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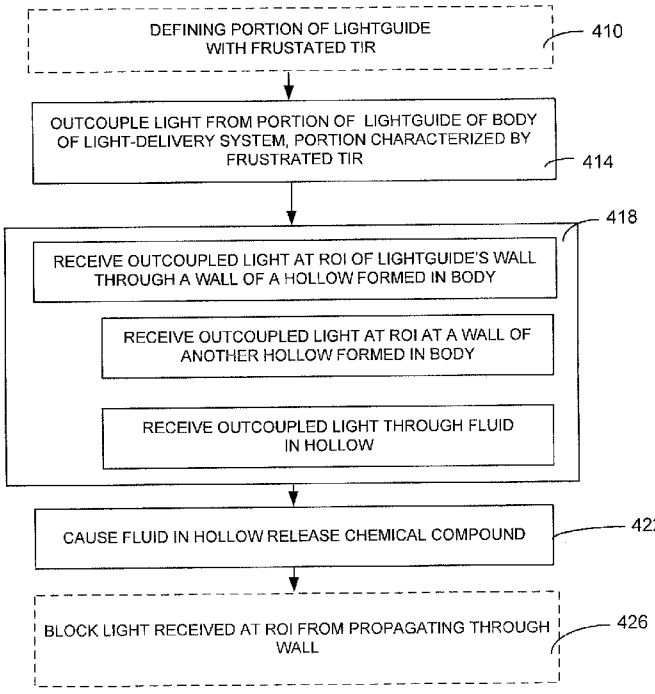


FIG. 4

(57) Abstract: Light-guiding system including a body with hollows and a lightguide repositionable along a length of a hollow. Light delivered between proximal and distal ends of the body along the lightguide is outcoupled through a portion of lightguide that has frustrated TIR, to irradiate and sterilize a surface of the body that contains microorganisms. When outcoupled radiation passes through fluid present in a hollow, a chemical compound is release by the fluid to interact with microorganisms. Optionally, a surface of a body and/or hollow is coated with material blocking outcoupled light.

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REDUCING INFECTIONS FROM CATHETERS AND IMPLANTED DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims benefit of and priority from the US Provisional Patent Applications nos. 61/986,295 filed on April 30, 2014 and 61/990,164 filed on May 08, 2014. The disclosure of each of the above-referenced patent applications is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to methods and devices for limiting the adherence of microbes on medical devices (such as indwelling catheters and lines, for example) and other elements implanted in the biological tissue, and for reducing the likelihood of infection, of tissue or blood stream, associated with implants. These devices are especially relevant to indwelling catheters and lines which remain in place for multiple days and as a result are a common source of infections.

BACKGROUND

[0003] Indwelling devices and contraptions, commonly used in hospital and home-care setting, often remain in place as implants for multiple days. These indwelling devices include but are not limited to central line catheters (which, in operation, provide access to the central venous system and can be used to sample blood, deliver medications and fluids, and perform hemodialysis) and/or urinary catheters (which, when implanted in tissue, allow the evacuation of the bladder at the bedside). Patients having the indwelling devices installed or implanted are at a significantly higher risk of infection. For example, the urinary tract infections, resulting from indwelling Foley urinary catheters, are commonplace in urology and result in a significant cost and drain of resources from medical care to effectuate the cure thereof. Blood stream infections cause by the implantation of a central line (CLABSI) are both frequent and, for many patients, may become detrimental. In both cases, the catheter itself provides a route for microbes in the environment to enter the body, to grow and migrate up the surface of the foreign object, and to disseminate to

organs, tissues, and/or into the blood stream. Understandably, these infections are sources of multiple impediments both for a patient and a clinician.

[0004] Various strategies have been considered to limit catheter associated infections. For example, some guidelines and protocols (see, for example, http://www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf) for ensuring the sterility during catheter placement and for keeping the insertion point sterile are being adopted at many hospitals and clinics. With implementation of these new protocols, the rates of the associated infection have dropped but not been reduced to zero. Furthermore, adherence to these expanded protocols requires significant resources and time on the part of the medical facility and clinicians and, therefore, carries a significant cost of implementation. Additional strategies for reduction of infections from indwelling catheters and devices include the employment of catheters and devices constructed from or coated with anti-microbial materials. The efficacy of these devices is currently being debated, with some studies showing improvement, and other studies suggesting a limited benefit from the use of such devices. The known drug-based approaches are accompanied with all the challenges known to be associated with drug resistance of the biological tissue. There remains, therefore, a need for operationally and/or structurally simple and low-cost catheters and implant devices the use of which prevents the growth and migration of microbes along the surfaces of the devices, and that do not cause and/or overcome the operational shortcoming associated with the potential for drug resistance of the hosting tissue.

SUMMARY

[0005] Embodiments of the invention are directed to a device and method for using the same in microbe-resistant catheters and implants. Specifically, embodiment of the invention provide the long-needed solution to the problem of sterilization of the catheter surfaces after the catheter has been placed in the biological tissue, by using light to directly or indirectly kill and/or disrupt the microorganisms aggregated at the catheter.

Embodiments of the invention provide a light delivery system, which includes a body made of a biocompatible material and having an axis, proximal and distal ends, and at least two hollows passing through the body from the proximal end to the distal end. The first hollow defines a first

volume (that is open to an ambient medium at the distal end through a first opening) and is dimensioned to provide fluid communication between the proximal and distal ends. The second hollow defines a second volume that, at the distal end, is shielded from the ambient medium with a cap impenetrable to a fluid. The light delivery system also includes a lightguide having a light-outcoupling element at an end of the lightguide. The lightguide dimensioned to be removably insertable into the second hollow from the proximal end.

[0006] Embodiments of the invention additionally provide a method for operating a light delivery system having a body. Such method includes a step of outcoupling light from a lightguide at a portion of the lightguide to form outcoupled light, where the portion is structured to cause frustration of the total internal reflection in the lightguide. The method additionally includes a step of receiving the outcoupled light at a region of a wall of the body through a wall of a first hollow formed in the body. The step of receiving, in one embodiment, include receiving the outcoupled light that has transmitted through a fluid in said first hollow and, optionally, causing the fluid to release a chemical constituent thereof in response to transmitting the outcoupled light through the fluid. In the latter case, the method additionally includes a step of interacting the chemical constituent with an organic matter disposed on a wall of the body. Alternatively or in addition, the step of receiving includes irradiating an organic matter at the region with the outcoupled light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Details, features and advantages of embodiments of the invention will become apparent from the following Detailed Description with the accompanying generally not-to-scale Figures, of which:

[0008] Figs. 1A and 1B are schematic diagrams of an embodiment of a catheter structured to allow a removable insertion of a lightguide, along which light having anti-microbial effect is delivered to intraluminal and extraluminal surfaces of the catheter;

[0009] Figs. 2A and 2B are schematic diagrams of an embodiment of a catheter structured to allow a removable insertion of a lightguide, along which delivery light in a form of short optical pulses is delivered to the catheter's luminal surfaces to trigger a spatially localized anti-microbial effect;

[0010] Fig. 3 provides an illustration of the operable cooperation between a lightguide (such as that employed in the embodiments of Figs. 1A, 1B, 2A, and 2B and a corresponding source of light.

[0011] Fig. 4 is a flow-chart illustrating an embodiment of the method according to the idea of the invention.

DETAILED DESCRIPTION

[0012] As used herein, the term "implant" generally refers to a device or material used for repairing or replacing part of the body, which is placed temporarily or permanently inside the tissue of the body. A problem of implantation-caused growth of microorganisms at and/or in the vicinity of the device implanted in biological tissue is solved by structuring such device to contain with a longitudinal hollow, passing along the length of a device from a proximal end towards and up to a distal end thereof, that defines an internal volume closed from the ambient tissue and dimensioned to accommodate a lightguide that is optically connected with a source of light at the proximal end of the device and that is configured to deliver, to the distal end of the device, optical radiation triggering anti-microbial processes during the interaction with the microorganisms.

[0013] An example of an embodiment 100 of a venous line catheter device and associated light delivery devices (structured, according to an idea of the invention, to enable UV-light-based sterilization of the catheter after it has been placed in the patient) is shown in Figs. 1A, 1B. Fig. 1A shows an axial cross-section of a distal end of the embodiment 100, while Fig. 1B illustrates a cross section of the distal end made perpendicularly to the axis of the catheter. The catheter 100 has an axis 104, an outer surface 106, and the body 110 that in one implementation is axially-symmetric and is constructed from a bio-neutral and/or biocompatible material (such as, for example, silicone and/or polyurethane). The body 110 defined at last two lumens (hollows) 120, 122 to provide access to the target (blood stream, for example) from the proximal end of the device (not shown): at the plane defining the termination of the distal end of the catheter 100 both lumens 120 and 122 are open to the ambient environment. So structured, the embodiment 100 could be used, for example, for hemodialysis with one lumen used to extract blood from the

target and the other used to return blood to the target. Alternatively or in addition, such structure can be used to facilitate the delivery of drugs, medication, or fluids through one lumen, and withdraw of blood or testing the target via the other lumen. A third lumen130 is also defined within the body 110 (shown to be disposed axially within the body 110), and is generally dimensioned differently from the lumens 120, 122. In addition, and unlike the lumens 120, 122, the lumen 130 is entirely isolated from the ambient environment (such as interior tissues or fluids of the patient) with the cap 130A. The isolation of the inner hollow space of lumen 130 is intended to facilitate the use of the lumen 130 as a housing for a lightguide 140 that is removably inserted or placed inside the lumen 130 starting from the proximal end without the concern for contamination of the target tissue, surrounding the implanted embodiment 110, with bacteria brought on the lightguide 140 from the outside the embodiment. In a related implementation, the lumen 130 can be dimensioned to both provide a channel for the lightguide 140 and for simultaneous drug delivery into the volume of the lumen 130 from the proximal end of the catheter 100.

[0014] The lightguide 140 can be constructed, depending on the particular implementation, as a multi-mode or a single-mode waveguide (with or without a mechanically-protecting sheath). The distal portion of the lightguide 140 is equipped with a light-outcoupling element 150, structured to outcouple light guided along the lightguide 140 from the proximal to emit such light toward the catheter's side walls. This light outcoupler 150 can include a light-diffusing / light-scattering blob of material (such as Teflon or polymer) attached to the outer surface of the lightguide 140 to frustrate the total internal reflection of light inside the lightguide 140. In a related embodiment, the element 150 may include an optical lens, or simply a non-waveguiding material that allows light to disperse, spread out, and reach the catheter walls. In yet another related embodiment, alternatively or in addition, the element 150 is dimensioned as a distributed surface-relief structure (optionally periodic) such as, for example, a Bragg grating formed in an outer surface of the lightguide 150. The length of the light outcoupler element 150 can be relatively short so that the emanation of light from the lightguide 140 outwards is confined to a region of approximately 1 mm to 10 mm in length. In an alternative implementation the length of the element 150 is chosen to be between about 1 cm and 100 cm, to facilitate light delivery to large areas of internal surfaces of the body 110.

[0015] In one embodiment, the lightguide 140 is made moveable back and forth along the axis 104 in the lumen 130 (along the arrow 160, with the use of an appropriate pull-push mechanism having a control unit governing the linear velocity of the repositioning of the lightguide 140 and cooperated with the proximal end of the catheter; not shown) to deliver light energy (optical flux 154) along a larger length of the catheter, or even to the entire length of the catheter, in a sequential fashion. So structured, the embodiment 100 facilitates the irradiation of bacteria colonies (such as an intramural bacterial colony 162A and/or extramural bacterial colony 162B) formed in different locations along the length of the distal end of the catheter 100.

[0016] As illustrated in Fig. 1B, the embodiment 100 possesses mirror symmetry about the plane 104A.

[0017] Fig. 3 depicts schematically the operable cooperation between an external light source 310 used to launch light into the lightguide 140 This lightguide 140 and the source of light 310 are affixed in optical communication with one another either permanently or removably (in which latter case the embodiment of the invention facilitates the replacement of the lightguide as operationally appropriate). The light source 310 is configured to generate light in the ultraviolet portion of the spectrum (for example, from 200 nm to about 400 nm), or with the spectrum extending into the blue-wavelength portion (from 400 nm to about 500 nm). Examples of light emitters for use in the light source 410 include a light-bulb, an LED, and a laser source (optionally - a wavelength-tunable laser source). Such choice of light spectrum is made to address the problem of direct sterilization of microbes 162A, 162B. (The microbes of interest can include Coagulase-negative Staphylococcus (CNS) and Methicillin-resistant Staphylococcus aureus (MRSA), among others.) Alternatively or in addition, when at least one of the lumens 120, 122, 130 channels the drug provided to the catheter from the proximal end or when the body 110 contains drug elements pre-installed thereon (for example, embedded in a body 110), such choice of light facilitates triggering of a drug-based antimicrobial action detrimentally affecting the bacterial colonies.

[0018] In further reference to Fig. 3, the light source 310 may be equipped with an interlock mechanism structured such that delivery of light along the lightguide 140 only occurs if and when the lightguide outcoupler 150 is fully inserted into the catheter lumen 130. For example, the catheter lumen 130 and lightguide 140 can be fitted with paired electrodes that are only in contact when the lightguide 140 is fully inserted, and this electrical contact is detected through electrical measurements.

[0019] In a related embodiment, the catheter 100 can be modified to prevent the escape of the UV- or blue-light from the catheter's body and exposure of the ambient tissue in which the catheter 100 has been inserted. This is achieved by including a UV- or blue-light absorbing material within the body 110, or, alternatively or in addition, as layer (shown as layer 170) on the catheter's exterior surface 106. A heat-cured red ink such (provided by NuSil Technology, LLC) could be used to construct this material. Such absorbing material may include a biocompatible and non-toxic dye, embedded within a pre-determined region of the catheter's body 110 - for example, the "skin-depth" region defined by the depth of a hundred microns or so from the surface 106. Bio- and medically compatible heat-cured silicone ink that is absorbing in the blue and UV can be utilized to form this material. It should be understood that, while the specific embodiment of Figs. 1A, 1B illustrates a three-lumen version, generally the body 110 can be configured to include a different number of lumens (including but not limited to 1, 3, 4, or 5 lumens, for example).

[0020] A related embodiment 200 of the device of the invention (configured as a venous line catheter enabling pulsed light-based sterilization of the catheter after it is placed in the patient) is shown in Figs. 2A, 2B in further reference to Fig. 3. The configuration and structure of the embodiment 200 resembles and substantially follows that of the embodiment 100 of Figs. 1A, 1B, and can be used during the hemodialysis procedure and or for delivery of drugs to the target tissue as discussed above. When used with the external light source 310, such light source is configured to generate light in the near-infrared (NIR) portion of the spectrum from about 700 nm to about 2000 nm in a form of optical pulses (with durations from 1 millisecond to about 100 picoseconds, for example). It is appreciated that the light source 310, when used with the

embodiment 200, can be configured as a portable short-pulse laser such as a Q-switched laser, for example.

[0021] To make use of optical radiation in this portion of the spectrum, and in contrast with the embodiment 100, surfaces of the body 110 of the embodiment 200 additionally carry coatings of materials 260A, 260B, 260C. Specifically, the catheter 200 is designed to have a thin film of a NIR-radiation-absorbing material at or very near the luminal surfaces of the lumens 120 and 122, as well as the exterior surface 106 of the catheter. As these surfaces are rapidly heated by the short optical pulses delivered along the lightguide 140 from the external source of light, highly-localized thermal kill zones are formed at the lumen surfaces, where the coatings 260A, 260B, 260C facilitate minimization of the overall heating of the catheter 200. The localized absorption of short optical pulses can also generate photothermal stress fields that can be directly antimicrobial or anti-biofilm.

[0022] In one implementation, the NIR-absorption properties of the surface materials 260A, 260B, and 260C can be tuned by adjusting the concentration level of the optically absorbing such that some NIR-light is transmitted therethrough to remove or reduce a shadowing effect that otherwise would shield one side of the lumen from light exposure, thereby achieving the irradiation of most if not all of the body 110. An absorption level of approximately 10% is chosen in one embodiment. The use of NIR light in the embodiment 200 ensures the safety of the device 200 to the patient and to the clinical staff. NIR-light transmitted into the tissue (surrounding the implanted embodiment 200) from the outcoupler 150 through the body 110 is unlikely to induce damage to the tissue. In an alternative embodiment, the absorbing material 260A disposed on the exterior surface 106 is made to be sufficiently optically-opaque (at the chosen NIR wavelength) such that no light escapes the catheter. For example, an absorption of greater than 90% would significantly limit the escape of light energy.

[0023] In a related embodiment, the modalities discussed in reference to Figs. 1A, 1B, 2A, 2B, and 3 can be combined in that the light source 310 is configured to generate radiation in both UV/blue and near-infrared portions of the spectrum and couple this light into the input of the

lightguide 140 such as to trigger the destruction of the bacterial colonies 162A, 162B both photochemically and photothermally.

[0024] In another related embodiment, and in further reference to Figs. 2A, 2B, and 3, the light is delivered to the catheter 200 from the light source 310 (in any of the UV, visible, and NIR portions of the spectrum) at the time when a chosen light-activated drug is flushed into the catheter's hollows 120, 122 (and, optionally, 130). A non-limiting examples of such drug includes sodium nitroprusside (SNAP), which releases Nitric Oxide under exposure to visible and/or UV light. The material of the catheter's body 110 is chosen such that the delivered light is transmitted through the body, at least partially, to the intraluminal spaces defined by the hollows 120, 122 to expose the flushed solution containing such light-triggered drug with the optical flux 154, emanating from the outcoupler 150, to trigger localized and high-rate of release of the drug and thus to induce large transient concentrations of Nitric Oxide that can be antimicrobial. This drug solution, delivered to the lumen(s) of the embodiment 200, can optionally contain an addition of an anti-coagulant such as Heparin, for example.

[0025] In a related embodiment, the structure of the body 110 is designed such that the drug (such as Nitric Oxide) diffuses through the body 110 to deliver the released drug to the exterior surface 106 to provide extraluminal sterilization. Tin one implementation, for example, the body 110 is constructed from a material with high levels of diffusion. For example, polyurethane can be used to enhance gas diffusion through the material and heighten drug concentrations on the extraluminal surface.

[0026] In yet another related embodiment (not shown), the light outcoupling element 150 is cooperated with the portion of the lightguide 104 which, when inserted into the lumen 130, is positioned near the proximal end of the catheter 100, 200 such that the drug-containing solution flush is exposed to light 150 as the solution is flowed into the lumen. Such configuration facilitates the confinement of the outcoupled light 150 to one portion of the catheter and resulting in a catheter device that affords a shorter light-outcoupling element 150 and/or does not require a back-and-forth repositioning of the lightguide 104 along the lumen 130, while producing the

anti-microbial effect via distal translation of the fluid movement and/or flow down the lumen(s) of the device.

[0027] It is appreciated, therefore, that an implementation of an invention provides a light delivery system a body of which is made of a biocompatible material. Such body said body is formed to have an axis, proximal and distal ends, and at least two hollows passing through the body from the proximal end to the distal end. In a specific implementation, the body includes a tubular member. The body is formed to also contain a first hollow (that defines a first volume open to an ambient medium at the distal end through a first opening) and is dimensioned to provide fluid communication between the proximal and distal ends of the body. The body further contains a second hollow defining a second volume that, at the distal end, is shielded from the ambient medium with a cap impenetrable to a fluid. At least one of said at least two hollows extend along the axis and/or has a cylindrical surface. The light delivery system further includes a lightguide equipped with a light-outcoupling element at an end of the lightguide, said lightguide dimensioned to be removably insertable into the second hollow from the proximal end. In one implementation, the lightguide include optical fiber. In one related embodiment, the light-outcoupling element includes at least one of a light-diffusing unit appended to the lightguide, a prismatic element defined at a surface of the lightguide. The length of the light-outcoupling element, measured along the lightguide, is between 1 mm and 1,000 mm. Generally, the lightguide is dimensioned to position the light-outcoupling element adjacently to the cap when the lightguide is fully inserted into the second hollow from the proximal end. Alternatively or in addition, a surface of at least one hollow in the body carries a coating made of material that does not transmit thermal radiation. The material of the body is judiciously chosen to filter out a first portion of optical radiation (having a first wavelength) as a result of transmission of optical radiation through the material. Alternatively or in addition, in a related embodiment the system includes a mechanism configured to reposition an end of the lightguide when operably coupled thereto and/or an optical source configured to generate optical radiation guided by said lightguide when said lightguide is in optical communication with the optical source.

[0028] The present invention includes a method for operating a light delivery system having a body. Such method contains the steps of outcoupling light (from a lightguide-portion having frustrated total internal reflection) to form the outcoupled light; and receiving the outcoupled

light at a region of a wall of the body through a wall of a first hollow formed in the body. The step of receiving includes receiving the outcoupled light at a region of a wall of the second hollow formed in the body. An embodiment of the method further includes a step of blocking light received at the region from propagating through the wall of the second hollow.

At least one of the first and second hollows includes a lumen formed in the body along an axis of the body. The outcoupling of light may be preceded by frustrating the total internal reflection in the lightguide with an agglomeration of material on a surface of the lightguide. (for example, in one specific case, the outcoupling of light includes transmitting light guided by the lightguide through a prismatic element formed on a surface of the lightguide, while the receiving of the outcoupled light is accompanied by transmitting such light through a fluid in the first hollow. Furthermore, such specific implementation may include causing the fluid to release a chemical constituent thereof by transmitting the outcoupled light therethrough and, in addition, causing the chemical constituent to interact with an organic matter disposed on a wall of the body. Additionally or in the alternatively, the receiving includes irradiating an organic matter at the region with the outcoupled light. The portion of the lightguide characterized by the frustrated TIR can be repositioned along the body internally to the body. In one case, such repositioning is effectuated within a tubular structure formed in the body, said tubular structure having an open end and a closed end.

[0029] Fig. 4 is a flow-chart illustrating some of the steps of the method according to the idea of the invention. In particular, according to the embodiment 400, at step 414 light is outcoupled from a portion of a lightguide that has frustrated TIR to be received, at step 418, by a region-of-interest (ROI) of a lightguide's wall in transmission through a wall of a hollow formed in the body of the lightguiding system of the invention. These steps may be preceded by a step 410, at which the portion of the lightguide that is characterized by the TIR is pre-defined. The acquisition of light at the ROI may include defining such ROI at a wall of another hollow of the body and/or transmitting light through fluid filling a hollow of the body, for example. In the latter case, at step 422 the fluid may be caused to release a chemical compound contained therein as a result of transmission of light through the fluid. At optional step 426, light received at the ROI may be blocked from propagating through a wall of the body.

[0030] In a related embodiment of the system of the invention, at the proximal end of the body a programmable processor can be operably connected, which governs the processing of data

received from the system 100, 200 such as to extract the optical data characterizing the degree of contamination of the system 100, 200 with the unwanted species and progress of the process of sterilization of the system. Accordingly, an embodiment of the system may include a processor controlled by instructions stored in a memory. The memory may be random access memory (RAM), read-only memory (ROM), flash memory or any other memory, or combination thereof, suitable for storing control software or other instructions and data. Some of the functions performed by the discussed embodiments have been described with reference to flowcharts and/or block diagrams. Those skilled in the art should readily appreciate that functions, operations, decisions, etc. of all or a portion of each block, or a combination of blocks, of the flowcharts or block diagrams may be implemented as computer program instructions, software, hardware, firmware or combinations thereof. Those skilled in the art should also readily appreciate that instructions or programs defining the functions of the present invention may be delivered to a processor in many forms, including, but not limited to, information permanently stored on non-writable storage media (e.g. read-only memory devices within a computer, such as ROM, or devices readable by a computer I/O attachment, such as CD-ROM or DVD disks), information alterably stored on writable storage media (e.g. floppy disks, removable flash memory and hard drives) or information conveyed to a computer through communication media, including wired or wireless computer networks. In addition, while the invention may be embodied in software, the functions necessary to implement the invention may optionally or alternatively be embodied in part or in whole using firmware and/or hardware components, such as combinatorial logic, Application Specific Integrated Circuits (ASICs), Field-Programmable Gate Arrays (FPGAs) or other hardware or some combination of hardware, software and/or firmware components.

[0031] References throughout this specification to "one embodiment," "an embodiment," "a related embodiment," or similar language mean that a particular feature, structure, or characteristic described in connection with the referred to "embodiment" is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment. It is to be understood that no portion of disclosure, taken on its own and in possible connection with a figure, is intended to provide a complete description of all features of the invention.

[0032] In addition, it is to be understood that no single drawing is intended to support a complete description of all features of the invention. In other words, a given drawing is generally descriptive of only some, and generally not all, features of the invention. A given drawing and an associated portion of the disclosure containing a description referencing such drawing do not, generally, contain all elements of a particular view or all features that can be presented is this view, for purposes of simplifying the given drawing and discussion, and to direct the discussion to particular elements that are featured in this drawing. A skilled artisan will recognize that the invention may possibly be practiced without one or more of the specific features, elements, components, structures, details, or characteristics, or with the use of other methods, components, materials, and so forth. Therefore, although a particular detail of an embodiment of the invention may not be necessarily shown in each and every drawing describing such embodiment, the presence of this detail in the drawing may be implied unless the context of the description requires otherwise. In other instances, well known structures, details, materials, or operations may be not shown in a given drawing or described in detail to avoid obscuring aspects of an embodiment of the invention that are being discussed.

[0033] Furthermore, the described single features, structures, or characteristics of the invention may be combined in any suitable manner in one or more further embodiments.

CLAIMS

What is claimed is:

1. **A light delivery system**, comprising:

a body made of a biocompatible material,

said body formed to have an axis, proximal and distal ends, and at least two hollows passing therethrough from the proximal end to the distal end,

a first hollow defining a first volume that is open to an ambient medium at the distal end through a first opening therein, the first hollow dimensioned to provide fluid communication between the proximal and distal ends;

a second hollow defining a second volume that, at the distal end, is shielded from the ambient medium with a cap impenetrable to a fluid;

and

a lightguide equipped with a light-outcoupling element at an end of the lightguide, said lightguide dimensioned to be removably insertable into the second hollow from the proximal end.

2. A light delivery system according to claim 1, wherein said light-outcoupling element includes at least one of a light-diffusing unit appended to the lightguide, a prismatic element defined at a surface of the lightguide,

3. A light delivery system according to claim 2, wherein a length of said light-outcoupling element, measured along the lightguide, is between 1 mm and 1,000 mm.

4. A light delivery system according to claim 1, wherein said light guide is dimensioned to position the light-outcoupling element adjacently to the cap when the lightguide is fully inserted into the second hollow from the proximal end.

5. A light delivery system according to claim 1, wherein a surface of at least one hollow in the body carries a coating made of material that does not transmit thermal radiation.

6. A light delivery system according to claim 1, wherein a material said body is configured to filter out a first portion of optical radiation upon transmission of optical radiation therethrough, the first portion having a first wavelength.

7. A light delivery system according to claim 1, wherein said lightguide includes an optical fiber.

8. A light delivery system according to claim 1, further comprising a mechanism configured to reposition an end of the lightguide when operably coupled thereto.

9. A light delivery system according to claim 1, further comprising an optical source configured to generate optical radiation guided by said lightguide when said lightguide is in optical communication with the optical source.

10. A light delivery system according to claim 1, wherein at least one of said at least two hollows extend along the axis.

11. A light delivery system according to claim 1, wherein the body includes a tubular member.

12. A light delivery system according to claim 1, wherein at least one of said at least two hollows has a cylindrical surface.

13. **A method for operating a light delivery system** having a body, the method comprising:

outcoupling light from a lightguide at a portion of the light guide to form outcoupled light, the portion having frustrated total internal reflection; and

receiving the outcoupled light at a region of a wall of the body through a wall of a first hollow formed in the body.

14. A method according to claim 13, wherein the receiving includes receiving the outcoupled light at a region of a wall of the second hollow formed in the body.

15. A method according to claim 14, further comprising blocking light received at the region from propagating through the wall of the second hollow.

16. A method according to claim 15, wherein at least one of the first and second hollows includes a lumen formed in the body along an axis thereof.

17. A method according to claim 13, wherein the outcoupling includes frustrating the total internal reflection in the lightguide with an agglomeration of material on a surface of the lightguide.

18. A method according to claim 13, wherein the outcoupling includes transmitting light guided by the lightguide through a prismatic element formed on a surface of the lightguide.

19. A method according to claim 13, wherein said receiving includes receiving the outcoupled light that has transmitted through a fluid in said first hollow.

20. A method according to claim 19, further comprising causing the fluid to release a chemical constituent thereof by transmitting the outcoupled light therethrough.

21. A method according to claim 20, further comprising interacting the chemical constituent with an organic matter disposed on a wall of the body.

22. A method according to claim 13, wherein the receiving includes irradiating an organic matter at the region with the outcoupled light.

23. A method according to claim 13, further comprising repositioning the portion of the lightguide along the body internally to the body.

24. A method according to claim 23, wherein the repositioning includes repositioning the portion of the lightguide within a tubular structure formed in the body, said tubular structure having an open end and a closed end.

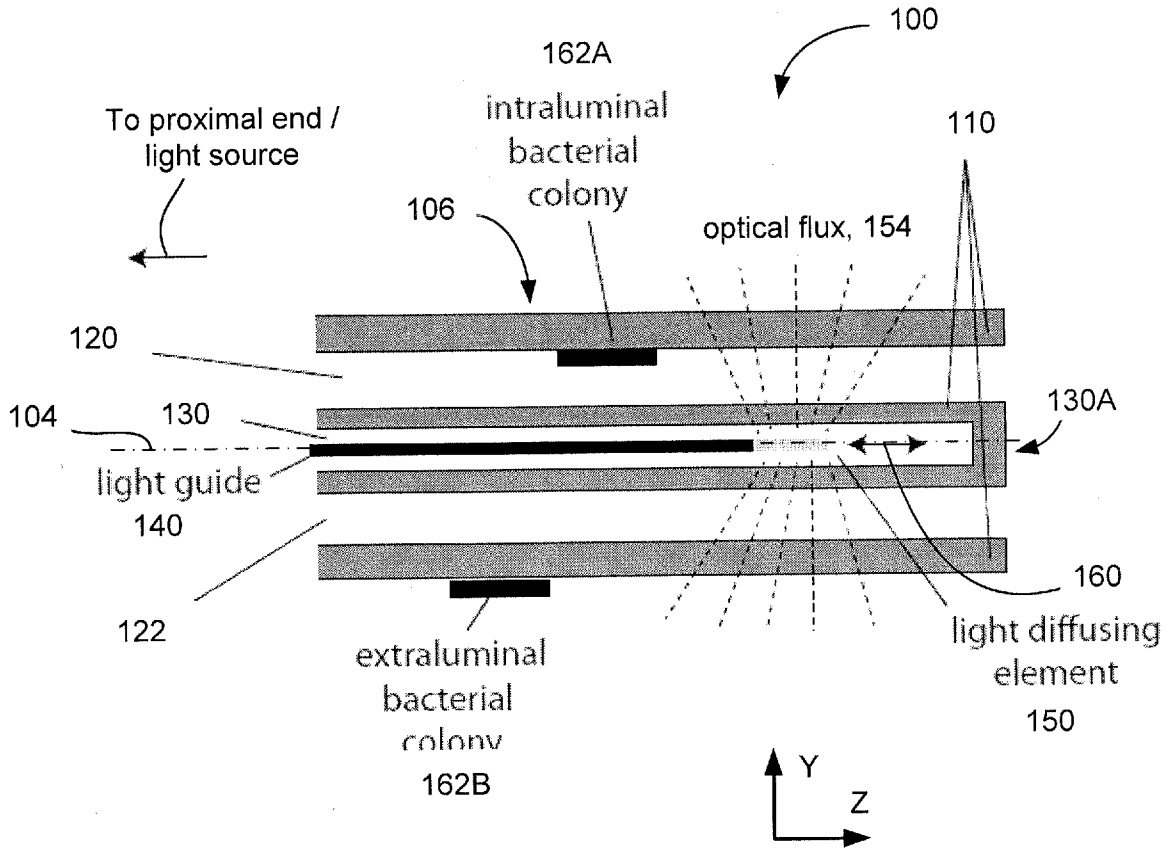

100
162A
intraluminal bacterial colony
To proximal end / light source
110
106
optical flux, 154
120
104
130
130A
light guide
140
160
122
light diffusing element
150
extraluminal bacterial colony
162B
Y
Z

FIG. 1A

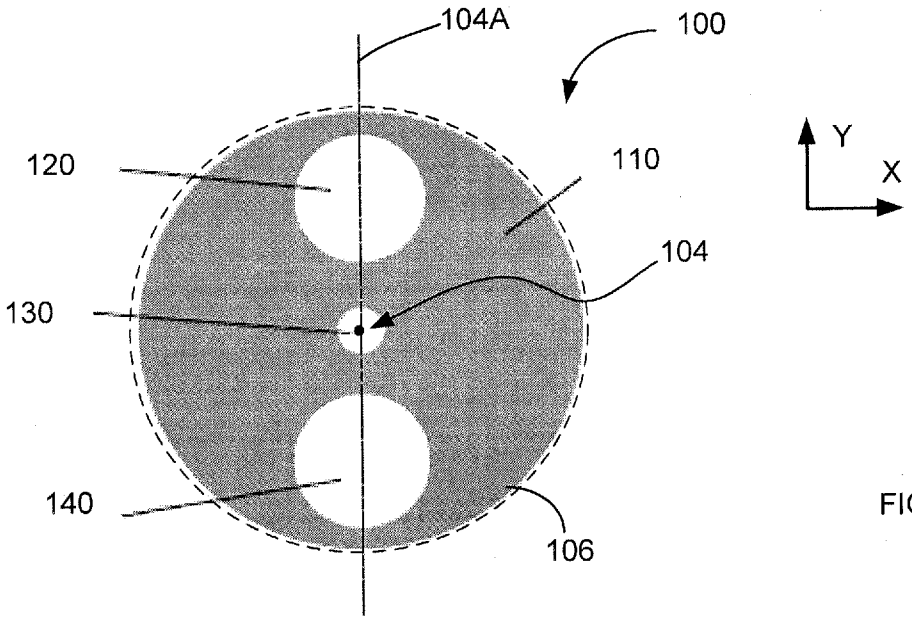

104A
100
120
110
Y
X
104
130
140
106

FIG. 1B

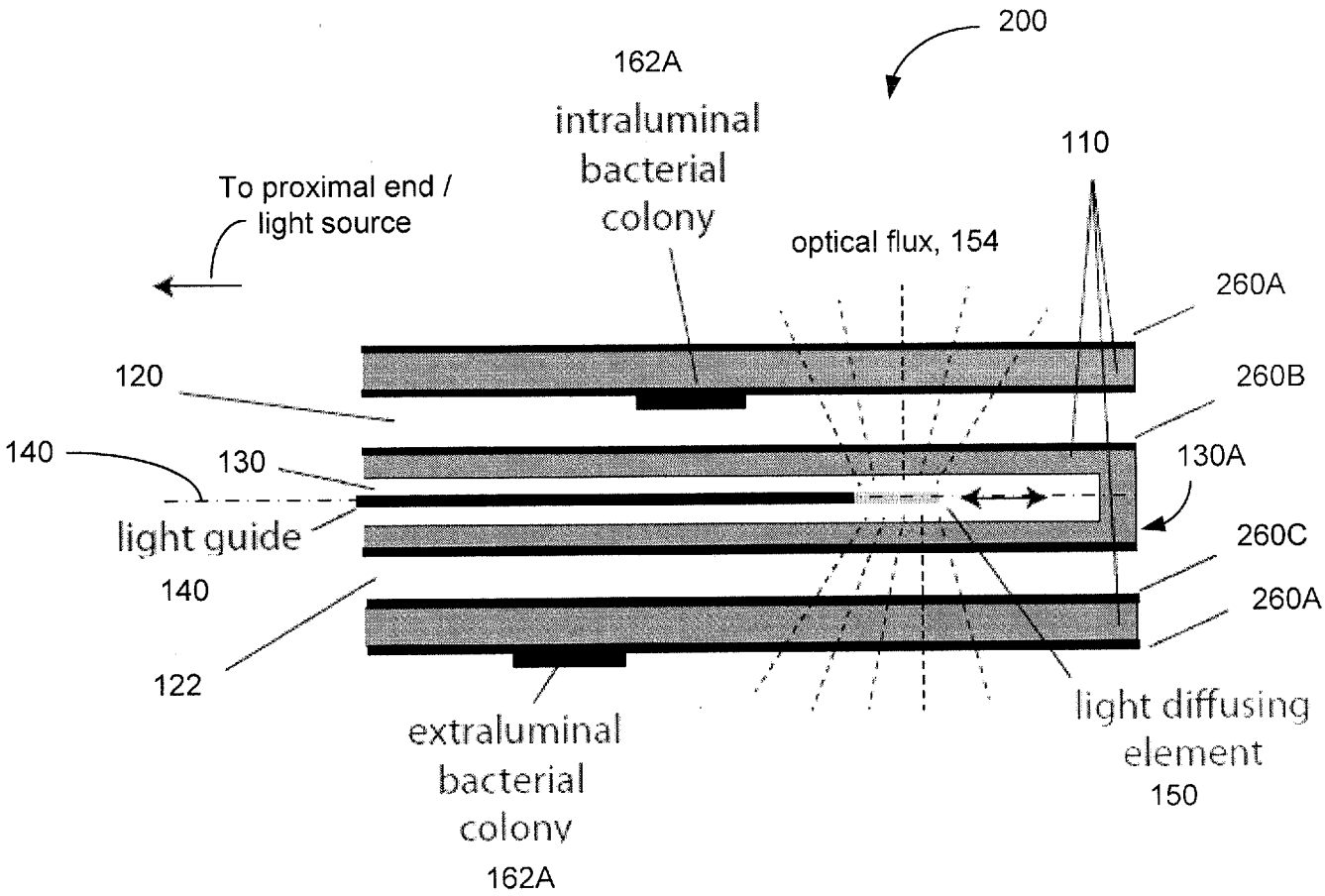

200
162A
intraluminal bacterial colony
110
To proximal end / light source
optical flux, 154
260A
120
260B
140
130
130A
light guide
140
260C
260A
122
extraluminal bacterial colony
162A
light diffusing element
150

FIG. 2A

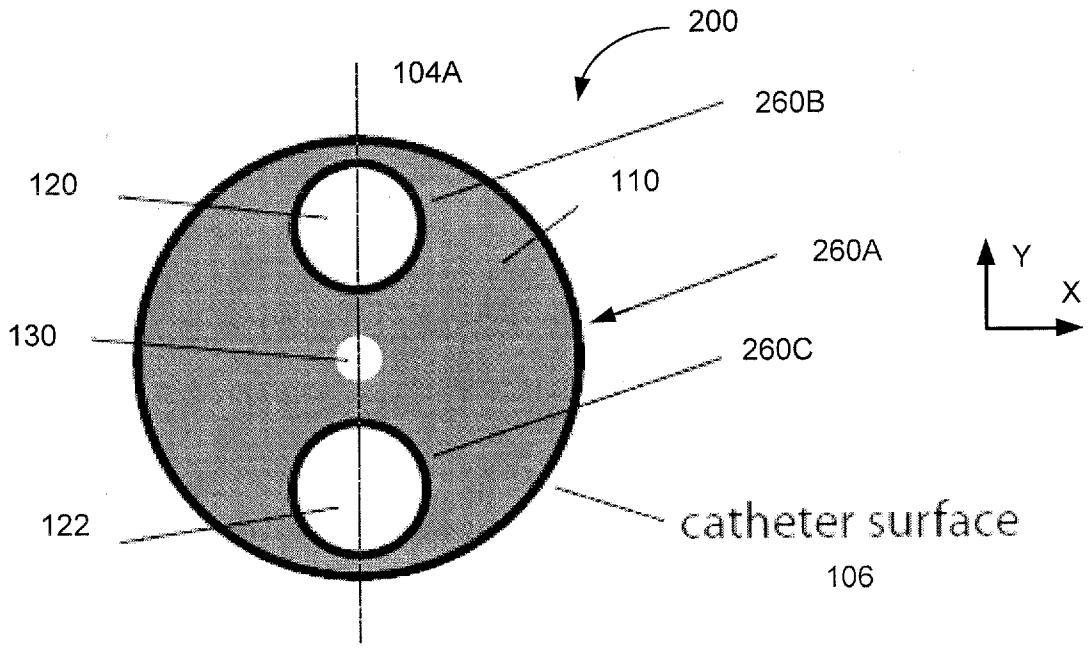
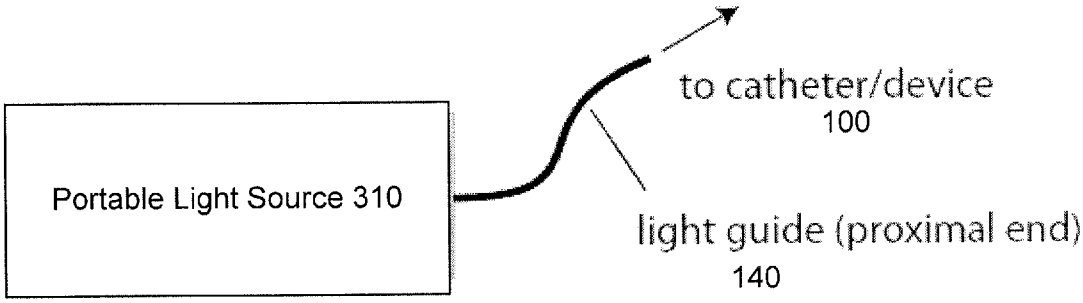

200
104A
260B
120
110
260A
Y
X
130
260C
122
catheter surface
106

FIG. 2B

FIG. 3


Portable Light Source 310
to catheter/device
100
light guide (proximal end)
140

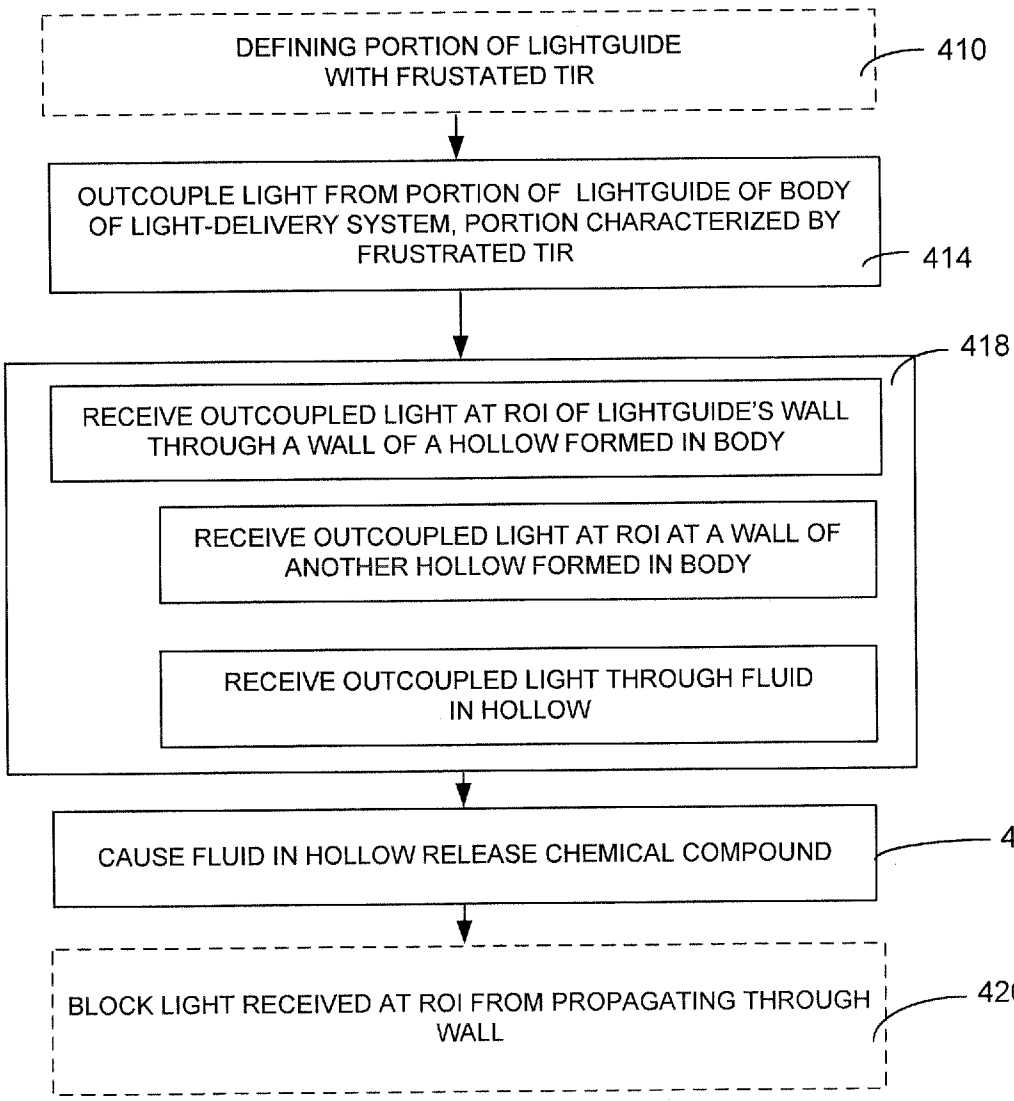

DEFINING PORTION OF LIGHTGUIDE WITH FRUSTATED TIR
410
OUTCOUPLE LIGHT FROM PORTION OF LIGHTGUIDE OF BODY OF LIGHT-DELIVERY SYSTEM, PORTION CHARACTERIZED BY FRUSTRATED TIR
414
418
RECEIVE OUTCOUPLED LIGHT AT ROI OF LIGHTGUIDE'S WALL THROUGH A WALL OF A HOLLOW FORMED IN BODY
RECEIVE OUTCOUPLED LIGHT AT ROI AT A WALL OF ANOTHER HOLLOW FORMED IN BODY
RECEIVE OUTCOUPLED LIGHT THROUGH FLUID IN HOLLOW
CAUSE FLUID IN HOLLOW RELEASE CHEMICAL COMPOUND
422
BLOCK LIGHT RECEIVED AT ROI FROM PROPAGATING THROUGH WALL
426

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/28001

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61M 39/16, 39/06; A61L 2/08 (2015.01)
CPC - A61M 39/16, 39/06; A61L 2/0029
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(8) Classification(s): A61B 18/18; A61M 39/06, 39/18; A61L 2/08, 2/18 (2015.01)
CPC Classification(s): A61B 18/18, 2018/2261, 2018/206; A61L 2/0029, 2/0088; A61M 39/06, 39/16, 39/105, 2039/082

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 practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); ProQuest; IEEE; Google Scholar; EBSCO
Keywords searched: light guide, cylindrical lumens, light-outcoupling, coating, cap, catheter, optical source, frustrated total internal reflection, microbe, filter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2008/0161748 A1 (TOLKOFF, M. et al.) July 3, 2008; figures 1-3, 9, 13A-16, 19A-19C; paragraphs [0049-0058], [0079], [0109-0117], [0123-0144]; claims 1 and 10	1, 2, 4, 7-13, 17-19, 23, and 24 3, 5, 6, 14-16, and 20-22
Y	US 2005/0031281 A1 (NATH, G.) February 10, 2005; figure 1; paragraphs [0022-0029]	3
Y	US 6,013,053 A (BOWER, B. et al.) January 11, 2000; figure 1b; column 4, lines 45-65; column 5, lines 45-67; column 6, lines 1-20; claim 24	5 and 14-16
Y	US 2010/0016844 A1 (PATEL, M. et al.) January 21, 2010; figures 1, 6; paragraphs [0038], [0047-0050]	6
Y	US 2008/0039768 A1 (FRANCIS, R.) February 14, 2008; figures 1, 12, 15; paragraphs [0177-0178], [0189-0191]	20-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 July 2015 (20.07.2015)	05 AUG 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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