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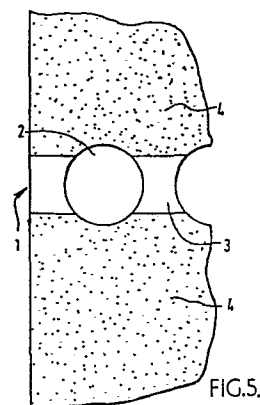
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54 Electric fuse.

57 The electric fuse comprises a porous filler and a combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors. These conductors comprise two kinds of metal so arranged that the current from one terminal to the other will pass successively and alternately through the two kinds of metal, beginning and ending in the first kind of metal. The second metal has pronounced reductions in cross-section defining one or more fuse elements, and is particularly suited to withstand for a long time a temperature at a fuse element near the melting point without significant deterioration. The first metal is selected to provide favorable conditions for current interruption with the arc burning between foot-points on parts of said first metal. The electric fuse may be used under marginal conditions both in respect of the steady state operating current and of the operating voltage and provides with an extremely fast action and current limiting operation. Such operating conditions are generally associated with fuses used for the protection of semi-conductor devices.



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"Electric Fuse"

The invention relates to electric fuses and in particular to fuses to be used under marginal conditions both in respect of the steady state operating current and of the operating voltage and in particular to fuses with an extremely fast action and current limiting operation. Such operating conditions are generally associated with fuses used for the protection of semi-conductor devices.

It is the object of the invention to indicate a design that permits to extend these marginal conditions within given limitations in size and without increasing the power loss encountered.

The invention is generally limited to enclosed fuses with fuse conductors embedded in a porous filler, and where the fuse conductor consists of successive parts of different metals in the direction of current flow. Such bi-metallic fuses are known to the trade and used because they allow advantages of an economic nature without necessarily being associated with any inferior performance. However, it is also the object of the invention to achieve a significantly superior performance under marginal operating conditions without sacrificing the economic advantages known from prior art.

Prior art includes fuses where the current successively passes a part of the fuse conductor made of copper, then a part made of silver, and finally again a part of copper, the parts so arranged that the fuse element, namely the part intended to melt and open the circuit, is situated entirely in the silver part, while the parts that primarily serve to conduct electricity and the heat created in the fuse element are made from the less expensive metal copper. This results in a fuse that by and large behaves like a fuse with the entire fuse conductor made of silver.

A typical example of such prior art and an example which is also the construction coming closest to the present invention as a forerunner is that disclosed in US patent 2,781,434. With a knowledge of the present invention, the prior art so disclosed superficially resembles the present invention, but a closer study will reveal that this is not the case.

For instance, said patent disclosure says (col.1, line 24 p.p.) ".....and which are nevertheless capable of limiting major fault currents at least to the same extent as comparable fuses having links consisting entirely of silver."

Here the expression "at least" might appear to be anticipating the present invention, but it becomes obvious from the rest of the disclosure that this "at least" should be read in the sense of "up to" because there are nowhere else in the patent text the slightest mention of any possible improvement in performance. Only the economic advantages are disclosed and claimed.

Moreover, it is cautiously mentioned that even if the arc should burn into the copper part, it will not be detrimental to the performance. For instance (col.3, line 42 p.p.) "The silver strip 2 does not need to be as long as the required back-burning distance of the link.....", and (line 47 p.p.) "For reasons of economy the length of the silver strip 2 ought to be less.....".

Thus reading claim 7. of the prior art in connection with the citations above from the disclosure, the conclusion is, that this claim is added to be sure to include the most economic design and not with any idea of a deliberate preference for this version, mentioned at the very last, because it might involve any specific advantage of performance. This indicates that the effect achieved by a fuse according to the present invention is in fact an unexpected effect, that hitherto has remained unnoticed and therefore neither disclosed, nor claimed in any prior art.

In contrast to this it is disclosed and claimed that following the present invention significant advantages can be realized.

ginal cases that decide how high a current rating and how high a voltage rating it is possible to assign to a fuse, and it is clearly demonstrated that a fuse according to the invention can be assigned significantly higher ratings than fuses of similar dimensions, but using conventional fuse conductors of silver.

For better understanding of the invention reference may be had to the accompanying drawings, wherein:

Fig 1. is a plane view of a fuse conductor in one metal and according to prior art.

Fig 2. is a plane view of a fuse conductor in two metals demonstrating the difference between prior art and the invention.

Fig. 3. is a plane view of a fuse conductor for use at a higher value of voltage.

Fig 4. is a plane view of a fuse conductor according to the invention, but for different working conditions.

Fig. 5. is a detail of fig. 4.

The fuse conductor of fig. 1. consists of a thin plate of silver intended to carry the current in the direction coinciding with its largest dimension. Across this direction of current flow, fuse elements have been created by punching openings in the conductor. In fig. 1. there are a number of holes in a row, namely four, thereby creating five instances of reduced cross-section forming five fuse elements at the locations indicated by (1), and this pattern of fuse elements is repeated five times along the length of the fuse, so that the fuse can be adapted to a voltage rating five times that of a single fuse element.

It is also part of prior art to let the series of openings across the fuse conductor begin with "half" openings, that is with the center of the opening coming essentially in the contour of the edge. In case of only two half openings we have the equivalent of a notched fuse conductor. The openings can have any suitable shape besides the simple circular shape shown, and instead of openings it is also known to use reductions of the thickness of the conductor to constitute the fuse element, - or to use any other practical way of providing reduced cross-section.

By a design that impels the arc to burn predominantly between copper electrodes in stead of between silver electrodes superior performance is achieved.

The fact that the conditions preferred according to the invention pretty well coincides with the maximum savings in expensive silver is an incidental, but most wellcome supplementary advantage.

The facts of physics that makes the invention work are associated with the desire for the highest possible arc voltage once the interrupting arc is established. Careful investigations using two sets of fuses, identical except for the metal used for the fuse conductor, have shown that in the case where the metal is copper, the arc voltage will reach a higher value, reach it earlier, and retain it longer than in the case where the metal in the fuse conductor is silver.

However, the obvious solution of just using copper in stead of silver is only possible in the cases where the only duty of the fuse is to interrupt high values of overcurrent. If the fuse is also required to carry current of a value in the neighborhood of its marginal current carrying capacity for a long time, the temperature at the fuse element would be so high that it would be subject to fast deterioration due to progressive oxydization resulting in unwanted operation of the fuse.

The invention explores prior art in the light of this hitherto unnoticed advantage of copper by locating the thermally highly stressed fuse element in the part made of silver, while at the same time locating the part made of copper as close to the fuse element as compatible with an avoidance of the tendency to be subject to progressive oxydization.

Under such circumstances the arc will quickly burn back through the silver and come to the copper part, and the desired high and lasting arc voltage will be realized.

It is clear that the full advantage of the invention is only obtained when it is needed, namely in case of marginal values of the system voltage, where it is decisive for a successful operation that the arc voltage is both high and sustained. However, it is those mar-

The fuse conductor shown in fig. 2. can be conceived as simply according to prior art as disclosed in US patent 2,781,434 , but depending on the dimensions selected it can also be according to the present invention. For simplicity it only shows the fuse elements (1) formed by the punching of circular openings (2) in the part made of silver (3) located between the outer parts of the fuse conductor made of copper (4), but special attention should be directed to the location of the transitions (5) between silver and copper.

The critical dimension defining the invention is the distance between the center of the fuse elements (1) and the transitions (5), because this distance shall be long enough to ensure that the temperature of any part of copper does not exceed the value of temperature that leads to harmful progressive oxydization, while on the other hand, the amount of silver located in between must burn away before the arc can be established between foot-points on copper.

The invention centers on the means available to achieve the desirable, but hitherto unnoticed effect resulting from an early transition of the arc from silver to copper.

As the flow of electric current and the flow of heat in a metal to a great extent coincides, the object of design must be to achieve the reduction of cross-section in as short a distance as practical. An important means to that end is to increase the number of openings in a given width of conductor, that is, to have many small openings in stead of a few large ones, and to locate the fuse elements essentially midway in between the transition lines (5). Further improvements can be achieved by proper deviations from the simple circular form in various ways generally known to the man skilled in the art.

The degree to which this critical distance can be diminished also depends on the operating temperature of the fuse element. The most unfavorable case is that of the temperature of the fuse element being almost the melting point of silver.

However, operation that close to the melting point 0059334 is not a normally advisable practice, and therefore it is more usual to assign to the fuse a certain value of current, a rated current, which is a limiting value up to which limit the manufacturer of the fuse can assure proper operation. Such limitations allows the safe lowering of the length of current flow in the silver and thereby increases the benefit of the invention!

The fuse conductor shown on fig. 3. is made according to the invention. It shows the use of a higher number of openings with intervening fuse elements across the width of the fuse conductor and also the use of several bands of fuse elements over the length, making it possible to design the fuse for any desired value of voltage.

The fuse conductor shown on fig. 4. is similar to that of fig. 3. except that the length of silver is shown to be less than the diameter of the openings. A detail is shown enlarged on fig. 5.

It should be mentioned that the shown use of two or more different metals in the fuse conductor does not relate to the use of the so-called M-effect, where one metal at a certain temperature forms an alloy with another metal, thereby altering the electrical and other physical properties of the fuse conductor. However, there is no reason why this M-effect cannot be compatible with and used in combination with a fuse conductor according to the invention.

So far the invention has been explained only on the basis of prior art, namely the use of composite fuse conductors with the metals silver and copper, but similar advantages can be had from other combinations of different metals.

Of such other metals special mention should be made of aluminium. In contrast to copper, aluminium will not be subject to harmful progressive oxydization because the first oxide film formed will be mechanically strong and impervious to oxygen and therefore protect against further oxydization. This implies that in case aluminium is used in place of silver and together with

copper as explained, the fuse element can assume a temperature even above the melting point of aluminium, the molten aluminium being retained within the oxide film until it bursts. However, because of the lower temperature it can be used with less distance to the copper, and because aluminium at the temperature of the arc reacts with quartz, a frequently used component of the porous filler of the fuse, the burn-back velocity in aluminium will be higher than for silver. Both of these properties lead to a faster transfer of the arc foot-points to copper to realize the effect according to the invention. 0059334

It is also foreseen that for special applications it can be advantageous to use the combination of silver with aluminium in stead of copper, because the faster burn-back of aluminium will lead to a fast growth of arc voltage due to elongation, while the more precise operation of silver in the opening of small overloads warrants the use of silver for the location of the fuse elements.

In general the invention opens the possibility to exploit many more combinations of different metals, each with its particular advantages in the two parts of the bi-metallic fuse conductor. such other combinations will occur to the man skilled in the art when the desired special properties of the fuse and its operating conditions are specified.

1. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising two kinds of metal so arranged that the current from one terminal to the other will pass successively and alternately through the two kinds of metal, beginning and ending in the first kind of metal, the second metal having pronounced reductions in cross-section defining one or more fuse elements, said second metal being particularly suited to withstand for a long time a temperature at a fuse element near the melting point without significant deterioration and said first metal being selected to provide favorable conditions for current interruption with the arc burning between foot-points on parts of said first metal.

2. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising two kinds of metal so arranged that the current from one terminal to the other will pass successively and alternatively through the two kinds of metal, beginning and ending in the first kind of metal, the second metal having pronounced reductions in cross-section defining one or more fuse elements, said second metal being particularly suited to withstand for a long time a temperature at a fuse element near the melting point without significant deterioration and said first metal being selected to provide favorable conditions for current interruption with the arc burning between foot-points on said first metal, with the transitions between the first and the second metal as close in the direction of current flow to the fuse elements as compatible with essentially non-deterioration of said first metal.

3. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising two kinds of metal so arranged that the current from one terminal to the other will pass successively and alternatively through the two kinds of metal, beginning and ending in the first kind of metal, the second metal having pronounced reductions in cross-section defining one or more fuse elements, said second metal being particularly suited to withstand for a long time a temperature at a fuse element near the melting point without significant deterioration and said first metal being selected to provide favorable conditions for current interruption with the arc burning between foot-points on said first metal, with the transitions between the first and the second metal as close in the direction of current flow to the fuse elements as compatible with essentially non-deterioration of said first metal when the fuse operates for a long time at or below its rated current.

4. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising parts of copper and silver so arranged that the current from one terminal to the other will pass successively and alternatively through copper and silver, beginning and ending in copper, with the silver having pronounced reductions in cross-section defining one or more fuse elements and with the transitions between copper and silver as close in the direction of current flow to the fuse elements as compatible with essentially non-deterioration of the copper even with the fuse elements operating for a long time at a temperature near the melting point of silver.

5. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising parts of copper and silver so arranged that the current from one terminal to the other will pass successively and alternatively through copper and silver, beginning and ending in copper, with the silver having pronounced reductions in cross-section defining one or more fuse elements and with the transitions between copper and silver so close in the direction of current flow to the fuse elements that a substantial part of the arcing time will be with the arc burning from copper to copper when the fuse operates under the most severe conditions defined by its rating, yet far enough to be compatible with essentially non-deterioration of the copper when the fuse operates for a long time at or below its rated current.

6. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising parts of copper and aluminium so arranged that the current from one terminal to the other will pass successively and alternatively through copper and aluminium beginning and ending in copper, with the aluminium having pronounced reductions in cross-section defining one or more fuse elements and with the transitions between copper and aluminium as close in the direction of current flow to the fuse elements as compatible with essentially non-deterioration of the copper even with the fuse elements operating for a long time at a temperature around the melting point of aluminium.

7. In an enclosed fuse with a porous filler the combination of a pair of terminals mutually insulated except for one or more metallic fuse conductors comprising parts of copper and aluminium so arranged that the current from one terminal to the other will pass successively and alternatively through copper and aluminium, beginning and ending in copper, with the silver having pronounced reductions in cross-section defining one or more fuse elements and with the transitions between copper and aluminium so close in the direction of current flow to the fuse elements that the amount of aluminium in the fuse becomes a minimum compatible with essentially non-deterioration of the copper when the fuse operates for a long time at or below its rated current.

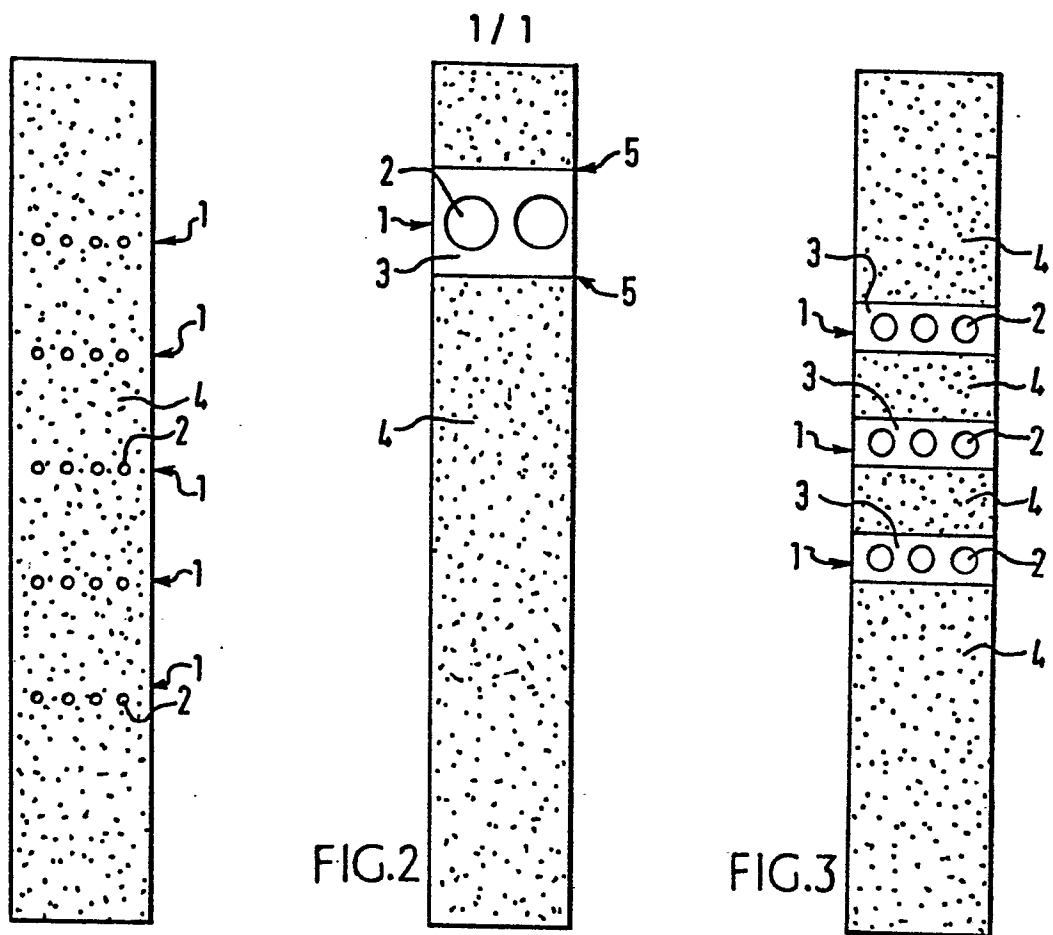


FIG. 1.

FIG. 2

FIG. 3

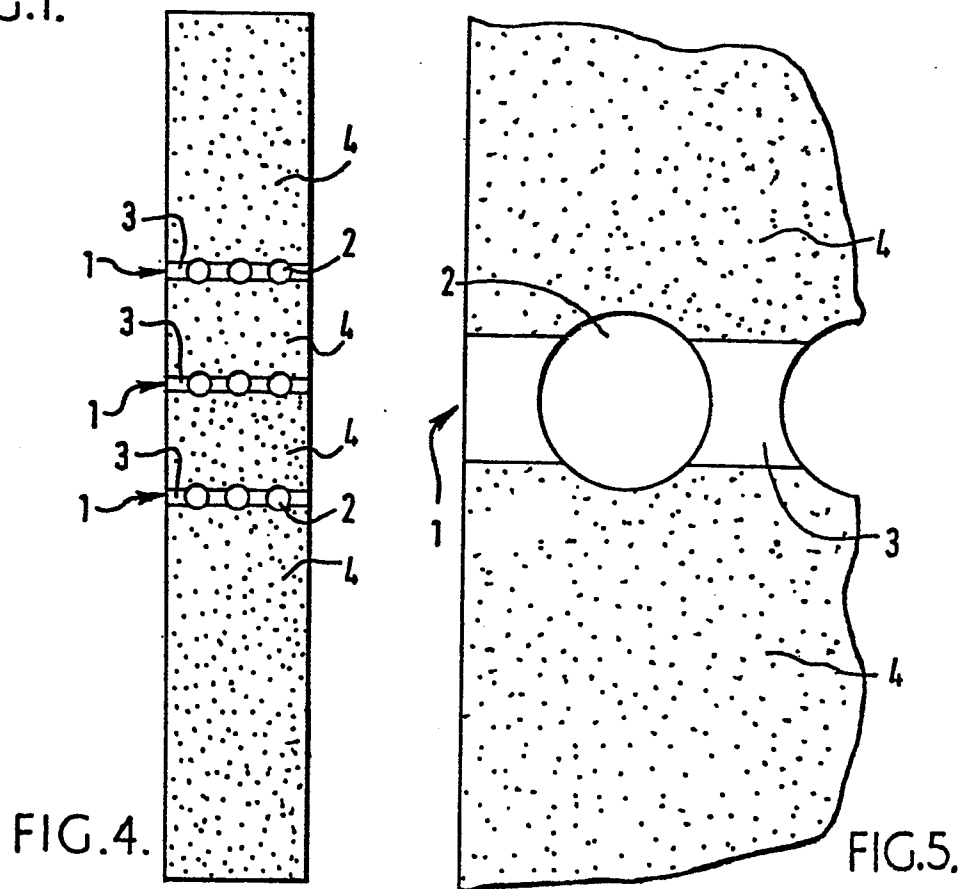


FIG. 4.

FIG. 5.