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(54) **Subsea electrical fuse**

Elektrische Unterwassersicherung

Fusible électrique sous-marin

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a subsea electrical fuse adapted to be operated in a pressurized environment and to an electronic device comprising such fuse.

BACKGROUND

[0002] Oil platforms are often used in offshore oil and gas production. In the operation of offshore oil platforms, it can be necessary to install electronics under water, e.g. for controlling functions of a subsea Christmas tree or a subsea blowout preventer. More recently, subsea processing facilities were established in which processing equipment such as electrically driven pumps and gas compressors are relocated to the ocean floor. The subsea processing facility requires a power grid as well as control, monitoring and communication systems. It needs to be ensured that the installed equipment operates reliability even under the high pressures exerted by the sea water at great depths of water of e.g. more than 1000, 2000 or even more than 3000 meters.

[0003] To protect equipment from overcurrents or short-circuits, electrical fuses can be installed which interrupt an electrical connection if the current through the fuse becomes too large. A conventional fuse comprises a fuse body, which may be made of ceramic, glass, plastic, fiberglass or the like, and a fuse element. The fuse element is generally a metal strip or wire and is mounted between two electrical terminals of the fuse. At currents above the rated current, the fuse element melts, thereby interrupting the electrical circuit. The faulty circuit can thus be isolated, whereby damage to other electronic components of the system can be prevented.

[0004] For protecting electronic equipment subsea, a conventional fuse can be placed in a pressure resistant canister and maintained at a pressure of about one atmosphere. The canister needs to be thick walled in order to withstand the high pressures at water depths of more than 3000m. Penetrators are further required to provide an electrical connection to the fuse through the wall of the canister. This solution of providing a subsea fuse is very cost intensive due to the canister and the penetrators and further requires a considerable amount of space. Also, such canisters tend to be very heavy, resulting in substantial costs for transportation and installation.

[0005] To overcome these problems, solutions are known in which electronic components are placed in pressure compensated canisters in which a pressure is maintained that is almost equal to the surrounding water pressure. At a deployment depth of 3000m, the pressure inside the canister would accordingly be close to 300 bar. Electronic components are often incompatible with such high pressures. Conventional fuses would for example collapse in such a high pressure environment.

[0006] The document WO 2006/032,060 A2 discloses a fuse for high voltage/high current application, wherein the fuse comprises an insulative substrate, such as a melamine substrate, which is metalized with a fuse element. The fuse element extends to multiple surfaces of the substrate.

[0007] The document WO 2008/122,309 A1 discloses a double sided plate comprising a strip conductor safety fuse. The plate has at least one strip conductor safety fuse in the form of a strip conductor comprising a safety fuse element. An electric circuit is interrupted by fusion and evaporation of the safety fuse element.

Summary

[0008] Accordingly, there is a need to provide a fuse for subsea use that is compact and that can be manufactured cost efficiently.

[0009] This need is met by the features of the independent claims. The dependent claims describe preferred embodiments of the invention.

[0010] According to an aspect of the invention, a subsea electrical fuse adapted to be operated in a pressurized environment is provided. The fuse comprises a section of conductor trace on a printed circuit board. The conductor trace section has a first connection section and a second connection section. It further comprises at least one fuse element, the fuse element being a section of the conductor trace that has a reduced cross section compared to the cross section of the connection sections. The at least one fuse element provides an electrical connection between the first connection section and the second connection section. The fuse element is adapted to melt if an electric current through the fuse element exceeds a threshold current. Thereby, the electrical connection that is provided by the fuse element between the first and second connection sections is interrupted.

[0011] As the fuse is provided by a conductor trace on a printed circuit board (PCB), the fuse can be pressurized. It is capable of being operated in a liquid filled pressure compensated enclosure in which, depending on the deployment depth, pressures of more than 100 bar, 200 bar or even more than 300 bar may prevail. Further, as it does not need to be protected in a pressure resistant enclosure, it is compact and can be produced cost efficiently.

[0012] In an embodiment, the fuse element has a width in the range of 0.1 to 2 mm. If the conductor trace has a constant thickness, the cross section of the conductor trace will be determined by its width. The width of the fuse element may thus be used to adjust its current rating. In other embodiments, it is also conceivable to vary the thickness of the conductor trace for changing its cross section.

[0013] The thickness of the conductor trace may lie within a range of 17-100μm, it may for example be 35μm.

[0014] The first and second connection sections of the conductor trace section may have a width of at least 1mm, preferably at least 3mm. This may ensure a reliable electrical connection towards the fuse.

[0015] The length of the fuse element may lie within a range of about 0.5mm to about 10mm, preferably within a range of about 1mm to about 5mm.

[0016] In an embodiment, the conductor trace section comprises at least two fuse elements connected in series between the first and the second connection section. The first and second connections sections can thus be spaced further apart and the breaking capacity of the fuse may be increased. The fuse elements may be adapted so as to break (or melt) simultaneously when the threshold current is exceeded. This may be achieved by precisely controlling the width of the fuse elements. In particular for short circuit protection, the required tolerances are low enough so that a configuration of the fuse in which the fuse elements break essentially simultaneously can be achieved.

[0017] The conductor trace section may further comprise at least one cooling section which provides an electrical connection between two fuse elements. The cooling section may comprise a section of the conductor trace that has a cross section larger than the cross section of the fuse elements. It may for example have a larger width, which may be equal to the width of the connection sections. The fuse can thus comprise a number of alternately arranged fuse elements and cooling sections, which are connected in series between the first and second connection sections. Cooling may furthermore be provided by the first and second connection sections, in particular if they have a width larger than the width of the fuse elements.

[0018] The fuse may for example comprise 3, 4, 5 or even more fuse elements, and accordingly, 2, 3, 4 or more intermediary cooling sections. Between 1 and 10 fuse elements may for example be provided. When the fuse blows and the fuse element melts, an arc may form between the two adjacent cooling pads (or a cooling pad and a connection section). As a certain voltage is required to maintain each arc, connecting several fuse elements in series leads to a series of arcs which requires a high voltage to be maintained, thus resulting in a fast extinction of the arcs. The cooling pads may provide an area in which the PCB and the dielectric liquid are cooler than close to the fuse elements, thereby preventing a jumping of the arc across the cooling pads and the formation of a larger arc over the entire fuse (i.e. between the two connection sections).

[0019] The different fuse elements may have substantially the same width. A simultaneous melting of the fuse elements may thus be achieved. The first and second connection sections and the one ore more cooling sections may also have the same (larger) width.

[0020] In an embodiment, the conductor trace section comprises at least two fuse elements disposed on different sides of the printed circuit board. The fuse may thus be made even more compact.

[0021] In an embodiment, the conductor trace section may comprise at least two segments disposed on different sides of the printed circuit board, wherein each segment comprises a fuse element and at least one cooling section. One of said segments comprises the first connection section and another of said segments comprises the second connection section. The segments are connected in series between said first and second connection sections. The cooling section of a segment on one side of the PCB is coupled to the cooling section of a neighbouring segment on the other side of the PCB by means of one or more vias. Again, the width of the cooling section is larger than the width of the fuse elements. Vias (also termed "Vertical Interconnect Access") are electrical connections between different sides or layers of a printed circuit board. They can be provided by electroplated holes, annular metallic rings, small metallic rivets or the like.

[0022] The circuit track section may for example comprise a plurality of such segments disposed alternately on opposite sides of the PCB. A compact design of the fuse may thus be achieved even when implementing a larger number of fuse elements. It should be clear that other configurations are also conceivable, for example a number of fuse elements connected in series on each side of the PCB, the two series on the different sides of the PCB being interconnected by vias.

[0023] In an embodiment, each connection section has a tapered end towards which one of the at least one fuse element is coupled. The tapered end may increase the breaking capability of the fuse. The ends of the cooling sections towards which the fuse elements are coupled may certainly also be tapered.

[0024] In an embodiment, the subsea electrical fuse comprising the at least one fuse element is adapted to have a breaking capacity of at least 200 A at 24V AC (alternating current), or even of at least 1000 A at 690V AC. This means that the fuse is capable of breaking at least this short circuit current for the given voltage. With such breaking capacities, the fuse can be used to achieve an effective short circuit protection. The breaking capacity may for example be adapted by adjusting the number of fuse elements and cooling sections connected in series and/or by adjusting their geometry. In particular the distance of the connection sections may be adjusted by changing fuse element member and geometry in order to control the breaking capacity.

[0025] The current rating of the fuse (i.e. the threshold current above which the fuse 'blows') can be tailor made in accordance with the respective application, for example by choosing the number of fuse elements and their width. The subsea electrical fuse may for example be designed to have a current rating in a range between 0.1-50A at e.g. 24V or 690V AC. In other configurations, the current rating may lie in the range of 2A to 40A or of 10A to 20A at these voltages.

[0026] The conductor trace which makes up the fuse may be a copper trace. The conductor trace section may be coated with a solder resist coating for insulation. This can prevent leakage currents and short circuits.

[0027] According to a further aspect of the invention, a subsea electronic device comprising at least one subsea electrical fuse having any of the configurations mentioned above is provided. By means of the fuse, an effective short circuit or overcurrent protection of the subsea electronic device is achieved.

[0028] In an embodiment, the subsea electronic device further comprises a pressure compensated enclosure filled with dielectric liquid, the subsea electrical fuse being disposed in said enclosure in said dielectric liquid. The dielectric liquid can act as a high resistance path if an arc occurs when the one or more fuse elements melt. The dielectric liquid may further have a cooling effect which can lead to a faster extinction of the arc. This can result in a reduced arc time and thus in a faster circuit break time of the fuse. It may furthermore lead to an increased short circuit breaking capacity and a higher voltage rating.

[0029] The printed circuit board on which the subsea electrical fuse is provided may comprise further electronic components of the electronic device or may be electrically coupled such electronic components (i.e. the PCB with the fuse and the electronic components may be provided separately). The electronic components may be supplied with electric power through the subsea electrical fuse. Accordingly, if a short circuit occurs in one of the electronic components, the fuse will interrupt the power supply and prevent further damage to upstream or downstream components, such as transformers or the like.

[0030] The features of the aspects and embodiments of the invention mentioned above and those yet to be explained below can be combined with each other unless noted to the contrary.

Brief description of the drawings

[0031] The forgoing and other features and advantages of the invention will become further apparent from the following detailed description read in conjunction with the accompanying drawings. In the drawings, like reference numerals refer to like elements.

Figure 1 shows a schematic drawing of a subsea electrical fuse according to an embodiment.

Figure 2 shows a schematic drawing of a subsea electrical fuse according to another embodiment.

Figure 3 shows a sectional side view of a part of the subsea electrical fuse of Fig. 2.

Figure 4 shows a schematic drawing of a subsea electronic device according to an embodiment of the invention which comprises a subsea electrical fuse provided on a printed circuit board.

[0032] In the following, embodiments of the present invention will be described in detail with reference to the accompanying drawings. It is to be understood that the following description of the embodiments is given only for the purpose of illustration and is not to be taken in a limiting sense.

[0033] It should be noted that the drawings are to be regarded as being schematic representations only, and elements in the drawings are not necessary to scale with each other. Rather, the representation of the various elements is chosen such that their function in general purpose becomes apparent to a person skilled in the art.

[0034] Figure 1 shows a subsea electrical fuse 10. The fuse 10 is adapted to operate in a high pressure environment, e.g. at pressures which prevail at water depths of more than 1000m, 2000m or even more than 3000m. The fuse is adapted for a placement into a pressure compensated enclosure, such as a subsea canister comprising one or more pressure compensators, which is filled with dielectric liquid. The pressure of the dielectric liquid is equalized to the surrounding water pressure by means of the pressure compensator.

[0035] The fuse comprises a section of a conductor trace 11 on the printed circuit board 12. The conductor trace can be made of any material suitable for the production of traces on a PCB, for example copper. Any known and suitable manufacturing process can be used to pattern the PCB.

[0036] The copper trace section 11 which makes up the fuse comprises the following structural features. For contacting the fuse, it comprises a first connection section 13 and a second connection section 14. These may be contacted in different ways. Conductor traces on the circuit board 12 may directly lead to (and contact) one or both connection sections 13,14, so that the fuse can be directly connected to circuitry on the PCB 12. The connection sections may also be contacted mechanically, e.g. by a clamp, a socket or the like. Other possibilities include mounting a connector to a connection section or contacting it by vias in the PCB. It should be clear that these are only some examples for contacting the connection sections 13, 14 of fuse 10 and that further ways of contacting are certainly conceivable.

[0037] The first connection section 13 is electrically coupled to the second connection section 14 by an alternating series of fuse elements 15 and cooling sections 18. Each connection section is coupled to a fuse element, with fuse elements being coupled towards one another by means of an intermediate cooling section. All elements are connected in series between the first and second connection sections 13, 14.

[0038] The fuse elements 15 are sections of the conductor trace 11 that have a width smaller than the width of the connection sections 13, 14 and the cooling sections 18. In the present example, the height or thickness of the conductor trace 11 is the same over the circuit board 12, so that the cross section of the trace is proportional to its width. The cross section of the conductor trace is proportional to the electrical conductivity. Accordingly, the conductivity or resistance of the fuse element can be controlled by adjusting its width. In other configurations, it is also possible to adjust the electrical conductivity by adjusting the height or thickness of the fuse element. Yet this involves a more complex manufacturing process. Due to their smaller cross section, the fuse elements 15 may also be termed 'weak links'.

[0039] As the fuse elements do have a smaller width (smaller cross section) and thus a lower conductivity, the fuse elements will heat up until they melt if a large enough current passes through them. The threshold current above which the fuse elements break or melt, i.e. the fuse blows, defines the current rating of the fuse. When the fuse element melts, an arc will form between the unmelted remnants of the conductor trace. If there are several fuse elements connected in series, as in Figs. 1 and 2, a series of arcs will form, each arc forming between a pair of cooling sections 18 or between a cooling section 18 and a connection section 13, 14. A certain voltage is required to maintain each arc. If the sum of the voltages required for maintaining each arc is made higher than the voltage available in the circuit, the arcs will be extinguished quickly. The sum of voltages can be increased by increasing the number of fuse elements in series. The current flow is terminated when the arcing stops. The time until the current flow is stopped is the circuit break time of the fuse. The melting of the fuse elements efficiently stops the current flow through the fuse and thus through connected circuits.

[0040] As illustrated in Fig. 1, the width of the fuse elements 15 is smaller than the width of the connection sections 13, 14 and the width of the cooling sections (also termed cooling pads) 18. The connection sections and the cooling sections will thus not be affected by the current flow, as the fuse elements will melt before these sections experience any detrimental effects.

[0041] Even when operated below the current rating, the fuse elements may warm up. The larger width and the higher electrical conductivity of the connection sections and the cooling sections will reduce the heating. Accordingly, the cooling sections provide a cooler surface, and thus an area in which the PCB and the dielectric liquid are cooler than at the fuse elements. This ensures that if a series of arcs if formed when the fuse blows, the arcs will not jump across the cooling sections to form one large arc over the entire fuse. By providing several fuse elements in series, it can be achieved that at each arc (i.e. between two cooling sections or a cooling section and a connection section), the voltage required to sustain the arc is lower than the voltage available. For example, an arc may requires about 50V to maintain. In a 250V system, the fuse can be configured to have 6 fuse elements 15 in series. Thereby the system will provide a maximum of 250/6 = 42V for each arc. This is not enough to maintain the arc (which requires 50V) and the arc will thus extinguish. Accordingly, the fuse can be tailored to the particular system voltage by adjusting the number of fuse elements connected in series.

[0042] The actual width of the fuse elements depends on the desired current rating. For a conductor trace thickness of 35μm, the width may lie in a range between about 0.1mm and about 2mm. For lower or higher ratings, smaller or larger conductor trace widths can be used, respectively. Preferably, the fuse elements are configured to have substantially the same width. This way, a simultaneous breaking of the fuse elements, in particular in short circuit protection, can be ensured.

[0043] For different conductor trace thicknesses, the width of the fuse elements can be adjusted to maintain the cross section of the conductor and thus the current rating. A range of current ratings can be realized with the fuse 10. When protecting a circuit operating at 24 V AC, the fuse may have a current rating in the range of 1A to 50A, in particular of 10A to 50A. Other ranges in which the current rating may lie include 2A to 40 A or 4A to 20A. The current rating may for example be 4 or 5A. When operated at 690V, the fuse may can be adapted to a lower rating due to the higher voltage, it may be adapted to have a rating between 0.1A and 50A, in particular between 10 and 50 A. Other ranges in which the current rating may lie include 5A to 30A and 10A to 20A. The fuse can be adjusted to these ratings by varying the width of the one or more fuse elements.

[0044] Further parameters of the fuse can be adjusted in order to meet the demands of a specific application. The width of the cooling pads may for example be increased to lower the operation temperature of the fuse elements. Further, the length of the fuse elements can be varied. By increasing the length, a larger separation of the connection sections can be achieved. The length of a fuse element 15 may for example lie within a range from 1mm to 10mm.

[0045] The number of fuse elements 15 can also be adjusted, with a corresponding change to the number of intermediate cooling sections 18. In the example of Fig. 1, three fuse elements 15 (and two cooling sections 18) are provided. In other configurations, between 1-10 fuse elements may be provided (with 0-9 cooling sections, respectively). The positions at which the current flow is interrupted and the distance between the connection sections can be fine tuned this way. By modifying the parameters mentioned above, the breaking capacity of the fuse can be adjusted. It may be increased by increasing the spatial separation between the connection sections. In an exemplary configuration for a 24 V AC application, the fuse 10 has a breaking capacity of at least 200 A, i.e. it is capable of breaking a short circuit current which is at least this high. For a 690V DC application, the fuse 10 can be adapted to have a breaking capacity of at least 1000A.

[0046] The fuse can be used for overcurrent or short circuit protection. For overcurrent protection, the fuse can be configured to have a current rating that is only a fraction above the nominal current at which the fuse is operated. When used for short circuit protection, the threshold current at which the fuse is triggered can be 2-3 times higher than the nominal current. The configuration again depends on the particular application.

[0047] The printed circuit board (PCB) 12 can be manufactured to only comprise the conductor trace section 11 providing the fuse, or it can be manufactured to comprise further conductor traces, pads and other structures (not shown) commonly used on PCBs. In the latter case, the PCB 12 may certainly comprise electric components such as chips, ICs (integrated circuits), resistors, capacitors and other components in the assembled state. The fuse can be coupled to these components by conductor traces (not shown) connected to the connection sections 13 and 14. The fuse 10 can for example be connected in series with the power supply which feeds the circuitry provided on PCB 12. In other configurations, the fuse can be connected in series with a power supply by contacting the connection section 13, 14.

[0048] If a short circuit occurs in a circuit that is supplied through the fuse, the current through the fuse will exceed the current rating and the fuse will interrupt the electrical connection to the power supply as the fuse elements melt. Thereby, further damage to the circuitry or other upstream or downstream components can be prevented. Also, in case of a short circuit, a voltage drop will occur in the power supply system. As the fuse has a short circuit break time, the faulty circuit can be isolated quickly, thereby removing the voltage drop and ensuring a continued operation of other circuits that are supplied from the same electric power supply.

[0049] Fig 2, illustrates a further embodiment of the fuse 10 to which the explanations given above are equally applicable. For reasons of clarity, the outline of the PCB 12 is not shown in Fig 2. The fuse 10 of Fig. 2 comprises five fuse elements 15, three of which are located on the front side of the PCB and two of which are located on its backside (dashed lines).

[0050] The conductor trace section 11 can thus be divided into the segments 21, 22 and 23 which are located on the PCB front side and the segments 25 and 26 which are located on the PCB backside. Segments 21 and 23 each comprise a connection section 13/14, a fuse element 15 and a cooling section 18. The intermediate segments 22, 25 and 26 each comprise two cooling sections and a fuse element. The segments are connected in series and are located alternately on the front and back sides of the PCB. The cooling pads of neighboring segments overlap and are electrically connected to each other by means of several vias 30. Vias 30 are through holes that pass through the PCB and electrically connect the front to the back side, e.g. by means of electroplating, annular metal rings, rivets or the like.

[0051] This is in more detail illustrated in the sectional side view of Fig. 3 which shows a part of the fuse 10 of Fig. 2. Segment 21 comprises the connection section 13. Its cooling section 18 overlaps the cooling section 18 of segment 25 on the other side of PCB 12. The two overlapping cooling sections 18 are connection by the vias 30 which pass through the PCB 12.

[0052] An electrical connection is thus established from the first connection section 13 to the second connection section 14, the connection comprising the five fuse elements 15 disposed alternately on different sides of the PCB. By such arrangement, the fuse can be designed more compact and the breaking capacity can be increased.

[0053] The features of the above embodiments can certainly be combined. A range of different arrangements of the fuse elements on the PCB are thus conceivable. As an example, one side of the PCB may comprise a serial arrangement of such segments (e.g. as in Fig. 1), which is connected to a similar arrangement on the other side of the PCB by means of vias. In other configurations, a multilayer PCB may be used in which the conductor trace segment at least partially runs inside the PCB. The leakage of waste products of the molten fuse element may thus be prevented.

[0054] Fig. 4 schematically illustrates a subsea electronic device 40 which comprises a pressure compensated enclosure 41, e.g. a subsea canister comprising one or more pressure compensators. The enclosure 41 is filled with a dielectric liquid 42, such as oil, in particular transformer oil or silicone oil, or other types of dielectric liquids. The dielectric liquid enables the device 40 to maintain an inside pressure which is equalized to the surrounding water pressure when device 40 is deployed subsea. It can further provide electric insulation and cooling for the electronics disposed in enclosure 41.

[0055] In the example of Fig. 4, a transformer 43 is shown which supplies the electric component 45 with electrical energy. Electronic component 45 comprises the printed circuit board 12, on which electronic elements, such as integrated circuits, chips, resistors, capacitors and the like can be mounted (not shown). Electronic component 45 may for example be a controller, a communication component, a switching component or the like.

[0056] The electronic component 45 is supplied with electric power via the fuse 10 which is provided on the PCB 12. Fuse 10 can have any of the above-outlined configurations. The fuse 10 is configured so that it is triggered if a short circuit occurs in the electronic component 45. This means that the fuse layout, i.e. the dimensions of the fuse elements and the cooling sections is adjusted so that the fuse elements will melt at a threshold current which is lower than the expected short circuit current. In consequence, the transformer 43 is electrically separated from the electronic component 45 after the occurrence of a short circuit. Accordingly, damage to the transformer 43, components upstream of the transformer or downstream of the electronic component 45 can be prevented. Also, the fuse limits the damage to electronic component 45, which may otherwise heat up substantially and as a result may be completely destroyed and may pollute the dielectric liquid 42.

[0057] Note that Fig. 4 only illustrates an exemplary arrangement and that other arrangements are certainly conceivable. Fuse 10 may for example be provided on a PCB which is separate from the electronic component

45. It may then be electrically coupled to the electronic component 45, e.g. by means of a connector or the like.

[0058] The fuse 10 is submerged in the dielectric liquid 42. The dielectric liquid acts as a high resistance path for an arc occurring when the fuse elements melt. Furthermore, the dielectric liquid has a cooling effect which assists in extinguishing the arc. Accordingly, the arc time can be reduced, resulting in a faster circuit break time of fuse 10. Small leakage currents that may remain after the triggering of the fuse do in the present embodiment not matter, as the main objective of the fuse is short circuit protection.

[0059] As the dimension of the fuse elements can be made small compared to the size of the contact sections and the cooling sections, only a limited amount of copper is melting when the fuse blows, so that the pollution of the dielectric liquid 42 with waste products can be kept small. A further possibility is the use of a multilayer PCB in which the fuse elements are provided in an inner layer so as to prevent the escape of any waste products after the triggering of the fuse.

[0060] The skilled person will appreciate that figures 1 to 4 only show exemplary embodiments of the subsea electrical fuse, and that the fuse can be provided in a range of configurations in dependence on the particular application. The features explained above with respect to the figures and the different embodiments of the invention can be combined in other combinations as the ones illustrated. With the subsea electrical fuse, an effective short circuit or overcurrent protection of subsea electronics can be achieved. The fuse is compact, easy to produce and can be operated in high pressure environments of more than 100, 200 or even 300 bar.

Claims

1. Subsea electrical fuse adapted to be operated in a pressurized environment in a pressure compensated enclosure (41), the fuse (10) being provided by a section of conductor trace (11) on a printed circuit board (12), the conductor trace section (11) comprising

   - a first connection section (13) and a second connection section (14) for electrically contacting the fuse (10), and
   - at least one fuse element (15), the fuse element (15) being a section of the conductor trace (11) that has a reduced cross section compared to the cross section of the connection sections (13, 14), the at least one fuse element (15) providing an electrical connection between the first connection section (13) and the second connection section (14),

   wherein the fuse element (15) is adapted to melt if an electric current through the fuse element exceeds a threshold current, thereby interrupting the electrical connection that the fuse element (15) provides between the first and second connection sections (13, 14),

   characterized in that

   the fuse (10) is submerged and pressurized in a dielectric liquid (42), the dielectric liquid providing a high resistance path for an arc occurring when the at least one fuse element (15) melts.

2. Subsea electrical fuse according to claim 1, wherein the fuse element (15) has a width in the range of 0.1 to 2 mm.

3. Subsea electrical fuse according to claim 1 or 2, wherein the first and second connection sections (13, 14) of the conductor trace section (11) have a width of at least 1mm, preferably at least 3mm.

4. Subsea electrical fuse according to any of the preceding claims, wherein the conductor trace section (11) comprises at least two fuse elements (15) connected in series between the first and the second connection sections (13, 14).

5. Subsea electrical fuse according to claim 4, wherein the conductor trace section (11) further comprises at least one cooling section (18) which provides an electrical connection between two fuse elements (15), the cooling section (18) comprising a section of the conductor trace (11) that has a cross section larger than the cross section of the fuse elements (15).

6. Subsea electrical fuse according to claim 4 or 5, wherein the fuse elements (15) have substantially the same width.

7. Subsea electrical fuse according to any of the preceding claims wherein the conductor trace section (11) comprises at least two fuse elements (15) disposed on different sides of the printed circuit board (12).

8. Subsea electrical fuse according to claim 7, wherein the conductor trace section (11) comprises at least two segments (21, 25) disposed on different sides of the printed circuit board (12), wherein each segment comprises a fuse element (15) and at least one cooling section (18), wherein one of said segments (21) comprises said first connection section (13) and wherein another of said segments (23) comprises said second connection section (14), wherein said segments are connected in series between said first and second connection sections (13, 14) and wherein the cooling section (18) of a segment (21) on one side of the PCB (12) is coupled to the cooling section (18) of a neighbouring segment (25) on the other

side of the PCB (12) by means of one or more vias (30).

9. Subsea electrical fuse according to claim 8, wherein the conductor trace section (11) comprises a plurality of said segments (21-26) disposed alternately on opposite sides of the PCB (12).

10. Subsea electrical fuse according to any of the preceding claims, wherein each connection section (13, 14) has a tapered end towards which one of the at least one fuse element (15) is coupled.

11. Subsea electrical fuse according to any of the preceding claims, wherein the subsea electrical fuse (10) comprising the at least one fuse element (15) is adapted to have a breaking capacity of at least 200 A at 24V AC, or even of at least 1000 A at 690V AC.

12. Subsea electrical fuse according to any of the preceding claims, wherein the conductor trace section (11) is coated with a solder resist coating for insulation.

13. Subsea electronic device comprising at least one subsea electrical fuse (10) according to any of claims 1-12.

14. Subsea electronic device according to claim 13, further comprising a pressure compensated enclosure (41) filled with dielectric liquid (42), the subsea electrical fuse (10) being disposed in said enclosure (41) in said dielectric liquid (42).

15. Subsea electronic device according to claim 13 or 14, wherein the printed circuit board (12) on which the subsea electrical fuse (10) is provided comprises further electronic components of the electronic device (40) or is electrically coupled to another printed circuit board comprising such electronic components, the electronic components being supplied with electric power through the subsea electrical fuse (10).

Patentansprüche

1. Elektrische Unterwassersicherung, welche dafür ausgelegt ist, in einer unter Druck stehenden Umgebung in einer druckkompensierten Umhüllung (41) betrieben zu werden, wobei die Sicherung (10) durch einen Abschnitt einer Leiterbahn (11) auf einer Leiterplatte (12) vorgesehen ist, wobei der Leiterbahnabschnitt (11) umfasst:

   - einen ersten Verbindungsabschnitt (13) und einen zweiten Verbindungsabschnitt (14) zum elektrischen Kontaktieren der Sicherung (10), und
   - wenigstens ein Sicherungselement (15), wobei das Sicherungselement (15) ein Abschnitt der Leiterbahn (11) ist, welcher einen verminderten Querschnitt im Vergleich zum Querschnitt der Verbindungsabschnitte (13, 14) aufweist, wobei das wenigstens eine Sicherungselement (15) eine elektrische Verbindung zwischen dem ersten Verbindungsabschnitt (13) und dem zweiten Verbindungsabschnitt (14) bereitstellt,

   wobei das Sicherungselement (15) dafür ausgelegt ist zu schmelzen, falls ein durch das Sicherungselement fließender elektrischer Strom einen Schwellenwertstrom überschreitet, wodurch die elektrische Verbindung unterbrochen wird, welche das Sicherungselement (15) zwischen dem ersten und dem zweiten Verbindungsabschnitt (13, 14) bereitstellt,
   dadurch gekennzeichnet, dass
   die Sicherung (10) in eine dielektrische Flüssigkeit (42) eingetaucht und mit Druck beaufschlagt ist, wobei die dielektrische Flüssigkeit einen hochohmigen Pfad für einen Lichtbogen bereitstellt, der auftritt, wenn das wenigstens eine Sicherungselement (15) schmilzt.

2. Elektrische Unterwassersicherung nach Anspruch 1, wobei das Sicherungselement (15) eine Breite im Bereich von 0,1 bis 2 mm aufweist.

3. Elektrische Unterwassersicherung nach Anspruch 1 oder 2, wobei der erste und der zweite Verbindungsabschnitt (13, 14) des Leiterbahnabschnitts (11) eine Breite von wenigstens 1 mm, vorzugsweise von wenigstens 3 mm aufweisen.

4. Elektrische Unterwassersicherung nach einem der vorhergehenden Ansprüche, wobei der Leiterbahnabschnitt (11) wenigstens zwei in Reihe geschaltete Sicherungselemente (15) zwischen dem ersten und dem zweiten Verbindungsabschnitt (13, 14) umfasst.

5. Elektrische Unterwassersicherung nach Anspruch 4, wobei der Leiterbahnabschnitt (11) ferner wenigstens einen Kühlabschnitt (18) umfasst, welcher eine elektrische Verbindung zwischen zwei Sicherungselementen (15) bereitstellt, wobei der Kühlabschnitt (18) einen Abschnitt der Leiterbahn (11) umfasst, welcher einen Querschnitt aufweist, der größer als der Querschnitt der Sicherungselemente (15) ist.

6. Elektrische Unterwassersicherung nach Anspruch 4 oder 5, wobei die Sicherungselemente (15) im Wesentlichen dieselbe Breite aufweisen.

7. Elektrische Unterwassersicherung nach einem der

vorhergehenden Ansprüche, wobei der Leiterbahnabschnitt (11) wenigstens zwei Sicherungselemente (15) umfasst, die auf verschiedenen Seiten der Leiterplatte (12) angeordnet sind.

8. Elektrische Unterwassersicherung nach Anspruch 7, wobei der Leiterbahnabschnitt (11) wenigstens zwei Segmente (21, 25) umfasst, die auf verschiedenen Seiten der Leiterplatte (12) angeordnet sind, wobei jedes Segment ein Sicherungselement (15) und wenigstens einen Kühlabschnitt (18) umfasst, wobei eines der Segmente (21) den ersten Verbindungsabschnitt (13) umfasst und wobei ein anderes der Segmente (23) den zweiten Verbindungsabschnitt (14) umfasst, wobei die Segmente zwischen dem ersten und dem zweiten Verbindungsabschnitt (13, 14) in Reihe geschaltet sind und wobei der Kühlabschnitt (18) eines Segments (21) auf einer Seite der Leiterplatte (12) mit dem Kühlabschnitt (18) eines benachbarten Segments (25) auf der anderen Seite der Leiterplatte (12) mittels einer oder mehrerer Durchkontaktierungen (30) gekoppelt ist.

9. Elektrische Unterwassersicherung nach Anspruch 8, wobei der Leiterbahnabschnitt (11) mehrere der Segmente (21-26) umfasst, die abwechselnd auf gegenüberliegenden Seiten der Leiterplatte (12) angeordnet sind.

10. Elektrische Unterwassersicherung nach einem der vorhergehenden Ansprüche, wobei jeder Verbindungsabschnitt (13, 14) ein sich verjüngendes Ende aufweist, mit dem das Sicherungselement bzw. eines der Sicherungselemente (15) gekoppelt ist.

11. Elektrische Unterwassersicherung nach einem der vorhergehenden Ansprüche, wobei die elektrische Unterwassersicherung (10), die das wenigstens eine Sicherungselement (15) umfasst, dafür ausgelegt ist, ein Ausschaltvermögen von wenigstens 200 A bei 24 V Wechselstrom oder sogar von wenigstens 1000 A bei 690 V Wechselstrom aufzuweisen.

12. Elektrische Unterwassersicherung nach einem der vorhergehenden Ansprüche, wobei der Leiterbahnabschnitt (11) mit einer Lötstopplack-Beschichtung zur Isolation versehen ist.

13. Elektronische Unterwasservorrichtung, welche wenigstens eine elektrische Unterwassersicherung (10) nach einem der Ansprüche 1-12 umfasst.

14. Elektronische Unterwasservorrichtung nach Anspruch 13, welche ferner eine druckkompensierte Umhüllung (41) umfasst, die mit dielektrischer Flüssigkeit (42) gefüllt ist, wobei die elektrische Unterwassersicherung (10) in der Umhüllung (41) in der dielektrischen Flüssigkeit (42) angeordnet ist.

15. Elektronische Unterwasservorrichtung nach Anspruch 13 oder 14, wobei die Leiterplatte (12), auf welcher die elektrische Unterwassersicherung (10) vorgesehen ist, weitere elektronische Komponenten der elektronischen Vorrichtung (40) umfasst oder mit einer anderen Leiterplatte, die solche elektronischen Komponenten umfasst, elektrisch gekoppelt ist, wobei die elektronischen Komponenten über die elektrische Unterwassersicherung (10) mit elektrischer Leistung versorgt werden.

Revendications

1. Un fusible électrique sous-marin adapté de façon à être actionné dans un environnement sous pression dans une enceinte à compensation de pression (41), le fusible (10) étant fourni par une section de piste conductrice (11) sur une carte à circuits imprimés (12), la section de piste conductrice (11) comprenant

- une première section de raccordement (13) et une deuxième section de raccordement (14) destinée à une mise en contact électrique du fusible (10), et
- au moins un élément fusible (15), l'élément fusible (15) étant une section de la piste conductrice (11) qui possède une section transversale réduite en comparaison de la section transversale des sections de raccordement (13, 14), le au moins un élément fusible (15) fournissant une connexion électrique entre la première section de raccordement (13) et la deuxième section de raccordement (14),

dans lequel l'élément fusible (15) est adapté de façon à fondre si un courant électrique au travers de l'élément fusible dépasse un courant seuil, interrompant ainsi la connexion électrique que l'élément fusible (15) fournit entre les première et deuxième sections de raccordement (13, 14),
caractérisé en ce que
le fusible (10) est immergé et placé sous pression dans un liquide diélectrique (42), le liquide diélectrique fournissant un trajet à haute résistance pour un arc se produisant lorsque le au moins un élément fusible (15) fond.

2. Le fusible électrique sous-marin selon la revendication 1, dans lequel l'élément fusible (15) possède une largeur dans la plage de 0,1 à 2 mm.

3. Le fusible électrique sous-marin selon la revendication 1 ou 2, dans lequel les première et deuxième sections de raccordement (13, 14) de la section de piste conductrice (11) possèdent une largeur d'au moins 1 mm, de préférence d'au moins 3 mm.

4. Le fusible électrique sous-marin selon l'une quelconque des revendications précédentes, dans lequel la section de piste conductrice (11) comprend au moins deux éléments fusibles (15) raccordés en série entre la première et la deuxième sections de raccordement (13, 14).

5. Le fusible électrique sous-marin selon la revendication 4, dans lequel la section de piste conductrice (11) comprend en outre au moins une section de refroidissement (18) qui fournit une connexion électrique entre deux éléments fusibles (15), la section de refroidissement (18) comprenant une section de la piste conductrice (11) qui possède une section transversale plus grande que la section transversale des éléments fusibles (15).

6. Le fusible électrique sous-marin selon la revendication 4 ou 5, dans lequel les éléments fusibles (15) possèdent sensiblement la même largeur.

7. Le fusible électrique sous-marin selon l'une quelconque des revendications précédentes dans lequel la section de piste conductrice (11) comprend au moins deux éléments fusibles (15) disposés sur des côtés différents de la carte à circuits imprimés (12).

8. Le fusible électrique sous-marin selon la revendication 7, dans lequel la section de piste conductrice (11) comprend au moins deux segments (21, 25) disposés sur des côtés différents de la carte à circuits imprimés (12), chaque segment comprenant un élément fusible (15) et au moins une section de refroidissement (18), un desdits segments (21) comprenant ladite première section de raccordement (13) et un autre desdits segments (23) comprenant ladite deuxième section de raccordement (14), lesdits segments étant raccordés en série entre lesdites première et deuxième sections de raccordement (13, 14), et la section de refroidissement (18) d'un segment (21) sur un côté de la carte PCB (12) étant couplée à la section de refroidissement (18) d'un segment voisin (25) sur l'autre côté de la carte PCB (12) au moyen d'un ou de plusieurs trous d'interconnexion (30).

9. Le fusible électrique sous-marin selon la revendication 8, dans lequel la section de piste conductrice (11) comprend une pluralité desdits segments (21-26) disposés de manière alternée sur des côtés opposés de la carte PCB (12).

10. Le fusible électrique sous-marin selon l'une quelconque des revendications précédentes, dans lequel chaque section de raccordement (13, 14) possède une extrémité en biseau à laquelle un des au moins un élément fusible (15) est couplé.

11. Le fusible électrique sous-marin selon l'une quelconque des revendications précédentes, dans lequel le fusible électrique sous-marin (10) comprenant le au moins un élément fusible (15) est adapté de façon à présenter une capacité de coupure d'au moins 200 A à 24V AC ou même d'au moins 1000 A à 690V AC.

12. Le fusible électrique sous-marin selon l'une quelconque des revendications précédentes, dans lequel la section de piste conductrice (11) est revêtue d'un revêtement d'épargne de soudage destiné à une isolation.

13. Un dispositif électronique sous-marin comprenant au moins un fusible électrique sous-marin (10) selon l'une quelconque des revendications 1 à 12.

14. Le dispositif électronique sous-marin selon la revendication 13, comprenant en outre une enceinte à compensation de pression (41) remplie d'un liquide diélectrique (42), le fusible électrique sous-marin (10) étant disposé dans ladite enceinte (41) dans ledit liquide diélectrique (42).

15. Le dispositif électronique sous-marin selon la revendication 13 ou 14, dans lequel la carte à circuits imprimés (12) sur laquelle le fusible électrique sous-marin (10) est placé comprend en outre des composants électroniques du dispositif électronique (40) ou est électriquement couplé à une autre carte à circuits imprimés comprenant lesdits composants électroniques, les composants électroniques étant alimentés par une énergie électrique par l'intermédiaire du fusible électrique sous-marin (10).

FIG 1

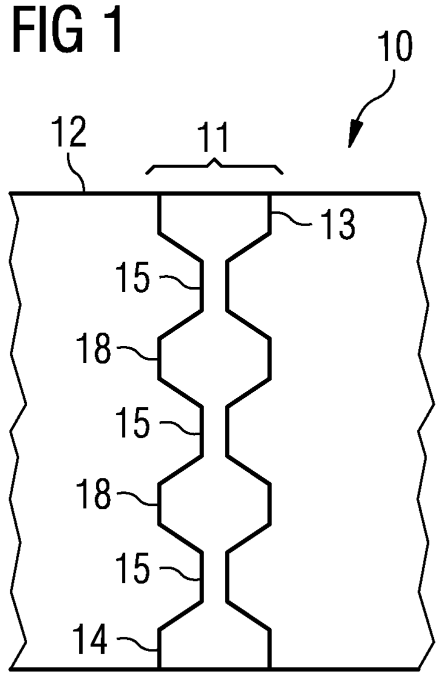
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FIG 2

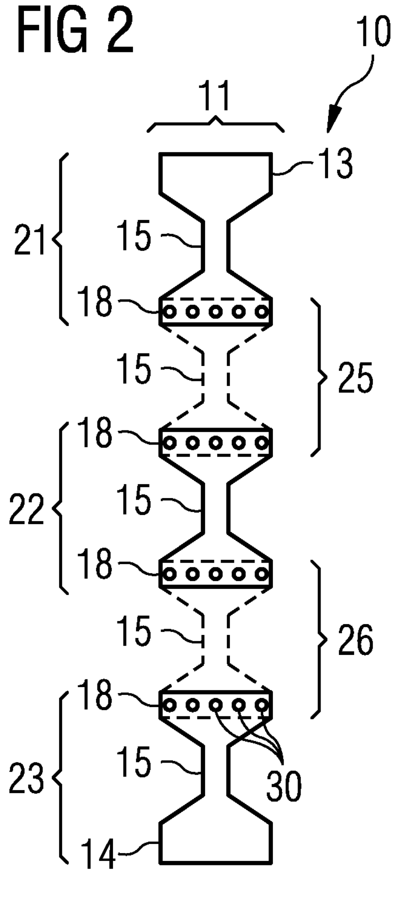
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FIG 3

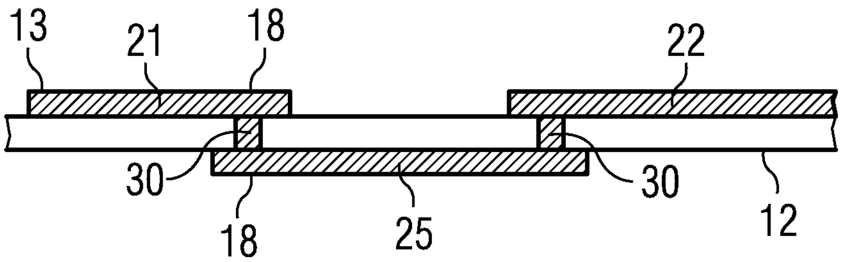
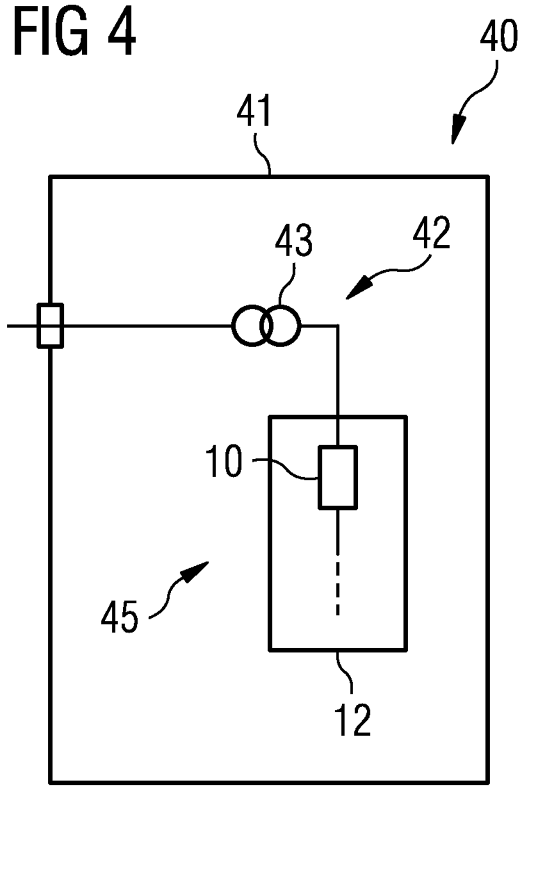


FIG 4



REFERENCES CITED IN THE DESCRIPTION

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