

[54] **CHARGED PARTICLE ANALYZER
WITH MEANS TO DETERMINE THE
COORDINATE POSITION OF THE
SAMPLE**

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[58] Field of Search **250/49.5 A, 49.5 B, 49.5 PE,
250/49.5 ED, 49.5 AE, 51.5; 356/154, 165**

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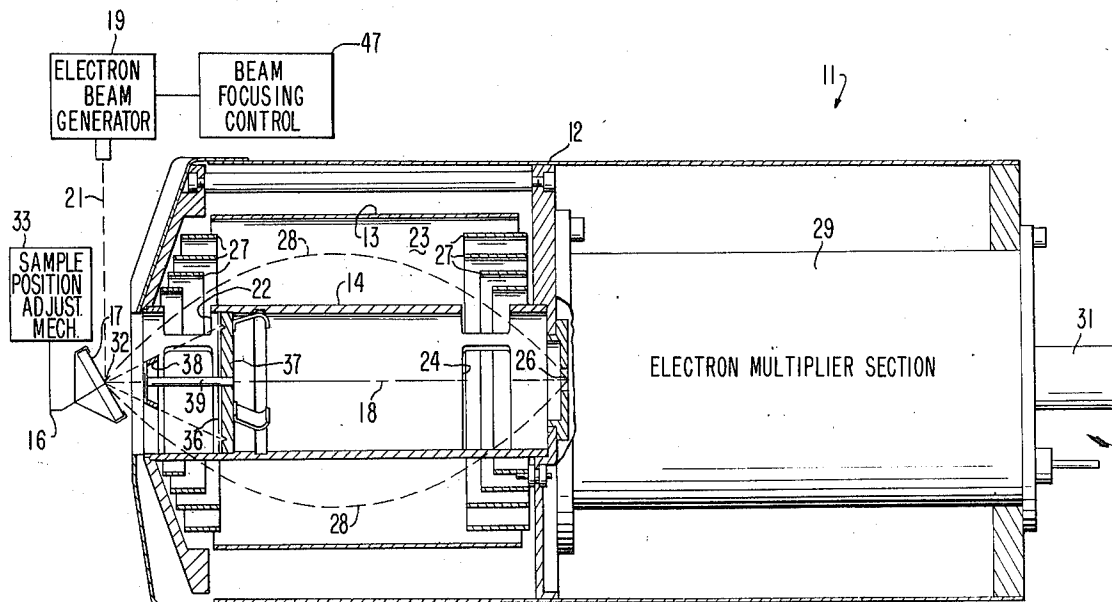
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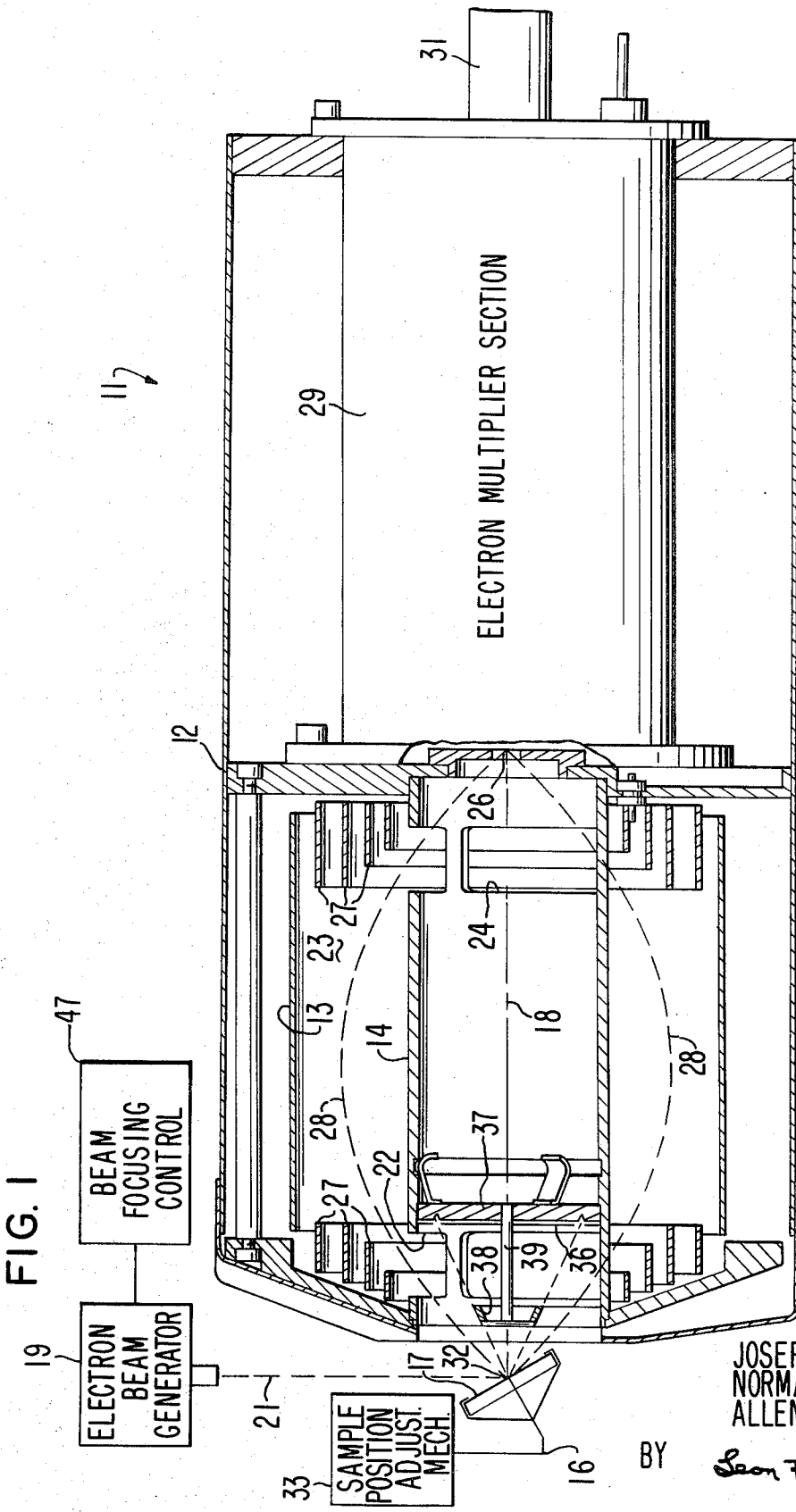
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[57] **ABSTRACT**

A cylindrical mirror analyzer is described having apparatus for quickly and accurately positioning the area of a sample to be investigated at the proper position for analysis. The cylindrical analyzer includes a pair of coaxial and radially spaced apart cylinders and suitable mechanism for supporting a sample to be investigated on their common axis. Means are provided for forming in the space between the cylinders a charged particle deflecting field which will deflect towards the inner cylinder any charged particles within such space which have issued from the sample. Slots in the inner cylinder define a path for the passage of particles from the sample into the space between the cylinders for deflection and then back through the inner cylinder to the cylindrical axis where such particles are collected for analysis of their energy. A screen of fluorescent material is disposed at a location at which it will be activated by particles issuing from the sample because of the bombardment, and a shield is disposed between the fluorescent screen and the sample to project an unactivated or shadow area on the screen. The positional relationship of the shadow on the screen is indicative of the coordinate position of the area on the sample from which the radiation is emitted and, hence, is indicative of the location of the area under investigation.

8 Claims, 11 Drawing Figures





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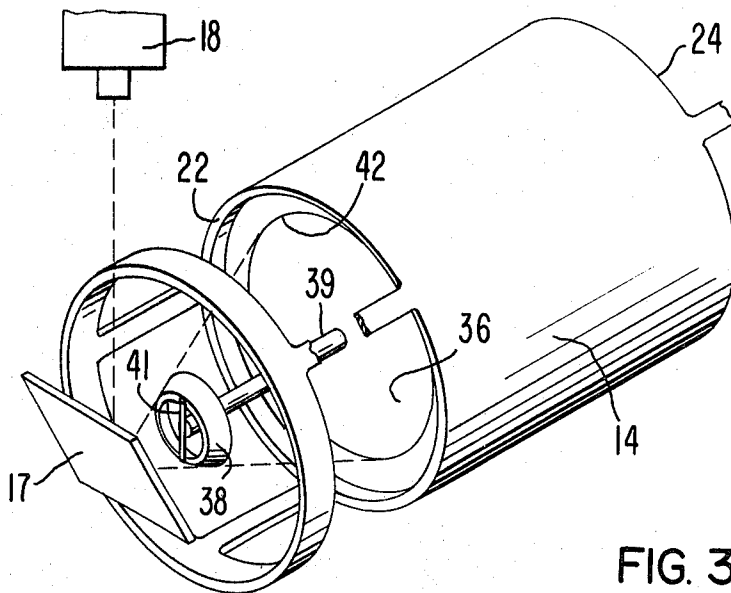


FIG. 2

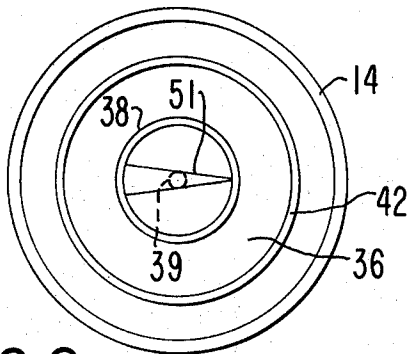


FIG. 9

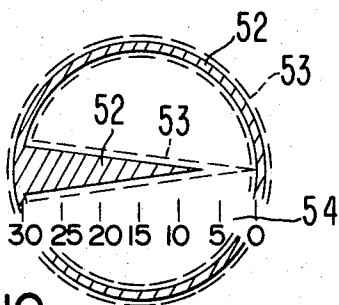


FIG. 10

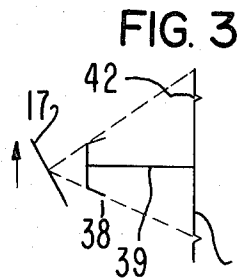


FIG. 3

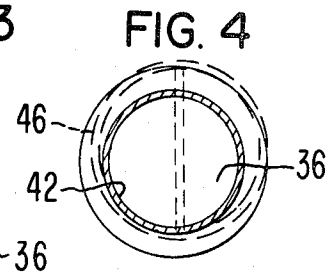


FIG. 4

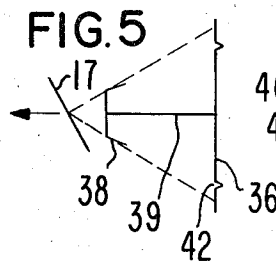


FIG. 5

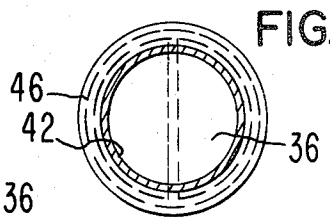


FIG. 6

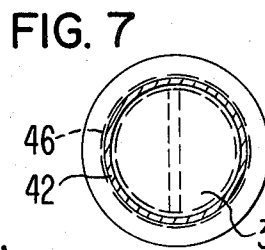


FIG. 7

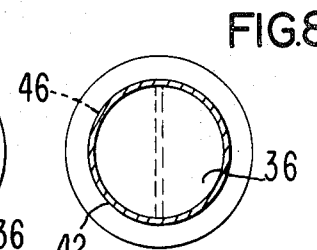


FIG. 8

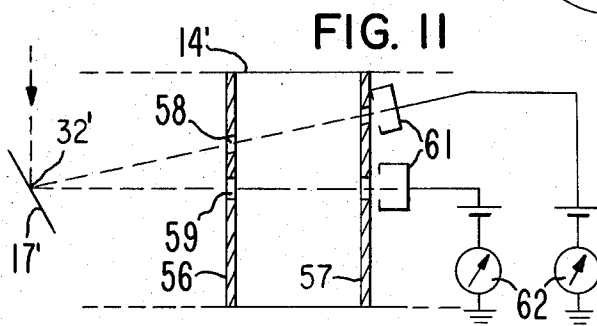


FIG. 11

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CHARGED PARTICLE ANALYZER WITH MEANS TO DETERMINE THE COORDINATE POSITION OF THE SAMPLE

BACKGROUND OF THE INVENTION

This invention relates to spectroscopic analysis of a sample of material or the like and, more particularly, to a simple and effective means for accurately positioning the area of a sample to be investigated at the proper location for analysis.

It is becoming increasingly important for many purposes to determine the exact crystalline structure or elemental make up of a particular sample of material. For example, these properties of a solid state device to be used in microelectronics must be known since the electrical characteristics of a solid state device are quite dependent upon the material and structure within and on the surface of the device. That is, most solid state devices rely upon having a particular crystalline structure or doping for proper operation, whereas the presence of any unwanted materials or contaminants will deleteriously affect such operation.

Various analytical instruments have been developed to determine the properties and characteristics of a sample of material. A general type which has been found most useful is that which includes means for bombarding a sample with a beam of radiation, such as X-radiation or electrons, and then analyzing the spectra of the resulting radiation. This spectra is dependent upon the atomic structure of the material of the sample and, thus, provides desired information on the make-up or crystalline structure of the sample. Many analytical instruments of this type rely upon the deflection or diffraction of the radiation issuing from a bombarded point on the sample to determine the energy characteristics of such radiation. It will be appreciated that for such an instrument to be accurate the point on the sample from which the radiation issues must be accurately located with respect to the instrument. However, each instrument is most often used to successively analyze various samples of differing dimensions and the like. This has made it difficult to assure that the area under investigation on each sample will be precisely located for bombardment at a location which does not change for various samples. Moreover, because it is often desirable to analyze a plurality of different areas on a particular sample, the apparatus for supporting the sample with respect to the instrument is ordinarily adjustable so that the sample can be manipulated to present for analysis the various areas of interest. While this ability to manipulate the sample provides flexibility, it compounds the problem of assuring that the coordinate position with respect to the apparatus of the area to be bombarded is correctly set. This is particularly true in the case of samples having irregular surfaces.

The problem is particularly acute with respect to that type of analyzer described in the paper "Cylindrical Capacitor As An Analyzer" appearing in VOL. 38, No. 9 (September 1967) issue of the *Review of Scientific Instruments* and known in the industry as a cylindrical mirror analyzer. Many believe this type of analyzer provides better results than other types such as the spherical deflection or diffraction type (see the Paper "Comparison of the Spherical Deflector and the Cylindrical Mirror Analyzers" in Vol. 39, No. 1 (January 1968) of the *Review of Scientific Instruments*), but by the same

token its resolution and accuracy is quite dependent upon properly locating the area under investigation with respect to the analyzing portion of the instrument.

At the present, those using spectroscopic instruments to analyze samples now locate the sample by a trial and error method. That is, one analyzing a sample under investigation generally has a fairly good idea of at least one of the materials which is expected to be found and, after adjusting the instrument for such material, moves the sample until the energy spectrum distribution read by the instrument corresponds to the expected energy distribution for the material. It will be appreciated, though, that this is a fairly inaccurate and time consuming process. If one moves the sample in one direction relative to the beam and instrument in order to try to improve the energy distribution readout, he changes the location of the spot in other directions. Thus, one must continually adjust and readjust in order to obtain as close as one can the desired energy spectrum readout. Since the impinging beam must be focused onto the sample to obtain the proper readout, the beam focus also must be adjusted for each movement of the sample, thereby adding a further adjustment which must be made in the attempt to properly position the sample.

SUMMARY OF THE INVENTION

The present invention provides a quite simple and effective apparatus for quickly positioning a sample in the proper location for examination by a spectroscopic instrument of the radiation issuing from the sample due to bombardment thereof by a beam of radiation. In this connection, it should be noted that when a sample of material is bombarded with a beam of radiation, the sample emits radiation in a wide range of directions. However, it is only radiation which is emitted from a particular direction which is analyzed. Applicants have found that the remaining radiation emitted in other directions can be effectively used to provide the desired information as to the coordinate position of the area on the sample being bombarded. Since this remaining radiation need not be preserved for later analysis, the manner in which the remaining radiation can be used to indicate the coordinate position is quite flexible. Most desirably, the radiation is used to provide a simple visual indication of the proper positioning of the sample by means of having the sample activate a fluorescent screen and having a shield or the like disposed between the screen and the sample to cast a shadow on such screen. The relationship of the shadow to the screen is an indication of the location from which the radiation emanates and, hence, can be used to properly position such location and thus the area being bombarded. Most desirably, the shield has a simple geometrical form and the screen is appropriately marked so that movement of the sample to a location at which the shadow cast by the shield will align itself with the markings on the screen will indicate the proper positioning of the sample.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the accompanying two sheets of drawings:

FIG. 1 is a partially sectioned and broken-away, side elevational view of a preferred embodiment of the in-

vention with certain aspects of the arrangement shown schematically;

FIG. 2 is a partial perspective view of the preferred embodiment of the invention shown in FIG. 1 further illustrating structural features thereof;

FIGS. 3-8 are schematic showings depicting the manner in which the apparatus of the invention can be used to properly locate a sample relative to the analyzing portion of the instrument;

FIG. 9 is an end elevational view depicting a modified form of the invention;

FIG. 10 illustrates a shadow cast on a fluorescent screen by the modified form of the invention depicted in FIG. 9; and

FIG. 11 is a schematic side elevational view of another preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As has been mentioned previously, the problem of assuring that the area of a sample being bombarded is at the proper location relative to the analyzing apparatus is particularly acute in connection with cylindrical mirror analyzers since although these analyzers are quite accurate, their resolution is largely dependent upon the proper positioning of the area being bombarded. For this reason, the instant invention is especially applicable to this type of analyzer and will be described in detail in connection with its combination with such an analyzer.

With reference to FIGS. 1 and 2, a cylindrical mirror analyzer is generally referred to by the reference numeral 11. Analyzer 11 includes an outer, generally cylindrical housing 12 within the front portion of which is mounted a pair of coaxial and radially spaced apart cylindrical electrodes 13 and 14. As is illustrated, the smaller diameter cylinder 14 is within cylinder 13 and means, diagrammatically depicted at 16, are provided for supporting a sample 17 to be analyzed, such as a solid state wafer, at a location exteriorly of the cylinders 13 and 14 but on their common axis 18. An electron beam generator or gun 19 is positioned to direct a beam of radiation 21, e.g., an electron beam, toward a location on such axis from a direction generally perpendicular thereto. The point at which the beam 21 intersects axis 18 is also the point at which sample 17 is to be positioned on the axis.

As stated earlier, and as is brought out in the articles identified above, the impingement of the beam 21 of radiation onto the sample will cause radiation, such as deflected primary electrons or emitted secondary electrons, to issue from the location on the sample at which it is bombarded. This radiation will emanate from the bombarded area in all directions from the surface being bombarded. Cylindrical mirror analyzer 11 receives and analyzes a first portion of this radiation. More particularly, inner cylinder 14 is slotted at 22 adjacent its front end for passage of such first portion of the radiation into the space 23 between the inner and outer cylinders 14 and 13. In accordance with conventional practice, means are provided for forming in the space 23 a charged particle deflecting field, such as an electrostatic field, having a polarity which will cause the electrons issuing from sample 17 and traveling into space 23 to be deflected toward the inner cylinder 14.

In the particular embodiment being described, the radiation issuing from sample 17 is electron radiation, and the electrostatic field is provided by making outer cylinder 13 negative with respect to both inner cylinder 14 and sample 17. Inner cylinder 14 is also slotted at 24 adjacent its rear end to enable electrons deflected by the field in space 23 to again pass through the inner cylinder for focusing at a collection point 26 on axis 18. As is illustrated, a plurality of annular intermediate electrodes 27 are provided within the space 23 adjacent the slots both at 22 and 24. Such intermediate electrodes carry appropriate potentials to assure uniformity of the field adjacent the slots.

Depending on the potential in space 23, electrons issuing from sample 17 having a certain energy and issuing at a predetermined spherical angle will follow a path such as that indicated by the dotted lines 28 for focusing at 26. It will be seen from the drawing that the only way electrons can reach the point 26 is by traveling through the slots at both 22 and 24, such as along path 28.

The electrons are collected for analysis at 26 by a conventional electron multiplier section 29. It will be appreciated that by rapidly sweeping the potential difference between cylindrical electrodes 13 and 14, electrons of various energies issuing from sample 17 will be successively focused at collection point 26 and, hence, provide an indication of the energy distribution of the electrons issuing from sample 17. Such distribution can be suitably fed, as in conventional, from the electron multiplier section to a readout device such as an oscilloscope by means of output lead 31.

As has been mentioned previously, to assure correct and high resolution readings from the analyzer 11, it is necessary that the area on sample 17 being bombarded by beam 21 be at a preselected point 32 on axis 18. However, because samples of varying dimensions are analyzed and it is often desirable to analyze a plurality of different areas on any particular sample, one cannot assure that the bombarded area is always at the proper point merely by rigidly fixing the sample support means 16 with respect to the analyzer. The result is that each time an area on a sample is to be investigated, the sample must be manipulated such as by means of a suitable support adjusting mechanism as is diagrammatically represented in the drawings at 33. The previously explained prior method of attempting to properly position the sample by the trial and error adjustment and readjustment of the sample location and of the primary beam focus and direction until a proper reading is obtained is both time consuming and inaccurate.

As a particularly salient feature of the instant invention, it includes means responsive to that portion of the radiation issuing from the sample which is not analyzed by indicating the coordinate position of the area being bombarded on the sample. With this knowledge, one using the apparatus can simply adjust the primary beam direction and the position of the sample until the coordinate position being bombarded corresponds with the proper point 32 on axis 18. Most desirably, such means provides a direct visual indication of the coordinate position of the spot being bombarded. To this end, a surface or screen of fluorescent material is disposed at a location at which it will intercept a portion of the radiation not following the path 28, and a shield is in-

terposed between the sample and the screen in the path of such radiation so that the shield will intercept some of such radiation and thereby form a shadow on the fluorescent screen. The position of the shadow on the screen will depend, of course, on the point from which the radiation is emanating. Thus, the positional relationship of such shadow on the screen provides an indication of the coordinate position of the area on the sample from which the radiation is issuing and, hence, the area on the sample being bombarded. For best results and most simple operation, the screen of fluorescent material is placed across the axis 18 and the shield is made symmetric with respect to such axis. With such an arrangement, the point of bombardment of the sample can be centered on the axis merely by making the shadow of the shield on the screen also symmetric with respect to such axis. In the particular embodiment being described, the fluorescent screen is provided as a layer 36 of fluorescent material on the outer surface of a septum 37 blocking line-of-sight passage of radiation between the sample and collection point 26. Such fluorescent material can be any one of the phosphors which will be activated by the particular radiation emanating from the sample 17. When the emanating radiation is electron radiation as is the case in connection with the embodiment being described, a suitable phosphor is zinc orthosilicate.

The shield in the instant embodiment is in the form of an annulus 38 which is concentrically supported on axis 18 by a post 39 which extends axially outward from septum 37. As is best illustrated in FIG. 2, a tie rod 41 is secured to the free end of post 39 and projects radially outward therefrom to connect annulus 38 with such post.

Fluorescent screen 36 includes a marking to facilitate the visual determination of the positional relationship of the shadow of annulus 38 on the screen. More particularly, a circular mark 42 is scribed through the layer of fluorescent material 36 so that a ring having no fluorescent material is provided on such screen. The ring is inscribed on such surface at a location at which it will represent the base of a conical surface having the point 32 as an apex and the annulus 38 lying on its surface. In this connection, it will be noted that the annulus 38 is in the shape of a truncated conic section lying on the previously mentioned conic section defined by the point 32 and the ring 42. This particular configuration of the ring facilitates obtaining a proper reading from the radiation responsive arrangement as will be more fully understood later, as well as facilitates its construction.

It will be understood that the analyzer 11, sample 17 and the electron beam gun 19 are disposed in an evacuated chamber when it is desired to carry out an analysis.

For an understanding of the simplicity and ease with which the arrangement of the instant invention enables the proper positioning of a sample to be investigated, reference is now made to FIGS. 3-8 which schematically illustrate a representative adjustment of a sample to the proper location. With reference to FIGS. 3 and 4, the sample 17 is shown at a location at which the area under investigation is below and somewhat to the left of the point 32 on the axis. When the sample is bombarded by radiation, this improper positioning of

the sample will be shown by the position of shadow 46 on screen 36 (FIG. 4) being off center to the right and high with respect to inscribed circle 42. By simply visually checking the location of such shadow, then, the operator will learn that the sample must be manipulated upward and to the right, or the primary beam direction must be changed. When the shadow 46 is concentric with the circular mark 42 as is illustrated in FIG. 6, the operator will see that the shadow has a larger diameter than the mark. He will thus know that the sample must be moved outward along the axis 18 before the point being bombarded thereof coincides with the point 32 on such axis. He will thus move the sample 17 outward with the adjustment mechanism 33 until the shadow 46 overlies the ring 42 as is illustrated in FIG. 7. He will then note that the shadow 46 has a fairly large width primarily composed of penumbra. The large penumbra indicates that electron beam 21 is not focused to a point on the sample. That is, with proper focusing the shadow has a minimum width and is almost all umbra. The operator can then suitably adjust the beam focusing control 47 to obtain the proper focusing. FIG. 8 illustrates the proper relationship of the shadow 46 to the scribed circle 42 to indicate that the sample is properly located. Upon visually noting this proper positioning, an operator is assured that the readings from the analyzers are accurate and have good resolution.

In some instances, it is desirable to be able to determine the size of the area being bombarded on the sample. FIGS. 9 and 10 illustrate a modified form of the invention which is especially useful for this purpose, as well as for providing the proper positioning on the axis as discussed above. For this purpose, the shield 38 includes a portion of varying widths as viewed from the sample to provide on the screen a shadow having an umbra whose width varies depending upon the size of the bombarded area of the sample. That is, the shield construction is the same as that of the previously described embodiment except that rather than having tie rod 41 securing the shield to the post 39, a wedge or triangularly shaped member 51 performs this function. FIG. 10 illustrates the umbra 52 and penumbra 53 of the shadow cast by the shield arrangement on the fluorescent screen 36. As is illustrated, the umbra itself tapers to a point on the screen. The location of this point on the screen is dependent upon the relation of the width of the wedge member 51 and the size of the area from which the radiation is emanating. By appropriately marking the screen with indicia, such as with the scale 54, representative of various sizes, one can determine the size of the area being bombarded by visually noting the location of the end of the umbra relative to the scale. That is, for any given size of the bombarded area, there is a location along the varying width of member 51 at which radiation will not be completely shielded from reaching screen 36. It is at such point at which the point of the umbra will appear on the screen and provide the desired visual indication of the size of the area being bombarded on the sample.

As mentioned previously, the use of the emitted radiation not being relied upon to provide the analysis to aid in properly locating the sample provides flexibility in choosing the particular manner in which to pinpoint the proper positioning of the sample. FIG. 11

schematically illustrates another embodiment of the invention in which such radiation is utilized. Those portions of the embodiment of FIG. 11 which are the same as those of the previously described embodiments are referred in the drawing by primed, like numerals. That is, the inner cylinder is referred by the reference numeral 14', the sample by the reference numeral 17', the point on the axis at which the sample must be located for proper resolution by the reference numeral 32'.

Rather than relying upon a direct visual display on a fluorescent screen, the embodiment of FIG. 11 relies upon meter readings to provide the desired indication of when the bombarded portion of the sample is at the desired point 32'. That is, means in the form of a pair of septa 56 and 57 define a pair of radiation collimators 58 and 59 whose axes intersect at the point 32'. When the bombarded portion of the sample is located at the point 32', a maximum amount of radiation will be able to pass through both of the collimators 58 and 59, whereas when the bombarded point is off the axis or point 32', little or no radiation will be capable of traveling through the collimators 58 and/or 59. Means are associated with each of the collimators for registering the variation of the amount of radiation which passes through the collimators. Such means is schematically illustrated as collection cups 61 which can include, of course, suitable electron multipliers and are connected to ammeters 62. It will be appreciated that in order to properly position the sample 17' at the point 32' with this embodiment, one need only manipulate the sample until the readings on each of the meters 62 is at its maximum.

While the invention has been described in connection with preferred embodiments thereof, it will be appreciated by those skilled in the art that many variations and other embodiments are possible within the scope of the invention.

What is claimed is:

1. Apparatus for determining properties of a sample, said apparatus comprising means for generating a beam of radiation, means for supporting the sample at a location to interact with the beam of radiation whereby electrically charged particles issue from the area of interaction of the beam with the sample, an analyzer for analyzing a first portion of said electrically charged particles, said analyzer comprising a pair of coaxial and radially spaced-apart cylinders with the sample supported exteriorly of said cylinders on the common axis thereof, means for forming a charged-particle deflect-

ing field in the space radially between said cylinders, means defining a path for the first portion of said electrically charged particles to enter the space between said cylinders whereby in response to said deflecting field said first-portion particles are deflected to said common axis, and means disposed on said common axis for collecting said first portion of electrically charged particles, and means responsive to a second portion of said electrically charged particles comprising a screen of fluorescent material activable by the impingement thereon of electrically charged particles, said screen being disposed to intercept said second portion of said electrically charged particles, and a shield interposed between the sample and said screen in the path of said second-portion particles whereby a shadow of said shield is projected upon said screen, said screen being provided with a mark whereby the configuration of said shadow with respect to said mark indicates the coordinate position of the area on the sample at which the beam of radiation interacts with the sample.

2. Apparatus of claim 1 further comprising means for varying the location of the sample relative to both said beam of radiation and said analyzer whereby the coordinate position of the area on the sample at which said beam interacts with the sample can be controllably adjusted.

3. Apparatus of claim 1 wherein said screen is located within the inner cylinder of said coaxial pair of cylinders.

4. Apparatus of claim 1 wherein said shield is symmetric with respect to the common axis of said coaxial cylinders.

5. Apparatus of claim 1 wherein said shield is annular to project an annular shadow on said screen, and said mark is circular, whereby the area of interaction of the beam of radiation with the sample intercepts the common axis of said coaxial cylinders when the annular shadow of said shield is aligned with said circular mark.

6. Apparatus of claim 5 wherein said annular shield is a truncated cone, the apex of which is the point on the common axis of said cylinders at which the beam of radiation will optimally interact with the sample.

7. Apparatus of claim 1 wherein the width of said shield varies from one portion thereof to another, whereby the width of the umbra of the shadow of said shield upon said screen varies depending upon the size of the area of interaction of the beam of radiation with the sample.

8. Apparatus of claim 7 wherein said shield is of wedge shape.

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