April 6, 1954 N. C. ANDERSON ET AL 2,674,677

PHOTOCONDUCTIVE CELL

Filed March 17, 1951

FIG. 1

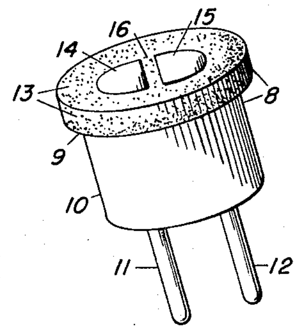


FIG. 2

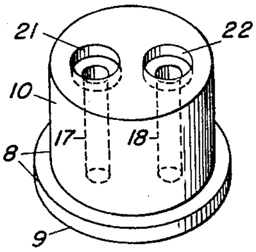


FIG. 3

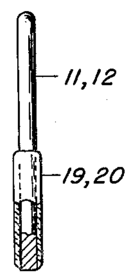


FIG. 4

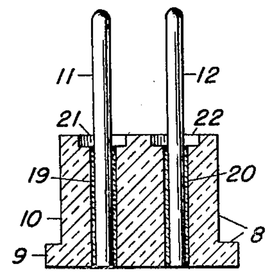


FIG. 5

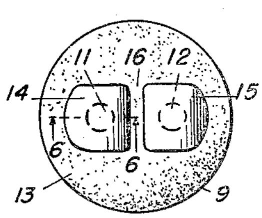


FIG. 6

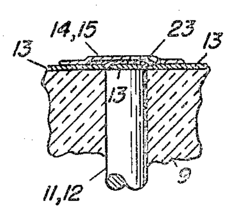
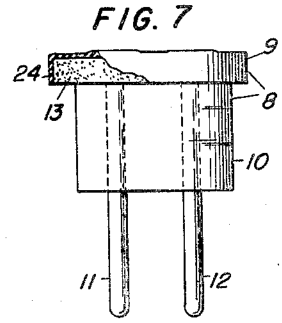


FIG. 7



INVENTORS N.C. ANDERSON
P.N. BREDESEN
P.J. CADE

BY A. T. Downs

ATTORNEY

Patented Apr. 6, 1954 2,674,677

UNITED STATES PATENT OFFICE

2,674,677

PHOTOCONDUCTIVE CELL

Norman C. Anderson, Auburndale, Philip N. Bredesen, Arlington, and Phillip J. Cade, Winchester, Mass., assignors to Combustion Control Corporation, Cambridge, Mass., a corporation of Massachusetts

Application March 17, 1951, Serial No. 216,226

5 Claims. (Cl. 201—63)

1

This invention relates to improvements in photoelectric cells of the photoconductive type.

An object of this invention is to decrease the size of photoconductive cells.

Another object is to improve the mechanical reliability of photoconductive cells.

Another object is to simplify photoconductive cells whereby such cells can be fabricated more easily and cheaply.

Most of the practical photoconductive cell structures of the prior art have comprised a variety of photoconductive materials positioned within different types of hermetically sealed envelopes. Generally speaking, these envelopes were similar to or the same as those utilized for enclosing the electrode structures of vacuum tubes. The photoconductive materials were either deposited or otherwise applied directly to the inner envelope walls, or they were supported by additional structure located within the envelopes. Simple electrodes or complex grid structures were used to make direct electrical connections to the photoconductive materials, and conventional feed-through pins sealed in the envelope walls provided the necessary external connections to the electrodes or grid structures.

The fabrication of these photoconductive cells was relatively difficult and expensive because of the complex and time-consuming procedures required. In particular, the preparation of the glass envelopes to receive the photoconductive materials, the positioning of the electrodes or grid structures within the envelopes, and the sealing of the feed-through pins to the envelope walls could only be performed by skilled technicians. Moreover, the evacuating, filling, and hermetically sealing of the envelopes added considerably to the cost and time required to process these cells.

The prior art cells were also extravagant in the amount of material consumed in housing a relatively small amount of photoconductive material. That is, a relatively large cell envelope was always used to enclose a small area of photoconductive material of extreme thinness because of the ease of assembly within a large envelope and the consequent manufacturing economy. However, the relatively large size of these cells precluded their use in many applications for which they were otherwise admirably suited.

Some of the objections to photoconductive cells of the hermetically sealed envelope type were overcome by a radically different structure. This structure comprised a solid glass disc having a complex grid applied thereto and upon which

2

grid a thin coat of photoconductive material was deposited. The active surface surrounding the grid was sealed from harmful oxidizing vapors by a thin coat of paraffin. This assembly was coupled and interconnected to supporting means having conventional pins for mating with a socket.

This structure was relatively difficult to fabricate, however, notwithstanding the absence of an envelope, because of the complex grid and the necessity for interconnecting the end terminals of the grid to the pins of the supporting means. Furthermore, the size of this cell was unduly large because of the complex grid.

Accordingly, a preferred embodiment of the photoconductive cell of this invention contemplates two metallic pins mechanically coupled to one another by a small glass bead having a solid, cylindrical shape. Approximately half of the shaft of each of these pins protrudes from the bead so that the bead assembly can be coupled to a two-prong female socket.

The non-protruding ends of each of the pins are, preferably, flush with one of the circular, flat surfaces of the cylindrical bead whereby a small portion of the bead surface appears therebetween. A thin layer of photoconductive material is deposited directly to this flat surface, thereby electrically interconnecting the two pins. A set of electrodes, applied directly upon the surface of the photoconductive material and over the pin ends, assures the permanence of the electrical contact between the flush pin ends and the layer of photoconductive material. The entire bead surface covered with photoconductive material, and also the exposed electrode surfaces, are coated with a sealing compound whereby the active surface of the cell is isolated from the effects of water vapor and other oxidizing fluids, thereby stabilizing the characteristics of the cell.

The area of the photoconductive material common to both electrodes is the active portion of the cell. When the appropriate wave lengths of radiant energy impinge thereupon, the electrical impedance of the cell, as measured between the two pins, varies in the manner characteristic of photoconductive materials.

The advantages of this cell structure are numerous. Most important of all, photoconductive cells can now be constructed in small sizes hitherto unattainable. If lead sulfide is used as the photoconductive material, for example, the bead may be of the order of .12 inch in its largest dimension. The cells are also easily and economically fabricated by relatively unskilled technicians because of the simple design which in no way requires the use of envelope evacuating, filling and sealing procedures, or the complex interconnection of parts. Furthermore, because the cell structure of this invention is essentially a solid mass, it is capable of withstanding considerable mechanical and thermal stresses.

In order that all of the features of this invention and the mode of operation thereof may be readily understood, a detailed description follows hereinafter with reference being made to the drawings, wherein:

Fig. 1 is a perspective view of a preferred embodiment of the photoconductive cell of this invention with the protective cell cover removed;

Fig. 2 is a perspective view of a blank suitable for use as a body for the cell shown in Fig. 1;

Fig. 3 is an elevational view, partly in section, of a pin utilized in the cell of Fig. 1;

Fig. 4 is a sectional view of the ceramic blank shown in Fig. 2, with two pins shown in full inserted therein;

Fig. 5 is a plan view of the active portion of the cell shown in Fig. 1;

Fig. 6 is a partial sectional view taken along line **6**—**6** of Fig. 5, and showing the means for mechanically and electrically coupling a cell pin to the surrounding photoconductive material; and

Fig. 7 is an elevational view of the cell shown in Fig. 1 with part of the cover which seals the active portion of the cell removed.

The preferred embodiment of the photoconductive cell of this invention shown in Fig. 1 comprises a glass or ceramic body **8** having a disc-shaped, upper portion **9**, and a cylindrical, lower, supporting portion **10**. From a generic aspect, however, the bead may assume practically any shape that is capable of supporting a layer of photoconductive material. Moreover, the cell shown in Fig. 1 is an end view cell. If a different directional response is required, appropriate changes must be made in the geometrical shape of the active area exposed to the impinging radiation. This can be accomplished, generally, by changing the bead shape to form the desired geometrically shaped active area.

Metallic pins **11** and **12** are sealed to body **8** so that a substantial part of the pin shafts protrude therefrom. The opposite ends (not shown) of pins **11** and **12** are flush with the upper surface of disc portion **9**. The top and side surfaces of the disc portion **9** are covered with a layer of photoconductive material **13**. Electrodes **14** and **15** mechanically and electrically couple the flush ends of pins **11** and **12** (not shown) to the thin layer of photoconductive material **13** whereby the electrical impedance measured between pins **11** and **12** is determined, principally, by the small area of photoconductive material **13** at **16** between electrodes **14** and **15**.

The photoconductive material at **16** is the active portion of the cell structure, that is, the appropriate wave lengths of radiant energy must impinge thereupon to cause the characteristic photoconductive impedance variation. The exposed surface of photoconductive material **13** is, preferably, covered by a protective coating of sealing compound (not shown) whereby the active area at **16** is isolated from water vapor and other oxidizing fluids which tend to impair the stability of the cell.

The cell structure shown in Fig. 1 is several times larger than the actual size of the preferred embodiment. For example, electrodes **14** and **15** are spaced from one another by the relatively short distance of approximately .06 inch, and the top, circular surface of disc portion **9** which supports these electrodes has a diameter of approximately .30 inch. Similar cells have been constructed, however, wherein the largest dimension of the cell was of the order of .12 inch.

Electrical circuit connections are made to the cell by inserting pins **11** and **12** into a small-sized, two-prong female socket. The projecting rim of disc portion **9** with respect to body portion **10** merely facilitates the manual insertion and removal of the cell from its socket and is, therefore, not actually required for the operation of the cell.

The detailed fabrication of the cell of Fig. 1 is as follows: the initial step comprises the construction of the blank of body **8** shown in Fig. 2. This blank is, preferably, of an insulating material, such as glass or most ceramics, so as not to create an electrical conducting path between the pins which are to be ultimately sealed thereto. The cell will function with decreased sensitivity, however, even though the blank is constructed of a semi-conducting material.

Pin holes **17** and **18** are drilled or otherwise formed so as to pass completely through body **8** from its upper to its lower surface. The diameter of these holes should be sufficiently large to receive the glazed portion **19**—**20** of pin **11**—**12** shown in Fig. 3. After the pins **11** and **12** are inserted therein as shown in Fig. 4, cups **21** and **22** are filled with solder glass and the entire assembly is heated in an oven until the pins are mechanically bonded to body **8** by the resulting flow and hardening of the solder glass within cups **21** and **22**, and the glass of the glazed portions **19** and **20** of pins **11** and **12**, respectively. It should be obvious, however, that pins **11** and **12** are not limited to the construction shown in the drawings, nor need they necessarily be sealed to body **8** in the manner hereinbefore described.

Body **8** is not affected as to form by this heating process because it has a melting temperature higher than the oven temperature used to seal pins **11** and **12** thereto.

The circular, top surface of disc portion **9** is then ground with a fine polish to remove any impurities appearing therein, and the entire assembly is thereafter cleaned by a conventional cleaning method, such as immersion in an acid bath.

Photoconductive material **13** is then deposited or otherwise applied to at least the circular, top surface of disc portion **9** between and immediately surrounding the flush ends of pins **11** and **12**. From a generic aspect, however, the photoconductive material can be applied to the entire, exposed surface of body **8**, with but a relatively slight loss of sensitivity because of the partial shorting effect thereof upon the active area **16** of photoconductive material between electrodes **14** and **15**. The sensitivity of the cell is proportionately higher, however, if photoconductive material **13** is applied only to the top and side surfaces of disc portion **9**, as is shown in Fig. 1.

The application of photoconductive material **13** can be performed by methods and apparatus well known in the photoconductive cell art and used heretofore, for example, to deposit photoconductive material directly to the inner glass walls of cells having hermetically sealed envelopes. The activation of photoconductive material **13** after or during its application can, likewise, be performed by methods and apparatus well known in the art. The application and activation of photoconductive materials is discussed in "Photoelectricity and Its Application" by Zworykin and Ramberg, pages 175–195, 1949 edition, and also the references cited therein.

In the usual case, there is a sufficiently large mechanical discontinuity between the flush ends of pins 11 and 12 and the adjacent, polished, top surface of disc portion 8, to cause a corresponding circular cracking of the applied photoconductive material 13. The presence of these cracks causes the impedance of the cell, as measured between pins 11 and 12, to assume a variable and unpredictable, unstable value; therefore, electrodes 14 and 15, shown in plan view in Fig. 5, are applied directly to photoconductive material 13 in the locale of pins 11 and 12 so as to electrically bridge these cracks. Electrodes 14 and 15 can be of gold evaporated upon photoconductive material 13 through an electrode mask, or they can be the resulting solid deposited by the spraying or brushing of an aqueous colloidal suspension, such as aquadag. The spacing and the width of electrodes also accurately define the active area 16 of the cell. An improved electrical and mechanical bond can be provided between electrodes 14 and 15 and the underlying photoconductive material 13 by applying a thin deposit of silver paste 23 upon the surface of photoconductive material 13, as is shown in the partial sectional view of Fig. 6.

The active area of the cell may be accurately defined, however, by utilizing pins having a square shaft or the like, or, in applications wherein such definition is not necessary, the electrodes may be eliminated if the photoconductive material adheres sufficiently to the pins to make a good electrical connection thereto.

The entire exposed surfaces of photoconductive material 13 and electrodes 14 and 15 are, preferably, isolated by cover 24 shown in Fig. 7, a portion of which cover is removed merely to improve the clarity and understanding of the figure. This cover hermetically seals photoconductive material 13 from the effects of water vapor and other oxidizing fluids so that the cell characteristics will be maintained for a relatively long period of time. From a generic aspect, however, the novel structure of this invention will function without a cover, but with less satisfactory characteristics. The material used for cover 24 should, preferably, readily transmit the frequencies of radiant energy to which photoconductive material 13 is responsive. A compound manufactured by the General Electric Company and sold as "Silicone Compound, No. 9980," is satisfactory for use with most photoconductive materials.

Optimum perforance has been attained by the novel cell structure of this invention by utilizing activated lead sulfide for photoconductive material 13. In particular, the sensitivity and resistance characteristics of lead sulfide are conducive to a minimum cell size of the order of .12 inch, high sensitivity, and a cell output impedance sufficiently low for direct coupling to conventional amplifying apparatus.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. A photoconductive cell, comprising a plurality of conducting pins, a solid bead of insulating material mechanically coupling said pins to one another so that one of the ends of each of said pins is flush with a common surface of said bead, a thin layer of photoconductive material deposited upon said surface and said flush pin ends thereby electrically interconnecting said pins, and a compound covering for isolating said photoconductive material from oxidizing fluids.

2. A photoconductive cell as defined in claim 1 wherein said photoconductive material is activated lead sulfide.

3. A photoconductive cell, comprising two elongated conducting pins, a solid unitary bead having a disc-shaped circular upper portion with a diameter of approximately .30 inch and a cylindrical lower supporting portion with a diameter of less than .30 inch whereby said bead includes a projecting rim, said pins being mechanically coupled by said bead so that one of the ends of each of said pins is flush with the fully exposed circular surface of said disc-shaped upper portion, a layer of photoconductive material deposited upon said exposed circular surface and said flush pin ends thereby electrically interconnecting said pins, two electrodes applied to said layer of photoconductive material so as to accurately define the active area of said cell and improve the mechanical and electrical bonding of said flush pin ends to said photoconductive material, and a protective compound covering hermetically sealing said layer of photoconductive material.

4. A photoconductive cell as defined in claim 3 wherein said photoconductive material is activated lead sulfide.

5. A photoconductive cell, comprising a pair of conductor pins, a solid bead of insulating material mechanically coupling said pins to one another so that one end of each of said pins protrudes from said bead, a thin layer of photoconductive material, mechanical means to support said thin layer, and electrical means to connect said layer across the other ends of said conductor pins.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,316,350	Case	Sept. 16, 1919
1,697,451	Baird	Jan. 1, 1929
1,790,736	Wald	Feb. 3, 1931
2,036,457	Calsow	Apr. 7, 1936
2,327,487	Bach	Aug. 24, 1943
2,423,476	Billings	July 8, 1947
2,448,516	Cashman	Sept. 7, 1948
2,480,113	Betzler	Aug. 30, 1949
2,516,873	Havens	Aug. 1, 1950
2,547,173	Rittner	Apr. 3, 1951