

Description

Technical Field

This invention relates the methods for making doped glass bodies and, more particularly, to methods for making a depressed refractive index outer claddings for optical fibers.

Background of the Invention

Optical fibers have become increasingly important as a medium for transmitting large quantities of information in the form of lightwaves. Each optical fiber comprises a thin solid glass cylinder, known as the core of the fiber, surrounded by a glass sleeve, known as the cladding, which has a lower refractive index than the core. There are a number of ways of making optical fiber, one way being, first, to construct a glass tube, and then to vapor-deposit glass that will eventually constitute part of the cladding and the core on the inner surface of the glass tube by the method taught, for example, in the U.S. patent of MacChesney, et al. No. 4,217,027 granted August 12, 1980, now generally known as the modified chemical vapor deposition (MCVD) technique. When used in such manner, the glass tube is known conventionally as a substrate tube. After deposition, the entire structure is collapsed to make a preform rod, and glass drawing techniques are used to form a continuous optical fiber from the preform. The vapor deposited glass of the optical fiber may be doped so as to have a refractive index that is higher and/or lower than that of undoped glass; in any event, the refractive index of the core must be higher than that of the cladding layer for efficient transmission of lightwaves in the usual manner. One way of obtaining this difference is to dope the cladding layer with fluorine, which depresses the refractive index with respect to that of undoped glass (silicon dioxide).

For large preforms, an oversized core is deposited in the substrate tube and the collapsed preform rod is inserted into a second tube, called an overclad tube, that is collapsed onto the rod. This is the hybrid or "rod-in-tube" approach as described, for example, in the U.S. patent of J. W. Baumgart et al., No. 4,820,322, granted April 11, 1989. One may likewise wish to dope such overclad tubes with fluorine to depress their refractive indices.

Both substrate and overclad glass tubes may be made, first, by depositing glass soot on a mandrel to form a cylindrical porous soot form of glass particulate. The deposited porous soot cylinder is then consolidated into a glass tube by heating the soot cylinder in a furnace. Prior to consolidation, fluorine can be introduced as a dopant by adding a fluorine containing gas to the reactant stream of the torch during soot deposition, or by adding a fluorine containing gas to the

furnace atmosphere at a temperature below the consolidation temperature. During the consolidation step, preferential volatilization of fluorine from the porous cylindrical tube surfaces typically produces a non-uniform distribution of fluorine through the thickness of the consolidated glass tube. Such non-uniformities can cause problems with the efficiency of lightwave transmission and reproducibility of the fiber.

One approach to this problem is to consolidate glass soot previously doped with fluorine while flowing a fluorine-containing gas over it in the furnace. Another proposal, described in the U.S. patent of Berkeley, No. 4,629,485, granted December 16, 1986, is to dope the previously undoped soot during the consolidation step by flowing fluorine gas about the heated soot cylinder before and during consolidation. We have found that it is difficult with either of these approaches to obtain the desired uniformity of fluorine doping through the thickness of the final tube; also, such processes increase the expense of production because the highly reactive fluorine, at the high temperature required for consolidation, inevitably damages various furnace parts during its use.

Patent abstracts of Japan, Vol. 7, No.232 (C-190)[1377], October 14, 1983, describes a method for sintering glass containing volatile dopants which is carried out under specifically pressurized conditions so as to contain volatile dopants in the glass material. This requires that the raw material be placed in a vessel of high purity glass and sealed under a reduced pressure of about one Torr. Then the vessel is put in a high-pressure sintering furnace and a gas for pressurization such as argon is introduced into the furnace. The vessel is heated under pressure to effect the sintering of the glass material. The need for evacuating and sealing the glass and for sintering under a controlled applied pressure complicates the production of optical fibers.

Accordingly, there is a well-recognized need in the industry for a convenient and inexpensive method for doping a glass tube, destined to be the cladding layer of an optical fiber, with a refractive index reducing, and highly reactive, dopant such as fluorine, in such manner that the reduced refractive index is substantially uniform through the thickness of the tube. There is also a need for such a method that does little or no damage to furnace parts.

According to the present invention there is provided a method as defined in claims 1 or 7.

In accordance with one embodiment of the invention, glass fiber with a depressed refractive index outer cladding is made by, first, depositing fluorine-doped silica soot on a mandrel by directing silicon-containing and fluorine-containing gases through a flame toward the mandrel. The porous soot cylinder is then consolidated by enclosing it within an encapsulation structure which is located in a conventional furnace. The soot cylinder is heated sufficiently to consolidate

it into a glass tube, but during this consolidation the encapsulation structure confines the fluorine gas to remain largely within the soot cylinder and thus within the final glass tube.

The atmosphere within the encapsulation structure is kept substantially stagnant during the consolidation step; that is, during consolidating, there is virtually no gas flow within or through the encapsulating structure. However, the volume enclosed by the encapsulation structure communicates with the furnace volume by gaps having a relatively high impedance to gas transfer, whereby any dopant diffused into the volume contained by the encapsulation structure is substantially confined within the encapsulation structure. In accordance with another embodiment, the volume enclosed by the encapsulation structure is only slightly greater than the volume of the soot cylinder. As a consequence of these features, relatively little of the fluorine in the soot cylinder diffuses into the volume enclosed by the encapsulating structure before the gaseous concentration within the encapsulation structure is sufficient to inhibit further net volatilization of fluorine from the soot cylinder. We have found that, in prior art methods, it is an escape from the soot cylinder of fluorine dopant during consolidation that is primarily responsible for dopant non-uniformities in the substrate tube. By confining the fluorine gas, we limit the escape of fluorine from the soot cylinder. Moreover, as will be explained more fully below, whatever fluorine does escape does not lead to doping level non-uniformities because the fluorine gas in the encapsulation structure is caused to be of substantially equal concentration throughout the volume of the glass soot cylinder.

Brief Description of the Drawing

FIG. 1 is a schematic view of apparatus for making a soot cylinder that may be used in conjunction with an illustrative embodiment of the present invention;

FIG. 2 is a schematic sectional view of apparatus in accordance with an illustrative embodiment of the invention for consolidating the soot cylinder made as shown in FIG. 1;

FIG. 3 is a schematic view of apparatus for depositing glass on the inner surface of a cylindrical substrate tube made by the apparatus of FIG. 2; FIG. 4 is a graph of ideal refractive index versus distance along a transverse section of an optical fiber;

FIG. 5 is a graph of refractive index versus distance along a transverse section of a glass substrate tube made in accordance with the prior art; FIG. 6 is a graph of refractive index versus distance along a transverse section of a glass substrate tube made in accordance with the invention;

FIG. 7 is a schematic view of a portion of the soot cylinder and a portion of the encapsulation structure of FIG. 2.

Detailed Description

It is to be noted that the drawings are illustrative and symbolic of the invention and the scale or relative proportion of the elements shown is not necessarily accurate. Further, it is to be noted that the present invention explicitly contemplates both single mode and multimode optical fiber lightguides, regardless of any specific description drawing or example set forth herein.

Referring now to FIG. 1, there is illustrated a known method for forming a soot cylinder 11 on a mandrel 12 which may be used in conjunction with the invention. Gaseous components are mixed in a burner 13 which emits a flame 14 within which silicon may be reacted to form silicon dioxide (silica soot) that is deposited on the mandrel to constitute the soot cylinder 11. As is known in the art, a gaseous silicon-containing gas from a source 16, a fluorine-containing gas from a source 17, an oxygen-containing gas from a source 18 and gaseous fuel from a source 19, are combined in the burner or torch for projection toward the soot cylinder 11. As described, for example, in the aforementioned MacChesney et al. patent and in the paper, "Fabrication of Optical Wave Guides by the Vapor Deposition Process," by P. C. Schultz, *Proceedings of the IEEE*, Vol. 68, No. 10, October, 1980, pps. 1187-1190, any of various gases may be used as the silicon-containing, fluorine-containing, oxygen-containing and fuel gases. The silicon compound may illustratively be SiCl_4 , the fluorine compound may be SiF_4 , the oxygen may be O_2 and the fuel may be hydrogen.

After its formation, the soot cylinder 11 (also sometimes known as a soot boule or soot form) is consolidated within a furnace 21 as shown in FIG. 2. The soot cylinder is supported by a mandrel 20, which may be either the same or different from the mandrel 12 of FIG. 1, and a pedestal 25. The furnace, as is well known, comprises heating elements 22 which may be in the form of a conductive coil or a plurality of conductors. It also typically includes a muffle 23, which is a cylinder of refractory material used for maintaining the heat balance within the furnace. Since such refractory materials are typically reactive to fluorine, these furnace parts are typically damaged by any of the prior art methods that use a flow of fluorine before or during the glass consolidation. Prior to consolidation, the soot cylinder is purged by flowing past it and through it helium from a source 27. This flow is shut off during consolidation, illustratively by a valve 28.

In accordance with the invention, during consolidation, the soot cylinder 11 is encased by a gas-impermeable encapsulation structure 29 which may be

of quartz or a similar material that is unlikely to contaminate the porous soot cylinder 11. The volume enclosed by the encapsulation structure 29 is only slightly larger than the volume enclosed by the soot cylinder 11; preferably, the ratio of the volume enclosed by encapsulation structure 29 to the volume enclosed by the soot cylinder 11 is 1.4:1 or less (for purposes of this calculation, the mandrel volume is considered to be part of the soot cylinder volume). The purpose of the encapsulation structure 29 is to confine fluorine gases within the soot cylinder and to cause the atmosphere surrounding the soot cylinder to be substantially saturated with fluorine during consolidation, thereby to make a more uniform refractive index profile across the width of the consolidated glass tube.

In accordance with one embodiment of the invention, after the soot cylinder 11 has been consolidated to form a solid glass tube, the mandrel 20 is removed and the tube is used as a substrate; that is, core material is deposited within the tube by the process shown schematically in FIG. 3. Although the tube may directly be used as a substrate tube, preferably the tube is drawn by conventional glass drawing techniques to increase its length and reduce its diameter prior to its use as a substrate tube. Substrate tube 30 is, of course, fluorine-doped glass made by the process of FIG. 2. As described in more detail in the aforementioned MacChesney et al. patent, a silicon-containing gas, together with an oxygen-containing gas, are introduced into the left end of the tube as shown by arrow 31. A flame 32 is moved axially along the tube as shown by arrow 33. The heat causes silicon to react with oxygen or oxygen-containing gas to form silicon dioxide particles which deposit on the inner wall of the substrate tube downstream from the flame. The high temperature flame traverses the area of deposited silica causing consolidation of the particles into a thin glass layer. Several layers are deposited in this manner until the desired composition profile and glass thickness are obtained. The deposited silicon dioxide (or silica) particles 35 may be undoped or may alternatively be doped (as known in the art) so as to have a different refractive index than that of undoped glass.

After complete deposition of glass on the interior of the substrate tube 30, the substrate tube 30 is collapsed into a solid cylindrical preform structure. The outer portion of the preform structure conforms in composition to the substrate tube 30, while the inner portion corresponds in composition to the deposited glass 35. Alternatively, according to the known "rod-in-tube" process, the cylindrical preform structure can be fitted into a larger overclad tube that is then collapsed to make a larger preform. Such overclad tube can be made by the process illustrated in FIG. 2.

After fabrication of the preform, the preform is

placed in a furnace which heats and softens one end of it such that it may be grasped by a tool and drawn in the form of a partially-molten fiber. As is known in the art, the preform is progressively fed into the furnace as the fiber is drawn from the partially-molten end of the preform. A furnace for drawing an optical fiber from a preform is described, for example, in the U.S. patent of Andrejco, No. 4,450,333 granted May 22, 1984, which, for reasons of brevity, is not shown and described herein. While the preform may have a diameter of 19 millimeters, the optical fiber is drawn to have a total diameter of typically only about 125 microns. The glass composition of the core of the fiber corresponds to that of the deposited soot 35 of FIG. 3 while the cladding level of the fiber ordinarily corresponds partly to the deposited particles 35 and also to the composition of substrate tube 30 (and thus of soot cylinder 11).

Referring to FIG. 4, which is a graphical representation of an ideal refractive index versus distance along the width of an optical fiber having a central axis at location 36, it is important for proper lightwave transmission that the refractive index 37 of the core of the fiber be higher than the refractive index 38 of the outer cladding of the fiber. This is because an interface having a good reflectivity must be formed between the cladding and the core of the fiber for light to be reflected appropriately during its transmission through the optical fiber. If the refractive index of the cladding level is non-uniform, or if the difference of refractive indices at the surface between the core and the cladding is not sufficiently great or is non-uniform in the axial direction, the optical fiber may not be capable of transmitting lightwaves as intended.

FIG. 5 is a graphical representation of refractive index through the wall of a substrate tube of the prior art in a direction perpendicular to its axis. Assuming that the substrate tube is doped with fluorine, the refractive index profile 39 varies inversely with doping. A reference profile 40 showing the refractive index of an ideal, uniformly-doped glass is included for reference purposes. Distance 42 is the outer surface of the tube, while distance 43 is the inner surface (the central axis of the tube would be to the right of distance 43). A problem with fluorine-doped substrates of the prior art is that, during consolidation, the fluorine doping tends to escape from the soot cylinder predominantly at its surfaces; thus, at the surfaces 42 and 43 of the substrate tube, the refractive index is less depressed than at a region 44 removed from the surfaces.

With the present invention, the encapsulation structure 29 limits the amount of fluorine dopant that escapes and insures that the dopant is uniformly distributed within the soot cylinder. Referring to FIG. 6, this results in a profile of 45 that differs only slightly from the ideal shown by curve 40. Moreover, note that the profile 45 is substantially uniform with respect to

distance rather than being non-uniform as is profile 39 of FIG. 5.

FIG. 7 shows an enlarged section of part of the encapsulation structure 29 and soot cylinder 11 of FIG. 2. During the heating of the soot cylinder, fluorine molecules 48 from both the interior and surface regions of the soot cylinder diffuse into the gap 49 between the encapsulation structure 29 and the soot cylinder. The atmosphere in gap 49 is stagnant and so it quickly saturates with fluorine. During the remaining portion of the consolidation cycle, the number of fluorine molecules leaving the soot cylinder 11 is substantially compensated by the number of fluorine molecules returning to it from the enclosure atmosphere. Since there is no sink for fluorine molecules, the gas phase concentration tends toward uniformity along the entire width of the soot cylinder. The concentration gradient, or concentration difference, between fluorine in the soot cylinder and that in the gas phase is significantly reduced, which significantly reduces further volatilization of fluorine from the cylinder. Preferential volatilization at the surfaces is substantially eliminated so that when the soot is collapsed into solid glass, the fluorine doping is uniform with respect to distance, as shown by profile 45 of FIG. 6. Moreover, we theorize that a uniform distribution of substantially stagnant gas-phase fluorine during consolidation tends to smooth out differences in dopant concentration in the original soot cylinder by making generally uniform any gradient between solid-phase and gas-phase fluorine along the volume of the cylinder. Given sufficient time the gas-phase fluorine will come into equilibrium with that in the soot cylinder, thus eliminating the driving force for further fluorine volatilization from the soot cylinder.

Referring to FIG. 6, the difference in refractive index between the actual profile 45 and the ideal profile 40 is a function of the volume of encapsulation structure 29 with respect to the volume of a soot cylinder 11. If the ratio of those volumes is very small, a relatively small proportion of the fluorine escapes from the soot cylinder before equilibrium is reached. Also, only a small time is required before a uniform fluorine distribution is achieved. We have found that, as a practical matter, encapsulation structure 29 can easily be made so that it encloses a volume which is only about 1.4 times the volume enclosed by soot cylinder 11. Other ratios could be used, however, depending on the extent to which one wishes to tolerate a longer time to reach a uniform fluorine distribution or a larger gap between the actual profile 45 and the ideal profile 40 of FIG. 6. Notice in FIG. 2 that a significant portion of the volume within the encapsulation structure is consumed by mandrel 20 which is relatively unreactive with fluorine.

Referring again to FIG. 2, since it is desired that the atmosphere within the encapsulation structure 29 be stagnant, the volume within structure 29 should

ideally be hermetically sealed from the volume within furnace 23. We have found that, as a practical matter, design and operation of the structure is greatly simplified by allowing a gap 52 around its periphery to communicate between the furnace volume and the encapsulation structure volume. We have found that with gap 52 of about 0.2 centimeters, and in the absence of forced flow, there is a sufficient impedance to the transfer of gases from the encapsulation structure to the furnace volume that the atmosphere within the encapsulation structure remains substantially stagnant during consolidation. On the other hand, this small gap is sufficient to permit helium purging under pressure prior to consolidation as was described before, and also to allow for differences in thermal expansion and contraction during operation. A gap 51 of 0.2 centimeters also surrounds the mandrel 20.

In experimental versions that we have made, the encapsulation structure 29 had a length of fifty centimeters and an inner diameter of 14.4 centimeters. The supporting mandrel 20 had an outer diameter of 1.9 centimeters. The soot cylinder had an outer diameter of fourteen centimeters and axial length of forty centimeters, and it rested on a pedestal 25 having an outer diameter of 14.2 centimeters. Consolidation experiments resulted in refractive index profiles substantially as shown in FIG. 6.

While the invention has been discussed in the context of optical fiber fabrication, other optical devices require carefully controlled refractive indices, and for such purpose, the invention may offer advantages. In particular, the invention may be used to make fluorine-doped overclad tubes for use in the rod-in-tube process as was alluded to above. It can be appreciated from the foregoing that, because the invention does not involve any external flow of fluorine gases, there is little damage to various furnace elements and gas transmission apparatus. Escaped fluorine gas does corrode encapsulation structure 29, but since such gas is substantially stagnant, the corrosion is minimal and we have found that the structure 29 may be reused many times. One advantage of doping with fluorine during the soot-forming process illustrated in FIG. 1 is that the fluorine is confined to the delivery lines of burner 13 and to an exhaust and scrubbing system used in conjunction with the process of FIG. 1, both of which are more corrosion resistant than the furnace elements used during consolidation. However the doping is performed, consolidation in accordance with the invention may be of benefit. In principle, the invention may be beneficial for reducing loss of any gaseous dopant during consolidation of glass used for any purpose.

Claims

1. A method for making optical fibers comprising the steps of: forming a cylinder of first silica soot; consolidating the cylinder to form a substrate tube; collapsing the substrate tube to form a preform; including in the preform a second glass body surrounded by the glass tube and having a higher refractive index than that of the glass tube; and drawing optical fiber from the preform, the optical fiber having a cladding layer, surrounding a central core region, which has a lower refractive index than that of the core region, wherein:

the step of forming the first silica soot cylinder includes the step of including in the soot cylinder a fluorine dopant that depresses the refractive index of the silica soot to be lower than the refractive index of undoped silica; and

the step of consolidating the soot cylinder comprises the step of enclosing the soot cylinder in an encapsulation structure, and thereafter heating the soot cylinder to a sufficient temperature to consolidate the soot cylinder, the heating being the absence of a forced gas flow into the encapsulation structure resulting in a substantially stagnant atmosphere within the encapsulation structure;

wherein the encapsulation structure is contained within a furnace volume and the volume enclosed by the encapsulation structure communicates with the furnace volume by gaps having a relatively high impedance to gas transfer, whereby any dopant diffused into the volume contained by the encapsulation structure is substantially confined within the encapsulation structure.

2. The method of claim 1 further characterized in that:

the dopant is fluorine.

3. The method of claim 2 further characterized in that:

the step of forming the soot cylinder comprises the steps of directing a gaseous silicon-containing material and a gaseous fluorine-containing material through a flame toward a body such that silica soot impregnated with fluorine is deposited on the body.

4. The method of claim 3 further characterized in that:

the volume enclosed by the encapsulation structure is sufficiently small that, during the consolidation of the soot cylinder, the fluorine released by the soot cylinder substantially saturates the atmosphere contained by the encapsulation structure.

5. The method of claim 4 further characterized in that:

the ratio of the volume enclosed by the encapsulation structure to the volume of the soot cylinder is less than about 1.4:1, whereby only a relatively small amount of the dopant escapes into the volume enclosed by the encapsulation structure before reaching equilibrium.

6. The method of claim 7 further comprising the steps of:

forming a second soot cylinder by the same method as that described in claim 1 for forming the first soot cylinder;

consolidating the second soot cylinder to form a glass cylinder by the same method as that described in claim 1 for consolidating the first soot cylinder;

fitting the glass cylinder over the preform;

and collapsing the glass cylinder on the preform to enlarge the size of the preform.

7. A method for making fluorine-doped glass comprising the steps of directing a fluorine-containing gas and a silicon-containing gas through a flame toward a body such that fluorine-doped silica soot collects on the body;

placing the soot within an encapsulation structure;

placing the encapsulation structure within a furnace; and

heating the silica soot in a substantially stagnant atmosphere within the encapsulation structure to a sufficient temperature to consolidate, into solid glass, the fluorine-doped silica soot;

wherein the encapsulation structure is contained within a furnace volume and the volume enclosed by the encapsulation structure communicates with the furnace volume by gaps having a sufficiently high impedance to gas transfer to cause any fluorine dispersed into the volume contained by the encapsulation structure to be substantially confined within the encapsulation structure.

8. The method of claim 7 wherein:

the volume enclosed by the encapsulation structure is sufficiently small that, during the consolidation of the soot cylinder, the fluorine released by the soot cylinder substantially saturates the atmosphere contained by the encapsulation structure.

9. The method of claim 7 wherein:

the ratio of the volume enclosed by the encapsulation structure to the volume of the silica soot is less than about 1.4:1, whereby only a rel-



atively small amount of the dopant is released into the volume enclosed by the encapsulation structure before reaching an equilibrium condition between fluorine volatilizing from the soot and fluorine entering the soot.

10. The method of claim 7 wherein:
the fluorine-containing gas is SiF_4 .

Patentansprüche

1. Verfahren zur Herstellung von optischen Fasern mit folgenden Schritten:
Bildung eines Zylinders aus ersten Silica-Flocken;
Konsolidierung des Zylinders zur Bildung eines Substratrohres; Kollabieren lassen des Substratrohres zur Bildung einer Vorform; Einschließen in der Vorform eines zweiten Glaskörpers umgeben von dem Glasrohr und mit einem höheren Brechungsindex als das des Glasrohres; und Ziehen optischer Fasern von der Vorform, wobei die optische Faser eine Mantelschicht aufweist, die eine zentrale Kernregion umgibt und einen niedrigeren Brechungsindex als den der Kernregion aufweist,
wobei der Schritt der Bildung des Zylinders aus ersten Silica-Flocken den Schritt des Einschließens eines Fluordotierungsmittels in dem Flockenzylinder umfaßt, welches Dotierungsmittel den Brechungsindex der Silica-Flocken unter den Brechungsindex des undotierten Silica herabdrückt und
wobei der Schritt der Konsolidierung des Flockenzylinders den Schritt des Einschließens des Flockenzylinders in eine Einkapselungsstruktur umfaßt, wonach der Flockenzylinder auf eine genügende Temperatur erhitzt wird, um den Flockenzylinder zu konsolidieren, und die Erhitzung in der Abwesenheit eines erzwungenen Gasstromes in die Einkapselungsstruktur vor sich geht, was zu einer im wesentlichen stagnierenden Atmosphäre innerhalb der Einkapselungsstruktur führt;
wobei die Einkapselungsstruktur innerhalb eines Ofenvolumens enthalten ist und das von der Einkapselungsstruktur umschlossene Volumen mit dem Ofenvolumen über Spalte mit relativ hohem Widerstand gegenüber Gasübertragung in Verbindung steht, wobei Dotierungsmittel, welches in das von der Einkapselungsstruktur enthaltene Volumen eindiffundiert, im wesentlichen auf die Einkapselungsstruktur begrenzt bleibt.
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Dotierungsmittel Fluor ist.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß der Schritt der Bildung des Flockenzylinders die Schritte enthält, daß ein gasförmiges, Silicium enthaltendes Material und ein gasförmiges, Fluor enthaltendes Material durch eine Flamme zu einem Körper gerichtet wird, so daß Silica-Flocken imprägniert mit Fluor sich auf dem Körper niederschlagen.
4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß das von der Einkapselungsstruktur umschlossene Volumen genügend klein ist, daß während der Konsolidierung des Flockenzylinders das von dem Flockenzylinder freikommende Fluor im wesentlichen die durch die Einkapselungsstruktur umschlossene Atmosphäre sättigt.
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß das Verhältnis des von der Einkapselungsstruktur umschlossenen Volumens zu dem Volumen des Flockenzylinders kleiner als ungefähr 1,4 : 1 ist, wobei nur ein relativ kleiner Betrag des Dotierungsmittels in das von der Einkapselungsstruktur umschlossene Volumen vor Erreichen des Gleichgewichtes entweicht.
6. Verfahren nach Anspruch 7, gekennzeichnet durch folgende Schritte:
Bilden eines zweiten Flockenzylinders durch das gleiche Verfahren, wie in Anspruch 1 zur Bildung des ersten Flockenzylinders beschrieben;
Konsolidieren des zweiten Flockenzylinders zur Bildung eines Glaszylinders durch das gleiche Verfahren wie in Anspruch für die Konsolidierung des ersten Flockenzylinders beschrieben;
Schieben des Glaszylinders über die Vorform; und
Kollabieren lassen des Glaszylinders auf der Vorform zur Vergrößerung der Abmessung der Vorform.
7. Verfahren zur Herstellung von mit Fluor dotiertem Glas mit folgenden Schritten:
Lenken eines Fluor enthaltenden Gases und eines Silicium enthaltenden Gases durch eine Flamme zu einem Körper, so daß mit Fluor dotierte Silica-Flocken sich auf dem Körper sammeln;
Verbringen der Flocken innerhalb einer Einkapselungsstruktur;
Plazieren der Einkapselungsstruktur innerhalb eines Ofens; und
Erhitzen der Silica-Flocken in einer im wesentlichen stagnierenden Atmosphäre innerhalb der Einkapselungsstruktur auf eine genügende Temperatur zur Konsolidierung der mit Fluor dotierten



Silica-Flocken in solides Glas;

wobei die Einkapselungsstruktur innerhalb eines Ofenvolumens enthalten ist und das von der Einkapselungsstruktur umschlossene Volumen mit dem Ofenvolumen über Spalte in Verbindung steht, die einen genügend hohen Widerstand gegenüber Gasübertragung aufweisen, so daß das in das Volumen der Einkapselungsstruktur dispergierte Fluor im wesentlichen auf die Einkapselungsstruktur begrenzt bleibt.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß das von der Einkapselungsstruktur umschlossene Volumen genügend klein ist, so daß während der Konsolidierung des Flockenzylinders das von dem Flockenzylinder freikommende Fluor im wesentlichen die durch die Einkapselungsstruktur umschlossene Atmosphäre sättigt. 5 10
9. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß das Verhältnis des von der Einkapselungsstruktur umschlossenen Volumens zu dem Volumen der Silica-Flocken kleiner als ungefähr 1,4 : 1 ist, wobei nur ein kleiner Betrag des Dotierungsmittels in das von der Einkapselungsstruktur umschlossene Volumen freigelassen wird, bevor ein Gleichgewichtszustand zwischen dem aus den Flocken flüchtigen Fluor und dem in die Flocken eintretenden Fluor erreicht wird. 15 20 25 30
10. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß das Fluor enthaltende Gas SiF_4 ist. 35

Revendications

1. Procédé de fabrication de fibres optiques comprenant les étapes suivantes : formation d'un premier cylindre de suie de silice; consolidation du cylindre pour former un tube de substrat; écrasement du tube de substrat pour former une préforme; insertion dans la préforme d'un deuxième corps en verre entouré par le tube en verre et présentant un indice de réfraction supérieur à celui du tube en verre; et étirage de la fibre optique à partir de la préforme, la fibre optique présentant une couche de gainage qui entoure une région centrale appelée coeur et présente un indice de réfraction inférieur à celui de la région du coeur, dans lequel :
l'étape de formation du premier cylindre de suie de silice comprend l'étape d'insertion dans le cylindre de suie d'un dopant au fluor qui amène l'indice de réfraction de la suie de silice à une valeur inférieure à l'indice de réfraction de la silice 40 45 50 55

non dopée, et

l'étape de consolidation du cylindre de suie comprend l'étape d'insertion du cylindre de suie dans une structure d'encapsulation et, ensuite, de chauffage du cylindre de suie à une température suffisante pour consolider le cylindre de suie, le chauffage en l'absence d'un flux de gaz forcé dans la structure d'encapsulation créant une atmosphère essentiellement stagnante à l'intérieur de la structure d'encapsulation;

procédé dans lequel la structure d'encapsulation est contenue à l'intérieur d'un volume de four et le volume contenu par la structure d'encapsulation communique avec le volume de four par des orifices présentant une impédance relativement élevée à l'égard du transfert de gaz, tout dopant diffusé dans le volume contenu par la structure d'encapsulation étant essentiellement confiné dans la structure d'encapsulation.

2. Procédé selon la revendication 1, caractérisé en outre en ce que :
le dopant est le fluor.
3. Procédé selon la revendication 2, caractérisé en outre en ce que :
l'étape de formation du cylindre de suie comprend les étapes consistant à diriger une matière gazeuse contenant du silicium et une matière gazeuse contenant du fluor à travers une flamme vers un corps, de sorte que de la suie de silice imprégnée de fluor se dépose sur le corps.
4. Procédé selon la revendication 3, caractérisé en outre en ce que :
le volume contenu par la structure d'encapsulation est suffisamment petit pour que, pendant la consolidation du cylindre de suie, le fluor dégagé par le cylindre de suie sature sensiblement l'atmosphère contenue par la structure d'encapsulation.
5. Procédé selon la revendication 4, caractérisé en outre en ce que :
le rapport du volume contenu par la structure d'encapsulation au volume du cylindre de suie est inférieur à environ 1,4:1, seule une quantité relativement faible de dopant s'échappant dans le volume contenu par la structure d'encapsulation avant d'atteindre l'équilibre.
6. Procédé selon la revendication 7, caractérisé en outre par les étapes suivantes:
la formation d'un deuxième cylindre de suie par le même procédé que celui décrit dans la revendication 1 pour former le premier cylindre de suie;
la consolidation du deuxième cylindre de 8



suie pour former un cylindre de verre par le même procédé que celui décrit dans la revendication 1 pour consolider le premier cylindre de suie;

l'ajustage du cylindre de verre sur la préforme; 5

et l'écrasement du cylindre de verre sur la préforme pour augmenter les dimensions de la préforme.

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7. Procédé de fabrication de verre dopé au fluor comprenant les étapes suivantes :

diriger un gaz contenant du fluor et un gaz contenant du silicium à travers une flamme vers un corps, de sorte que de la suie de silice dopée au fluor se dépose sur le corps; 15

placer la suie à l'intérieur d'une structure d'encapsulation;

placer la structure d'encapsulation à l'intérieur d'un four, et 20

chauffer la suie de silice dans une atmosphère essentiellement stagnante à l'intérieur de la structure d'encapsulation à une température suffisante pour consolider, dans le verre solide, la suie de silice dopée au fluor; 25

dans lequel la structure d'encapsulation est contenue à l'intérieur d'un volume de four et le volume contenu par la structure d'encapsulation communique avec le volume de four par des orifices ayant une impédance suffisamment élevée au transfert de gaz pour amener tout le fluor dispersé dans le volume contenu par la structure d'encapsulation à être essentiellement confiné à l'intérieur de la structure d'encapsulation. 30

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8. Procédé selon la revendication 7, dans lequel :

le volume contenu par la structure d'encapsulation est suffisamment petit pour que, pendant la consolidation du cylindre de suie, le fluor dégagé par le cylindre de suie sature essentiellement l'atmosphère contenue par la structure d'encapsulation. 40

9. Procédé selon la revendication 7, dans lequel :

le rapport du volume contenu par la structure d'encapsulation au volume de la suie de silice est inférieur à environ 1,4:1, seule une quantité relativement faible du dopant étant libérée dans le volume contenu par la structure d'encapsulation avant d'atteindre un équilibre entre le fluor s'évaporant de la suie et le fluor pénétrant dans la suie. 45 50

10. Procédé selon la revendication 7, dans lequel :

le gaz contenant le fluor est du SiF_4 . 55

