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DIELECTRIC-TYPE CHARGED PARTICLE DETECTOR

Filed March 5, 1968

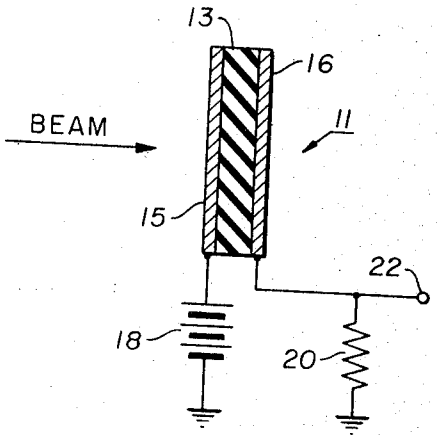


Fig. 1.

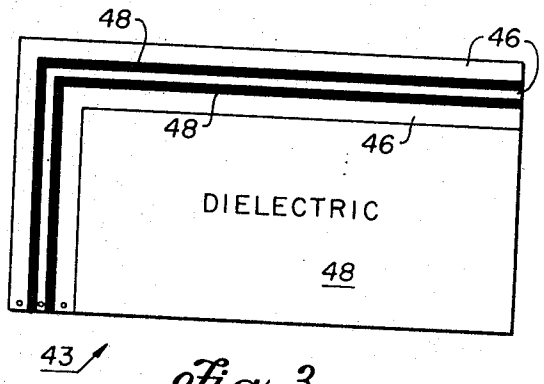


Fig. 3.

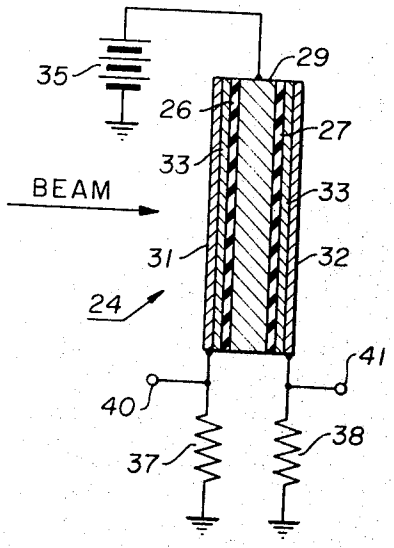


Fig. 2.

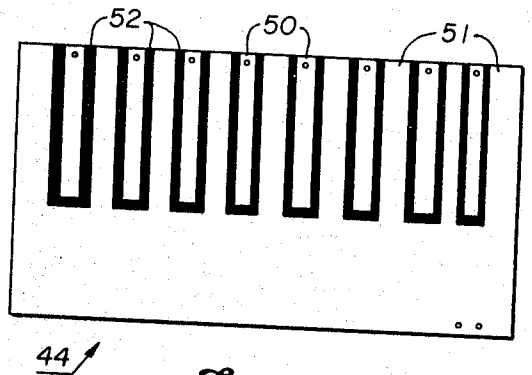


Fig. 4.

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DIELECTRIC-TYPE CHARGED PARTICLE DETECTOR

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ABSTRACT OF THE DISCLOSURE

A charged particle detector comprised of a thin dielectric in intimate contact with a pair of electrodes across which a voltage is applied to extract a current from the dielectric upon its being irradiated with charged particles that cause the dielectric to become proportionately electrically conductive.

Background of the invention

The present invention relates generally to particle detectors, and more particularly, it pertains to a detector having a dielectric element that is irradiated with the particles to be detected.

The invention disclosed herein was made under, or in, the course of Contract No. AT(04–3)–400 with the U.S. Atomic Energy Commission.

Secondary emission monitors (SEM) are widely used for detecting the current of a charged particle beam. Such devices operate on the principle of secondary emission in the form of electrons being emitted from a foil surface when an energetic charged particle beam impinges on the foil. A high positive bias potential is applied to a second foil that is separated from the first foil. The positive bias voltage causes the electrons to be collected on the second foil. The resultant foil current is proportional to the beam current and therefore may be used to indicate the intensity of the beam current as well as its location. However, to obtain a high degree of spacial resolution with an SEM, it is necessary to arrange the foils in complex patterns. For good spacial resolutions, narrow, closely spaced patterns are required. Frames for holding the foils therefore become correspondingly smaller and complex, and the electrical connections thereto difficult. For very high resolution, the required foil patterns, frames and connections become so intricate as to make an SEM impracticable.

Summary of the invention

Briefly, the invention is the discovery that irradiation of a dielectric with charged particles raises a proportionate number of the electrons in the dielectric to a conduction band, and that application of a voltage to the irradiated dielectric through metal electrodes in intimate contact therewith results in an electric current proportional to the intensity of irradiation impinging on the dielectric positioned directly between opposing electrode surfaces. In accordance with the invention, closely spaced electrodes are easily arranged in intricate and complex patterns on opposite sides of a dielectric. The resulting device is especially useful for indicating the intensity and location of a charged particle beam with a high degree of resolution. Such a device is easily manufactured, and it is adaptable for mounitng in a simple frame that may be made integral with the detector to achieve optimum thermal conduction. The frame also may be conveniently positioned in the beam path, and provides means for making electrical connections to the detector.

It is an object of the invention to extract a current from a dielectric being irradiated with charged particles.

Another object is to detect the location and intensity of a charged particle beam with a high degree of resolution.

Another object is to simplify the construction and mounting of a charged particle beam detector.

Other objects and advantageous features of the invention will be apparent in a description of an embodiment, given by way of example only, to enable one skilled in the art to readily practice the invention, and described hereinafter with reference to the accompanying drawing.

Brief description of the drawing

FIGURE 1 is a cross sectional view of a dielectric-type charged particle detector according to the invention.

FIGURE 2 is a cross sectional view of a dielectric-type charged particle detector having dual dielectric detecting elements and one common electrode.

FIGURE 3 is a side view of an electrode pattern for the charged particle detector of FIGURE 1 or FIGURE 2.

FIGURE 4 is a side view of another possible electrode pattern for the detector of FIGURE 1 or FIGURE 2.

Description of an embodiment

Referring to the drawing, there is shown in FIGURE 1 a charged particle detector **11** comprising a dielectric element **13** in intimate contact with a pair of metal electrodes **15** and **16**. A voltage source **18**, in series with a load resistor **20**, is connected across the electrodes. Upon irradiation of the element **13** with charged particles, as for example with an electron beam of a long linear accelerator, a number of electrons in the dielectric element are raised to conduction bands. The number of electrons raised to a conduction band is proportional to the intensity of irradiation of the element **13**. The voltage applied across the electrodes **15** and **16** from the source **18** causes a current flow through the dielectric and external circuit that includes the electrodes, source **18** and load resistor **20**. An output signal is produced thereby, and it can be displayed on an oscilloscope connected across the resistor. The output signal is proportional to the intensity of irradiation of the portion of dielectric between directly opposing surfaces of the electrodes.

In practice it is found preferable that the electrodes be molecularly bonded to the dielectric to ensure electrical conduction therebetween during irradiation of the dielectric.

Any type of dielectric material or electrode metal should give significant detection currents. The primary criteria for the detector materials is that the dielectric material be resistant to the radiation to which it is exposed, and that the dielectric material and electrodes be sufficiently thin to avoid destructive thermal rises.

One convenient method of constructing the detector **11** (FIGURE 1) is to anodize one face of a sheet of aluminum foil, such foil being generally commercially available. The anodized face is aluminum oxide (Al_2O_3) which is a dielectric that is resistant to destruction when irradiated with charged particles. The exposed aluminum oxide may then be coated with another metal, thereby forming a detector wherein the aluminum oxide is a dielectric element between two metal electrodes.

The detector **11** (FIGURE 1) can also be made by coating each side of a wafer of dielectric, for example, a wafer of Al_2O_3, with a metal that is a good electrical conductor, using standard techniques for obtaining a good metal-to-ceramic bond.

It is anticipated that other dielectric materials may provide an increased efficiency of extracted output current for specifically applied source voltages and intensi-

ties of irradiation over the efficiency obtained with aluminum oxide. It is expected that higher efficiencies can be obtained with dielectric compounds formulated with elements from the following groups listed in the Periodic Table: Groups I and V, e.g., Na_3Sb; I and VI, e.g., Cu_2O; I and VII, e.g., CuBr; II and IV, e.g., Mg_2Si; II and V, e.g., Cd_3P_2; II and VI, e.g., CdS; III and V, e.g., AlSb; III and VI, which includes Al_2O_3; IV and IV, e.g., SiC; IV and VI, e.g., PbS; V and VI, e.g., As_2O_3; and VI and VI, e.g., TeO_2. It is also expected that three-element dielectric compounds such as $PbCO_3$, $ZnSiAs_2$, $CdGeP_2$, etc., would give higher efficiencies. Generally, dielectrics with small band gaps, and constructed in such a way (i.e., to be low in impurities and crystal imperfections) as to have long recombination times, are expected to be most efficient. However, a dielectric so constructed would also be sensitive to radiation so that a compromise is necessary to give a dielectric that has a reasonable efficiency and is relatively insensitive to radiation.

Furthermore, the detector is not critical as to which electrode is presented to the charged particles, and it will operate with only an exposed end of the dielectric element presented to the radiation; the detector is not sensitive to the polarity of the source; and it is found to conduct equally in either direction.

In FIGURE 2 is shown a detector **24** having dual dielectric elements **26** and **27** in contact with opposite faces of a common electrode **29**. Outer electrodes **31** and **32** may be molecularly bonded to the dielectric elements by means of a metallic bonding material **33**. Equal voltages are applied in parallel across each half of the detector **24** by means of a voltage source **35**. Load resistors **37** and **38** are connected in series, respectively, with each half of the detector to provide individual outputs at terminals **40** and **41**.

The detector **24** may be conveniently constructed by making the electrode **29** of aluminum foil. The dielectric elements **26** and **27** may be made of aluminum oxide by anodizing both faces of the foil. The metallic bonding material **33** may be a very thin coating of titanium, while the electrodes **31** and **32** may be gold coated over the titanium.

In FIGURES 3 and 4 are shown electrode plates **43** and **44** with representative electrode patterns. The plate **43** is comprised of conducting strips **46** over a dielectric **48**, while the plate **44** is comprised of conducting strips **50** and **51** over a dielectric **52**. Either or both of the patterns could be coated, for example, over the dielectric element **13** (FIGURE 1). Alternatively, the detector **24** could have the pattern of FIGURE 3 coated over the dielectric element **26** (FIGURE 2) and the pattern of FIGURE 4 coated over the dielectric element **27**.

With one pattern coated on the detectors in the manner described, the intensity of a charged particle beam and its location in one direction can be detected, while with two patterns the beam location in two directions can be detected. Known electronic circuitry and devices may be connected to the strips **46**, **50** and **51** and foil electrode for processing and displaying the detected information.

The detectors **11** and **24** can be simply fabricated by masking and vacuum deposition of electrons or by chemically milling or etching the desired patterns by means of well-known printed circuit techniques.

Detectors exemplifying the invention were constructed and tested. One such detector was an aluminum oxide ceramic disc having electrodes formed by vacuum deposition of a very thin coating of gold over titanium. The aluminum oxide was approximately 2 mm. thick, while the deposited electrodes were less than .025 mm. thick. The electrodes on one side of the disc were arranged in a pattern of 2 mm. wide, ½" long parallel strips, and the opposite side was arranged in a like pattern, shifted 90° with respect to the first pattern.

Other detectors similar to detector **24** were constructed with 0.5 mm. thick aluminum foil having both faces anodized to form aluminum oxide dielectric elements 0.018 mm. to 0.1 mm. thick. Gold was vacuum-deposited on both sides of the elements to form electrodes in patterns substantially as shown in FIGURES 3 and 4. The foil may be first integrally mounted in a frame and then etched while in the frame. This permits attachment of the foil to the frame in such a way as to make the frame a heat sink and thereby give the detector optimum thermal conduction properties. Such a frame is also a convenient means for providing electrical connections to the detector as well, providing a convenient support for mounting the detector.

The constructed detectors were tested with a 5 mev. linear accelerator with peak beam currents ranging from 1 ma. to 30 ma. A potential of 400 volts was placed across opposing electrodes. It was found that with applied potentials of 8000 volts/mm. of aluminum oxide dielectric, there was an extracted detection current between opposing electrodes which ranged from 2–4% of impinging beam current.

While the embodiment of the invention has been shown and described, further embodiments or combinations of those described herein will be apparent to those skilled in the art without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. A charged particle detector, comprising:
first and second metal electrodes, and a first dielectric element in intimate contact with said first and second electrodes,
said element electrically insulating said first electrode from said second electrode,
said element being responsive to impingement of charged particles to cause detectable electrical conduction between said first and second electrodes upon application of an electrical potential thereacross,
said element being a ceramic, and said second electrode being a vacuum deposition of a conducting metal over a molecular bonding metal on said element.

2. A charged particle detector according to claim **1**, wherein at least one of said electrodes is arranged to have a plurality of electrically independent conducting strips.

3. A charged particle detector according to claim **1**, wherein
said first electrode is an aluminum foil, and
said element is an anodized coating of aluminum oxide on said foil.

4. A charged particle detector according to claim **1**, further including
a third metal electrode, and
a second dielectric element in intimate contact with said first and third electrodes,
said second element being responsive to impingement of charged particles to cause detectable electrical conduction between said first and third electrodes upon application of an electrical potential thereacross.

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