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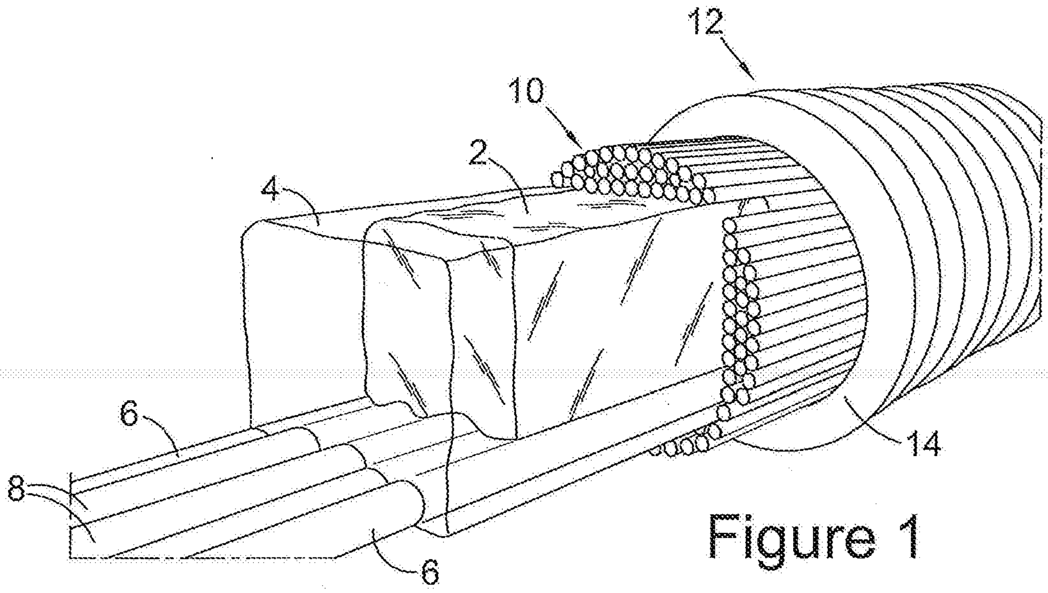

Figure 1

06 11 15

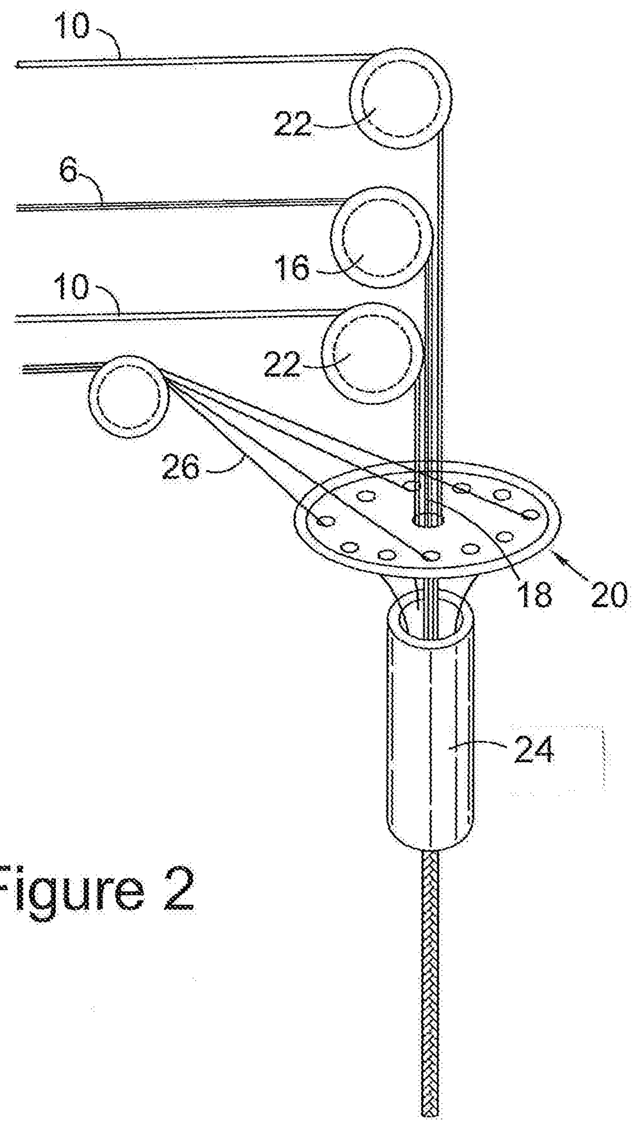

Figure 2

Electronically Functional Yarns

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.

International Patent Publication No. WO2006/123133, the contents whereof are hereby incorporated by reference, discloses a multi-filament yarn including an operative devices 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.

Yarns of the above International Publication 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. 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 composite yarn comprises a series of electronic devices with conductive interconnects coupled thereto mounted on a plurality of carrier fibres with the interconnects extending over the carrier fibres; a plurality of packing fibres around the carrier fibres, the devices and the interconnects, which 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 retaining sleeve around the packing fibres, wherein the carrier fibres , the devices and the interconnects are confined within the plurality of packing fibres retained in the sleeve. The packing fibres alone can fill spaces between the devices. However, a filler can be included to fill spaces between the devices within the packing fibres. 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 can be untwisted; i.e. extend generally parallel to the yarn axis, but may be selectively bunched or twisted to fill spaces between the devices. A separate filler material may also be used for this purpose. 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.

The electronic devices incorporated in yarns of the invention can take many forms, including operative devices such as silicon chips and electronic dice, and signaling devices such as light, sound or symbol generators. 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 have diameters in the range 50-100µm.

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 must hold the devices as this process is completed. Polybenzimidazole or aramid based fibres such as PBI or Normex are examples of some which can be used as carrier fibres. Typically four carrier fibres will extend side by side providing a platform for the devices to which they are attached. The devices themselves can be 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 interconnects, typically fine copper wire of around 150µm diameter, normally extend on and/or between the carrier fibres, and can extend between the carrier fibres past devices to which they are not coupled.

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. 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 fabric, or a woven or knitted braid. A fibre or yarn structure is though preferred to most easily accommodate bends and twists.

In manufacturing a yarn according to the invention the electronic devices are mounted in sequence on a plurality of carrier fibres with their interconnects coupled thereto. The carrier fibres with the mounted devices and interconnects, are then fed centrally through a channel with packing fibres extending generally parallel to the channel axis around the sides thereof to form a fibre assembly, the packing fibres preserving a substantially uniform cross-section along the length of the fibre assenbly that is fed into a sleeve forming unit in which a sleeve is formed around the assembly to form a composite yarn and from which the composite yarn is withdrawn. The channel can be formed centrally in a carrousel having separate openings around its periphery through which 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. 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. Any bunching or twisting to fill the spaces between the devices with packing fibres can be effected between the channel and the sleeve forming unit.

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 an embodiment of the invention; and

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

In the yarn shown in Figure 1 a semiconductor chip 2 is sealed in a polymeric micro-pod 4 which extends around four 400µm polyester 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 50µm) extend around the pod 4, the carrier fibres 6, and the interconnects 8. As shown they extend substantially parallel to the yarn axis, but may be bunched or twisted to fill the spaces 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 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. 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.

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 protecting 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 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 carrousel 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.

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 carrousel 20 which are woven or braided in the sleeve unit 24 which is typically a braiding head. 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.

CLAIMS:

1. An electronically functional composite yarn comprising a series of electronic devices with conductive interconnects coupled thereto mounted on a plurality of carrier fibres with the interconnects extending over the carrier fibres; a plurality of packing fibres around the carrier fibres, the devices and the interconnects, which 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 retaining sleeve around the packing fibres, wherein the carrier fibres, 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 packing fibres fill spaces between devices.

3. A functional yarn according to Claim 2 wherein the packing fibres are selectively bunched or twisted to fill spaces between the devices.

4. A functional yarn according to any preceding Claim wherein the packing fibres are independent from one another.

5. A functional yarn according to any of Claims 1 to 3 wherein at least some of the packing fibres are bonded together.

6. A functional yarn according to any preceding Claim wherein a filler fills spaces between devices within the packing fibres.

7. A functional yarn according to any preceding Claim wherein each device is enclosed in a protective polymeric micro-pod.

8. A functional yarn according to any preceding Claim wherein the electronic devices are semiconductor dice.

9. A functional yarn according to any preceding Claim wherein the interconnects extend between carrier fibres past devices to which they are not coupled.

10. A functional yarn according to any preceding Claim wherein the retaining sleeve is a fibre structure.

11. A functional yarn according to Claim 10 wherein the retaining sleeve comprises a supplementary yarn helically wound around the packing fibres.

12. A functional yarn according to Claim 10 wherein the retaining sleeve comprises a woven braid.

13. A functional yarn according to Claim 10 wherein the retaining sleeve comprises a knitted braid.

14. A method of manufacturing a composite yarn incorporating electronic devices comprising:

    mounting electronic devices with interconnects coupled thereto in sequence on a plurality of carrier fibres;
    feeding the carrier fibres with the mounted devices and interconnects centrally through a channel with packing fibres extending generally parallel to the channel axis around the sides thereof to form a fibre assembly, the packing fibres 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 sleeve is formed around the assembly to form a composite yarn; and
    withdrawing the composite yarn from the sleeve forming unit.

15. A method according to Claim 14 wherein the channel is formed centrally in a carrousel having openings around its periphery; and wherein fibres are fed through the peripheral openings to the sleeve forming unit in which they are processed to form the sleeve.

16. A method according to Claim 15 wherein the sleeve forming unit is a braiding head.

17. A method according to any of Claims 14 to 16 wherein the packing fibres are bunched or twisted between the devices as the fibre assembly passes from the channel to the sleeve forming unit.

18. A method according to any of Claims 14 to 17 wherein a filer is injected into the fibre assembly between the devices as the fibre assembly passes from the channel to the sleeve forming unit.