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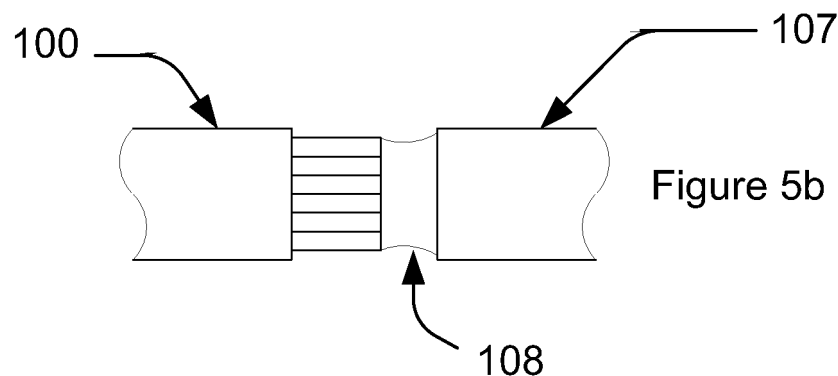
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(54) **Method of forming a connection between a multi-strand conductor and another conductor**

(57) In order to connect a multi-strand conductor 100 to another conductor 107, the end of the multi-strand conductor is cut so as to form a substantially flat surface 104. A laser beam 201 is directed at the cut end 104 of conductor 100 to weld strands 105 of the conductor 100 together to form a convex end surface 106. The convex

end surface 106 is then positioned adjacent to and aligned with the solid conductor 107. A laser beam 202 is then directed at the convex end surface 106 and the solid conductor 107 causing the end surface 106 to weld together with the solid conductor 107. The method may also be used to connect a pair of multi-strand conductors 100a, 100b together.



Description

[0001] The present invention relates to a method of forming a connection between a multi-strand conductor and another conductor, in particular for use in connecting a sensor intended for use in a high temperature or harsh environment to external circuitry via one or more strand wires.

[0002] Sensors intended for use in harsh environments, for example an automotive exhaust system, typically comprise a sensing element connected to external circuitry by a conducting link. The conducting link might typically comprise a solid conductor embedded in an insulating material within a tube. Such an arrangement not only provides mechanical support but also protection from the harsh environment.

[0003] The connection between the solid conductor of the conducting link and the appropriate contacts of the sensor is traditionally achieved by the use of multi-strand conductors. Usually, the multi-strand conductors will be provided with an insulating sheath. The use of such insulated multi-strand conductors provides flexibility, easing the task of making the connection. According to the state of the art, the connection between the multi-strand conductors and the contacts of the sensor and the solid conductor of the conducting link is carried out using an intermediate connection method. Commonly this might involve say crimping a connection element to the stripped end of the multi-strand conductor, the connection element in turn welded or interference fitted to the solid conductor or the sensor contact.

[0004] The use of such an intermediate connection method means that there is an air gap between the end of the insulating sheath of the multi-strand conductor and the insulating material of the conducting link. The air within the gap will expand and contract as the sensor is exposed to changes in temperature. Such expansion and contraction will create a pumping action which can suck moisture along the flexible wires and so corrode the connections and cause failures of the sensor. This can be partially remedied by partially filling the gap with a semi-flexible plug. This surrounds the connections and provides support as well as reducing the volume of air within the connection.

[0005] This problem was addressed in US5269056 wherein the use of lasers to weld a multi-strand conductor to a solid conductor is disclosed. However, this method requires the simultaneous use of multiple lasers to ensure beams are simultaneously focussed on the weld from a number of different angles to ensure that the strands do not separate in the welding process. Requiring multiple laser beams to implement this technique increases its cost. Furthermore, in many instances it may be difficult or impossible to direct laser beams on to the joint from all the required angles, due to the size or shape of nearby components.

[0006] It is therefore an object of the present invention to provide a new method of connecting a multi-strand

conductor to another conductor that at least partially overcomes or alleviates the above problems.

[0007] According to a first aspect of the invention there is provided a method of making a connection between a multi-strand conductor and another conductor, the method comprising the steps of: providing a multi-strand conductor having an end cut in a plane substantially orthogonal to its longitudinal axis; providing a sheath around the cut end; performing a first weld at the cut end so as to weld the strands of the multi-strand conductor together to form a convex surface at the cut end; positioning said convex surface in contact with said other conductor; and performing a second weld so as to weld said convex surface and said other conductor together to form a connection.

[0008] This thus provides a method of making connections between a multi-strand conductor and another conductor that is compatible with high temperature operation and large temperature cycles and resistant to moisture ingress. The first weld which forms the convex surface of the end portion of the multi-strand conductor helps to prevent the separation of the strands during the second weld. This may enable the second weld to be achieved by use of a single energy source.

[0009] The sheath is preferably retained in position whilst the first weld is performed. In such circumstances the sheath acts to contain the strands preventing them from separating before they are welded together.

[0010] The sheath may be provided over substantially the full length of the conductor or may be provided only over the end of the conductor for the purpose of implementing the method. The sheath may be preformed. The sheath is preferably formed of an insulating material.

[0011] The sheath may be stripped from the end portion of the multi-strand conductor after the first weld. A pre-stripping groove may be formed in the sheath. The pre-stripping groove may facilitate stripping. The pre-stripping groove may be formed prior to first weld.

[0012] The first weld may be performed using a spatially limited energy source. Such spatially limited energy source may comprise a laser beam. The laser beam may be applied to the cut end in a substantially axial direction. The beam may be substantially circular in cross section. In such cases, the beam may have a diameter substantially equal to the diameter of the cut end of the multi-strand conductor.

[0013] The multi-strand conductor may be held with the cut end substantially horizontal during the first weld. This can help to retain the welded portion of the strands within the sheath.

[0014] The second weld may be performed using one or more spatially limited energy sources. Such spatially limited energy sources may comprise laser beams. If more than one energy source is used, the second weld is preferably performed using a plurality of spatially limited energy sources arranged around said convex surface of said multi-strand conductor and said other conductor. Preferably, the spatially limited energy sources

are arranged approximately uniformly around the circumference of said convex surface of said multi-strand conductor and said other conductor.

[0015] An insulating plug may be fitted around said connection between the multi-strand conductor and the other conductor after the second weld is performed. The insulating plug may reduce the volume of air around the weld so as to reduce the pumping effect caused by temperature cycling and so reduce the ingress of moisture. The alignment of the multi-strand conductor and the other conductor may be arranged to facilitate use of a particular form of insulating plug. As a further alternative a suitable insulating material may be applied over the connection to form the insulating plug. Since the method of the present invention provides a connection that is no wider than the conductors (as opposed to the use of a crimped connection in the prior art), it is easier to extend the sealing plug over the connection and results in a lesser volume of air being trapped.

[0016] The multi-strand conductor is preferably cut using a suitable cutting disc. One suitable form of cutting disc is a surgical cutting disc. Preferably the end surface is substantially flat after the cutting. This helps ensure that all the strands weld together during the first weld.

[0017] The multi-strand conductor and the other conductor are preferably formed from the same material or from materials having similar thermal coefficients and/or similar melting points. This helps to ensure a good connection is formed by the welding process.

[0018] The multi-strand conductor may be comprised of strands of a single material or may be comprised of strands of two or more different materials. Such a combination may provide better mechanical strength to the connecting leads and/or lower connection resistance and/or maintain better mechanical integrity during the welding process. This may be of particular importance if the connection is used for connection to a resistive sensor means wherein the resistance of the connection may need to be limited to a low level to improve sensor sensitivity. In the present invention, the first weld creating the convex end surface helps to ensure a secure connection is formed during the second weld if the multi-strand conductor comprises strands of two or more different materials.

[0019] In one preferred implementation the material comprising the strands in the multi-strand conductor may be Copper or an alloy of Copper. In embodiments comprised of strands of two or more different materials in the multi-strand conductor, the materials comprising the strands may be Copper, Steel and/or Nickel. Such combinations may be of particular use for high temperature applications. A combination of Copper and Steel may also result in a connection having greater strength under tension.

[0020] The other conductor may be formed of any suitable material. In one preferred embodiment suitable for high temperature applications, the other conductor may

be formed of Nickel. Alternatively the other conductor might typically be formed of Iron, Constantan, Copper, Nickel or Aluminium alloys.

[0021] The multi-strand conductor may comprise any suitable number of strands. If the multi-strand conductor is comprised of strands of two or more different materials, it may comprise any suitable number or proportion of strands of each material.

[0022] The other conductor may be a solid conductor or a further multi-strand conductor as desired or as appropriate. Such solid conductors may comprise linear solid conductors in the form of rods, wires cables or similar or alternative forms forming electrical contacts for a sensor or other device. In the event that the other conductor is a multi-strand conductor it is preferably provided with a convex surface on its end portion by the method above.

[0023] The method may be used to provide an electrical connection between a sensor and a conducting link wherein the conducting link is a conducting link of the type comprising a solid conductor embedded in an insulating material within a tube. The sensor may be provided in a harsh environment, such as an automotive exhaust. In such circumstances the conducting link may provide a connection to external circuitry such as external monitoring or control circuitry. The sensor may comprise a thermocouple.

[0024] According to a second aspect of the present invention there is provided an electrical connection formed according to the method of the first aspect of the present invention.

[0025] The connection of the second aspect of the present invention may incorporate any or all features of the method of the first aspect of the present invention as required or as desired.

[0026] According to a third aspect of the present invention there is provided a method of preparing the end of a multi-strand conductor for connection to another conductor, the method comprising the steps of: cutting the end of said multi-strand conductor in a plane substantially orthogonal to its longitudinal axis; providing a insulating sheath around the cut end; and performing a weld at the cut end so as to weld the strands of the multi-strand conductor together to form a convex surface at the cut end.

[0027] The method of the third aspect of the present invention may incorporate any or all features of the method of the first aspect of the present invention as required or as desired.

[0028] According to a fourth aspect of the present invention there is provided a multi-strand conductor prepared in accordance with the method of the third aspect of the present invention.

[0029] The conductor of the fourth aspect of the present invention may incorporate any or all features of the method of the first or third aspects of the present invention as required or as desired.

[0030] In order that the invention can be more clearly understood exemplary embodiments will now be described further below, by way of example only and with

reference to the accompanying drawings:

- Figure 1 shows a multi-strand conductor with a flat orthogonally cut end;
- Figure 2 shows the exposure of the cut end to energy in accordance with the method of the present invention;
- Figure 3 shows the formation of a convex end portion in response to the exposure of figure 2;
- Figure 4 shows the convex end portion of the multi-strand connector from figure 3 after it is stripped of its insulating sheath;
- Figure 5a shows the positioning of the stripped convex end portion of figure 4 adjacent to a solid conductor for forming a connection according to the method of the present invention;
- Figure 5b shows the connection formed following exposure of the positioned stripped convex end portion of figure 5a to energy according to the method of the present invention;
- Figure 6a shows the positioning of the stripped convex end portion of figure 4 adjacent to a second such stripped convex end portion of a strand conductor for forming a connection according to the method of the present invention; and
- Figure 6b shows the connection formed following exposure of the positioned stripped convex end portions of figure 6a to energy according to the method of the present invention.

[0031] Referring now to figure 1 there is shown a multi-strand conductor 100 in the form of a linear cable covered by an insulating sheath 101. In order to connect the conductor 100 to another conductor, the method of the present invention is employed. The first step is to cut the end of the multi-strand conductor so as to form a substantially flat surface 104 that is substantially perpendicular to the axis of the conductor 100. This may be achieved using a surgical cutting disc. Cutting with pinchers or similar will result in a deformed rather than a flat surface. A groove 102 is made in the insulating sheath 101, thereby defining an end portion 103 of the insulating sheath 101.

[0032] The next step is illustrated in figure 2. A laser beam 201 is directed at the cut end 104 of conductor 100. The laser beam 201 has a substantially circular cross-section with a diameter substantially equal to the diameter of the conductor 100. This results in the strands 105 of the conductor 100 welding together to form a con-

vex end surface 106, as is shown in figure 3. The end portion 103 of the insulating sheath can then be removed to expose the ends of strands 105 and in particular convex end surface 106. Keeping the end portion 103 in place during the laser weld helps to contain the strands 105 helping to ensure that a secure weld 106 is formed incorporating all the strands.

[0033] These steps provide a conductor 100 wherein the strands 105 are fused at their end to form a convex surface 106. This facilitates connecting the conductor 100 to other conductors since there is a much lesser chance of the strands 105 separating during the connection process.

[0034] Turning now to figures 5a and 5b the connection of the conductor 100 to a solid conductor 107 is illustrated. In figure 5a, the convex end surface 106 is positioned adjacent to and aligned with the solid conductor 107. A laser beam 202 is then directed at the convex end surface 106 and the solid conductor 107. The laser beam causes the end surface 106 to weld together with the solid conductor 107 forming connection 108, shown in figure 5b.

[0035] In alternative embodiments, two or more laser beams 202 may be used for welding or the single laser beam 202 may be rotated around the joint. Additional beams may speed up the process and help to ensure a more secure and symmetrical weld, reducing the chance of a strand 105 becoming separated from the connection 108 during the welding process. However, since in the method of the present invention the strands 105 are already connected in the convex end portion 106 there is a low chance that they will become separated in the welding process. This means that the welding at this stage may be carried out by means of one or a series of bursts of laser illumination from a single source rather than the multiple sources required in prior art methods.

[0036] As a further possibility, an insulating plug (not shown) may be provided around the connection 108, the exposed strands 105 and the exposed end of conductor 107, if required or desired.

[0037] The method of the present invention may also be used to connect a pair of multi-strand conductors 100a, 100b as is illustrated in figures 6a and 6b. Similarly to the above, in figure 6a, the convex end surfaces 106a, 106b are positioned adjacent to and aligned with one another. A laser beam 202 is then directed at the convex end surfaces 106a, 106b. The laser beam causes the end surfaces 106a, 106b to weld together forming connection 108, shown in figure 6b. As previously, two or more laser beams 202 may be used for welding, if desired.

[0038] As a further possibility, an insulating plug (not shown) may be provided around the connection 108 and the exposed strands 105 of conductors 100a, 100b, if required or desired.

[0039] In alternative embodiments, the conductor 100 may comprise strands 105 of two or more materials. By incorporating the first welding step to form the convex end surface 106 secure welds between multi-strand con-

ductors 100 having strands of two or more different materials and other conductors may readily be formed. The formation of such connections would not be reliable using the prior art methods due to the risk of separating of the strands 105.

[0040] The above method may be particularly suited to forming a connection between a multi-strand conductor 100 and a solid conductor providing a conducting link between a sensor provided in a harsh environment and external circuitry.

[0041] It is of course to be understood that the invention is not to be restricted to the details of the above embodiments which are described by way of example only.

Claims

1. A method of making a connection between a multi-strand conductor and another conductor, the method comprising the steps of: providing a multi-strand conductor having an end cut in a plane substantially orthogonal to its longitudinal axis; providing a sheath around the cut end; performing a first weld at the cut end so as to weld the strands of the multi-strand conductor together to form a convex surface at the cut end; positioning said convex surface in contact with said other conductor; and performing a second weld so as to weld said convex surface and said other conductor together to form a connection.
2. A method as claimed in claim 1 wherein the sheath is formed of an insulating material.
3. A method as claimed in claim 1 or claim 2 wherein the sheath is retained in position whilst the first weld is performed and then the sheath is stripped from the end portion of the multi-strand conductor after the first weld.
4. A method as claimed in claim 3 wherein a pre-stripping groove is formed in the sheath prior to the first weld.
5. A method as claimed in any preceding claim wherein the multi-strand conductor is held with the cut end substantially horizontal during the first weld.
6. A method as claimed in any preceding claim wherein the first weld is performed using a spatially limited energy source.
7. A method as claimed in any preceding claim wherein the second weld is performed using one or more spatially limited energy sources.
8. A method as claimed in claim 7 wherein the second weld is performed using a plurality of spatially limited energy sources arranged around said convex surface of said multi-strand conductor and said other conductor.
9. A method as claimed in any one of claims 6 to 8 wherein the or each spatially limited energy source comprises a laser beam.
10. A method as claimed in any preceding claim wherein an insulating plug is fitted around said connection between the multi-strand conductor and the other conductor after the second weld is performed.
11. A method as claimed in claim 10 wherein the alignment of the multi-strand conductor and the other conductor is arranged to facilitate use of a particular form of insulating plug and/or wherein a suitable insulating material is applied over the connection to form an insulating plug.
12. A method as claimed in any preceding claim wherein the multi-strand conductor is cut using a surgical cutting disc.
13. A method as claimed in any preceding claim wherein the end surface is substantially flat after the cutting.
14. A method as claimed in any preceding claim wherein the multi-strand conductor and the other conductor are formed from the same material or from materials having similar thermal coefficients and/or similar melting points.
15. A method as claimed in any preceding claim wherein the multi-strand conductor is comprised of strands of a single material or is comprised of strands of two or more different materials.
16. A method as claimed in any preceding claim wherein the materials comprising the strands are Copper or an alloy of Copper, Steel and/or Nickel and wherein the other conductor is formed of Iron, Constantan, Copper, Nickel or Aluminium alloys.
17. A method as claimed in any preceding claim wherein the other conductor is a solid conductor or a further multi-strand conductor.
18. A method as claimed in any preceding claim wherein in the event that the other conductor is a multi-strand conductor it is provided with a convex surface on its end portion.
19. A method of preparing the end of a multi-strand conductor for connection to another conductor, the method comprising the steps of: cutting the end of said multi-strand conductor in a plane substantially orthogonal to its longitudinal axis; providing an insulating sheath around the cut end; and performing a

weld at the cut end so as to weld the strands of the multi-strand conductor together to form a convex surface at the cut end.

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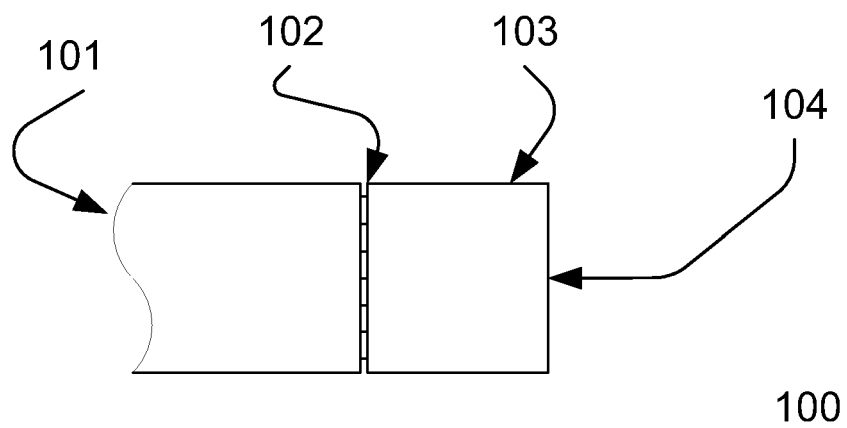


Figure 1

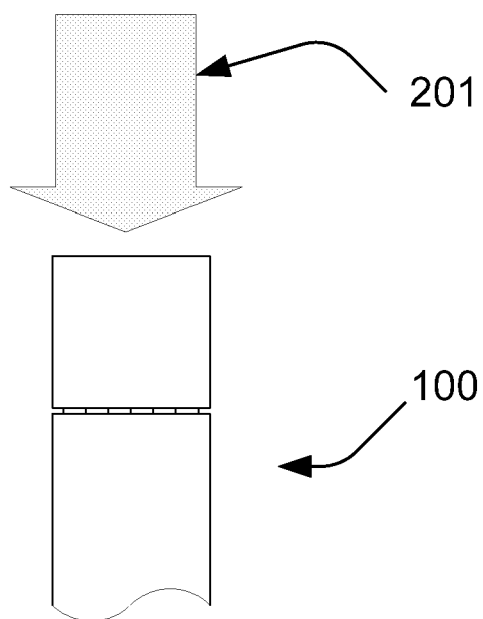


Figure 2

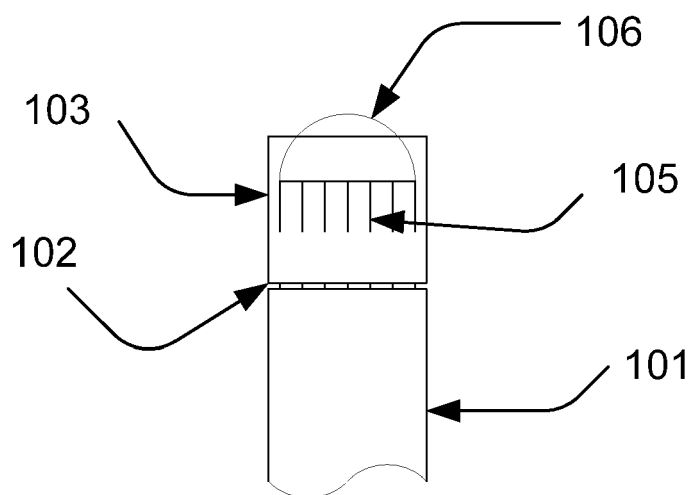


Figure 3

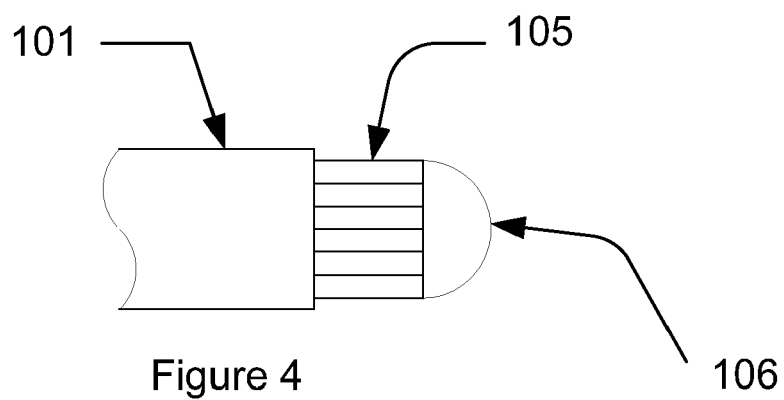
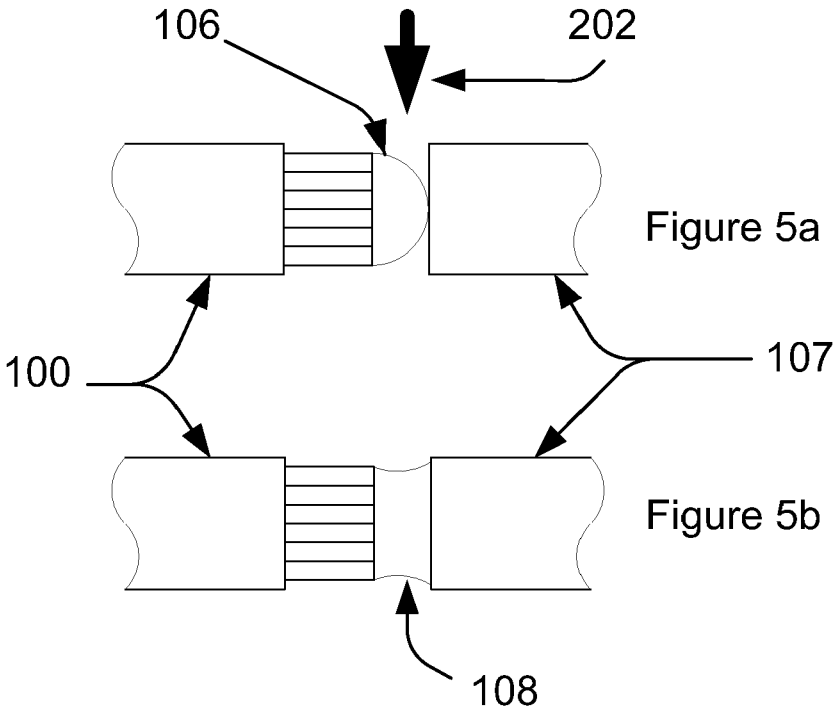


Figure 4



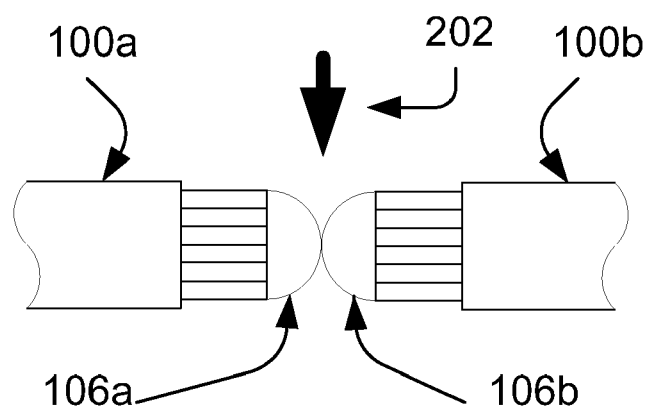


Figure 6a

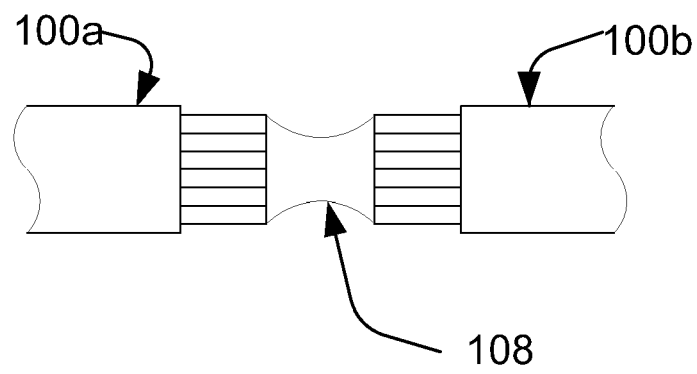


Figure 6b



EUROPEAN SEARCH REPORT

Application Number
EP 10 15 0795

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
			H01R
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 9 April 2010	Examiner Vautrin, Florent
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 10 15 0795

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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09-04-2010

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REFERENCES CITED IN THE DESCRIPTION

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