



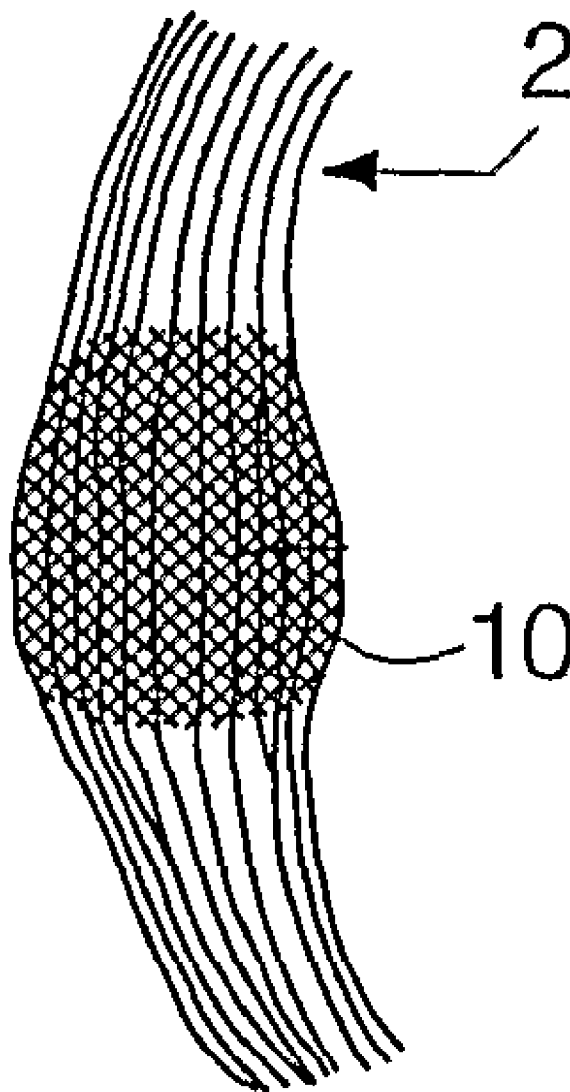
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YARNS**(30) **Foreign Application Priority Data**

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D02G 1/00 (2006.01)(52) **U.S. Cl. 57/210; 57/243; 139/383 R; 57/333**(57) **ABSTRACT**(21) Appl. No.: **11/914,194**(22) PCT Filed: **May 16, 2006**(86) PCT No.: **PCT/GB2006/001804**§ 371 (c)(1),
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An operative device, such as an electronic chip, apiezoelectric, thermal or optical device, is confined within the filaments of a length of multi-filament yarn. The filaments around the device form a capsule and the filaments can be bonded to each other to reinforce such a capsule. The capsule can also comprise a resin to provide protection for the confined device. An additional layer of filaments can be created around the original filaments. Methods and apparatus for confining the devices within yarns are described.



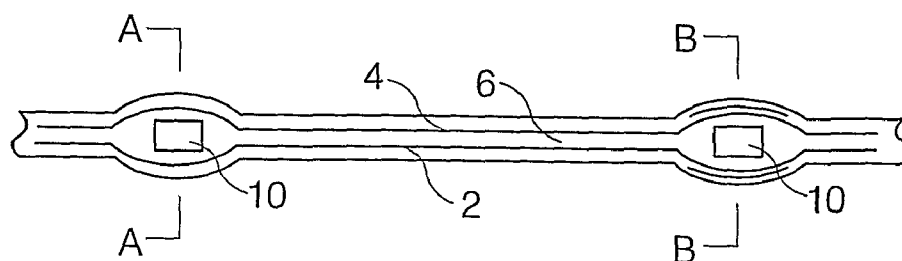


FIGURE 1

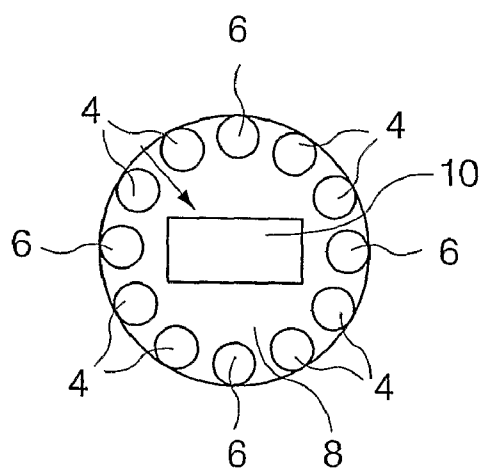


FIGURE 2

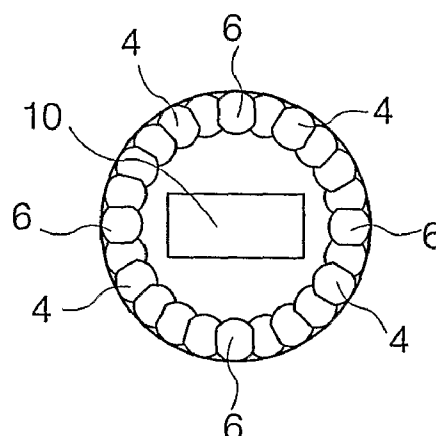


FIGURE 3

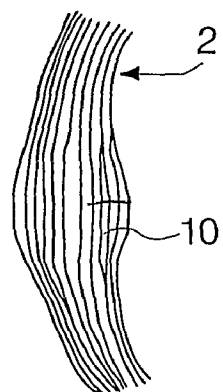


FIGURE 7

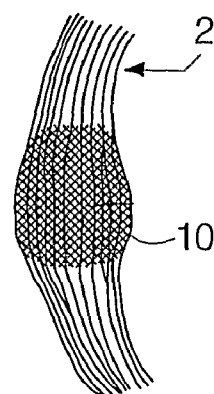


FIGURE 8

FIGURE 4

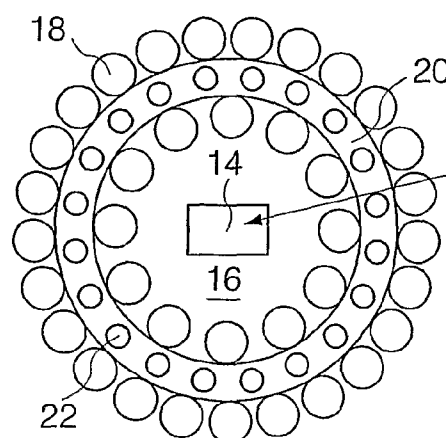
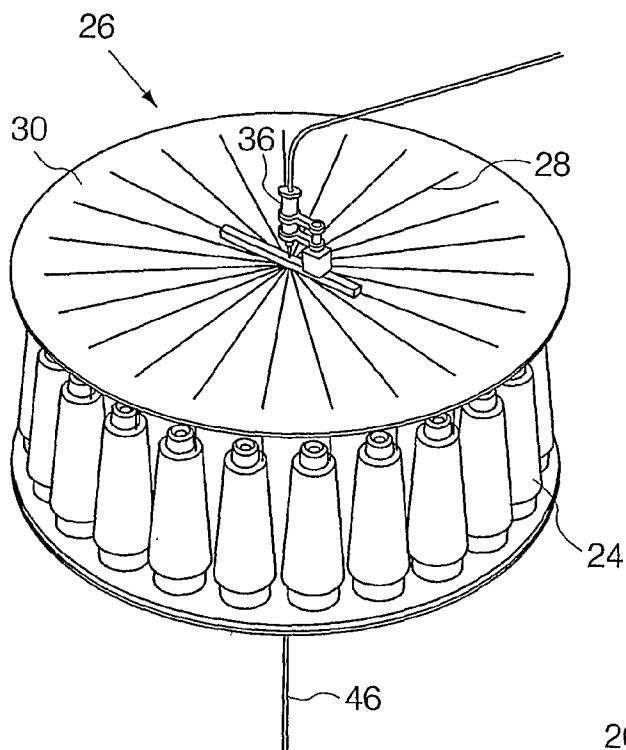
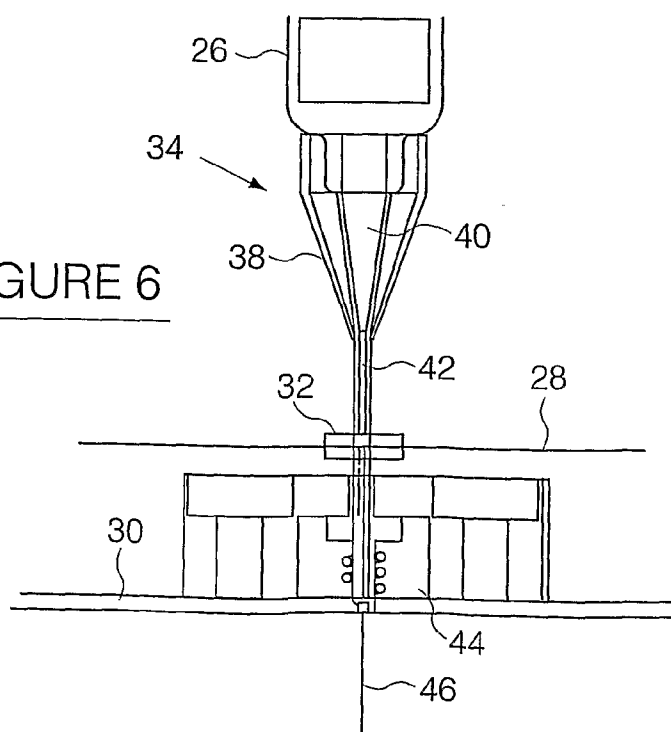


FIGURE 5

FIGURE 6



OPERATIVE DEVICES INSTALLED IN YARNS

[0001] This invention relates to operative devices and their incorporation in yarns. It relates particularly to the provision of protection for such devices for use in situations in which they would be vulnerable to damage. The invention also provides means by which operative devices may be readily incorporated into every day items and particularly fabric products.

[0002] Operative devices such as silicon chips have application in many areas and can be used as sensors and processors of useful information, and transmitters of such information or data. They can be used in RF tagging; position and movement sensors; strain sensors; pressure sensors and signal processors. It is known to fit them in clothing products to monitor movements or characteristics of the wearer.

[0003] It has been proposed to integrate electronic components in individual fibres for use in woven material, and in this respect reference is directed to International Patent Specification No WO 02/095839. However, the integrated component is subject to considerable strain as the fibre is subject to flexure, as well as during its installation in the fibre by the extrusion process to which reference is made. Reference is also directed to International Patent Specification No: WO 02/084 617, and to British Specification No: 2 323 254.

[0004] The present invention is directed specifically at the installation of an operative device within a length of a multi-filament or multi-fibre yarn. The term "filament" is used herein to encompass both filaments and fibres in yarns of this type. The yarn may, consist of natural and/or synthetic filaments (or fibres). The device can be confined in such a yarn by separating the filaments of the yarn, and installing the device therein with the filaments spread around it. As a progressive installation, this can be conducted in a pultrusion process, with a series of devices being installed seriatim in the same length of yarn. The devices can have conductors connected to them, which conductors can also become part of the yarn or filaments of the yarn. Thus, not only is the device confined within the yarn, but connected conductors can also become an integral part of the yarn construction. The operative device itself can take any suitable form, including electronic, such as a piezzo-electric crystal device or a silicon chip referred to above; magnetic (including ferro-magnetic and paramagnetic); optical, providing reflective or generated light signals, or showing symbols such as bar codes; and thermal to generate a signal upon heating or cooling. The device can also respond chemically to an external or internal influence, rendering the invention useful in pharmaceutical and cosmetic applications.

[0005] In the preferred method of confining a device in a multifilament yarn to form a length of yarn according to the invention, a plurality of filaments are delivered centripetally to a central axis, and then drawn along that central axis. An operative device is delivered to the conjoining filaments at the axis to install the device between the filaments as the filaments are drawn along the axis. This method can be carried out as a continuous process with operative devices being delivered seriatim such that they are installed in successive lengths of yarn drawn along the axis. Resin can be delivered continuously to the central axis, or intermittently with each operative device, to secure and protect the device when it is confined within the yarn.

[0006] The method described above can be readily adapted to form first and second layers of filaments around the device by delivering a further plurality of filaments to the central axis defined by the already formed multi-filament yarn. They can be drawn into and around the yarn with or without resin as required. It is also possible to install a shock-absorbing layer around the first filament layer, which is held in place by the second filament layer formed in this second stage.

[0007] Apparatus for carrying out the method of the invention typically comprises supplies of individual filaments disposed around a central aperture to deliver filaments thereto; a mechanism for delivering operative devices to the central aperture; and means for drawing yarn formed from said filaments from the central aperture. The supplies of filaments may be mounted on a carousel having an axis coincident with the central aperture. It can include supplies of additional filaments disposed around the path of yarn drawn from the aperture to deliver yarn to the path and create an additional layer of filaments around yarn drawn from the central aperture. These can be mounted on a further carousel with a central aperture aligned with that of the first.

[0008] A device according to the invention can be confined within a capsule around the device and comprising the yarn fibres and/or filaments. Such a capsule can be sealed around the device and at both ends to provide complete protection for the device. The capsule may comprise the fibres and/or filaments and a resin cured therebetween, and in this variant the resin can also be cured around the device. In an alternative arrangement, adjacent filaments of the yarn are bonded to each other around the device, typically by thermal bonding. In this variant the device can be separately encased in a resin mass within the capsule. It is also possible to create first and second layers of filaments around the device, possibly with a shock-absorbing layer between them using for example, the method outlined above.

[0009] As noted above, one or more devices according to the invention can be encapsulated in a single length of yarn, and the yarn can be used in various forms of fabric including knitted, braided, stitch bonded and woven fabrics. If conductors are connected to the device or devices and extend within the fabric, then a central processor or power source spaced from the electronic device itself, can be readily connected thereto along those conductors. Of course, such conductors may not be needed in all circumstances, as the device may provide its own power source. Depending upon its load requirements, it may be able to generate sufficient power either from ambient light or heat, or movement. If a device is being used to monitor adjacent movement or ambient variations, then its power requirements may be very low indeed.

[0010] The invention will now be described by way of example and with reference to the accompanying schematic drawings wherein:

[0011] FIG. 1 illustrates a length of yarn with two operative devices installed therein;

[0012] FIG. 2 is a cross-section taken on line A-A of FIG. 1 illustrating one technique for installing a device in the yarn;

[0013] FIG. 3 is a cross-section taken on line B-B of FIG. 1 showing another technique for installing a device in the yarn;

[0014] FIG. 4 is a view similar to those of FIGS. 2 and 3, showing the creation of multiple layers of filaments around a device in the yarn;

[0015] FIG. 5 is a perspective view of a carousel of filament supply spools in apparatus according to the invention for confining operative devices in a multi-filament yarn;

[0016] FIG. 6 is an enlarged sectional view taken at the centre of the other plate of the carousel of FIG. 5, showing how the yarn is formed around the operative device;

[0017] FIG. 7 illustrates a length of yarn with a device installed within thermally bonded filaments; and

[0018] FIG. 8 illustrates a length of yarn with a device installed within a capsule defined by resin impregnated filaments.

[0019] FIG. 1 illustrates a notional length of yarn with two operative devices installed at different locations therealong. The yarn 2 is a multi filament yarn comprising fibre and conductive filaments 4, 6. Each electronic device does, of course, create an expanded section of yarn, and although this will be evident in the yarn, it would not be inconsistent with some yarns used in various fabrics. Accordingly, in many fabrics the presence of anything unusual in the constituent yarns will not be readily apparent.

[0020] Typical yarn diameters around a device will be of the order of 1 mm using filaments of approximately 0.15 mm diameter. The volume of a typical device to be installed will be less than 0.5 mm^3 . The shape of the device is not critical, but it is normally rectanguloid, cylindrical or spherical. Spherical devices of diameter as little as 0.5 mm are contemplated.

[0021] FIG. 2 illustrates how the filaments in the yarn can be distributed around the device to confine it within the yarn. It also shows how the conductive filaments and fibre filaments are distributed. As can be seen four conductive filaments 6 are located at opposite ends of perpendicular diameters in the yarn cross-section, with two fibre filaments 4 located therebetween. Resin 8 is cast within the volume defined by the filaments 4 and 6, and around the electronic device or chip 10. The resin will normally be a polymer resin such as polyester or polyurethane resin; and the fibre filaments polyester or polyamide. The conductive filaments will normally be metal filament wires in the form of a polymeric monofilament yarn with either a copper or silver metal core wire.

[0022] The cured resin 8 provides a solid casing and protection for the chip 10, which is sealed not only around the chip towards the yarn surface, but also at its ends within the yarn. The resin thus forms a solid capsule which provides effective protection for the chip even when the yarn in which it is confined is subject to the inevitable rigours of flexure during use, and particularly if used to form part of a fabric; thermal stress of the kind to which it will be subject during post processing and washing, and physical damage arising from contact with other bodies.

[0023] FIG. 3 illustrates an alternative technique for confining and protecting an electronic device confined between the filaments of a multi filament yarn. In this variant, conductive filaments 6 are located as they are in FIG. 2, at the opposite end of perpendicular diameters. However, in FIG. 3 three fibre filaments 4 are shown between adjacent conductive filaments 6. The reason for this is to ensure that adjacent filaments are in proper contact. Heat is applied to the filaments in a carefully controlled manner to soften and then melt abutting external sections of filament so that a bond is created when the fibres are allowed to cool. Using heat to create these thermal bonds has the benefit of interfering less directly with the enclosed chip 10, but does, of course, expose the chip to heat. What, or which of the two techniques described herein should be used does therefore depend very much upon the nature of the component filaments in the yarn; the characteristics of the chip, and its potential vulnerability on the one hand to heat and on the other to a chemical resin, as well as the need to ensure that the chip is securely held or encapsulated within the filaments of the yarn. In this respect, it should be

noted that impregnating with resin the volume defined by the yarn filaments around the chip wholly envelopes or encapsulates the chip thereby providing maximum stability and protection. The thermal bonding technique of FIG. 3 does not so readily provide a seal at the axial ends of the chip but as a consequence, the chip is more readily accessible by virtue of being more exposed at its ends.

[0024] FIG. 4 shows how two layers of filaments can be arranged around an operative device in a multi-filament yarn. A group of inner filaments 12 creates a first protective layer around an operative device 14 within a mass of resin 16 in a manner similar to the arrangements described above with reference to FIGS. 2 and 3. Outer filaments 18 form a second layer around the first layer, and in the arrangement shown a shock-absorbing layer 20 is interposed between the first and second layers. The use of two separate layers of filaments enables the inner layer to provide protection for the operative device. The outer layer, as well as providing some additional protection, can serve to identify the nature of the confined device 14, for example by being colour coded.

[0025] The shock-absorbing layer 20 is not essential to the arrangement of FIG. 4, and can be omitted. However, by providing what can be a relatively stiff shell around the protective device, it enables the use of a softer resin encapsulating the device 14, and this can be of value in some circumstances. The layer 20 is typically a ring pre-formed from a length of plastics tube, itself reinforced by auxiliary filaments 22. These auxiliary filaments can be glass fibre filaments, but metal filaments could also be used, depending upon the nature of the operative device 14 and the influence they might have on its function.

[0026] FIGS. 5 and 6 illustrate a preferred process for confining an operative device within a multi-filament yarn of the invention. A plurality of spools 24 are arranged in a carousel 26 from which filaments 28 are drawn through appropriate openings in an upper plate 30, and then drawn to the carousel axis as indicated. At the axis the filaments 28 are drawn into a manifold from which they are drawn downwards along the axis. The carousel 26 will normally rotate during the process to impart a twist to the drawn yarn, but may be stationary.

[0027] The filaments 28 are drawn into and through the manifold 32 at a steady rate. At intervals, an operative device such as a microchip is injected into the space between the conjoining filaments with a predetermined mass of polymer resin from a syringe 34. The syringe 34 has a reservoir 36 of resin from which the resin is drawn through a tip 38 defining a passage having a generally cylindrical cross-section. The operative device is delivered to a central chamber 40 in the tip, and when activated the syringe delivers the device and a mass of resin along the duct 42 to the manifold 32. The delivery of devices to the chamber 40, and the operation of the syringe 34 will be determined by a computer (not shown).

[0028] Between the manifold 32 and the upper plate 30 of the carousel 26 the filaments and resin encapsulated device pass through a curing station 44. This will provide an appropriate curing environment for the resin, such as a heated zone or ultraviolet light, and the yarn 46 can be drawn down from the curing station 44 in the form of successive lengths, each including an encapsulated operative device. What is described is essentially pultrusion process in which the drawing down of the finished yarn 46 provides the essential movement of the filaments 28 from the spools 24.

[0029] It will be appreciated that a completed multi-filament yarn 46 of the kind referred to above can be drawn through a second carousel which delivers additional filaments to form a second layer of filaments around the first layer formed by the filaments 28. The result is an arrangement

similar to that described above with reference to FIG. 4, and shock-absorbing layers (20) can similarly be introduced between the first and second layers of filaments so formed.

[0030] Whatever technique is adopted, in preferred embodiments of the invention the electronic device is effectively confined in a resilient capsule integrated as an element in the length of yarn. This does, of course, alter the physical and mechanical properties of the yarn as a whole, and this must be taken into account when the yarn is subject to subsequent treatment or use. Some of the elastic properties of the yarn will have been lost, as will a degree of flexibility if only for the reason that the capsule itself will be substantially inflexible, with bending strains being transferred directly to opposite axial ends of the capsule. The elastic modulus of the yarn will be influenced by the dimensions of the chip which is encapsulated between the fibres/filaments of the yarn. Stresses will also be generated during the encapsulation process as a consequence of heating or shrinkage, and these stresses have to be taken into account.

[0031] FIGS. 7 and 8 provide some guidance as to the increased stresses the yarn filaments will undergo as a consequence of confining an electronic device in a section thereof. Because the capsule can be substantially rigid or inflexible, when the yarn is bent this has to be accommodated in other sections. Most importantly, this flexure may focus particularly on the section of the yarns where they engage or merge with the capsule ends. For this reason it is important as far as possible to preserve the integrity of the yarns in the capsule area, and this is, of course, of especial significance in embodiments in which heat is applied to thermally bond adjacent filaments. On the other hand, when the filaments are thermally bonded, the yarn cross-section at which the filaments adjoin the capsule is less well defined, allowing filament bending to be concentrated at different adjacent locations.

[0032] Although in the above description the operative device confined in the yarn is identified as a silicon chip, it will be understood that other devices can also be confined in this manner. As noted above, a suitable operative device might take any form, such as electronic, magnetic, optical or thermal.

[0033] The present invention provides a means by which a continuous process can be used to confine operative devices in multi-fibre or multi-filament yarns. Pultrusion is a continuous process that produces little waste of materials. A pultrusion process embodying the invention can be used to draw soft skin and hard core filament fibres through pre-formed plates and around an electronic device before the device is encapsulated using one of the techniques referred to above. A twist can be imparted to the yarn as desired after the electronic device is installed, and the capsule formed. The result is a continuous string of encapsulated devices, which can be used as a yarn in various applications such as those referred to above, or merely as a supply of encapsulated devices having many different applications. They can be separated for sale or use very simply, and in yarn form can be readily stored.

1. A length of multi-filament yarn including an operative device within a portion thereof, the device being confined between the filaments of the yarn.

2. A length of multi-filament yarn according to claim 1 wherein the device comprises at least one of electronic, magnetic, optical and thermal elements, or combinations thereof.

3. A length of multi-filament yarn according to claim 1 wherein the fibres and/or the filaments of the yarn form a capsule around the device.

4. A length of multi-filament yarn according to claim 3 wherein the capsule forms an enclosure sealed around the device and at both ends.

5. A length of multi-filament yarn according to claim 3 where the capsule comprises the filament and a resin cured therebetween.

6. A length of multi-filament yarn according to claim 5 wherein the resin is cured around the device.

7. A length of multi-filament yarn according to claim 3 wherein adjacent filaments of the yarn are bonded to each other around the device.

8. A length of multi-filament yarn according to claim 7 wherein adjacent filaments are thermally bonded.

9. A length of multi-filament yarn according to claim 7 wherein the device is encased in a resin mass within the capsule.

10. A length of multi-filament yarn comprising a first layer of filaments confining an operative device and a second layer of filaments extending around the first layer.

11. A length of multi-filament yarn according to claim 10 including a shock-absorbing layer between the first and second filament layers.

12. A length of multi-filament yarn according to claim 10 wherein at least one of the yarn filaments is electrically conductive.

13. (canceled)

14. (canceled)

15. A length of multi-filament yarn according to claim 12 wherein said at least one yarn filament is coupled to the device to form an electrical connection thereto.

16. A length of multi-filament yarn according to claim 10 wherein the device is a silicon chip, a ferro-magnetic polymeric chip or a phase change chip.

17. A fabric comprising at least one length of yarn according to claim 10.

18. (canceled)

19. (canceled)

20. Yarn comprising successive lengths thereof according to claim 10.

21. A method of confining an operative device in a multi-filament yarn, comprising delivering a plurality of filaments centripetally to a central axis and drawing them along the axis; and delivering an operative devices to the conjoining filaments at the axis to install the device between the filaments as the filaments are draw along the axis.

22. A method according to claim 21 including the step of applying resin to the yarn to hold the device between the yarns thereof.

23. A method according to claim 21 wherein a capsule comprising the fibres and/or filaments is formed around the device.

24. A method according to claim 22 wherein a resin is cast and cured between the fibres and/or filaments to form the capsule.

25. A method according to claim 24 wherein the resin is also cast and cured around the device.

26. A method according to claim 23 wherein adjacent filaments around the device are bonded to one another.

27. A method according to claim 26 wherein said filaments are thermally bonded.

28. A method according to claim 26 wherein the device is encased in a resin mass within the capsule.

29. A method according to claim 21 wherein the plurality of filaments delivered centripetally and drawn along the axis

form a first layer of filaments around the device, the method including the step of delivering a further plurality of filaments towards the axis and drawing them parallel to the axis to form a second layer of filaments around the first layer.

30. A method according to claim **29** including the step of introducing a shock-absorbing layer between the first and second filament layers.

31. A method according to claim **21** wherein at least one of the filaments is electrically conductive and coupled to the device to form an electrical connection thereto.

32. (canceled)

33. A method according to claim **21** wherein a plurality of devices are confined in successive lengths of the same yarn.

34. Apparatus for confining an operative device in a multi-filament yarn, which apparatus comprises supplies of individual filaments disposed around a central aperture to deliver filaments thereto; a mechanism for delivering operative devices to the central aperture; and means for drawing yarn formed from said filaments from the central aperture.

35. Apparatus according to claim **34** wherein the supplies of filaments are mounted on a carousel having an axis coincident with the central aperture.

36. Apparatus according to claim **34** including means for delivering an encapsulating resin to the central aperture with a said operative device.

37. Apparatus according to claim **34** including means for bonding filaments together around an operative device confined thereby.

38. Apparatus according to claim **34** including supplies of additional filaments disposed around the path of yarn drawn from the aperture to deliver yarn to the path and create an additional layer of filaments around yarn drawn from the central aperture.

39. Apparatus according to claim **38** wherein the supplies of additional filaments are mounted on a carousel having an axis coincident with the path.

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