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Zingaro

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[54] **LOW ENERGY X-RAY DETECTOR**

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[52] **U.S. Cl.** **250/272,** 250/370
[51] **Int. Cl.** **G01n 23/20**
[58] **Field of Search** 250/272, 273, 370, 371

[56] **References Cited**
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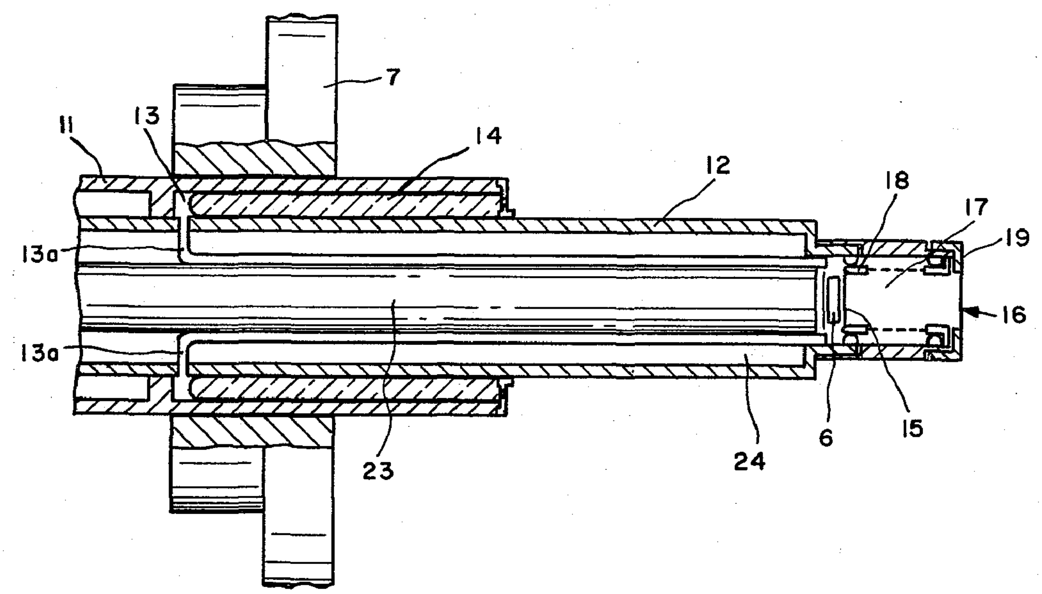
[57] **ABSTRACT**

A detector for low energy x-rays employs a lithium doped silicon crystal and an FET preamplifier cooled cryogenically. In order to avoid contamination of the crystal and FET by oil vapors and other condensates produced during evacuation of an instrument for producing soft x-rays, the detector is provided with two ultra-thin windows spaced apart and defining a space which connects with the instrument. Thus, while the instrument is evacuated air is also withdrawn from the space between the windows, and when air is introduced, the air flows through a filter prior to entering that space. The air is thus filtered to remove contaminants. The windows consist of thin films of a synthetic resin which transmit low energy x-rays substantially without attentuation but because they are so thin, they are unable to withstand any substantial pressure.

8 Claims, 4 Drawing Figures



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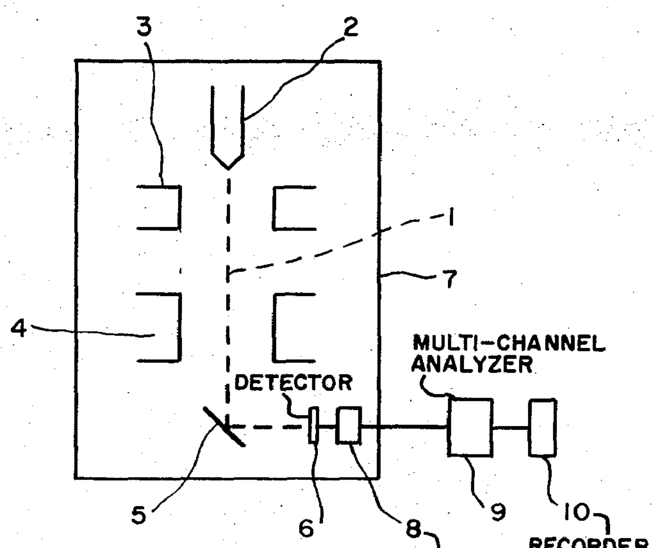

Fig. 1

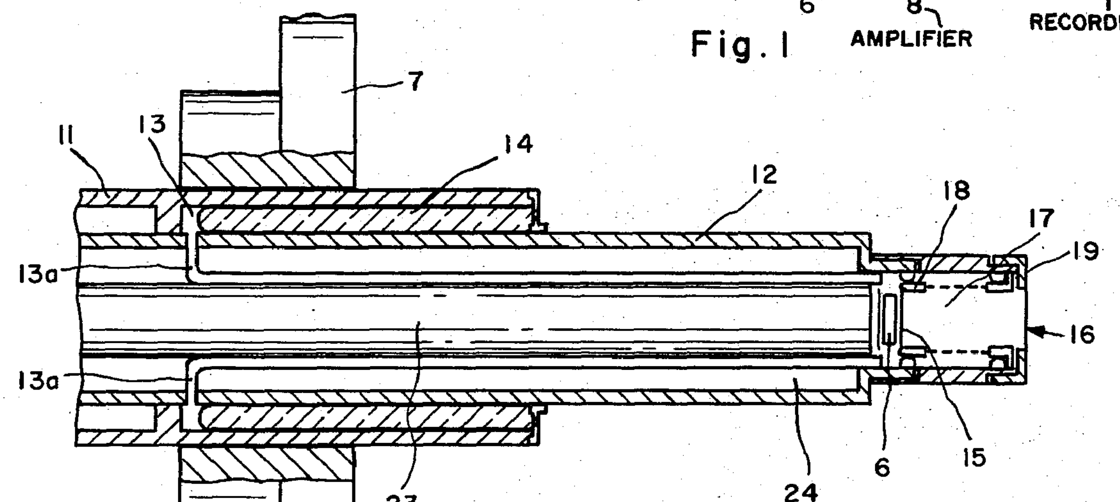

Fig. 2

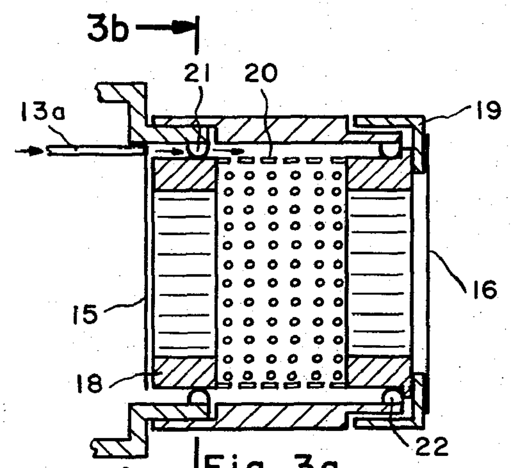

Fig. 3a

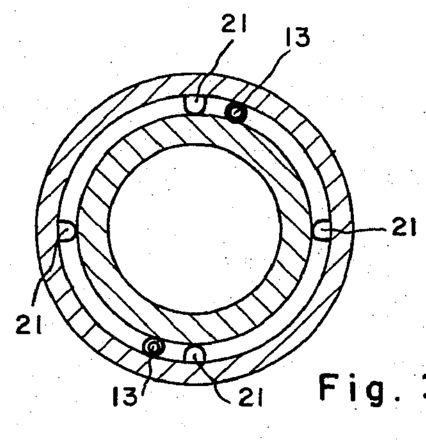

Fig. 3b

LOW ENERGY X-RAY DETECTOR

The invention relates to a detector of low energy x-rays which are very difficult to detect because they are rapidly attenuated by most materials, even air. Low energy x-rays are generally associated with the lower atomic number elements, especially below element number 10 of the periodic table, and usually have extremely long wave-lengths. In particular, low energy x-rays are considered to be x-rays having a wave-length longer than 10 A.

BACKGROUND OF THE INVENTION

The detection of low energy x-rays has been very difficult because they are attenuated very rapidly by most materials, including air. It has been found necessary, for example, to evacuate an instrument in which low energy x-rays are produced in order to provide a low attenuation path between the source and the detector. Even the detector presents a problem for if it has an entrance window, as it usually does if it is a gas-type detector such as a proportional counter, the window absorbs most, if not all, the radiation.

It has been proposed for example to use a lithium doped silicon crystal coupled to an FET, both being held at cryogenic temperatures, as a detector of low-energy x-rays. In this instrument, which is described in J. Appl. Phys., Vol. 43 No. 11, Nov. 1972, p. 4786–4792, low energy x-rays, obtained by bombarding a surface of anodized aluminum for example with a proton beam are produced by the oxygen in the oxide coating. These x-rays are of such long wave-length, e.g. > 20 A, that unless the path between the source and the detector is evacuated and a low absorption window is used, these x-rays cannot be detected. Accordingly, the detector, i.e., the silicon wafer, is exposed directly to the x-rays which are produced. That is, while x-rays are produced the window is temporarily removed.

This instrument may be used for examining different samples and, hence, must be reevacuated each time a sample is placed in the instrument. During evacuation small amounts of oil vapor and moisture are introduced into the instrument by the pump which is used. Oil vapors have a very deleterious effect on the silicon wafer, and therefore, the wafer must be protected during evacuation by a gate or window which is inserted in front of the wafer and removed after evacuation. While this insures that the wafer will not be damaged during evacuation, and insures that the low energy x-rays can be readily detected because no window is placed between the wafer and the source during operation, it is necessary to provide a means of opening the gate which can be quite cumbersome.

It is an object of the invention to provide a detector for low energy x-rays which is permanently protected both during evauccation and return to normal atmosphere and which attenuates those x-rays only slightly thereby greatly simplifying the construction and use of the detector.

SUMMARY OF THE INVENTION

Since, for detecting low energy x-rays, the detector ideally should have no window, or if a window is required, it should interface, at least on one side with a vacuum, this requires a window which is not only extremely thin, but which is not porous.

All attempts to make a window thin enough to transmit without substantial attenuation low energy x-rays, also have been found to be porous. Thus, thin resin films either break, or have pores whereas non-porous metal films such as beryllium are too thick.

Hence, in accordance with this invention, a dual window is placed between the detector and the evacuated space in which the low energy x-rays are produced. Each of the windows can be made sufficiently thin so that they transmit low energy x-rays substantially without attenuation. Yet, even though they are so thin that they are porous, the windows enclose a space which is always at the same pressure as that in the instrument so that they will not rupture or collapse. This space further in accordance with the invention is connected with the evacuable space within the instrument so that when the instrument is evacuated the space between the windows is also evacuated. A filter is provided in the passageway to remove contaminants which may enter this space when the instrument is opened to the atmosphere so that the detector, at all times, is protected.

Preferably, a solid state detector is used since it is more efficient because of its geometry and the absence of an analyzing crystal for detecting low energy x-rays. The detector is also maintained at a very low temperature cryogenically. The inner window in front of the detector serves to protect the detector from contaminants should the outer window fail.

DESCRIPTION OF THE INVENTION

FIG. **1** shows schematically an instrument for generating and detecting low energy x-rays;

FIG. **2** shows a detector, according to the invention, for low energy x-rays; and

FIG. **3**a and **3**b show in side cross-section and a section along the line A—A′ of the chamber between the two thin windows.

X-rays are produced, as an example, when electrons of sufficient potential strike a target. Each element of the target material produces x-rays having a specific wave-length which is characteristic of that element. The lower the atomic number of the element, the longer the wave-length and generally, elements below magnesium in the Periodic System of the Elements generate x-rays having wave-lengths so long, e.g. greater than 10 A, that they are readily absorbed in air and are generally designated "soft" x-rays.

Thus, as shown in FIG. **1**, a beam of electrons **1** generated by a cathode **2** is focussed by a condenser coil **3** and deflected by a coil **4** to impinge on a target **5** producing x-rays which are intercepted by a silicon-lithium detector **6**. In order to detect "soft" x-rays which may be emitted by lighter elements in the target such as oxygen, nitrogen, or carbon, the electron beam producing device as well as the target **5** and detector **6** are enclosed in an evacuable housing **7** which can be evacuated to a high vacuum, i.e. 10^{-6} mm, Hg or better, by an oil-diffusion pump, not shown. In order to remove one target and substitute another the housing must be opened to the atmosphere.

The output of the detector is amplified by an FET preamplifier **8**, which is coupled to a multi-channel analyzer **9**. The output of the analyzer, which can be set to respond to a range of elements present in the target is coupled to a recording device **10** for displaying the intensities of the x-rays emitted by the element or elements in the target.

The detector **6**, as shown in FIG. **2** is housed in a sleeve **11** which extends through the wall of housing **7** at one end of an inner sleeve **12** which is spaced from the outer sleeve **11** and forms a passageway **13** and **13***a* connecting the space in which the detector **6** is located with the interior of the housing.

Within passageway **13** a filter **14** of aluminum oxide or zeolite is provided which removes (during the cycling to atmosphere) oil vapors, and other contaminants which may be present or introduced during evacuation of the housing. Passageways **13***a* are welded to the cold finger **23** and thereby serve as additional traps for oil or water vapor.

Separating the detector **6** from the interior of the housing are two ultra-thin windows **15** and **16** which consist of a synthetic polyester resin such as Formvar, Collodion or polypropylene.

Windows **15** and **16** are mounted on rims **18** and **19** which are attached to a cylindrical screen **20.** Rim **18** is supported and located by projections **21** of the inner end of sleeve **12,** while rim **19** is supported and located by projections **22.**

These windows are so thin that they may readily rupture if the pressure differential on opposite sides of the window approaches atmospheric pressure. Consequently, when the housing is open to the atmosphere, air flows through filter **14,** passageway **13,** and tubes **13***a* into the space **17** between the windows.

The detector **6** is coupled to an FET preamplifier (shown here as part of the detector). To operate efficiently, the detector and FET must be cooled to cryogenic temperatures by a cold finger **23.** In order to avoid heating by conduction, the cold finger is separated from the inner sleeve **12** by an evacuated space which thermally insulates the cold finger.

When the housing is evacuated, air is withdrawn from the detector space **17** through tubes **13***a* and passageway **13.** Oil vapors which are generated during evacuation by the pump are prevented from reaching the detector **6** by the filter **14.** There is no danger to the detector caused by the presence of oil vapors. Moreover, because the windows are so thin, the attenuation of x-rays of even very long wave-length such as those generated by carbon and even lower atomic number elements can reach the detector without removing the window. The danger of rupturing the window is, of course, minimized by providing a plurality of conducts

13a which allows the pressure to equalize on the opposite sides of each window quickly and efficiently.

It is apparent that other modifications are possible without departing from the spirit and scope of this invention.

What is claimed is:

1. A detector for low energy x-rays adapted to operate in an evacuable chamber in which said x-rays are produced comprising a contaminant-sensitive element responsive at cryogenic temperatures to low-energy x-rays, a pair of spaced x-ray permeable membranes separating said x-rays responsive element from the interior of said chamber, said membranes defining a space which is connected with the interior of said chamber through a passageway, filter means within said passage for removing foreign materials which are capable of contaminating said x-ray-responsive element and rendering said element inoperative, and means in contact with said x-ray responsive element to maintain said x-rays responsive element at a cryogenic temperature.

2. A detector for low energy x-rays as claimed in claim **1** in which the membranes are ultra-thin synthetic resin films covered with a thin metal coating.

3. A detector for low energy x-rays as claimed in claim **2** in which the synthetic resin film is coated with a thin layer of beryllium.

4. A detector for low energy x-rays as claimed in claim **1** in which the x-ray responsive element is lithium doped silicon.

5. A detector for low energy x-rays as claimed in claim **4** in which the means for maintaining the x-ray responsive element at a cryogenic temperature is tube containing liquid nitrogen.

6. A detector for low energy x-rays as claimed in claim **1** including a housing which is insertable into said evacuable chamber and which is provided with a passageway connecting said evacuable space with the space between said membranes one of which is an end-wall of said housing within said evacuable chamber.

7. A detector for low energy x-rays as claimed in claim **2** in which the synthetic resin film is polypropylene.

8. A detector for low energy x-rays as claimed in claim **3** in which the synthetic resin film is polyproylene.

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