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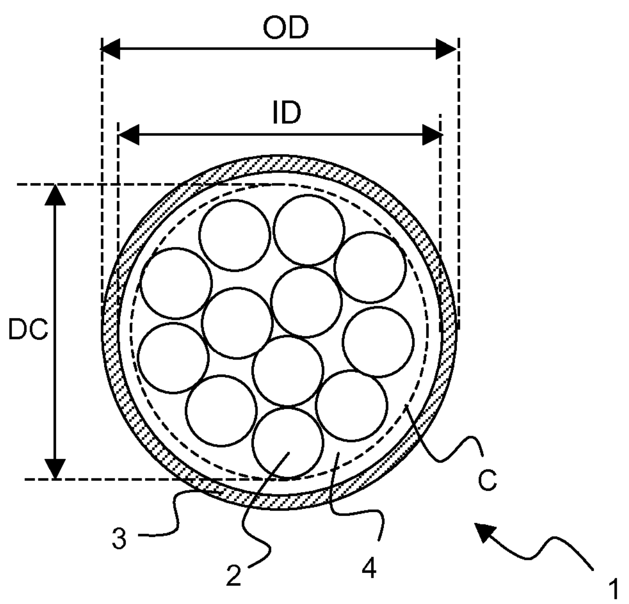

Figure 2

(57) Abstract: It is disclosed an optical cable for Communications comprising at least one micromodule, the micromodule comprising a retaining element and number N of optical fibers housed in said retaining element. The diameter of a circumference encircling the number N of optical fibers is 90% to 95% of an inner diameter of the retaining element. The retaining element is made of a film grade polymeric material having an elongation at break equal to or higher than 500%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3.

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OPTICAL COMMUNICATION CABLE AND MANUFACTURING PROCESS

Technical field

The present invention relates to the field of optical cables for communications and to the process for the manufacturing thereof. In particular, the present invention relates to an optical cable for communications including at least one micromodule, to a micromodule for such an optical cable and to the manufacturing thereof.

Background art

An optical cable for communications typically comprises a number optical fibers. The optical fibers housed in an optical cable may be arranged in one or more bundles, each bundle of optical fibers being housed in a respective retaining element. The bundle of optical fibers with the respective retaining element is typically termed "micromodule".

A micromodule typically comprises 2 to 12 optical fibers arranged substantially parallel to the axis of the micromodule or according to an open helix pattern (generally termed "S-Z") about the axis of the micromodule. The retaining element is generally made of a polymeric material, in particular a thermoplastic material, optionally charged with mineral fillers. The space between the optical fibers within the retaining element may be empty, or it may be filled with jelly, talc or water-swellable yarns for preventing propagation of water within the micromodule.

The one or more micromodules form the so-called "optical core" of the optical cable. The optical core is generally inserted into a protective sheath that is also made of a polymeric material. The protective sheath typically has a number of elongated reinforcing elements arranged in the thickness thereof and parallel to the axis of the optical cable.

US 5,155,789 discloses a telecommunications cable comprising a series of optical fibers split into modules, each of which is enveloped by a thin supporting sheath, the sheaths being in contact with the optical fibers. The supporting sheath is made of a plastic, such as polyethylene, polypropylene or polyamides. The supporting sheath is constituted by a layer of thickness laying in the range a few thousandths of a millimeter to a few tenths of a millimeter and preferably laying in the range one-hundredth of a millimeter to one-tenth of a millimeter. The supporting sheath material may extend between the fibers to obtain a more intimate contact, and indeed the optical fibers may be completely embedded in the material constituting the supporting sheath.

US 5,671,312 discloses a cable comprising a series of optical fibers, each of which fibers is covered in a primary sheath. The optical fibers are collected together in modules that may contain some variable number of optical fibers. Each module is itself wrapped in a thin supporting sheath that is easily tearable and that is intended to keep the optical fibers in contact with one another so as to provide mechanical coupling between them.

US 6,334,015 discloses a telecommunication cable comprising a plurality of optical fibers. A thin and generally cylindrical retaining sheath envelops the optical fibers. The retaining sheath tightly grips a predetermined number N of optical fibers to hold the optical fibers in a group and thereby constitute a compact module. The retaining sheath is extruded into a thermoplastics material. The material of the retaining sheath has a thickness less than 0.3 mm, preferably in the range from 0.1 to 0.2 mm. For example, the material of the retaining sheath is an amorphous thermoplastics material, for example polyvinylchloride (PVC) or an elastomer; or a charged thermoplastics material, for example polyethylene or a polyolefin such as ethylene vinyl acetate (EVA), containing a sufficient quantity of one or more mineral charges.

US 6,937,802 discloses a telecommunication cable including a plurality of modules, each with a thin retaining sheath for clamping optical fibers together. Each retaining sheath contains plural respective modules and is mechanically coupled to the retaining sheaths of the respective modules to form super-modules that contact an outside jacket. The thickness of the sheath is at most about a few tenths of a millimeter, typically from 0.1 mm to

0.5 mm.

The above listed documents teach optical fibers contained in modules having a thin sheath. The modules houses the optical fibers as tightly as possible to ensure the coupling (or clamping) thereof.

WO 01/21706 discloses a material for forming thin films, in particular for the outer sheath of a micromodule for an optical cable. The material consists of a composition containing an olefin polymer and a filler amount ranging between 25 and 65 wt.% of the composition, said material in undivided state having a tensile strength ranging between 6 and 20 MPa and an elongation at break ranging between 50 and 300 %.

US 7,082,241 discloses a telecommunication cable of the microcable or minicable type having optical fibers contained in a thin retaining sheath. The retaining sheath clamps the optical fibers to hold the optical fibers in groups. The retaining sheath is in contact with and mechanically coupled to the optical fibers. The coupling between the optical fibers and the retaining sheath referred to above is defined as a mechanical coupling between two members, meaning that any stress applied to one of the members is transferred to the other member or that if one of the members is stressed the other is also stressed, without this necessitating any bonding or other fixing of one of the members to the other. The retaining sheath has a thickness of the order of a few tenths of a millimeter, typically 0.25 mm. The material of the retaining sheath is an amorphous thermoplastic material, an elastomer, or a thermoplastic material that can contain mineral charges.

US 6,658,184 discloses a telecommunications cable module comprising a plurality of optical fibers. The optical fibers are surrounded by a flexible tube referred to as a "skin". The thickness of the skin lays in the range 0.05 mm to 0.25 mm, and is preferably 0.15 mm. The skin is of a thermoplastic elastomer having flexible diol segments, with a melting point greater than 130°C and initial tearing strength. The material disclosed preferably presents breaking elongation laying in the range 50% to 300% and tensile strength laying in the range 5 MPa to 15 MPa. The material has hardness on the Shore D scale of less than 50. The elastomer properties are provided by flexible segments in the polymer chain (copolymers with polyether segments).

US 6,215,931 discloses a bundle of optical fibers surrounded by a buffer tube in near-tight configuration. The buffer tube is made from a thermoplastic polyolefin elastomer having a room temperature modulus of elasticity below about 500 MPa and a low temperature (-40°C) modulus of elasticity below about 1500 MPa. The buffer material has a Melt Flow Index above about 3.. The thermoplastic polyolefin elastomer material used to form the buffer tube may also contain organic or inorganic fillers. The thermoplastic polyolefin elastomer material forming the buffer tube has an elongation at break <500% at room temperature. If the modulus of elasticity and elongation at break are low enough, the buffer tube can be easily removed without special tools and without damaging the optical fiber or fibers disposed therein.

WO 2006/034722 discloses a micromodule comprising a plurality of optical fibers and a retaining element for containing the optical fibers. The retaining element of the micromodule is made of a thermoplastic polymeric composition having an elastic module lower than 500 MPa at 20°C, an ultimate tensile strength comprised between 5 and 10 MPa, and an elongation at break comprised between 30% and 80%. The retaining element has a thickness which is preferably comprised between 0.1 and 0.2 mm. In the case of a micromodule containing 12 optical fibers, the micromodule has an overall size having a maximum transversal dimension comprised between 1.25 mm and 1.45 mm.

Summary of the invention

The Applicant faced the problem of reducing the external diameter of the micromodules for packing them in a number as high as possible within the optical cable sheath. Such a need is particularly felt in the so-called FTTx (Fiber-To-The-x) market that denotes the portion of the optical communication network that reaches the premises (home, offices and the like) of the end user. In such network the conduits for the passage of the micromodules can be narrow because provided in old buildings and/or because already partially hindered, for example by other cables, for example electrical cables.

Preferably, a micromodule containing twelve optical fibers and having an external diameter equal to or lower than 1.30 mm was sought.

When facing the problem of reducing the micromodule size, especially the diameter thereof, the Applicant focused on the possible reduction of the wall thickness of the retaining element, but such a reduction shall take into account some aspects:

- the extrudability of the material into thin layer; and
- the tearability of the material for exposing and splicing the optical fibres contained in the retaining element.

These two aspects are contradictory in that, while the extrudability into thin layer requires materials with a significant elongation at break, an easy tearability - advantageously attainable by hand – implies low elongation at break.

A decrease in the elongation at break value of a polymeric material to improve the tearability thereof can be obtained by adding inorganic filler to the mixture, but such addition generally impairs the extrudability into thin film.

The Applicant noticed that materials commonly used for the manufacturing of retaining elements can not be extruded in very thin film layers (e.g. with a thickness equal to or lower than 0.130 mm), more specifically cannot be extruded by a process industrially affordable and replicable. In view of the low thickness the retaining elements made of such material often break during extrusion.

The Applicant tested film grade materials for manufacturing retaining elements by extrusion about optical fibers. In the following description and in the claims, as “film grade material“ is intended a polymeric material adapted to be extruded in a thin film, typically of 0.01-0.05 mm, without defects or tearing in the extruded product. Such polymeric materials are characterized by a number of chemical features (e.g. a branched structure, amount of crystallinity) and/or physical features (e.g. density, tearability). The elongation at break of this kind of material is typically higher than that of materials traditionally used for fabricating retaining element, i.e. it may be higher than 500% (a typical value is 800%).

Retaining elements with reduced thickness (comprised in the range 0.077 mm to 0.130 mm, for containing twelve optical fibers) were extruded in substantially tight contact with the optical fibers using a film grade material. No breakage of the retaining element occurred during extrusion.

The Applicant found that in spite of the high elongation at break of the material from which the retaining element is extruded, the tearability of the retaining element off the optical fibers was acceptable.

Regrettably, the Applicant noticed that the optical fibers housed in the micromodules produced as described above showed unacceptable bending losses. In particular, the Applicant noticed that when optical cables comprising micromodules produced as described above are subjected to bending (for example due to the winding on bobbin), adhesion of the optical fibers to the retaining element is not uniform along the cable, thus inducing irregular bending of the micromodule.

The Applicant perceived that acceptable bending losses may be obtained if the optical fibers are not in tight contact with the retaining element of the micromodule. In particular, the Applicant found that acceptable bending losses are obtained when the diameter of the circumference circumscribing the optical fibers is comprised in a predetermined percentage range of the internal diameter of the retaining element.

However, for preserving the above mentioned external diameter (i.e. equal to or lower than 1.30 mm, for example of 1.15 mm for a twelve optical fiber micromodule) while housing the optical fibers in a way loose enough to obtain the desired bending losses, a further reduction of the thickness of the retaining element is required.

A further reduction in the retaining element thickness could give rise to problem of extrudability even using film grade material. Also, a so thin retaining element was believed to be unsuitable to provide the optical fibers housed therein with an adequate mechanical protection, especially when the micromodule is wound on spools or the like.

The Applicant found that micromodule having retaining element extruded using a film grade material with such a low thickness can be obtained by selecting properly the film grade material. Surprisingly, it has been found that the loose housing of the fibers inside such a thin retaining element was effective to separate the fibers from the mechanical stress thereby providing suitable mechanical protection.

Furthermore the Applicant has found that such retaining element, in spite of its high elongation at break, shows an improved tearability and may be easily removed from the optical fibers without using any special tool.

Amongst possible film grade materials characterized by different chemical and physical features, the Applicant identified as film grade polymer materials useful for the present invention those polymers characterized by an elongation at break equal to or higher than 500%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3.

In the present description and claims as “elongation at break” it is meant elongation at break measured according to the test method IEC 811-1-1; as “melt flow index” it is meant the melt flow index measured according to the test method ISO1133; and as “density” it is meant density measured according to the test method ISO1183-D.

According to a first aspect, the present invention provides an optical cable for communications comprising at least one micromodule, the micromodule comprising a retaining element and number N of optical fibers housed in the retaining element, wherein:

- the diameter of the circumference encircling the number N of optical fibers is 90% to 95% of an inner diameter of the retaining element; and
- the retaining element is made of a film grade polymeric material having an elongation at break equal to or higher than 500%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3.

Preferably, the retaining element has a thickness ranging from 0.030 mm to 0.125 mm, more preferably from 0.050 mm to 0.110 mm.

Preferably, the retaining element is made of a polymeric material having an elongation at break equal to or higher than 600%.

Preferably, the film grade polymeric material is uncharged. In the present description and claims as “uncharged polymeric material” it is meant a polymer base containing an amount of at least one inorganic component from 0 to 2wt%.

According to a preferred embodiment, the number N of optical fibers is equal to 12, and an outer diameter of the retaining element ranges from 1.15 mm and 1.3 mm.

According to another preferred embodiment, the number N of optical fibers is equal to 4, and an outer diameter of the retaining element ranges from 0.75 mm to 0.89 mm.

According to a second aspect, the present invention provides a micromodule for an optical cable for communications comprising a retaining element and a number N of optical fibers housed in the retaining element, wherein:

- a diameter of a circumference encircling the number N of optical fibers is 90% to 95% of an inner diameter of the retaining element; and
- the retaining element is made of a film grade material having an elongation at break equal to or higher than 500%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3.

Preferably, the retaining element has a thickness ranging from 0.030 mm to 0.125 mm, more preferably from 0.050 mm to 0.110 mm.

Preferably, the retaining element is made of a polymeric material having an elongation at break equal to or higher than 600%.

Preferably, the film grade polymeric material is uncharged.

According to a preferred embodiment, the number N of optical fibers is equal to 12, and an outer diameter of the retaining element ranges from 1.15 mm and 1.3 mm.

According to another preferred embodiment, the number N of optical fibers is equal to 4, and an outer diameter of the retaining element ranges from 0.75 mm to 0.89 mm.

According to a third aspect, the present invention provides use of a polymeric material having an elongation at break equal to or higher than 500%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3 for manufacturing a retaining element for a micromodule of an optical cable for communications.

According to a fourth aspect, the present invention provides a process for manufacturing a micromodule for an optical cable for communications, the process comprising:

- providing a number N of optical fibers; and
- providing a retaining element around the number N of optical fibers thus forming the micromodule,

wherein said providing comprises extruding a film grade material, the film grade material having an elongation at break equal to or higher than 500%, a melt flow index MFI lower than 3 g/10 min and a density lower than 1 g/cm^3, wherein the diameter of a circumference encircling the number N of optical fibers is 90% to 95% of an inner diameter of the retaining element.

Preferably, the step of extruding is performed by means of extrusion assemblies comprising a tip element and a die element.

Preferably, the tip element and the die element have a draw down ratio DDR ranging from 4.5 to 8.5.

Preferably, the step of extruding is performed at a line rate ranging from 40 m/min to 150 m/min.

Advantageously, the extruding step is performed by tubing extrusion.

As “tubing extrusion” it is herein meant an extrusion process where tip e die are aligned so that the extruded material exits therefrom with a defined crown cross section value that, by stretching, reaches a final crown cross section value (internal and external diameters). The value of the final crown cross-section depends on the extrusion flow and the line speed.

Brief description of the drawings

The present invention will become fully clear by reading the following detailed description, given by way of example and not of limitation, to be read by referring to the accompanying drawings, wherein:

- Figure 1 is a cross-section view of an optical cable including a number of micromodules;
- Figure 2 is a cross-section view of a micromodule according to a preferred

embodiment of the present invention;

- Figures 3a and 3b schematically show an apparatus for manufacturing the micromodule of Figure 2, according to a first and second variant, respectively;
- Figure 4 is a sectional view of extrusion tooling assemblies suitable for extruding the retaining element of the micromodule of Figure 2; and
- Figure 5 is an enlarged view of a portion of the extrusion tooling assemblies of Figure 4 encircled by the circle E.

Detailed description of preferred embodiments of the invention

Figure 1 shows an optical cable 5 according to an embodiment of the present invention.

The optical cable 5 comprises a number of micromodules 1 forming an optical core 10 and an outer sheath 6. Two opposite reinforcing longitudinal elements 7 are preferably arranged in the thickness of the outer sheath 6. The micromodules 1 are preferably stranded according to a helix of the "SZ" type within the outer sheath 6. The optical cable 5 depicted in Figure 1 includes twelve micromodules 1. However the optical cable 5 may comprise any number of micromodules 1. For instance, an optical cable 5 may comprise 24, 36 or 60 micromodules 1, each comprising 12 optical fibers 2.

In case the optical cable 5 comprises 60 micromodules 1 (not all shown in Figure 1), the diameter of the optical core 10 (indicated as D in Figure 1) is preferably of about 10.3 mm. Besides, preferably, the diameter D of the optical core 10 is no more than 90% of the inner diameter of the outer sheath 6 (indicated as ID' in Figure 1). If the diameter D of the optical core 10 is equal to 90% of the inner diameter ID' of the outer sheath 6, the inner diameter ID' of the outer sheath 6 is substantially equal to 11.5 mm. The diameter of each reinforcing longitudinal element is preferably equal to 1.2 mm, and the thickness of the outer sheath 6 is preferably equal to 2.2 mm. The overall diameter of the optical cable 5 is accordingly substantially equal to 16 mm.

With reference to Figure 2, each micromodule 1 comprises a number N of optical fibers 2 and a retaining element 3 for containing the optical fibers 2. The retaining element 3 is arranged in a radially outer position with respect to the N optical fibers 2. The N optical fibers 2 are preferably stranded according to a helix of the "SZ" type within the retaining element 3. Each optical fiber 2 has an outer diameter of 0.250 mm. By way of non limiting example, the micromodule 1 shown in Figure 2 comprises N=12 optical fibers 2.

Figure 2 shows a circle C enclosing the N optical fibers 2. The diameter (indicated as DC in Figure 2) of the circle C depends on the number N of optical fibers 2 comprised in the micromodule 1 and on a parameter K, indicative of the pattern according to which the optical fibers 2 are arranged within the micromodule 1. Preferably, the diameter DC of the circle C is of from 90% to 95% of the inner diameter of the retaining element 3 (indicated as ID in Figure 2). Preferably, the outer diameter of the retaining element 3 (indicated as OD in Figure 2) is of from 1.15 mm to 1.30 mm. The thickness of the retaining element 3 is preferably of from 0.030 mm to 0.125 mm, more preferably from 0.050 mm to 0.110 mm.

Table I herein after shows values of the diameter DC of the circle C, of the inner diameter ID and of the outer diameter OD relative to embodiments of the micromodule 1 according to the invention, comprising different numbers N of optical fibers 2, assuming that the thickness of the retaining element 3 is 0.050 mm.

Table I

N	K	diameter of C (mm)	DC / ID (%)	ID (mm)	OD (mm)
4	2.410	0.603	92.69	0.65	0.75
6	2.900	0.725	96.67	0.75	0.85
8	3.300	0.825	91.67	0.90	1.00
10	3.637	0.909	95.70	0.95	1.05
12	3.984	0.996	94.85	1.05	1.15

Table II herein after shows the values of the diameter DC of the circle C, the inner diameter ID and the outer diameter OD relative to five different embodiments of the micromodule 1, comprising five different numbers N of optical fibers 2, assuming that the thickness of the retaining element 3 is 0.125 mm.

Table II

N	K	diameter of C (mm)	DC / ID (%)	ID (mm)	OD (mm)
4	2.410	0.603	94.14	0.64	0.89
6	2.900	0.725	95.39	0.76	1.01
8	3.300	0.825	94.83	0.87	1.12
10	3.637	0.909	94.70	0.96	1.21
12	3.984	0.996	94.85	1.05	1.30

The above tables show that, in case the micromodule 1 comprises N=12 optical fibers 2, the external diameter OD of the retaining element 3 (and therefore of the whole micromodule 1) lies in the sought range 1.15 mm to 1.30 mm. In case the number of optical fibers per micromodule decreases, even lower values of the external diameter OD may be obtained. For instance, a micromodule with 4 optical fibers advantageously has an external diameter OS lying in the range 0.75 mm to 0.89 mm. This advantageously allows obtaining very compact micromodules, and accordingly optical cables with increased optical fiber density.

The retaining element 3 is preferably made of a film grade material having an elongation at break equal to or higher than 500%, preferably equal to or higher than 600%, more preferably equal to or higher than 800%, a melt flow index (MFI) lower than 3 g/10 min and a density lower than 1 g/cm^3.

The film grade material is preferably an uncharged material.

In particular, the Applicant has performed extrusion tests by using polymer materials as set forth in Table III.

Table III

Example	Elongation at break	Melt flow index (g/10min)	Density (g/cm^3)
1	>800%	2.4	0.920

2*	700%	40	1.160
3*	600%	0.4	1.160

Example 1: linear low density polyethylene BPD3220 produced by INEOS O&P Europe (Lyndhurst, Hampshire, UK);

Example 2* (comparative): elastomer polymer consisting of rigid polyester blocks and flexible polyether or polyester blocks produced under the name Sipolprene 46185 by SIPOL S.p.A. (Mortara, Italy);

Example 3* (comparative): thermoplastic compound containing inorganic filler produced under the name Casico™ FR4805 by Borealis A/S (Kongens Lyngby, Denmark).

Micromodules having an internal diameter of 1.05 mm and an external diameter of 1.15 mm were manufactured using the polymer material of Example 3*: unacceptable tearing in the retaining elements were observed.

Micromodules having the same size as above were manufactured using the polymer material of Example 2*: the optical fibers contained in the retaining elements made with this material showed unacceptable attenuation both in substantially tight configuration and when the diameter of the circumference C was as according to the invention.

Micromodules having the same size as above were manufactured using the polymer material of Example 1: the attenuation of the optical fibers contained in the retaining elements made with this material was within the prescribed limit; the retaining elements could be easily removed.

Figures 3a and 3b schematically show an apparatus for manufacturing the micromodule of Figure 2 according to a first and second variant, respectively.

In particular, the apparatus of Figure 3a comprises a fiber unrolling stage 100, a talc injection stage 200, an S-Z winding stage 300, an extrusion stage 400 and a stretching and collecting stage 600.

The fiber unrolling stage 100 preferably comprises N spools of optical fibers (schematically represented by circles in Figure 3a), N being equal to the number of optical fibers included in a single micromodule.

The stretching and collecting stage 600 preferably comprises a stretching drum 610 and a collecting drum 620 connected by means of one or more pulleys 630.

The extrusion stage 400 preferably comprises a supply unit 400b and extrusion tooling assemblies 400a. The supply unit 400b preferably supplies the extrusion tooling assemblies 400a with the film grade material to be extruded for forming the retaining element 3.

Figure 4 and 5 show the extrusion tooling assemblies 400a in further detail. The extrusion tooling assemblies 400a preferably comprise a tip element 40 and a die element 41.

The tip element 40 has a lateral wall defining a central cavity 40'. The lateral wall preferably has a first part 401, a second part 403 and a tapered part 402 joining the first part 401 and the second part 403. The first part 401 is preferably substantially in the form of a hollow cylinder having a length L1 equal to 33.3 mm, an internal diameter DI1 equal to 10 mm, and an external diameter preferably increasing substantially linearly from a minimum DO1min of 13.9 mm to a maximum DO1max of 16.83 mm next to the tapered part 403. The tapered part 402 preferably has a length L2 equal to 31.4 mm. The lateral wall of the tapered part 402 is preferably conformed so that the external surface thereof has a frustoconical shape with aperture α of 30° about, while the internal surface thereof defines a cavity with a frustoconical portion and a cylindrical portion. Next to the first part 401, the tapered part 402 has an internal diameter equal to DI1, i.e. 10 mm, and an external diameter equal to DO1max, i.e. 16.83 mm. Next to the second part 403, tapered part 402 preferably has an internal diameter DI2 e.g. of 2 mm and an external diameter DO2 e.g. equal to 2.6 mm. The second part 403 preferably has a length L3 equal to 6 mm. The lateral wall of the second part 403 is preferably conformed so that the external surface thereof has a polygonal cross-section shape (e.g. a dodecahedron). The second part 403 preferably has an internal diameter equal to DI2, i.e. 2 mm, and a maximum external diameter equal to DO2, i.e. 2.6 mm.

The die element 41 of the extrusion tooling assemblies 400a preferably has a base 410 and a sidewall 411. The base 410 has a hole 412, and the sidewall 411 defines a conical cavity whose vertex corresponds to the aperture 412. The hole 412 preferably has a shape matching with the cross-section of the external surface of the lateral wall of the second part 403, and has a diameter higher than the maximum external diameter DO2 of the second part 403, e.g. 2.8 mm.

For mounting the extrusion tooling assemblies 400a, the tip element 40 is inserted in the conical cavity of the die element 41, until the free end of the second part 403 engages with the hole 412 (see Figure 4), thus forming an annular slit 42 (that can be seen in Figure 5).

The operation of the apparatus of Figure 3a will be now described in detail.

First of all, at the fiber unrolling stage 100, N optical fibers 2 are unrolled from the respective spools. The optical fibers 2 are then passed through the talc injection stage 200 that injects talc between the optical fibers 2. Then, the optical fibers 2 are passed though the S-Z winding stage 300, that preferably winds them according to an open helix (or "S-Z") pattern, thus forming a fiber bundle. Then, the fiber bundle is passed through the extrusion stage 400 that extrudes the retaining element 3 around the fiber bundle.

More particularly, in the extrusion stage 400, the fiber bundle is housed in the central cavity 40' of the male part 40 so that it exits the extrusion tooling assembly 400a through the second part 403 engaging the hole 412. The supply unit 400b preferably supplies film grade material to the extrusion tooling assembly 400a, so that the portion of the conical cavity of the die element 41 external to the tip element 40 is filled with the film grade material. The retaining element 3 is then obtained by extruding the film grade material around the fiber bundle through the annular slit 42.

The extrusion process is performed at a temperature preferably ranging from 150° to 300°C and at a pressure preferably ranging from 100 to 200 atm. As well known to skilled in art, the selection of the more suitable process parameters depend on the materials employed in the manufacturing process and on the characteristics of the final product sought. The dimension of the resulting micromodule depends on, for example, extrusion flow, line speed, tooling (e.g. tip and die) dimensions.

After extrusion, the temperature of the micromodule lowers from the extrusion temperature to room temperature (20°C).

The micromodule is then stretched by the stretching drum 610 and collected on the collecting drum 620.

The apparatus of Figure 3b differs from the apparatus of Figure 3a in that it does not comprise the talc injection stage 200, whereas it comprises a jelly injection stage 200' between the S-Z winding stage 300 and the extrusion stage 400. The operation of the apparatus of Figure 3b is substantially the same as the apparatus of Figure 3a. Accordingly, a detailed description thereof will not be repeated.

The Applicant has performed some tests using the above apparatuses of Figure 3a and Figure 3b.

In a first test, the apparatus of Figure 3a was used. N was equal to 12, the tip element 40 had DI2 equal to 1.5 mm and DO2 equal to 2.1 mm, while the die element 41 had the hole 412 with diameter of 2.3 mm. The above mentioned BPD3220 was used for extruding the retaining element 3. The internal diameter ID of the retaining element 3 was 1.05 mm, while the external diameter OD was 1.15 mm. The draw down ratio DDR was 4.00, while the draw balance ratio DBR was 1.00, wherein the draw down ratio DDR is defined as:

$$DDR = \frac{\phi_F^2 - \phi_M^2}{\phi_{ext}^2 - \phi_{int}^2} \qquad [1]$$

and the draw balance ratio DBR is defined as:

$$DBR = \frac{\phi_F \phi_{int}}{\phi_{ext} \phi_M} = \frac{\phi_F / \phi_M}{\phi_{ext} / \phi_{int}}, \qquad [2]$$

where ϕ_F is the die diameter of the hole 412, ϕ_M is the external diameter of the tip element 40 (i.e. DO2), ϕ_{ext} is the external diameter of the extruded retaining element 3 (i.e. OD) and ϕ_{int} is the internal diameter of the extruded retaining element 3 (i.e. ID). The line rate was 50 m/min.

The retaining element 3 of the micromodule 1 obtained with this first test was very easy to remove, due to the space between the retaining element 3 and the optical fibers 2 housed therein. The micromodule 1 was unrolled from the collecting drum 620 and was bent to form a skein. Bending losses were in an acceptable range. Thermal cycles from -30°C and +60°C have been performed, without giving raise to any performance decrease. Ageing tests at 85°C for 7 days have been conducted and, also in this case, the outcome of the test was positive.

In a second test, the apparatus of Figure 3b was used. N was equal to 12, the tip element 40 had DI2 equal to 2.0 mm and DO2 equal to 2.6 mm, while the die element 41 had the hole 412 with diameter of 2.85 mm. The above mentioned BPD3220 was used for extruding the retaining element 3. A silicon gel suitable for the application in contact with optical fiber was used at the jelly injection stage 2'. The internal diameter ID of the retaining element 3 was 1.05 mm, while the external diameter OD was 1.15 mm. The draw down ratio DDR was 6.19, while the draw balance ratio DBR was 1.00. The line rate was 75 m/min.

The retaining element 3 of the micromodule 1 obtained with this second test was very easily removed, though the force to be applied was higher than in the first test, due to the adhesion force induced by the jelly. The micromodule 1 was unrolled from the collecting drum 620 and was coiled loosely. Bending losses were in an acceptable range. Thermal cycles from -30°C and +60°C were performed, without giving raise to any performance decrease. Ageing tests at 85°C for 7 days were carried out and also in this case the outcome of the test was positive (ease at tearing, acceptable optical fiber attenuation).

The Applicant has performed further tests providing positive outcome, whose parameters are briefly summarized herein after in Table IV.

Table IV

DI2	DO2	diameter of hole 412	DDR	DBR	line rate (m/min)
2	2.6	2.8	4.91	0.98	50
2	2.6	2.85	6.19	1.00	80

In the above tests, N was equal to 12, the internal diameter ID of the retaining element 3 was equal to 1.05 mm and external diameter OD of the retaining element 3 was equal to 1.15 mm. Jelly was used instead of talc for all the above tests. Also in these tests, the retaining element 3 was very easy to remove and bending losses were in an acceptable range.

CLAIMS

1. An optical cable for communications (5) comprising at least one micromodule (1), said micromodule (1) comprising a retaining element (3) and number N of optical fibers (2) housed in said retaining element (3), wherein:
   - a diameter of a circumference (C) encircling said number N of optical fibers (2) is 90% to 95% of an inner diameter (ID) of said retaining element (3); and
   - said retaining element (3) is made of a film grade polymeric material having an elongation at break equal to or higher than 500%, a melt flow index MFI lower than 3 g/10 min and a density lower than 1 g/cm^3.
2. The optical cable according to claim 1 wherein the retaining element (3) has a thickness ranging from 0.030 mm to 0.125 mm.
3. The optical cable according to claim 2, wherein said retaining element (3) has a thickness ranging from 0.050 mm to 0.110 mm.
4. The optical cable according to any of the preceding claims, wherein said retaining element (3) is made of a polymeric material having an elongation at break equal to or higher than 600%.
5. The optical cable according to any of the preceding claims, wherein said film grade polymeric material is uncharged.
6. The optical cable according to any of the preceding claims, wherein said number N of optical fibers is equal to 12, and an outer diameter of said retaining element (3) ranges from 1.15 mm and 1.3 mm.
7. The optical cable according to any of claims 1 to 5, wherein said number N of optical fibers is equal to 4, and an outer diameter of said retaining element (3) ranges from 0.75 mm to 0.89 mm.
8. A micromodule (1) for an optical cable for communications (5) comprising a retaining element (3) and a number N of optical fibers (2) housed in said retaining element (3), wherein:

- a diameter of a circumference (C) encircling said number N of optical fibers (2) is 90% to 95% of an inner diameter (ID) of said retaining element (3); and
- said retaining element (3) is made of a film grade material having an elongation at break equal to or higher than 500%, a melt flow index MFI lower than 3 g/10 min and a density lower than 1 g/cm^3.

9. The micromodule (1) according to claim 8, wherein said retaining element (3) has a thickness ranging from 0.030 mm to 0.125 mm.

10. The micromodule (1) according to claim 9, wherein said retaining element (3) has a thickness ranging from 0.050 mm to 0.110 mm.

11. The micromodule (1) according to any of claims 8 to 10, wherein said retaining element (3) is made of a polymeric material having an elongation at break equal to or higher than 600%.

12. The micromodule (1) according to any of claims 8 to 11, wherein said film grade polymeric material is uncharged.

13. The micromodule (1) according to any of claims 8 to 12, wherein said number N of optical fibers is equal to 12, and an outer diameter of said retaining element (3) ranges from 1.15 mm and 1.3 mm.

14. The micromodule (1) according to any of claims 8 to 12, wherein said number N of optical fibers is equal to 4, and an outer diameter of said retaining element (3) ranges from 0.75 mm to 0.89 mm.

15. Use of a polymeric material having an elongation at break equal to or higher than 500%, a melt flow index MFI lower than 3 g/10 min and a density lower than 1 g/cm^3 for manufacturing a retaining element (3) for a micromodule (1) of an optical cable for communications (5).

16. A process for manufacturing a micromodule (1) for an optical cable for communications (5), said process comprising:
    - providing a number N of optical fibers (2); and
    - providing a retaining element (3) around said number N of optical

fibers (2) thus forming said micromodule (1),

wherein said providing comprises extruding a film grade material, said film grade material having an elongation at break equal to or higher than 500%, a melt flow index MFI lower than 3 g/10 min and a density lower than 1 g/cm^3, wherein the diameter of a circumference (C) encircling said number N of optical fibers (2) is 90% to 95% of an inner diameter (ID) of said retaining element (3).

17. The process according to claim 16, wherein said step of extruding is performed by means of extrusion assemblies (400a) comprising a tip element (40) and a die element (41).

18. The process according to claim 17, wherein said tip element (40) and said die element (41) have a draw down ratio DDR ranging from 4.5 to 8.5.

19. The process according to claim 17 or 18, wherein said step of extruding is performed as tubing extrusion.

20. The process according to any of claims 16 to 19, wherein said step of extruding is performed at a line rate ranging from 40 m/min to 150 m/min.

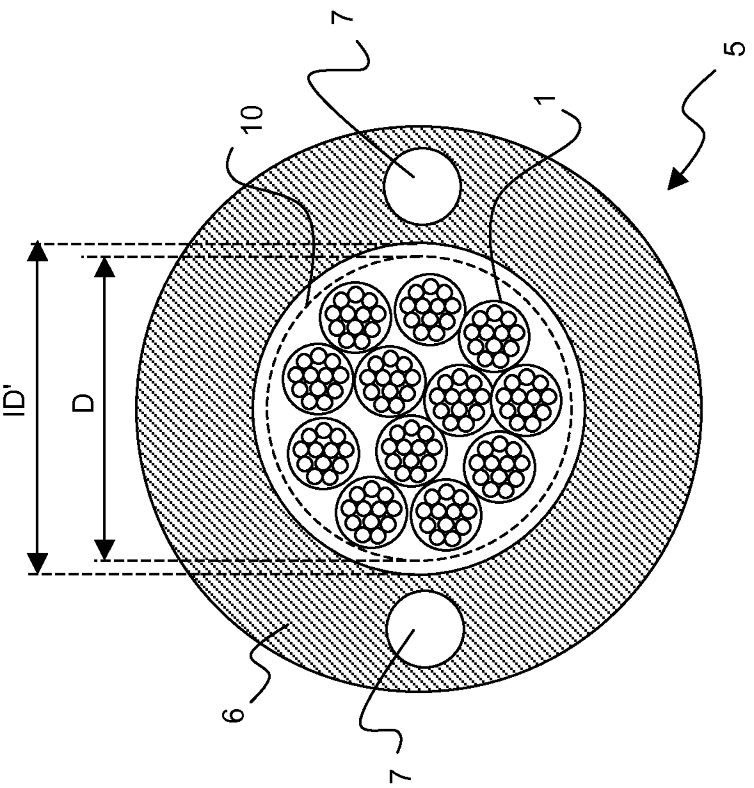

Figure 1

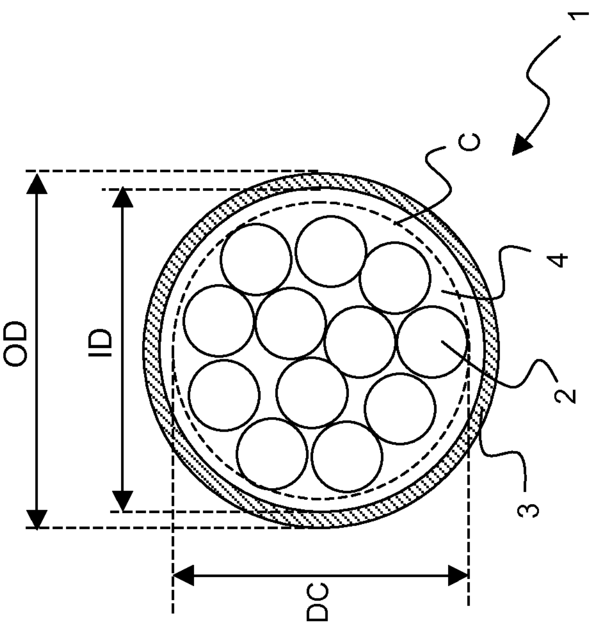

Figure 2

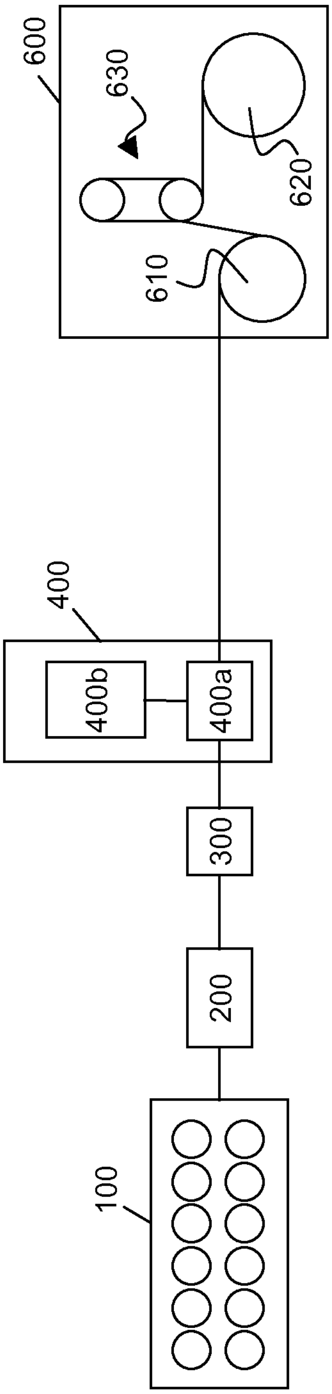

Figure 3a

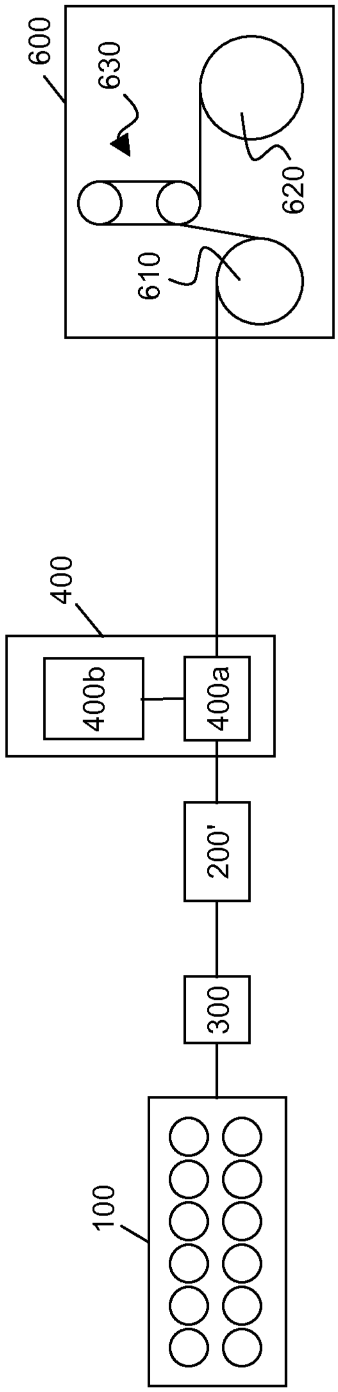

Figure 3b

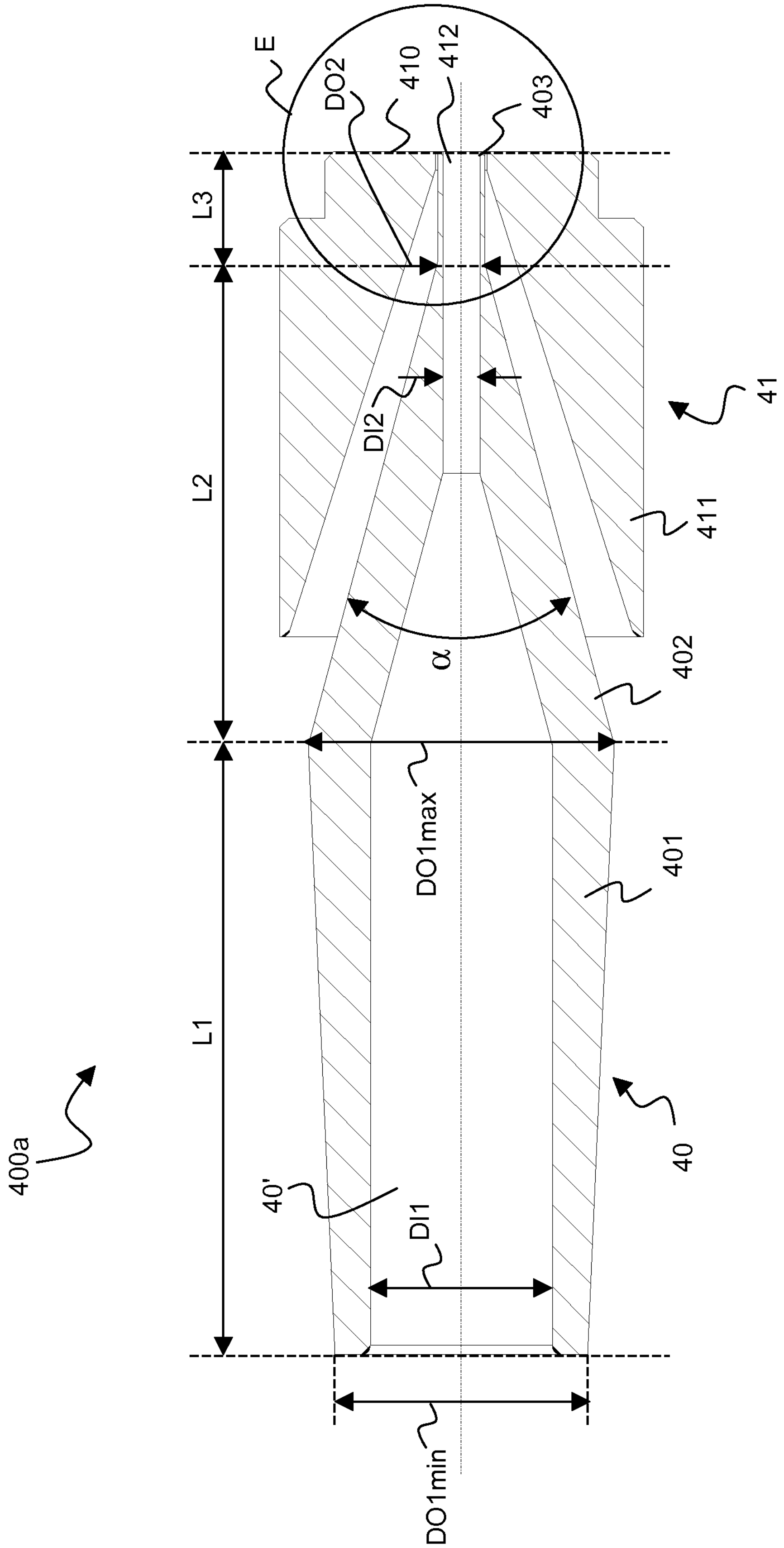
E
DO2
410
412
403
L3
L2
L1
41
DI2
411
α
402
DO1max
401
400a
40
40'
DI1
DO1min

Figure 4

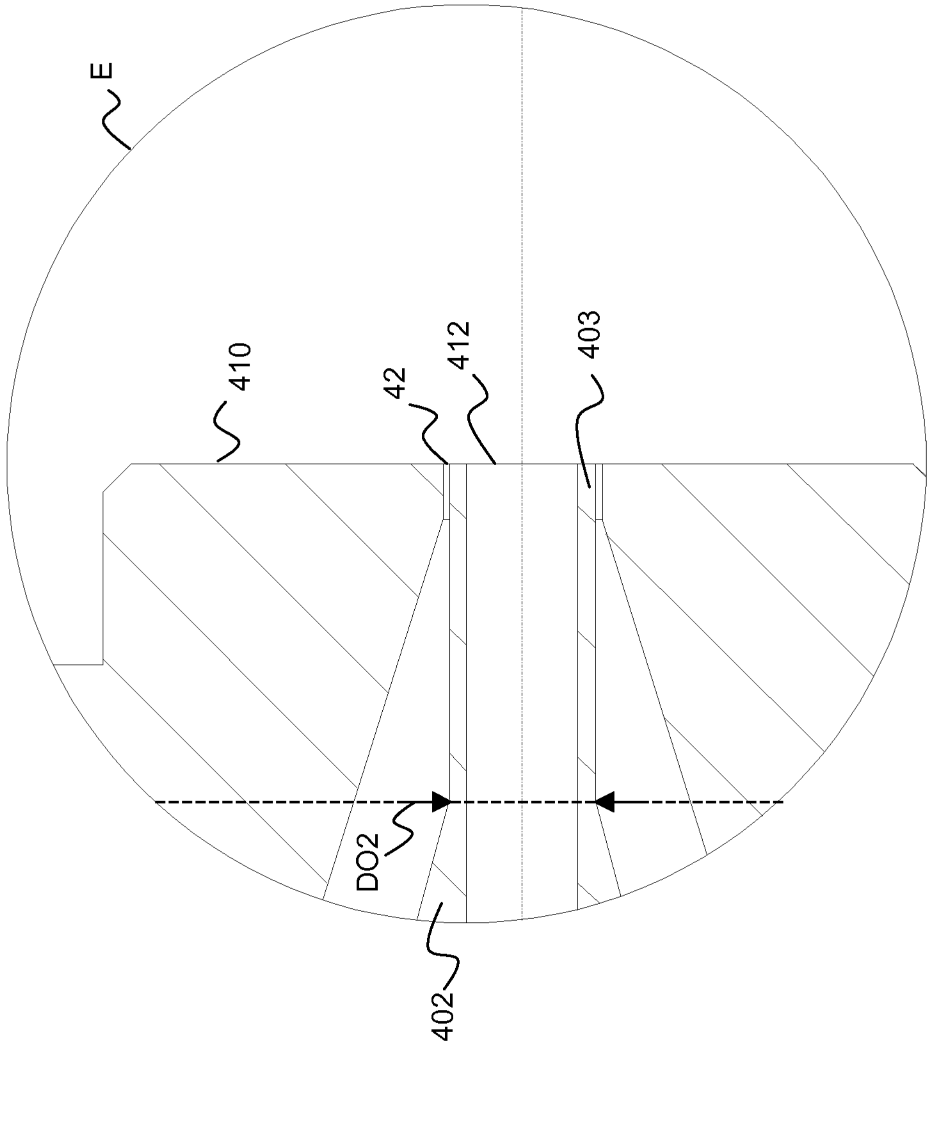

Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/062491

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, WPI Data, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/063650 A1 (CASTELLANI LUCA [IT] ET AL) 24 March 2005 (2005-03-24) abstract; figures 1,2 paragraphs [0023] - [0025] paragraphs [0035] - [0040] -----	1-20
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2010	06/04/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Faderl, Ingo

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/062491

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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