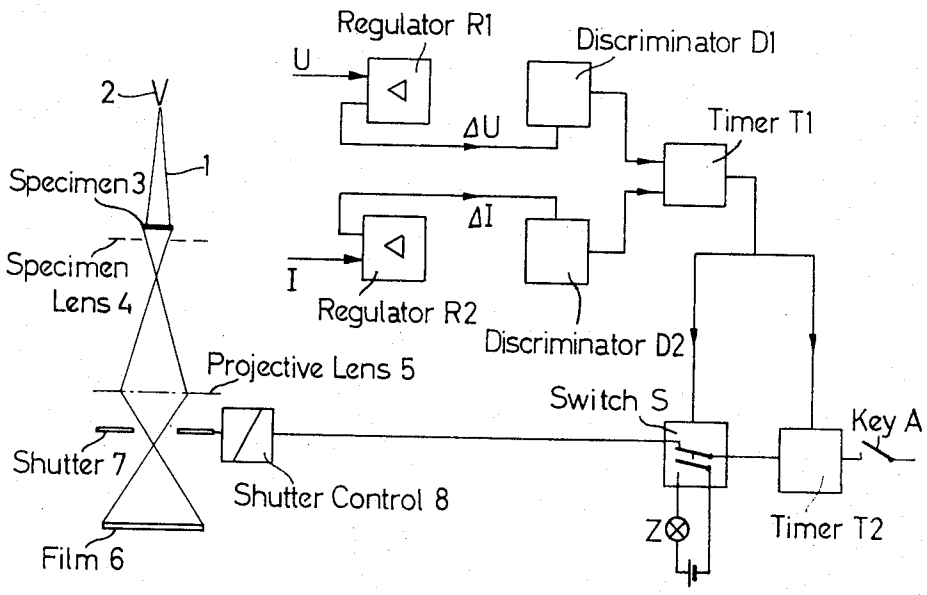
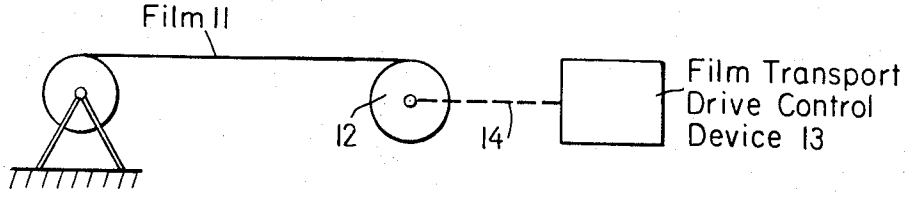

Regulator R1
Discriminator D1
U
ΔU
Timer T1
2
V
1
Specimen 3
ΔI
Specimen Lens 4
I
Regulator R2
Discriminator D2
Projective Lens 5
Switch S
Key A
Shutter 7
Shutter Control 8
Z
Timer T2
Film 6

FIG. 2


Film 11
12
14
Film Transport Drive Control Device 13

PARTICLE BEAM APPARATUS HAVING A DATA STORAGE CONTROL SYSTEM

This is a continuation of application Ser. No. 30,908, filed Apr. 22, 1970 for "Particle Beam Apparatus," assigned to the same assignee, and now abandoned.

DESCRIPTION OF THE INVENTION

The invention relates to particle beam apparatus. More particularly, the invention relates to particle beam or corpuscular ray apparatus which includes a storage device for storing data provided by the particle optical system of the particle beam apparatus via a specimen.

In electron microscopes, it is customary to photographically store or record the particle optical images produced by, for example, irradiating a specimen with an electron beam. This is especially desirable since in high dissolution investigations, a relatively long period is necessary in order to provide visually detectable images. The invention also extends into the field of other particle beam microscopes such as, for example, ion microscopes and electron diffraction devices which permit the extraction of specific data via a specimen. The invention may be utilized to advantage when, instead of a photographic record or storage, the storage or record is provided on another medium such as, for example, a magnetic tape.

Image dissolution in particle beam apparatus, and thus the quality of the storage or record of the data or information provided by the apparatus via the specimen, depends to a considerable extent upon the constancy of various electrical and mechanical limiting magnitudes or qualities. Important magnitudes or quantities which influence the proper operation of the particle beam apparatus are the acceleration voltages of the cathode system and the excitation currents or voltages of the particle optical lenses, utilized to focus the particle beam on the storage device and to produce the magnified image or diffraction diagrams, or the like. Other factors may considerably impair the quality of the record provided by the storage device. One ordinarily skilled in the art is familiar, for example, with the thermal drift of the specimen, which may be traced to the absence of a thermal balance and thereby to a varying temperature difference within the specimen, or in the portions of the apparatus connected with the specimen. Mechanical shocks to the particle beam apparatus and disturbing fields which extend into the region of the particle beam, due to insufficient shielding, are also inconstancies of operational magnitudes or quantities, in the sense of my invention, having an adverse effect on the quality of the stored record.

The inconstancies in the operational magnitudes of the particle beam apparatus are not continuously in evidence. Thus, the electrical operational magnitudes of the particle beam apparatus may be considered to be mostly constant, after a warmup period, provided that new switching processes do not occur and that the thermal drift is substantially completed when a thermal balance is reached after a period determined by the structure, and especially by the specimen support. Disturbing mechanical shocks or outside fiels also decay. Otherwise, basic measures must be undertaken to remove the disturbing influences.

The principal object of the invention is to provide new and improved particle beam apparatus.

An object of the invention is to provide new and improved particle beam apparatus which provides a record of data provided by the particle optical system via a specimen.

An object of the invention is to provide particle beam apparatus which prevents the storage of data provided by the particle optical system via a specimen upon the presence of inconstancies in the operational magnitudes of the particle beam apparatus which adversely affect the quality of the data stored.

An object of the invention is to provide particle beam apparatus for providing a photographic image of data provided by the particle optical system via a specimen, which apparatus prevents waste of photographic record media.

An object of the invention is to provide particle beam apparatus which functions with efficiency, effectiveness and reliability.

In accordance with the invention, particle beam apparatus comprises an electron beam microscope including a particle optical system and storage means for storing data provided by the particle optical system via a specimen. The particle beam apparatus includes storage control means coupled to the storage means for controlling the operation of the storage means. Discriminator means is coupled to the storage control means for determining inconstancies in operational magnitudes of the particle beam apparatus which adversely affect the quality of the data stored by the storage means and for transmitting the inconstancy determinations to the storage control means to prevent the operation of the storage means.

The particle optical system includes lenses and the discriminator means determines inconstancies in the excitation currents and excitation voltages of the lenses of the particle optical system.

The particle optical system includes a cathode system having an accelerating voltage and the discriminator means determines inconstancies in the accelerating voltage of the cathode system. The operational magnitudes or quantities include the bias of the control electrode, relative to the actual cathode, as well as the acceleration voltage of the cathode system and the excitation current of a magnetic lens and the excitation voltage of an electrostatic lens. The operational magnitudes also include mechanical and thermal disturbances which may be determined by appropriate measurand apparatus.

The discriminator means controls the storage control means to prevent the operation of the storage means upon the occurrence of the inconstancies. The discriminator means controls the storage control means to interrupt the operation of the storage means upon the occurrence of the inconstancies. The discriminator means controls the storage control means to prevent the operation of the storage means during an interval in which the inconstancies occur. The operation of the storage means may be prevented for a specific period of time, which may be independent of the period during which the inconstancies occur. If, after such period, the inconstancies are still present, the storage means may again be prevented from operation for such period of time.

The discriminator means comprises discriminators for determining inconstancies in operational magnitudes of the particle beam apparatus which adversely affect the quality of the data stored by the storage

means and timing means coupled between the discriminators and the storage control means for controlling the storage control means to prevent the operation of the storage means during an interval in which the inconstancies occur.

The storage means may comprise photographic apparatus having an exposure shutter. The storage control means then comprises a shutter control device coupled to the shutter. Thus, a photographic exposure occurs only when there is no presence of inconstancies in operational magnitudes, or when any inconstancies of operational magnitudes which are present are only limited to those which do not adversely affect the photographic record.

The storage means may comprise moving picture photographic apparatus having a film transport drive. The storage control means then comprises a film transport drive control device coupled to the film transport drive. This provides another advantage of the particle beam apparatus of the invention. Such advantage is the saving of storage or record material. Heretofore, photographic images of specimen details were produced by electron microscopic magnification, regardless of the occurrence of inconstancies in operational magnitudes. After the photographic records were provided, the best ones were selected for evaluation purposes. In accordance with the invention, the selection is made at the time of the production of the photographic image, by selecting a specific time for the recording operation, thereby eliminating any waste of photographic record media.

The discriminator means further comprises additional timing means coupled between the timing means and the shutter control device for determining the exposure time of the photographic apparatus. The discriminators may interrupt the operation of the additional timing means during the interruption of the storage means. The predetermined exposure time then substantially combines individual time intervals wherein the best imaging and recording conditions prevail in the particle beam apparatus. The discriminator means also comprises signal means for indicating the duration of the interval during which the operation of the photographic apparatus is prevented.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing, wherein:

FIG. 1 is a schematic block diagram of an embodiment of the particle beam apparatus of the invention; and

FIG. 2 is a schematic block diagram of a modification of the particle beam apparatus of FIG. 1.

The particle beam apparatus of the invention comprises a well known electron microscope. Since the electron microscope is known, only the most pertinent parts are illustrated in the FIG. 1 and are described herein. An electron beam 1 is emitted by a cathode 2 and penetrates a specimen 3. This is usually accomplished after the electron beam is bunched by capacitor lenses. In the direction of the electron beam, behind the specimen 3, a specimen lens 4 and a projective lens 5 are provided. The projective lens 5 produces a magnified sharp image of the transparent specimen 3 on a record medium, photographic plate, photosensitive film, storage medium, or the like, 6.

A shutter 7 controls the exposure time of the particle beam on the photographic plate or film 6. The shutter 7 comprises two rotatable halves which cooperate with each other. A shutter control unit 8 comprises a magnet, or any other suitable means, for controlling the operation of the shutter.

In accordance with the invention, recording on the photosensitive material 6 must be prevented during the occurrence of inconstancies of the operational magnitudes or quantities such as, for example, the acceleration voltage U and the objective lens current I, which would adversely affect the quality of the stored record or photographic image produced. The particle beam apparatus comprises a discriminator system for determining inconstancies in operational magnitudes of the particle beam apparatus which adversely affect the quality of the data stored by the storage or photographic device.

The discriminator system comprises discriminators D1 and D2 of known type. A regulator R1 for the acceleration voltage is connected in the input of the discriminator D1 and a regulator R2 for the lens current is connected in the input of the discriminator D2. The regulator R1 supplies the discriminator D1 with the oscillation magnitudes or variations ΔU of the acceleration voltage and the regulator R2 supplies the discriminator D2 with the oscillation magnitudes or variations ΔI of the lens current.

The discriminator D1 compares the variations ΔU of the acceleration voltage with predetermined magnitudes and the discriminator D2 compares the variations ΔI of the lens current with predetermined magnitudes. The discriminator circuits D1 and D2 thus supply output signals to a timer or timing circuit T1, connected to their outputs, when the variations ΔU AND ΔI are within permissible limitations.

The discriminator system of the invention includes a switch S connected in the energizing current circuit of the shutter control 8. When the contacts of the switch S are closed in the manner illustrated in the FIG. 1, and a key A is depressed, the photographic plate 6 is exposed for a specific period of time, determined by an additional timer or timing circuit T2. The additional timing circuit T2 is connected in the energizing current circuit of the shutter control 8.

When the discriminators D1 and D2 determine that disturbing inconstancies in operational magnitudes are present, the signal produced thereby switches the switch S to its position opposite that shown in the FIG. 1. When the switch S is switched by the output signal of the discriminators D1 and D2, the contacts are opened in the energizing current circuit of the shutter control 8 and are closed in a signal circuit comprising a signaling device Z. The opening of the energizing circuit prevents the initiation of a new photographic recording process in the microscope or interrupts a photographic recording process being undertaken in said microscope. The closing of the signal circuit energizes the signal device Z to indicate that the photographic process has been prevented or interrupted, and remains in indicating condition for as long as such process is prevented or interrupted.

Thus, after the inconstancies of variations ΔU and ΔI of the operational magnitudes or quantities have been adequately controlled, damped or reduced, the photographic film 6 is exposed for the required period of time. The discriminator system functions, via the timer or timing circuit T1, not only on the switch S, but also on the additional timer or timing circuit T2 in a manner

whereby the operation of the timer T2 is interrupted during the interruption of the exposure of the photographic film **6.**

The timing circuit or timer T1 of the discriminator system of the invention functions to interrupt or prevent the operation of the photographic apparatus for a predetermined period of time, determined by its time delay. The timer T1 may also function to prevent the photographic process for a predetermined period of time independent from the duration of inconstancies present in the operational magnitudes.

The signal device Z of the signal circuit may comprise any suitable visual or audible alarm device which remains energized during the period that the photographic process is prevented or interrupted.

The variations ΔU and ΔI may be derived directly from the operational magnitudes. It is most appropriate to insure that the most desirable times are selected for photographic recording, by a suitable selection of one or more operational magnitudes which are utilized to produce switching signals for prevention or interruption.

Each of the aforedescribed components and the coupling of the aforedescribed components is disclosed in a paper by A.Engel, H. Everding and O. Wolff, entitled: "MESSGERATE ZUR UNTERSUCHUNG DER SCHWANKUNGEN VON HOCHSPANNUNG UND LINSENSTROM BEIM ELEKTRONENMIKROSKOP MIT ELEKTROMAGNETISCHEN LINSEN," which is "MEASURING INSTRUMENTS FOR TESTING THE FLUCTUATION OF HIGH VOLTAGE AND LENS CURRENT IN AN ELECTRON MICROSCOPE WITH ELECTROMAGNETIC LENSES." This paper appears on pages 162 to 165 of VERHANDLUNGEN BAND I, PHYSIKALISCH-TECHNISCHER TEIL, or LECTURES, VOLUME I, PHYSICAL TECHNICAL PART, of the VIERTER INTERNATIONALER KONGRESS FUR ELEKTRONENMIKROSKOPIE or FOURTH INTERNATIONAL CONFERENCE ON ELECTRON MICROSCOPY, held in Berlin, Germany, from Sept. 10 to Sept. 17, 1958, and published by Springer-Verlag Berlin, Gottingen, Heidelberg, 1970.

FIG. **2** illustrates a modification of an embodiment of FIG. **1** in which the film **6** is replaced by moving picture photographic film **11.** The motion picture film **11** is moved by a film transport drive or reel **12.** A film transport drive control device **13** is mechanically coupled to the film transport drive **12** via any suitable coupling linkage **14.** The film transport drive control device may comprise any suitable device such as, for example, a speed and direction controlled motor.

While the invention has been described by means of a specific example and in a specific embodiment, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. Particle beam apparatus comprising an electron beam microscope including a particle optical system including lenses, means applying excitation currents to the lenses and means applying excitation voltages to the lenses and a cathode system and means applying an accelerating voltage to the cathode system and storage means for storing data provided by said particle optical system via a specimen, said particle beam apparatus including

storage control means coupled to said storage means for controlling the operation of said storage means; and

discriminator means electrically connected to said storage control means for determining variations from predetermined normal operating levels of the excitation currents and excitation voltages applied to the lenses and variations from a predetermined normal operating level of the accelerating voltage of said cathode system of said particle optical system of said particle beam apparatus which adversely affect the quality of the data stored by said storage means and for transmitting the variation determinations to said storage control means to control said storage control means to prevent the operation of said storage means upon the occurrence of said variations.

2. Particle beam apparatus as claimed in claim **1,** wherein said discriminator means includes timing means.

3. Particle beam apparatus as claimed in claim **2** wherein said discriminator means comprises a plurality of discriminators and said timing means is coupled between said plurality of discriminators and said storage control means.

4. Particle beam apparatus as claimed in claim **3,** wherein said storage means comprises photographic apparatus having an exposure shutter and said storage control means comprises a shutter control device coupled to said shutter.

5. Particle beam apparatus as claimed in claim **4,** wherein said discriminator means further comprises additional timing means coupled between said timing means and said shutter control device for determining the exposure time of said photographic apparatus.

6. Particle beam apparatus as claimed in claim **5,** wherein said discriminator means further comprises signal means for indicating the duration of the interval during which the operation of said photographic apparatus is prevented.

7. Particle beam apparatus as claimed in claim **3,** wherein said storage means comprises moving picture photographic apparatus having a film transport drive and said storage control means comprises a film transport drive control device coupled to said film transport drive.

* * * * *