Our Ref: 531850

P/00/001
Section 29

AUSTRALIA

Patents Act 1990

PATENT REQUEST : STANDARD PATENT

I/We, being the person/s identified below as the Applicant, request the grant of a patent to the person/s indicated below as the Nominated Person/s, for an invention described in the accompanying standard complete specification.

Full application details follow.

[71] [70] Applicant/s and Nominated Person/s:
Pirelli Cable Corporation,
of 710 Industrial Drive, LEXINGTON, South Carolina, 29072, UNITED STATES OF AMERICA

[54] Invention Title:
Process for manufacturing optical fiber ribbons

[72] Name/s of actual inventor/s: (optional)

[74] Address for service in Australia:
DAVIES COLLISON CAVE, Patent Attorneys
10 Barrack Street, SYDNEY NSW 2000 Attorney Code : CA

BASIC CONVENTION APPLICATION/S DETAILS:

[31] Appln No.:	[33] Country:	Code:	[32] Date:
08/171,023	UNITED STATES OF AMERICA	US	21 December 1993

Basic Applicant/s: Mujibar M Rahman; Jose' L Tondi-Resta; Jonathan G Fitz; Ben H Wells

DATED this NINETEENTH day of DECEMBER 1994

Pirelli Cable Corporation
By Patent Attorneys
DAVIES COLLISON CAVE

ANTHONY J COWLE, FIPAA

Fee: $ 280.00

$ 051810 191294

5010

681207

P/00/008 28/5/91
Section 29(1)
Regulation 3.2(2)

AUSTRALIA

Patents Act 1990

NOTICE OF ENTITLEMENT

PIRELLI CABLE CORPORATION, of 710 Industrial Drive, Lexington, South Carolina, 29072, United States of America, the Applicant/Nominated Person in respect of Australian Patent Application No. 81602/94 state the following:-

The Nominated Person is entitled to the grant of the patent because the Nominated Person has entitlement from the actual inventors, MUJIBAR M RAHMAN, JOSE LUIS TONDI-RESTA, JONATHAN G FITZ and BEN H WELLS, by assignment.

The Nominated Person is entitled to claim priority from the basic application listed on the patent request form because the Nominated Person has entitlement from the applicants of the basic application listed on the patent request form, and because the basic application is the first application made in a Convention country in respect of the invention.

Dated this 6th day of June, 1997

.....

a member of the firm of
DAVIES COLLISON CAVE
for and on behalf of
the applicant(s).

AUSTRALIAN PATENT OFFICE

P:\WPDOCS\AMD\531850.DOC - 6/6/97

AU9481602

(12) PATENT ABRIDGMENT (11) Document No. AU-B-81602/94
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 681207

(54) Title
PROCESS FOR MANUFACTURING OPTICAL FIBER RIBBONS

International Patent Classification(s)
(51)[6] **C03C 025/02** **B29C 047/02** **G02B 006/00**

(21) Application No. : **81602/94** (22) Application Date : **19.12.94**

(30) Priority Data

(31) Number	(32) Date	(33) Country
171023	**21.12.93**	**US UNITED STATES OF AMERICA**

(43) Publication Date : **29.06.95**

(44) Publication Date of Accepted Application : **21.08.97**

(71) Applicant(s)
PIRELLI CABLE CORPORATION

(72) Inventor(s)
MUJIBAR M RAHMAN; JOSE LUIS TONDIRESTA; JONATHAN G FITZ; BEN H WELLS

(74) Attorney or Agent
DAVIES COLLISON CAVE , GPO Box 3876, SYDNEY NSW 2001

(56) Prior Art Documents
JP 61-63810
US 4710638
US 5037763

(57) Claim

1. A process for manufacturing an optical fibre ribbon containing a plurality of longitudinally extending optical fibres and having differently facing first and second surfaces which lie in parallel rectilinear planes, comprising the following steps:

(a) aligning said longitudinally extending optical fibres into a substantially planar array of parallel and adjacent optical fibres with the longitudinal axes of the fibres in a rectilinear plane;

(b) extruding a layer of radiation curable coating material on said planar optical fibre array to provide a coated planar array of parallel optical fibres with differently facing first and second coated surfaces, said array forming a substantially thin and relatively wide ribbon; and

(c) passing the coated planar array between a pair of spaced curing radiation sources, respectively at opposite sides of the same portion of the array passing therebetween and each of said sources including a curing radiation emitter and a radiation focussing reflector, the emitter being between the reflector and the coated planar array and both of said sources simultaneously and uniformly directing curing radiation toward each other and substantially perpendicular to said surfaces and respectively, focussing the curing radiation from said sources onto said first surface and said second surface therebetween so that most of the

. . ./2

radiation from one of said pair of sources substantially uniformly impinges on one of said surfaces and most of the radiation from the other of said pair of sources substantially uniformly impinges on the other of said surfaces.

15. An apparatus for manufacturing an optical fibre ribbon having a plurality of longitudinally extending optical fibres therein, comprising:

means for aligning said longitudinally extending optical fibres into a substantially planar array of parallel and adjacent optical fibres as they are advanced in the direction of their lengths;

means for extruding a radiation curable coating material layer on said planar optical fibre array as said optical fibres are advanced, to provide a ribbon having a width transverse to the direction of advance greater than the thickness of the ribbon transverse to the width of the ribbon and providing first and second differently facing major surfaces on said layer;

oven means for curing said radiation curable coating material layer on said planar array with curing radiation as said ribbon is advanced, said oven means comprising:

a first lamp for emitting radiation which will cure the material of said layer and a second lamp for emitting radiation which will cure the material of said layer, said first lamp and said second lamp being spaced from each other in the direction transverse to the direction of advance of the ribbon for receiving a portion of said ribbon between, and spaced from, said first lamp and said second lamp and with a first one of said major surfaces facing said first lamp and with a second one of said major surfaces facing said second lamp;

a first reflector disposed at the side of said first lamp opposite from said second lamp for directing curing radiation of said first lamp toward said second lamp and substantially perpendicularly to said first one of said major surfaces, said first reflector also being a focussing reflector for focussing curing radiation of said first lamp on said first one of said major surfaces;

a second reflector disposed at the side of said second lamp opposite from said first lamp for directing curing radiation of said second lamp toward said first lamp and substantially perpendicularly to said second one of said major surfaces, said second reflector also being a focussing reflector for focussing curing radiation of said second lamp on said second one of said major surfaces;

whereby said oven means uniformly and simultaneously cures said radiation curable coating material layer on said planar array.

Our Ref: 531850

P/00/011
Regulation 3:2

AUSTRALIA

Patents Act 1990

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Applicant(s): Pirelli Cable Corporation
710 Industrial Drive
LEXINGTON South Carolina 29072
UNITED STATES OF AMERICA

Address for Service: DAVIES COLLISON CAVE
Patent & Trade Mark Attorneys
Level 10, 10 Barrack Street
SYDNEY NSW 2000

Invention Title: Process for manufacturing optical fiber ribbons

The following statement is a full description of this invention, including the best method of performing it known to me:-

FIELD OF THE INVENTION

The present invention relates to an improved process for manufacturing optical fiber ribbons of both the thin and thick variety, which through uniform curing minimises the thicknesses of curable coating materials which is applied to the ribbon fibers and which is necessary to ensure the structural integrity of the ribbon.

BACKGROUND OF THE INVENTION

Because of their high bandwidth capacity and small physical size, optical fibers are now used in a wide variety of applications. However, optical fibers are fragile, and are also susceptible to stress and bending, which cause optical attenuation. Consequently, adequate mechanical protection of the fibers is necessary.

One way to protect optical fibers is to arrange and package them into a planar array of individual fibers covered by a curable coating material, forming a ribbon-like structure. This ribbon structure not only provides for the mechanical protection of the individual optical fibers, but through orderly alignment provides stability, and also makes splicing easier. See, for example, U.S. Patent No. 4,900,126.

Currently, optical fiber ribbons are of two types: thin or thick. Thick ribbons, i.e. having a coating thickness of about 100 microns, are used primarily in situations requiring a robust structure capable of handling mechanical abuse without losing structural integrity or optical performance. However, planar arrays of optical fibers covered by a thick coating of curable material suffer warpage problems, are thicker than necessary if the sole purpose of the coating is to provide protection for the fiber, decrease the packing efficiency, i.e. the number of fibers which can be accommodated in a given volume, and create undesirable stresses due to thermal expansion. Therefore, it is desirable to keep the coating thickness to a minimum.

Thin ribbons have a much thinner coating of curable material, e.g. about 25 microns or less, covering the optical fiber array than the thick variety, requiring less coating material and therefore having greater packing efficiency. However, if the films are too thin, they will tend to form depressions or menisci between the fiber interstices during curing, resulting in a nonplanar ribbon surface. Further, variations in fiber size or alignment within the array also cause the outer surface of the ribbon to become nonplanar, forming edges or "ribs" which may interlock with other ribbons.

A further difficulty in using thin film ribbons is the need for a high interfibre bonding strength. Thin films unlike the thick variety may not provide sufficient support for the ribbon structure, thereby requiring stronger interfibre adhesive materials. However, increased interfibre bonding strength affects the mobility of the individual fibres and their optical performance within cables. Also, if it becomes necessary to separate the individual fibres for splicing, the bonding material must be removed, and the strong adhesives may remove identifying ink markings or colours on the individual fibres as well, rendering the individual fibres unidentifiable and seriously complicating the splicing operation. Despite these drawbacks, it is nonetheless desirable to keep the coating thickness to a minimum.

In reality, a thin or thick ribbon has a certain minimum thickness "wrapping around" the fibres rather than simply filling the interstices between them. This extra support simultaneously creates a smooth planar ribbon surface as well as holds the fibres together without requiring an unusually high interfibre bonding force. The more planar the array of individual fibres, the thinner the coating layer necessary to achieve this stability.

However, even with perfect fibre alignment and coating uniformity, non-uniform curing of the coating material will seriously compromise the planarity of the ribbon. Conventional UV curing ovens do precisely that. Due to the optical conditions within the oven, one of the two faces of the ribbon is cured more quickly than the other, initial planarity is lost and the ribbon warps. Multiple ovens may be configured so that their sum total radiation is equal on both faces of the ribbon. However, this will not correct the warpage problem since the radiation within the individual ovens will still be unbalanced.

Despite various technical advances in this art for minimising the planar coating thicknesses of fibre optic ribbons, conventional curing ovens through imbalanced or uneven curing prevent capitalisation on advances for obtaining planarity of the fibres. These advances, however, came to full fruition in the present invention which overcomes the problems associated with uneven curing of fibre ribbons during manufacture.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved curing process which simultaneously and uniformly cures curable coating materials along both faces of an optical fibre ribbon, thereby preventing warpage due to uneven curing.

AUSTRALIAN PATENT OFFICE

The present invention also seeks to provide a manufacturing process which allows the reduction of the minimum coating thickness necessary for maintaining a fibre ribbon's integrity during processing and handling.

The present invention also seeks to provide a manufacturing process which uniformly cures curable coating materials on both sides of a ribbon in a single pass, simultaneously and at the same rate.

In one broad form, the present invention provides a process for manufacturing an optical fibre ribbon containing a plurality of longitudinally extending optical fibres and having differently facing first and second surfaces which lie in parallel rectilinear planes, comprising the following steps:

(a) aligning said longitudinally extending optical fibres into a substantially planar array of parallel and adjacent optical fibres with the longitudinal axes of the fibres in a rectilinear plane;

(b) extruding a layer of radiation curable coating material on said planar optical fibre array to provide a coated planar array of parallel optical fibres with differently facing first and second coated surfaces, said array forming a substantially thin and relatively wide ribbon; and

(c) passing the coated planar array between a pair of spaced curing radiation sources, respectively at opposite sides of the same portion of the array passing therebetween and each of said sources including a curing radiation emitter and a radiation focussing reflector, the emitter being between the reflector and the coated planar array and both of said sources simultaneously and uniformly directing curing radiation toward each other and substantially perpendicular to said surfaces and respectively, focussing the curing radiation from said sources onto said first surface and said second surface therebetween so that most of the radiation from one of said pair of sources substantially uniformly impinges on one of said surfaces and most of the radiation from the other of said pair of sources substantially uniformly impinges on the other of said surfaces.

In a further broad form, the present invention provides an apparatus for manufacturing an optical fibre ribbon having a plurality of longitudinally extending optical fibres therein, comprising:

means for aligning said longitudinally extending optical fibres into a substantially

AUSTRALIAN PATENT OFFICE

planar array of parallel and adjacent optical fibres as they are advanced in the direction of their lengths;

means for extruding a radiation curable coating material layer on said planar optical fibre array as said optical fibres are advanced, to provide a ribbon having a width transverse to the direction of advance greater than the thickness of the ribbon transverse to the width of the ribbon and providing first and second differently facing major surfaces on said layer;

oven means for curing said radiation curable coating material layer on said planar array with curing radiation as said ribbon is advanced, said oven means comprising:

a first lamp for emitting radiation which will cure the material of said layer and a second lamp for emitting radiation which will cure the material of said layer, said first lamp and said second lamp being spaced from each other in the direction transverse to the direction of advance of the ribbon for receiving a portion of said ribbon between, and spaced from, said first lamp and said second lamp and with a first one of said major surfaces facing said first lamp and with a second one of said major surfaces facing said second lamp;

a first reflector disposed at the side of said first lamp opposite from said second lamp for directing curing radiation of said first lamp toward said second lamp and substantially perpendicularly to said first one of said major surfaces, said first reflector also being a focussing reflector for focussing curing radiation of said first lamp on said first one of said major surfaces;

a second reflector disposed at the side of said second lamp opposite from said first lamp for directing curing radiation of said second lamp toward said first lamp and substantially perpendicularly to said second one of said major surfaces, said second reflector also being a focussing reflector for focussing curing radiation of said second lamp on said second one of said major surfaces;

whereby said oven means uniformly and simultaneously cures said radiation curable coating material layer on said planar array.

AUSTRALIAN PATENT OFFICE

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the following detailed description of the presently preferred embodiments thereof, which description should be considered in conjunction with the accompanying drawings in which:

Fig. 1 is an end cross-sectional view of an optical fibre ribbon produced by the process of the present invention;

Fig. 2 is a schematic diagram of a conventional elliptical oven for curing an

AUSTRALIAN PATENT OFFICE

optical fiber ribbon;

Fig. 3 is an end cross-sectional view of a warped optical fiber ribbon;

Fig. 4 is a schematic diagram of the oven configuration of the present invention employing dual opposed lamps with elliptical reflectors for curing an optical fiber ribbon;

Fig. 5 is a schematic perspective view of the oven configuration shown in Fig. 4;

Figs. 6 and 7 are fragmentary, cross-sectional views of portions of reflectors having a dichroic layer for reflecting ultraviolet radiation and absorbing or transmitting longer wavelengths;

Fig. 8 is a schematic view of a manufacturing process of the present invention; and

Fig. 9 is an end cross-sectional view of an optical fiber ribbon of the invention with two plastic coating layers.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to Fig. 1, there is shown a cross sectional view of an optical fiber ribbon produced in accordance with the process of the present invention, which is designated generally by the numeral 1. The ribbon comprises a plurality of longitudinally extending individual optical fibers 2, each comprising a core 3 and a cladding 4, and each preferably having a layer 5 of a conventional protective coating material, e.g. a plastic, thereon. The plurality of longitudinally extending fibers 2, each preferably having the same or similar diameters d, are arranged in a planar array 6, the center of each fiber being aligned along an axis 7 transverse to the longitudinal direction of the optical fibers, and the entire array being covered with a cured layer 8 of adhesive matrix coating material, e.g. UV curable acrylate, not only filling the interstices 9 between adjacent optical fibers 2 but also covering the fibers 2, including the portions 10 of the end fibers in the array 6.

Conventional ovens, by rapidly heating the ribbon fibers and matrix materials during processing and failing to uniformly cure the curable coating materials, warp even perfectly aligned planar arrays 6, whereas the process of the present invention eliminates or reduces these warpage problems, allowing smoother and thinner planar coatings for both thin and thick ribbons. Prior to describing the process of the present invention, however, the particular equipment employed in the process will be discussed.

For the purpose of curing coating materials on optical fiber ribbons, curing ovens are typically used to irradiate and cure, i.e. harden, the curable coating materials, forming

a hardened ribbon structure having strength and stability. The structure of a conventional elliptical curing oven is illustrated schematically in Fig. 2 where the numeral 11 designates generally an elliptical curing oven having a single elongated lamp 12 located at one focal axis of an elliptical reflector 13a surface. Lamp 12 preferably radiates energy at a wavelength which will cause the coating material layer 8 to cure, e.g. ultraviolet ("UV") and may, for example, be a medium pressure mercury vapour lamp powered by microwaves and of the type sold by Fusion Systems Corporation, Rockville, Md. The elliptical reflector 13a focuses most of the radiant energy from the lamp 12 on the ribbon 1 within a quartz tube 14 located at the focal point of a second elliptical reflector 13b, and also directs radiant energy onto the surface of reflector 13b. The radiant energy is emitted along the axial length of the lamp 12 and reflected onto the ribbon 1 by both of the elliptical reflectors 13a and 13b, preferably distributing the radiant energy uniformly along the axial length of the tube 14. The ribbon 1 with the uncured plastic material layer 8 thereon is passed longitudinally within the bore of the quartz tube 14 where it is subjected to the radiant energy reflected by the reflectors 13a and 13b and received directly from the lamp 12 causing the material of the layer 8 to commence to cure.

The optical efficiency (energy received and reflected by the reflectors vs. total energy emitted by the radiation source) of the conventional oven configuration shown in Fig. 2 is approximately 75%, i.e. only 75% of the emitted radiation actually contacts the uncured coating material layer 8 on ribbon 1 within quartz tube 14. However, the radiation striking the faces of flat ribbon 1 is not uniform. Instead, the amount of radiation energy received by the face 1a nearer the lamp 12, directly and indirectly from lamp 12, is approximately 70% of the radiation striking the entire ribbon 1. The remaining 30% strikes the opposite ribbon face 1b indirectly, i.e. reflected off of reflector 13b. Therefore the faces 1a and 1b of ribbon 1 receive different amounts of curing radiation, both faces cure at different rates and thus contract at different rates. This 70/30 curing differential causes greater contraction along the ribbon face having higher UV exposure, face 1a, resulting in warpage of the ribbon 1, as shown in Fig. 3.

One attempt to provide uniform irradiation of ribbon 1 is to use a pair of conventional ovens of the type shown in Fig. 2 in series with each other, i.e. displaced with respect to each other in the direction of advance of the ribbon, but with the oven components interchanged. Face 1a, while passing through a first oven, receives 70% of the curing radiation and face 1b 30%, but upon entry to a second and reversed oven, the

face lb is nearer the lamp 12 and these percentages are reversed. However, prior to reaching the second oven, uneven curing and the subsequent uneven contraction has already begun, which results in a warped ribbon.

Warpage damage due to curing variations is especially problematic in the case of Original Equipment Manufacturers ("OEM") reflectors which, not being designed specifically for optical fiber ribbon production, nay vary greatly in reflective and focal properties, resulting in commensurate variance in radiation dosages striking the faces of ribbon 1.

It will be apparent that if the ribbons are warped during curing not only is the possible packing efficiency in a cable reduced but also the interlocking problems of stacked ribbons are increased.

The oven configuration utilised in the process of the present invention to overcome the warpage problems caused by non-uniform irradiation, employs a curing oven having a configuration different from that of the conventional ovens discussed heretofore. Shown schematically in Fig. 4 and in schematic perspective in Fig. 5 is an oven 15 having a pair of elliptical reflectors 16a and 16b, as before, but each having a radiation emitting lamp 17a and 17b, respectively, along a focal axis thereof. Both reflectors 16a and 16b direct the radiation toward each other and uniformly and simultaneously focus the radiant energy from lamps 17a and 17b, respectively, onto oppositely facing surfaces of the ribbon 1 in a quartz tube 18, which may be the same as the quartz tube 14, through which the ribbon 1, having layer 8 of a curable coating material thereon is passed. Although the quartz tube is shown with a corresponding shape to that of the ribbon, it may be circular. Instead of the conventional serial applications of uneven radiation to achieve uniform radiation application, the oven configuration of the present invention provides a one-pass simultaneous and uniform curing treatment at both faces, la and lb, of the fiber ribbon 1, avoiding the uneven contraction and warpage damage to fiber optic ribbons caused by conventional oven systems.

Although the reflectors used in conventional ovens can be used in the oven of the present invention, a problem with the use of such reflectors is that not only the desired energy wavelengths, e.g. short wavelengths of UV radiation, are reflected and directed by the reflectors 16a and 16b upon the ribbon 1. Instead conventional reflectors reflect the entire spectrum of radiant energy emitted by the lamps, which includes not only the desired UV radiation but undesired longer wavelength visible light and Infrared ("IR")

radiation as well. Since the principal effect of IR radiation is heat, reflected IR heat energy focused upon the faces of ribbon 1 can heat the surfaces of faces 1a and 1b instantaneously to high temperatures which do not reduce quickly, thereby often causing warpage and/or thermal damage to the structure of the ribbon 1.

In the preferred embodiment of the present invention, the heat problem of IR radiation is reduced by employing dichroic reflectors, which by their nature are double refracting, i.e. have good reflectance for one wavelength, e.g. UV, but poor reflectance for another e.g. IR, thereby providing focused UV curing radiation while reducing the unwanted IR radiation. Dichroic reflectors are formed by coating on the reflector surface a thin layer of material having an index of refraction selected to either transmit, reflect or absorb the incident radiation, and are available, for example, from the aforesaid Fusion Systems Corporation.

An example of one type of a dichroic reflector which can be used in the present invention is shown in fragmentary cross-section in Fig. 6. Reflector 19 has a reflective surface 19a preferably made of an opaque material, e.g. stainless steel, and capable of forming a specular finish upon polishing. A thin layer 20 of an absorbing coating, preferably black, is deposited on the polished reflective surface 19a and also polished to a specular finish. One or more layers 21 of a dielectric material having dichroic properties are then deposited atop the coating 20 on said dichroic reflector 19, and similarly polished to a specular finish. To achieve good UV reflectivity, while keeping IR and visible light radiation to under 10 percent of the total, several coatings or "stacks" of dielectric coating layers 21 are deposited and polished separately before deposition of a subsequent layer. Their reflective effects are cumulative.

As shown in Fig. 6, radiant energy 22 in the short wavelength ultraviolet spectrum is reflected and focused by the dielectric material coating layer 21 whereas the longer wavelengths, visible light 23 and infrared radiation 24, are absorbed by the absorptive coating layer 20. Thermal energy absorbed by layer 20 is conducted to the dichroic reflector 19, which is preferably made of a material that is thermally conductive, and transferred to the exterior surface side 19b of the reflector 19. This conducted heat is easily removed by convective cooling, e.g., an air flow on the exterior surface 19b.

Alternatively, as shown by Fig. 7, a transparent reflector 25 and dichroic dielectric coating layer 21 reflects the shorter UV 22 wavelengths, as in the previous embodiment, but allows the longer wavelengths of visible light 23 and IR radiation 24 to pass through

instead of being absorbed. An advantage of this embodiment over the previous one is that no cooling device would be necessary.

In accordance with the above discussion, high quality thin and thick optical fiber ribbons can be manufactured by a process using the oven configuration of the present invention. Uniform rates of curing and contraction of the curable coating material layer 8 and reduced radiant heating of the ribbon, along both faces of ribbon 1 allows the manufacture of much thinner ribbons than possible in conventional curing ovens. Uniformity in radiation has the added advantage of benefiting fully from the many recent advances in fiber planarity and extrusion techniques, optimising and minimising the film thicknesses required for both the thin and thick ribbon types.

The process of the present invention is illustrated schematically in Fig. 8. Although the schematic is horizontally related, the apparatus may be a vertical assembly. Individual optical fibers 2 are formed by conventional techniques, and preferably, each is coated with protective coating material 5 to protect each fiber 2. A plurality, i.e two or more, of the fibers 2, preferably having identical diameters, are aligned longitudinally into parallel, planar array 6 of closely adjacent fibers, seen along an edge in Fig. 8. The fibers can be coated or marked with UV or thermally curable, coloured inks for identification purposes.

The array 6 of longitudinally aligned and parallel fibers 2 then passes through an extrusion die 27, which evenly extrudes a curable coating material 8, such as an UV curable acrylate resin, onto array 6 filling the interstices 9 between the individual fibers 2, and coating the peripheral portions 10 of the end fibers, resulting in a smooth and planar ribbon. As the so-coated fibers 2 are advanced through quartz tube 18, the extruded coating material layer 8 is then irradiated in oven 15 by radiation of a wavelength which will cause the coating to cure, e.g. ultraviolet radiation. Preferably, other wavelengths, e.g. IR, are not directed on the surface of the ribbon by using dichroic reflectors 16a and 16b of the type described in connection with Figs. 6 and 7. The thickness of the material extruded by die 27 onto planar fiber array 6 varies according to the particular ribbon type desired, i.e. thin or thick. Coating material for the layer 8 preferably has a tensile modulus of at least 30 MPa and relatively low adhesion to the fibers 2, which not only binds the individual optical fibers 2 together, but also restricts the fibers 2 from moving relative to each other during handling while permitting the layer 8 to be relatively easily stripped from the fibers for connection purposes without

removing any identification marking on the fibers 2. Such materials are known in the art. However, if desired, the material for the layer 8 can have a bonding to the coating material of the layer 5 which permits interfiber movement, examples of such materials being set forth in U.S. Patent No. 4,900,126. Normally, unless the layer 5 has been coated with a release agent prior to the application of the coating material for the layer 8, the material of the layer 8 will be different from the material of the layer 5.

Thicker layers of extruded coating material 8 are required on ribbons manufactured in conventional equipment which has higher incident IR radiation, lessor quality extrusion dies and/or non-uniform radiation dosages in order to guarantee a minimum spot thickness due to misalignment of the fibers. Because of the manufacturing improvements of the present invention, however, much thinner extrusion coatings for both thin and thick ribbons are now possible. Whereas conventional 'thin" ribbons have, as a practical matter, a thickness for the layer 8 of approximately 25 microns, thin ribbons manufactured according to the process of the present invention have a layer 8 thickness of approximately 5 - 15 microns. Whereas conventional "thick" ribbons are approximately 100 microns thick, the thickness can now be reduced to 30 - 60 microns. The thickness of the layer 8 is measured along a radius of an optical fiber 2 which is normal to the plane defined by the longitudinal axes of the optical fibers 2.

After extruding the layer 8 of curable coating material onto fiber array 6, the coated array 6 passes through the oven 15 of the present invention, which simultaneously exposes both major surfaces or faces 1a and 1b to substantially equal curing radiation and uniformly cures the layer 8. The duration of exposure and the amount of radiation to which the ribbon is exposed is controlled by the speed of the ribbon 1 through the improved oven and by the radiation level of the lamps 17a and 17b. The simultaneous and uniform irradiation of the coating material of the layer 8 causes uniform curing of the layer 8 and eliminates warping.

The cured or still curing ribbon 1 then passes onto a second pulley 28 and then to a rotating drum (not shown), onto which the ribbon can be wound.

If the identifying markings or coatings on the fibers 2 can be cured by the radiation from the lamps 17a and 17b, e.g. UV radiation, such markings or coatings will cure, or commence to cure, at the same time as the layer 8.

The encapsulating layer can comprise a plurality of coatings of the same or different materials. Thus, in addition to the layer 8 of coating material, the cured ribbon

1 formed in the above process can be passed through a bath of a molten plastic coating material to form a layer 29 (Fig. 9) or passed through a second extrusion die similar to die 27 for depositing a layer 29 of the plastic coating material on the ribbon 1. Preferably, the plastic coating material for the layer 29 is an acrylate resin or other radiation curable plastic which also cures when subjected to UV radiation, forming a hard protective outer coating, as shown in Fig. 9. As with the application of the layer 8 of extruded coating material, the improved process of the present invention allows for much thinner films or layers 29 of plastic coating material than the prior art. For example, the total thickness of the layers 8 and 29 of protective plastic coatings on optical fiber ribbons can be reduced from 25 microns as in the prior art, down to 5 - 15 microns with the use of the methods and apparatus of the present invention. Plastic coating material 29 forms a protective layer around ribbon 1 and preferably has a high modulus, i.e. a tensile modulus of at least 30 MPa and its bonding of layer to the fibers 2 need not be considered and can be of a material different from the material for the layer 8, thereby providing a robust package for the optical fibers 2 encased therein.

A further advantage of simultaneous and uniform irradiation of ribbon 1 is that unlike conventional ribbon manufacturing the process of the present invention is not prone to producing warped or curved ribbons at any particular production speed.

Although positioning the UV ovens directly opposite one another about the curable coating cable material provides uniform irradiation of relatively flat ribbons, it should be understood that alternate positionings of the ovens in relation to the curable material which will subject the ribbons to simultaneous and uniform radiation may be employed to accommodate different ribbon geometries.

Although preferred embodiments of the present invention have been described and illustrated, it will be apparent to those skilled in the art that various modifications may be made without departing from the principles of the invention.

THE CLAIMS

1. A process for manufacturing an optical fibre ribbon containing a plurality of longitudinally extending optical fibres and having differently facing first and second surfaces which lie in parallel rectilinear planes, comprising the following steps:

(a) aligning said longitudinally extending optical fibres into a substantially planar array of parallel and adjacent optical fibres with the longitudinal axes of the fibres in a rectilinear plane;

(b) extruding a layer of radiation curable coating material on said planar optical fibre array to provide a coated planar array of parallel optical fibres with differently facing first and second coated surfaces, said array forming a substantially thin and relatively wide ribbon; and

(c) passing the coated planar array between a pair of spaced curing radiation sources, respectively at opposite sides of the same portion of the array passing therebetween and each of said sources including a curing radiation emitter and a radiation focussing reflector, the emitter being between the reflector and the coated planar array and both of said sources simultaneously and uniformly directing curing radiation toward each other and substantially perpendicular to said surfaces and respectively, focussing the curing radiation from said sources onto said first surface and said second surface therebetween so that most of the radiation from one of said pair of sources substantially uniformly impinges on one of said surfaces and most of the radiation from the other of said pair of sources substantially uniformly impinges on the other of said surfaces.

2. The process as set forth in claim 1, wherein steps (b) and (c) are repeated, building up successive layers of cured material on said array.

3. The process as claimed in claim 1 or 2, wherein said radiation curable coating material is acrylate resin.

4. The process as claimed in claim 1 or 2, wherein said curable coating material layer, when cured, has a tensile modulus of at least 30 MPa.

AUSTRALIAN PATENT OFFICE

5. The process as claimed in any one of claims 1 to 4, wherein said curable coating material layer, has a thickness dimension when cured from about 5 to 15 microns.

6. The process as claimed in any one of claims 1 to 4, wherein said curable coating material layer has a thickness dimension when cured from about 30 to 60 microns.

7. The process as claimed in claims 1 to 6, wherein at least one of said optical fibres is marked with a curable ink for identification purposes.

8. The process as claimed in claim 7, wherein said ink is cured by ultraviolet radiation.

9. The process as claimed in claim 7, wherein said ink is thermally cured.

10. The process as claims in any one of claims 1 to 9, wherein a release agent is interposed between each of said optical fibres and said curable coating material layer.

11. The process as claimed in any one of claims 1 to 10, wherein each of said reflectors has a radiation reflecting surface facing its respective emitter which has the shape of a portion of an ellipse.

12. The process as claimed in claim 11, wherein said reflectors share a common focal axis along which the coated planar array is passed.

13. The process as claimed in any one of claims 1 to 12, wherein said reflectors are dichroic and reflect curing radiation more than other radiation emitted by the curing radiation emitters.

14. The process as claimed in any one of claims 1 to 13, wherein said curing radiation is ultraviolet radiation.

AUSTRALIAN PATENT OFFICE 30

15. An apparatus for manufacturing an optical fibre ribbon having a plurality of longitudinally extending optical fibres therein, comprising:

means for aligning said longitudinally extending optical fibres into a substantially planar array of parallel and adjacent optical fibres as they are advanced in the direction of their lengths;

means for extruding a radiation curable coating material layer on said planar optical fibre array as said optical fibres are advanced, to provide a ribbon having a width transverse to the direction of advance greater than the thickness of the ribbon transverse to the width of the ribbon and providing first and second differently facing major surfaces on said layer;

oven means for curing said radiation curable coating material layer on said planar array with curing radiation as said ribbon is advanced, said oven means comprising:

a first lamp for emitting radiation which will cure the material of said layer and a second lamp for emitting radiation which will cure the material of said layer, said first lamp and said second lamp being spaced from each other in the direction transverse to the direction of advance of the ribbon for receiving a portion of said ribbon between, and spaced from, said first lamp and said second lamp and with a first one of said major surfaces facing said first lamp and with a second one of said major surfaces facing said second lamp;

a first reflector disposed at the side of said first lamp opposite from said second lamp for directing curing radiation of said first lamp toward said second lamp and substantially perpendicularly to said first one of said major surfaces, said first reflector also being a focussing reflector for focussing curing radiation of said first lamp on said first one of said major surfaces;

a second reflector disposed at the side of said second lamp opposite from said first lamp for directing curing radiation of said second lamp toward said first lamp and substantially perpendicularly to said second one of said major surfaces, said second reflector also being a focussing reflector for focussing curing radiation of said second lamp on said second one of said major surfaces;

whereby said oven means uniformly and simultaneously cures said radiation curable coating material layer on said planar array.

AUSTRALIAN PATENT OFFICE

16. The apparatus as claimed in claim 15, wherein said first and second lamps are

ultraviolet radiation emitters.

17. The apparatus as claimed in claim 15 or 16, wherein said oven means further comprises: tube means which is at least partially transparent to said curing radiation for encircling, and permitting the passage of, said planar array of optical fibres covered by said radiation curable coating material layer while said layer is being cured said oven means, said tube means being disposed intermediate said first lamp and said second lamp.

18. The apparatus as claimed in claim 17, wherein said tube means is a quartz tube having a bore larger than the maximum dimension of said planar array of optical fibres with said layer thereon.

19. The apparatus as claimed in any one of claims 15 to 18 wherein said first reflector has a reflecting surface facing said first lamp which has the shape of a portion of an ellipse with two focal lines, the first lamp being at one of the two focal lines and said second reflector has a reflecting surface facing said second lamp which has the shape of a portion of an ellipse with two focal lines, the second lamp being at one of the two focal lines of the reflecting surface of said second reflector.

20. The apparatus as claimed in claim 19 wherein said first reflector and said second reflector have a common focal axis intermediate said first lamp and said second lamp and at a ribbon advanced between said first lamp and said second lamp.

21. The apparatus as claimed in any one of claims 15 to 20 wherein each of said first reflector and said second reflector is dichroic and reflects curing radiation more than other radiation emitted by said first lamp and said second lamp.

22. The apparatus as claimed in any one of claims 15 to 21 wherein said means for extruding a radiation curable coating material layer comprises means for extruding a layer of radiation curable acrylate resin on said planar optical fibre array.

AUSTRALIAN PATENT OFFICE

23. The apparatus as claimed in any one of claims 15 to 22 wherein said means for extruding a radiation curable coating material layer comprises means for extruding a layer of a radiation curable material on said planar optical fibre array which material, when cured has a tensile modulus of at least 30 MPa.

24. A process for manufacturing an optical fibre ribbon substantially as herein described with reference to the accompanying drawings.

25. An apparatus for manufacturing an optical fibre ribbon substantially as herein described with reference to the accompanying drawings.

DATED this 6th day of June 1997

PIRELLI CABLE CORPORATION
By Its Patent Attorneys
DAVIES COLLISON CAVE

AUSTRALIAN PATENT OFFICE

ABSTRACT

A process for manufacturing an optical fiber ribbon containing two or more optical fibers. The fibers are aligned longitudinally in a planar array and covered with a radiation curable coating material. The curable material is then cured by ultraviolet radiation simultaneously and uniformly directed on opposite surfaces of the coating material on the planar array, forming a fiber ribbon array. Further layers of radiation curable material may be similarly formed on the first layer. Also, the product of such process and apparatus for performing the process which includes a fixed source of radiation at one side of the coated array and a second source of radiation at the opposite side of the coated array for simultaneously irradiating both sides of the same length of the coated array.

FIG. 1

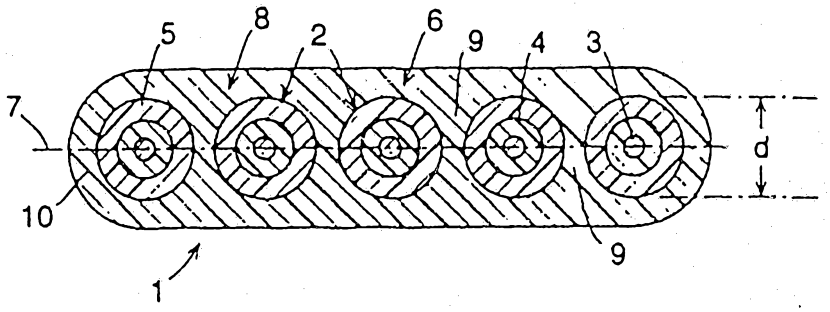


FIG. 2
Prior Art

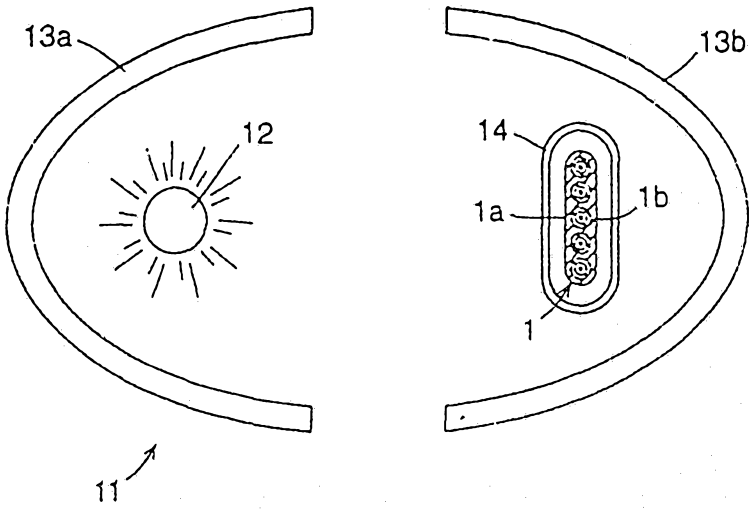


FIG. 3

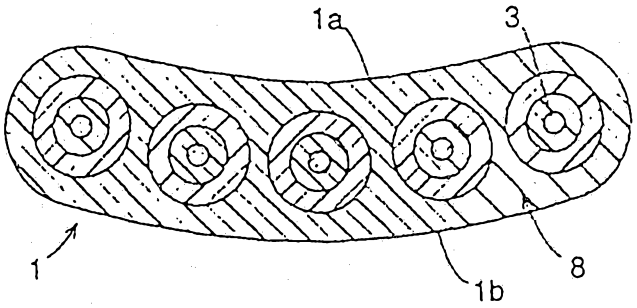
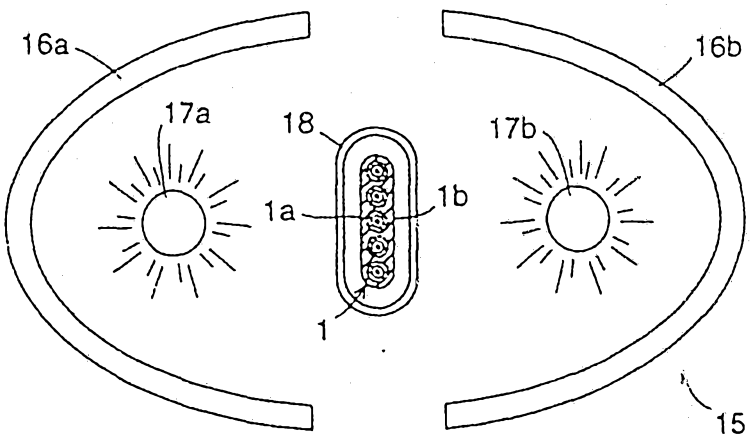


FIG. 4



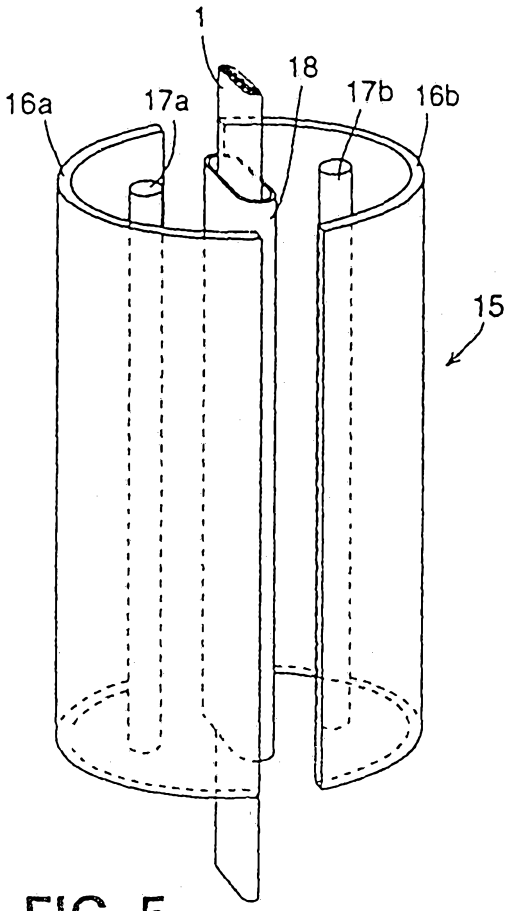
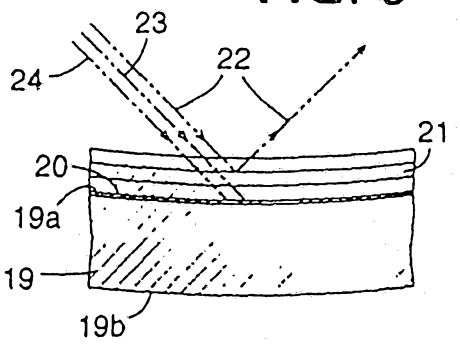


FIG. 5

FIG. 6



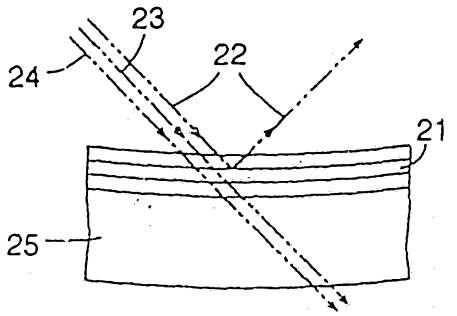


FIG. 7

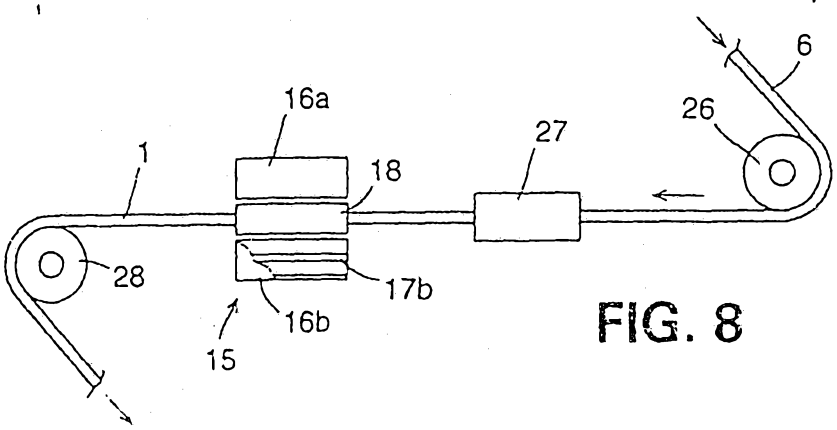


FIG. 8

FIG. 9

