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Tamura et al.

[11] **3,894,233**

[45] **July 8, 1975**

[54] **ION MICROPROBE ANALYZER**

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[73] Assignee: **Hitachi, Ltd.**, Japan

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Jan. 8, 1973 Japan 48-4701

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

[51] **Int. Cl.** **H01j 37/26**

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

[56] **References Cited**

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Assistant Examiner—C. E. Church

Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

An ion microprobe analyzer including a detector of secondary particles emitted from a specimen by bombarding a specimen with an ion beam, and means for recording or displaying the relationship between currents of the secondary particles and specific ions. According to this ion microprobe analyzer the influence on the measurement of the work function of a surface of the specimen is eliminated and the measurement of a concentration distribution of an element in a direction toward the depth of the specimen can be measured precisely.

18 Claims, 7 Drawing Figures

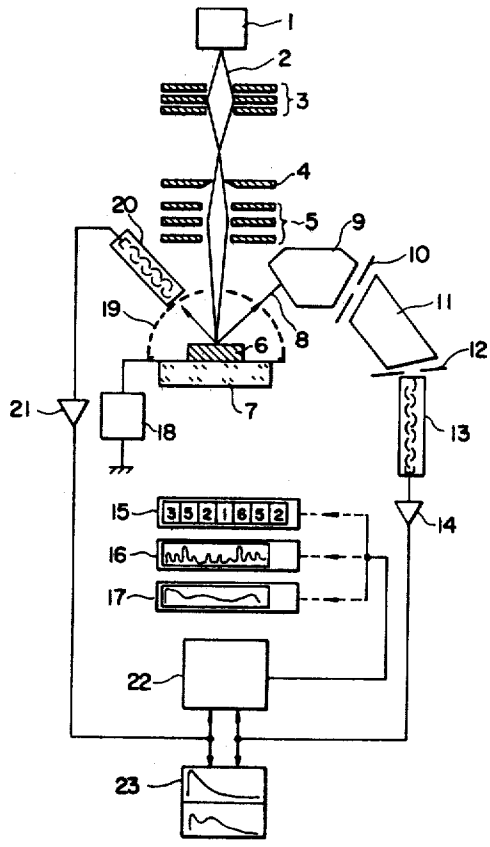


FIG. 1
PRIOR ART

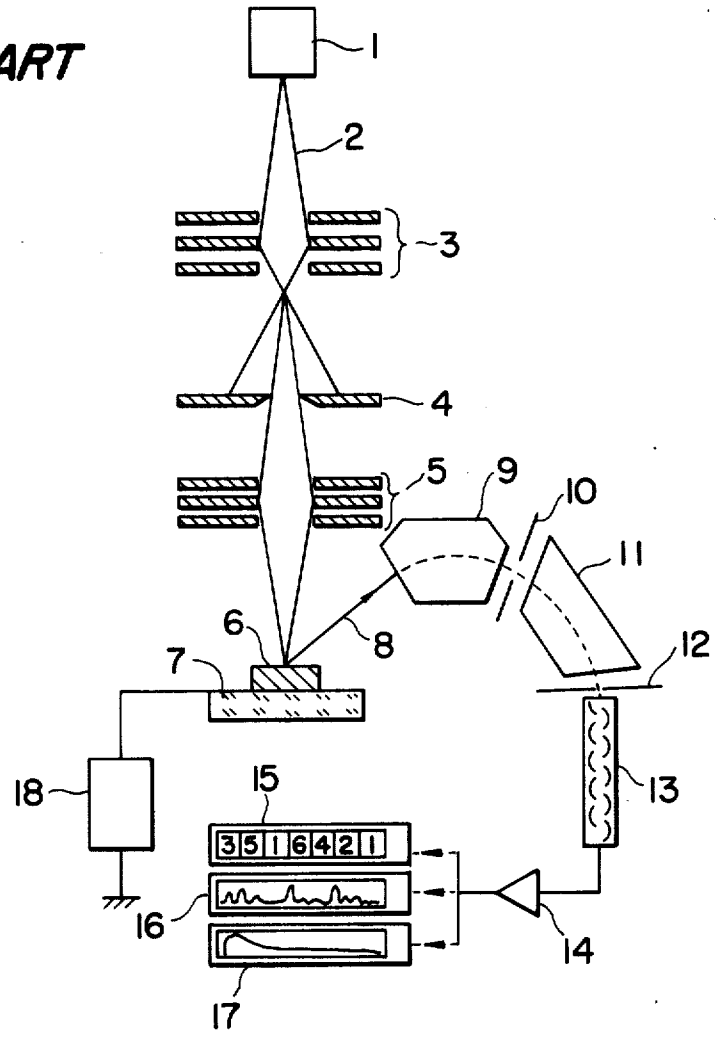


FIG. 2
PRIOR ART

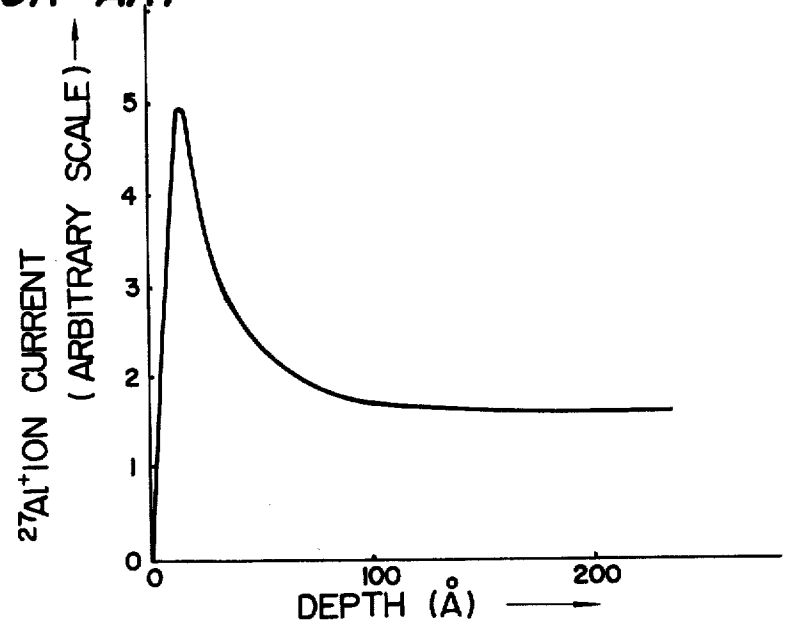


FIG. 3

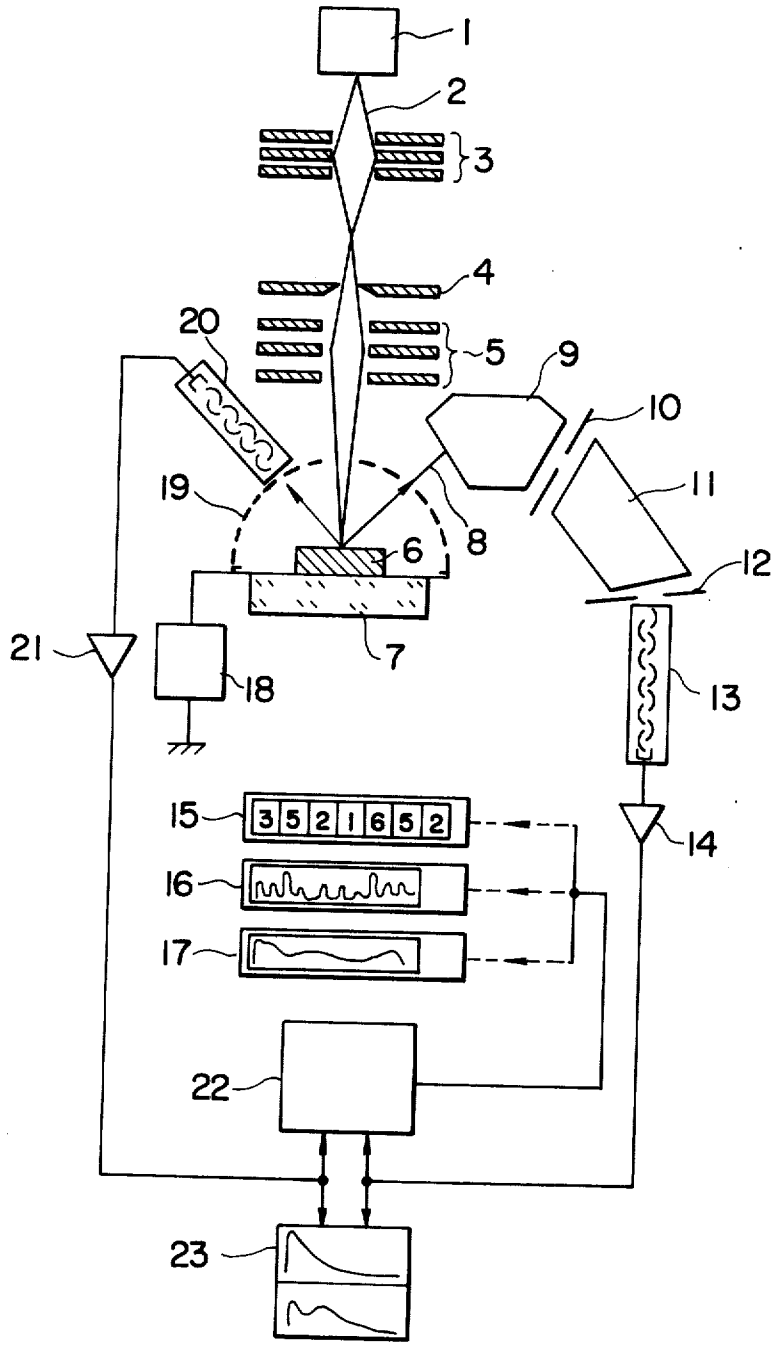


FIG. 4

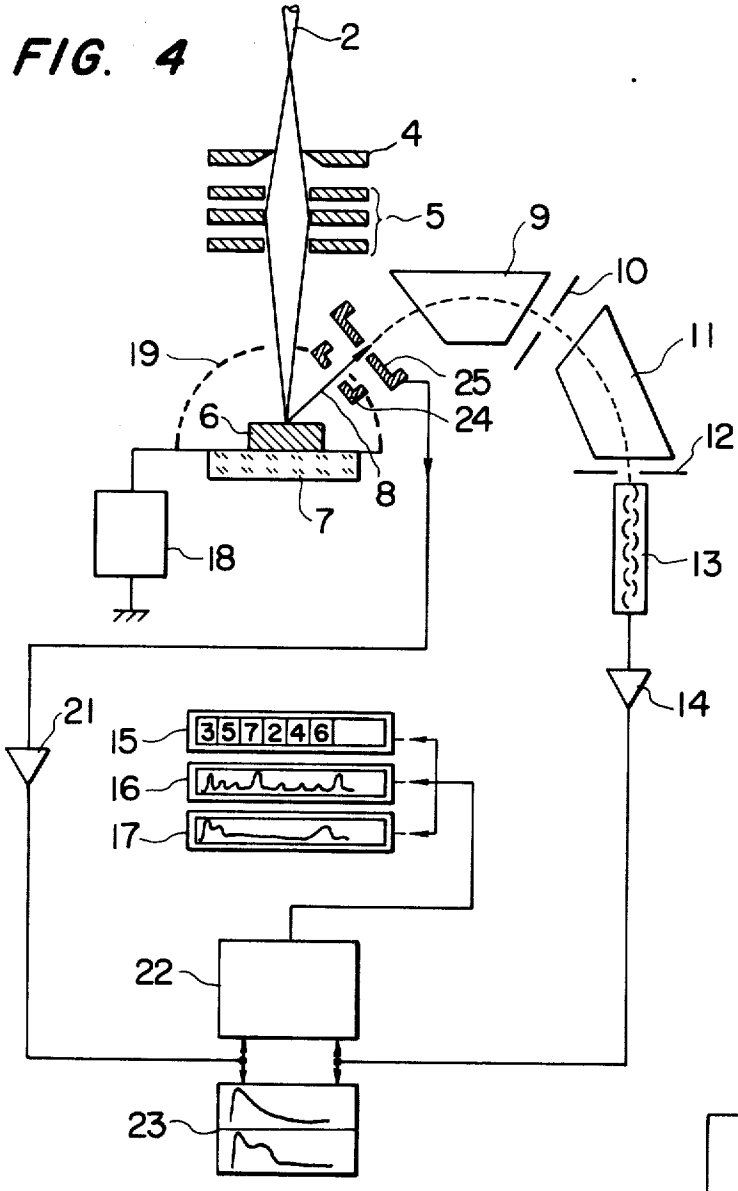

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FIG. 5

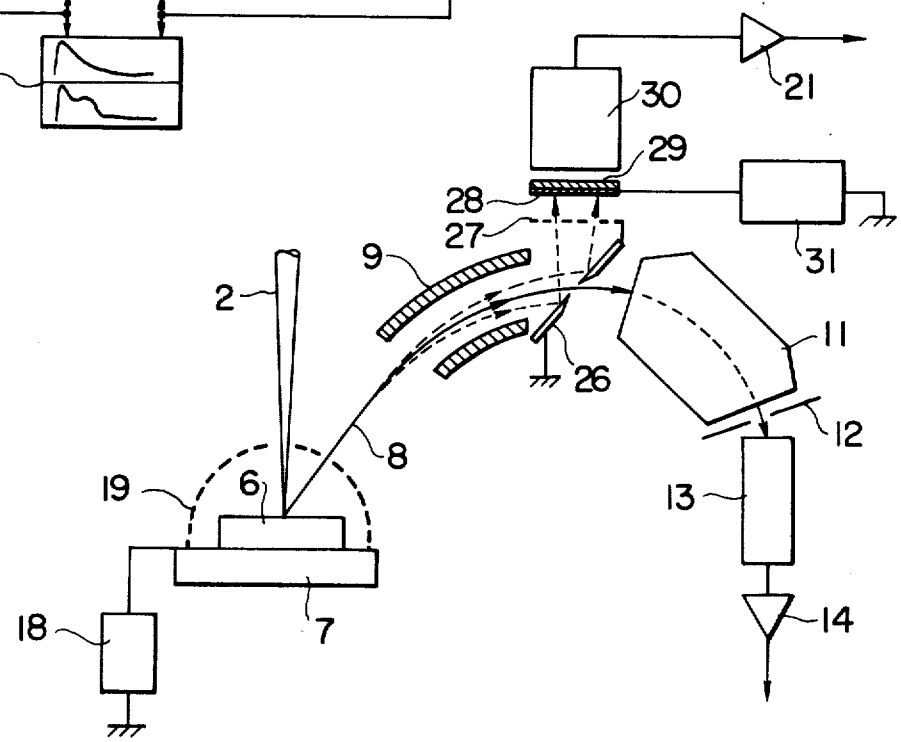

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FIG. 6

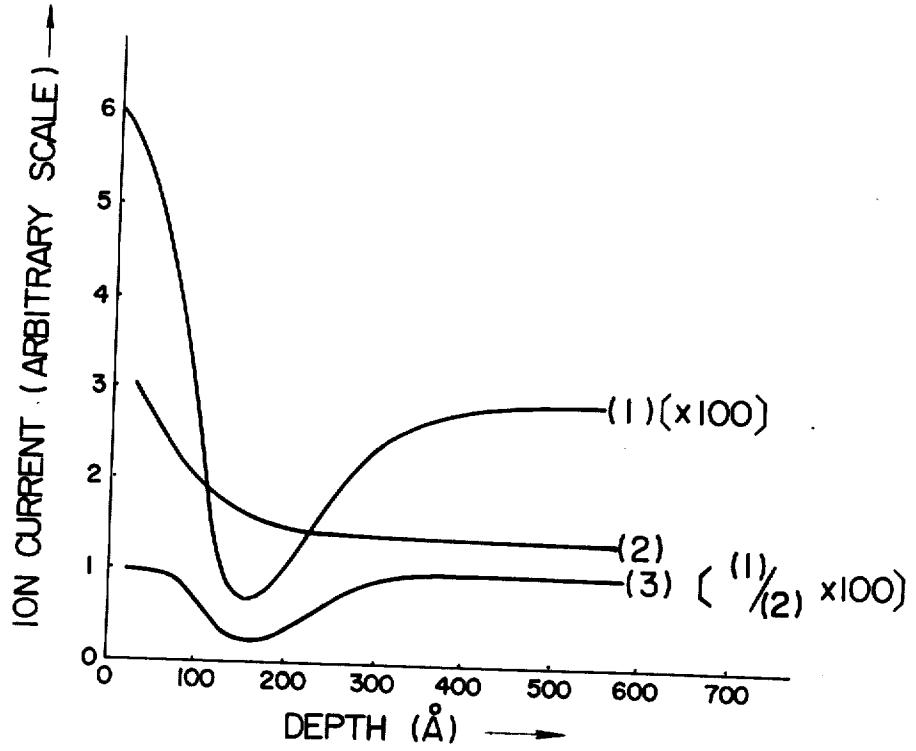
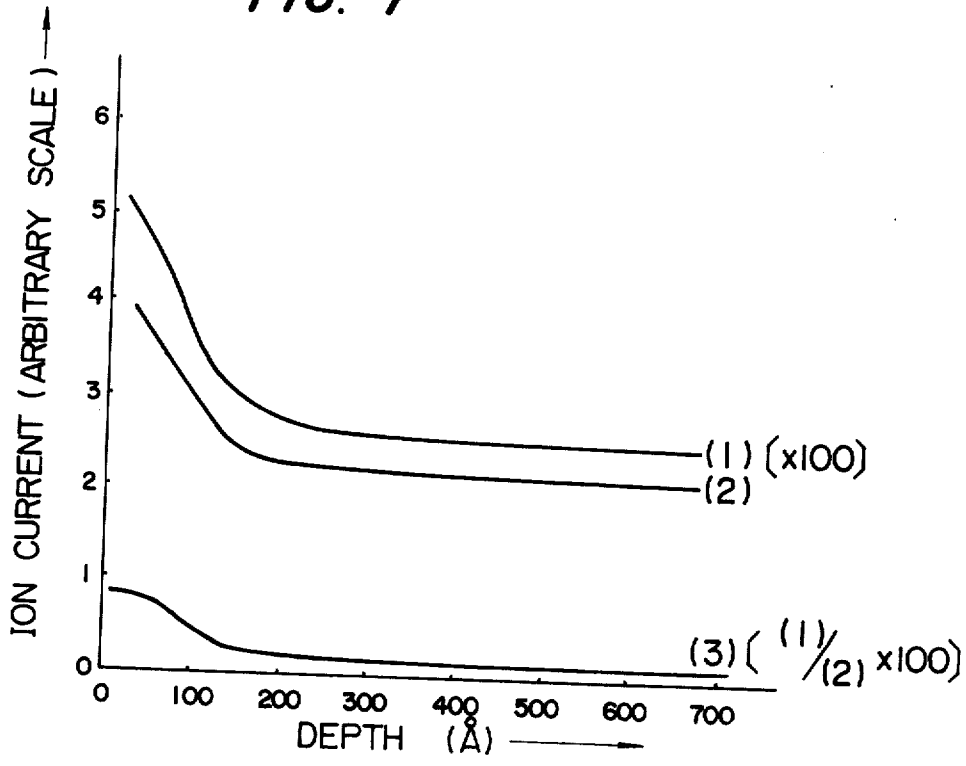

ION CURRENT (ARBITRARY SCALE)
0
1
2
3
4
5
6
0
100
200
300
400
500
600
700
DEPTH (Å)
(1)(x100)
(2)
(3) ((1)/(2) x100)

FIG. 7


ION CURRENT (ARBITRARY SCALE)
0
1
2
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5
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100
200
300
400
500
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700
DEPTH (Å)
(1) (x100)
(2)
(3) ((1)/(2) x100)

ION MICROPROBE ANALYZER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improvements in an ion microprobe analyzer, and more particularly to an ion microprobe analyzer for measuring a concentration distribution of an element in a direction toward the depth of a specimen.

2. Description of the Prior Art

The ion microprobe analyzer has the features of (a) being capable of analysis of the thin surface layer of a specimen and (b) being capable of measurement of the concentration distribution of a specific ion, that is, an element in a direction toward the depth of the specimen. The feature (b) is an advantage not possessed by other types of analyzers and is profitably put into practical use at present.

This ion microprobe analyzer is utilized in analysis of (1) iron and steel materials, (2) semiconductor materials, (3) surface treating materials, (4) insulator materials, (5) surface pollution, (6) organic materials, and so forth.

A conventional type ion microprobe analyzer has a construction such as shown in FIG. **1**, for example. The ion microprobe analyzer includes an ion gun **1** for emitting a primary ion beam **2**, electrostatic lenses **3** and **5** which are arranged in two steps for focusing the primary ion beam **2** on a specimen **6**, a slit **4** for collimating the primary ion beam **2**, a specimen holder **7** for holding the specimen **6**, an electrostatic sector **9** and a magnetic sector **11** to form a double focusing mass spectrometer for mass analysis of a specific ion in a secondary ion beam **8** which is emitted from the specimen **6**. The device further includes slits **10** and **12** for collimating the secondary ion beam **8** to be mass analyzed by the electrostatic sector **9** and the magnetic sector **11**, an ion detector **13** for detecting the secondary ion beam **8** to be mass analyzed, an amplifier **14** for amplifying the output of the ion detector **13**, a rate meter **15**, recorders **16** and **17** for visualizing by recording or displaying the output of the secondary ions by way of a digital or an analog signal. A high voltage power supplying source **18** is connected to specimen holder **7** for applying a secondary ion accelerating voltage.

It is well known in the conventional ion microprobe analyzer that the secondary ion beam **8** which is emitted from the sample **6** by the bombardment of the primary ion beam **2** is mass analyzed by the double focusing mass spectrometer, and an elemental analysis of the specimen is carried out. In the analytical method to measure the concentration distribution of the element in the direction toward the depth of the specimen by the ion microprobe analyzer, at first, the mass spectrometer is adjusted so as to be able to detect a specific ion (ions to be analyzed), then the primary ion beam **2** is generated to bombard the specimen **6**, the secondary ion beam **8** is analyzed with respect to the mass-to-charge ratio by the mass spectrometer, and the current of the specific ions according to the bombarding times of the primary ion beam is recorded or displayed on the recorders **15** and **16**.

An in-depth analysis is then carried out from the relationship between the current of the specific ions and the bombarding times of the primary ion beam. But such conventional apparatus which is used in the in-depth analysis has certain disadvantages.

In general, the secondary ion yield, that is, the ratio of the quantity of secondary ions to that of the incident primary ions, is influenced greatly by the work function of the surface of the specimen. The larger the work function of the surface of the specimen, the larger will be secondary ion yield of the sample.

When the surface of the specimen is exposed to the air, an oxidized layer or a nitride layer is formed at the surface of the specimen, and hence the work function of the surface of the specimen becomes large. Therefore in the in-depth analysis by use of the conventional apparatus, the ion current of the secondary ions from the surface of the specimen shows a steep rising characteristic during the early stages of analysis, that is, in the thin surface layers.

FIG. **2** is a graph which was obtained from in-depth analysis by the conventional ion microprobe analyzer. In this analysis, a primary ion of $^{40}Ar^{+}$, a specimen of naturally oxidized Al, a primary ion energy of 10 KeV and an ion current of 1μA is used. In FIG. **2**, the axis of abscissa and vertical represent the depth (A) from the surface of the specimen and $^{27}Al^{+}$ ion current (arbitrary unit), respectively. As apparent from this Figure, there is a steep change in the current of the secondary ion ($^{27}Al^{+}$) in the neighborhood of the surface of the specimen. This steep change does not correspond to a change of concentration distribution of the element to be analyzed, but is due to a change of the work function of the surface of the specimen. It is clear from this result that the precise concentration distribution of the element cannot be obtained by the conventional ion microprobe analyzer. This consequence also appears in case of metals, compounds, semiconductors and so forth.

As mentioned above, in the in-depth analysis by the conventional ion microprobe analyzer, there is a possibility that an erroneous measure of the concentration distribution of the element will be obtained. In such a case, the information relating to the surface of the specimen which is most desired cannot be obtained. This is one of the largest defects in the conventional ion microprobe analyzer.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an ion microprobe analyzer which has a remarkably enhanced precision of analysis in the direction toward the depth of a specimen.

Another object of the present invention is to provide an ion microprobe analyzer which is able to measure precisely the concentration distribution of a specific ion, that is, an element, in the direction toward the depth of the specimen, in spite of the condition of the surface of the specimen.

In order to accomplish these objects, the ion microprobe analyzer of the present invention includes a detector of secondary particles emitted from the specimen in response to the bombarding of the specimen with a primary ion beam and means for determining the relationship between the current of the secondary particles and the current of the specific ions.

The secondary ion yield is not merely a constant of the substance, but is due to a product of the numbers of secondary ions generated in the specimen by a probability of the secondary ions emitted from the specimen into a vacuum without being neutralized. That is, the probability of a survival of the secondary ions gener-

ated in the specimen is due to the work function of the surface of the specimen. Moreover, the probability of the neutralization of the secondary ions does not depend on the element contained in the specimen.

The principle of the present invention is based on a physical phenomenon as mentioned above. That is, when the place on the specimen which is bombarded by the primary ion beam is fixed, it is considered that the secondary ion beam which includes all ion species emitted from the specimen increases in proportion to the individual ion currents of each element, and therefore an overall change of the ion current or a part thereof has a definite relationship to the sum of the ion currents of each element.

Therefore, by measuring the secondary particles or a part thereof and comparing the current caused by the secondary particles with that of the specific ion, the influence of the work function of the surface of the specimen is compensated and is eliminated, and hence the measurement of the concentration distribution of the element in the direction toward the depth of the specimen can be accomplished precisely.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood by referring to the following detailed description in conjunction with the accompanying drawings, wherein;

FIG. **1** is a schematic of a conventional ion microprobe analyzer;

FIG. **2** is a diagram showing the concentration distribution of Aluminium (Al in the direction toward the depth of the specimen within a naturally oxidized Al specimen measured by the conventional ion microprobe analyzer;

FIG. **3** is a schematic diagram of an embodiment of the present invention;

FIG. **4** is a schematic diagram of another embodiment of the present invention;

FIG. **5** is a schematic diagram of a further embodiment of the present invention;

FIG. **6** is a diagram showing the concentration distribution of Chromium (Cr) within a thermally treated stainless steel specimen in the direction toward the depth of the specimen measured by the present invention;

FIG. **7** is a diagram showing the concentration distribution of oxygen (O) within an oxidized stainless steel specimen in the direction toward the depth of the specimen measured by the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will now be described with reference to FIG. **3**, including an ion gun **1**, a primary ion beam **2**, electrostatic lens **3** and **5** which are arranged in two steps, a slit **4**, a specimen **6**, a specimen holder **7**, a secondary ion beam **8**, an electrostatic sector **9**, a magnetic sector **11**, slits **10** and **12** wherein slit **10** is usually called a β-slit, an ion detector **13**, an amplifier **14**, a rate meter **15**, recorders **16** and **17**, a high voltage power supplying source **18** for accelerating secondary particles, a shielding electrode **19** made of a conductor mesh in the shape of a hemisphere and which is provided for stabilizing the electric field around the specimen **6** by establishing a common potential for the specimen holder **7** and the specimen **6**. A detector **20** is provided for secondary particles emitted from the specimen, that is secondary ions, secondary electrons, etc. which is, for example, a secondary electron multiplier, or a monitoring electrode. An amplifier **21** is provided for amplifying the output of the detector **20**. A ratio circuit **22** is provided for comparing outputs of the amplifiers **14** and **21**, and a recorder **23** includes two elements for recording the respective outputs of the amplifiers **14** and **21**. The shielding electrode **19** may be replaced by a hemisphere electrode having holes for passing the primary ion beam and the secondary particles.

In the apparatus, the secondary ion beam **8** is separated in accordance with the mass-to-charge ratio of the ions by a double focusing mass spectrometer comprising the electrostatic sector **9** and the magnetic sector **11**, and then the separated beam portion is detected by the ion detector **13**. The total secondary particles are detected by the detector **20**. The ion currents detected by the detectors **13** and **20** are respectively amplified by the amplifiers **14** and **21**. In one case, a ratio of the outputs of the amplifiers **14** and **21** is calculated by the ratio circuit **22**, and the result calculated is indicated by recording or displaying on the rate meter **15**, the recorders **16** and **17**, and in another case, the results from the amplifiers **14** and **21** are designated directly on the recorder **23** whereby a comparison of the secondary particles to the specific ions is carried out.

FIG. **4** is a schematic view showing another embodiment of the present invention, and in this apparatus, a detector of secondary particles from the specimen is provided between the specimen and a mass spectrometer, which is, for example, an electrostatic sector of the mass spectrometer. In FIG. **4**, numeral **24** depicts an electrode for extracting a secondary ion and **25** depicts the electrode for detecting the secondary ion. When the detector is for example a secondary electron amplifier a first dynode of the secondary electron amplifier corresponds to the electrode **25**. The numerals other than those as mentioned above depict the same parts similarly designated in the apparatus of FIG. **3**. In the apparatus of FIGS. **3** and **4**, since the detector detects the primary ions which are reflected by the sample in addition to the secondary particles, the accuracy of the measurement is not sufficiently high.

FIG. **5** is a schematic view showing a further embodiment of the present invention and in this apparatus a detector of secondary particles from the specimen is provided between the electrostatic sector and the magnetic sector of the analyzer portion. In FIG. **5**, numeral **26** depicts an ion-electron converter comprising an electrode having a through hole and also having a function of a β-slit of a conventional apparatus, and which is made of, for example stainless steel or Al which is stable in the emission of a secondary electron. A metal mesh **27** is provided so as to avoid a disturbance in the trajectory of the secondary ions by the electric field appearing between the ion-electron converter **26** (means for converting an ion input to a electron output) which is at ground potential, and the scintillator **29** whose potential is maintained at the same as that of the ion-electron converter **26**, thereby maintaining a running field for the secondary ion as a no potential space. A scintillator **29** is provided for converting the secondary electrons emitted from the ion-electron converter **26** to light, and on a surface of which there is provided an electrode **28** made of elements of a low atomic number, for example Al, having a thickness not more than sev-

eral 100 A, for example 400 A, whereby the secondary ions are accelerated by the potential which is applied between the scintillator and the ion-electron converter **26**, for example, 10 KV and the efficiency of fluorescence is thereby enhanced. A photo multiplier **30** is provided for amplifying the light emitted from the scintillator **29**.

In this apparatus, the ion-electron converter may be used with a β-slit. In addition, the parts **26** to **30** may be replaced by a monitoring electrode, or a β-slit and a photo multiplier. The numerals other than those mentioned above identify the same parts similarly designated in the apparatus of FIG. **3** or **4**.

In this embodiment, though the particles are referred to as positive ions, it is also possible to operate using negative ions. In such a case the secondary particles are negative ions and secondary electrons.

In this apparatus, when the magnetic sector **10** is adjusted so as to detect specific ions to be analyzed, the primary ion beam is directed to the specimen, and the secondary ions emitted from the specimen are separated in energy by the electrostatic sector **9**, only ions having particular energy arrive at the ion-electron converter **26**. Among these ions, only the ions having a particular narrow energy band pass the through hole of the ion-electron converter **26** and are analyzed by the magnetic sector **11**. Meanwhile, the ions having a broad energy band bombard the part of converter **26** other than the through hole of the ion-electron converter **26** and secondary electrons are thereby emitted. A part of the secondary electrons thus generated, which are directed toward and pass through the metal mesh **27**, are accelerated by the strong electric field between the ion-electron converter **26** and the thin film electrode **28**, and then bombard the scintillator **29**. Then the scintillator **29** emits the light which is converted to the electrons to be amplified by the photo multiplier **30**.

This method has a particular effect on the analysis in a case where the specimen is small and the secondary ion current therefrom is comparatively small. This method has a detection limit of about **3** figures higher than that measured by electrical current by a monitor electrode, and since this detector is provided behind the electrostatic sector, the disturbance produced by a reflection of the primary ions from the specimen, that is unavoidable in the apparatus shown in FIG. **3** or **4**, is eliminated, and hence a precise measurement can be obtained.

The mass analyzer of the present invention is not limited to a double focusing mass spectrometer, since a single focusing mass spectrometer, etc. may be used.

Next, the results measured by the apparatus of the present invention will be explained. These results were obtained by detecting secondary electrons obtained from a monitor electrode which serves as a β-slit provided between an electrostatic sector and a magnetic sector and then amplifying the detected secondary electrons by means of a secondary electron multiplier.

The first example is that of measuring a concentration distribution in the direction toward the depth of a specimen by utilizing positive secondary ions. In this case, the specimen **6** of heat treated stainless steel (SUS 32) and the shield electrode **19** are maintained at a positive 3 KV by the high voltage power supplying source **18**, and the potential of the first dynode of the secondary electron multiplier which is used as the detector is maintained at −2KV. The bombarding condition of the first ion beam is 10 KeV in energy, 10^{-7} A in ion current, $200\mu\ \phi$ in beam diameter.

In such a condition the mass spectrometer is adjusted and installed so as to measure the Cr^+ ion, the output of the secondary electron multiplier **13** is applied to one terminal of the two element recorder **23** via the amplifier **14**, and meanwhile the output of the detector for detecting secondary particles is applied to the other terminal of the recorder **23** via the amplifier **21**, whereby the Cr^+ ion current and total ion current are recorded at the same time for a function of time. Hence, a graph relating to a ratio of the two ions is produced.

The graph relating to the ratio of the two ions is automatically produced by using the ratio circuit **22**; that is, the outputs of amplifiers **14** and **21** are applied to the ratio circuit **22**, and the output of the ratio circuit **22** is displayed by the recorder **16** or **17**.

In FIG. **6**, the measured result is shown. The abscissa represents a depth (A) from the surface of the specimen and the ordinate represents the Cr^+ ion current and total secondary ion current (arbitrary unit) in curves (**1**) and (**2**), and the ratio of curves (**1**) and (**2**) is represented in a curve (**3**). The scale of curves (**1**) and (**3**) is designated by factor **100** in comparison to that of the curve (**2**).

As clear from a comparison of curves (**1**) and (**2**), the two graphs are different. In the curve (**1**) there is steep rising characteristic at a small depth, and with increasing depth, the Cr^+ ion current decreases abruptly, eventually reaches a minimum value, and then increases again and reaches a saturation level. The rising of the current at a small depth is not due to the high concentration of Cr, but to the influence of oxidation on the surface of the specimen.

This interpretation is based on the fact that the concentration of Cr is the highest at a surface of a bulk of the specimen, which is clarified when the surface of the bulk is exposed by elimination of an oxide layer of the specimen by ion etching.

Meanwhile the curve (**2**) shows the total ion current measured by the apparatus of the present invention at the same time as the measurement of Cr^+ ions. In this curve (**2**), the amount of ions is large in the neighborhood of the surface of the specimen, and decreases when the sputtering progresses in the direction toward the depth of the specimen.

The curve (**3**) shows the ratio of curves (**1**) and (**2**). The ratio is constant in the neighborhood of the surface of the specimen. At the depth of about 150 A the ratio is the smallest, then slowly increases and saturates in the depth of about 400 A. This result is explained as follows. When the surface of the specimen is oxidized and hence a chromium oxide film is formed on the surface thereof, since Cr in the layer close to the surface transfers to the surface, the concentration of Cr in the layer at the surface decreases, and hence the minimum value of Cr appears in the curve (**3**). When the ion etching is progressed and hence the oxide layer of the surface of the specimen is eliminated, the original stainless steel is exposed, and therefore the concentration distribution of Cr corresponds to the nature of the surface of the specimen. The condition is matched with the nature of the surface of the substance.

An embodiment using a negative ion is shown. In general, in a substance in which an electronegativity is high for example, F, O, Cl, S etc., a precise analysis is

possible by a method using a negative ion as a secondary ion and therefore an analysis of such elements is carried out by the negative ion by preference.

An example is an analysis of an oxidized stainless steel (SUS 32). In this measurement, the potentials of the specimen **6** and the electrode **19** are −3 KeV, the first dynode of the photomultiplier is maintained at −2 KeV, the accelerating voltage of the primary ion is 10 KV, and the ion current is 10^{-7} A. The results of the measurement are shown in FIG. **7**. In FIG. **7** the designation of the abscissa and ordinate are similar to those in FIG. **6**. The curves (**1**), (**2**) and (**3**) respectively show the value of $^{16}O^-$, a value of total ions and a ratio of curves (**1**) and (**2**). In this case, the values along the ordinate of curves (**1**) and (**3**) is 100 times of that of the curve (**2**). In the curve (**1**) there is a large peak in the neighborhood of the surface of the specimen, a peak decrease according to the increment of the depth, and it then becomes to have a constant value.

Meanwhile, the curve (**2**) shows the total ion current measured by the apparatus of the present invention at the same time as the measurement of O^- ions. In this case, the total ion current is similar to that of the O^- ions but the ratio of the change of the ion current is more sharp than that of O^- ion. The curve (**3**) shows the ratio of curves (**1**) and (**2**). From the curve (**3**), it is clear that there is much oxygen in the surface of the specimen, and the ratio therefore decreases according to the increment of the depth. In the neighborhood of the surface of the specimen, for example at 50 A in depth, the concentration of O is constant. This means that in the surface of the specimen a perfect oxide layer is constructed.

The example mentioned above relates to the use of stainless steel, but in the other metals or compounds etc. the same results can be obtained.

While the invention has been described by reference to particular embodiments thereof, it will be understood that numerous and further modifications may be made by those skilled in the art without actually departing from the invention. We, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What we claim is:

1. An ion microprobe analyzer comprising:
means for generating a primary ion beam;
means for bombarding a specimen with said primary ion beam;
means for detecting a part of the secondary particles emitted from all elements contained in the specimen as a result of the bombardment thereof by said primary ion beam;
means for mass-analyzing a part of the secondary ions in the secondary particles emitted from said specimen;
means for detecting ions of an element to be analyzed derived from the secondary ions in the mass-analyzing means; and
means for measuring the ratio of the output signals from said means for detecting a part of the secondary particles and said means for detecting ions of an element to be analyzed;
whereby the influence of the work function of the bombarded surface of the specimen can be determined so that a measurement of the concentration distribution of an element of the specimen in the direction of the depth of the specimen can be measured precisely.

2. An ion microprobe analyzer according to claim **1**, which further comprises a shielding electrode surrounding the specimen.

3. An ion microprobe analyzer according to claim **2**, in which said means for detecting a part of the secondary particles is provided outside of the shielding electrode.

4. An ion microprobe analyzer according to claim **2**, in which said shielding electrode is made of a conductor mesh in the shape of a hemisphere and has a common potential for the specimen holder and the specimen.

5. An ion microprobe analyzer according to claim **1**, in which said means for detecting a part of the secondary particles is provided between the specimen and said means for mass-analyzing secondary ions.

6. An ion microprobe analyzer according to claim **1**, in which said means for detecting a part of the secondary particles is a monitoring electrode.

7. An ion microprobe analyzer according to claim **1**, in which said means for detecting a part of the secondary particles is a secondary electron multiplier.

8. An ion microprobe analyzer according to claim **1**, further including a ratio circuit connected to said two detecting means, and in which said means for measuring the ratio comprises means for visually indicating the output from the ratio circuit connected to the respective means for detecting a part of the secondary particles and the ions of an element to be analyzed.

9. An ion microprobe analyzer according to claim **1**, in which said means for measuring the ratio comprises means for visually indicating at the same time the outputs from said means for detecting a part of the secondary particles and said means for detecting a part of the secondary ions.

10. An ion microprobe analyzer according to claim **1**, in which said means for mass-analyzing a part of the secondary ions includes an electrostatic sector and a magnetic sector and said means for detecting a part of the secondary particles is provided between said electrostatic sector and said magnetic sector.

11. An ion microprobe analyzer according to claim **10**, further comprising a shielding electrode surrounding the specimen.

12. An ion microprobe analyzer according to claim **10**,
in which said shielding electrode is made of a conductor mesh in the shape of a hemisphere and has a common potential for the specimen holder and the specimen.

13. An ion microprobe analyzer according to claim **10**, in which said means for detecting a part of the secondary particles comprises means for converting an ion input to an electron output having a through hole, a scintillater having an electrode, a mesh electrode disposed between said converting means and said scintillater and photo multiplier for receiving light from said scintillater.

14. An ion microprobe analyzer according to claim **13**, which further comprises a shielding electrode surrounding the specimen.

15. An ion microprobe analyzer according to claim **13**, in which said shielding electrode is made of a conductor mesh in the shape of a hemisphere and has a

common potential for the specimen holder and the specimen.

16. A method of measurement of the concentration distribution of an element in the direction of the depth of a specimen comprising the steps of:

a. generating a primary ion beam;

b. bombarding a specimen with said primary ion beam;

c. detecting a part of the secondary particles emitted from all the elements contained in the specimen as a result of the bombardment thereof by said primary ion beam and generating a signal representative thereof;

d. mass-analyzing a part of the secondary ions in the secondary particles emitted from said specimen;

e. detecting the ions of an element to be analyzed derived from the secondary ions in the mass-analyzing step (d) and generating a signal representative thereof; and

f. measuring the ratio of the output signals from detecting a part of the secondary particles in step (c) and detecting ions of an element to be analyzed in step (e);

whereby the influence of the work function of the surface of the specimen is determined and a measurement of the concentration distribution of the element in the direction of the depth of the specimen can be measured precisely.

17. A method of measurement according to claim **16**, which further comprises the step of (g) visually indicating said compared results after said step (f) of measuring the ratio.

18. An ion microprobe analyzer comprising:

first means for generating a primary ion beam;

second means for directing said primary ion beam onto a specimen, the concentration distribution of an element in which is to be measured;

third means for detecting a portion of each of the types of secondary particles emitted from said specimen as a result of the bombardment of said specimen with said primary ion beam and generating a first signal representative thereof;

fourth means for mass-analyzing a portion of the secondary ions included among the secondary particles emitted from said specimen;

fifth means for detecting the ions of a selected element from the secondary ions mass-analyzed by said fourth means and generating a second signal representative thereof; and

sixth means, coupled to said third means and said fifth means, for measuring the ratio of said first and second signals,

whereby the influence of the work function of the surface of said specimen bombarded with said primary ion beam can be determined, so that a measurement of the concentration distribution of an element in said specimen with respect to its depth in said specimen from the surface thereof may be precisely effected.

* * * * *