US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12386132
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Spreemann; Martin

Intermittently bonded fiber optic ribbon

Abstract

A method of fabricating an optical fiber ribbon is provided, the method including arranging a plurality of optical fibers adjacent to each other along a length of the optical fiber ribbon, applying an adhesive to the plurality of optical fibers, intermittently exposing the adhesive to a curing catalyst in at least one interstice between two adjacent optical fibers of the plurality of optical fibers to create bonding regions along the length of the optical fiber ribbon, and removing uncured adhesive from the plurality of optical fibers.

Inventors: **Spreemann; Martin (Berlin, DE)**

Applicant: **CORNING RESEARCH & DEVELOPMENT CORPORATION** (Corning, NY)

Family ID: **1000008751365**

Assignee: **CORNING RESEARCH & DEVELOPMENT CORPORATION (Corning, NY)**

Appl. No.: **18/103613**

Filed: **January 31, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20230176311 A1	Jun. 08, 2023

Related U.S. Application Data

continuation parent-doc WO PCT/US2021/045173 20210809 PENDING child-doc US 18103613
us-provisional-application US 63066390 20200817

Publication Classification

Int. Cl.: **G02B6/44** (20060101)

U.S. Cl.:

CPC **G02B6/448** (20130101); **G02B6/4403** (20130101);

Field of Classification Search

CPC: G02B (6/448); G02B (6/4403)

USPC: 385/114

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
3125812	12/1963	Simpson	N/A	N/A
5018007	12/1990	Ang et al.	N/A	N/A
6621973	12/2002	Hoffman	385/125	G02B 6/0096
2004/0175521	12/2003	Nakamura	428/35.2	B29C 35/0888
2005/0276543	12/2004	Bianchi	385/136	G02B 6/3807
2015/0131098	12/2014	Yang	356/402	A61B 5/14535
2016/0356976	12/2015	Sajima et al.	N/A	N/A
2017/0031121	12/2016	Blazer et al.	N/A	N/A
2017/0219792	12/2016	Debban et al.	N/A	N/A
2019/0369343	12/2018	Chalk	N/A	G02B 6/4411
2021/0191061	12/2020	Isaji et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
3428703	12/2018	EP	N/A
63-013008	12/1987	JP	N/A
2005-114830	12/2004	JP	N/A
2010-002743	12/2009	JP	N/A
2014-010439	12/2013	JP	N/A
2018/102135	12/2017	WO	N/A
2019/011417	12/2018	WO	N/A
2019/193790	12/2018	WO	N/A
2020/161971	12/2019	WO	N/A

OTHER PUBLICATIONS

International Search Report and Written Opinion of the International Searching Authority; PCT/US21/45173; dated Nov. 4, 2021; 15 pages; International Search Authority. cited by applicant

European Patent Application No. 21858818.4 Extended European Search Report dated Jun. 21, 2024; 8 Pages; European Patent Office. cited by applicant

---

Primary Examiner: Blevins; Jerry M

Background/Summary

PRIORITY APPLICATION (1) This application is a continuation application of International Application No. PCT/US2021/045173 filed on Aug. 9, 2021, which claims the benefit of priority to U.S. Provisional Application Ser. No. 63/066,390 filed on Aug. 17, 2020, the content of each of which is relied upon and incorporated herein by reference in their entirety.

FIELD

(1) The disclosure relates generally to optical fibers, and specifically to optical fiber ribbons in which the optical fibers are intermittently bonded together along the length of the optical fiber ribbon.

BACKGROUND

(2) A single optical fiber cable may contain many optical fibers (indeed, hundreds of optical fibers), and during installation of a fiber optic cable network, managing the connections between the optical fibers can be difficult. Thus, various portions of the optical fiber cable, such as individual optical fibers, buffer tubes, or ribbons, may be color coded for the purposes of identification when making such connections. Further, the optical fiber cable may contain optical fibers arranged in ribbons to allow for multiple optical fibers to be fusion spliced together in a single operation.

SUMMARY

(3) Embodiments of the disclosure relate to methods of fabricating an optical fiber ribbon. The method may include arranging a plurality of optical fibers adjacent to each other along the length of the optical fiber ribbon and applying an adhesive to the optical fibers. The optical fibers may then be intermittently exposed to a curing catalyst in one or more interstice between adjacent optical fibers to create bonding regions along the length of the optical fiber ribbon. The uncured adhesive may then be removed from the optical fibers.

(4) In an example embodiment the curing catalyst may be a light source, such as an ultraviolet (UV) light source, and the adhesive may be a photo curable adhesive, such as a UV curable adhesive. The intermittent exposure of the plurality of optical fibers to the light source may be accomplished by intermittently energizing and deenergizing the light source or by positioning a shutter between the light source and the optical fibers. Additionally, a mask may be provided between the light source and the optical fibers to define the areas exposed to the curing catalyst, which form the bonding regions.

(5) In some example embodiments, the uncured adhesive may be removed by application of a high pressure air source, e.g. air nozzles, sometimes referred to as “pneumatic air cleaners,” “air gun,” or “air knives”. The uncured adhesive may be collected and reused.

(6) Additional features and advantages will be set forth in the detailed description that follows, and, in part, will be readily apparent to those skilled in the art from the description or recognized by practicing the embodiments as described in the written description and claims hereof, as well as the appended drawings.

(7) It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understand the nature and character of the claims.

(8) The accompanying drawings are included to provide a further understanding and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and the operation of the various embodiments.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) While the specification concludes with claims particularly pointing out and distinctly claiming

the subject matter of the written description, it is believed that the specification will be better understood from the following written description when taken in conjunction with the accompanying drawings, wherein:
(2) FIG. **1** is partial, perspective view of an intermittently bonded optical fiber ribbon, according to an exemplary embodiment;
(3) FIG. **2** depicts an exemplary pattern for bonding regions of the optical fiber ribbon, according to an exemplary embodiment;
(4) FIG. **3** depicts another exemplary pattern for bonding regions of the optical fiber ribbon, according to an exemplary embodiment;
(5) FIG. **4** depicts a longitudinal cross-sectional view of a bond between two optical fibers of the optical fiber ribbon, according to an exemplary embodiment;
(6) FIG. **5** depicts a schematic representation of the method of fabricating the optical fiber ribbon, according to an exemplary embodiment; and
(7) FIG. **6** depicts a longitudinal cross-section of an optical fiber cable including an intermittently bonded optical fiber ribbon, according to an exemplary embodiment.

DETAILED DESCRIPTION

(8) Referring generally to the figures, various embodiments of an optical fiber ribbon having intermittent bonding regions as well as methods for producing such an optical fiber ribbon are provided. As described herein, the optical fiber ribbons according to the present disclosure are flexible such that the ribbons can be rolled, curled, or folded from the planar configuration conventionally associated with optical fiber ribbons to a more space-saving configuration. In this way, the ribbons may be carried in cables having smaller diameters, and/or the cables may have a higher fill ratio (i.e., fraction of cross-sectional area filled with optical fibers). In one example of typical intermittent bonding of optical fiber ribbons, the intermittent bonding is accomplished by inkjet printing of adhesive at predetermine intervals or patterns. However, inkjet printing may have limitations associated with the speed of the optical fibers moving under print heads. Further, inkjet printing may be sensitive to adjustment of the speed causing variations in the bond regions interval or pattern, which may in turn effect one or more characteristics of the optical fiber ribbon, such as flexibility or reliability. Another example intermittent bonding process includes coating and curing of an adhesive between adjacent optical fibers and then utilizing a cutting tool to selectively cut or slice the adhesive, such that adjacent optical fibers are bonded only at predetermined locations. However, the cutting tool method may have several drawbacks. For example, the cutting tool may cause damage to one or more of the optical fibers, if the cutting tool contacts the optical fibers. The speed of the optical fibers may be limited to enable accurate cutting of the adhesive. Additionally, the cutting tool may need to be cleaned or sharpened regularly, causing fabrication interruptions that may reduce output. In an example embodiment of the method disclosed herein, an adhesive may be applied to the adjacent optical fibers, and then be exposed to a curing catalyst at one or more predetermined locations to create bonded regions. The uncured adhesive is then removed, such as by a high pressure air source. The disclosed intermittent bonding method may be faster than the inkjet method or cutting tool method discussed above. The disclosed intermittent bonding method may be significantly less sensitive to adjustments in the speed of the optical fibers undergoing the curing process. Further, the disclosed intermittent bonding method may not expose the optical fibers to potential damage by physical contact with a cutting tool.
(9) In some example embodiments, the bonding regions allow for incorporation of identifying characteristics through the deposition of at a colored material on the bonding regions. For example, a material may be a color layer to provide identification of the ribbon. Each of these exemplary embodiments will be described in greater detail below, and these exemplary embodiments are provided by way of illustration, and not by way of limitation. These and other aspects and advantages will be discussed in relation to the embodiments provided herein.
(10) FIG. **1** depicts an exemplary embodiment of an optical fiber ribbon **10** according to the present

disclosure. The optical fiber ribbon **10** includes a plurality of optical fibers **12**. In the embodiment depicted, the optical fiber ribbon **10** includes twelve optical fibers **12**. In embodiments, the number of optical fibers **12** contained in the optical fiber ribbon **10** varies from four to thirty-six. Additionally, in embodiments, the optical fibers **12** may include an outer ink layer, which may further allow for arrangement of the optical fibers **12** in a color-coded pattern. For example, one convention for color-coding the optical fibers **12** is to arrange them in the following color sequence: blue, orange, green, brown, slate, white, red, black, yellow, violet, rose, and aqua. In embodiments containing more than twelve optical fibers **12**, the pattern of colors may be repeated. The optical fibers **12** are color-coded in this way to help organize and identify specific optical fibers **12** when making connections or splices.

(11) In embodiments, the optical fiber ribbon **10** has a first configuration in which the optical fibers **12** are arranged in a substantially planar row, which helps to organize the optical fibers **12** for mass fusion splicing. Further, as will be described more fully below, the optical fibers **12** also can be rolled, curled, or folded into a non-planar configuration (e.g., a circle or spiral) for space-saving packaging in an optical fiber cable, especially optical fiber cables having a circular cross-section. The optical fibers **12** of the optical fiber ribbon **10** are able to transition from the first configuration to the second configuration because the optical fibers **12** are only held together intermittently along the length of the optical fiber **12** by a plurality of intermittent bonding regions **14**.

(12) In a conventional optical fiber ribbon, the optical fibers are bonded to each other along their entire length to hold them in the planar configuration. According to the present disclosure, however, the optical fibers **12** are bonded intermittently along the length of the optical fiber ribbon **10** so that the optical fibers **12** are not rigidly held in the planar configuration. In between the intermittent bonding regions **14**, the optical fibers **12** are not bonded to each other along their length. In this way, the present optical fiber ribbon **10** provides the advantages of a ribbon with respect to fiber organization and mass fusion splicing while also allowing for a more compact cable design.

(13) FIG. **1** depicts the intermittent bonding regions **14** arranged widthwise across all the optical fibers **12**. In embodiments, the bonding regions **14** may be provided on one or both sides of the optical fiber ribbon **10**. For example, the bonding regions **14** may be on both sides of the optical fiber ribbon **10** at a particular location along the length, or for example, the bonding regions **14** may alternate sides (e.g., one or more bonding regions **14** on one side of the optical fiber ribbon **10** followed by one or more bonding regions **14** on the opposite side of the optical fiber ribbon **10**). Still further, in an example, all of the bonding regions **14** are provided on the same side of the optical fiber ribbon **10**.

(14) Additionally, in embodiments, the bonding regions **14** can be continuous or discontinuous across the width of the optical fiber ribbon **10**. For example, in embodiments, each bonding region **14** is comprised of one or more bonds holding adjacent optical fibers **12** together with the bonds being contiguous with each other, or in other embodiments, each bonding region **14** is comprised of one or more bonds holding adjacent optical fibers **12** together without the bonds being contiguous with each other.

(15) In other embodiments, the intermittent bonding regions **14** may be staggered across subsets of the optical fibers **12** in the optical fiber ribbon **10**. For example, within an intermittent bonding region **14**, as few as two of the optical fibers **12** may be bonded together at a particular location along the length of the optical fiber ribbon **10**. Notwithstanding the number and location of bonds across the width, the layer of material containing a colorant (described below) may extend across the entire width of the optical fiber ribbon in the bonding region **14** for identification purposes.

(16) FIGS. **2** and **3** provide example bonding patterns for bonds **16** between optical fibers **12** of the intermittent bonding regions **14**. For the purposes of describing the bonding patterns in FIGS. **2** and **3**, the optical fibers are numbered 1-12 going from top to bottom with respect to the orientation of those figures. For additional reference, the bonds between optical fibers are referred to as odd or

even. In the embodiments depicted in which there are twelve optical fibers, there are eleven bonds between the optical fibers, and thus, the odd bonds are the first (between optical fibers 1-2), third (3-4), fifth (5-6), seventh (7-8), ninth (9-10), and eleventh (11-12). The even bonds are the second (2-3), fourth, (4-5), sixth (6-7), eighth (8-9), and tenth (10-11). The number of bonds varies based on the number of optical fibers. In particular, the number of bonds between optical fibers is one less than the number of optical fibers.

(17) FIG. **2** depicts an embodiment of a bonding pattern in which the bonds **16** of each bonding region **14** are provided in an alternating pattern of bonding regions **14***a*, **14***b*. In the first bonding region **14***a*, the following odd pairs of optical fibers **12** are bonded to each other: 1-2, 3-4, 5-6, 7-8, 9-10, and 11-12. In the second bonding region **14***b*, the even pairs of optical fibers **12** are bonded to each other: 2-3, 4-5, 6-7, 8-9, and 10-11.

(18) FIG. **3** depicts an embodiment in which the bonds **16** of each bonding region **14** are staggered along the length of the optical fibers **12**. The bonds **16** between optical fibers **12** are provided in a repeating pattern. In a first bonding region **14***a*, the following optical fibers **12** are bonded to each other: 1-2, 6-7, and 11-12. In a second bonding region **14***b*, the following optical fibers **12** are bonded to each other: 3-4 and 8-9. In a third bonding region **14***c*, the following optical fibers **12** are bonded to each other: 5-6 and 10-11. In a fourth bonding region **14***d*, the following optical fibers **12** are bonded to each other: 2-3 and 7-8. In a fifth bonding region **14***e*, the following optical fibers **12** are bonded to each other: 4-5 and 9-10. The pattern of bonding regions **14** is repeated **14***a*, **14***b*, **14***c*, **14***d*, **14***e* along the length of the optical fiber ribbon **10**. Within one period of the repeating pattern, each optical fiber **12** is bonded to its one (in the case of edge fibers) or two adjacent optical fibers **12**.

(19) FIGS. **2** and **3** represent intermittent bonds **16** made between optical fibers **12**. The bonds **16** are provided in repeating patterns of bonding regions **14**. FIG. **2** depicts alternating bonding regions **14***a*, **14***b*, and FIG. **3** depicts a pattern of five repeating bonding regions **14***a*-**14***e*. In embodiments, the bonding regions may have as few as one bond **16** between two optical fibers **12** or as many bonds **16** as the number of optical fibers **12** divided by two (e.g., up to six bonds in a bonding region **14** for twelve optical fibers **12**, such as shown in bonding region **14***a* of FIG. **2**). In other embodiments, the bonding regions may have as many bonds as necessary to join each optical fiber **12** to its adjacent optical fiber or fibers **12** at the same longitudinal location (e.g., eleven bonds **16** to join twelve optical fibers **12**).

(20) As can be seen in FIGS. **2** and **3**, the spacing between bonding regions **14** is denoted by intervals A, B, and C. Interval A is the spacing between repeating elements, such as the spacing between a bonding region **14***a* and the next bonding region **14***a*. In embodiments, interval A is from 20 mm to 100 mm. Interval B is the spacing between adjacent even and odd bonds, such as the distance between the bond 1-2 and bond 2-3. In FIG. **2**, interval B is the midpoint of interval A, i.e., B=0.5A, which is 10 mm to 50 mm in embodiments, because the even and odd bonds are alternated. In FIG. **3**, interval B is the midpoint as shifted by interval C, which is the distance between even bonds or odd bonds (e.g., distance between bond 1-2 and bond 3-4 or between bond 2-3 and bond 4-5). In embodiments, interval C is from 0 mm to 20 mm. In FIG. **2**, interval C is 0 mm because all the odd bonds are in the same bonding region **14***a* and all the even bonds are in the same bonding region **14***b*. Thus, in the bonding pattern of FIG. **2**, interval B is at the midpoint of interval A (B=0.5A). In FIG. **3**, interval C is not 0 mm, and the bonding pattern is created by shifting each successive odd or even bond by interval C. Thus, the odd and even bonds form a stepped pattern across the bonding regions **14***a*-**14***e*. In this way, interval B becomes shifted from the midpoint of interval A by interval C (B=0.5A+C). In embodiments, interval B is from 0.5A to 0.75A when taking into account shifting by interval C.

(21) FIGS. **2** and **3** also depict a dimension D, which is the length of each bond **16**. In embodiments, the length D is from 1 mm to 10 mm. Embodiments of the bonds **16** will be described in greater detail in relation to FIGS. **4** and **5**, below.

(22) FIG. **4** depicts a longitudinal cross-section of a bond **16** between two optical fibers **12**. As can be seen in FIG. **4**, the optical fibers **12** have outer surfaces **18** that are in close proximity or are touching each other. The bond **16** joining the two optical fibers **12** is comprised of an adhesive **20**. In the embodiment of FIG. **4**, adhesive **20** is deposited on and is in contact with the outer surfaces **18** of the optical fibers **12**. The adhesive **20** is configured to bond the optical fibers **12** to each other, whereas the second material **22** is deposited for color-coding of the optical fiber ribbon **10** among a plurality of optical fiber ribbons in an optical fiber cable. In an embodiment, the adhesive **20** for bonding the optical fibers **12** together is a curable formulation, such as a photo curing adhesive, for example a UV-curable adhesive formulation) comprising one or more urethane acrylate oligomers, one or more acrylate monomers, one or more photoinitiators, an antioxidant, and other typical processing additives. In embodiments, the adhesive **20** has a Young's modulus of from 1 MPa to 50 MPa, an elongation at break greater than 200%, and/or a viscosity lower than 8000 cP at 25° C. Further, in embodiments, the adhesive **20** has a glass transition temperature of from −40° C. to 50° C.

(23) In some example embodiment a second material **22** is deposited on the adhesive **20**. In an example embodiments, the second material **22** may also be in contact with the outer surfaces **18** of the optical fibers **12**. The second material **22** may be configured as a color layer to enable identification of the Optical fiber ribbon **10**. The second material is a curable formulation (e.g., UV-curable formulation) comprising one or more urethane acrylate oligomers, one or more acrylate monomers, one or more photoinitiators, an antioxidant, and other typical processing additives. In embodiments, the second material **22** has a Young's modulus of from 100 MPa to 1500 MPa, an elongation at break of from 20% to 200%, and/or a viscosity lower than 30000 cP at 25° C. Further, in embodiments, the second material **22** has a glass transition temperature of from 0° C. to 100° C.

(24) In some example embodiments, the adhesive **20** and/or the second material **22** may be selected to have additional functionality or properties. For example, the second material **22** as the outer material may be selected to have a low coefficient of friction to allow for the optical fiber ribbons **10** to slide past each other more easily. Further, the adhesive **20** may be selected to be substantially clear (e.g., transmit at least 70%, at least 80%, or at least 90% of light having a wavelength in the range of 400 nm to 800 nm), whereas the second material **22** is selected to contain a colorant, such as a dye, an ink, or a pigment. In this way, the second material can provide color identification of the optical fiber ribbon **10**.

(25) FIG. **5** depicts a schematic representation of the method of fabricating the optical fiber ribbon **10**. A plurality of optical fibers **12** may be arranged adjacent to each other along a length of the optical fiber ribbon **10**. The optical fibers **12** may be disposed in contact or in very close proximity to each other, as discussed above in reference to FIG. **4**. The optical fibers may be feed through one or more processing steps illustrated by arrow A and described below.

(26) As the optical fibers progress through the process, the adhesive **20** may be applied to the optical fibers **12**. The adhesive **20** may be applied by spray, such as an aerosol mist, or may be applied mechanically, by brush or roller. In some example embodiments, the adhesive **20** may be applied by passing the optical fibers through an adhesive bath **100**. The optical fibers **12** may enter the adhesive bath **100** and pass under the surface of the adhesive, such as passing under a submergence bar, and then pass out of the adhesive bath **100**. The adhesive **20** may wet the periphery of the optical fibers **12**, such that adhesive **20** is disposed between each of the adjacent optical fibers **12**.

(27) The method continues with intermittently exposing the adhesive **20** to a curing catalyst in at least one interstice between two adjacent optical fibers **12** to create bonds **16** along the length of the optical fiber ribbon **10**. The curing catalyst may be heat, light, or other suitable catalyst. In an example embodiment, the adhesive **20** is a photo curing adhesive and the curing catalyst is a light source **110**. The light source may be selected to have sufficient lumens to cure the adhesive **20** in a predetermined exposure interval, e.g. as the optical fibers **12** pass the light source **110**. In some

example embodiments, the adhesive **20** is a UV curable adhesive, as discussed above, and the light source **110** is a UV light source.

(28) In an example embodiment, intermittent exposure of the adhesive **20** to the light source **110** or heat source, may be accomplished by intermittent energization and de-energization of the light source or heat source. Additionally or alternatively, the light or heat form the light source **110** or heat source, respectively, may be blocked from exposing at least a portion of the optical fibers **12**. For example, a shutter **112** may be disposed between the light source **110** and the plurality of optical fibers **12**. Rotation of the shutter **112**, as depicted by Arrow B, may allow light to pass to the optical fibers **12** at a predetermined interval. The predetermined interval may be defined by the speed of rotation of the shutter **112** and/or the width of an aperture in the shutter **112**. Further, in some example embodiments, the rotation of the shutter **112** may be synchronized with the travel speed of the optical fibers **12** relative to the light source **110**. For example, the rotation of the shutter **112** may enable sufficient light to pass to the optical fibers **12** to cure the adhesive **20** at the travel speed of the optical fibers **12**.

(29) In some example embodiments, a mask **120** is provided between the curing catalyst, e.g. light source **110**, and the optical fibers **12**. The mask **120** may block at least a portion of the light, such that the optical fibers are only exposed to the curing catalyst at predetermine areas defined by the mask **120**. For example, the mask **120** may include a plurality of apertures **122** defining the predetermine areas. In an example embodiments, the predefined areas and/or the intermittent exposure of the light source **110** may define the bonds **16** and/or the pattern of the bonding regions, such as the examples discussed above in reference to FIGS. **2** and **3**.

(30) Next, the method may continue with removing uncured adhesive **21** from the optical fibers **12**. The optical fibers **12** may travel toward a high pressure air source **130**. The high pressure air source may push the uncured adhesive backward, away from the direction of travel. The uncured adhesive **21** may collect at a barrier point due to adhesion, until overcome by gravity and falling off of the optical fibers **12**. Additionally or alternatively, the uncured adhesive **21** may be blown off of the optical fibers **12** by the high pressure air source **130**. The uncured adhesive **21** may be collected by a reservoir **132** positioned under the optical fibers **12**. In some example embodiments, the uncured adhesive **21** may be recycled to the adhesive bath **100** to minimize waste of the adhesive **20**.

(31) The high pressure air source **130** may be an air nozzle, such as a pneumatic cleaner, “air gun,” or “air knife” configured to provide sufficient air pressure to drive the adhesive off of the optical fibers **12**, but low enough to not damage or deform the optical fiber ribbon **10** and or the bonds **16**. The high pressure air source **130** may be any suitable air nozzle, and may include, as a non-limiting example, Model 5920 Air Gun with flat nozzle offered by Silvent (Portage, IN).

(32) As discussed above, a second material **22** may be applied to one or more of the bonds **16** enabling identification of the optical fiber ribbon **10**. In the case where the second material **22** provides color identification, a plurality of dots of the second material **22** may be inkjet printed on the bonds **16**. The dots may be substantially circular and have a diameter of from 50 μm to 350 μm. In an example embodiment, the second material **22** is applied over bonds **16** after the adhesive **20** has fully dried or cured. In other embodiments, the second material is applied over the bonds **16** before the adhesive **20** has fully dried or cured, such that the adhesive **20** and second material **22** intermix at the interface between the adhesive **20** and the second material **22**, which provides good adhesion therebetween.

(33) The color of the second material **22** can vary among the bonding regions **14**. For example, FIG. **1** shows three bonding regions **14** over a span of an optical fiber ribbon **10**. The bonding regions **14** are patterned in embodiments in order to identify the group of ribbons to which a particular optical fiber ribbon **10** belongs as well as identifying the specific ribbon **10** within the group. For example, an optical fiber cable containing 864 optical fibers may contain six groups of ribbons with each group having **144** fibers. The **144** fibers may be arranged as twelve ribbons **10**, each having twelve optical fibers **12** (that is, [twelve optical fibers in a ribbon]×[twelve ribbons in a

group]×[six groups in a cable]=864 optical fibers). Using the intermittent bonding regions **14**, the colors of two consecutive bonding regions **14** can be used to identify ribbon group, and the color of the following bonding region **14** can be used to identify the specific ribbon of the group.

(34) As mentioned above, the intermittently bonded optical fiber ribbon **10** allows for smaller cable diameters and/or higher fill ratios. FIG. **6** depicts an exemplary embodiment of an optical fiber cable **30** containing an intermittently bonded optical fiber ribbon **10**. The optical fiber cable **30** has a cable jacket **32** with an inner surface **34** and an outer surface **36**. In embodiments, the outer surface **36** is the outermost surface of the optical fiber cable **30**. The inner surface **34** defines a central bore **38** containing the optical fiber ribbon **10**. The central bore **38** has a diameter, which is the inner diameter ID of the cable jacket **32**. As shown in FIG. **6**, the central bore **38** is also filled with filling material **40**, which may be, e.g., strength members (such as aramid, cotton, basalt, and/or glass yarns), water blocking gels or powders, and/or fire retardant materials, among others.

(35) Conventionally, the inner diameter of the cable jacket had to be at least as large as the width of the optical fiber ribbon in the planar configuration in order to accommodate the entire optical fiber ribbon. However, this meant that much of the interior space of the optical fiber jacket went unfilled. According to the present disclosure, smaller cable diameters and/or higher fill ratios are achievable by reducing the maximum cross-sectional dimension of the optical fiber ribbon **10**. In particular, by rolling or curling the optical fiber ribbon **10** into, e.g., a circle or spiral, the inner diameter ID of the cable **30** can be smaller, providing an overall smaller and more highly filled cable design. Notwithstanding, the optical fiber ribbon **10** can still be removed from the optical fiber cable **30**, flattened into the planar configuration, and then easily be mass fusion spliced like a conventional optical fiber ribbon. For the sake of simplicity, a single optical fiber ribbon **10** was shown in the optical fiber cable **30**. However, in other embodiments, the optical fiber cable **30** may contain several tens or hundreds of optical fiber ribbons **10**. Further, such optical fiber ribbons **10** may be arranged in one or more buffer tubes within the central bore **38** of the cable jacket **32**.

(36) In an example embodiment, a method of fabricating an optical fiber ribbon is provided. The method including arranging a plurality of optical fibers adjacent to each other along a length of the optical fiber ribbon, applying an adhesive to the plurality of optical fibers, intermittently exposing the adhesive to a curing catalyst in at least one interstice between two adjacent optical fibers of the plurality of optical fibers to create bonding regions along the length of the optical fiber ribbon, and removing uncured adhesive from the plurality of optical fibers.

(37) In some example embodiment, the adhesive is a photo curable adhesive, and the curing catalyst is a light source. In an example embodiment, the adhesive is an ultraviolet (UV) curable adhesive and the light source is UV light source. In some example embodiment, intermittently exposing the adhesive to the curing catalyst includes intermittently energizing and deenergizing the light source. In an example embodiment, intermittently exposing the adhesive to the curing catalyst includes intermittently blocking the light source from exposing at least a portion of the plurality of optical fibers. In some example embodiment, intermittently blocking the light source includes rotation of a shutter disposed between the light source and the plurality of optical fibers. In an example embodiment, the rotation of the shutter is synchronized with a travel speed of the plurality of optical fibers relative to the light source. In some example embodiment, the method also includes providing a mask between the curing catalyst and the plurality of optical fibers, such that the plurality of optical fibers is only exposed to the curing catalyst at predetermine areas defined by the mask. In an example embodiment, removing the uncured adhesive includes directing a high pressure air source toward the plurality of optical fibers. In some example embodiment, the high pressure air source includes one or more pneumatic air cleaners. In an example embodiment, the method also includes collecting the uncured adhesive. In some example embodiment, the method of also includes applying a material to one or more of the bonding regions, wherein the material includes a colorant configured to identify the optical fiber ribbon. In an example embodiment, the material comprises a plurality of inkjet printed dots having a thickness of from 5 μm to 100 μm. In

some example embodiment, applying the material to one or more of the bonding regions includes inkjet printing the material onto one or more of the bonding regions.
(38) In another example embodiment, a method of fabricating an optical fiber ribbon is provided. The method including arranging a plurality of optical fibers adjacent to each other along a length of the optical fiber ribbon, passing the plurality of optical fibers through an adhesive, such that the adhesive coats the plurality of optical fibers, providing a mask between a curing light source and the plurality of optical fibers, such that the plurality of optical fibers is exposed to the curing light source at predetermine areas defined by the mask, intermittently exposing the adhesive to the curing light source in at least one interstice between two adjacent optical fibers of the plurality of optical fibers to create bonding regions along the length of the optical fiber ribbon; and removing uncured adhesive from the plurality of optical fibers by passing the plurality of optical fibers through a high pressure air source.
(39) Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is in no way intended that any particular order be inferred. In addition, as used herein, the article “a” is intended to include one or more than one component or element, and is not intended to be construed as meaning only one.
(40) It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the spirit or scope of the disclosed embodiments. Since modifications, combinations, sub-combinations and variations of the disclosed embodiments incorporating the spirit and substance of the embodiments may occur to persons skilled in the art, the disclosed embodiments should be construed to include everything within the scope of the appended claims and their equivalents.

Claims

1. A method of manufacturing an optical fiber ribbon, the method comprising: arranging a plurality of optical fibers adjacent to each other along a length of the optical fiber ribbon; applying an adhesive to the plurality of optical fibers; intermittently exposing the adhesive to light in at least one interstice between two adjacent optical fibers of the plurality of optical fibers to create bonding regions along the length of the optical fiber ribbon, the light emitted by a light source and configured to at least partially cure the adhesive, wherein intermittently exposing the adhesive to the light comprises at least one of: intermittently energizing and deenergizing the light source; providing, between the light source and the adhesive applied to the plurality of optical fibers, a mask having at least one aperture formed therein, wherein the plurality of optical fibers are passed by the mask such that the plurality of optical fibers is exposed to the light at predetermined areas defined by the mask, or providing a shutter between the light source and the adhesive applied to the plurality of optical fibers, wherein the shutter intermittently allows light to pass from the light source to the adhesive applied to the plurality of optical fibers; and removing uncured adhesive from the plurality of optical fibers.
2. The method of claim 1, wherein the adhesive comprises an ultraviolet (UV) curable adhesive and the light source is a UV light source.
3. The method of claim 1, wherein intermittently exposing the adhesive to the light comprises intermittently energizing and deenergizing the light source.
4. The method of claim 1, wherein intermittently exposing the adhesive to the light comprises providing the shutter between the light source and the adhesive applied to the plurality of optical fibers.
5. The method of claim 4, wherein the shutter is a rotating shutter, wherein intermittently exposing

the adhesive to the light comprises rotation of the shutter disposed between the light source and the plurality of optical fibers.
6. The method of claim 5, wherein the rotation of the shutter is synchronized with a travel speed of the plurality of optical fibers relative to the light source.
7. The method of claim 1, wherein intermittently exposing the adhesive to the light comprises: providing the mask having the plurality of apertures formed therein between the light source and the adhesive applied to the plurality of optical fibers, such that the plurality of optical fibers is exposed to the light at predetermined areas defined by the mask.
8. The method of claim 1, wherein removing the uncured adhesive comprises directing a high pressure air source toward the plurality of optical fibers.
9. The method of claim 8, wherein the high pressure air source comprises one or more pneumatic air cleaners.
10. The method of claim 8 further comprising: collecting the uncured adhesive.
11. The method of claim 1 further comprising: applying a material to one or more of the bonding regions, wherein the material comprises a colorant configured to identify the optical fiber ribbon.
12. The method of claim 11, wherein the material comprises a plurality of inkjet printed dots having a thickness of from 5 μm to 100 μm.
13. The method of claim 11, wherein applying the material to one or more of the bonding regions comprises inkjet printing the material onto one or more of the bonding regions.
14. An optical fiber ribbon manufactured according to the method of claim 1.
15. A method of manufacturing an optical fiber ribbon, the method comprising: arranging a plurality of optical fibers adjacent to each other along a length of the optical fiber ribbon; passing the plurality of optical fibers through an adhesive, such that the adhesive coats the plurality of optical fibers; providing a mask between a curing light source and the plurality of optical fibers, the mask having at least one aperture formed therein, wherein the plurality of optical fibers travel past the mask such that the plurality of optical fibers is exposed to the curing light source at predetermined areas defined by the mask, intermittently exposing the adhesive to the curing light source in at least one interstice between two adjacent optical fibers of the plurality of optical fibers to create bonding regions along the length of the optical fiber ribbon; and removing uncured adhesive from the plurality of optical fibers by passing the plurality of optical fibers through a high pressure air source.
16. The method of claim 15, wherein the adhesive comprises an ultraviolet (UV) curable adhesive and the curing light source is a UV light source.
17. The method of claim 15 further comprising: applying a material to one or more of the bonding regions, wherein the material comprises a colorant configured to identify the optical fiber ribbon.
18. The method of claim 17, wherein applying the material to one or more of the bonding regions comprises inkjet printing the material onto one or more of the bonding regions.
19. The method of claim 15, wherein intermittently blocking the curing light source comprises providing a shutter disposed between the curing light source and the mask, wherein the shutter intermittently allows light to pass from the curing light source and through the mask.
20. The method of claim 19, wherein the shutter is synchronized with a travel speed of the plurality of optical fibers relative to the curing light source.