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SCINTILLATION-TYPE ION DETECTOR EMPLOYING A SECONDARY EMITTER TARGET SURROUNDING THE ION PATH

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FIG. 1

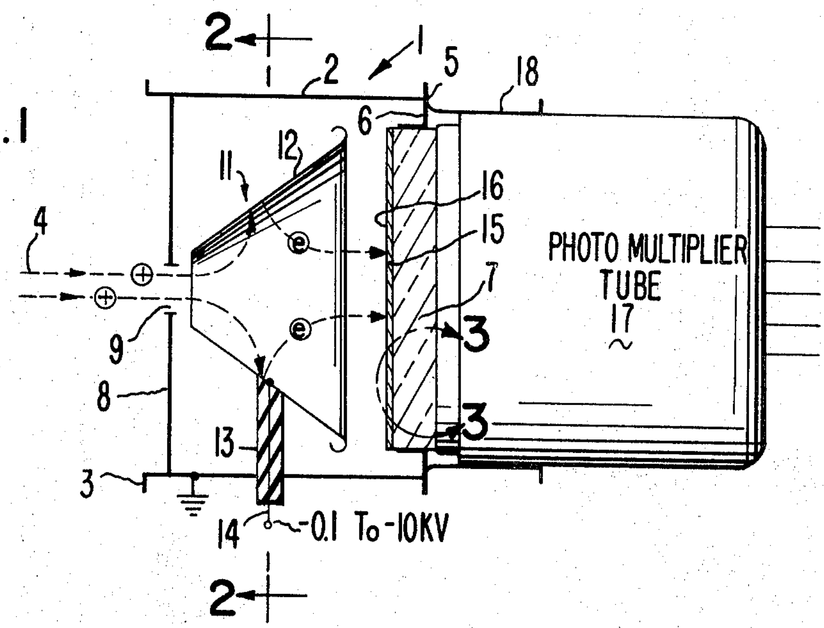


FIG. 2

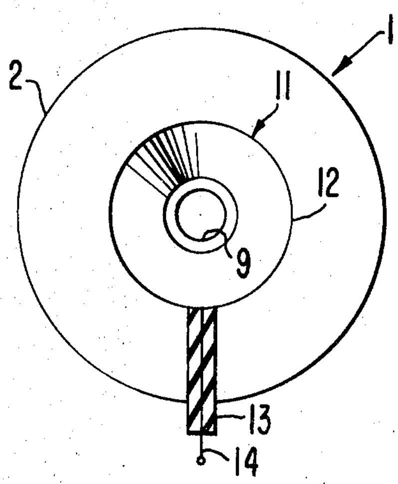
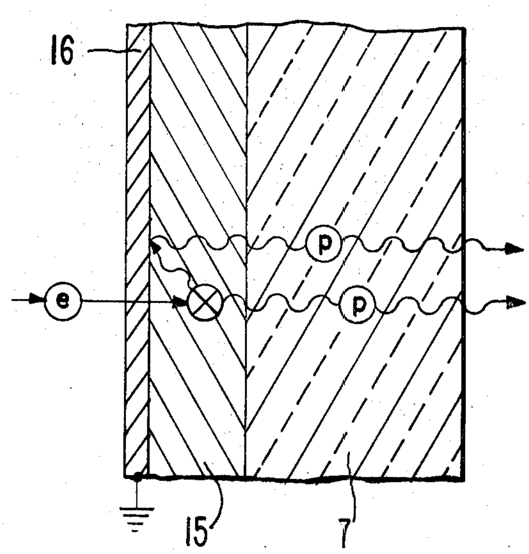


FIG. 3



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SCINTILLATION-TYPE ION DETECTOR EMPLOYING A SECONDARY EMITTER TARGET SURROUNDING THE ION PATH

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U.S. Cl. 250—71.5 3 Claims

ABSTRACT OF THE DISCLOSURE

A scintillation-type ion detector is disclosed. The detector includes an evacuable envelope structure containing a secondary emitter target electrode structure having a bore therethrough which is preferably of conical shape. The inside surface of the bore is bombarded by the ions to be detected and is made of a material that emits secondary electrons on being bombarded by ions. The secondary electron emission from the walls of the bore is focused onto a scintillator disposed facing the exit end of the bore to give an optical photon output which is transmitted through a window to a photo multiplier.

DESCRIPTION OF THE PRIOR ART

Heretofore, scintillation-type ion detectors have been constructed. In these prior detectors, the ion beam was caused to bombard a button-shaped secondary emitter electrode. Secondary electron emission from the button electrode was collected on a scintillator for converting the secondary electrons into optical photons. The photons were transmitted through a window portion of the evacuable envelope to a photomultiplier tube. Scintillation-type ion detectors, of the aforedescribed type, are disclosed in "Review of Scientific Instruments," vol. 37, No. 10 of October 1956, pages 1385–1390, and "Review of Scientific Instruments," vol. 31, No. 3, March 1960, pages 264–267.

One of the problems with this type of prior art ion detector has been that the structure was relatively complex because it lacked axial symmetry. In operation, positive ions entered along an axis and were drawn across the axis into a target secondary emitter electrode transversely disposed with respect to the axis. The secondary electrons emitted from the target were directed across the beam axis to a scintillator and photomultiplier unit transversely disposed of the beam axis. As a consequence, the ion detector had a generally T-shaped configuration with three relatively expensive vacuum-tight flange assemblies disposed on three sides. In addition, relatively inefficient focusing of the secondary electrons onto the scintillator was obtained, thereby yielding less than optimum detection sensitivity.

Therefore, a need exists for an improved scintillation-type ion detector having a simplified geometry and improved secondary electron focusing.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved scintillation-type ion detector.

One feature of the present invention is the provision of a scintillation-type ion detector having a secondary emitter electrode structure with a bore therein which is coaxially disposed of the ion beam path to be detected. In operation, the ions to be detected are collected on the inside surfaces of the bore to produce secondary electron emission. The secondary electrons are focused out the downstream end of the bore and onto a scintillator-photomultiplier disposed in axial alignment with the ion

beam path and bore, whereby the geometry of the scintillation-type ion detector structure is simplified.

Another feature of the present invention is the same as the preceding feature wherein the bore in the secondary emitter electrode structure is conically shaped with the small end of the bore facing upstream of the ion beam path and the large end of the bore being disposed facing a plate-shaped scintillator, whereby focusing of the secondary electron emission onto the scintillator plate is facilitated to provide improved ion detection sensitivity.

Other features and advantages of the present invention become apparent upon perusal of the following specification taken in connection with the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, longitudinal sectional, line diagram of a scintillation-type ion detector of the present invention,

FIG. 2 is a sectional line diagram of the structure of FIG. 1 taken along line **2**—**2** in the direction of the arrows, and

FIG. 3 is an enlarged sectional view of a portion of the structure of FIG. 1 delineated by line **3**—**3**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the figures, there is shown a scintillation-type ion detector **1** incorporating features of the present invention. The ion detector **1** includes a tubular body **2**, as of stainless steel, flanged at one end **3** for being sealed in a vacuum-tight manner to the vacuum envelope of a structure which produces a beam of ions **4**, the current of which, is to be measured. The other end of the tubular body member **2** is provided with a flange **5** for making a vacuum-tight connection to an annular metallic frame member **6** of a circular plate-like optically transparent window **7**, as of glass, which is sealed across and closes off the downstream end of the tubular body section **2**.

A transverse conductive disc **8** is disposed across the upstream end of the detector body **2** and includes a centrally disposed ion beam aperture **9** through which the beam **4** enters the detector **1**. A secondary electron emitter electrode structure **11**, having an axially directed bore **12** therethrough, is disposed on the axis of the beam path **4** intermediate the beam entrance partition **8** and the window **7**. The inside surface of the bore **12** is made of a material having a good secondary electron emission ratio such as stainless steel. The emitter electrode **11** is fed with a suitable negative potential as of minus 0.1–10 kv. relative to the body **2** via lead-in insulator structure **13** and a lead **14**.

A scintillator layer **15** is disposed on the face of the window plate structure **7** facing the secondary emitter electrode **11**. The structural detail of the scintillator **15** and window are more fully disclosed in FIG. 3. The window member comprises a circular disc or plate **7** of glass having the scintillator phosphor layer **15** deposited thereon to a thickness of approximately 10 microns. A photomultiplier tube **17**, such as an RCA 4517 photomultiplier, is disposed in axial alignment with he ion beam path **4** adjacent the outside surface of the window **7**. A tubular adapter **18** holds the photomultiplier tube **17** to the tubular detector body **2**. The spectral distribution of the phosphor **15** should be matched to the spectral response of the photomultiplier tube **17**.

A suitable phosphor **15** is either a Sylvania or RCA P–4 phosphor. A thin pinhole free conductive coating as of aluminum **16** is deposited, as by sputtering, over the inside surface of the phosphor **15** to a thickness of approximately 2000 A. The aluminum layer **16** should be free of pinholes to form an opaque barrier between the beam entrance slit **9** and the phosphor **15** and photomultiplier tube **17** to prevent photons of light passing into or generated within the ion detector chamber **2** from passing through the layer **16** into the photomultiplier to produce background noise or currents. The aluminum layer **16** serves as an electron permeable electrode structure and is electrically connected to ground potential or to the potential of the tubular body **2**. Alternatively, the electrode structure **16** may be operated at an independent potential, if desired.

In operation, positive ions entering the beam entrance opening **9** pass into the secondary emitting electrode structure **11** and are collected generally at glancing angles of incidence on the interior surfaces **12** of the secondary emitter. Secondary electrons emitted from the emitter **12** are focused onto the conductive layer **16** and scintillator layer **15**. The voltages are such that the electrons are driven through the very thin aluminum electrode **16** and into the phosphor **15**. Within the phosphor layer, the high energy electrons are captured to produce emitted optical photons P which pass through the optically transparent window **7**, as of glass **2**, into the photomultiplier tube. In the photomultiplier **17**, the photons are converted into an electron current and substantial gain can be obtained in the photomultiplier tube. The aluminum electrode **16** also serves to reflect photons through the window **7** that are back-scattered from the scintillating event within the phosphor **15**, thus improving the efficiency with which the electrons are converted into useful photons, i.e., photons which are detectable by the photomultiplier tube **17**.

By making the bore **12** in the secondary emitting electrode **11** conical, the secondary electron emission yield is improved, since the ions are more likely to be collected on the secondary emitting surface **12** at a glancing angle of incidence, thereby improving the secondary electron emission yield. In addition, the conical shape for the bore **12** facilitates focusing of the emitted electrons into a spot on the scintillator **15**, thereby reducing the chance that certain of the electrons will escape without producing photons in the scintillator **15**. Focusing the electrons to a spot on the phosphor **15** reduces the size of the required entrance aperture in the photomultiplier tube **17**, thereby reducing the unwanted dark current output thereof. The axial symmetry of the detecotr **1** facilitates its construction and thereby results in lower manufacturing costs.

The ion detector **1** of the present invention is especially useful for measuring the ion beam output of a mass spectrometer or ion vacuum gauge and is particularly desirable for use in an electrostatically focused mass spectrometer. In the later case, the surrounding nature of the secondary electron emitting electrode facilitates collection of ions having substantial components of velocity transverse to the ion beam path **4**. The ion detector **1** may also be utilized to advantage in magnetically focused mass spectrometers, but in such cases it is generally desirable to provide a magnetic shield surrounding the ion detector **1** to shield the magnetic field of the spectrometer out of the regions of the secondary emitting electrode **11** and photomultiplier tube **17**. When measuring the ion current for relatively light ions, such as helium ions, the gain of the ion detector **1** may be readily varied by varying the potential applied to the secondary emitting electrode **11**. For example, the gain is variable from 10^3 to 10^9 by varying the minus potential applied to the secondary emitter etlectrode **11** from −500 volts to −7.5 kv. Use of the stainless steel secondary emitting structure **11** allows the ion detector **1** to be unaffected by surface gases which tend to collect on the surfaces of the electrodes in use. In one example of an ion detector of the present invention, the ion collector electrode **11** had a cone angle of 40°, i.e., the half angle of the cone was 40°. In other words, its solid included angle was 80°.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a scintillation type ion detector, means forming a secondary emitter electrode structure for bombardment by the ions to be detected to give off secondary electron emission, means forming a scintillator for bombardment by the emitted secondary electrons to produce optical photon emission, means forming an evacuable envelope containing said secondary emitter electrode and said scintillator, means forming an optically transparent gas-tight window portion of said evacuable envelope for transmission of the optical photons through the wall of said envelope to an optical detector, the improvement wherein, said secondary emitter electrode structure has a bore surrounding the ion beam path and wherein the walls of said bore form the secondary electron emitter such that the ions are admitted into said bore at one end thereof and are collected on the inner surfaces of said bore to produce the secondary electrons which are focused by the inside surfaces of said bore onto said scintillator, wherein said bore in said secondary emitter electrode structure is conically shaped and said conical bore being disposed with its small end facing upstream of the ion path.

2. The apparatus of claim **1** wherein said optical window is a plate with said scintillator disposed upon the inside face of said plate, the plane of said plate being substantially perpendicular to the longitudinal axis of said bore, and said downstream end of said bore being disposed facing said plate for focusing the secondary electrons out the downstream end of said bore onto said scintillator.

3. The apparatus of claim **2** including means forming a photomultiplier disposed adjacent the outside surface of said window plate for detecting the optical photons, said photomultiplier means being disposed in axial alignment with the longitudinal axis of said bore.

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U.S. Cl. X.R.

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