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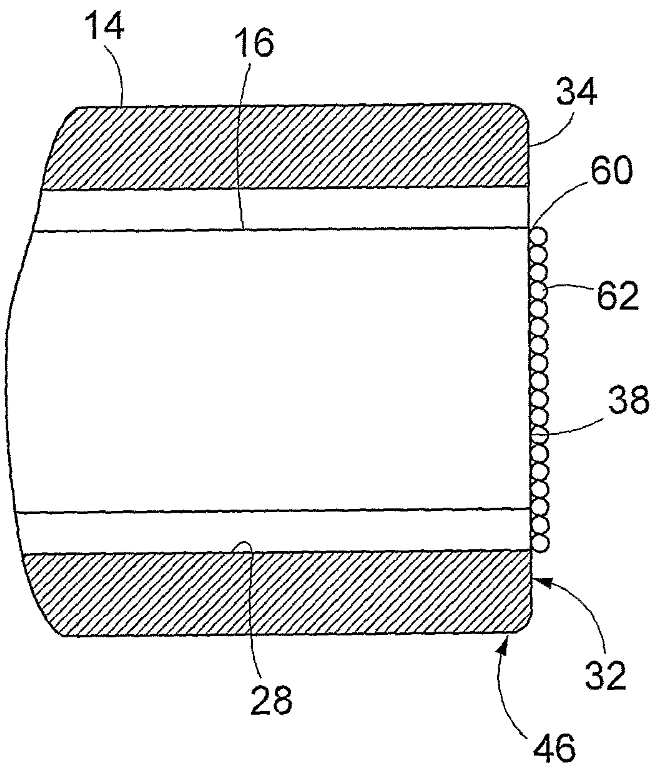
**(54) Title:** OPTIC FIBER INSTRUMENT WITH MICROSPHERE DIFFRACTION SURFACE




**(57) Abstract:** A manually manipulated illuminator used in microsurgery comprises an optic fiber that transmits light through the instrument and emits the light through hollow glass microspheres secured to the distal end surface of the optic fiber. The hollow glass microspheres provide a large refractive index change at the optic fiber distal end as the light penetrates the glass sphere walls and crosses the glass/gas/glass interface. This creates an exceptionally good diffusing effect in the light emitted from the illuminator, spreading the light out uniformly over a broad area.

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# OPTIC FIBER INSTRUMENT WITH MICROSPHERE DIFFRACTION SURFACE

This patent application claims the benefit of provisional patent application serial no. 60/649,809, filed February 3, 2005.

## Background of the Invention

(1) Field of the Invention

The present invention pertains to a manually manipulated illuminator that is used in microsurgery, and in particular ophthalmic surgery.

(2) Description of the Related Art

In ophthalmic surgery, the microsurgical instruments used are significantly reduced in size to enable their use in the minute area inside the eye. In many ophthalmic surgery procedures, it is necessary that a light source be provided inside the patient's eye so that a surgical sight on the interior wall of the eye or other interior area of the eye is well illuminated. Common ophthalmic surgery procedures involve first making a small incision into the eye for insertion of an illuminator, and making a small incision into the eye for insertion of the instrument to be used by the surgeon in performing the particular surgical procedure. It can be appreciated that the surgical instrument and the illuminator used in these procedures are significantly reduced in size to reduce the trauma to the eye caused by the incisions needed to insert the instruments into the eye interior.

The typical microsurgical illuminator comprises a handle with a small cannula or cylindrical metal sleeve projecting from a distal end of the handle. The sleeve is typically the size of a hypodermic needle. An optic fiber passes through the center of the handle and the metal sleeve. A length of the optic fiber extends out of the handle to a proximal end of the fiber that is connected to a light source. The distal end of the optic fiber is positioned in the metal sleeve adjacent the distal end of the sleeve. The sleeve is inserted through the eye incision in ophthalmic surgery procedures. When the optic fiber proximal end is connected to the light source, the illuminating light is transferred through the optic fiber and is emitted from the optic fiber distal end. Due to the reduced surface area of the fiber distal end required for reducing the size of the instrument sleeve, typically to the size of a 20 gauge needle, the amount of illumination provided to the surgical sight by the optic fiber distal end is limited.

## Summary of the Invention

The present invention provides a microsurgical illuminator, particularly for use in ophthalmic surgery, that overcomes the limited light emission problem of prior art illuminators. The microsurgical illuminator of the present invention is comprised of a handle, a canula or metal sleeve projecting from the distal end of the handle, and a length of optic fiber passing through the handle and the canula. The proximal end of the optic fiber is provided with a connector for connecting the optic fiber to any of the available light sources typically used with microsurgical illuminators. The distal end of the optic fiber and the distal end of the illuminator canula are both provided with flat surfaces that are positioned in the same plane. In the preferred embodiment, the plane occupied by the optic fiber distal end and the canula distal end is oriented perpendicular to the center axis of the canula. The improvement in the light emitting pattern of the present invention is provided by a plurality of glass microspheres on the optic fiber distal end surface. In the preferred embodiment, a novel optical coating is applied to the optic fiber distal end that improves the illumination output characteristics from the optic fiber. The optical coating is comprised of an adhesive carrier, for example an ultraviolet curable acrylic or equivalent, and a plurality of hollow glass microspheres suspended throughout the adhesive carrier matrix. The hollow glass microspheres secured to the optic fiber distal end surface provide a large refractive index change at the optic fiber distal end as light penetrates the glass sphere walls and crosses the glass/gas interface of the hollow microspheres. This creates an exceptionally good light diffusing effect, spreading the light uniformly over a broad area in front of the optic fiber distal end surface. In use with the microsurgical illuminator, this provides for a wide field of uniform illumination from the single optic fiber. The hollow nature of the glass microspheres allows for a better (wider angle) diffusion coating than one made with solid glass spheres, because of the larger index changes the light must go through when passing through the glass wall of the spheres and the gas contained in the hollow interiors of the spheres.

## Brief Descriptions of the Drawings

Further features of the invention are set forth in the following detailed description of the preferred embodiment of the invention and in the drawing figures wherein:

figure 1 is a fragmentary, side elevation view, partially in section, of the microsurgical illuminator of the present invention;

figure 2 is an enlarged partial side view, in section, of the distal end of the microsurgical illuminator of figure 1; and,

figure 3 is a view of the distal end of the illuminator.

## Description of the Preferred Embodiment

The microsurgical illuminator 10 shown in the drawing figures is described herein as used in ophthalmic surgery. However, it should be understood that this description is illustrative only, and that the illuminator of the invention may be used in other types of surgical procedures and in environments other than that described.

The microsurgical illuminator 10 shown in Figure 1 is basically comprised of a handle 12, a cannula or instrument tip 14 projecting from the handle, and a length of optic fiber 16 having a portion that passes through the handle and the tip and having a length extending from the handle.

The handle 12 is elongated and has opposite distal 18 and proximal 20 ends. A center bore 22 having a center axis extends through the interior of the handle between its opposite ends. The handle exterior surface 24 has a circumferential dimension approximately that of a pen or pencil providing a familiar and comfortable feel to the surgeon's hand when holding the handle. A portion 26 of the handle exterior surface is ribbed or grooved, providing a gripping surface.

The cannula or tip 14 is a rigid, tubular sleeve preferably constructed of surgical steel. The tip has an interior bore 28 with a center axis that is coaxial with the center axis of the handle. A proximal end 30 of the tip is received in the handle interior bore at the handle distal end and is secured thereto. The tip projects axially from the handle distal end 18 for a significant portion of its length to a distal end 32 of the tip. An enlarged partial view of the tip distal end 32 is shown in Figure 2. The distal end of the tip 14 is formed with a flat annular surface 34 that surrounds the center bore 28 of the tip. In the preferred embodiment of the invention, the flat annular surface 34 is positioned in a plane that is oriented at a right angle to the length of the tubular tip 14. However, in variations of the instrument, the flat annular surface may be positioned at another angle.

The optic fiber 16 in the preferred embodiment of the invention is a single strand of optic fiber. The fiber has a significant length that extends between opposite proximal 36 and distal 38 end surfaces of the fiber. A flexible insulating tube 40 surrounds the fiber. The tube 40 extends along a portion of the fiber length from a proximal end 42 of the tube at the fiber proximal end 36, to a distal end 44 of the tube at the proximal end 30 of the cannula tip 14. The optic fiber 16 extends beyond the tube distal end 44, through the interior of the tip 14 to the optic fiber distal end 38 positioned at the tip distal end 32. The fiber distal end 38 is substantially flat and is generally perpendicular to the center axis of the fiber at the tip distal end 38. In the preferred embodiment of the invention, the optic fiber distal end surface 38 is positioned in the same plane as the tip annular end surface 34. Thus, the optic fiber distal end surface 38 is oriented perpendicular to the center axis of the tip 14. In alternate embodiments of the instrument, the optic fiber distal end surface 38 is positioned in the same plane as the tip annular end surface 34, and both surfaces are oriented at an angle relative to the center axis of the tip 14.

Although, an annular spacing is shown between the exterior surface of the optic fiber distal end 38 and the interior surface of the sleeve or tip 28, the sleeve and fiber are shown if Figure 2 magnified many times. The optic fiber will fit snug in friction engagement in the interior bore of the sleeve.

The optic fiber proximal end 36 is secured in the center of a light source connector 48. The connector has an end plug 50 that is complementary to a connecting socket 52 of a commercially available light source 54. There are many different available light sources 54 used in microsurgery and the connector plug 50 can be altered so that the illuminator 10 of the invention may be used with any of these available light sources. The proximal end of the optic fiber 36 extends completely through the connector 48 and the fiber proximal end surface 36 is positioned in the same plane as the proximal end surface 56 of the connector plug 50.

A novel optical coating has been applied to the output facet or distal end surface 38 of the optic fiber for the purpose of modifying the optical output characteristics from the fiber in a desired manner. The optical coating consists of an adhesive carrier, for example, an ultraviolet curable acrylic or equivalent 60, with suspended hollow glass microspheres 62 entrained throughout the adhesive carrier matrix. The coating covers over the entire distal end surface 38 of the optic fiber, but does not extend beyond the fiber end surface.

The particular adhesive carrier matrix is chosen to have similar optical refraction (index) characteristics to the optic fiber core 16. In the case of surgical illumination optic fibers, acrylic (PMMA) core optic fibers are typically used for disposable instruments. These optic fibers have a refractive index of $n = 1.49$. An ultraviolet curable acrylic adhesive has been proven to be one example of a successful adhesive with a matching optical index and the additional benefit of rapid ultraviolet curing, as well as biological compatibility with human tissues. Epoxy adhesives could also work as the adhesive carrier.

The hollow glass microspheres 62 are suspended in the adhesive 60 prior to curing of the adhesive. The microspheres 62 are tiny glass bubbles (typically soda-lime glass, with gas filled cores) typically air. The size of the glass bubbles typically have an average diameter of 30 microns. An example of such hollow glass microspheres is the Scotchlite™ glass bubbles S60HS provided by the 3M Company of St. Paul, Minnesota. These hollow glass microspheres are typically not used for optical purposes, but are marketed as a lightweight filler material for molded plastics, etc. The use of these particular hollow glass microspheres gives the instrument a considerable cost advantage over optical quality solid spheres, which are commercially produced in much smaller quantities. The construction of the hollow glass microspheres provides a large refractive index change at the optic fiber distal end 38 as light penetrates the glass sphere walls and crosses the glass/gas interface which creates an exceptionally good diffusing effect, spreading the light out uniformly over a broad angular area. In use with the illumination instrument 10, this provides for a wide field of uniform illumination from the single optic fiber 16 which is advantageous in ophthalmic surgery, etc. The hollow nature of the glass microspheres allows for a better (wider angle) diffusion coating than one made with solid glass spheres, because of the larger index changes the light must go through.

In use of the instrument, with the light source turned on and the connector plug 50 inserted into the light source socket 52, the light emitted from the light source is transmitted through the optic fiber 16 to the optic fiber distal end surface 38. The light is then emitted from the optic fiber distal end surface 38 and penetrates the glass sphere walls. The light crosses the glass/gas/glass interface of each microsphere 62, which diffuses the light and spreads the light uniformly over a broad angular area. The large refractive index of the microspheres provides for a wide field of uniform illumination from the single optic fiber 16, which is advantageous in microsurgical procedures such as ophthalmic surgery. The wide field of illumination compensates for the single optic fiber used and the reduced size of the sleeve tip. The hollow nature of the glass microspheres allows for a better (wider angle) diffusion coating than one made with solid glass spheres because of the larger refractive index changes that the light goes through as the light passes through the hollow interiors of the spheres.

While the present invention has been described above by referring to a specific embodiment of the invention, it should be understood that modifications and variations of the invention may be constructed without departing from the scope of the invention defined by the following claims.

**What is Claimed is:**

1. A microsurgical instrument comprising:

an instrument handle having an interior bore through the handle;

a rigid tubular sleeve projecting from the handle, the sleeve having an interior bore through the sleeve;

an optic fiber extending through the handle interior bore and the sleeve interior bore, the optic fiber having a distal end surface; and,

a plurality of hollow microspheres on the optic fiber distal end surface.

2) The instrument of Claim 1, further comprising:

the sleeve having an annular end surface positioned in a plane; and,

the optic fiber distal end surface being positioned in the plane of the sleeve annular end surface.

3) The instrument of Claim 2, further comprising:

the sleeve being perpendicular to the plane of the sleeve annular end surface and the optic fiber distal end surface.

4) The instrument of Claim 2, further comprising:

the plurality of microspheres extending outwardly beyond the sleeve annular end surface.

5) The instrument of Claim 1, further comprising:

the plurality of microspheres being arranged in a single layer of microspheres on the optic fiber distal end surface.

6) The instrument of Claim 5, further comprising:

the plurality of microspheres being only on the optic fiber distal end surface and not extending beyond the optic fiber distal end surface.

7) The instrument of Claim 1, further comprising:

the plurality of microspheres being mixed in an adhesive carrier that has been applied to the optic fiber distal end surface and secures the plurality of microspheres on the optic fiber distal end surface.

8) The instrument of Claim 7, further comprising:

the optic fiber having a refractive index; and,

the adhesive carrier having a refractive index that is equivalent to the optic fiber refractive index.

9) The instrument of Claim 1, further comprising:

the plurality of microspheres being hollow glass microspheres.

10) The instrument of Claim 9, further comprising:

the plurality of hollow glass microspheres having interior volumes filled with a gas.

11) The instrument of Claim 9, further comprising:

the plurality of hollow glass microspheres being soda-lime glass microspheres with air filled interior volumes.

12) The instrument of Claim 1, further comprising:

the plurality of microspheres having an average size of 30 microns.

13) The instrument of Claim 1, further comprising:

the sleeve having reduced dimensions that allow insertion of the sleeve through an eye incision in ophthalmic surgery procedures, and the sleeve interior bore being occupied solely by the optic fiber.

14) A microsurgical instrument comprising:

an instrument handle having an interior bore through the handle;

a rigid tubular sleeve projecting from the handle, the sleeve having an interior bore through the sleeve;

an optic fiber extending through the handle interior bore and the sleeve interior bore, the optic fiber having a proximal end adapted for receiving light from a light source and an opposite distal end with a distal end surface; and, a plurality of hollow glass microspheres on the optic fiber distal end surface, the microspheres being mixed in an adhesive carrier that secures the microspheres on the optic fiber distal end surface.

15) The instrument of Claim 14, further comprising:

the sleeve having an annular end at an opposite end of the sleeve from the handle, the sleeve annular end being positioned in a plane; and,

the optic fiber distal end surface being positioned in the plane of the sleeve.

16) The instrument of Claim 14, further comprising:

the sleeve having an end surface at an opposite end of the sleeve from the handle; and,

the plurality of microspheres extending from the optic fiber distal end surface beyond the sleeve end surface.

17) The instrument of Claim 14, further comprising:

the optic fiber having a refractive index; and,

the adhesive carrier having a refractive index that is equivalent to the optic fiber refractive index.

18) The instrument of Claim 14, further comprising:

the plurality of hollow glass microspheres having interior volumes filled with a gas.

19) The instrument of Claim 14, further comprising:

the plurality of hollow glass microspheres being soda-lime glass microspheres with air filled interior volumes.

20) The instrument of Claim 14, further comprising:

the plurality of microspheres having an average size of 30 microns.

21) An ophthalmic surgery instrument comprising:

a handle having opposite proximal and distal ends and an interior bore extending through the handle between the handle proximal and distal ends;

a rigid tubular sleeve tip projecting from the handle distal end, the sleeve tip having opposite proximal and distal ends and the sleeve tip proximal end being secured to the handle distal end, the sleeve tip having an interior bore extending through the sleeve tip between the sleeve tip proximal and distal ends;

an optic fiber having a length with opposite proximal and distal ends, a portion of the optic fiber length extending through the handle bore and the sleeve tip bore with the optic fiber distal end being positioned adjacent the sleeve tip distal end, the optic fiber proximal end being adapted for connection to a separate light source;

an adhesive carrier on the optic fiber distal end; and,

a plurality of hollow glass microspheres suspended in the adhesive carrier on the optic fiber distal end.

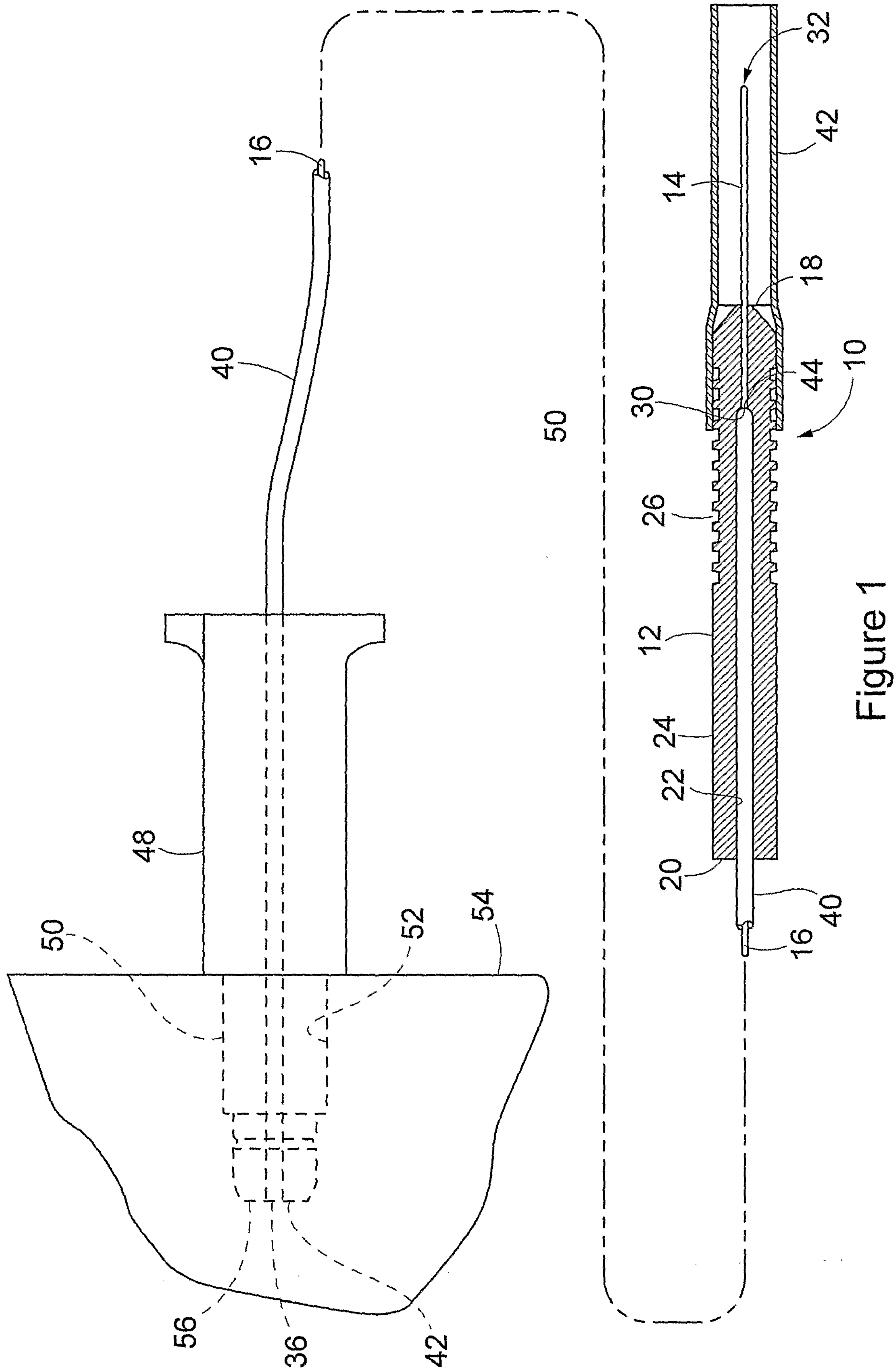


Figure 1

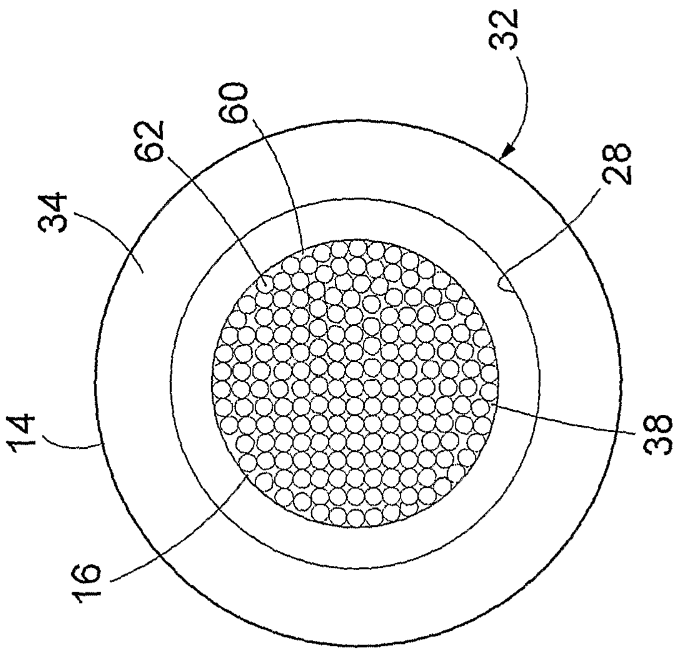


Figure 3

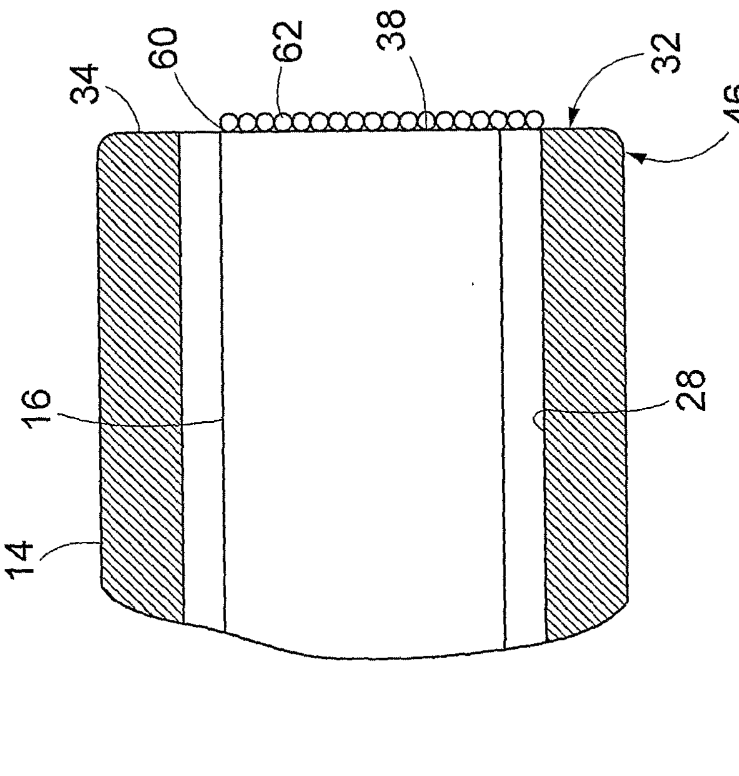


Figure 2