

[54] **MASS DEPENDENT ION MICROSCOPE
HAVING AN ARRAY OF SMALL MASS
FILTERS**

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250/309, 250/396**

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

[58] Field of Search **250/309, 396, 377, 398,
250/399, 292, 281, 282**

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—James W. Lawrence

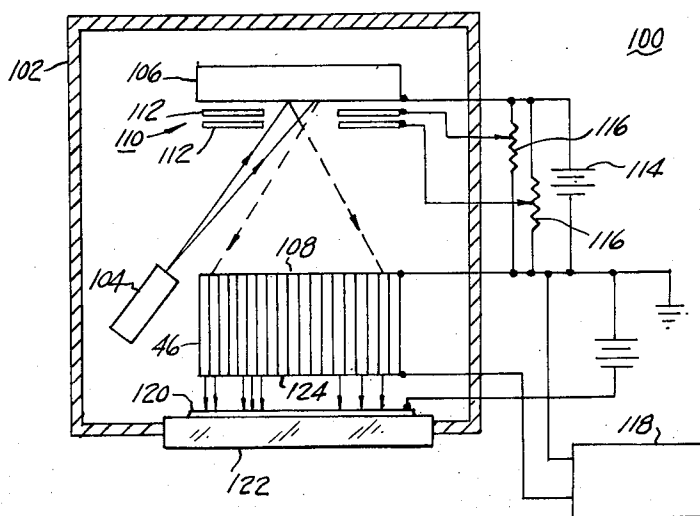
Assistant Examiner—C. E. Church

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[57] **ABSTRACT**

A mass dependent ion microscope having an array of very small mass filters, interposed between the source of an ion image and an image transducer for transmitting on a point-for-point basis only ions of a predetermined mass-to-charge ratio, is described. The point-for-point transmission by the mass filter array preserves the image information of the original ion image and permits the filtered ion image to be visually observed on a phosphor screen or otherwise detected. The individual filter elements of the array may be either of the monopole or quadrupole structure fabricated from glass.

28 Claims, 9 Drawing Figures



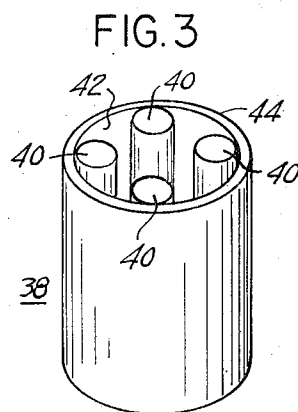
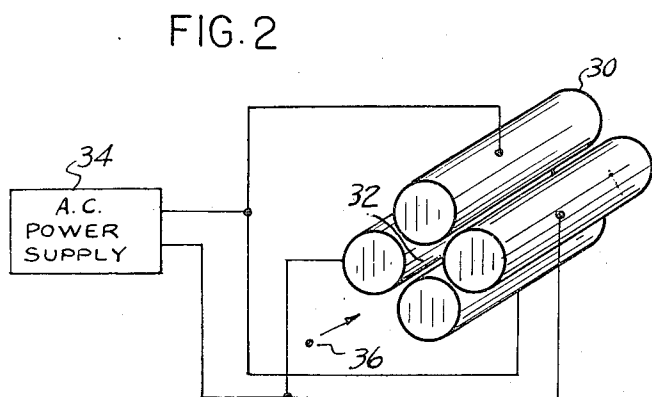
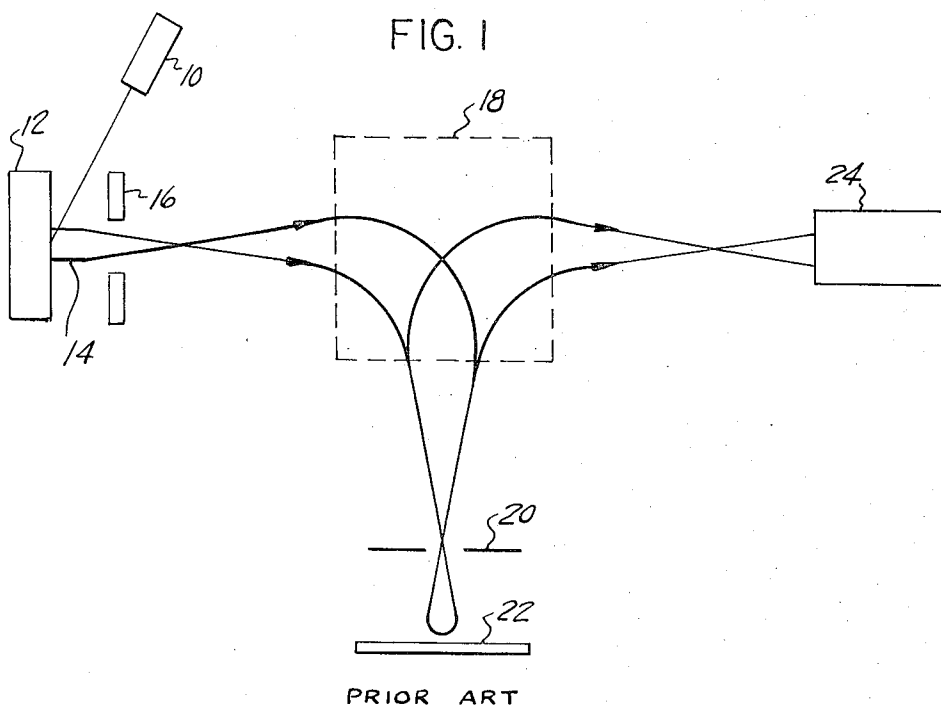


FIG. 4

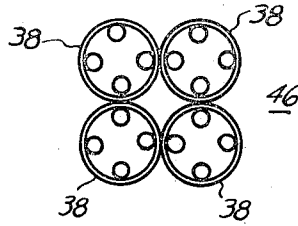


FIG. 9

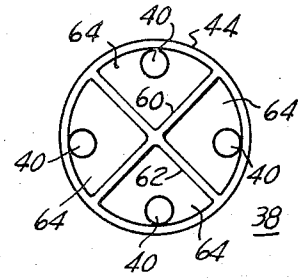


FIG. 5

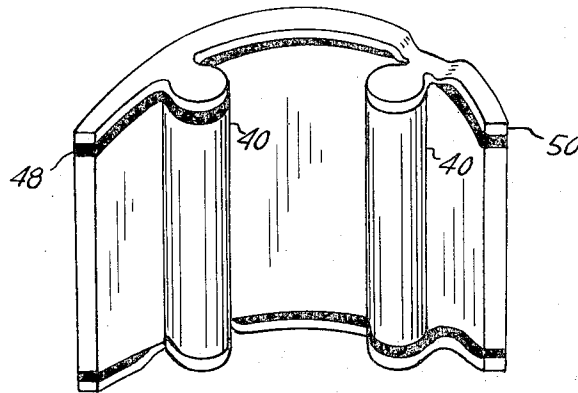


FIG. 6

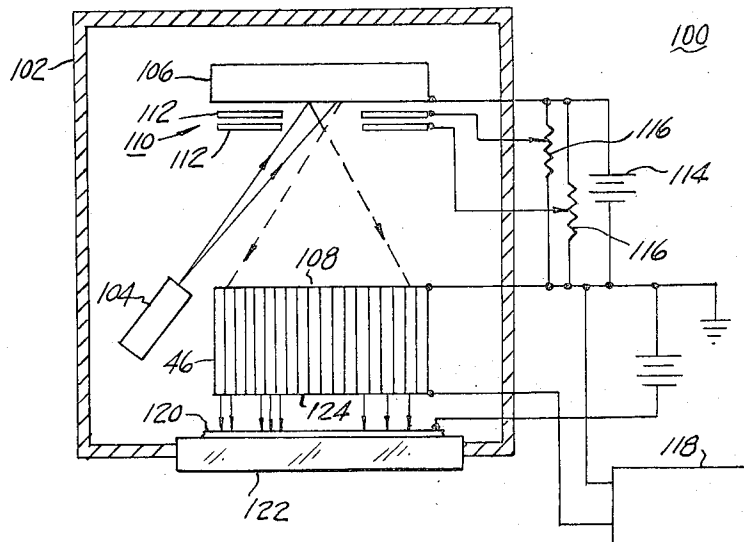


FIG. 8

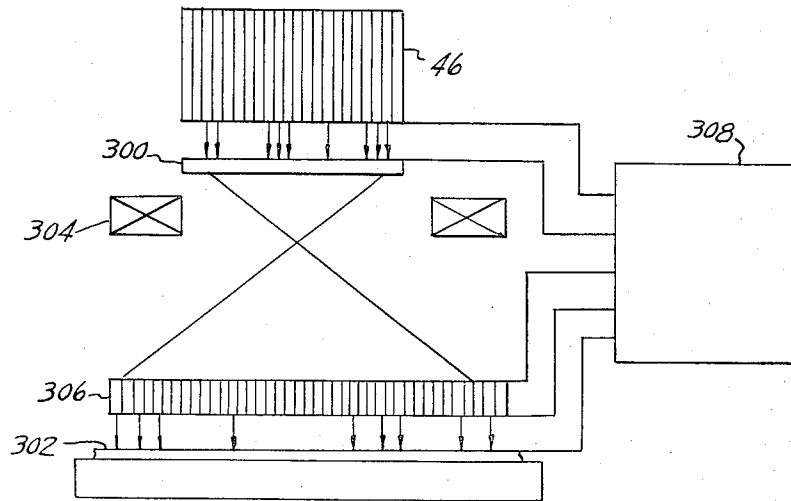
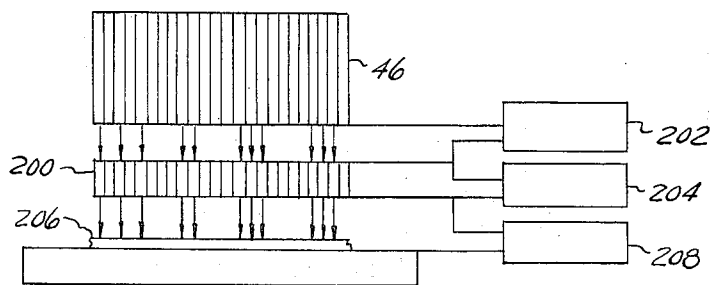


FIG. 7



MASS DEPENDENT ION MICROSCOPE HAVING AN ARRAY OF SMALL MASS FILTERS

BACKGROUND OF THE INVENTION

The invention is related to the field of ion separation and analysis, and in particular to the field of ion microscopy for the characterization of a surface. The importance of surface characterization is evident from the rapid growth of electron spectroscopy and electron microscopy. More recently, however, emission microscopy and, in particular, ion emission microscopy, have become important tools in the characterization and investigation of surfaces and bulk processes. This tool can be used for the detection and determination of gas adsorption on metal surfaces, heterogeneous catalytic chemical reactions, gaseous corrosion of metals, surface and bulk diffusion in solids, ion implantations, phase transitions in alloys and many other surface and bulk processes.

Ion emission microscopy is the imaging of the ions emitted from a stimulated surface to produce a detectable image which may be visually displayed or recorded by any of the various methods known in the art. A typical ion emission microscope consists of a sample holder, which supports the sample to be investigated in a preferred orientation with respect to the microscope. A means is generally provided to stimulate the sample to emit ions. The sample may be stimulated by heating to cause thermionic emission, by irradiating with energetic particles such as electrons, ions, beta or alpha particles, or may be stimulated by electromagnetic radiation, such as x-rays, gamma rays, ultraviolet, or intensive radiation such as radiating with a laser source. Independent of the method used, the function of the stimulation is to cause the sample to emit ions. Whether the ion is positively or negatively charged is relatively immaterial to the function of the ion microscope. The emitted ions are then detected to produce a visual or recorded image of the ion pattern emitted by the sample. A new dimension has recently been added to ion emission microscopy, namely mass dependent imaging of the surface being investigated. Mass dependent imaging is a method whereby the image is formed by the emitted ions of a particular mass or species. This is accomplished by interposing a mass filter or spectrometer between the ion source, i.e., the specimen or sample emitting the ions, and the converter converting the ion image into a visual or recorded image. One known method for generating a mass dependent image is discussed in the article "Microanalysis by the Emission of Secondary Ions" by R. Castaing and G. Slodzian, European Regional Conference on Electron Microscopy, Deft. 1, 169. This method of the prior art illustrated in FIG. 1 uses an ion source 10 irradiating an object 12 to eject secondary ions 14. The emitted secondary ions 14 pass through an immersion lens 16 and pass through a magnetic analyzer 18 which deflects the ions to mass resolving slit 20 which acts as a first order mass discriminator. The ions passing through the slit 20 are reflected by an electrostatic mirror 22, acting as an energy discriminator, back to the magnetic analyzer 18 where they are deflected to an image converter 24 where a visible image of the filtered ion pattern is formed. This method has been incorporated into an Ion Analyzer Model IMS-300 produced by CAMECA of France and is available in the United States from CAMECA Instruments, Inc., of Elmsford, New York.

Because of the use of a magnet in combination with a slit aperture for ion discrimination, the CAMECA instrument embodies a compromise between the area being analyzed and the degree of mass discrimination obtainable. Further, the mass discrimination elements are complex and require critical adjustments and control.

The disclosed mass dependent ion microscope overcomes many of these problems by incorporating an array of quadrupole mass filters in place of the magnetic mass separation. Quadrupole mass filters as disclosed in the W. Paul et al. U.S. Pat. No. 2,939,952 and the U. Von Zahn U.S. Pat. No. 3,197,633 are well known in the art and need not be discussed in detail for the understanding of the disclosed invention. However, it is pointed out that the quadrupole mass filter is a linear device, i.e., its mass filtering action takes place along a relatively straight path, in contrast to the deflected path of a magnetic mass filter, and therefore, a plurality of quadrupole filter elements may be grouped in the form of an array with each quadrupole element in the array having its entrance aperture lying in a common input plane, and its output aperture lying in a common output plane. The feasibility of fabricating an array of quadrupole structures based on methods developed for fabricating microchannel electron multipliers was first disclosed by the Applicant in a paper "Recent Advances in Quadrupole Mass Spectrometry" delivered at the 1972 Pittsburgh Conference, Analytical Chemistry and Applied Spectroscopy, Mar. 10, 1972 and subsequently published in the *International Journal of Mass Spectrometry and Ion Physics* 9 (1972) "Drawn Glass Mass Filter Structures" by J. P. Carrico, W. B. Colson, and F. T. King. This method has the unique advantage that it permits the fabrication of very small quadrupole elements of relatively low cost.

Each quadrupole filter in addition to filtering out the unwanted ions also transmit on a point-for-point basis the ion pattern incident on the input plane to the output plane so that the image content of the ion pattern is preserved during the mass filtering process. This type of image relay structure is comparable to the discrete fibers in a typical fiber optic bundle or a discrete channel in a microchannel electron multiplier array. The mass dependent ion output from the quadrupole array is then caused to produce a visual or recorded image.

SUMMARY OF THE INVENTION

The disclosed invention is a mass dependent ion microscope having an array of quadrupole mass filters to spatially filter, on a point-for-point basis, the ion pattern emitted from the sample, to produce a detectable image representative of the emitted ions of a specific mass or species. The ion microscope comprises a sample holder for holding a sample to be investigated, a means for stimulating the emission of ions from the surface of the sample to form an ion image indicative of the surface condition. An ion lens for focusing the emitted ion image at the input of an array of quadrupole mass filters. Electronic circuitry for generating a dynamic electrostatic field between the electrodes in each element of the quadrupole filter to cause the filter array to transmit only ions of a predeterminable mass or species and means for detecting the mass dependent ion image exiting the quadrupole filter. In the preferred embodiment, the mass dependent ion image is con-

verted to a magnified visual image and displayed on a phosphor screen. However in alternate embodiments, the ion image may be recorded on photographic film, quantitatively recorded as a function of position, or converted to television type signals for remote display and/or recording. Image intensification and additional image magnification may be provided as required to intensify and enhance the mass dependent ion image leaving the quadrupole filter.

One objective of the invention is to provide a mass dependent ion microscope using an array of quadrupole mass filters for separating the ions evolved from the sample according to their mass. Another objective of the invention is to provide a mass dependent ion microscope in which the ion separation is accomplished electrostatically. Still another objective of the invention is to provide a mass dependent ion microscope wherein the degree of ion separation is independent of the sample area being investigated. Another objective of the invention is to provide a mass dependent ion microscope wherein the ion separation is accomplished linearly, along an axis generally parallel to the axes of the magnification and relay lens of the system providing a relatively simple and efficient ion microscope. These and other objects of the invention will be apparent upon reading the following specification and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the prior art.

FIG. 2 is an illustration of the essential elements of the quadrupole mass filter.

FIG. 3 is a perspective of glass drawn quadrupole element.

FIG. 4 is an end view of an array of glass drawn quadrupole elements.

FIG. 5 is a sectional view of a glass drawn quadrupole element showing a preferred method of applying electrical contact to the conductive rods.

FIG. 6 is a preferred embodiment of the mass dependent ion microscope.

FIG. 7 is an alternate embodiment of the mass dependent ion microscope having an array of microchannel electron multipliers for converting the ion image into a corresponding electron image and for amplifying the corresponding electron image.

FIG. 8 is an alternate embodiment including an ion to electron converter and a post filtering electron lens for increasing the magnification of the electron image.

FIG. 9 is an end view showing one way monopole filter elements may be made using glass drawing technology.

DETAILED DESCRIPTION OF THE INVENTION

The key element in the disclosed mass dependent ion microscope is an array of quadrupole mass filters. Therefore, prior to discussing the preferred embodiment of the ion microscope, it may be best to briefly describe the quadrupole mass filter and the structure of the array of quadrupole mass filter which hereafter will be referred to as the quadrupole array.

The structure of a single quadrupole mass filter is illustrated in FIG. 2 and includes four parallel electrical conductors 30 which may be cylindrical as shown or have alternate hyperbolic configurations as is well known in the art. A dynamic electric field is generated

in the space 32 between the four conductors by applying an alternating electrical potential to the four conductors as shown from a variable frequency AC power supply 34. An ion 36 longitudinally injected into the space 32 between the conductors will be caused to oscillate under the influence of the dynamic field as it traverses the length of the quadrupole filter as a result of its injection energy in the longitudinal direction. The dynamics of the behavior of the ions in the dynamic field are well known in the art (ref. Paul et al. U.S. Pat. No. 2,939,952) and need not be discussed in detail. However, it will suffice to say that the magnitude and frequency of the dynamic field can be adjusted so that only one ion species, i.e., an ion having a specific mass-to-charge ratio will have a stable oscillatory path through the filter, while all other ions having different mass-to-charge ratios will have unstable oscillatory paths. The oscillations of the unstable ions quickly exceed the boundaries of the dynamic field and these ions are lost, either by collecting on the conductors or elsewhere in the system. Another significant feature of the quadrupole filter is that the stable ions do not have to be injected into the quadrupole filter parallel to the conductors, but may enter the filter at an angle with predeterminable limits and still pass successfully therethrough. In this manner the quadrupole structure functions as a mass filter selectively transmitting ions of a predeterminable mass-to-charge ratio.

The symmetrical configuration of the quadrupole structure permits the quadrupole mass filters to be stacked or bundled in parallel to form an array of quadrupole mass filters in the same way individual channel electron multipliers are stacked to form an array of microchannel electron multipliers with imaging capabilities as shown in U.S. Pat. No. 3,128,408 by Goodrich et al.

To prevent cross-talk, i.e., to prevent an unstable ion rejected from one quadrupole element from crossing over to an adjacent quadrupole element and exiting the array as a filtered ion from the adjacent element, it is necessary to surround each quadrupole element with a physical boundary which will absorb any unstable ion whose oscillations exceed the boundaries of the dynamic field of the particular element. The physical boundary on each element of the quadrupole array as required to prevent cross-talk is inherent in the glass drawn quadrupole structure 38 as illustrated in FIG. 3. The four parallel rods 40 are fused to the internal surface 42 of the glass tube 44. The four rods 40 and the tube 44 are made from glass, and are drawn and fused using methods developed for drawing microchannel electron multiplier arrays and are well known in the art. To obtain high conductivity in the four rods 40 a material, such as a copper doped sodium silicate glass may be used, which becomes highly conductive when heated in a reducing atmosphere. The tube 44 may be made of an alternate material, such as a high lead glass, Corning Glass Code 8161 for example, which develops a high resistive surface when heated in the same reducing atmosphere. The high resistance surface on the inner-surface 42 of tube 44 between the parallel rods 40 eliminates surface charging by the expelled unstable ions, and establishes a uniform potential gradient between the conductors 30, thus avoiding field fringing effects.

An alternate embodiment of the mass filter may be the monopole structure as disclosed by Von Zahn in

U.S. Pat. No. 3,197,633. The monopole structure could readily be formed using glass drawing techniques by including two mutually perpendicular conductive planar members 60 and 62 diametrically dividing the inside of the glass tube 44 of the quadrupole element into four equal sections 64. Each section containing one rod 40 symmetrically disposed between the planar members 60 and 62 as illustrated in FIG. 9.

A simple array 46 of glass drawn quadrupole filters 38 are shown in FIG. 4. Although the illustrated array is comprised of only four elements, in actual practice the array 46 will comprise many elements depending upon the physical size and number of resolution elements desired. Arrays having more than 10,000 elements are possible. The quadrupole elements of the array may be arranged in the illustrated "square" pattern or may be bundled in other suitable patterns such as the well-known staggered pattern conventionally used in stacking cylindrical elements.

FIG. 5 is a cut-away view of a quadrupole element illustrating one method for applying electrical power from the AC power supply to the individual glass rods 40. At one end of the quadrupole element the ends of the two diagonally opposite rods 40 are covered with a insulating material 48 having sufficient thickness to prevent electrical breakdown under the influence of the alternating potential generated by the AC power supply. The insulating material may be an evaporated coat of silicon monoxide or any other suitable material. The entire end of the quadrupole element is then covered with a conductive material, such as by evaporating, from a head-on direction, a metal film 50. The metal film 50 makes electrical contact with the two rods 40 not having the insulating material previously applied over the ends and does not make electrical contact with the rods having the insulating material 48 applied. Electrical contact to the two insulated rods is made from the opposite end of the quadrupole element using the same method. The insulating material 48 at the opposite end of the element is applied over the ends of the other two rods as shown. In this manner applying the electrical potential from the AC power supply to the opposite ends of the quadrupole array applies the correct potential to each of the four rods as required. Alternate methods for making electrical contact to the individual rods are known and equally applicable.

A preferred embodiment of the mass dependent ion microscope 100 is illustrated in FIG. 6. The microscope is enclosed in an evacuable housing 102 and includes a source 104 irradiating a sample 106 with the ionizing energy. The ionizing energy may be any one of a combination of various types of energies known in the art, which will react with the sample to release ions. The form of ionizing energy may include energetic particles, such as alpha or beta particles, neutrons or even ions, or may be x-rays, γ rays, ultraviolet light, or intense electromagnetic energy such as emitted by a laser. The irradiating energy reacts with the sample 106 causing ions to be emitted from the surface forming an ion image indicative of the composition of the sample in the area irradiated. Alternatively, the sample may be heated, either by thermal conductivity, electromagnetic radiation, or R.F. induction, causing the sample to emit ions by thermionic emission.

The emitted ion image is accelerated to the input 108 of an array of quadrupole mass filters 46 by means of an ion lens 110 illustrated as electrostatic lens elements

112. The electrical potential of the sample 106, and the lens 110 are appropriately biased by an electrical power supply illustrated as a battery 114 and variable resistors 116 so as to cause the emitted ions to be focused on the input face of the quadrupole array 46. The quadrupole array 46 is energized by a variable AC power supply 118 generating a dynamic field in each quadrupole element of the array. The dynamic field in each quadrupole element filters the input ion image and transmits only those ions having a predetermined mass-to-charge ratio, as previously described. All of the other ions are adsorbed by the individual quadrupole elements. Therefore, the ion image exiting the opposite end of the quadrupole array comprises ions of a predetermined mass-to-charge ratio. As is well known in the art of quadrupole filters, the frequency and amplitude may be adjusted to permit the transmission of any ion species having a predetermined mass-to-charge ratio. The ion image exiting the quadrupole array 46 is accelerated to an image transducer, illustrated as a phosphor screen 120 deposited on a transparent window 122. By placing the transducer in close proximity to the output end 124 of the quadrupole array 46, and applying an appropriate potential between the array and the transducer by means of a power supply 124, the exiting ion image will be proximity focused on the transducer.

Although the transducer is illustrated as a phosphor screen generating a visible image corresponding to the transmitted ion image, the transducer may equally take other forms, including an electrical readout. The electrical readout may be quantitative type of counting the number of ions incident within each resolution element, or may be of the T.V. type from which the image may be reconstructed on a cathode ray tube.

An alternate embodiment of the mass dependent ion microscope is illustrated in FIG. 7. For simplicity, the evacuable housing 102, the source 104, sample 106, ion lens 110 and associated power supplies are not shown. The filtered ion image exiting the quadrupole array 46 are proximity focused on a microchannel electron multiplier array 200 through the use of appropriate spacings and an appropriate potential supplied by power supply 202. The filtered ions striking the input face and the insides of the channels in the electron multiplier array cause the emission of electrons forming an electron image corresponding to the incident ion image. A potential bias applied across the electron multiplier array 200 by a DC power source 204 causes the emitted electron image to be amplified in the multiplier array 200 generating an intensified electron image. The intensified electron image is then proximity focused on a transducer 206 by appropriate spacings and an appropriate potential supplied by power supply 208. The transducer 206 may be a phosphor screen deposited on a transparent window, as illustrated, producing a visible image or may be an electrical readout as discussed with reference to FIG. 6. It is recognized that power supplies 202, 204 and 208 may be a single power supply capable of producing the appropriate potentials for the microchannel array 200, and those required for proximity focusing the ion and electron images.

FIG. 8 illustrates another alternate embodiment capable of magnifying the mass dependent ion image after it has been converted to an electron image. As in FIG. 7, the evacuable housing 102, the source 104, the sample 106, the ion lens 110 and associated power

supplies are not shown, but are implicit in the illustrated embodiment. The filtered ion image exiting the quadrupole array is proximity focused on a first transducer 300 which converts the incident ion image to an electron image. The first transducer 300 may be a channel electron multiplier array as discussed with reference to FIG. 7 or may be any other type of element capable of converting an incident ion image to a comparable electron image such as a thin oxide membrane or phosphor-photocathode sandwich, wherein the ions striking the phosphor generate light, and the photocathode emits electrons in proportion to the emitted light on a point-for-point basis. Other types of ion to electron transducers are known in the art, and are too numerous to be discussed in detail. The electron image emitted by the first transducer is magnified and focused on the second transducer 302 by means of an electron lens 304. The electron lens may be an electrostatic lens or a magnetic lens as shown. The second transducer 302 may be a phosphor screen or an electrical readout as previously discussed and may as illustrated incorporate a microchannel electron multiplier array 306 between the first transducer 300 and the second transducer 302 to intensify the magnified electron image. A common power supply 308 is provided to supply the proper operating potentials to the appropriate elements of the mass dependent ion microscope as shown.

While a preferred and two alternate embodiments of the mass dependent ion microscope have been illustrated and described, it is not intended that the invention be restricted to the illustrated embodiments. One versed in the art will readily recognize that various elements of the embodiments may be rearranged or interchanged and the objective of the invention still be achieved. Accordingly, it is intended that the illustrative and descriptive materials herein be used to illustrate the principles of the invention and not limit the scope thereof.

What is claimed is:

1. A mass dependent ion microscope comprising:
means for supporting a sample to be investigated;
means for stimulating said sample to emit an ion image representative of the sample;
means for magnifying said emitted ion image;
an array of mass filters receiving said magnified ion image, transmitting therethrough on a point-for-point basis, the ions of said magnified ion image having a predeterminable mass-to-charge ratio, and absorbing ions having a different mass-to-charge ratio; and
means receiving said transmitted ion image having a predetermined mass-to-charge ratio for generating a detachable output signal indicative of said transmitted ion image.
2. The mass dependent ion microscope of claim 1 further including an evacuable enclosure.
3. The mass dependent ion microscope of claim 2 wherein said means for stimulating is a source of energetic particles.
4. The mass dependent ion microscope of claim 3 wherein said source of energetic particles is an ion source.
5. The mass dependent ion microscope of claim 3 wherein said source of energetic particles is an electron source.

6. The mass dependent ion microscope of claim 2 wherein said means for stimulating is a source of ionizing radiation.

7. The mass dependent ion microscope of claim 6 wherein said source of ionizing radiation is a source of x-rays.

8. The mass dependent ion microscope of claim 6 wherein said source of ionizing radiation is a source of λ rays.

9. The mass dependent ion microscope of claim 6 wherein said source of ionizing radiation is a source of intense electromagnetic radiation.

10. The mass dependent ion microscope of claim 9 wherein said source of electromagnetic radiation is a laser.

11. The mass dependent ion microscope of claim 2 wherein said means for stimulating is means for heating said sample to cause thermionic emission.

12. The mass dependent ion microscope of claim 2 wherein said array is an array of quadrupole mass filters comprising a plurality of individual laterally enclosed quadrupole elements disposed in a parallel relationship with respect to each other, each quadrupole element receiving a like portion of said magnified ion image and transmitting therethrough on a point-for-point basis ions of a predeterminable mass-to-charge ratio and absorbing all other ions having a different mass-to-charge ratio.

13. The mass dependent ion microscope of claim 12 wherein each individual quadrupole element comprises:

- four conductor rods of a predeterminable radius and length symmetrically disposed about a longitudinal axis;
- a surface laterally enclosing said four conductor rods; and
- means for supporting said rods within said enclosing surface.

14. The mass dependent ion microscope of claim 13 wherein said surface is a glass cylinder having a high resistance internal surface and said conductor rods are glass rods having low resistance external surfaces wherein said glass rods are fused to the internal surface of said cylinder supporting said rods in said cylinder.

15. The mass dependent ion microscope of claim 12 wherein said quadrupole array further includes means for generating an alternating electrical signal having a predeterminable frequency and predeterminable amplitude, said electrical signal applied to predetermined conductors in each of said quadrupole elements generate a dynamic electric field operative to cause ions of a predetermined mass-to-charge ratio to have a stable trajectory through said elements and ions having a different mass-to-charge ratio to have unstable trajectories.

16. The mass dependent ion microscope of claim 2 wherein said array is an array of monopole mass filters comprising a plurality of individual laterally enclosed monopole elements disposed in parallel relationship with respect to each other, each monopole element receiving a like portion of said magnified ion image and transmitting therethrough on a point-for-point basis ions of a predeterminable mass-to-charge ratio and absorbing all other ions having a different mass-to-charge ratio.

17. The mass dependent ion microscope of claim 1 wherein means for generating a detectable output sig-

nal is a phosphor screen disposed proximate said quadrupole array for generating on a point-for-point basis a visible image representative of said transmitted ion image.

18. The mass dependent ion microscope of claim 17 wherein said means for generating a detectable output signal further includes an array of microchannel electron multipliers, disposed between said quadrupole array and said phosphor screen, said microchannel array receiving said transmitted ion image and generating on a point-for-point basis an amplified electron image representative of said transmitted ion image, further said phosphor screen receiving said amplified electron image and generating on a point-for-point basis a visible light image representative of said electron image.

19. The mass dependent microscope of claim 17 wherein said means for generating a detectable output signal further includes an array of microchannel electron multipliers, disposed between said quadrupole array and said ion detector, said microchannel array receiving said transmitted ion image and generating on a point-for-point basis an amplified electron image representative of said transmitted ion image, further said ion detector receiving said amplified electron image and generating on a point-for-point basis a visible light image representative of said electron image.

20. The mass dependent ion microscope of claim 19 wherein said ion detector is a planar array of discrete detector elements, each detector element individually operative to store an electrical charge indicative of the number of incident ions, said detector further including means for electronically interrogating in a predetermined sequence each individual detector element and generating an electrical signal indicative of the number of ions incident on each detector element.

21. The mass dependent ion microscope of claim 19 wherein said ion detector is a storage element operative to store an electrostatic image indicative of said transmitted ion image, said detector further including means for scanning said electrostatic image and generating an electrical signal indicative of the electrostatic image.

22. The mass dependent ion microscope of claim 17 wherein said means for generating a detectable output signal further includes:

means disposed proximate said quadrupole array for

converting on a point-for-point basis said transmitted ion image into an electron image; and an electron lens disposed between said means for converting and said phosphor screen for magnifying and focusing said electron image on said phosphor screen.

23. The mass dependent ion microscope of claim 22 wherein said means for generating further includes an array of microchannel electron multipliers disposed between said electron lens and said phosphor screen for amplifying said electron image.

24. The mass dependent ion microscope of claim 1 wherein said means for generating a detectable signal is an ion detector generating an electrical signal indicative of said transmitted ion image.

25. The mass dependent ion microscope of claim 24 wherein said means for generating a detectable output signal further includes:

means disposed proximate said quadrupole array for converting on a point-for-point basis said transmitted ion image into an electron image; and an electron lens disposed between said means for converting and said ion detector for magnifying and focusing said electron image on said ion detector.

26. The mass dependent ion microscope of claim 25 wherein said means for generating further includes an array of microchannel electron multipliers disposed between said electron lens and said ion detector for amplifying said electron image.

27. The mass dependent ion microscope of claim 26 wherein said ion detector is a planar array of discrete detector elements, each detector element individually operative to store an electrical charge indicative of the number of incident ions, said detector further including means for electronically interrogating in a predetermined sequence each individual detector element and generating an electrical signal indicative of the number of ions incident on each detector element.

28. The mass dependent ion microscope of claim 26 wherein said ion detector is a storage element operative to store an electrostatic image indicative of said transmitted ion image, said detector further including means for scanning said electrostatic image and generating an electrical signal indicative of the electrostatic image.

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