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H. J. LIEBL
METHOD OF OPERATING AN ION MICROPROBE
USING SECONDARY ELECTIONS
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3,479,505

FIG. 1

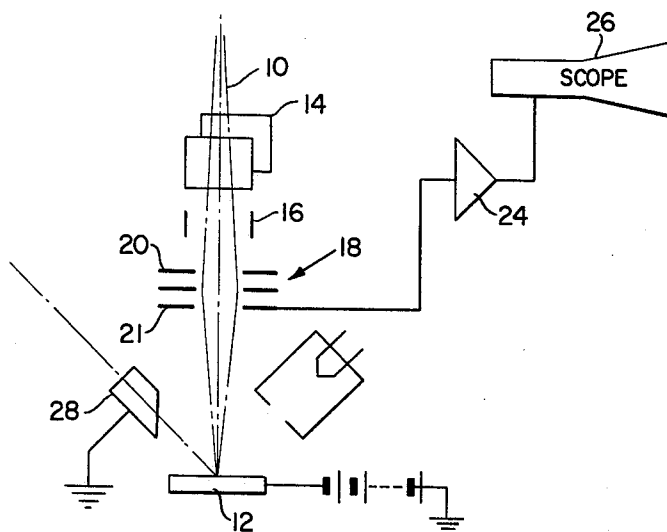
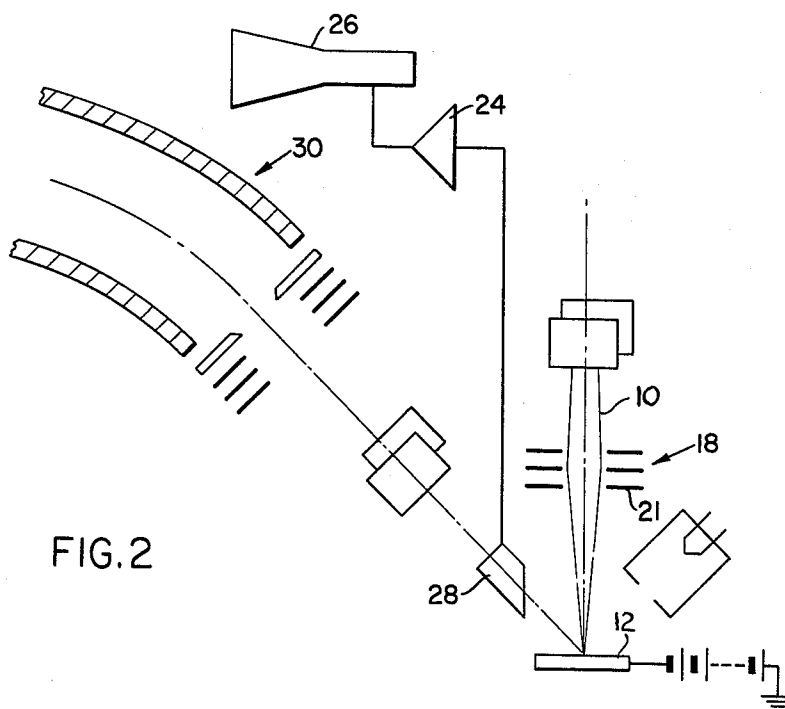


FIG. 2



INVENTOR.
HELMUT J. LIEBL

BY

Hyman Stone

ATTORNEY

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3,479,505 METHOD OF OPERATING AN ION MICROPROBE USING SECONDARY ELECTIONS

Helmut J. Liebl, Goleta, Calif., assignor to Applied Research Laboratories, Inc., Glendale, Calif., a corporation of Delaware

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3 Claims

ABSTRACT OF THE DISCLOSURE

Secondary electrons emitted by a specimen in an ion microprobe are used to produce an electrical signal to be displayed on a kinescope. The ion beam is scanned in a raster pattern across the specimen, and the kinescope scanning is synchronized with the ion beam. Comparison of the kinescope display with an optical image of the specimen enables quick determination of the instantaneous position of the ion beam on the specimen.

This invention relates to a novel method of operating an ion probe of the general type described and claimed in my copending application for patent, Ser. No. 494,388, filed Oct. 11, 1965, and entitled, "Ion Microprobe," and more particularly, to a novel method of operation which facilitates the precise determination of the spot on the surface of a specimen where the ion beam impinges.

In general, an ion probe of the type with which the present invention is concerned includes an ion source, means for accelerating ions away from the source toward a specimen to be analyzed, means for focusing the ions so accelerated into a relatively narrow beam so that they impinge only upon a very small area of the specimen, and usually an ion analyzer for analyzing ions sputtered from the surface of the specimen by the ion beam. Instruments of this type are capable of great sensitivity in the chemical analysis of materials. They have been shown to be able to detect elements that are present in a specimen material in amounts of only a few parts per billion.

One problem in the operation of an ion microprobe of the stated type is to determine with precision the exact spot where the ion beam impinges on the specimen at any given moment. It is not a difficult matter to arrange a microscope in the apparatus for visual observation of the specimen while it is under bombardment by the ion beam, but by itself this does no good, because the ion beam produces no immediate, visible indication of its presence. There is no glow at the point of impingement, nor any immediately apparent visible change in the nature of the surface.

In the operation of the ion probe as described in the hereinabove identified copending application, the ion beam may be scanned in a raster pattern over a limited portion of the surface of a specimen, while a similar pattern is produced synchronously upon the face of an oscilloscope. An electrical signal is produced indicative of the instantaneous ion emission at a selected mass and energy from the surface of the specimen, and is applied in amplified form to modulate the intensity of the electron beam of the oscilloscope. The oscilloscope thus produces a light image indicating the variations in concentration of a particular element, which image can, in many cases, be matched with an image of the surface of the specimen as seen through a microscope. The matter becomes difficult, however, when operating the microprobe with very small currents in the ion beam, because the secondary ions, which are collected to produce the electrical signal, are then very few, and the image on the oscilloscope is apt to

lack adequate detail for easy matching with the image in the microscope.

Accordingly, an important object of the present invention is to improve the operation of an ion microprobe of the stated type, and to facilitate the determination of the point at which the ion beam impinges upon a specimen at any given moment.

Briefly, according to the invention, it has now been found that if electrons emitted by the specimen are collected and used to produce the signal for modulating the oscilloscope, an image of improved clarity and detail can be produced, thereby facilitating the determination of the location of the ion beam upon the surface of the specimen. The number of electrons emitted by the specimen in response to ion bombardment greatly exceeds the number of ions emitted of any given mass and energy. For a given beam current, therefore, a larger electrical signal can be obtained from the electron emission than from the emission of only selected ions. This is particularly true in those cases where the selected ions are those of elements that are present in the specimen only in very small proportions. The electron emission is also a function of the composition of the surface, and has been found to vary with fully adequate sensitivity to enable ready matching of the oscilloscope image with the image in the microscope.

The practice of the invention is expected to find its greatest utilization in connection with use of the ion probe for work other than ion analysis such as, for example, when the probe is used for etching a material by sputtering, or for depositing a layer of a material from the ion beam upon a selected area of a body, or when it is used for inspecting bodies such as miniature semiconductor devices for defects.

Different materials in or on the surface of the specimen emit electrons at different respective rates in response to ion bombardment of a given magnitude. Compositional irregularities such as grain boundaries in materials, for example, emit electrons at different rates from other portions of the specimen, and thus show up in the electrically produced image. Many such irregularities are also visible when the surface is viewed through a microscope, so that an observer is enabled to locate very precisely the position of the ion beam at any given moment. In the event that naturally occurring irregularities are insufficient to enable ready identification of the desired area on the specimen, a selected material different from the major constituent materials of the specimen may be applied to the surface of the specimen in accordance with a predetermined pattern to provide positively identifiable reference points or areas.

A presently preferred embodiment of the invention will now be described in connection with the drawing, wherein:

FIGURE 1 is a fragmentary, schematic diagram of a portion of an ion microprobe arranged for the practice of the presently preferred embodiment of the invention, and,

FIGURE 2 is a similar view to that of FIGURE 1, but showing the microprobe arranged for the practice of an alternative form of the invention.

The drawing shows only that portion of the microprobe which must be modified for the practice of the present invention from the arrangement shown in my hereinabove identified copending application, and that application may be referred to for a complete description of an operative ion microprobe of the kind with which the present invention is primarily concerned. As shown in FIGURE 1, a beam 10 of ions generated by any desired means is directed toward a specimen material 12 and impinges thereon in a spot of microscopic dimensions. The beam

10 passes between two pairs of deflection plates 14 and 16, respectively, and is then focused by a uni-potential lens 18 upon the surface of the specimen 12. Means (not shown) are provided for applying deflection voltages to the plates 14 and 16 to cause the beam 10 to scan across a pre-selected area of the surface of the specimen. Such scanning may be in the manner of a television raster, or, alternatively, under manual control, as in a manually driven cross-slide.

Ordinarily, as heretofore operated for analysis of secondary ion emission, the outer plates 20 and 21 of the uni-potential lens, which serves as the objective lens for focusing the ion beam, are grounded, and the specimen is biased positively about 2½ kv. with respect to ground. Positive ions sputtered from the surface of the specimen 12 are collected by a grounded tubular electrode 28, and directed into a double focusing mass spectrometer for analysis.

In the practice of the invention in its preferred form, the specimen is biased negatively with respect to ground by a few hundred volts, and the electrode 21 of the objective lens 18 nearest the specimen 12 is ungrounded and connected to the input of a DC amplifier 24. Thus, electrons emitted by the specimen are accelerated toward and collected by the adjacent electrode 21 of the objective lens. The current thus produced constitutes an electrical signal representative of the instantaneous rate of electron emission.

The signal is amplified by the amplifier 24 and applied to the control grid of an oscilloscope 26 for modulating the intensity of its trace. The electron beam of the oscilloscope 26 is detected synchronously with the deflection of the ion beam 10, but, of course, across a much wider range so that the raster on the oscilloscope, when raster scanning is used, represents a greatly enlarged image of the scanned portion of the surface of the specimen. The image produced by the oscilloscope is then compared with the optical image produced by a microscope (not shown) aimed at the specimen, thus enabling precise determination of the position of the ion beam at any given moment.

Images produced by the oscilloscope in the practice of the invention are sharp and clear even with currents of 10⁻⁸ ampere in the ion probe. It is also possible, by using methods of accelerating the electrons from the specimen, and by having them impinge on a scintillation crystal, the output of which is fed to a photomultiplier, to obtain useful images on the oscilloscope when the current in the ion beam is even smaller than 10⁻¹⁰ ampere. One such arrangement for accelerating the electrons and using a scintillation crystal is described in an article by T. E. Everhart and R. F. M. Thornley entitled "Wideband Detector for Micro-Microampere Low-Energy Electron Currents" in the Journal of Scientific Instruments 37, pp. 246-248 (1960).

In accordance with the second embodiment of the invention as shown in FIGURE 2, the secondary electrons from the specimen 12 are collected by the electrode 28 that is normally used for accelerating positive ions from the specimen into mass spectrometer 30. In this case, the front element 21 of the objective lens is left grounded, and the collecting electrode 28 is ungrounded and connected to the input of the amplifier 24. The specimen

again is biased a few hundred volts negatively. Substantially the same results are achieved in this as in the first embodiment of the invention. The selection of an electrode for collecting the electrons is largely a matter of convenience.

In both of the herein described embodiments of the invention, it is possible to change the bias voltage to suit the operator's or designer's convenience, provided only that the collecting electrode is maintained positive with respect to the specimen. It is believed that the arrangements described herein, however, are probably the most convenient and simple in the present state of the art.

What is claimed is:

1. Method of operating an ion probe of the type wherein a beam of ions is focussed upon a microscopically small area of a specimen and scanned across the specimen to bombard successive incremental portions thereof to facilitate determination of the points of impingement of the beam on the specimen, said method comprising the steps of collecting electrons emitted by the specimen in response to bombardment by the ion beam, producing an electrical signal indicative of variations in the numbers of electrons emitted from the successive incremental portions as the beam is scanned, and producing a visual display in response to the electrical signal so produced, thereby enabling a comparison between the visual display and an optically produced image of a portion of the specimen.

2. Method of determining the point of impingement of an ion beam upon the surface of a specimen comprising the steps of scanning a sharply focussed ion beam across a selected portion of the specimen, producing an electrical signal responsively to electrons emitted by the surface in response to the ion beam, the electrical signal being indicative of the instantaneous rate of electron emission from the specimen, and producing a visual display in response to the electrical signal so produced, thereby enabling a comparison between the visual display and an optically produced image of the selected portion of the specimen.

3. Method in accordance with claim 2 wherein the electrons are collected by an electrode arranged symmetrically around the ion beam whereby changes in the potential of the electrode do not substantially divert the ion beam.

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WILLIAM F. LINDQUIST, Primary Examiner