

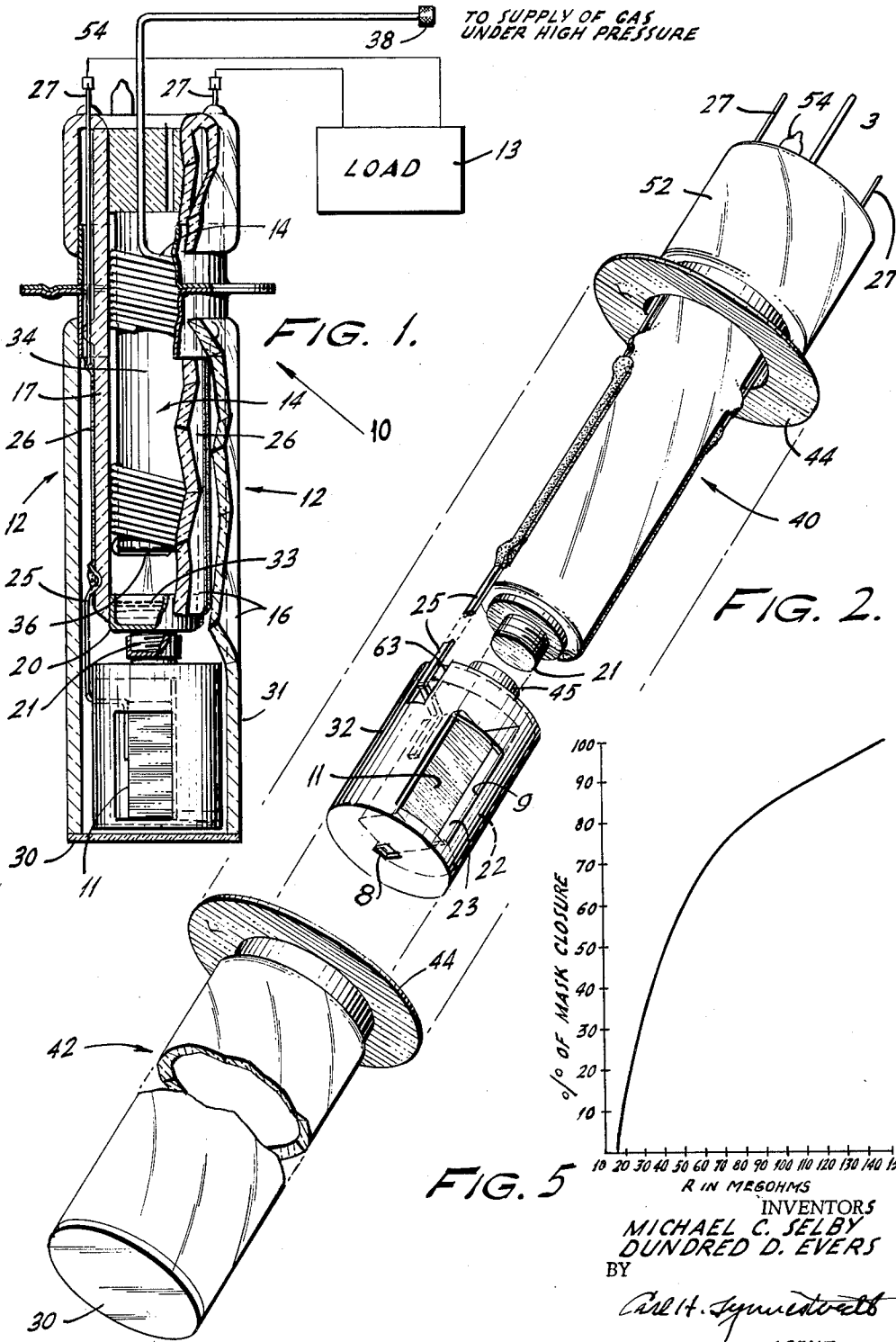
Oct. 23, 1962

M. C. SELBY ETAL  
PHOTOCONDUCTOR DEVICE

3,060,338

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2 Sheets-Sheet 1



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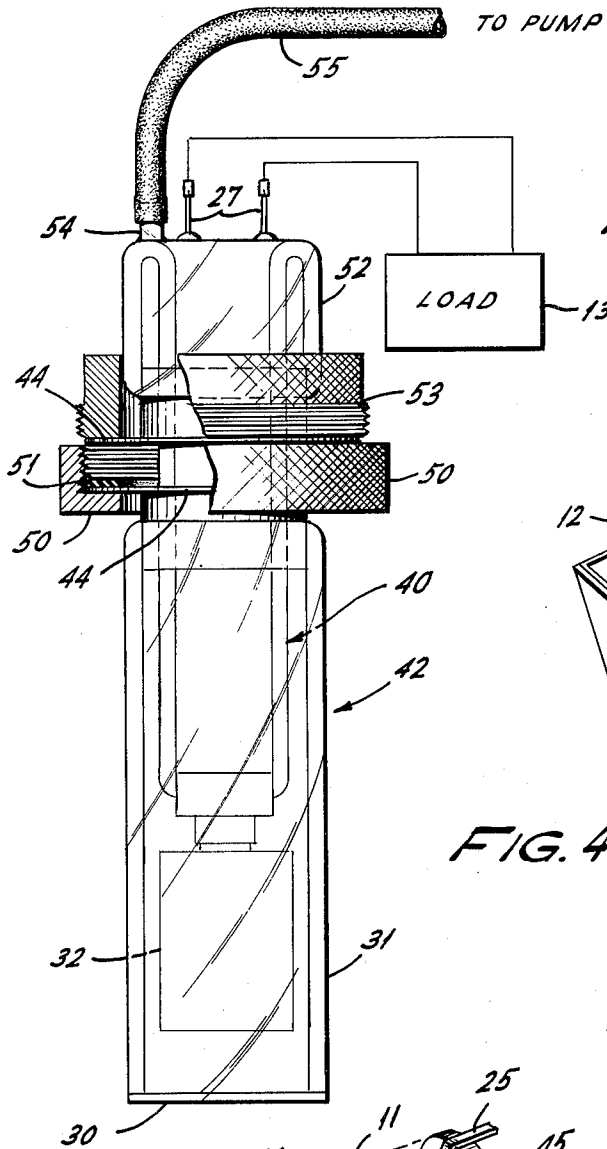


FIG. 3.

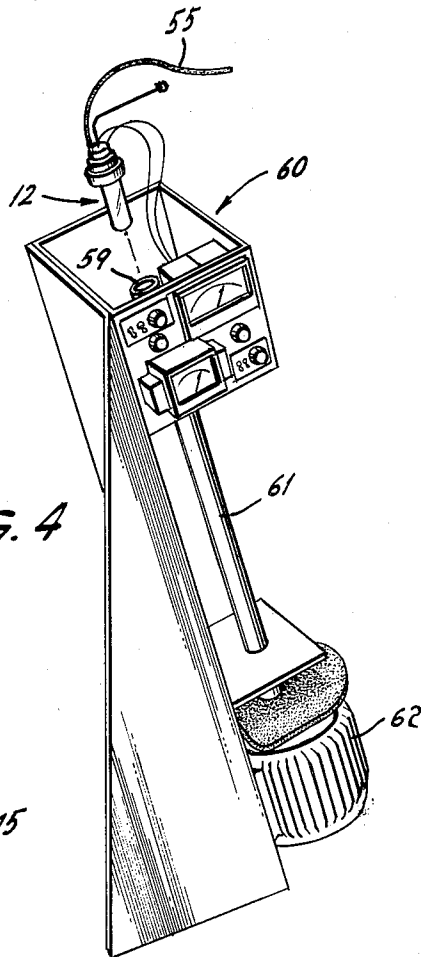


FIG. 4

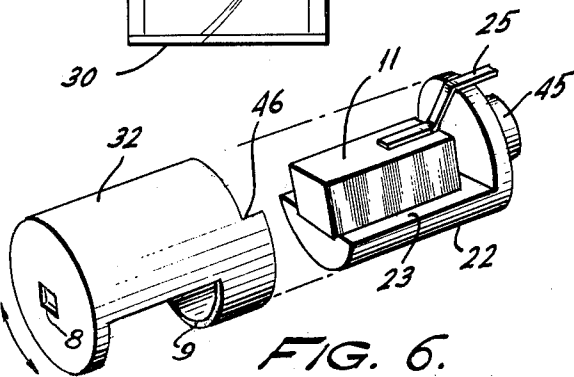


FIG. 6.

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**PHOTOCONDUCTOR DEVICE**

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3 Claims. (Cl. 313-101)

This invention relates generally to the photoconductor art and more particularly to improvements in the construction of photoconductor devices.

The term "photoconductive" as used herein is to be construed as referring to the process whereby the conductivity of a material is increased by exposure to radiation. Representative of such materials, but by no means exhaustive thereof, are the well known photoconductors such as the metal sulphides, selenides, oxides and halides and semiconductors such as germanium, silicon, and the intermetallic compounds.

Moreover, the term radiation as used in its present context refers to any radiation which results in the direct excitation of electrons. Included within this term is the gamut of photon radiation including infrared, visible, ultra violet, X-ray and gamma rays, as well as excitation induced by particles such as electrons, alpha-particles, beta-rays or other nuclear radiation. It will be understood therefore that the term photoconductivity is meant to include for present purposes the analogous phenomenon of increased conductivity produced by nuclear irradiation, a process which is commonly referred to as "bombardment-induced conductivity."

While the principles of this invention will be seen to have general application to the field of photoconductor devices generally, the invention, for illustrative purposes, will be described with reference to the fabrication of a photoconductive infrared detector employing an N-type gold-doped germanium wafer as the photoconductive element.

With the increasing use of photoconductor devices in such strategic and critical applications as space vehicle instrumentation, missile guidance, and innumerable and expanding commercial applications, it has become of paramount importance to provide means for fabricating products of uniform and predictable characteristics. Among other advantages this permits the free interchange of parts, which in numerous applications avoids the undesirable, complex and costly procedure of redesigning auxiliary and complementary equipment to compensate for parameter changes which would otherwise occur through substitution of dissimilar parts. Duplication on a mass production basis of the photoconductive material per se, which material is the heart of any photoconductor device, is consequently a highly desirable manufacturing objective.

The complexity of producing photoconductive elements to predescribed operating standards is manifest when the unpredictable behavior of photoconductive materials is taken into account. Photoconductivity is a structure-sensitive phenomenon. Depending on its impurity content and structural defects, a given material can, and does, show a baffling variety of behavior, with the result that present procedures for fabricating crystals having a predetermined impedance are largely, if not exclusively, empirical in nature. The impedance characteristics of any batch of crystals produced under similar manufacturing conditions is roughly defined by a bell curve, cells having the required impedance being selected from the resulting wide assortment. This technique is obviously both inefficient and expensive.

It is accordingly a general objective of the present in-

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vention to provide a unique method of fabricating photoconductor devices which overcomes the mentioned limitations of the prior art thereby facilitating the interchangeability of parts and permitting their economic mass production.

It is a more particularized object of the present invention to provide a novel system of controlling the impedance of a photoconductive element to permit its economic fabrication to prescribed operating parameters.

It is another object of this invention to provide a photoconductor device having unique and simplified means for controlling its rest impedance.

It is a still further object of the invention to provide a method of impedance control which is simple and inexpensive.

In achievement of the foregoing general objectives we employ a shield designed to permit the photosensitive element to view controlled amounts of background radiation. For present purposes the term "background radiation" is used to signify radiation not received directly from the source being detected and includes radiation incident upon the cell and emanating from the cell's environment. By this simple but novel expedient a cell falling within the requisite sensitivity range but having too high a resistance for some particular purpose may be custom made for any defined job by adjusting the radiation shield for increased background pickup which improves cell conductivity and lowers its resistance to the required value. In the opposite situation, namely, one in which the impedance of the cell is low, the radiation shield is adjusted for minimal background pickup.

The above and other objectives within contemplation will be apparent by reference to the accompanying detailed description and drawings, in which:

FIGURE 1 illustrates an infrared detection system embodying the present invention;

FIGURE 2 is an exploded view of the detector cell assembly shown in FIGURE 1;

FIGURE 3 is a partially sectionalized showing of test apparatus permitting preliminary adjustment of crystal impedance prior to its permanent encapsulation.

FIGURE 4 schematically illustrates one arrangement for carrying out impedance calibration;

FIGURE 5 is a graph showing the range of impedance control attainable by varying the exposure of an N-type gold doped germanium crystal to background radiation; and

FIGURE 6 is an enlarged showing of one type of shield construction and showing its manner of assembly.

Referring to FIGURE 1, there is illustrated an infrared detection system 10 the photoconductive element of which is a single crystal 11 of the type whose impedance characteristic is shown plotted in FIGURE 5. The photoconductor cell 12 which contains this crystal is normally coupled to a complex of auxiliary circuitry here schematically illustrated for purpose of simplicity as load 13. In order to optimize power transfer of the radiation induced signal resulting from the change in resistance of the photoconductive element when irradiated by infrared radiation, the impedance of the cell and load must be matched. In many situations once this impedance match is designed into the auxiliary circuitry it is impractical or undesirable from a number of standpoints to redesign or adjust the circuit each time a replacement of the radiation detecting cell takes place. To avoid this problem it is desirable to provide a replacement part having an impedance identical to that of the part being replaced.

Infrared detectors of the general type and construction shown are well known. To provide a system of requisite sensitivity, namely, one having optimum spectral response and capable of detecting small temperature differentials,

requires the germanium photoconductive element 11, to be maintained at cryogenic temperatures. Optimum results are obtainable by cooling the germanium crystal to liquid-nitrogen temperatures, i.e., to a temperature of approximately  $-196^{\circ}\text{C}$ .

In order to bring the crystal to the desired operating temperature the cooling assembly, or cryostat 14, is provided. This assembly operates on the Joule-Thomson expansion principle and is housed within a double walled insulating jacket 16 of conventional Dewar construction. Forming an hermetic closure for the reentrant, depending portion of the internally disposed tube 17 of this jacket is a metal cup 20 typically composed of a Kovar alloy or other material of high thermal conductivity.

Depending from and integral with this cup is an externally threaded stud or boss 21 onto which is screwed the cell mounting block 22. A portion of this block is provided with a flat 23, on which the photoconductive element 11 is mounted. An insulated filament 25 makes electrical connection to one face of the element, the connection to the opposed face being through the cell mounting block 22 with which the photoconductive element is in electrical contact. Platinum ribbons 26 (FIGURE 1) fused to outer surface portions of the inner tube 17 electrically interconnect the cell terminals or prongs 27 with the photoconductive element. To protect the germanium crystal 11 from atmospheric contamination while permitting its free infrared irradiation, an infrared transmissive window 30, composed for example of sapphire, seals the outside cylinder 31 hermetically encasing the germanium crystal 11. In accordance with the method aspects of the invention, cell impedance is controlled by regulating the crystal's exposure to environmental or background radiation, namely, that radiation principally emanating from structure immediately surrounding the crystal. A preferred means for accomplishing this is through use of a radiation shield 32 having an aperture 9, its method of assembly and adjustment being described in detail below.

In operation, this cell crystal is cooled by a body of liquid nitrogen 33 (FIGURE 1) which is produced and replenished within the cup 20 by means of the cryostat 14.

This cryostat comprises a plastic, cylindrical mandrel 34 upon which is helically wound a coil of finned metal tubing 35 terminating in an orifice 36. Gas is discharged from this orifice to atmospheric pressure. Nitrogen gas at a pressure of 1200 p.s.i. and at approximately room temperature is applied to the other end of the tubing through hydraulic coupling 38. The Joule-Thomson cooling produced on expansion of this gas to atmospheric pressure causes a lowering of temperature and the cooled expanded air is constrained by the inside walls of the insulating sleeve 17 to pass back over the gas conducting tube where it cools the incoming high-pressure gas. By this process of regenerative cooling the temperature at the orifice 36 is progressively lowered until the liquification temperature of nitrogen is reached.

The body 33 of liquid nitrogen thus produced within cup 20 maintains crystal 11 at a temperature approximately equal to that of liquid nitrogen. As a result, the sensitivity of this system, particularly to long-wave infrared radiation is very much greater than that attainable from systems in which the infrared detector operates at room temperatures.

Before the photoconductive element 11 is permanently encapsulated within the photoconductor cell 12 its impedance is adjusted to the prescribed value through the novel expedient of an impedance controlling radiation shield. The photoconductor cell, prior to its permanent assembly, consists of two separable halves, see FIGURE 2. The upper half 40 contains the inner tube portion 17 which carries the photoconductive cell and is insertable within the lower half or window end 42, the two parts being provided with alignable metallic flanges 44

to facilitate hermetic juncture of the two halves. The depending end of the inner tube 17 carries a threaded stud 21 which permits temporary assembly of the crystal-carrying block 22, the block being provided with an internally threaded annulus 45 engageable with the stud. Cells having the requisite sensitivity are soldered to this block and then frictionally fitted with an apertured shield 32 initially adjusted to bring the cell's impedance roughly to the value ultimately desired. This shield is further provided with an aperture or diaphragm 8 to permit controlled irradiation of the crystal 11 by radiation emanating from the source being detected. This shield is configured to provide an extensive range of adjustment through use of an elongated cut-out portion 46. (See FIGURE 6.) A typical range of impedance control obtainable by this process is shown in FIGURE 5, in which the change in impedance is plotted against variation in mask closure.

The degree of exposure necessary to produce the required impedance is usually a matter of trial and error. However, graphs of the general type illustrated in FIGURE 5 forecasting the general effect of mask adjustment permit an intelligent guess to be made as to the approximate degree of exposure needed in any particular case. In certain uncritical applications this first approximation will often be the only adjustment necessary.

Referring to FIGURE 3 there is shown apparatus adapted to permit impedance adjustment of the cell under actual environmental conditions without the necessity of permanently encapsulating the crystal. The apparatus consists of an internally threaded cap 50 constructed to accommodate the flange elements 44. With the window end 42 of the cell in position as shown, a gasket 51 of suitable material, such as rubber, is positioned over the flange 44 of the tube's lower half and the upper half of the cell, with the shield's crystal mounted, is lowered into the cavity defined by the glass tube 31. An externally threaded plug 53 apertured to pass the hat portion 52 of the cell's upper half mates with the cap 50 permitting compression of the flange-gasket assembly into air-tight closure. The cell is then evacuated through exhaust tubulation 54, the cell being connected to a pump (not shown) by flexible hosing 55. With the unit thus temporarily assembled the cryostat 14 is inserted within the cavity formed by the reentrant tube portion 17, liquid nitrogen is applied and the temperature of the crystal reduced to approximately that of liquid nitrogen. The cell 12, see FIGURE 4, is then placed within a well 59 provided in a test fixture 60 the well communicating through a tube 61 with a radiating body 62. The background radiation seen by the cell when inserted within well 59 is that emanating from the cell's enclosing structure which for all practical purposes is at ambient temperature. This background radiation is substantially identical to that which the photoconductive element will see under actual operating conditions. For calibration purposes the cell's sensitivity in terms of  $500^{\circ}$  black body response is measured and its impedance determined. If the cell meets the sensitivity requirement and the impedance is out of specification the unit is disassembled, the radiation shield 32' repositioned, and the measurements made again. This process is repeated until the desired impedance level is reached. The radiation shield 32' may at this stage be replaced by one having a slot 63 (FIGURE 2) custom fit for that particular cell but of a width sufficient to permit a limited range of adjustment if deemed desirable. Following this the two halves of the cell are joined at flange elements 44 by means of a "Helicare" weld or other suitable method, and the Dewar flask is again evacuated and the exhaust tubulation 54 pinched off. The mask or shield 32 is normally merely frictionally locked in place but may, if desirable, be anchored as by soldering, crimping, or by other suitable means.

In summary, we have discovered a unique method and

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means for regulating the impedance of a photoconductive element, which method basically consists of providing the radiation-sensitive element with means adjustable to regulate the exposure of said element to background radiation incident thereupon to control the element's rest impedance. By this simple, inexpensive technique the limitations of the prior art are avoided permitting the simplified custom tailoring of photoconductive elements to a predetermined impedance characteristic.

Although the invention has been described with particular reference to specific practice and embodiments it will be understood by those skilled in the art that the apparatus of the invention could be changed and modified without departing from the essential scope of the invention as defined in the appended claims.

We claim:

1. A radiation detecting device, comprising: a photoconductive body having a rest operating characteristic dependent upon its irradiation by background illumination; and shield means having a first aperture providing for exposure of a portion of said body to radiation emanating from a source to be detected and having a second aperture for regulating the rest characteristic of said body through movement of said second aperture relative to said body to provide variable shielding of other portions of said body from background radiation.

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2. A radiation detecting device, comprising: a photoconductive body having a rest impedance dependent upon its irradiation by background illumination; shield means having a first aperture providing for exposure of a portion of said body to radiation emanating from a source to be detected and second aperture means for regulating the rest impedance of said body through movement of said second aperture means relative to said body to provide variable shielding of other portions of said body to background radiation.

3. A radiation detecting device, comprising: a photoconductive body having a rest impedance dependent upon its irradiation by background illumination; a shield having a first aperture providing for exposure of a portion of said body to radiation emanating from a source to be detected and second aperture means for regulating the rest impedance of said body through selective shielding of said body from background radiation.

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