Nov. 19, 1968 D. SCIAKY 3,412,294

ARRANGEMENT OF THE DIODE AS A SINGLE UNIT AND IN A GROUP

Filed Aug. 30, 1965 3 Sheets-Sheet 1

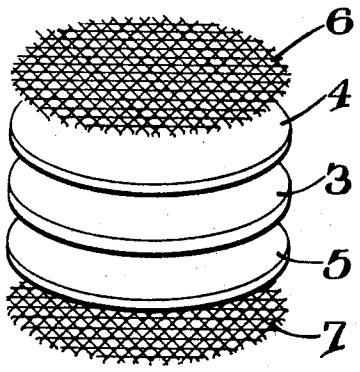


Fig. 4

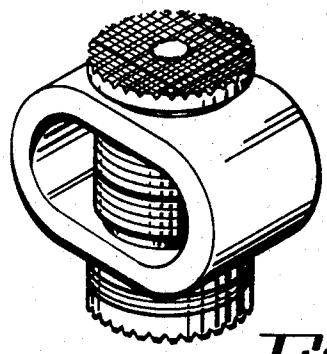


Fig. 3

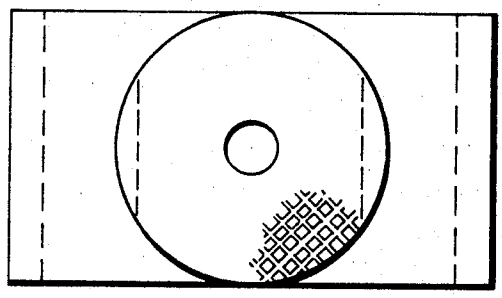


Fig. 2

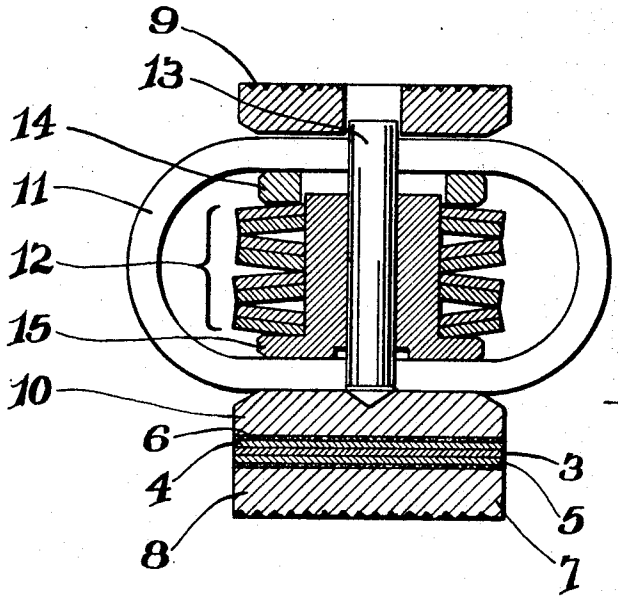


Fig. 1

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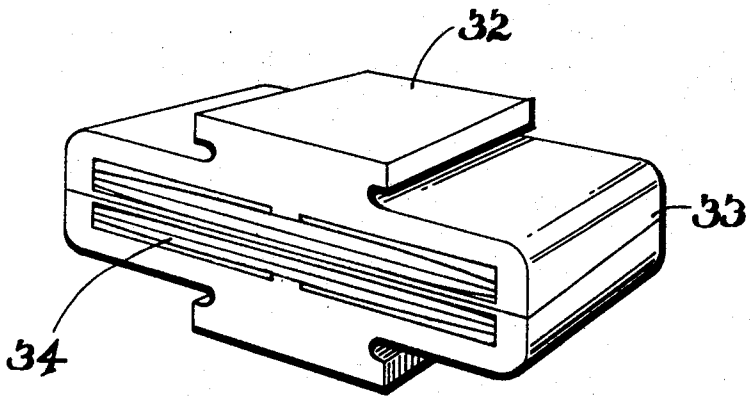


Fig. 6

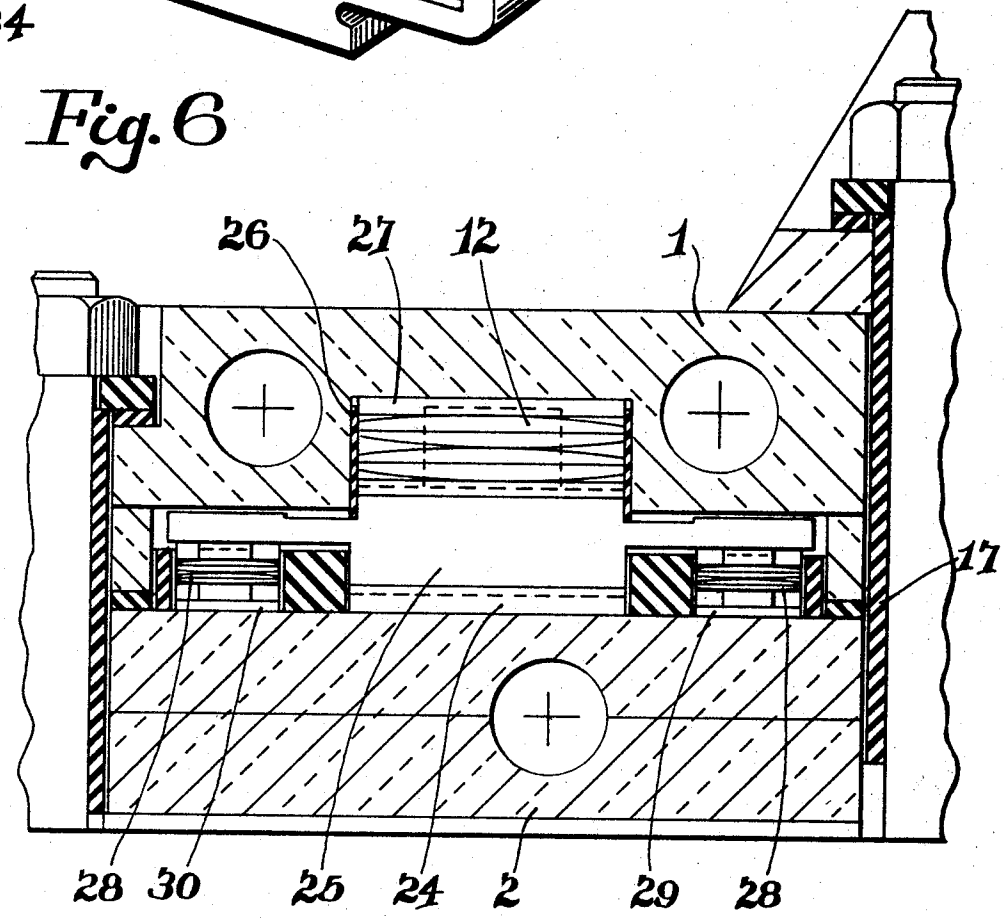


Fig. 5

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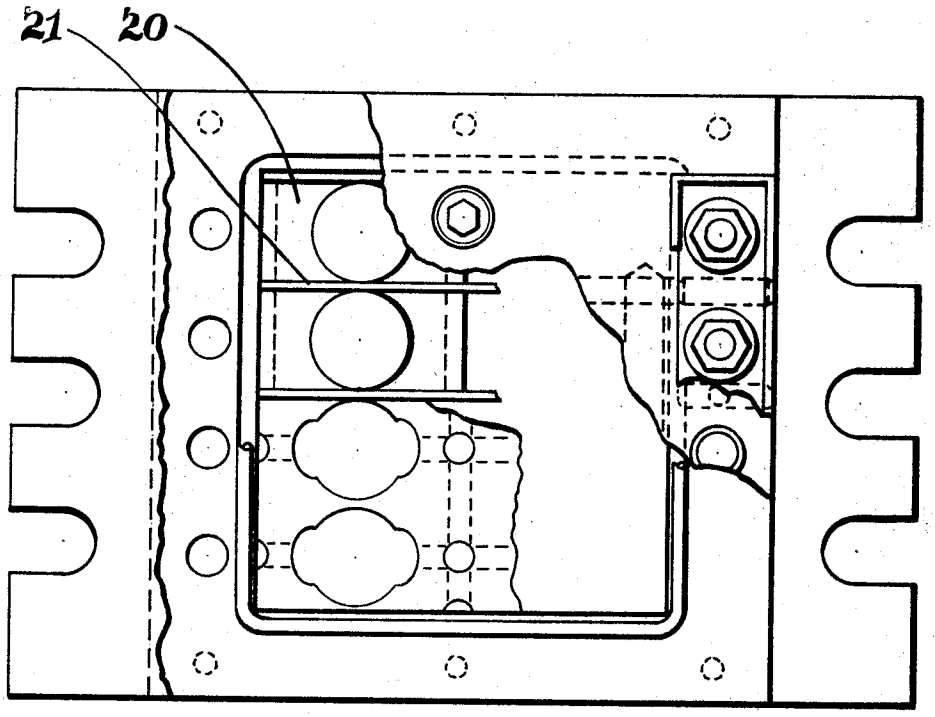


Fig. 8

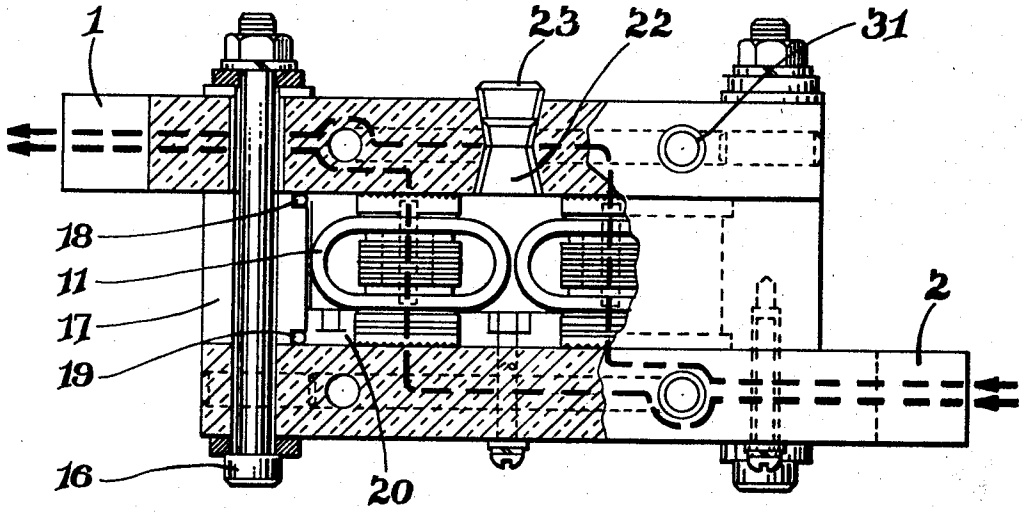


Fig. 7

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3,412,294

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ARRANGEMENT OF THE DIODE AS A SINGLE UNIT AND IN A GROUP

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9 Claims. (Cl. 317—234)

ABSTRACT OF THE DISCLOSURE

The present invention relates to a demountable semiconductor assembly for use in the rectification of very high currents. The invention is characterized by the use of spring means to maintain a force against the contacting surfaces to the semi-conductor element at a preset level and by the use of high current conductors surrounding the semi-conductor and the force producing means. Further means are provided for removing the heat generated in the semi-conductor, the contacting surfaces and the current conductors resulting from the passage of the high current.

In semiconductor type diodes, particularly those used as rectifiers with high currents in the order of hundreds and thousands of amperes, the energy losses due to the voltage drop across the semiconductor and its connections with the current circuit are considerable. The resulting heat and temperature rise within the semiconductor and its connections puts a definite limit to the allowable operating current. For example, a silicon diode of 5/8" diameter is rated by its manufacturer only for a continuous unidirectional current of 275 amps providing the maximum temperature of the diode does not exceed 190° C. A higher continuous current could result in damage to the diode assembly and the joint of the flexible lead. A further increase in the current magnitude would sometimes melt the washers—usually of molybdenum—which are used on both sides of the silicon disk as protective means against cracking through thermal expansion.

The energy losses are inherently localized in a very small volume of material and consequently the temperature rise is relatively high. In the aforementioned silicon diode unit the continuous energy losses amount to 550 watts for a typical operation where the maximum current is 2,000 amperes and where the voltage drop is 2 volts. Considering the relatively small mass of the diode assembly, the temperature rise is rapid and high and would certainly destroy the unit if its level were not kept relatively low by a limited rating of the continuous current.

One of the factors which limits the current that can be passed through a diode is the connection between the diode surface and the lead which connects the diode to the external circuit. If the flexible lead is joined to the center of a diode disk having for example a diameter of 1", the distribution of current from this joint into the body of the diode will result in an extremely high current density at the joint and in an uneven distribution of current from the center of the diode to its periphery. Inasmuch as destruction of a diode results from exceeding some limiting temperature across any portion of the junction, it is evident that the center of the diode, since it is carrying a higher current density than any other section of the junction, would reach a higher temperature. Although the other section of the diode can carry additional current without overheating, the total current which can be carried by the diode would be limited by the current density at the center.

When one considers rectification of higher alternating currents, in the order of 10,000 amps, one is confronted with the necessity of using a great number of rectifying

diodes and this entails problems of limiting space requirement, distributing the load equally, etc. among the diodes and insuring an effective removal of heat. For continuous currents, in the order of 100,000 amps, or more, these difficulties become almost insurmountable and the cost of the arrangement excessive.

The difficulties mentioned above make it impossible to use particularly silicon diodes at relatively high temperatures at which they can safely operate, and results in the necessity of using a multiplicity of diodes.

The object of the present invention is:

To produce a single diode assembly in which the current distribution is uniform over the full surface of the diode;

To produce a structure in which the current carrying members are effectively cooled and kept at a uniform temperature by circulating cooling water or other fluids;

To produce a structure in which a very effective and uniform cooling of the diode is realized;

To insure through pressure means a permanent and uniform contact over the full surface of the diode and between the diode assembly and its supporting members which carry the rectified current;

To make a structure comprising a multiplicity of diodes in which the current is distributed equally among the diodes;

To produce a diode assembly capable of passing high currents, which is extremely compact;

To produce a sealed structure in which the diodes are surrounded by a heat conducting medium of high dielectric power which also protects them against contamination from the atmosphere;

To produce a structure comprising a multiplicity of diodes each of which can be easily replaced in the event of failure.

FIG. 1 is a cross section of a single diode assembly.

FIG. 2 is a plan view of same.

FIG. 3 is the perspective of the same diode assembly.

FIG. 4 shows the relative arrangement of a silicon diode with its group of disks.

FIG. 5 is a cross section of a variation of the diode assembly arrangement of FIG. 1.

FIG. 6 is another arrangement of the current conducting and pressure exerting members which can be used in conjunction with the diode arrangement in FIG. 4.

FIG. 7 shows the cross section of a structure comprising a multiplicity of diode assemblies as per FIG. 1, which, however, can also comprise the diode assemblies of FIG. 5 and FIG. 6.

FIG. 8 shows a top view of the assembly shown in FIG. 7.

FIG. 1 shows in detail, according to the invention, the arrangement of the diode assembly of FIG. 7 between the conducting plates **1** and **2**. The diode **3** is inserted between the washers **4** and **5** as indicated on FIG. 4. Wire mesh disks **6** and **7** which may be made of fine gold plated copper wire are provided above the washer **4** and below the washer **5**. The current conducting member **8** which may be made of silver or silver plated copper is provided with a serrated surface as shown on FIG. 2 in order to insure a good contact with conducting plate **2** of FIG. 7. The two current carrying members **9** and **10** are silver brazed over their entire surface onto a flexible conductor **11** of rectangular cross section. In this way the current can flow from **2** (FIG. 7) through **8**, **7**, and **5** to the diode **3** and then in turn through **4**, **6**, **10**, **11** and **9** through the serrated surface to the conducting plate **1**. A set of spring washers of the Belleville type **12** is centered around the members **13**, **14** and **15** and is compressed by the action of the bolts **16** shown on FIG. 7, so as to produce a high and permanent contact force

between the conducting members. This force is determined by the degree of compression of the Belleville washers allowed by the insulating spacer **17** which surrounds the structure FIG. 7. The chamber containing the diodes is sealed against the atmosphere by means of the O-ring seals **18** and **19**.

FIGS. 7 and 8 show an insulating plate **20** provided with circular openings in which the diodes are nested and which determine the spacing between the diode assemblies. Insulating separators **21** secure the parallelism of the diode assemblies and prevent the flexible conductors **11** from contacting each other. Port **22** which allows the introduction of a thermally conducting and protective medium into the chamber is closed by a plug **23**. Conducting plates **1** and **2** are provided with holes or notches for connection to current carrying members not shown on the figure. Conducting plates **1** and **2** are provided with channels **31** through which the cooling fluid, for example water, is circulated. The arrangement of these channels is such that an effective removal of the heat from every one of the diode assemblies is achieved so as to allow the flow of the highest possible electric currents without detrimental temperature rise of the diodes or other components.

FIG. 5 shows a particularly compact arrangement of a diode assembly according to the invention. Its principal parts are a set **24** of the diodes and washers as shown on FIG. 4, a current carrying member **25**, a set of Belleville washers **12** of the type shown on FIG. 1, an insulating sleeve **26**, and an insulating washer **27**. Two sets of smaller Belleville washers **28** insulated by the washers **29** and **30** force the two flexible arms of conducting member **25** into effective contact with conducting plate **1**, while the Belleville washers **12** force the center part of said conducting member **25** against the assembly **24** to produce effective contact among themselves and with conducting plate **2**. Spacer **17** made of insulating material limits the compression of the Belleville washers **12** and **28** and seals the diode chamber against the atmosphere.

FIG. 6 according to the invention is a variation of the diode assemblies FIGS. 1 and 5. Here a flexible current conducting member **32** made of two halves welded together at the joint **33** plays the role of the parts **9**, **10**, **11**, **13**, **14** and **15** of FIG. 1. Two leaf springs **34** are the pressure exerting means. The diode and its group of disks of FIG. 4 can be combined with FIG. 6 as a compact diode assembly.

It can be seen, particularly from FIGS. 7 and 8, that according to the invention an extremely compact rectifying unit is obtained having a high current carrying capacity.

The two dotted lines on FIG. 7 show that the current is evenly distributed on the two rows of diode assemblies of FIG. 8.

The very high current carrying capacity of the structure according to the invention can be seen from the following:

The diodes shown on FIG. 7 are silicon diodes of 1" diameter and through the use of this novel arrangement each one of the eight diode assemblies shown can carry a continuous current of 2,000 amps and a peak current of 5,000 amps with a temperature rise of only 125° C. The overall dimensions of the chamber containing the diodes are only 4¼" wide, 4¼" long, and 1½" high, and such an arrangement can safely carry a continuous current of 16,000 amps and a peak current of 40,000 amps. With six structures as per FIG. 7 a continuous current of 100,000 amps and a peak current of 250,000 amps can be carried. It is understood that semiconductors made of material other than silicon may be used. With the heretofore known arrangements of diodes of the silicon type or other types it would be difficult, and even impractical, to obtain currents of such a magnitude because a great multiplicity of diodes would have to be used and their connection and arrangement in groups would require a space many more times than that required by the arrangement according to the invention. Moreover, the equal distribution of current in this great number of individual diodes and their effective cooling would not be possible.

Because of their compactness the structures according to the invention can be connected immediately onto the current transformer, thus reducing the otherwise high power losses in the high current connections and achieving in such a rectifying arrangement an overall high efficiency.

From the foregoing, it is believed that the objects, advantages, construction and utility of my present invention will be readily comprehended by persons skilled in the art, without further description. Although the invention has been herein shown and described in a simple and practicable form, it is recognized that certain parts or elements herein are representative of other parts or elements that may be used in substantially the same manner to accomplish substantially the same results. Therefore, it is to be understood that the invention is not to be limited to the exact details described herein, but is to be accorded the full scope and protection of the appended claims.

Having described my invention, what is claimed as novel is:

1. A diode structure comprising an upper water cooled conducting plate, a lower water cooled conducting plate, insulating means for maintaining said plates at a fixed distance and parallel to one another, a cylindrical recess on the bottom of the said upper conducting plate, spring washer means within said recess, insulating means around said springs, a conducting member having a central circular section in association with said spring washer means for transmitting the force exerted by said spring through said circular section to a semi-conductor wafer assembly resting on the top surface of the aforementioned lower conducting plate, two flexible arms extending outward from the central section and diametrically opposite each other, spring means below the end of each flexible arm disposed so as to urge said ends of flexible arms upward so as to contact said first mentioned conducting plate, the reaction being taken by the lower water cooled conducting plate.

2. In a diode structure the combination comprising an upper conducting plate, a lower conducting plate, insulating means for maintaining said plates at a fixed distance from and parallel to one another and arranged so as to form a closed chamber, an insulating plate formed with a multiplicity of circular openings mounted on the inner surface of the lower conducting plate and a multiplicity of diode assemblies and force producing elements nested one in each circular opening each comprising a semiconductor disc shaped diode with contacting, current conducting discs in contact with each circular surface of said diode, force producing means for maintaining a contacting force between all discs surfaces and separate flexible current conducting means insulated from and surrounding said force producing means and arranged so as to pass current from the inside surface of the upper conducting plate through the diode assembly and into the inside surface of the lower conducting plate.

3. In a diode structure as in claim **2**, additional means for removing heat generated at the diode junction.

4. In a diode structure as in claim **2**, means for filling the chamber with a heat conductive medium, sealing means to prevent the heat conductive medium from escaping from the chamber.

5. In a diode assembly as per claim **1**, means for circulating a cooling fluid through channels in the two conducting plates.

6. A diode assembly as per claim **5**, including means for connecting the conducting plates to an external circuit.

7. A diode assembly as in claim **5**, including means for dividing the current equally among the diodes.

8. A diode assembly as in claim **5**, including means for maintaining a maximum temperature differential between conducting plates and diodes.

9. A diode structure comprising an upper conducting plate, a lower conducting plate, insulating means for maintaining said plates at a fixed distance and parallel to one another, an insulating plate provided with a multiplicity of circular openings mounted on the inner surface of the lower conducting plate, a multiplicity of diode assemblies nested one in each opening, each of the said diode assemblies comprising a bottom disc shaped current conducting member for making contact with aforesaid lower conducting plate, a semiconductor diode disc, metal washers contacting each circular surface of the semiconductor diode disc, wire mesh discs contacting the exposed surfaces of the aforementioned washers, current conducting discs in contact with each of the exposed circular surfaces, one of said current conducting discs formed with a cylindrical recess at its center, an insulating pin nested in said recess, an insulating bushing surrounding the said insulating pin, compression spring washers surrounding the said bushing, means for insulating said washers from any electrical conducting element, flexible conductors of rectangular section surrounding the aforesaid insulating bushing and washer assembly, a top disc shaped current conducting member for making contact on one of its circular surfaces with the inside surface of the aforementioned upper conducting plate and on its circular surface with a portion of the outer surface of the aforementioned flexible conductors. All the elements being so arranged

that they are symmetrically disposed about the axis of the insulating pin and are guided by said insulating pin.

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