

Dec. 22, 1959

F. W. PARRISH

2,918,612

RECTIFIER

Filed Aug. 19, 1957

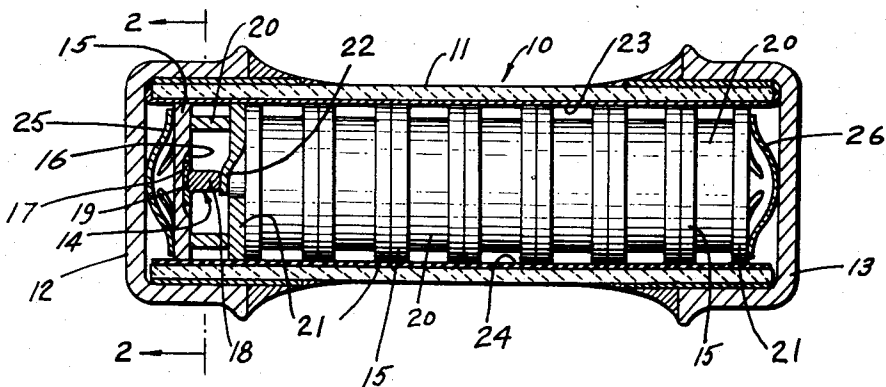


FIG. 1.

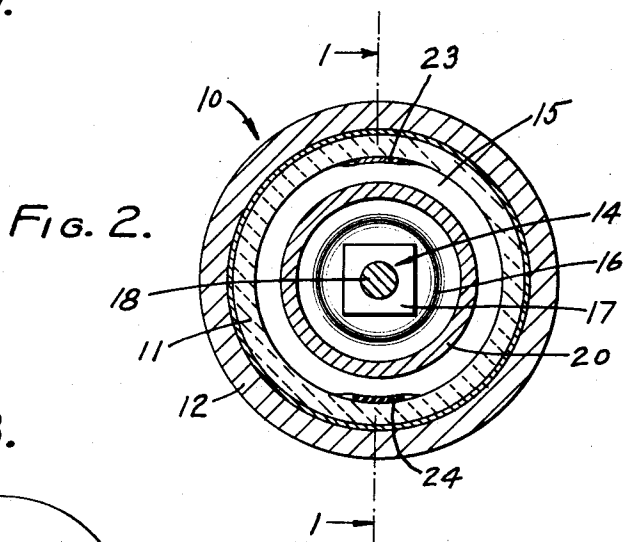
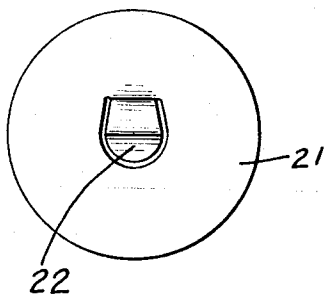


FIG. 3.



INVENTOR.
FRANK W. PARRISH

BY

D. Gordon Angus
ATTORNEY

1

2,918,612

RECTIFIER

Frank W. Parrish, Lakewood, Calif., assignor to International Rectifier Corporation, El Segundo, Calif., a corporation of California

Application August 19, 1957, Serial No. 678,984

11 Claims. (Cl. 317—234)

This invention relates to rectifiers, and particularly to a means for reducing corona discharge therein.

It frequently is observed that a great deal of corona discharge is developed that is bothersome to surrounding electrical circuits when rectifiers, particularly of the crystal junction type, are operated at relatively high voltages. An object of this invention is to provide in a hermetically sealed crystal junction rectifier, a means for reducing corona discharge therein. An allied object is to improve the heat transfer characteristics of such a rectifier so as to enable the capacity of a rectifier of a given size to be uprated by reducing its working temperature. Rectifier ratings are drastically cut as temperatures increase, and a means for reliably improving heat transfer and thereby lowering the operating temperature of a rectifier permits a rectifier of a given size to be used to handle a larger load than is possible at a higher temperature.

According to this invention, an impermeable envelope encloses a rectifier which may be a crystal junction type rectifier, along with a quantity of a fluorochemical substance selected from the group consisting of $C_8F_{16}O$ and $(C_4F_9)_3N$.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 is a cross section of a rectifier incorporating this invention taken at line 1—1 of Fig. 2;

Fig. 2 is a cross section taken at line 2—2 of Fig. 1; and

Fig. 3 is a plan view of a part of the rectifier of Fig. 1.

As shown in Fig. 1, a rectifier assembly 10 has an outer envelope which includes a cylindrical tube 11 and a pair of conductive metallic caps 12, 13. The tube 11 may be made of any suitable insulating material, such as porcelain, glass, or other ceramic, and has an opening at both ends. These openings are closed by the metallic caps to provide a hermetic seal for the space within the envelope.

A crystal junction rectifier 14 is shown in detail in Fig. 1. This rectifier includes a base plate 15 which is provided with a dimple 16 at the center thereof. Within this dimple there is soldered or otherwise conductively affixed to said base plate a wafer 17 of a semi-conductor material such as silicon or germanium. In the practice of this invention, silicon is the preferred semi-conductor element.

An anode contact 18 is welded to the free surface of the wafer 17. This anode contact is made of one of or a mixture of metals belonging to group III of the periodic chart of the elements, aluminum being the preferred substance when silicon is used. The welding of the anode contact to wafer 17 produces a crystal junction 19 which is shown as a curved line in cross section in Fig. 1. The rectifying action of the rectifier is thought to take place at this junction. An insulating spacer washer 20 abuts the base plate on the same side as the wafer and has a somewhat lesser diameter than the base plate. A contact washer 21 bears against the spacer washer and has a tongue 22 punched in its center which makes contact with

2

the anode contact 18 of the crystal junction rectifier. It will thereby be seen that a unidirectionally conductive circuit can be established between the base plate 15 and the contact washer 21. The crystal junction rectifier 14 just described is repeated as many times as desired in order to build up the necessary load carrying and voltage resisting rectifier assembly.

In order to improve the division of voltage in the reverse direction of current flow, a voltage divider strip 23 is laid along the wall of the tube 11 in contact with the edge of each of the base plates and contact washers. This voltage divider strip has a resistance which is somewhat less than the resistance of the cells in the reverse direction of current flow, of the order of magnitude of about 75% of the least resistance of the rectifier stack, which least resistance occurs at high temperature. There is thereby provided a shunt circuit for current flow alongside and in parallel with the rectifiers which causes an approximately equal voltage division between the individual rectifiers 14, this strip acting as a voltage divider. It will be understood that the resistance of this divider strip will be high enough that it does not amount to a complete shunt for a major portion of the current. On the directly opposite side from the voltage divider strip there is a compression strip 24 made of elastic rubber or other soft material which tends to maintain the spacer washers and the base plates in contact with the voltage divider strip.

Spring contacts 25 and 26 are provided in contact with metallic caps 12 and 13, and bear respectively against the left and right hand crystal junction rectifiers 14. That is, spring contact 25 bears against the base plate 15 of the left hand rectifier 14, and spring contact 26 bears against the right hand contact washer 21 of the right hand rectifier 14. In this manner, the rectifiers are held compressed against each other and the contacts 25 and 26 provide conductive means by which the metal caps are connected to opposite sides of the rectifier stack.

It will be noted that the spacer washers 20 limit the amount of compression which can be exerted on the surface of the anode contact and thereby upon the wafer 17.

A silicon, crystal junction type rectifier in which this invention may favorably be carried out has been disclosed above. According to this invention, the space within the envelope is provided with a quantity of a substance for reducing corona. It has been found that in operation, rectifiers of the type described above often produce an undesirable amount of radio noise and corona. By providing a dielectric within the envelope as set forth below, a marked and striking diminution in noise and corona is obtained. It is better for the space within the envelope to be substantially completely filled with this substance, allowing only room for thermal expansion. However, occasionally better cooling can be obtained by using a lesser amount of substance so that a substantial quantity of the substance can be in the vapor or gaseous state, and the rest in a liquid state for improving thermal transfer.

The substance for reducing corona is selected from a group consisting of compounds with the empirical formula $C_8F_{16}O$ and $(C_4F_9)_3N$. Both of these compounds are completely fluorinated. That is, all of their hydrogen has been replaced by fluorine. This appears to account for many of their favorable qualities. The former compound is sold by Minnesota Mining and Manufacturing Co., 900 Fauquier Avenue, St. Paul, Minnesota, under the trade name Fluorochemical O-75, and the latter is sold by the same company in Minnesota under the trade name Fluorochemical N-43. Both of these substances are notable for their inertness at ordinary temperatures, ordinary temperatures being defined as the region between approximately $-60^\circ C.$ and $+300^\circ C.$ Both of these compounds are also very stable thermally, the former

being able to be heated as high as 600° and the latter as high as 500° C. without evidence of decomposition.

The structure of the substance having the empirical formula $C_8F_{16}O$ has not been definitely established, but it is believed to contain a 5 or 6 membered ring with a fluorinated side chain. The oxygen atom is contained in the ring. This substance appears to be a completely fluorinated cyclic ether.

The substance having the empirical formula $(C_4F_9)_3N$ is a completely fluorinated tributyl amine, having the name heptacosafuorotributylamine. Although the substance has the structure of a tertiary amine it has none of the properties usually associated with this type of compound.

The above compounds are also identifiable and definable by some of their physical properties which are as follows:

	$C_8F_{16}O$	$(C_4F_9)_3N$
Boiling point, ° C.	101	177
Density (g./cc. at 25° C.)	1.760	1.872
Refractive index (25° C.)	1.276	1.2910
Specific heat (Cal./g. ° C. at 25°-40° C.)	0.26	0.27
Dielectric strength (ASTM-D377), kv.	37	40
Dielectric constant (100 cy./sec. at 25° C.)	1.85	1.86
Volume resistivity (ohm-cm. at 25° C.)	10^{14} - 10^{16}	10^{14} - 10^{16}
Formula weight	416	671

When a rectifier of the type shown in the drawings is even partially filled with either of the above substances or with a mixture of the two, a marked reduction, even to the point of entire elimination of corona and radio noise in normal rectifier operating range is obtained. In addition, thermal heat transfer is greatly improved.

The term "envelope" as used herein denotes structure which surrounds the crystal junction rectifier. Primarily, this envelope comprises the tube 11 and caps 12 and 13. These elements enclose the entire structure. In addition, insulating spacer washers 20 form a secondary portion of the envelope when imperforate, but would not form a part of the envelope if perforated. It will be observed that there is a spacing between at least part of the rectifier structure and the envelope; for example, the space between cap 12 and the left-hand face of base plate 15, as shown in Fig. 1. Other spacings shown are between the right-hand face of all of the base plates and the inside surface of the spacer washers (if imperforate), and between the outside surface of the spacer washers, the portion of the base plates outside thereof, and the tube 11. Preferably, the fluorochemical will bathe the surfaces of the rectifier that are spaced from the tube. Whether it also contacts the tube is not critical, although a completely filled assembly is desirable.

When only a portion of the space within the envelope is filled, the contact of the hot crystal junction rectifier with the substances will tend to vaporize them and the vapor will transfer its heat at the envelope boundary, where it is condensed and thence flows back to the rectifier. It is perhaps more favorable, however, to have a liquid to liquid contact between the tube wall and the dielectric, wherein the above substance makes direct contact in its liquid state with both the junction and the inside of the envelope for improving thermal transfer between the two.

This invention is not to be limited by the embodiments shown in the drawings and described in the description, which are given by way of example and not of limitation, but only in accordance with the scope of the appended claims. Particularly with respect to the construction of the hermetically sealed rectifier in which the fluorochemical is used, it is to be recognized that while the aforesaid silicon rectifier appears to benefit from the use of fluoro-chemicals more than any other known type of rectifier, other types of rectifiers also show improve-

ments from the use of said substances. Therefore, the type of rectifier, or the configuration of the hermetically sealing envelope is not a limitation on this invention.

I claim:

1. A hermetically sealed rectifier comprising: a crystal junction for rectifying current supplied thereto; a gas-tight envelope enclosing said junction; a quantity of a substance selected from the group consisting of $C_8F_{16}O$ and $(C_4F_9)_3N$ within said envelope and in contact with said junction for reducing corona discharge during operation of said rectifier; and electrically conductive means included in said envelope and connected to said junction for providing electrical connections to said rectifier.

2. Apparatus according to claim 1 in which the $C_8F_{16}O$ is a completely fluorinated cyclic ether, characterized by its chemical inertness at ordinary temperatures, boiling point of 101° C., density at 25° C. of 1.760 grams/cubic centimeter, refractive index at 25° C. of 1.276, and specific heat of 0.26 calorie/gram/° C. at 25-40° C.; and in which the $(C_4F_9)_3N$ is heptacosafuorotributylamine, characterized by its chemical inertness at ordinary temperatures, boiling point of 177° C., density at 25° C. of 1.872 grams/cubic centimeters, refractive index at 25° C. of 1.2910, and specific heat 0.27 calorie/gram/° C. at 25-40° C.

3. Apparatus according to claim 2 in which the crystal junction comprises a silicon wafer and an anode contact conductively attached thereto.

4. A hermetically sealed rectifier comprising: an envelope comprising an insulator tube have an opening at each of its ends and a conductive cap at each of said ends for closing the openings; a crystal junction rectifier within said envelope, said crystal junction including a wafer of semi-conducting material and an anode contact conductively attached thereto; means making an electrical connection between said wafer and one of said caps; means making an electrical connection between said anode contact and the other of said caps; and a quantity of a substance selected from the group consisting of $C_8F_{16}O$ and $(C_4F_9)_3N$ within said envelope for reducing corona discharge during operation of said rectifier.

5. Apparatus according to claim 4 in which the $C_8F_{16}O$ is a completely fluorinated cyclic ether, characterized by its chemical inertness at ordinary temperatures, boiling point of 101° C., density at 25° C. of 1.760 grams/cubic centimeters, refractive index at 25° C. of 1.276, and specific heat of 0.26 calorie/gram/° C. at 25-40° C.; and in which the $(C_4F_9)_3N$ is heptacosafuorotributylamine, characterized by its chemical inertness at ordinary temperatures, boiling point of 177° C., density at 25° C. of 1.872 grams/cubic centimeter, refractive index at 25° C. of 1.2910, and specific heat 0.27 calorie/gram/° C. at 25-40° C.

6. Apparatus according to claim 5 in which the wafer consists of silicon and the anode contact consists essentially of a group III metal.

7. Apparatus according to claim 6 in which the anode contact consists essentially of aluminum.

8. In a hermetically-sealed crystal-junction type rectifier assembly in which a crystal junction rectifier is enclosed in an envelope, there being a spacing between at least part of the rectifier and the envelope, a quantity of a substance selected from the group consisting of $C_8F_{16}O$ and $(C_4F_9)_3N$ in said spacing and in contact with the rectifier for reducing corona discharge during operation of the rectifier.

9. Apparatus according to claim 8 in which the $C_8F_{16}O$ is a completely fluorinated cyclic ether, characterized by its chemical inertness at ordinary temperatures, boiling point of 101° C., density at 25° C. of 1.760 grams/cubic centimeter, refractive index at 25° C. of 1.276, and specific heat of 0.26 calorie/gram/° C. at 25-40° C.; and in which the $(C_4F_9)_3N$ is heptacosafuorotributylamine, characterized by its chemical inertness at ordinary temperatures, boiling point of 177° C., density at 25° C. of

1.872 grams/cubic centimeter, refractive index at 25° C. of 1.2910, and specific heat 0.27 calorie/gram/° C. at 25-40° C.

10. Apparatus according to claim 9 in which the junction rectifier is a silicon rectifier.

11. Apparatus according to claim 10 in which there is a plurality of rectifiers in said envelope arranged in a stack.

5

2,462,911

2,750,540

2,817,797

References Cited in the file of this patent

UNITED STATES PATENTS

Skinker ----- Mar. 1, 1949

Waldkotter et al. ----- June 12, 1956

Coyle ----- Dec. 24, 1957