(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 191 632 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
26.12.2018 Bulletin 2018/52

(21) Application number: **15762682.1**

(22) Date of filing: **04.09.2015**

(51) Int Cl.:
D02G 3/36 *(2006.01)* ***D02G 3/44*** *(2006.01)*

(86) International application number:
PCT/GB2015/052553

(87) International publication number:
WO 2016/038342 (17.03.2016 Gazette 2016/11)

(54) **ELECTRONICALLY FUNCTIONAL YARNS**

ELEKTRONISCH FUNKTIONELLE GARNE

FILS À FONCTIONNALITÉ ÉLECTRONIQUE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **08.09.2014 GB 201415837**

(43) Date of publication of application:
19.07.2017 Bulletin 2017/29

(60) Divisional application:
18207658.8

(73) Proprietor: **Nottingham Trent University**
Nottinghamshire NG1 4BU (GB)

(72) Inventors:
- **DIAS, Tilak Kithsiri**
  Nottingham NG11 7GE (GB)
- **RATHNAYAKE, Anura**
  Nottingham NG1 4GG (GB)

(74) Representative: **Potter Clarkson LLP**
The Belgrave Centre
Talbot Street
Nottingham NG1 5GG (GB)

(56) References cited:
WO-A2-2008/080245
DE-B3-102012 108 036
GB-A- 2 472 026
JP-A- 2013 189 718
US-A1- 2013 092 742

EP 3 191 632 B1

Description

[0001] This invention relates to yarns incorporating electronic devices and their manufacture. It relates particularly to such yarns in which the devices and electrical connections thereto are protected. Also part of the invention is a method of manufacturing the yarns for incorporation into fabric products for example, although other uses are contemplated.

[0002] International Patent Publication No. WO2006/123133 discloses a multi-filament yarn including an operative device confined between the yarn filaments, and a method for its manufacture. The yarn filaments are typically polyester or polyamide. One or more of the yarn filaments can be electrically conductive and coupled to the device to form an electrical connection thereto. These filaments can be metal filament wires in the form of a polymeric monofilament yarn with either a copper or silver metal core wire. The device may take one of various forms, such as a silicon chip, a ferro-magnetic polymeric chip or a phase change chip.

[0003] Reference is also directed to Japanese Patent specification No. 2013189718A and US Patent publication No. 2013/092742. Both describe yarns carrying electronic devices within a protective outer layer or sheath.

[0004] WO 2008/080245 discloses filamentous structure having textile character and comprising electronic components integrated into it. Said structure has an electronic filament part which substantially consists of the electronic components, flex wires electrically contacting the same and possible additional elements for mechanically stabilizing the structure. A textile filament part is wound around the electronic filament part and substantially consists of at least one textile filament.

[0005] GB 2472026 relates to a signalling device comprising a semi-conductor chip confined with the filaments of a multi-filament yarn and conductive elements extending from the chip in both directions along the yarn to form an antenna. The chip is in an enclosed capsule comprising filaments of the yarn and the filaments may have resin cured between them and the antenna may be bound in the resin. The antenna elements may be entrained in the yarn filaments and the yarn may extend beyond the antenna in both directions. The chip may comprise multiple components one of which may be a light-emitting diode, a sound emitting device or a signal transmitter. The yarn may include conductive filaments connected to the chip. The yarn may be bent to form the shape of the antenna. The chip may be mounted onto a conductive backing also confined within the multi-filaments. A series of filaments may be fed radially by drawing along a central axis, the chip and backing being delivered to the filaments at the axis at which point a resin is added and the composite moulded in a split tubular mould while the yarn is held stationary.

[0006] DE-B-10 2012 108036 discloses a cable made of fibers or wire products, which are twisted together and are stranded with each other or braided. The cable has a cable force transducer that is placed in the cable with a pressure- or traction force converter. The fibers or wire products of the cable directly exert a pressure or traction force on the traction force transducer during the tensile strain of the cable. The pressure- or traction force transducer generates an evaluable electric voltage which is proportional to the pressure or traction force.

[0007] Yarns of the above International Publications are effective and can be used in fabric products. However, where the device has an electrical connection the connection will be exposed on the yarn surface and thereby compromised by contact with other yarns or elements, or by external conditions. The Japanese and US references go some way towards addressing this issue, but do not provide a resolution. A primary aim of the present invention is to avoid risk of such exposure and thereby enhance the efficiency of a device in a series of devices installed in a yarn. Another aim is to incorporate devices and connections thereto in a yarn in such a manner that they are unobtrusive. According to the invention an electronically functional yarn comprises a plurality of carrier fibres forming a core; a series of electronic devices mounted on the core with conductive interconnects extending along the core; a plurality of packing fibres extending generally parallel to the yarn axis around the core, the devices and the interconnects, which packing fibres preserve a substantially uniform cross-section along the length of the yarn and between the devices; and wherein the packing fibres are enclosed within a retaining sleeve around the packing fibres, and the core, the devices and the interconnects are confined within the plurality of packing fibres retained in the sleeve. The interconnects can comprise at least one conductor that extends the length of the yarn. By mounting the devices and interconnects on carrier fibres they are more easily retained in the body of the yarn and within the packing fibres. The packing fibres are untwisted; i.e. extend generally parallel to the yarn axis to fill spaces between the devices. A separate filler material may also be used for this purpose. The packing fibres extend generally parallel to the yarn axis to preserve a substantially uniform cross-section along the length of the yarn and between the devices, and a separate filler material can also be used to fill spaces between the devices. The packing fibres, and a filler material if used, may be selected to either encourage or discourage the absorption of moisture by the composite yarn. In preferred embodiments the carrier fibres include at least some which are arranged in a planar array and the electronic devices may all be mounted on one side of the array. The devices can then be easily mounted on at least two of the carrier fibres, but mounting on one can be sufficient in many applications. This means that different devices can be mounted on different ones or groups of the carrier fibres.

[0008] The electronic devices incorporated in yarns of the invention can take many forms, including operative devices such as a silicon chip signaling devices such as light, sound or symbol generators, micro-controllers and

energy harvesting devices. Particularly suitable for use in yarns of the present invention are ultra thin electronic dice. The packing fibres in yarns of the invention can be independent from one another; i.e. relatively movable, but at least some may be bonded to secure the integrity of the yarn, particularly around a device. Such a bond can be an adhesive bond, or established by heating the relevant zone. Some independence is preferred to allow the fibres relative movement when the yarn is bent or twisted. This assists in maintaining a high degree of uniformity in the overall yarn diameter. The packing fibres can be natural fibres, man-made fibres or synthetic fibres such as polyester or polyamide, and typically have diameters in the range 10-15μm.

[0009] The carrier fibres for the devices can be of the same material as the packing fibres, but the material will normally have a high melting point, typically above 350°C, and have a high level of thermal and chemical stability. The reason for this is to ensure they can withstand the heat generated when interconnects are coupled to the electronic devices. Semiconductor chips with solder pads for the interconnects are normally first mounted on the carrier fibres and the interconnects, for example fine copper wire, can be coupled to the pads by using a reflow soldering technique. This technique involves depositing a small quantity of solder paste on the solder pads and then applying heat to melt the paste and then create a strong metallic bond. The carrier fibres forming the yarn core must hold the devices as this process is completed, and will normally have diameters in the range 10-100 μm. Polybenzimidazole or aramid based fibres such as PBI, Vectran or Nomex are examples of some which can be used as carrier fibres. Typically the core will consist of or include four carrier fibres extending side by side providing a platform for the devices to which they are attached, although the devices will not necessarily be attached to or mounted on all the fibres forming the platform. The devices themselves are normally enclosed in a polymeric micro-pod which also encloses the adjacent length of carrier fibres to establish the attachment, normally with the solder pads on the device and the interconnects. The devices and the carrier fibres can also be hermetically sealed between two ultra thin polymeric films. The interconnects, typically fine copper wire of around 150 μm diameter, normally extend on and/or between the carrier fibres.

[0010] The retaining sleeve can take many different forms, and may vary depending upon the form taken by the packing fibres and to some extent, the intended use of the yarn. It will normally be a fibre structure comprising one or more of natural, man-made and synthetic fibres. Typical sleeves are interlaced fibre structures, but interlooped knitted fibre structures can also be used. Its function is to preserve the arrangement of the packing fibres around the devices, carrier fibres and interconnects. It can take the form of a separate yarn helically wound around the packing fibres, a woven or knitted fabric structure, or a woven or knitted braid. A fibre or yarn structure is though preferred to most easily accommodate bends and twists.

[0011] The invention is also directed at a method of manufacturing a composite yarn incorporating a series of electronic devices. The method comprises mounting electronic devices with conductive interconnects coupled thereto in sequence on a core consisting of a plurality of carrier fibres; feeding the carrier fibres with the mounted devices and interconnects centrally through a channel with packing fibres around the sides thereof to form a fibre assembly around the core, the packing fibres extending generally parallel to and preserving a substantially uniform cross-section along the length of the fibre assembly; feeding the fibre assembly into a sleeve forming unit in which a retaining sleeve is formed around the assembly to form the composite yarn; and withdrawing the composite yarn from the sleeve forming unit. The channel through which the core with the mounted devices is fed can be formed centrally in a carrousel having separate openings around its periphery through which sleeve fibres are fed for forming the sleeve. This arrangement is particularly suitable when the sleeve is to be braided as braiding fibres can be fed through the carrousel directly into a braiding unit forming the sleeve around the packing fibre assembly. However, as described below, the sleeve fibres can be warp or weft fibres feeding into a circular warp or weft knitting head. The yarn may be withdrawn from the sleeve forming unit with the packing fibre assembly being effectively drawn in a pultrusion process at a rate determined by the speed at which the sleeve forming unit operates. If any filler material is to be used this may be added at the entrance to the channel.

[0012] The invention will now be described by way of example and with reference to the accompanying schematic drawings wherein:

Figure 1 shows a broken perspective view of a yarn according to a first embodiment of the 30 invention;

Figure 2 shows the sequence of stages in the manufacture of a yarn according to the invention;

Figure 3 is a longitudinal sectional view of a yarn according to an embodiment not according to the invention;

Figure 4 is a lateral cross sectional view of the yarn of Figure 3;

Figure 5 illustrates a procedure for mounting electronic devices and conductive interconnects on carrier fibres in the manufacture of a yarn according to the invention; and

Figure 6 shows the sequence of stages in an alternative procedure in the manufacture of a yarn according to the invention.

[0013] In the yarn shown in Figure 1 a semiconductor chip 2 is sealed in a polymeric micro-pod 4 which extends around four 100μm PBI carrier fibres 6. The chip shown is 900μm long and has a square cross section of 500 x 500μm. Two 150μm copper filament interconnects 8 extend from the chip 2 within the pod 4 over the carrier fibres 6. Polyester packing fibres 10 (diameter 10μm) extend around the pod 4, the carrier fibres 6, and the interconnects 8. As shown they extend substantially parallel to the yarn axis, around and between the pods 4. A filler (not shown) may also be used for this purpose. Some twisting of the packing fibres around the pods 4 can also be of value to provide a protective layer, but this will depend upon the shape of the pod. The linear arrangement of packing fibres shown can be more appropriate when the pod 4 is rectanguloid or cylindrical in shape. Whatever arrangement is selected some of the packing fibres 10 can be bonded together by adhesive or heating to provide an hermetic seal around the pod. An hermetic seal can also be established by sandwiching the devices, their interconnects and the carrier fibres between two normally ultra-thin polymeric films. Bonding of at least some of the outer packing fibres is avoided, thereby allowing relative movement to accommodate bending or twisting of the yarn with minimum affect on the uniformity of the yarn as a whole.

[0014] A sleeve 12 surrounds the packing fibres 10 to stabilize the fibre assembly with the pods 4 and interconnects 8 held centrally therein, and particularly to provide additional protection of the interconnects from exposure and mechanical stress during use. Thus, fabrics including yarns according to the invention can survive washing and tumble drying for example, in addition to normal wear and tear during use, with less risk of compromise to the interconnects and the functionality of the chips or other devices installed in the yarn. The sleeve shown comprises a separate textile yarn 14 helically wound around the packing fibres 10. Alternative forms of sleeve are woven or knitted braids. A wide variety of fibres can be used for the sleeve, as noted above, which is normally a textile structure with fibres of diameter in the range 10-50μm.

[0015] A process for manufacturing a yarn of the invention is illustrated in Figure 2. Carrier fibres 6 populated with electronic devices (pods 4 not shown in Figure 2) such as semiconductor chips are delivered round a guide pulley 16 to a central channel 18 in a disc 20. Packing fibres 10 are delivered round guide pulleys 22 also to the channel 18 on opposite sides of the carrier fibres 6. More than two delivery paths for the packing fibres 10 can be made if desired if a more dense or diverse layer of fibres is required around the carrier fibres 6 in the manufactured yarn. If a filler is to be inserted between the pods 4 this can be injected at this stage. Any adhesive or heat treatment of the packing fibres 10 is also applied at this stage.

[0016] The assembly comprising the carrier 6 and packing 10 fibres passes from the channel 18 to a sleeve unit 24. In the process shown in Figure 2 the sleeve comprises separate textile yarns 26 delivered through openings in the periphery of the disc 20 which are knitted, woven or braided in the sleeve unit 24. Any twisting or bunching of the packing fibres 10 is carried out as the assembly passes from the channel 18 to the sleeve unit 24. The completed yarn emerges from the sleeve unit as shown, normally by being drawn at an appropriate rate.

[0017] Figures 3 and 4 illustrate an embodiment not according to the invention in which the interconnects 30 extend over the electronic devices 32 on the opposite side from the core 34 comprising the carrier fibres, and into the core from either side of each device. Each device is typically a semiconductor packaged die 36 attached to the core 34 by a layer 38 of adhesive on one side with copper interconnects 30 soldered thereto on the other side. The device 36 and the attached sections of the core 34 and the interconnects 30 are enclosed in a polymeric resin micro-pod 42. Alternatively or additionally, the devices, interconnect and carrier fibres can be hermetically sealed between two ultra-thin polymeric films. The packing fibres 40 that are shown in a relatively regular formation in Figure 4, are mobile and can be twisted and/or bunched as shown in figure 3 around and between the micro-pods to preserve a substantially uniform cross section for the completed composite yarn. A filler can also be used for this purpose if required. A textile sleeve comprising fibres 44 surrounds the packing fibres.

[0018] Figure 5 illustrates how each electronic 32 device may be mounted on the core 34 in a yarn of the kind shown in Figures 3 and 4. A layer 38 of adhesive is applied to one or more carrier fibres in the core 34; the device 32 bearing solder pads 46 is mounted on the adhesive layer 38, and the adhesive bond is cured by ultraviolet spot curing. Copper wire 48 is laid on the solder pads 46; solder paste 50 is applied and the joints are secured by infra-red reflow soldering. The copper wire is then cut as required to create individual interconnects, or left if it is to bypass one or more adjacent devices. The device and attached sections of the wire 48 and core 34 are then enclosed in a resin set by ultraviolet spot curing to form the micro-pod 42.

[0019] The manufacturing process shown in Figure 6 illustrates particularly an alternative technique for installing the packing fibres and creating the sleeve. The core 34 carrying the devices 32 in their micro-pods 42 and interconnects, is fed centrally around a first guide roller 52 to a central opening in a disc 54. Sleeve fibres 56 and packing fibres 58 are fed from respective second and third guide rollers 60 to alternate openings 62 and 64 around the periphery of the disc 54. From the disc 54 the packing fibres 58 are fed to a central duct 66 which also receives the core 34 carrying the devices and micro-pods. The sleeve fibres 56 pass through a stationary yarn guide tube 68, and then through a rotatable cylindrical yarn guide 70 to a needle cylinder 72
where the fibres are interlooped to form the sleeve. The completed composite yarn is drawn from the needle cylinder 72 at a rate commensurate with the knitting process. The same materials as are referred to above can be used

for the carrier fibres; the packing fibres, and the sleeve fibres, in the process of Figure 6

[0020] The central duct 66 has a shaped conical opening for receiving the packing fibres 58, to ensure they are arranged around the core 34 and its micropods and interconnects. The duct 66 extends the full length of the yarn guide tube 68 and rotatable cylindrical yarn guide 70 to retain the packing fibres within the sleeve fibres as they are positioned to be knitted into the sleeve in the needle cylinder 72. Thus, in the completed yarn, the packing fibres within the sleeve surround and enclose the carrier fibres, micropods and interconnects ensuring that the interconnects extend along the core. The process illustrated would use a warp knitting process in which the cylindrical yarn guide 70 oscillates to properly orient the sleeve fibres prior to knitting. The process can be adapted for weft knitting, but the orientation of the fibres around the duct 64 prior to knitting is more complex.

Claims

1. An electronically functional yarn comprising a plurality of carrier fibres (6) forming a core with a series of electronic devices (2) mounted thereon, and conductive interconnects (8) extending from the devices along the core, **characterised in that** a plurality of packing fibres (10) extend generally parallel to the yarn axis around the core, the devices and the interconnects, which packing fibres preserve a substantially uniform cross-section along the length of the yarn and between the devices; and wherein the packing fibres are enclosed within a retaining sleeve (12) around the packing fibres, and the core, the devices and the interconnects are confined within the plurality of packing fibres retained in the sleeve.

2. A functional yarn according to Claim 1 wherein the packing fibres (10) are independent from one another.

3. A functional yarn according to Claim 1 or Claim 2 wherein at least some of the packing fibres (10) are bonded together.

4. A functional yarn according to any preceding Claim including a filler material in spaces between devices (2) within the packing fibres (10).

5. A functional yarn according to any preceding Claim wherein the carrier fibres (6) are arranged in a substantially planar array.

6. A functional yarn according to any preceding Claim wherein each device (2) is mounted on at least two carrier fibres (6).

7. A functional yarn according to any preceding Claim wherein the interconnects (8) comprise at least one conductor extending between carrier fibres (6) past devices to which it is not coupled.

8. A functional yarn according to any preceding Claim wherein the retaining sleeve (12) is a fibre structure.

9. A functional yarn according to Claim 8 wherein the retaining sleeve (12) comprises a supplementary yarn (14) helically wound around the packing fibres; an interlaced fibre structure, or an interlooped knitted fibre structure.

10. A method of manufacturing a composite yarn incorporating a series of electronic devices (2) comprising:

    mounting electronic devices (2) with conductive interconnects (8) coupled thereto in sequence on a core consisting of a plurality of carrier fibres (6);
    feeding the carrier fibres with the mounted devices and interconnects centrally through a channel (18) with packing fibres (10) around the sides thereof to form a fibre assembly around the core, the packing fibres extending generally parallel to and preserving a substantially uniform cross-section along the length of the fibre assembly;
    feeding the fibre assembly into a sleeve forming unit (24) in which a retaining sleeve (12) is formed around the assembly to form the composite yarn; and
    withdrawing the composite yarn from the sleeve forming unit.

11. A method according to Claim 10 wherein the channel (18) is formed centrally in a disc (20; 54) having openings around its periphery; and wherein sleeve fibres (26; 56) are fed through the peripheral openings (62) to the sleeve forming unit (24; 72) in which they are processed to form the sleeve.

12. A method according to Claim 10 or Claim 11 wherein the channel (18) extends into the sleeve forming unit (24).

13. A method according to any of Claims 10 to 12 wherein the carrier fibres (6) are arranged in a substantially planar array.

14. A method according to any of Claims 10 to 13 wherein each device (2) is mounted on at least two carrier fibres (6).

15. A method according to Claims 10 to 14 wherein the sleeve forming unit (24) comprises a braiding head; a circular weft knitting head, or a circular warp knitting

head.

16. A method according to any of Claims 10 to 15 wherein a filler is injected into the fibre assembly between the devices (2) as the fibre assembly passes from the channel (18) to the sleeve forming unit (24).

Patentansprüche

1. Elektronisch funktioneller Faden, der mehrere Trägerfasern (6) umfasst, die einen Kern mit einer Reihe von daran befestigten elektronischen Vorrichtungen (2) ausbilden,
und leitende Verbindungselemente (8), die sich von den Vorrichtungen entlang des Kerns erstrecken, **dadurch gekennzeichnet, dass** sich mehrere Packfasern (10) im Allgemeinen parallel zu der Fadenachse um den Kern, die Vorrichtungen und die Verbindungselemente herum erstrecken, wobei die Packfasern einen im Wesentlichen einheitlichen Querschnitt entlang der Länge des Fadens und zwischen den Vorrichtungen erhalten; und wobei die Packfasern innerhalb einer Haltehülse (12) um die Packfasern herum eingeschlossen sind, und der Kern, die Vorrichtungen und die Verbindungselemente innerhalb der mehreren in der Hülse gehaltenen Packfasern begrenzt sind.

2. Funktioneller Faden nach Anspruch 1, wobei die Packfasern (10) unabhängig voneinander sind.

3. Funktioneller Faden nach Anspruch 1 oder 2, wobei wenigstens einige der Packfasern (10) aneinander gebunden sind.

4. Funktioneller Faden nach einem der vorhergehenden Ansprüche, einschließlich eines Füllmaterials in Freiräumen zwischen Vorrichtungen (2) innerhalb der Packfasern (10).

5. Funktioneller Faden nach einem der vorhergehenden Ansprüche, wobei die Trägerfasern (6) in einer im Wesentlichen ebenen Anordnung angeordnet sind.

6. Funktioneller Faden nach einem der vorhergehenden Ansprüche, wobei jede Vorrichtung (2) an wenigstens zwei Trägerfasern (6) befestigt ist.

7. Funktioneller Faden nach einem der vorhergehenden Ansprüche, wobei die Verbindungselemente (8) wenigstens einen Leiter umfassen, der sich zwischen Trägerfasern (6) vorbei an Vorrichtungen, mit denen er nicht verbunden ist, erstreckt.

8. Funktioneller Faden nach einem der vorhergehenden Ansprüche, wobei die Haltehülse (12) eine Faserstruktur ist.

9. Funktioneller Faden nach Anspruch 8, wobei die Haltehülse (12) einen zusätzlichen Faden (14), der spiralförmig um die Packfasern gewickelt ist; eine verflochtene Faserstruktur oder eine verwobene gestrickte Faserstruktur umfasst.

10. Verfahren zum Herstellen eines Verbundfadens, der eine Reihe elektronischer Vorrichtungen (2) enthält, Folgendes umfassend:

    Befestigen von elektronischen Vorrichtungen (2) mit leitenden Verbindungselementen (8), die daran in Reihe gekoppelt sind, an einen Kern, der aus mehreren Trägerfasern (6) besteht;
    Zuführen der Trägerfasern mit den befestigten Vorrichtungen und Verbindungselementen mittig durch einen Kanal (18) mit Packfasern (10) um dessen Seiten herum, um eine Faseranordnung um den Kern herum auszubilden, wobei sich die Packfasern im Allgemeinen parallel dazu erstrecken und einen im Wesentlichen einheitlichen Querschnitt entlang der Länge der Faseranordnung erhalten;
    Zuführen der Faseranordnung in eine hülsenbildende Einheit (24), in der eine Haltehülse (12) um die Anordnung herum ausgebildet ist, um den Verbundfaden auszubilden; und Entnehmen des Verbundfadens aus der hülsenbildenden Einheit.

11. Verfahren nach Anspruch 10, wobei der Kanal (18) mittig in einer Scheibe (20; 54) ausgebildet ist, die Öffnungen um ihren Umfang herum aufweist; und wobei Hülsenfasern (26; 56) durch die Umfangsöffnungen (62) zu der hülsenbildenden Einheit (24; 72) zugeführt werden, in der sie verarbeitet werden, um die Hülse auszubilden.

12. Verfahren nach Anspruch 10 oder 11, wobei sich der Kanal (18) in die hülsenbildende Einheit (24) erstreckt.

13. Verfahren nach einem der Ansprüche 10 bis 12, wobei die Trägerfasern (6) in einer im Wesentlichen ebenen Anordnung angeordnet sind.

14. Verfahren nach einem der Ansprüche 10 bis 13, wobei jede Vorrichtung (2) an wenigstens zwei Trägerfasern (6) befestigt ist.

15. Verfahren nach den Ansprüchen 10 bis 14, wobei die hülsenbildende Einheit (24) einen Flechtkopf; einen runden Kulierwirkkopf oder einen runden Kettenwirkkopf umfasst.

16. Verfahren nach einem der Ansprüche 10 bis 15, wo-

bei ein Füllstoff in die Faseranordnung zwischen den Vorrichtungen (2) eingespritzt wird, während die Faseranordnung von dem Kanal (18) hin zu der hülsenbildenden Einheit (24) durchläuft.

Revendications

1. Fil électroniquement fonctionnel comprenant une pluralité de fibres porteuses (6) formant une âme avec une série de dispositifs électroniques (2) montés dessus,
et des interconnexions conductrices (8) s'étendant depuis les dispositifs le long de l'âme, **caractérisé en ce qu'**une pluralité de fibres de garnissage (10) s'étendent généralement parallèles à l'axe de fil autour de l'âme, les dispositifs et les interconnexions, lesquelles fibres de garnissage conservent une section sensiblement uniforme suivant la longueur du fil et entre les dispositifs ; et dans lequel les fibres de garnissage sont contenues au sein d'un manchon de retenue (12) autour des fibres de garnissage, et l'âme, les dispositifs et les interconnexions sont confinés au sein de la pluralité de fibres de garnissage retenues dans le manchon.

2. Fil fonctionnel selon la revendication 1, dans lequel les fibres de garnissage (10) sont indépendantes les unes des autres.

3. Fil fonctionnel selon la revendication 1 ou la revendication 2, dans lequel au moins certaines des fibres de garnissage (10) sont liées ensemble.

4. Fil fonctionnel selon une quelconque revendication précédente, comportant un matériau de charge dans des espaces entre des dispositifs (2) au sein des fibres de garnissage (10).

5. Fil fonctionnel selon une quelconque revendication précédente, dans lequel les fibres porteuses (6) sont agencées en un ensemble sensiblement plan.

6. Fil fonctionnel selon une quelconque revendication précédente, dans lequel chaque dispositif (2) est monté sur au moins deux fibres porteuses (6).

7. Fil fonctionnel selon une quelconque revendication précédente, dans lequel les interconnexions (8) comprennent au moins un conducteur s'étendant entre des fibres porteuses (6) au-delà de dispositifs auxquels il n'est pas couplé.

8. Fil fonctionnel selon une quelconque revendication précédente, dans lequel le manchon de retenue (12) est une structure de fibre.

9. Fil fonctionnel selon la revendication 8, dans lequel le manchon de retenue (12) comprend un fil supplémentaire (14) enroulé hélicoïdalement autour des fibres de garnissage ; une structure de fibre entrelacée ou une structure de fibre tricotée liée.

10. Procédé de fabrication d'un fil composite incorporant une série de dispositifs électroniques (2) comprenant :

    le montage de dispositifs électroniques (2) avec des interconnexions conductrices (8) couplées à ceux-ci en séquence sur une âme consistant en une pluralité de fibres porteuses (6) ;
    l'apport des fibres porteuses avec les dispositifs et interconnexions montés au centre à travers un canal (18) avec des fibres de garnissage (10) autour de leur côté pour former un ensemble de fibres autour de l'âme, les fibres de garnissage s'étendant généralement parallèles à et conservant une section sensiblement uniforme suivant la longueur de l'ensemble de fibres ;
    l'apport de l'ensemble de fibres dans une unité de formation de manchon (24) dans laquelle un manchon de retenue (12) est formé autour de l'ensemble pour former le fil composite ; et
    le retrait du fil composite de l'unité de formation de manchon.

11. Procédé selon la revendication 10, dans lequel le canal (18) est formé au centre dans un disque (20 ; 54) ayant des ouvertures autour de sa périphérie ; et dans lequel des fibres de manchon (26 ; 56) sont apportées à travers les ouvertures périphériques (62) à l'unité de formation de manchon (24 ; 72) dans laquelle elles sont traitées pour former le manchon.

12. Procédé selon la revendication 10 ou la revendication 11, dans lequel le canal (18) s'étend dans l'unité de formation de manchon (24).

13. Procédé selon l'une quelconque des revendications 10 à 12, dans lequel les fibres porteuses (6) sont agencées en un ensemble sensiblement plan.

14. Procédé selon l'une quelconque des revendications 10 à 13, dans lequel chaque dispositif (2) est monté sur au moins deux fibres porteuses (6).

15. Procédé selon les revendications 10 à 14, dans lequel l'unité de formation de manchon (24) comprend une tête de tressage ; une tête de tricotage de trame circulaire ou une tête de tricotage de chaîne circulaire.

16. Procédé selon l'une quelconque des revendications 10 à 15, dans lequel une charge est injectée dans l'ensemble de fibres entre les dispositifs (2) à mesure que l'ensemble de fibres passe du canal (18) à l'unité

de formation de manchon (24).

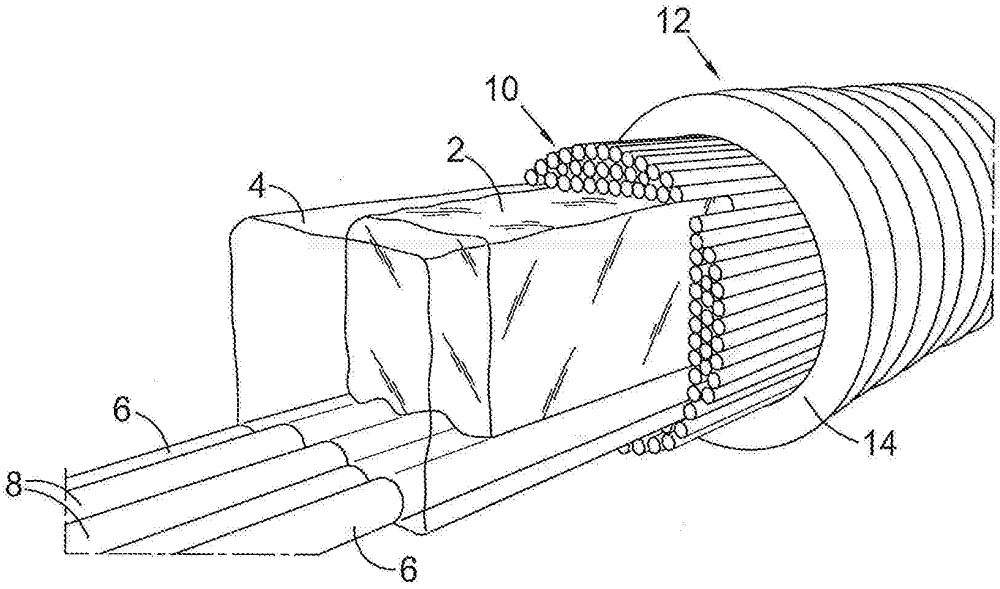

Figure 1

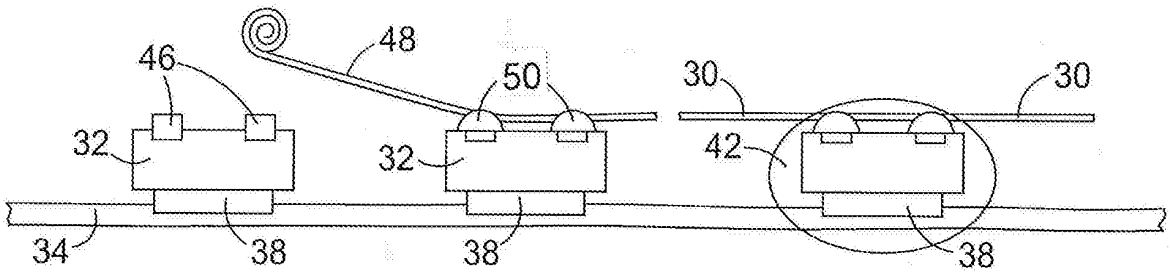

Figure 5

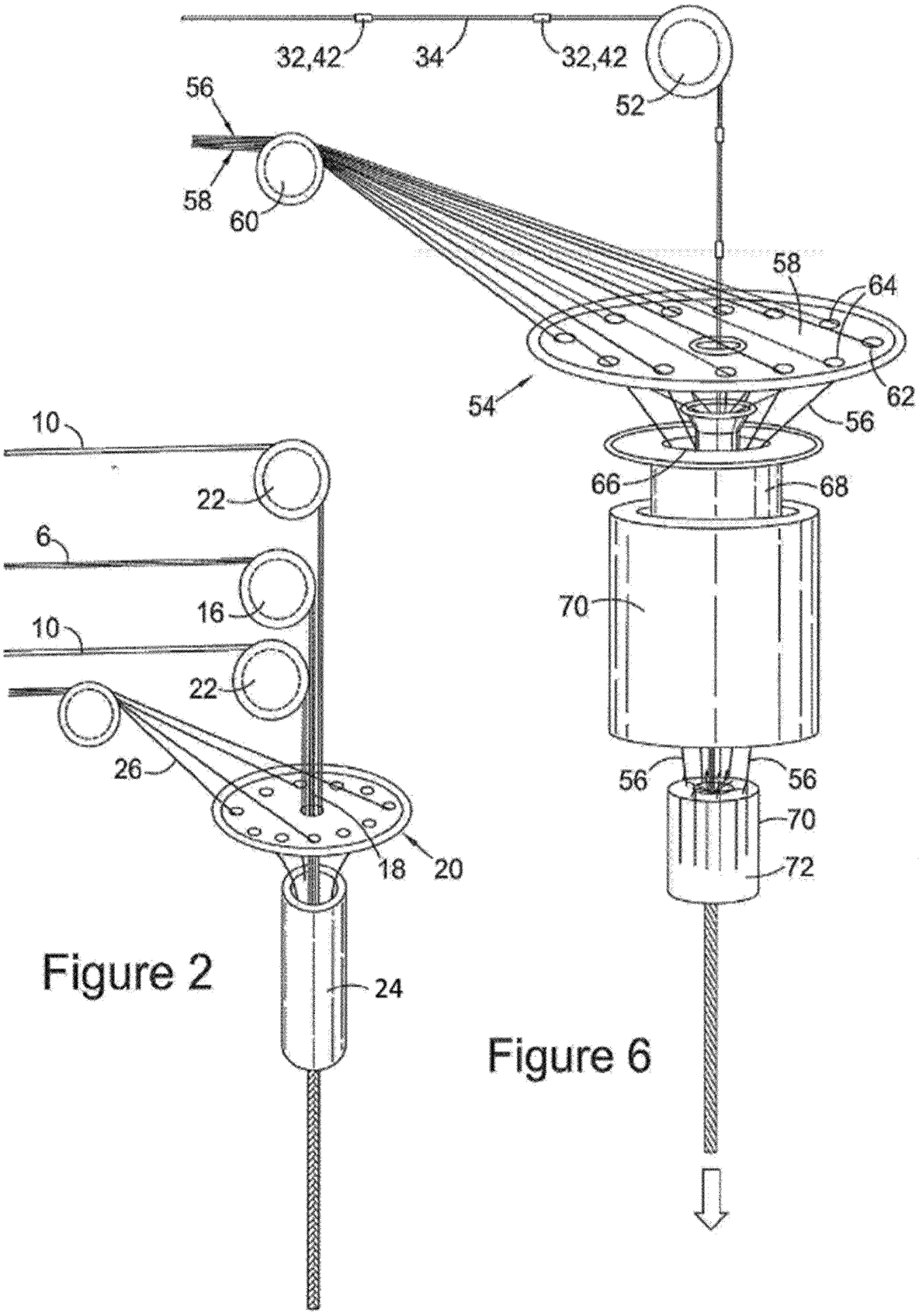

Figure 2

Figure 6

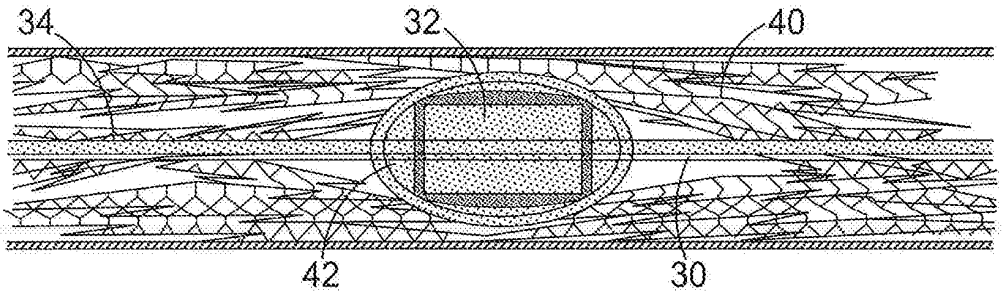

Figure 3

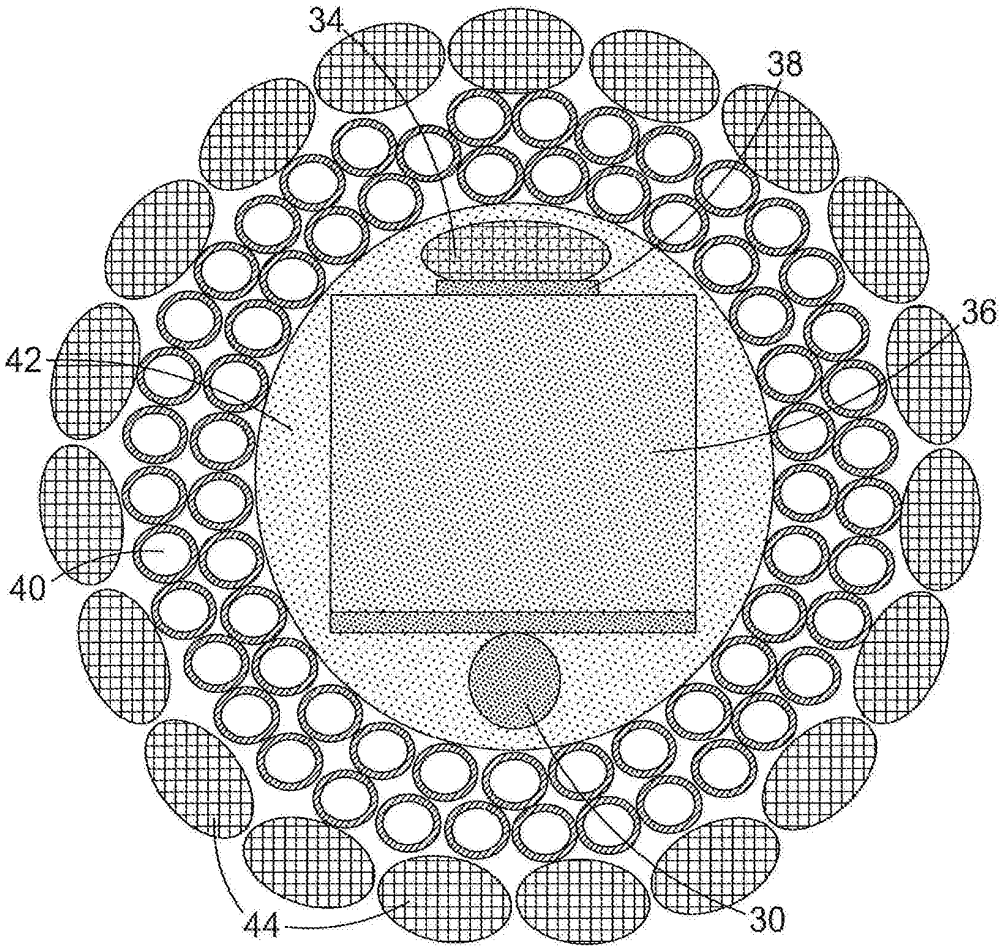

Figure 4

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2006123133 A **[0002]**
- JP 2013189718 A **[0003]**
- US 2013092742 A **[0003]**
- WO 2008080245 A **[0004]**
- GB 2472026 A **[0005]**
- DE 102012108036 B **[0006]**