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Valentine et al.

[11] **3,916,190**

[45] **Oct. 28, 1975**

[54] **DEPTH PROFILE ANALYSIS APPARATUS**

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[52] **U.S. Cl.** **250/305**; 250/307; 250/309

[51] **Int. Cl.**[2] **H01J 39/00**

[58] **Field of Search** 250/305, 306, 307, 309, 250/310

[56] **References Cited**

UNITED STATES PATENTS

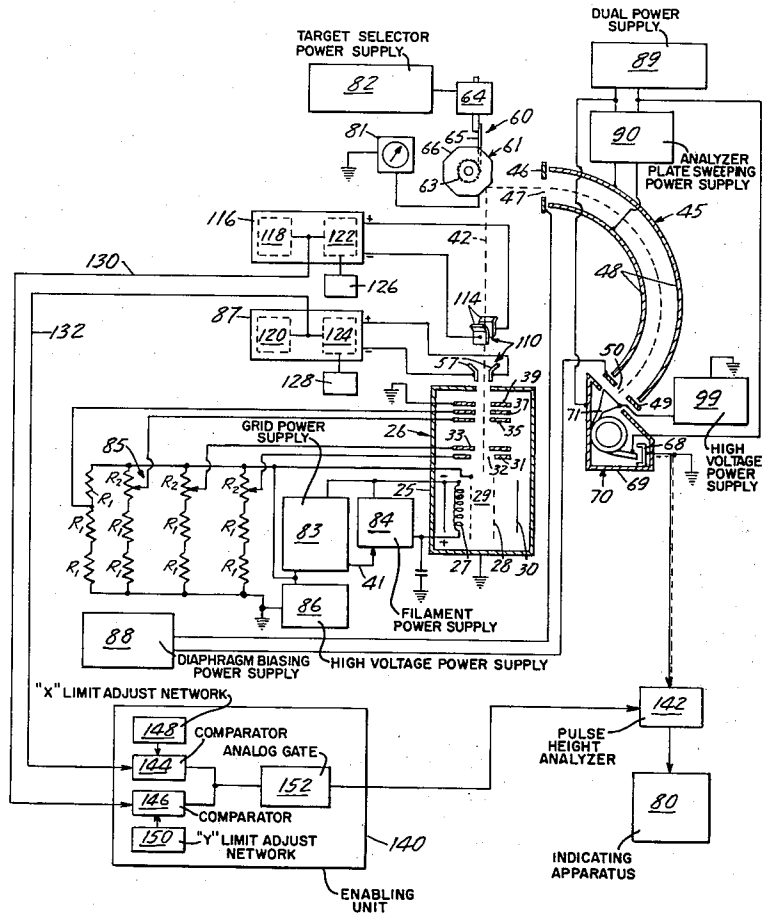
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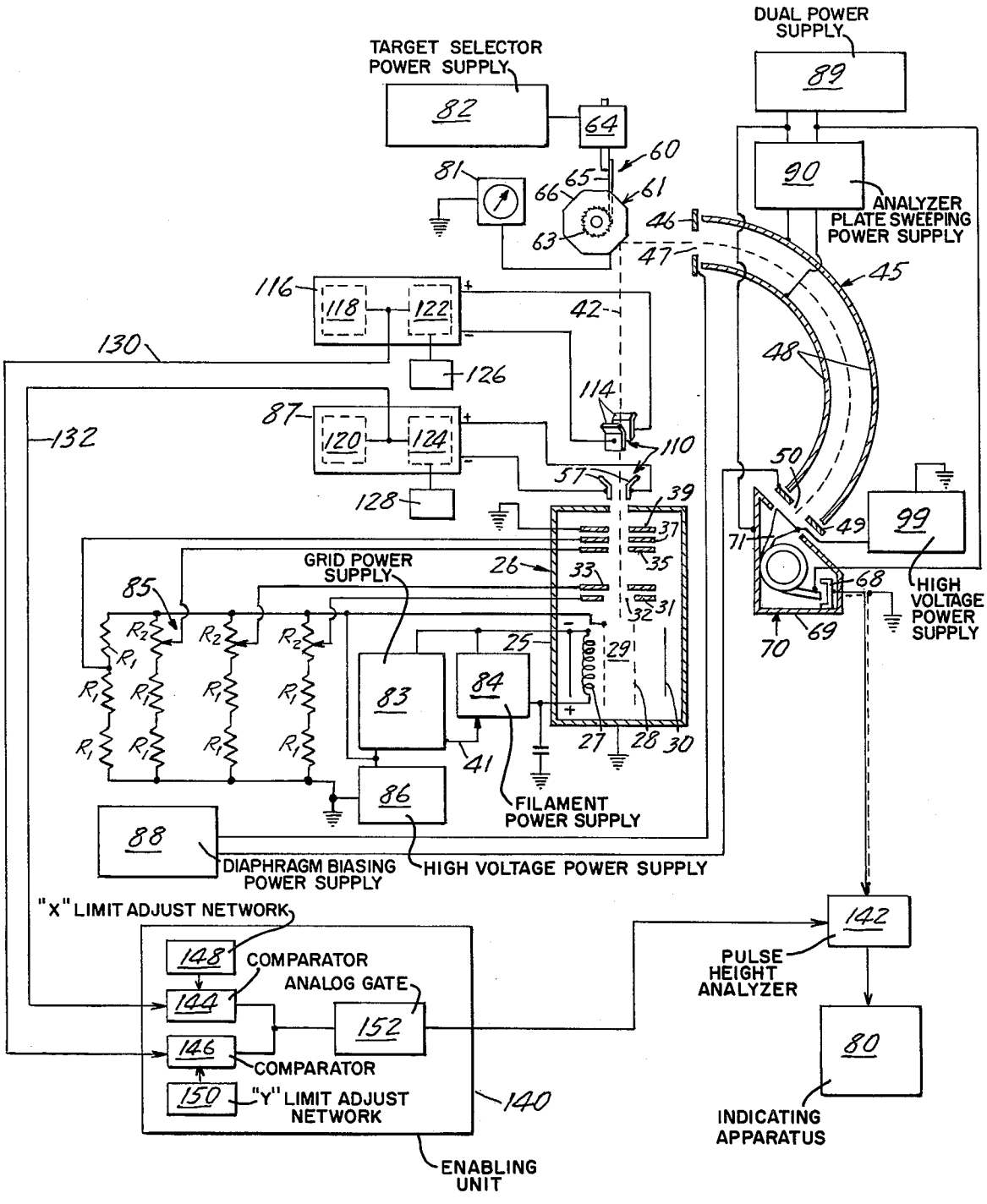
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[57] **ABSTRACT**

An apparatus and method for depth profile analysis in which atoms are removed from a surface by sputtering thereby forming a crater from successively exposed portions of a solid, which portions are then elementally analyzed. The improvement of the present invention comprises deflecting a primary ion beam across the surface to form a crater extending about a predetermined region of the surface and enabling the production of a signal indicative of surface atoms of a given mass only when the primary ion beam is impinging upon a smaller portion of the predetermined region, thereby ensuring that the signal is representative of atoms within the smaller portion, such as at the bottom of the crater.

12 Claims, 1 Drawing Figure




DUAL POWER SUPPLY
89
TARGET SELECTOR POWER SUPPLY
82
64
60
81
65
66
61
63
90
ANALYZER PLATE SWEEPING POWER SUPPLY
46
47
45
116
118
122
42
130
126
48
114
87
120
124
110
132
57
50
128
39
37
99
49
71
GRID POWER SUPPLY
26
33
35
68
HIGH VOLTAGE POWER SUPPLY
85
32
31
25
29
69
70
83
84
27
28
30
41
86
FILAMENT POWER SUPPLY
88
DIAPHRAGM BIASING POWER SUPPLY
HIGH VOLTAGE POWER SUPPLY
"X" LIMIT ADJUST NETWORK
142
148
COMPARATOR
ANALOG GATE
PULSE HEIGHT ANALYZER
144
152
146
COMPARATOR
80
150
"Y" LIMIT ADJUST NETWORK
140
INDICATING APPARATUS
ENABLING UNIT

DEPTH PROFILE ANALYSIS APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to apparatus and methods utilizing ion bombardment of solid surfaces to remove by sputtering portions of that surface, whereby a depth profile analysis of the solid may be performed.

2. Description of the Prior Art

In order to thoroughly analyze the composition of a solid it is conventional to sequentially remove outer layers and to analyze the newly exposed layers to varying depths. One technique for removal of successive layers to predetermined depths involves ion bombardment and sputtering of the surface atoms to form a crater in the surface of the solid. That technique is especially desirable in that it simplifies the analysis, since both the removal and analysis may be done simultaneously in a single operation wherein the newly exposed atoms are analyzed by conventional techniques.

One technique for achieving removal and analysis in a single operation involves secondary ion mass spectroscopy (SIMS). That technique sputters atoms from the sample and mass analyzes the sputtered ions formed during the sputtering process. Another technique for simultaneous removal and analysis involves ion scattering spectroscopy (ISS) such as that disclosed in U.S. Pat. Nos. 3,480,774, issued to Smith on Nov. 25, 1969, 3,665,182, issued to Goff and Smith on May 23, 1972 and 3,665,185, issued to Goff on May 23, 1972, in which such sputtering action is not an essential aspect for analysis purposes. In that technique, the energy of scattered primary ions is determined in order to infer the mass of the surface atoms from which the primary ions scattered, as opposed to SIMS where the sputtered ions are analyzed. The sputtering known to occur as the result of the primary ion beam bombardment has been used to advantage in order to enable depth profile analysis by the ISS technique.

In both methods, the accuracy of the depth profile analysis is limited by the simultaneous detection of atoms on both the walls and at the bottom of craters produced as the result of sputtering. Accordingly, data is received simultaneously from the walls and bottom of the crater and reduces the distinctions between various layers and interfaces, hence restricting the accuracy of the technique in the study of composite thin films and like layered structures. Since most ion beams have an approximately gaussian distribution of current density across the diameter of the beam, the problem of cratering is further accentuated.

One technique for reducing the "crater" effect utilized in the ion beam surface mass analyzer (ISMA) produced by Commonwealth Scientific Corporation, 500 Pendleton Street, Alexandria, Va., (see their Bulletin 70-73, dated Aug., 1973) involves mechanically aperturing the central 15 percent of the primary ion beam directed onto the sample. Only those secondary sputtered ions originating from a 4 mm center of an exposed 6 mm sample area are allowed to enter the mass spectrometer. Such a technique requires precise mechanical alignment and restricts the area of the sample which can be analyzed.

SUMMARY OF THE INVENTION

The present invention is directed to an improved technique for compositional depth profile analysis,

which technique is equally applicable to both SIMS and ISS methods. The method of the present invention accordingly comprises the steps of

providing a target support for supporting in a predetermined location a sample at least a portion of which is to be depth profile analyzed,

producing a beam of primary ions,

directing said primary ions along a beam axis toward the sample,

moving the primary ion beam with respect to said sample to cause the beam to traverse and to impinge on a predetermined region of said surface whereupon atoms on the surface within said region are sputtered from the surface,

transmitting ions indicative of such surface atoms within said region as have a given mass,

receiving the transmitted ions and converting the received ions into an electronic signal, and

sensing the position of the primary ion beam and enabling the production of the electronic signal when the beam is within a smaller portion of the predetermined region to produce a signal associated with only such surface atoms as have said given mass and are located within said smaller portion.

In one embodiment, the method is directed to secondary ion mass spectroscopy, in which ions sputtered from the predetermined region of the surface of the sample are directly mass analyzed in order to transmit only such sputtered ions as have a given mass. In another embodiment, the method is directed to ion scattering spectroscopy in which the beam of primary ions is controlled to have a known mass and substantially the same known kinetic energy, such that transmitted scattered ions may be caused to have a second known kinetic energy value less than the original kinetic energy of the primary beam. The mass of the surface atoms off which the primary beam ions scattered may be inferred from the second known energy value.

The apparatus of the present invention preferably includes members for moving the primary ion beam in at least two directions such that the predetermined region is defined by an area scanned by the primary beam. In such an apparatus the electronic signal is preferably gated when the beam is within a smaller portion of the scanned area.

The present invention thus eliminates the "crater" effect referred to hereinabove by first forming a crater extending over the dimensions of the scanned area, and secondly by passing only such electronic signals identifying surface compositions as are produced when the primary ion beam is within a smaller portion of the scanned area, such as at the bottom of the crater.

BRIEF DESCRIPTION OF THE DRAWING

The apparatus of the present invention will be more fully understood upon reading the following detailed description which refers to the accompanying drawing wherein the FIGURE is a schematic diagram illustrating a structure of the apparatus constructed in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The FIGURE is substantially that set forth as FIG. 2 in U.S. Pat. No. 3,665,182, the disclosure of which is incorporated herein by reference.

In the drawing there is shown a compact elemental analyzing apparatus comprising a multipositionable target support **60,** an ion generating means **26,** beam deflection members **110,** analyzer **45,** an ion detector **70,** enabling means **140,** pulse height analyzer **142** and indicating apparatus **80.**

In operation, the apparatus described above, with the exception of enabling means **140,** pulse height analyzer **142** and indicating apparatus **80,** is located within a vacuum chamber (not shown), a vacuum pump evacuates the chamber to a pressure of less than about 10^{-8} Torr. A getter and a cryopanel are positioned within the chamber to further purify the active elements remaining in the chamber. The pumping is discontinued and noble gas is released into the chamber. The noble gas atmosphere within the chamber is utilized to analyze the elements forming the solid surface of the sample. The noble gas used herein may be any noble gas, however, Helium (He), Neon (Ne) and Argon (Ar) are commonly used. Insulated electrical feed throughs or connectors provide the necessary electrical connections between the components within the chamber and the electrical apparatus located outside of the chamber.

The multipositionable target support **60** includes a rotatably octagonal target wheel **61** and wheel advancement means including tooth ratchet wheel **63** to sequentially advance the target wheel through an increment each time the solenoid is activated. On each planar spaced peripheral surface or face **66** of the octagonal wheel may be placed a sample which is to be elementally analyzed. The sample is held on each face by any suitable temporary fastening such as screw or spring fasteners. It should be apparent that the target wheel may be constructed with a different number of faces, e.g., hexagonal, and the ratchet wheel may have a different number of teeth numerically corresponding to the number of faces on the target wheel. The target support includes a sliding contact arm insulated from suitable supporting members and engageable with indents to electrically connect the wheel **61** and the sample being bombarded with a current measuring device **81** for monitoring the level of ion beam current. The solenoid **64,** which is a standard vacuum solenoid, is electrically connected to a target selector power supply **82** which is indpendently actuated for advancing and positioning successive samples into the predetermined target location. Any variety of similar multiple sample supports may likewise be provided.

The ion generating means preferentially comprises a grounded tubular housing **25,** essentially 2 × 3 × 4 inches (5.1 × 7.6 × 10 cm) adapted to support the operative components of the ion generator. The ion generator structure, essentially 1 × 1 × 3 inches (2.5 × 2.5 × 7.6 cm) includes a heated filament **27** for producing electrons, a highly transparent grid **28** having greater than 80 percent open area and defining within extractor plate **31,** an ionization region **29,** a repeller **30** encircling the filament **27,** a first **33,** second **35,** third **37,** and fourth **39,** anode plates, and a feed-back stabilization loop **41.**

A filament power supply **84** powers the filament to produce electrons and a grid power supply **83** biases the grid with respect to the filament. The produced electrons from the filament are accelerated by the grid **28** to a potential sufficient to ionize the noble gas atoms. For example, the electrons would have from 100 to 125 electron volts of energy, which is sufficient to ionize helium, which has an ionization potential of about 24 electron volts. The repeller **30** is at filament potential and repels or deflects any approaching electrons to result in a long electron path which increases the probability of the electrons striking an atom of the gas to ionize the gas atom.

If the static pressure of the noble gas within the evacuable chamber is increased, then the ion beam current is increased. Therefore, by regulating the electron current at a constant gas pressure the ion beam current is regulated. The feed-back stabilization loop **41** maintains a stable electron grid current which controls the ion beam current throughout pressure changes within the evacuable chamber.

An ion gun voltage divider network **85** biases the extractor plate **31** to a potential to extract positive ions from the ionization region **29.** The network **85** includes a number of resistors to selectively bias the extractor plate **31** and the anode plates **33, 35** and **37,** except the fourth anode plate **39** which is grounded.

The extractor plate **31** includes an extractor aperture **32** of about one-quarter inch (0.6 centimeters), located about the beam axis **42,** to extract the positive ions. The ions are then focused and apertured by the anode plates, forming a primary ion beam. Each anode plate has a potential applied thereto from the network **85.** The first anode plate **33** is primarily used to control, modulate and initially focus the extracted ions into a collimated beam. The second anode plate **35,** which is spaced from the first plate **33** a distance greater than the spacing between the other plates, is the primary beam collimating and focusing anode. The third anode plate **37** is run at a substantially fixed potential from the voltage divider network **85** and the fourth plate **39** is at ground potential, or could be connected to one side of a high voltage power supply **86** and biased with respect to ground. The anode plates are each formed with a small aperture and are constructed of very thin conductive material to control the ion flow and to maintain a monoenergetic beam. The plates are, for example, 0.010 inch (0.25 mm) thick to minimize the wall surface defining the apertures for minimizing of the interaction of the passed ions with the wall surface and loss of energy in the ions passing therethrough.

The beam passing out of the tubular housing **25** is now directed through the noble gas atmosphere towards the sample to be analyzed. Under normal conditions, beam perturbing collisions do not cause serious deviations in analysis.

Two pair of deflector plates **57** and **114,** positioned near the end of the housing **25** and on opposite sides of the beam axis serve to deflect the beam to scan the beam about a predetermined area of the sample. The plates **57** are charged by an ion deflector power supply **87,** while the plates **114** are charged by a similar ion deflector power supply **116.**

The power supplies **87** and **116** include time base sweep generators **118** and **120** respectively, such as Tektronix, Inc. Model 2B67, which may be used with the Tektronix, Inc. Model RM561A scope, and amplifiers **122** and **124.** Such supplies are capable of delivering ± 140 V sawtooth waveforms, and when used to charge one-half inch (1.27 cm) long by one-eighth inch (0.32 cm) wide deflection plates positioned at the exit aperture of the housing **25** are sufficient to deflect a 3500 eV Ne^{20} ion beam approximately 3 mm in the hor-

izontal direction and approximately 4.5 mm in the vertical direction at the specimen surface. Other deflection circuits providing either sawtooth, triangular or like waveshapes may similarly be employed. It is preferred that the outputs of the supplies **87** and **116** be ungrounded, hence providing equal positive and negative outputs to drive each plate of a given pair of deflection plates such that the beam axis is maintained at substantially ground potential. It is further preferred to provide a DC bias via bias supplies **126** and **128** on the output of each supply to facilitate positioning of the scanned beam on the sample surface. In one test, the primary beam diameter was about 1 mm, and the beam was scanned over a predetermined area approximately 3×4.5 mm. It is, of course, readily apparent that the number of lines and the size of the scanned area are readily controlled by varying the deflection voltage and repetition rates, the size of the deflection plates, and the energy of the primary ion beam.

Signals from the sweep generators **118** and **120** are also coupled via leads **130** and **132** to an enabling unit shown generally as **140,** which provides an enabling signal when the primary ion beam is positioned within the predetermined area. The enabling signal is coupled to a pulse height analyzer **142,** such as Ortec, Inc., Oak Ridge, Tennessee, Model 486, in order to trigger the passage of signals representative of a given mass on the sample surface to the indicating apparatus **80.**

The deflected ion beam strikes or bombards the sample on the sample surface about the predetermined area, thereby sputtering atoms from the surface and scattering at least some of the impinging primary ions from the surface atoms. The current to the sample by the impinging beam is measured by the current measuring device **81** and such measured current is used to determine the approximate current density striking the surface of the sample.

The energy analyzer **45** comprises an entrance diaphragm **46,** having a rectangular entrance slit **47,** an exit diaphragm **49,** having a rectangular exit slit **50,** and two curved electrostatic analyzer plates **48.** The entrance diaphragm **46** and exit diaphragm **49** may be charged by a diaphragm biasing power supply **88.** The diaphragms may be separately or simultaneously grounded or biased to similar or different positive potentials. The slits in the diaphragms have a preferred width of 0.005 inches (0.125 mm) and the entrance diaphragm is spaced about one centimeter from the surface of the sample being analyzed.

The analyzer plates **48** are charged by the output from an analyzer plate sweeping power supply **90** receiving power from a dual power supply **89.** The analyzer plate sweeping power supply **90** permits a suitable charge to be applied to the plates to direct ions having a predetermined mass and energy through the slit in the exit diaphragm. The analyzer plates **48** have a mean radius of **2** inches (5.1 cm). The illustrated analyzer **45** is a standard 127° energy analyzer.

The scattered ions are thus received from the sample by the energy analyzer and the ions having a predetermined energy value are passed therethrough. The number of ions being passed are detected and converted into electrons by the ion detector **70,** to be received by the electron collector **68.** The electron collector **68** converts the collected electrons into an electronic signal.

The ion detector **70,** within the enclosure **69,** is a continuous channel electron multiplier **71,** powered by a high voltage power supply **99,** having an 8 millimeter diameter cone entrance which encompasses the entire exit slit in the exit diaphragm of the 127° energy analyzer. The electron multiplier may be a commercially available device such as Model No. CEM-4028 manufactured by Galileo Electro-Optics Corporation, Galileo Park, Sturbridge, Mass. 01581.

In the present invention, the electronic signal is preferably coupled through the pulse height analyzer **142** to produce an output signal only when the signal from the analyzer exceeds a given intensity, thereby improving the signal to noise rejection ratio. The analyzer further acts as a controllable switch in that the production of an output signal is further controlled by the presence of the enabling signal from the enabling unit **140.**

It is intended to be within the scope of the present invention to selectively gate, i.e., to interrupt the production of the electronic signal indicative of a given mass in a variety of ways. Thus, while in the above embodiment an enabling signal is coupled to the pulse height analyzer **142,** it is within the scope of the present invention to controllably interrupt the production of the electronic signal in a number of other ways. For example, an electronically controlled shutter or grid may be provided adjacent the input or output slits of the analyzer **45.** Similarly, the power to the analyzer plates **48** and to the electron detector **70** may be electrically controlled in response to an enable signal.

In a preferred embodiment, the unit **140** comprises a pair of comparator units **144** and **146,** each of which is coupled via one of the leads **130** or **132** to a corresponding sweep generator **118** or **120.** Limit adjust signals for "*x*" and "*y*" axis are provided by networks **148** and **150** respectively, such that when a segment of a signal from one of the sweep generators is within the voltage limits provided by the networks **148** or **150,** an output signal is produced. Thus an output signal from one of the comparator units **144** and **146** would indicate only that the position of the primary ion beam is somewhere within that portion of the scanned area as is defined by lower limits on a single coordinate. When an output signal is produced from both comparator units **144** and **146,** the signals are then summed and coupled to the analog gate **152** to produce, as the enable signal referred to hereinabove, a DC pulse suitable for triggering conventional electronic switches.

Each of the comparator units **144** and **146** preferably include a first operational amplifier such as an integrated circuit type **741** connected in the voltage follower mode, with an input to the operational amplifier coupled through a variable resistor to the output from the sweep generators, to provide a high impedance input for the signals from the sweep generators. The limit networks **148** and **150** each preferably include two similarly connected type **741** operational amplifiers, the inputs of which are coupled through variable resistances to sources of DC potential to provide controllable voltage levels which may be set to establish the lower and upper limits respectively. The outputs of the operational amplifier coupled to the sweep generator is then compared with the output of each of the other type 741 operational amplifiers of the limit networks by additional operational amplifiers, such as National Semiconductor, Inc., Santa Clara, Calif., Model LM211's connected in a comparator mode. For exam-

ple, when the amplitude of the signal from the *x* axis sweep generator is greater than the lower limit set by one of the type 741 operational amplifiers in the *x* axis limit network **148,** a first comparator within the comparator unit **144** will produce an output signal. Similarly, when the amplitude of the signal from the *x* axis sweep generator is less than the upper limit set by the other type **741** operational amplifier in the *x* axis limit network **148,** a second comparator within the comparator unit **144** will produce a similar output signal. The *y* axis comparator **146** and *y* axis limit networks **150** are similarly operable. The outputs of both comparators **144** and **146** are then summed and coupled to the analog gate circuit **152** to control the production of an enable signal. The gate circuit **152** conveniently utilizes an integrated circuit gate such as Siliconix, Inc., Santa Clara, Calif., Model DG175.

In another embodiment, the enable signal is conveniently derived from circuits which sense the onset of each deflection cycle for both the *x* and *y* axis deflection of the primary ion beam, and which produce an output signal during a predetermined interval of time following each such onset. These output signals are then summed as in the above embodiment to control the production of an enable signal.

In one test of the above described improved depth profiling procedure, the lower and upper limits were set to activate the electronic signal during only the center one-fourth of a horizontal scan and the center one-half of a vertical scan. Thus when a 3500 eV Ne^{20} primary ion beam was scanned across a uniform gold target and a signal representing the ions scattered from the gold surface was displayed on a display device synchronized with the scanning of the primary beam, a uniformly illuminated portion of the display device corresponding to the scanned area, within the limits of the acceptance area of the spectrometer entrance slit, was observed. When the signal was then gated in the manner set forth hereinabove, the illuminated portion of the display was rectangular, being approximately one-half as large in the vertical direction and one-fourth as large in the horizontal direction as that initially scanned.

In another test, a 500 Angstrom thick film of copper evaporated on a glass slide was bombarded with a stationary 2,000 eV Ne^{20} beam. The resultant scattered ions were energy analyzed to detect copper atoms by conventional ion scattering techniques and the resultant output signal was plotted as a function of time. Such a plot is representative of the thickness of the film, inasmuch as the repeated bombardment and sputtering causes successive portions of the film to become exposed. Another portion of the film was then bombarded with a *x—y* deflected 2,000 eV Ne^{20} beam and the resultant electronic signal was gated in the manner set forth hereinabove. A similar plot of the analyzed signal as a function of time, normalized in time to the test with the stationary beam, indicated that the presence of copper atoms fell away sharply as the entire thickness of the film was sputtered from the glass, whereas with the stationary beam, the presence of copper atoms decreased much more gradually and appeared to asymptotically approach zero intensity. This indicated that the edges of the crater were sputtered away at a lower rate due to the lower intensity at the periphery of the beam diameter, thus illustrating that the signal is coming from different depths. For example, it is often desired to study the migration of atoms between adjacent layers of multilayered structures in which adjacent layers may have gross differences in electrical conductivity. The present invention makes possible such a study to a degree heretofore not obtainable.

The present invention is especially suited to improving the usefulness of SIMS in the study of layered films. It is well known that the sputtered ion yield is strongly dependent on the presence of active gases such as oxygen. Accordingly, in SIMS analyses of films, the detection of underlying layers is complicated, inasmuch as sputtered atoms from such newly exposed layers are often difficult to detect. This can cause the preponderance of the signal to result from the edges of craters produced upon sputtering, due to the prevalence of active gases at the original surface, such as are present due to absorbed O_2 or H_2O vapors. The present invention overcomes such limitations in that the signal from the edges is rejected, thereby facilitating the correct interpretation of the signal as corresponding to atoms emanating from the center of the craters.

It should be appreciated that when the present invention is utilized with SIMS apparatus, a method of mass analyzing the sputtered surface atoms is employed. Accordingly, the energy analyzer **45** is then replaced by a conventional mass analyzer positioned to accept ions formed of the sputtered atoms. The output of such mass analyzers is detected by a similar ion detector **70** and the output signal therefrom is coupled to a signal processing network and indicating apparatus similar to the pulse height analyzer **142** and apparatus **80.** An enabling signal from the enabling unit **140** controls the production of the output signal in like manner as that set forth hereinabove.

Having described the present invention with reference to a preferred embodiment, it is appreciated that changes may be made without departing from the spirit or scope of the invention as defined in the claims.

What is claimed is:

1. A method for improved compositional depth profile analysis comprising the steps of

a. providing a target support for supporting in a predetermined location a sample at least a portion of which is to be depth profile analyzed;

b. producing a beam of primary ions having a known mass substantially the same known kinetic energy;

c. directing said primary ions along a beam axis towards a surface of said sample;

d. transmitting scattered primary ions having a second known kinetic energy value less than the original kinetic energy of the primary ions indicative of surface atoms within a predetermined region of said surface as have a given mass; and

e. receiving the transmitted ions and converting the received ions into an electronic signal; wherein the improvement comprises

f. moving said primary ion beam with respect to said sample to cause said beam to traverse and to impinge on said predetermined region; and

g. sensing the position of the primary ion beam on said predetermined region and enabling the production of said electronic signal when the beam is within a smaller portion of the predetermined region to produce a signal associated with only such surface atoms as have said given mass and are located within said smaller portion.

2. A method according to claim 1, wherein the step of producing said beam of primary ions comprises producing a beam of primary ions having a known mass and substantially the same known kinetic energy, and said transmitting step comprises transmitting scattered primary ions having a second known kinetic energy value less than the original kinetic energy of the primary ions.

3. A method according to claim 1, wherein said transmitting step comprises transmitting such ions as are produced upon sputtering atoms from within said predetermined region and have a given mass.

4. A method according to claim 1, wherein the step of moving the primary ion beam further comprises moving the beam with respect to said sample in at least two directions such that said predetermined region is defined by an area scanned by said primary beam and wherein the step of sensing and enabling further comprises gating said electronic signal when the beam is within a smaller portion of said scanned area.

5. An apparatus for compositional depth profile analysis comprising

a. a target support for supporting in a predetermined location a sample at least a portion of which is to be depth profile analyzed;

b. ion generator means producing a beam of primary ions having a known mass and substantially the same known kinetic energy;

c. means for directing said primary ions along a beam axis towards a surface of said sample;

d. means for transmitting scattered primary ions having a second known kinetic energy value less than the original primary ion indicative of surface atoms within a predetermined region of said surface as have a given mass; and

e. means for receiving the transmitted ions and converting the received ions into an electronic signal; wherein the improvement comprises

f. means for moving said primary ion beam with respect to said sample to cause said beam to traverse and to impinge on said predetermined region; and

g. means for sensing the position of the primary ion beam on said predetermined region and for enabling the production of said electronic signal when the beam is within a smaller portion of the predetermined region to produce a signal associated with only such surface atoms as have said given mass and are located within said smaller portion.

6. An apparatus according to claim 5, wherein said means for producing said beam of primary ions comprises means for producing a beam of primary ions having a known mass and substantially the same known kinetic energy, and said means for transmitting ions comprises means for transmitting scattered primary ions having a second known kinetic energy value less than the original kinetic energy of the primary ions.

7. An apparatus according to claim 5, wherein said transmitting means comprises means for transmitting such ions as are produced upon sputtering atoms from within said predetermined region and have a given mass.

8. An apparatus according to claim 5, wherein said means for moving the primary ion beam further comprises means for moving the beam with respect to said sample in at least two directions such that said predetermined region is defined by an area scanned by said primary beam and wherein said means for sensing and enabling further comprises means for gating said electronic signal when the beam is within a smaller portion of said scanned area.

9. An apparatus according to claim 8, wherein said moving means is adapted to repetitively deflect said beam of primary ions in two substantially orthogonal directions across said area.

10. An apparatus according to claim 9, wherein said gating means comprises means synchronized to said repetitive deflection and adapted for sensing a predetermined time interval after the onset of each deflection, said predetermined time interval corresponding to the interval during which said primary beam is within said smaller portion.

11. An apparatus according to claim 9, wherein said moving means comprises at least two beam deflection members and is adapted for applying gradually varying amplitude signals to each of said members to form force fields resulting in said deflection and wherein said gating means comprises means adapted for sensing predetermined segments of each of said gradually varying amplitude signals corresponding to the interval during which said primary ion beam is within said smaller portion.

12. An apparatus according to claim 11, wherein said gating means further comprises means for setting said predetermined segment, means coupled to said moving means for receiving a said varying amplitude signal corresponding to that applied to each of said deflection members, means for comparing said predetermined segments with said varying amplitude signals and for providing trigger signals whenever the level of either of said varying amplitude signals are within said predetermined segments, and gate means responsive to said trigger signals for providing an enable signal whenever trigger signals indicating that both said varying amplitude signals within said predetermined segments are present.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,916,190

DATED : October 28, 1975

INVENTOR(S) : Alastair Valentine and Robert F. Goff

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 9, lines 1-12, cancel claims 2 and 3;

Column 9, line 50 to Column 10, line 8, cancel claims 6 and 7.

Signed and Sealed this

seventeenth Day of *February 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks