United States Patent

Wardly

[15] **3,679,896**

[45] **July 25, 1972**

[54] ELECTROSTATIC PRISM

[72] Inventor: **George A. Wardly**, Yorktown Heights, N.Y.

[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[22] Filed: **Dec. 23, 1969**

[21] Appl. No.: **887,603**

[52] **U.S. Cl.**.....**250/41.9 ME**, 250/49.5 A, 313/63

[51] **Int. Cl.**.....**H01j 39/34**

[58] **Field of Search**.....250/41.9 ME, 49.5 A, 49.5 PE, 250/49.5 C; 313/63

[56] **References Cited**

UNITED STATES PATENTS

3,309,517	3/1967	Liot	250/41.9
3,407,323	10/1968	Hand	250/41.9
3,461,306	8/1969	Stout et al.	250/49.5
3,397,311	8/1968	Saari et al.	250/41.9

OTHER PUBLICATIONS

Wardly, Thesis, A Study of Electron Bombardment Induced Conductivity in Thermally Grown Silicone Dioxide, '68

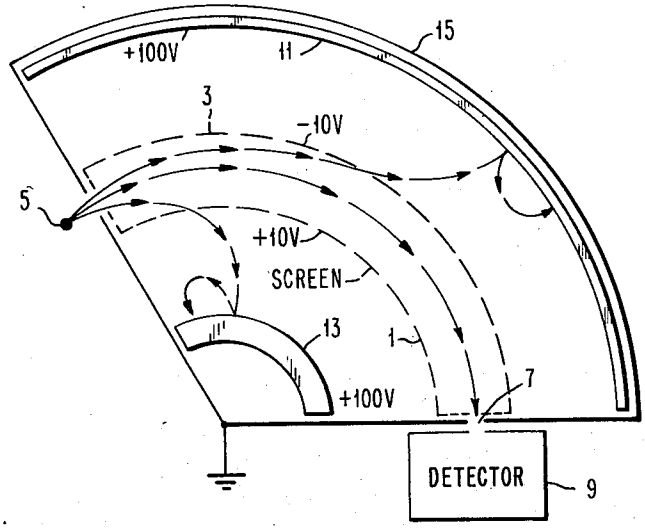
Wardly, Magnetic Contrast Analyzer, 6/69, pg. 298- 299, 1BMTDB, Vol. 12, No. 2.

Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—N. Moskowitz
Attorney—Hanifin and Jancin and John A. Jordan

[57] **ABSTRACT**

An electrostatic field to manipulate charged particles in a narrow band filter prism and energy discrimination prism arrangement is obtained by employing high transparency opposing screen electrodes. Adjacent each screen electrode particle attractor apparatus act to attract all particles outside the narrow band of particles. In the narrow band filter arrangement collector apparatus are provided to collect particles within the narrow band while in the discrimination arrangement collector apparatus are provided to collect both particles having energies above the narrow band and particles having energies below the narrow band.

16 Claims, 3 Drawing Figures



BEST AVAILABLE COPY

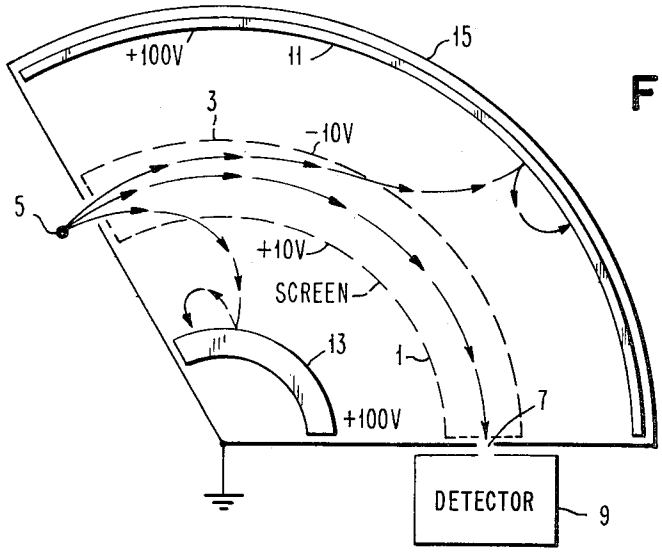


FIG. 1

FIG. 2

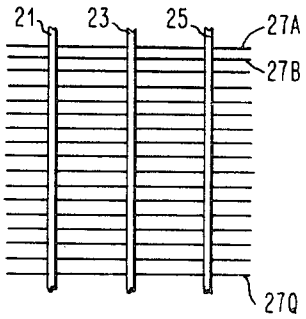
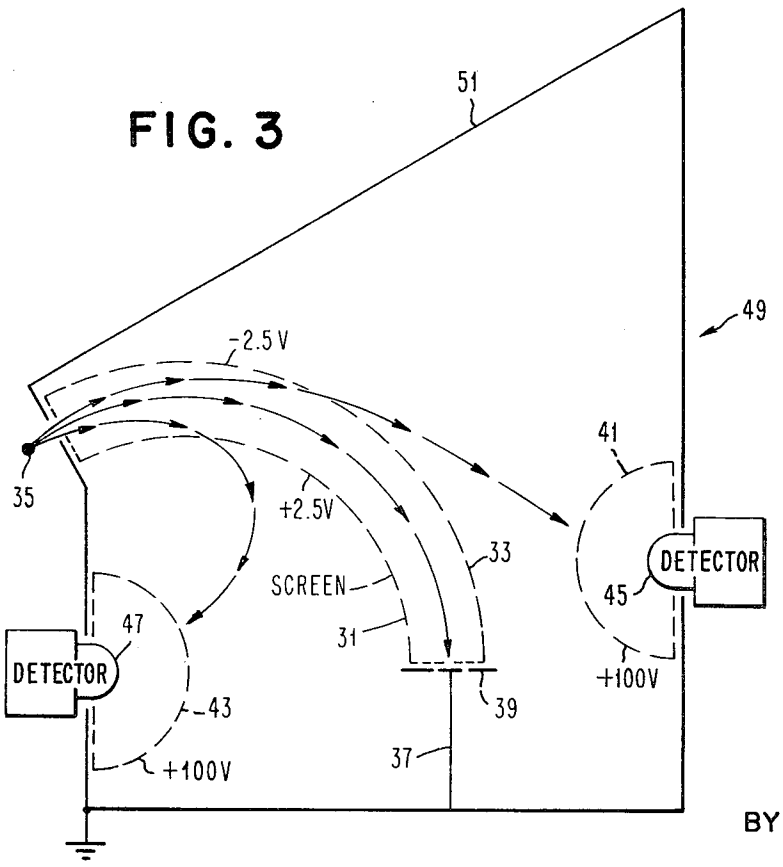


FIG. 3



INVENTOR
GEORGE A. WARDLY

BY John A Jordan
ATTORNEY

ELECTROSTATIC PRISM

BACKGROUND OF THE INVENTION

The present invention relates generally to the manipulation of charged particle beams and, more particularly, to electrostatic prisms used for creating an electrostatic field for manipulating and deflecting charged particles such as electrons and the like.

Electrostatic and magnetic prisms for deflecting electrons and ionized particles are known to have wide application as can be seen, for example, by their use in mass spectrometers, analyzers, electron microscopes, discriminators, filters and the like. It appears in most applications electrostatic prisms are preferred over magnetic prisms because of their good linearity and lack of hysteresis as well as field containment. One of the main difficulties with known electrostatic prisms, however, lies in the fact that the opposing electrodes used to effect the field exhibit little or no transparency to the particles being deflected. Accordingly, particles that impinge upon these electrodes may either themselves be reflected or alternatively cause secondary or tertiary particles to be generated which particles may in turn impinge upon the electrodes, etc., and finally be sensed as having an energy quite different from what is in fact the case. The effect of such spurious particles may be characterized as noise.

The problem is compounded by the fact that in opposing plate electrode arrangements, a minimum plate width to gap ratio must be maintained to provide uniform fields between the electrodes. Accordingly, useful electrode gaps require the opposing electrode areas to be relatively large.

In accordance with the principles of the present invention, the problem of spurious particles in electrostatic prisms, which particles introduce a high degree of noise in the output of the device employing the prism, is met by employing high transmission screens as opposing electrodes with particle attraction apparatus on each side of the screen. Prisms so made may be used, for example, as a narrow band prism or electrostatic prism discriminator.

It is therefore an object of this invention to provide an improved electrostatic prism.

It is a further object of this invention to provide an improved electrostatic prism employing high transmission screens as opposing electrodes with particle attraction apparatus adjacent each screen and particle collection apparatus.

It is yet another object of this invention to provide an improved narrow band electrostatic prism.

It is yet further another object of this invention to provide an improved electrostatic prism discriminator.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a preferred embodiment of the electrostatic prism in accordance with the present invention in a narrow band prism arrangement.

FIG. 2 shows an example of one form of high transmission screening that may be employed in the arrangements of FIGS. 1 and 3.

FIG. 3 shows a preferred embodiment of the electrostatic prism in accordance with the present invention in a prism discriminator arrangement.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the embodiment shown in FIG. 1, an electrostatic prism exhibiting narrow band energy filtering properties with high signal-to-noise ratio is provided.

As shown in FIG. 1, a high transparency conductive screening is employed as each of the opposing electrodes 1 and 3 to thereby create an electrostatic field therebetween to effect particle deflection. The screen electrodes 1 and 3 are held by any of a variety of support apparatus, in a planar or plate-type arrangement so that the plane of the screen extends from the plane of the paper.

It is to be understood, of course, that other than planar type arrangements are possible.

Where the screen electrodes 1 and 3 are to deflect negatively charged particles, as for example electrons, the polarity of the potential applied would be as shown i.e., screen electrode 1 positive and screen electrode 3 negative. It is clear that for deflection of positive particles this polarity would be reversed. For the narrow band filter application of FIG. 1, a 10 volt magnitude at each electrode would provide an appropriate field for deflecting electrons so that electrons of a selected energy will pass through exit aperture 7 in FIG. 1. As shown in FIG. 1, the screen electrodes 1 and 3 are arranged to form concentric arcs of approximately 127° so that the angular path of particles from object or source 5 to exit aperture 7 traverses 127° 17'. It is clear that the object to image angular distance is chosen to optimize the focal or discrimination properties of the electrostatic prism. A nominal starting point is to provide 127° 17' between object and image although a non-zero angular aperture and an object lying outside the prism can alter the optimum design from the above 127° 17'.

Any of a variety of finely woven conductive mesh arrangements may be employed as opposing electrodes in FIGS. 1 and 3 in accordance with the present invention. It is clear however, that since the angle of incidence of the particles is small, the finer the mesh, particularly the thinner the cross-sectional dimension of the mesh, the higher will be the transparency.

It is also clear that the greater the spacing between mesh members the higher will be the transparency. However, it is evident that to achieve an effectively uniform field pattern between opposing screens the spacing between individual screen or mesh lines or members in at least one direction must be small compared to the gap or separation between the screens.

FIG. 2 shows one form of screen exemplary of those that may be employed. It is evident that any of a variety of conductive materials may be used. For example, gold or a gold plated alloy may be employed to advantage since it is not susceptible to oxidation and exhibits good electrical properties. However, it is clear that materials having a lower secondary emission characteristic than gold may also be employed to advantage.

As shown in FIG. 2, the screen arrangement may be fabricated, for example, by photoetching a 2-mil thick sheet of phosphor bronze. Support members 21, 23 and 25 may, for example, each be 20 mils. wide and spaced from one another by 200 mils. Each of screen lines 27A through 27Q may be, for example, 2 mils. wide and spaced from one another by 20 mils. After etching, the screen may be plated with gold.

When the screening configuration of FIG. 2 is employed in the electrostatic prism, in accordance with the present invention, it is arranged so that the particles move in a direction normal to members 21, 23 and 25. The wide spacing between these latter members aids in obtaining high transparency while the relatively close spacing between lines 27A through 27Q insures an effectively uniform field between opposing screens. Screening arrangements, akin to that of FIG. 2, have been calculated to transmit 80 to 90 percent of a beam of charged particles, such as electrons, approaching the screen at normal incidence, i.e., orthogonal to the screen surface. At the other extreme, the screen has been calculated to transmit as high as 50 percent of a beam of particles approaching the screen within one degree of the tangent to the screen.

In addition to the high transmission screening 1 and 3, narrow band filter arrangement of FIG. 1 also employs a pair of particle attractor plates 11 and 13 which may be fabricated from any of a variety of conductive materials, preferably of low secondary emission yield. These plates are each biased with a reasonably large potential so that particles, passing through either of the screen electrodes 1 or 3 because they are

outside the band of energy being selected, are attracted to one or the other of the respective plates **11** or **13** where they are suppressed. Likewise, any secondary or tertiary particles which may result from collision of the primary particles and the screen electrodes may also be collected.

As shown in FIG. **1** where the particles being investigated are electrons, biasing each attractor plate **11** and **13** with a +100-volt potential provides an adequate field to attract and hold particles having energies outside the selected energy band. It is clear that where positively charged particles are being investigated, the polarity of plates **11** and **13** would be negative and the magnitude of such polarity would depend upon the particular positively charged particle being considered.

The prism arrangement in accordance with the present invention may be housed in any of a variety of container or chamber apparatus. As shown in FIG. **1**, a chamber **15** is employed which acts as a grounded electrostatic and magnetic shield arrangement. Source **5** is a source capable of producing a beam of electrons and particle collection detector device **9**, which may be any of a variety of conventional electron collectors, such as a scintillation counter or detector, acts to collect and determine electrons in the selected energy band. Alternatively, a simple electrode arrangement could be employed at **9** to collect and detect particles and the current produced by the collected particles determined.

It can be seen from FIG. **1** that electrons having an energy greater than the selected energy band to be filtered are transmitted through screen **3** and attracted to plate **11** where same are suppressed. Likewise, electrons having an energy less than the selected energy band to be filtered are transmitted through screen **1** and attracted to plate **13** where same are suppressed. Accordingly, only electrons having an energy within the narrow collection band, as defined by the relationship between the parameters of the source **5** and exit aperture **7**, are passed to detector **9** since the high transmission characteristics of the opposing screened electrodes prevents any significant number of electrons outside of the energy band from creating noise by producing any of reflected, secondary or tertiary electrons, some of which would be collected by detector **9**.

In FIG. **3**, there is shown an electrostatic prism discriminator in accordance with the principles of the present invention. As in the case of the narrow band filter arrangement in FIG. **1**, the wide band energy discriminator arrangement in FIG. **3** employs high transparency conductive screening as opposing electrodes **31** and **33** to thereby create an electrostatic field to effect particle deflection. However, instead of the exit aperture **7**, as employed in the narrow band filter of FIG. **1**, the discriminator of FIG. **3** employs a knife-edge energy level discrimination plate **37** to provide a fine energy interception line for division between what may be called the high and low energy particles. Plate **37**, which is grounded at one end, may be fabricated from any of a variety of conductive materials. Orthogonally affixed to the end of grounded discrimination plate **37** is a section of high transparency conductive screening **39**, akin to screening **31** and **33**.

The screen electrodes **31** and **33** and screen section **39** may be held by any of a variety of support apparatus in a planar or plate-type arrangement so that the plane of the screen extends from the plane of the paper. The angular distance between particle beam source **35** and screen section **39** is nominally 127° 17′. It should be noted that the function of screen section **39** is to correct for the "end effect" of screen electrodes **31** and **33** whereby the fringe field between these electrodes is not uniform at the ends thereof. Conductive screen section **39**, which is not in physical contact with screen electrodes **31** and **33**, acts to effect a distribution of the field at the ends of these electrodes so as to provide a reasonably uniform field thereat. In addition, screen **39** reduces the penetration of fields generated by the potentials on screens **41** and **43** into the space between screens **31** and **33**.

It should be noted that in FIG. **1** a narrow band of particle energies is detected and the opposing screen electrode arrangement is employed to allow unwanted particles outside this narrow band to be readily transmitted and suppressed. However, in FIG. **3**, wide bands of particle energies on adjacent sides of a narrow band are to be detected and the opposing screen electrode arrangement is employed to allow the wanted particles outside this narrow band to be transmitted for detection. In either instance, the high transmission characteristic of the prism screening reduces the effects of reflected and lower order particles.

Accordingly, in FIG. **3** particle collection detector devices, such as a pair of conventional scintillation counters or detectors are employed, as shown at **45** and **47** on each side of the chamber. It is clear, however, that in place of the pair of scintillation counters other forms of detectors could be used. For example, a pair of conventional electrodes could be used to measure the current produced by the particles collected thereat. Surrounding each of counters **45** and **47** are particle attractor screens **41** and **43**, also fabricated from high transmissive screening. Where the discriminator is to be used to discriminate between the high and low energies of negatively charged particles, as for example electrons, establishing a +100-volt potential, as shown, on each of attractor screens **41** and **43** provides a sufficient field for attracting the electrons. Likewise, for electron use, 10 KV scintillation counters may be used for particle collection and counting and opposing electrode screens **31** and **33** may be biased to +2.5 volts and −2.5 volts, respectively, as shown.

It is clear that the electrostatic prism discriminator of FIG. **3** may be housed in any of a variety of container or chamber apparatus. As shown in FIG. **3**, the grounded chamber **49** is designed so that the top surface **51** extends upwardly so as to provide sufficient room for high energy particles to clear the chamber before being angularly attracted to detector **45**.

As can be seen with reference to FIG. **3**, particles above a selected energy level, are determined by the opposing potential applied to the prism screens **31** and **33**, are attracted to scintillation counter **45** while particles below the selected energy level are attracted to scintillation counter **47**. A relatively few particles having an energy within the narrow band of discrimination plate **37** will not be detected.

It is evident that the discrimination arrangement of FIG. **3** may readily be employed in electron microscopy voltage contrast work. However, other applications are likewise readily apparent.

What is claimed is:

1. An electrostatic prism device for creating a field to deflect particles of a beam of charged particles comprising:

a source for producing a beam of charged particles;

chamber means having an entrance aperture for passing said beam of charged particles into said chamber means;

a pair of oppositely poled high transparency screen electrode means mounted within said chamber means in curved spaced apart relationship to create a curved electrostatic field space therebetween extending in an arc from said aperture so as to receive therein in said field space said beam of charged particles passing through said aperture into said chamber; and

a pair of particle attractor means each exhibiting a voltage potential having a polarity opposite to that of the polarity of said charged particle, one of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent one of said high transparency screen electrode means and the other of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent the other of said high transparency screen electrode means.

2. The device as set forth in claim **1** wherein said chamber means includes exit aperture means at the end of said curved field space opposite said entrance aperture so that particles of selected energy traverse an angular path within said curved field space to said exit aperture.

3. The device as set forth in claim **2** wherein particle collection means act to collect and detect particles of said selected energy exiting through said exit aperture means.

4. The device as set forth in claim 1 further including a pair of particle collector means, one of said pair of particle collector means arranged to collect particles attracted by the said one of said particle attractor means and the other of said particle collector means arranged to collect particles attracted by the said other of said particle attractor means.

5. The device as set forth in claim 4 further including energy level discrimination plate means positioned at the end of said curved field space opposite to said entrance aperture so as to intercept selected particles within a predetermined narrow energy band to thereby divide the remainder of said particles into high and low energy groups.

6. An electrostatic prism device for creating a field to deflect particles of a beam of charged particles comprising:

a source for producing a beam of charged particles;

chamber means having an entrance aperture for passing said beam of charged particles into said chamber means;

a pair of particle transmissive electrically conductive screening means mounted within said chamber means in curved spaced apart relationship extending in an arc from said aperture so as to receive in the space therebetween said beam of charged particles passing through said aperture into said chamber;

means to apply a potential between said screening means to create an electrostatic field in said curved space therebetween for deflecting said beam of charged particles; and

a pair of particle attractor means each biased with a voltage potential having a polarity opposite to that of the polarity of said charged particles one of said pair of particle attractor means mounted within said chamber means, exterior to said space, adjacent one of said screening means and the other of said pair of particle attractor means mounted within said chamber means, exterior to said space, adjacent the other of said screening means.

7. The device asset forth in claim 6 wherein each of said pair of particle attractor means is in the form of a section of particle transmissive electrically conductive screening means and wherein said device further includes a pair of particle collection means with one of said pair of particle collection means mounted to collect particles passing through one of said pair of screening means and with the other of said pair of particle collection means mounted to collect particles passing through the other of said pair of screening means.

8. The device as set forth in claim 6 further including a grounded energy level discrimination plate positioned within said chamber means at the end of said space opposite to said entrance aperture to intercept selected ones of said particles having a predetermined narrow energy band to thereby divide the remainder of said particles into high and low energy groups.

9. The device as set forth in claim 6 wherein said particles are electrons.

10. The device as set forth in claim 6 wherein said screening means are particle transmissive up to 50% for particles approaching said screen within one degree of the tangent to the screen.

11. The device as set forth in claim 6 wherein said pair of particle attractor means each comprise a conductive plate of low secondary emissive material which acts to attract and hold particles in accordance with the energy of the said particles.

12. The device as set forth in claim 11 wherein said chamber means includes an exit aperture in said chamber at the end of said space opposite to said entrance aperture and wherein collector means are provided to collect particles having energies falling within the narrow band of energies required for particles to pass through said exit aperture.

13. The device as set forth in claim 12 wherein said particles are electrons.

14. A narrow band electrostatic prism device for filtering particles of a selected narrow band of energy from a beam of charged particles comprising:

source means for producing a beam of charged particles;

chamber means having an entrance aperture for receiving said beam of charged particles into said chamber and an exit aperture angularly displaced from said entrance aperture for exiting selected ones of said particles entering said chamber;

electrostatic field forming means mounted within said chamber means for forming an electrostatic field extending in an angular path between said entrance aperture and said exit aperture, said field forming means including a pair of oppositely poled high transmission screening electrode means mounted in spaced apart relationship to form an angular field space extending from said entrance aperture to said exit aperture;

a pair of particle attractor means each exhibiting a voltage potential having a polarity opposite to that of the charge of the particles of said beam of charged particles, one of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent one of said high transmission screening electrode means for attracting high energy particles and the other of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent the other of said high transmission screening electrode means for attracting low energy particles; and

particle collection means for collecting and detecting particles having energy within the narrow band of energy required to effect traversal of a trajectory within said angular field space to said exit aperture.

15. An electrostatic prism energy level discriminator for discriminating between the high energy and low energy particles of a beam of charged particles comprising:

source means for producing a beam of charged particles;

chamber means having an entrance aperture for receiving said beam of charged particles into said chamber;

electrostatic field forming means mounted within said chamber means for forming an electrostatic field extending in an angular path from said entrance aperture, said field forming means including a pair of oppositely poled high transmission screening electrode means mounted in spaced apart relationship to form an angular field space extending from said entrance aperture;

particle interception plate means mounted at the end of said angular path opposite to said entrance aperture so as to intercept particles within a selected narrow energy band;

a pair of particle attractor means each exhibiting a voltage potential having a polarity opposite to that of the charge of the particles of said beam of charged particles, one of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent one of said high transmission screening electrode means for attracting high energy particles and the other of said pair of particle attractor means mounted within said chamber means, exterior to said field space, adjacent the other of said high transmission screening electrode means for attracting low energy particles; and

a pair of particle collection means for collecting and detecting said particles, one of said pair of particle collection means arranged to collect and detect high energy particles attracted by the said one of said pair of particle attractor means and the other of said particle collection means arranged to collect and detect low energy particles attracted by the said other of said particle attractor means.

16. The discriminator as set forth in claim 15 wherein said pair of particle attractor means each comprise high transmission screening means respectively positioned between its corresponding particle collector means and said electrostatic field forming means.

* * * * *