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(54) IMPROVEMENTS IN OR RELATING TO SEMI-CONDUCTOR MOUNTS

(71) We, SEMIKRON GESELLSCHAFT FUR GLEICHRICHTERBAU UND ELEKTRONIK m.b.h. a German Company of Wiesentalstrasse 40, 8500, Nurnberg, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a semiconductor rectifier arrangement.

In particular the present invention relates to a semi-conductor rectifier arrangement of the type in which two unencapsulated rectifiers each having an anode and a cathode and at least one pn-junction, are each fastened to a heat dissipating or cooling member having means for the passage of a coolant.

Controllable semi-conductor rectifiers, such as thyristors, may be switched from a non-conducting to a conducting state, when connected in series with an A.C. supply, at any desired time during a half wave by applying a pulse to a control electrode. Such a controllable semi-conductor device therefore provides a contactless switch. In view of this advantage and other advantages inherent in such devices, thyristors are increasingly used to switch and control high currents, for example in electrical welding, in antiparallel arrangements to provide full wave A.C. control.

In such devices, disc-shaped thyristors are provided with cooling elements which may be cooled by liquid thus enabling the device to be relatively small and have a high current handling capability.

The assembly of such an arrangement is complicated since it is necessary for the thyristor as mentioned above to have a cooling element at each of its two contact surfaces in order to dissipate the heat uniformly on each side. The cooling elements must therefore be assembled so that they are electrically insulated from one another. Hoses may be provided for the inlet and outflow of the coolant, which is preferably water, between the cooling elements. With known arrangements a considerable length of hose is necessary in view of the different potentials of the cooling elements and of the negligible conductance of the coolant. For example with an alternating terminal voltage of 500 volts rms and a coolant operating temperature of about 60° if it is required, for the rate of heat dissipation in the coolant to be only a few watts, then if the coolant is water the hose between the cooling elements must be about 50 centimeters long, since the coolant acts as a parallel resistance.

Further arrangements have been proposed in which a housing part supporting an unencapsulated rectifier element is also designed as a cooling element so as to optimise the power loss heat dissipation. The cooling element is provided with a channel in its interior for the passage of coolant so that the coolant is conducted as close as possible, past the rectifier element. Such an arrangement does improve the operating behaviour of such semi-conductor rectifiers, however the requirement for the long external coolant lines as mentioned above is still present.

Further arrangements have been proposed in which the cooling member carrying the rectifier elements is provided with a cavity in its interior the cavity serving as a channel for the passage of coolant, the coolant channel being formed by recesses in a base or lid portion of a two-piece cooling member or alternatively by suitably arranged partitions in a hollow body member. It has been proposed inter alia to provide the cooling channels in a massive ceramic cover member. Tests however have shown that heat dissipation in such structures leaves room for improvement.

It is an object of the present invention to provide a semi-conductor rectifier arrangement that overcomes or at least reduces the above mentioned problems.

According to the present invention there is provided a semi-conductor rectifier arrangement comprising two unencapsulated semiconductor rectifiers each having an anode and a cathode and at least one pn-junction,

each semi-conductor rectifier being mounted on and having its cathode in electrical contact with a respective substantially planar contact member, the anode of each semi-conductor rectifier being electrically connected to that contact member which is connected to the cathode of the other semi-conductor rectifier, each contact member being mounted on a metallised surface of a thermally conductive electrically insulating plate which is connected to or forms part of a cooling element provided with a plurality of mutually parallel channels connected to an inlet and to an outlet through which cooling fluid may pass, said cooling channels being parallel to the substantially planar contact members, the semi-conductor rectifiers and associated electrical connections being embedded in insulating material, and surrounded by a housing provided with apertures both for the inflow and outflow of coolant and/or electrical connections to be made to the semi-conductor rectifiers.

The invention will now be described in more details by way of example only with reference to the accompanying drawings wherein:—

FIGURE 1 is a perspective view of one embodiment of the present invention.

FIGURE 2 is a perspective view of a second embodiment.

FIGURE 3 is a part cross-sectional and part frontal view of a slightly modified version of the embodiment shown in Figure 1.

Referring to the drawings, it will be appreciated that parts of the embodiment shown in Figures 1 and 2 which are common will be referred to by the same numeral.

Referring firstly in particular to the embodiment shown in Figure 1 a cooling member is provided by a plate 1 of thermally good conducting material, for example copper, this is provided in its interior with cooling channels 2 which are parallel to one another and parallel to the planar upper surface of the plate 1.

The channels 2 are blind bores which may be produced, for example, by drilling through one end 7 of the plate 1 the ends of the bores then being plugged. The channels 2 pass at one end through a first transverse cooling channel 3 and at their other end they connect with a similar transverse cooling channel 6. The transverse channels 3 and 6 interconnect the cooling channels 2 and may be formed in the plate 1 in a manner as described for the channels 2. In order to provide for the circulation of coolant through the channels 2 a connector 4 is provided at each end of the plate 1 with one of the connectors 4 opening into the transverse cooling channel 3 and the other connector 4 opening into the transverse cooling channel 6 for the inlet or outlet of the coolant.

As shown the connectors 4 are disposed on the lower surface of the plate 1, in which case the transverse cooling channels 3 and 6 are also sealed at their ends. It is to be understood however that if desired the connectors 4 could be disposed on one of the end surfaces of the plate 1.

The upper surface of the plate 1 is planar and surface-treated for the subsequent attachment of rectifier elements. The area of the plate 1 and hence the surface 6 is determined by the arrangement of the rectifier elements and the components required to connect them together electrically. The cross section of the cooling channels 2 and the transverse coolant channels 3 is determined by the quality of coolant required to assure a constant temperature difference between the surface of the plate 1 bearing the rectifier elements and the associated surface around which the coolant flows. The coolant channels 2 and the transverse coolant channels 3 may have a cross section other than the circular cross section of the illustrated embodiment.

Instead of forming the cooling member as a plate 1 as described above it may be produced from a pressing or by an injection moulding technique and may comprise two plate-shaped metal components which are each provided with a surface having the same number of identically designed and arranged trough-shaped recesses, for example corrugated plates, and which two plate-shaped metal components are permanently and sealingly fastened together in a mirror image relationship so that the trough-shaped recesses form the coolant channels 2 and the transverse cooling channels. As in the embodiment of Figure 1 the connectors 4 for the external coolant connections open into the transverse connections 3.

In the embodiment shown in Figure 1 a wafer or thin plate 100 of a thermally good conducting electrically insulating material, preferably an oxide ceramic, is attached to the upper surface 6 of the plate 1 so that the plate 1 is insulated from the semi-conductor device. The insulating plate 100 of insulating material is provided with a thin layer of metal (not shown on the surface) intended for connection with the upper surface of the plate 1 to facilitate attachment, e.g. by soldering, and is provided with two mutually spaced metallised areas 110 on its upper surface which are intended for attachment to the rectifier elements. A pair of contact members 21 of an electrically and thermally good conducting material e.g. copper are fastened onto the insulating plate 100 by soldering to the respective metallised areas 110, the contact members 21 having a downwardly facing surface area that is not longer than the metallised area 110 on the insulating plate 100.

Mounted on each of the contact members 21 is a rectifier element 22 which has its cathode electrically and mechanically attached to the contact member 21 by soldering and in addition has a flexible upper contact electrode 23. Each contact member 21 also has a metal contact stud 24. In the case of a thyristor, as shown in the illustrated embodiment each rectifier element is additionally provided with a control electrode terminal 29 and an auxiliary cathode terminal 28. The downwardly facing surface area of each of the contact members 21 depends on the contact surface of the rectifier element 22 and on that of the contact stud 24. The cooling area of the plate 1 is at least equal to that of the two contact plates 21 and as shown in Figure 1 it is in fact larger since the insulating plate 100 has a surface area rather larger than the contact members 21. The thickness of the plate 1 is determined by the cross section of the required cooling channels 2 and the transverse cooling channels.

Each rectifier element 22 is permanently electrically connected to the one of the contact members 21 on which is mounted the other rectifier element, through a flexible conductor 23, metal contact bar 25, and contact stud 24. The contact bars 25 are each provided for this purpose with, for example, an opening for the passage of the conductor 23 and/or the contact stud and are fastened to the contact stud 24 and the conductor 23 by soldering. In order to connect conductors 23 and the contact stud 24 the contact bars may be suitably bent as shown in Figure 1. The design attachment and configuration of the bars 25 and the arrangement of the rectifier elements 22 and contact studs 24 on the contact member 21 is not critical.

The contact members 21 are each provided with a block shaped metal connecting member 26 which is fastened onto the contact members 21 or is a permanent part thereof and is situated on the contact members 21 projecting outwardly from the edge opposite to the mutually facing edges of the contact members 21. In order to permit a connection to an external current conductor preferably by means of a screw connection a threaded bore 27 is provided in the protruding surface of each connecting member 26. The size of each connecting member 26 is determined only by the given current handling capability of the rectifier arrangement.

The semi-conductor rectifier elements and associated electrical circuitry are subsequently embedded in insulating material the arrangement being surrounded with a housing having apertures both for inflow and outflow of coolant and further apertures for electrical connections to be made to the semi-conductor rectifier.

Referring now to Figure 2 another embodiment of the invention is shown having a different construction of the cooling member. In this embodiment the cooling member comprises a metal base plate 10 having upwardly extending walls defining a trough closed top 11. Within the trough 11 there are provided a plurality of partitions 20 which are perpendicular to the bottom surface and are made of metal or plastics material, the partitions 20 have dimensions which correspond to the inner mutually parallel dimensions of the base plate 10 and divide the trough 11 into channels 14. The partitions 20 are each provided adjacent each end thereof with opening 20*a*. Coolant flowing through openings 5 in the base plate 10 is thus able to flow through all the coolant channels 14, since each channel 14 is connected at each of its ends with one of the transverse channels formed by the openings 20*a*. A cover for the trough 11 and thus for the coolant channel arrangement is provided by the insulating plate 100 of oxide ceramic which is fastened to the base plate 20, for example by means of an adhesive. The other parts of the rectifier arrangement shown in Figure 1 are fastened to metallised areas 110 of the insulating plate 100 in the same manner as described above with respect to the embodiment shown in Figure 1.

The arrangement is subsequently embedded in insulating material and surrounded by a housing.

Figure 3 is a partially sectional and partially front view of the embodiment shown in Figure 1 but is modified in a manner that will now be described. The rectifier elements 22 complete with the plate 1 are disposed in a housing 30 of insulating material. The housing 30 is provided with openings for the passage of the connecting members 210*a* of the contact members 210 and the coolant connections 4. The coolant connections 4 are provided in the form of connecting studs which protrude from the underside of the housing 30. The insulating plate 100 is fastened on the plate 1, and the rectifier elements 22 are secured to contact members 210 which in turn are secured to a metallised portion 110 of the insulated plate 100.

The contact members 210 include a planar carrier portion 210*b* which corresponds to contact plate 21 of Figure 1 and in addition includes a tongue like integral extension 210*a* which forms a connecting bar and is arranged to be perpendicular to the contact surface of the carrier portion 210*b* and to protrude from the housing 30, thus corresponding to the member 26 of Figure 1.

The structure including plate 1, contact members 210, contact studs 24 and contact bar 25 together with the rectifier elements 22 is embedded in insulating material 35

which is preferably a plastics material, for example an epoxy resin.

In order to prevent undesirable mechanical stresses on the semi-conductor body of the rectifier elements 22 due to possible stresses caused in the casting operation the semi-conductor body may additionally be accommodated in a cup-shaped metal member and connected therethrough with a corresponding contact member 21 and be covered therein with silicone rubber.

In order to increase the mechanical strength of the housing 30 the lateral interior longitudinal surfaces in particular may be provided with reinforcing ribs.

A cover 31, provided to close the housing 30, also made of a plastics material, is preferably connected to the housing 30 by means of an adhesive. The cover 31 and the housing 30 may be designed to have mutually adapted engagement surfaces.

When the semi-conductor elements comprise thyristors the respective connections 28 and 29 for the control current and the auxiliary cathode respectively are connected to additional connecting members provided on a support member which is fastened electrically insulated from the connecting members 26 or 210*a* and the said additional connecting members extend from these points through openings provided in the housing cover 31 to permit connections to conductors outside the housing. These further connecting members may be attached to the connecting member 26 or 210*a* for example by means of an adhesive. The housing 30 or the cover 31 may be provided with further apertures for the passage of temperature monitoring devices for example which are permanently connected with various parts of the circuit including the rectifier elements 22 connected in anti-parallel relationship.

Certain features of the illustrated embodiments are the subject of patent no. 1,488,386.

WHAT WE CLAIM IS:—

1. A semi-conductor rectifier arrangement comprising two unencapsulated semiconductor rectifiers each having an anode and a cathode and at least one pn-junction, each semi-conductor rectifier being mounted on and having its cathode in electrical contact with a respective substantially planar contact member, the anode of each semiconductor rectifier being electrically connected to that contact member which is connected to the cathode of the other semi-conductor rectifier, each contact member being mounted on a metallised surface of a thermally conductive electrically insulating plate which is connected to or forms part of a cooling element provided with a plurality of mutually parallel channels connected to an inlet and to an outlet through which cooling fluid may pass, said cooling channels being parallel to the substantially planar contact members, the semi-conductor rectifiers and associated electrical connections being embedded in insulating material, and surrounded by a housing provided with apertures both for the inflow and outflow of coolant and/or electrical connections to be made to the semi-conductor rectifiers.

2. A semi-conductor rectifier arrangement as claimed in Claim 1 wherein the cooling element comprises a single metallic member having a plurality of mutually parallel channels therein said channels being interconnected at each of their ends by a pair of transverse channels to which connections are made for the inflow and outflow of coolant.

3. A semi-conductor rectifier arrangement as claimed in Claim 1 wherein the cooling element comprises trough part having a plurality of transversely and upwardly extending partitions dividing said trough into channels, said partitions being provided with openings at each end thereof such that one adjacent channel communicates with another and said thermally conductive electrically insulating plate comprises a cover member for closing said trough.

4. A semi-conductor rectifier arrangement as claimed in Claim 1 wherein the cooling element comprises a pair of corrugated sheet members, said sheet members being secured together one above the other in a manner to provide a plurality of channels, means being provided whereby each adjacent channel communicates with another at or near each of its ends.

5. A semi-conductor rectifier arrangement as claimed in any one of the preceding claims wherein the thermally conducting electrically insulating plate is provided, on the side which is secured to the substantially planar contact members, with a metallised surface.

6. A semi-conductor rectifier arrangement as claimed in any one of the preceding claims wherein the thermally conductive electrically insulating plate is made from an oxide ceramic.

7. A semi-conductor rectifier arrangement as claimed in any one of the preceding claims wherein a connection member is secured to each of the substantially planar contact members in a manner to provide good electrical connection between the connection member and the contact member, said connection member being secured to the contact member such that at least part of the connection member projects outwardly from the housing.

8. A semi-conductor rectifier arrangement as claimed in any one of claims 1 to 6 wherein each of the substantially planar contact members is provided with an integral extension said integral extension comprising

a connection member adapted to project outwardly from the housing.

9. A semi-conductor rectifier arrangement as claimed in claim 7 or claim 8 wherein the connection member is in the form of a block or tongue and is provided with a threaded bore for the connection to an external current conductor.

10. A semi-conductor rectifier arrangement as claimed in any one of the preceding claims wherein at least one of said semiconductor rectifiers is a controllable semiconductor rectifier element having at least one additional electrode for the control current, said arrangement comprising means for providing electrical connections for any additional electrodes of said controllable rectifier element including further additional connection members connected in an electrically insulating manner to said connecting means said additional connecting members, or respective parts associated therewith extending through an opening in said housing to allow electrical connections to be made outside said housing.

11. A semi-conductor rectifier arrangement as claimed in any one of the preceding claims wherein a cover of said housing is provided with further openings for passage of temperature monitoring devices which are permanently connected with parts of the anti-parallel circuit comprising the rectifiers and current conductor members.

12. A semi-conductor rectifier arrangement substantially as hereinbefore described with reference to and as illustrated in Figure 1 of the accompanying drawings.

13. A semi-conductor rectifier arrangement substantially as hereinbefore described with reference to and as illustrated in Figure 2 of the accompanying drawings.

14. A semi-conductor rectifier arrangement substantially as hereinbefore described with reference to and as illustrated in Figure 3 of the accompanying drawings.

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1569573 COMPLETE SPECIFICATION

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Sheet 1

Fig. 1

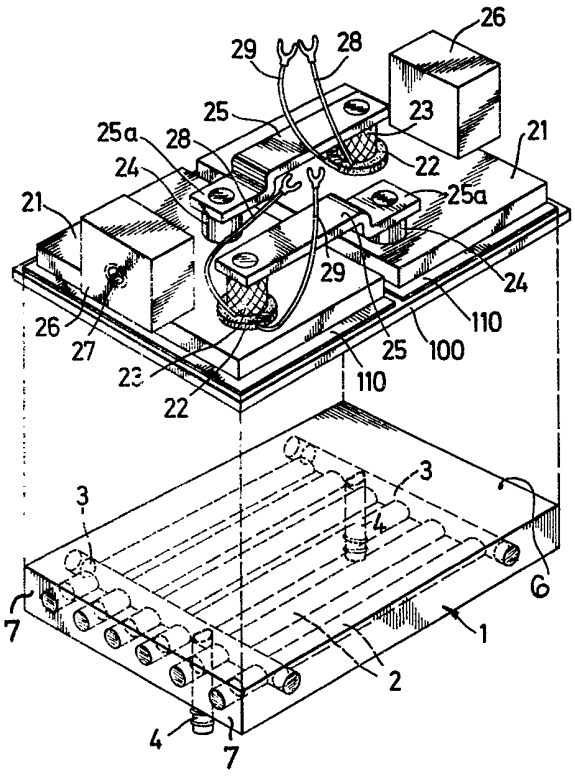
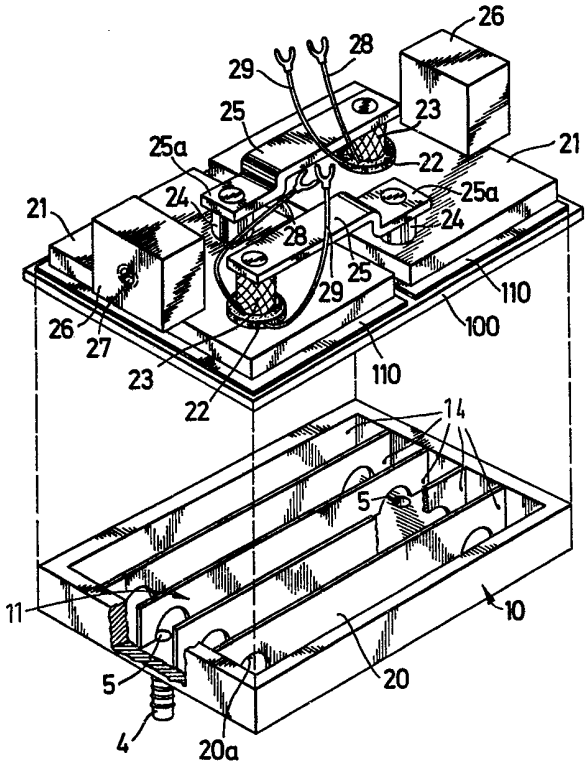


Fig. 2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Sheet 3

Fig. 3