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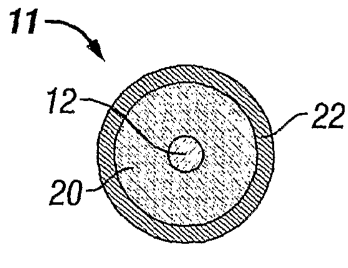
(54) **Title:** OPTICAL FIBER CABLE



(57) **Abstract:** An optical fiber that includes a metal coating (22) on its exterior, which metal coating enables the optical fiber to be used as a cable. The metal coating may be applied to the optical fiber by drawing the fiber through molten metal that freezes on the fiber surface. The metal coating may comprise nickel, copper, chromium, copper, tin, gold, aluminum, or any combination thereof. The coated optical fiber may be used in oilfield applications, including instances wherein the coated optical fiber supports the weight of at least one downhole tool. The coated optical fiber may also be used in other applications that require an optical fiber that has a strength that is comparatively higher than typical optical fibers.

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OPTICAL FIBER CABLE

BACKGROUND

The invention generally relates to optical fibers. More particularly, the invention relates to optical fiber cables that have the functionality of optical fibers with the structural integrity of more robust cables.

Typical optical fibers, such as those used in telecommunication applications, are often very fragile. This fragility greatly limits their possible application, unless additional components are incorporated into their structure to provide extra strength. Applications which require a higher strength fiber and therefore the incorporation of additional components include certain sensing applications, such as in the oil field, pipeline monitoring, tunnel monitoring, and power cable monitoring. In order to increase the strength of such optical fibers and therefore to enable their use in applications that require a higher strength fiber, such fibers are sometimes enclosed within a protective metal tube or cable.

However, even with or sometimes due to the inclusion of such additional components, the optical fiber may have certain characteristics that are undesirable. For instance, the optical fiber unit may have an unacceptably low tensile strength. Or, the optical fiber unit may have an unacceptably high density.

Thus, there exists a continuing need for an arrangement and/or technique that addresses one or more of the problems that are stated above.

SUMMARY

An optical fiber that includes a metal coating on its exterior, which metal coating enables the optical fiber to be used as a cable. The metal coating may be applied to the optical fiber by drawing the fiber through molten metal that freezes on the fiber surface. The metal coating may comprise nickel, copper, chromium, copper, tin, gold, aluminum, or any combination thereof. The coated optical fiber may be used in oilfield applications, including instances wherein the coated optical fiber supports the weight of at least one downhole tool. The coated optical fiber may also be used in other applications that require an optical fiber that has a strength that is comparatively higher than typical optical fibers.

Advantages and other features of the invention will become apparent from the following description, drawing and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic of a prior art optical fiber

Fig. 2 is a schematic of one embodiment of the present invention.

Fig. 3 is a schematic of one embodiment by which the metal coating is applied to an optical fiber.

Fig. 4 is a schematic of the optical fiber cable used as a slickline in an oilfield application.

Fig. 5 is a schematic of the optical fiber cable used within a permanent completion.

DETAILED DESCRIPTION

Figure 1 shows a prior art optical fiber 10, such as the typical optical fiber used for telecommunication applications. The prior art fiber 10 includes a core 12, a cladding 14, and a buffer 16. As is known, light is propagated through the core 12. The core 12 is made from silica. Cladding 14 usually has an index of refraction that is different that that of the core 14. The cladding 14 also typically has a diameter of 0.125mm. A buffer 16, which may be comprised of polyimide or acrylate, is applied around the cladding 14 and provides some protection to the core 12 and cladding 14. In order to provide more strength to the fiber 10, a metal tube or cable 18 may be placed surrounding the exterior of the fiber 10. As shown in Figure 1, the metal tube 18 surrounds buffer 16; however, alternatively, the metal tube 18 may replace the buffer 16 and surround the cladding 14 directly.

The present invention is the application of a metal coating on a cladding to provide the overall optical fiber unit with greater strength. The greater strength of the optical fiber unit enables its use in applications that require a higher-strength fiber, such as those applications previously indicated.

One embodiment of the present invention is generally shown in Figure 2 at 11. An optical fiber cable 11 comprises a core 12, a cladding 20, and a metal coating 22. The core 12 can be constructed and formed from materials as known in the prior art. The core 12 may be multimode or single mode. The cladding 20 surrounds the core 12, and the metal coating 22 surrounds the cladding 20.

As compared to the prior art optical fiber 10 of Figure 1, the cladding 20 of the present invention's fiber cable 11 has a diameter that is much larger than the cladding 14 of the prior art optical fiber 10. For instance, the cladding 20 may have a diameter that measures between 0.2

mm and 5.0 mm. Although the cladding 20 of the present invention has the same optical function as the cladding 14 of the prior art optical fiber 10, the larger diameter of the cladding 20 also adds to the strength and structural integrity of the present invention's optical fiber cable 11.

The metal coating 22 may comprise a coating of a metal that can bind to the silica that comprises the cladding 20. Acceptable metals include, but are not limited to, nickel, copper, chromium, copper, tin, gold, aluminum, or any combination thereof (such as nickel chromium). The metal coating 22 may be .05 mm to 0.55 mm thick.

In one embodiment, as shown in Figure 3, the metal coating 22 may be applied to the cladding 20 by drawing the cladding 20 and core 12, for instance in the direction of arrow 26, through a molten batch 24 of the relevant metal. The molten batch 24 of metal may be kept at a temperature higher than the melting temperature of the relevant metal or alloy. The relevant metal or alloy then freezes on the surface of the cladding 20 to form the metal coating 22 as the fiber 10 leaves the molten batch 24 and is exposed to temperatures lower than the melting point of the metal or alloy.

In comparison with the prior art optical fiber 10, the metal coating 22 provides the optical fiber cable 11 with a higher tensile strength (typically three or more times higher than steel) and a lower density (typically three or more times higher than steel).

The optical fiber cable 11 may also include multiple layers of metal coatings 22. Different metals may be used on each layer.

In one embodiment, the optical fiber cable 11 may be used in oil field applications, such as shown in Figures 4 and 5.

In Figure 4, the optical fiber cable 11 is used as a slickline, as the term is known in the oil field. The slickline optical fiber cable 11 is typically deployed from a reel, which may be housed in a truck, into a wellbore 30. A downhole tool 32, such as a packer, a sensor (for any parameter), or a perforating gun, may be attached proximate the lower end of the optical fiber cable 11. The higher-strength of the optical fiber cable 11 enables the optical fiber cable 11 to not only support its own weight (which can be significant given the length of cable that can be deployed into a wellbore), but also the downhole tool 32. The reel can be operated to deploy or retrieve the optical fiber cable 11 a multiple number of times.

In Figure 5, the optical fiber cable 11 is deployed as part of a permanent completion, including a production tubing 34. The production tubing 34 is deployed in the wellbore 30. The production tubing 34 serves as a fluid conduit between the surface 28 and downhole locations, including formations intersected by the wellbore 30. The optical fiber cable 11 may be deployed interior or exterior to the production tubing 34.

In any oilfield application, including those shown in Figures 4 and 5, the optical fiber cable 11 may be used as a sensor itself. For instance, the optical fiber cable 11 may be used as a temperature sensor using optical time domain reflectometry. In this case, the optical fiber cable 11 may be connected to an opto-electronic unit 40, as shown in Figure 5. As is known in the art, unit 40 may send optical pulses down the core 12 of the optical fiber cable 11, which signals are reflected back to the unit 40 via backscattered light. As disclosed in U.S. Patents No. 4,823,166 and 5,592,282 issued to Hartog, both of which are incorporated herein by reference, the backscatted light is analyzed to output a temperature profile along the length of the optical fiber cable 11. The optical fiber cable 11 may also be used as a pressure sensor by incorporating the relevant optical components within the cable 11. In one instance, the optical fiber cable 11 includes fiber Bragg gratings that, as known in the art, function with an opto-electronic unit 40 as an optical pressure sensor.

The optical fiber cable 11 may also be used to send optical signals to activate downhole tools, such as tool 32 or another tool incorporated into or proximate the production tubing 34. Other tools may include valves, sensors, guns, chokes, packers, and pumps. The optical fiber cable 11 would also be connected to a corresponding opto-electronic unit in this case.

In addition, the optical fiber cable 11 may also be used to transmit data to and from the surface 28 and a downhole location. The optical fiber cable 11 would also be connected to a corresponding opto-electronic unit in this case.

The optical fibre cable may also be used in other non-oilfield applications like fire detection in tunnels, pipeline monitoring, structure monitoring, aerospace, and process monitoring.

While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of the invention.

CLAIMS

I claim:

1. An optical fiber cable, comprising:

a core;

a cladding; and

a metal coating surrounding the cladding.

2. The cable of claim 1, wherein the cladding has a diameter between 0.2 mm and 5 mm.

3. The cable of claim 1, wherein the metal coating is comprised of a metal selected from the group consisting of nickel, copper, chromium, copper, tin, gold, aluminum, or any combination thereof.

4. The cable of claim 1, wherein the metal coating is applied to the cladding by drawing the cladding through a molten batch of a metal.

5. The cable of claim 4, wherein the metal is selected from the group consisting of nickel, copper, chromium, copper, tin, gold, aluminum, or any combination thereof.

6. The cable of claim 1, wherein the cable is used in an oilfield application.

7. The cable of claim 6, wherein the cable is used as a slickline.

8. The cable of claim 7, wherein the cable supports the weight of a downhole tool.

9. The cable of claim 6, wherein the cable is used in a permanent completion.

10. The cable of claim 1, wherein optical signals are transmitted through the core.

11. The cable of claim 10, wherein the optical signal comprises data.

12. The cable of claim 10, wherein the optical signal activates a downhole tool.

13. The cable of claim 10, wherein the optical signal comprises a temperature profile along the cable.

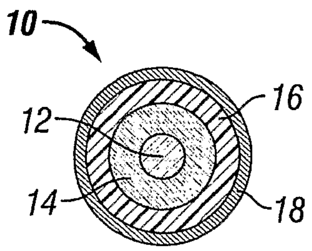

FIG. 1
(Prior Art)

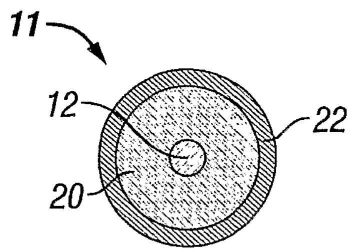

FIG. 2

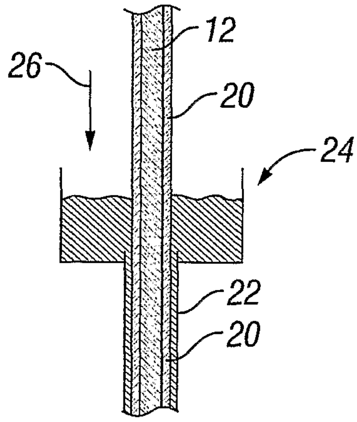

FIG. 3

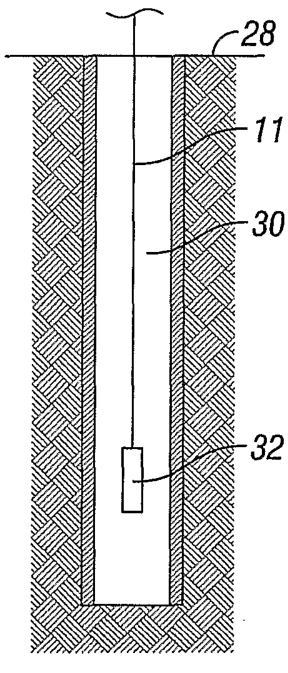

FIG. 4

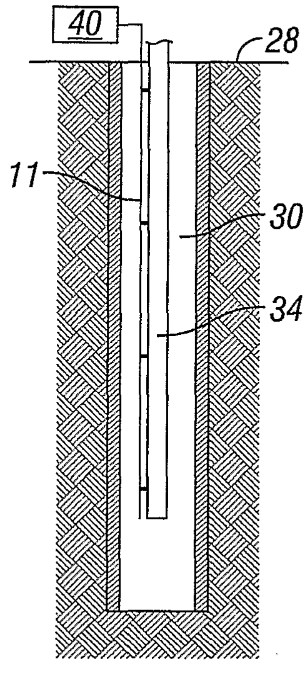

FIG. 5

INTERNATIONAL SEARCH REPORT

rnational Application No
T/GB2004/003007

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/44 E21B47/12 C03C25/10

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B E21B C03C

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

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

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 4 660 928 A (ASLAMI MOHD ET AL) 28 April 1987 (1987-04-28) column 1, line 1 - column 3, line 42 column 5, line 46 - column 6, line 37; figures 1-4	1,2,6-12
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 August 2004	02/09/2004

Name and mailing address of the ISA	Authorized officer
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rnational Application No
T/GB2004/003007

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 4 823 166 A (GOLD MARTIN P ET AL) 18 April 1989 (1989-04-18) cited in the application column 1, line 1 - column 4, line 37; figures 1,4,5	13
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A	US 2002/106179 A1 (CENS FABIEN ET AL) 8 August 2002 (2002-08-08) paragraphs ‘0035! - ‘0037!; figure 4	1,6-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

rnational Application No

T/GB2004/003007

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