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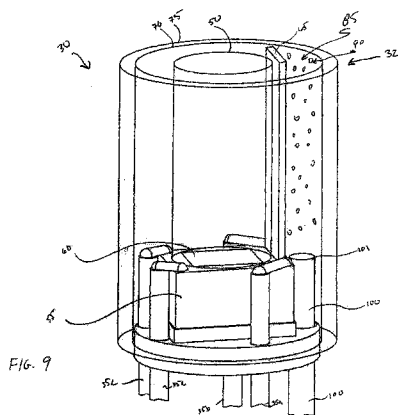
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(54) Title: LIGHT DIFFUSION APPARATUS



(57) Abstract: A light diffusing composition that optimizes image clarity from a SSID comprising a translucent matrix further comprising a plurality of hollow micro-particles. The plurality of hollow micro-particles are dispersed throughout the translucent matrix and a fluid is disposed within the hollow micro-particle. A refractive index of the fluid within the hollow micro-particle is different than a refractive index of the translucent matrix.

LIGHT DIFFUSION APPARATUS

CLAIM OF PRIORITY

This application claims priority to U.S. Provisional Application No. 61/247,892
5 filed on October 1, 2009 which is incorporated herein by reference in its entirety.

BACKGROUND

Minimally invasive diagnostic medical procedures are used to assess the interior
surfaces of an organ by inserting a tube into the body. The instruments utilized may have
10 a rigid or flexible tube and provide an image for visual inspection and photography, but
also enable taking biopsies and retrieval of foreign objects. Analysis of image data
collected during the inspection and photography of the interior of the body cavity is a
critical component of proper diagnosis of disease and other related conditions.

Percutaneous catheterization is a type of medical treatment that is generally less-
15 invasive than directly accessing an internal body site for treatment, such as when using
general surgery methods. In catheterization techniques, a long tubular catheter is
introduced into the body through a puncture site. It is then passed to an internal body site,
usually through passageways such as the vascular tree. Treatment or diagnostic
procedures may then be accomplished using the catheter by manipulation of the portion
20 of the catheter remaining outside the body.

Some medical imaging devices utilize laser sources coupled to a fiber optic light
guide to illuminate a target to be imaged. The nature of the light emitted from the fiber
can result in hot spots in the center of the image, image speckle, and lack of illumination
on the periphery of the target.
25

SUMMARY OF THE INVENTION

It has been recognized that it would be advantageous to develop a light diffusing
composition that provides an even illumination to optimize image clarity from a SSID. In
one embodiment of the present invention, a light diffusing composition comprises a
30 translucent matrix comprising a plurality of hollow micro particles. The plurality of

hollow micro particles are dispersed throughout the translucent matrix and a fluid is disposed within the hollow micro particle. The refractive index of the fluid within the hollow micro particle is different than a refractive index of the translucent matrix.

In one aspect of the present invention, the refractive index of the fluid is less than
5 the refractive index of the translucent matrix. In yet another aspect, the absolute value of the difference between the refractive index of the fluid and the refractive index of the translucent matrix is greater than approximately 0.4. In an additional embodiment, the refractive index of the fluid is greater than 1.0. In yet another embodiment, the refractive index of the fluid is less than the refractive index of the shell of the micro particle. In still
10 another embodiment, the refractive index of the fluid is greater than the refractive index of the translucent matrix.

In one embodiment of the present invention, a light diffusing composition is disclosed comprising an opaque matrix comprising a plurality of hollow micro particles, the plurality of hollow micro particles being dispersed throughout the opaque matrix. A
15 fluid is disposed within the hollow micro particle, wherein, a refractive index of the fluid within the hollow micro particle is different than a refractive index of the opaque matrix.

According to one embodiment of the present invention, a medical imaging device is disclosed comprising a SSID operatively coupled to a lens system. The medical imaging device further comprises a light source configured to propagate light near the
20 lens system and a matrix disposed on a distal end of the light source. The matrix comprises a plurality of fluid-filled compartments, wherein a refractive index of the fluid is different than a refractive index of the matrix.

In one aspect, the light source of the medical imaging device is oriented in a direction substantially parallel to an image plane of the SSID. In an additional aspect,
25 the matrix is a translucent matrix. In yet another aspect, the matrix is an opaque matrix. In yet another aspect, the absolute value of the difference between the refractive index of the fluid and the refractive index of the matrix is greater than approximately 0.4. In still another aspect, the matrix occludes the distal end of the elongated hollow member.

According to an additional embodiment of the present invention, a medical
30 imaging device is disclosed comprising a SSID operatively coupled to a lens system and a light source configured to propagate light near the lens system. A translucent matrix is

disposed on a distal end of the light source. The translucent matrix comprises a plurality of micro spheres dispersed throughout the translucent matrix, the micro spheres having a reflective outer surface.

In one embodiment of the present invention, a method of improving the image clarity of a miniature imaging device is disclosed. The method comprises providing a SSID operatively coupled to a lens system and a light source configured to propagate light near the lens system. The method further comprises propagating light through a translucent matrix and onto a target surface. The translucent matrix comprises a plurality of fluid-filled compartments, wherein a refractive index of the fluid is different than a refractive index of the translucent matrix. The method further comprises receiving light reflected from the target surface through the lens system and onto the SSID.

In one aspect of the present invention, the refractive index of the fluid is less than the refractive index of the translucent matrix. In another aspect, the absolute value of the difference between the refractive index of the fluid and the refractive index of the translucent matrix is greater than approximately 0.4. In still another aspect, the refractive index of the fluid is greater than the refractive index of the translucent matrix. In one embodiment of the present invention, the fluid is air. In still another embodiment, the translucent matrix consists of a pressure sensitive adhesive or structural adhesive.

20

BRIEF DESCRIPTION OF THE DRAWINGS

Additional features and advantages of the invention will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the invention; and, wherein:

25

FIG. 1 is an exemplary view of a medical imaging system in accordance with an embodiment of the present invention;

FIG. 2 is a side view of a micro-catheter in accordance with one embodiment of the present invention;

30

FIG. 3 is a perspective view of an imaging structure according to one embodiment of the present invention;

FIG. 4 is a perspective view of an imaging structure according to one embodiment of the present invention;

FIG. 5 is a side view of a light diffusing composition according to one embodiment of the present invention;

5 FIG. 6 is a side view of a light diffusing composition according to one embodiment of the present invention;

FIG. 7 is a side view of a light diffusing composition according to one embodiment of the present invention;

10 FIG. 8 a-c are side views of a light fiber and diffuser showing the diffusive affects of one embodiment of the present invention;

FIG. 9 is a perspective view of an imaging structure according to one embodiment of the present invention; and

FIG. 10 is a perspective view of an imaging structure according to one embodiment of the present invention.

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DETAILED DESCRIPTION OF EXAMPLE EMBODIMENT(S)

Reference will now be made to, among other things, the exemplary embodiments illustrated in the drawings, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is
20 thereby intended. Alterations and further modifications of the inventive features illustrated herein, and additional applications of the principles of the inventions as illustrated herein, which would occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the invention.

It must be noted that, as used in this specification and the appended claims,
25 singular forms of “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

An “SSID,” “solid state imaging device,” “SSID chip,” or “solid state imaging chip” in the exemplary embodiments generally comprises an imaging array or pixel array for gathering image data. In one embodiment, the SSID can comprise a silicon or silicon-
30 like substrate or amorphous silicon thin film transistors (TFT) having features typically manufactured therein. Features can include the imaging array, conductive pads, metal

traces, circuitry, etc. Other integrated circuit components can also be present for desired applications. However, it is not required that all of these components be present, as long as there is a means of gathering visual or photon data, and a means of sending that data to provide a visual image or image reconstruction.

5 The term “umbilical” can include the collection of utilities that operate the SSID or the micro-camera as a whole. Typically, an umbilical includes a conductive line, such as electrical wire(s) or other conductors, for providing power, ground, clock signal, and output signal with respect to the SSID, though not all of these are strictly required. For example, ground can be provided by another means than through an electrical wire, e.g.,
10 to a camera housing such as micromachined tubing, etc. The umbilical can also include other utilities such as a light source, temperature sensors, force sensors, fluid irrigation or aspiration members, pressure sensors, fiber optics, microforceps, material retrieval tools, drug delivery devices, radiation emitting devices, laser diodes, electric cauterizers, and electric stimulators, for example. Other utilities will also be apparent to those skilled in
15 the art and are thus comprehended by this disclosure.

 “GRIN lens” or “GRadiant refractive INdex lens” refers to a specialized lens that has a refractive index that is varied radially from a center optical axis to the outer diameter of the lens. In one embodiment, such a lens can be configured in a cylindrical shape, with the optical axis extending from a first flat end to a second flat end. Thus,
20 because of the differing refractive index in a radial direction from the optical axis, a lens of this shape can simulate the effects of a more traditionally shaped lens.

 “Matrix” refers to a surrounding substance within which something else is contained. In one embodiment, such a matrix comprises an opaque adhesive. In yet another embodiment, the matrix comprises a translucent adhesive or an opaque adhesive.
25 It is understood that the matrix may comprise any material suitable for housing diffusive elements described further herein to create the desired diffusive effect.

 With these definitions in mind, reference will now be made to, among other things, the accompanying drawings, which illustrate, by way of example, embodiments of the invention.

30 Referring now to FIG. 1, in one embodiment of the present invention, a medical imaging system 10 is disclosed comprising a micro-catheter 12 having an imaging device

disposed at a distal tip 15 of the micro-catheter 12. A processor 22, such as an appropriately programmed computer, is provided to control the imaging system 10 and create an image of anatomy adjacent the distal tip portion 15, within a patient (not shown), displayable on a monitor 24, and storable in a data storage device 26. An interface 28 is provided which supplies power to the imaging device 14 and feeds a digital image signal to the processor based on a signal received from the imaging device via an electrical umbilical, including conductive wires through the micro-catheter 12. A light source may also be provided at the distal end of the micro-catheter 12. In one aspect, the system further includes a fitting 16 enabling an imaging fluid, such as a clear saline solution, to be dispensed to the distal tip portion of the micro-catheter 12 from a reservoir 18 through an elongated tubular member removably attached to the micro-catheter 12 or through a lumen of the micro-catheter 12 to displace body fluids as needed to provide a clearer image. Fluids may be pumped to the distal end of the micro-catheter for other reasons described herein. A pump 20 is provided, and is manually actuated by a medical practitioner performing a medical imaging procedure, or can be automated and electronically controlled so as to dispense fluid on demand according to control signals from the practitioner, sensors, or according to software commands.

With reference now to FIGS. 2 and 3, according to one embodiment of the present invention, an imaging device 30 is disposed on a distal end of a micro-catheter 12. Micro-machined cuts 13 are disposed non parallel to a longitudinal direction of the micro-catheter 12 to enable a user, such as a medical practitioner, to guide and steer the distal end of the micro-catheter 12 within a cavity of a patient. In yet another aspect of the present invention, the micro-catheter 12 may incorporate structure and principles of operation from a micro-catheter disclosed in U.S. Patent No. 6,014,919 to Jacobsen et al., which is incorporated herein by reference in its entirety.

In one aspect of the invention, imaging device 30 comprises at least two conductive wires 35a, 35b for conducting electronic image data to the data processor 22 and for securing an imaging structure 36 between the at least two conductive wires 35a, 35b. As illustrated in FIG. 3 however, a plurality of conductive wires 35a, 35b, 35c, 35d may be utilized. The at least two conductive wires 35a, 35b are oriented along a longitudinal axis of the imaging structure 36 and are disposed within alignment apertures

40 of a planar support member 45. The planar support member 45 comprises at least two alignment apertures 40 disposed on opposing sides of the planar support member 45. The alignment apertures 40 are configured to receive and align the at least two conductive wires 35a, 35b along the longitudinal axis of the imaging structure 36. The imaging structure 36 is at least partially secured between the at least two conductive wires 35a, 35b and is disposed adjacent a top surface of the planar support member 45. In one aspect of the invention, the imaging structure 36 comprises a GRIN lens 50 optically coupled to a SSID 55 and disposed adjacent the SSID 55. The imaging structure further comprises an imaging array 60 disposed on a top surface of the SSID 55. In one embodiment, the GRIN lens 50 is positioned directly on top of the imaging array 60 of the SSID 55.

The at least two conductive wires 35a, 35b are operatively coupled to the imaging structure 36 and are configured to align the imaging structure 36 there between. In one aspect, the conductive wires 35a, 35b are bonded to the imaging structure 36 at contact points 56 disposed on the periphery of a top surface of the SSID 55. In yet another embodiment, the conductive wires, 35a, 35b are bonded to a side surface of the SSID 55.

In one embodiment, the alignment apertures 40 are oriented perpendicular to the top surface of the planar support member 45. However, the alignment apertures may also be disposed in any orientation which is not non-parallel to the planar support member 45 as required to optimally align the imaging structure 36 as desired. In one embodiment, the imaging structure is mounted and aligned such that the image plane of the imaging structure 36 is non parallel to a longitudinal axis of the micro-catheter 12. In one aspect of the invention, a light source (e.g., a fiber optic member, LED, etc.) 62 is disposed within an aperture of the planar support member 40 to provide light for imaging. In yet another aspect of the present invention, the imaging structure 30 may incorporate structure and principles of operation from an imaging device disclosed in U.S. Patent No. 7,166,537 to Jacobsen et al., which is incorporated herein by reference in its entirety.

Referring now to FIGS. 3 and 4, in yet another embodiment of the present invention, the imaging device 30 further comprises a light shield 65. In one aspect, the light shield 65 is bonded to a top surface of the SSID 55. In another aspect, the light shield 65 is bonded to a side surface of the SSID 55. In yet another aspect, the light

shield 65 is bonded to a top surface of the planar support member 40. In any event, the light shield 65 is oriented adjacent a side surface of the GRIN lens 50 to minimize stray light from entering the GRIN lens 50 during operation and to ensure proper alignment of the GRIN lens 50 on the imaging array 60 during operation and/or construction of the device. In one aspect of the invention, a first sleeve member 70 is disposed about the imaging structure 36. An adhesive is disposed within the first sleeve member 70 securing the components of the imaging structure 36 in place as well as securing the first sleeve member 70 to the imaging structure 36. In an additional embodiment, a second sleeve member 75 is disposed about the first sleeve member 70 and secured with an adhesive. In one aspect of the invention, the second sleeve member 75 comprises an opaque material to eliminate secondary light from impacting image quality.

In one aspect of the invention, the angle enclosing a cone of light emitted from the light source 62 is determined by the numerical aperture of the light source 62. In one embodiment, the numerical aperture of the light source 62 is approximately 0.22 resulting in an angle of approximately twenty-five degrees. In one aspect of the invention, lens systems used herein have an image capture angle of approximately sixty degrees. Thus, light from an undiffused light source results in hot spots, image speckle, and/or inadequate illumination on the periphery of the image capture area.

Referring now specifically to FIGS. 3 through 6, a light diffusing composition 80 to optimize image clarity is disposed within a distal end of the light source 62. In one embodiment of the present invention, the light diffusing composition 80 comprises a matrix 85 comprising a plurality of hollow micro-particles 90. The matrix 85 may comprise either a translucent or opaque material as desired for a particular application. The plurality of hollow micro particles 90 are dispersed throughout the matrix 85 and a fluid is disposed within the hollow micro-particles 90. A refractive index of the fluid within the hollow micro-particle 90 is different than a refractive index of the matrix 85.

Advantageously, the hollow micro particles 90 allow for predictable and controllable distribution of refractive indices within the matrix thereby optimizing light diffusion. In this manner an increase in illumination uniformity can be achieved, especially when viewing objects at close distances. In one aspect, the refractive index of fluid within micro particles 90 varies from particle to particle or is substantially

equivalent throughout all of the micro-particles 90 as is desired for a particular application. Additionally, the density of the micro-particles 90 within the matrix 85 depends on a particular application. For example, in one embodiment, the volumetric density of micro-particles 90 within the matrix 85 ranges from 0.5 to 1.5 with a nominal value of 1. In one aspect of the invention, the amount of resulting diffusion scales with the volumetric density of the micro-particles within the matrix. Thus the amount of diffusion can be optimized by varying the density of the micro-particles. Variations in the path length and angular distribution of the light rays emitted from the distal end of a light source 62 (due to the presence of the micro-particles) advantageously increases the area of illumination and flattens the distribution of light over the area to be illuminated.

In one aspect of the present invention, the refractive index of the fluid within the micro particle 90 is less than the refractive index of the matrix 85. In yet another aspect, the absolute value of the difference between the refractive index of the fluid and the refractive index of the matrix 85 is greater than approximately 0.4. In an additional embodiment, the refractive index of the fluid is greater than 1.0. In yet another embodiment, the refractive index of the fluid is less than the refractive index of the hollow micro particle 90. In still another embodiment, the refractive index of the fluid is greater than the refractive index of the matrix 85. In one embodiment, the micro-particles 90 dispersed throughout the matrix 85 have numerous dimensions as illustrated in FIG. 5. In yet another embodiment, the micro-particles 90 dispersed throughout the matrix have substantially equal dimensions. In one embodiment, the micro-particles 90 have a diameter ranging from ten to sixty-five microns (10 – 65 μm). In yet another embodiment, the micro-particles 90 have a diameter ranging from five to one hundred twenty microns (5 – 120 μm). However, it is understood that the exact size and shape of the micro particles 90 is tailored as desired for a particular application.

In one embodiment of the present invention, a light diffusing composition is disclosed comprising an opaque matrix comprising a plurality of hollow micro-particles 90, wherein the plurality of hollow micro-particles 90 are dispersed throughout the opaque matrix. A fluid is disposed within the hollow micro-particles 90, wherein the refractive index of the fluid within the hollow micro-particles 90 is different than the refractive index of the opaque matrix. The density of hollow micro-particles 90 dispersed

throughout the opaque matrix is sufficient to allow adequate light to pass through the matrix and illuminate a target area. That is, because the opaque matrix decreases the transmission of light through the matrix, the micro-particle density, is such that a substantial number of micro-particles 90 are in contact with one another thereby

5 permitting the transmission of light from micro-particle 90 to micro-particle 90, until the light exits the particular transmission conduit. The micro-particles 90 may be spherical, cubic, amorphous, or some other suitable shape, or a combination of any of these.

In another embodiment of the present invention, the matrix 85 comprises a translucent matrix having a plurality of micro spheres 90 dispersed throughout the

10 translucent matrix, wherein the micro-spheres 90 have a reflective outer surface. In this manner, light is dispersed through the composition 80 based on the reflective properties of the micro-spheres 90 disposed within the translucent matrix 85. In one aspect of the invention, the reflective outer surface of the micro-spheres 90 is coated with a reflective material such as zinc sulfide titanium dioxide, magnesium fluoride, silicon dioxide, etc.

15 In yet another aspect, the outer surface of the micro-spheres is also configured to have granular or rough areas. In this manner, diffuse reflection (e.g., Lambertian reflectance) of light emanating from the light source 62 may be attainable. While use of micro-spheres 90 are referenced in connection with this embodiment, it is understood that numerous shapes (e.g., cubes, prisms, amorphous shapes, etc.) of various materials may

20 be utilized to accomplish the desired light diffusion.

Referring now to FIG. 7, in yet an additional embodiment of the present invention, the matrix 85 comprises a plurality of fluid-filled compartments 91, wherein a refractive index of the fluid 92 within the compartment 91 is different than a refractive index of the matrix 85. In one embodiment, the light source 62 is oriented in a direction substantially

25 parallel to an image plane of the SSID 55. As noted above, the matrix 85 may comprise a translucent matrix or opaque matrix. The fluid-filled compartments 91 may comprise pockets of air disposed within the matrix 85 or some other fluid (e.g., argon, saline, nitrogen, etc.) as suits a particular application. In one aspect of the invention, the fluid is an inert fluid.

30 Referring now to FIGS. 8a through 8c, FIG. 8a illustrates how light exits an optical fiber in accordance with one embodiment of the present invention. FIG 8b

illustrates a model of an optical fiber and a matrix 85 containing hollow micro-spheres 90 in accordance with one embodiment of the invention. FIG 8c illustrates how the addition of the matrix 85 containing hollow micro-spheres 90 causes light to refract resulting in a more diffuse illumination.

5 In one embodiment of the present invention, the matrix 85 can be either a structure adhesive or a pressure sensitive adhesive (PSA). The optical properties of a PSA, as described below, allow the PSA to remain stable under high intensity light. Useful PSAs can be, for example, substantially free of unreacted monomers and oligomers and/or photo initiators, and substantially non-shrinking. The PSA materials
10 can be substantially free of UV-absorbing chromophores such as extended aromatic structures or conjugated double bonds. The Pressure-Sensitive-Tape Council has defined pressure sensitive adhesives as material with the following properties: (a) aggressive and permanent tack, (b) adherence with no more than finger pressure, (c) sufficient ability to hold onto an adherand, (d) sufficient cohesive strength, and (e) requires no activation by
15 an energy source. PSAs are normally tacky at assembly temperatures, which is typically room temperature or greater (i.e., about 20 degrees Celsius to about 30 degrees Celsius or greater). Materials that have been found to function well as PSAs are polymers designed and formulated to exhibit the requisite viscoelastic properties resulting in the desired balance of tack, peel adhesion, and shear holding power at the assembly temperature.
20 The most commonly used polymers for preparing PSAs are natural rubber-, synthetic rubber- (e.g., styrene butadiene copolymers (SBR) and styrene/isoprene/styrene (SIS) block copolymers), silicone ester-, polyalpha-olephin-, and various (meth) acrylate- (e.g., acrylate and methacrylate) based polymers.

A structural adhesive is a material used to bond high strength materials, such as
25 wood, composites, plastics, glass, or metal, so that the practical adhesive bond strength is in excess of 6.9 MPa (1000 psi) at room temperature. Because of the demands on performance, structural adhesives usually take part in curing and/or cross-linking reactions by external energy source such as UV or heat during assembly leading to the development of final adhesive properties. Structural adhesives may be classified in a
30 number of ways, such as physical form, chemical compositions, and curing conditions of the adhesives. Examples of structural adhesives contemplated herein are phenolic, epoxy,

acrylic, urethane, polyimide and bis-maleimide. It is understood herein that the matrix 85 referenced herein is not limited to a pressure sensitive adhesive or a structural adhesive. However, the matrix 85 may comprise a combination of different adhesives or may comprise some other suitable material or combination of suitable materials with the
5 desired optical characteristics for a particular application.

With reference now to FIGS. 5 through 10, in one embodiment of the present invention a light source 100 is disposed within an aperture of the planar support member 40 to provide light for imaging. While much of the structure of embodiments illustrated in FIGS. 9 and 10 are similar to those illustrated in FIGS. 3 and 4, some similar call-out
10 numbers are referenced herein. In one aspect, a distal end 101 of the light source 100 terminates prior to the distal end 32 of the imaging structure 31. In this embodiment, the light diffusing composition 80 described herein may be disposed within the first sleeve member 70 of the imaging structure 31. In one aspect, the matrix 85 of the light diffusing composition 80 is an adhesive as described herein securing all of the respective
15 components of the imaging structure 31 within the inner volume of the first sleeve member 70. Advantageously, the diffusive properties of the light diffusing composition 80 effectively increase the path length of the light emitted from light source 100 thereby improving image quality as noted herein. In one aspect, an outer portion of the GRIN lens 55 may be coated with an opaque material to minimize light intrusion from light
20 source 100 that has not been reflected from a target area. The opaque material may cover all or part of the outer portion of the GRIN lens.

Referring generally to FIGS. 3 through 7, in an additional embodiment of the present invention, a method of improving the image clarity of a miniature imaging device is disclosed comprising providing a SSID 55 operatively coupled to a lens system 50
25 (e.g., a GRIN lens or some other suitable lens system) and providing a light source 62 configured to propagate light near the lens system 50. The method further comprises propagating light through a translucent matrix 85 and onto a target surface, the translucent matrix 85 comprising a plurality of fluid-filled compartments 91. A refractive index of the fluid in the compartments 91 is different than a refractive index of the translucent
30 matrix 85. The method further comprises receiving light reflected from the target surface through the lens system 50 and onto the SSID 55.

In another aspect of the invention, the refractive index of the fluid is less than the refractive index of the translucent matrix 85. In yet another aspect of the invention, the absolute value of the difference between the refractive index of the fluid and the refractive index of the translucent matrix 85 is greater than approximately 0.4. In one
5 embodiment, the refractive index of the fluid is greater than the refractive index of the translucent matrix 85. Fluid within the compartments 91 may comprise air or any other fluid (e.g., saline, argon, nitrogen, etc.) suitable for the desired application. As noted in more detail above, in one embodiment of the present invention, the translucent matrix 85 consists of a *pressure sensitive adhesive or structural adhesive*. The translucent matrix 85
10 may also comprise some other suitable material with the desired optical characteristics that, when used in conjunction with the fluid-filled compartments 91, creates the desired diffusive effect.

In accordance with one embodiment of the present invention, the matrix may comprise a plurality of compartments that are substantially free of any fluid thereby
15 creating at least a partial vacuum within the compartment. That is, the pressure within the compartment is less than atmospheric pressure and in some instances is substantially less than (i.e., 100 kPa to 3 kPa) atmospheric pressure.

While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary
20 skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited, except as by the claims set forth below.

1. A light diffusing composition, comprising:
a translucent matrix comprising a plurality of hollow micro-particles, the plurality
of hollow micro-particles being dispersed throughout the translucent
5 matrix; and
a fluid disposed within the hollow micro-particle;
wherein, a refractive index of the fluid within the hollow micro-particle is
different than a refractive index of the translucent matrix.
- 10 2. The light diffusing composition of claim 1, wherein the refractive index of the
fluid is less than the refractive index of the translucent matrix.
3. The light diffusing composition of claim 1, wherein the absolute value of the
15 difference between the refractive index of the fluid and the refractive index of the
translucent matrix is greater than approximately 0.4.
4. The light diffusing composition of claim 1, wherein the refractive index of the
fluid is greater than 1.0.
- 20 5. The light diffusing composition of claim 1, wherein the refractive index of the
fluid is less than the refractive index of the hollow micro-particle.
6. The light diffusing composition of claim 1, wherein the refractive index of the
25 fluid is greater than the refractive index of the translucent matrix.
7. A light diffusing composition, comprising:
an opaque matrix comprising a plurality of hollow translucent micro-particles, the
plurality of hollow translucent micro-particles being dispersed throughout
the opaque matrix; and
30 a fluid disposed within the hollow translucent micro-particle;

wherein, a refractive index of the fluid within the hollow translucent micro-particle is different than a refractive index of the micro-particle's shell.

8. An medical imaging device, comprising
5 a SSID operatively coupled to a lens system;
a light source configured to propagate light near the lens system; and
a matrix disposed on a distal end of the light source, the matrix comprising a
plurality of fluid-filled compartments, wherein a refractive index of the fluid is
different than a refractive index of the matrix.
- 10 9. The medical imaging device of claim 8, wherein the light source is oriented in a
direction substantially parallel to an image plane of the SSID.
10. The medical imaging device of claim 8, wherein the matrix is a translucent matrix.
- 15 11. The medical imaging device of claim 8, wherein the matrix is an opaque matrix.
12. The medical imaging device of claim 10, wherein the absolute value of the
difference between the refractive index of the fluid and the refractive index of the
20 translucent matrix is greater than approximately 0.4.
13. The medical device of claim 8, wherein the matrix occludes the distal end of the
elongated hollow member.
- 25 14. An medical imaging device, comprising
a SSID operatively coupled to a lens system;
a light source configured to propagate light near the lens system; and
a translucent matrix disposed on a distal end of the light source, the translucent
matrix comprising a plurality of micro-spheres dispersed throughout the
30 translucent matrix, the micro-spheres having a reflective outer surface.

15. A method of improving the image clarity of a miniature imaging device, comprising:
- (a) providing a SSID operatively coupled to a lens system;
 - (b) providing a light source a light source configured to propagate light near the
5 lens system;
 - (c) propagating light through a translucent matrix and onto a target surface, the translucent matrix comprising a plurality of fluid-filled compartments, wherein a refractive index of the fluid is different than a refractive index of the translucent matrix; and
 - 10 (d) receiving light reflected from the target surface through the lens system and onto the SSID.
16. The method of claim 15, wherein the refractive index of the fluid is less than the refractive index of the translucent matrix.
- 15 17. The method of claim 15, wherein the absolute value of the difference between the refractive index of the fluid and the refractive index of the translucent matrix is greater than approximately 0.4.
- 20 18. The method of claim 15, wherein the refractive index of the fluid is greater than the refractive index of the translucent matrix.
19. The method of claim 15, wherein the fluid is air.
- 25 20. The method of claim 15, wherein the translucent matrix consists of a pressure sensitive adhesive or structural adhesive.
21. An medical imaging device, comprising
- a SSID operatively coupled to a lens system;
 - 30 a light source configured to propagate light near the lens system; and

a matrix disposed on a distal end of the light source, the matrix comprising a plurality of hollow compartments.

22. The medical imaging device of claim 21, wherein the pressure of the hollow
5 compartment is substantially less than atmospheric pressure.

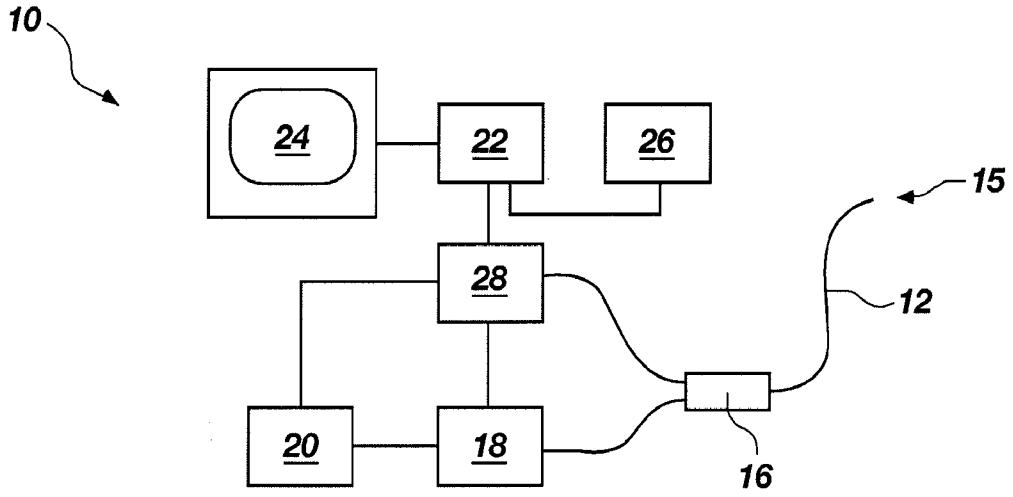


FIG. 1

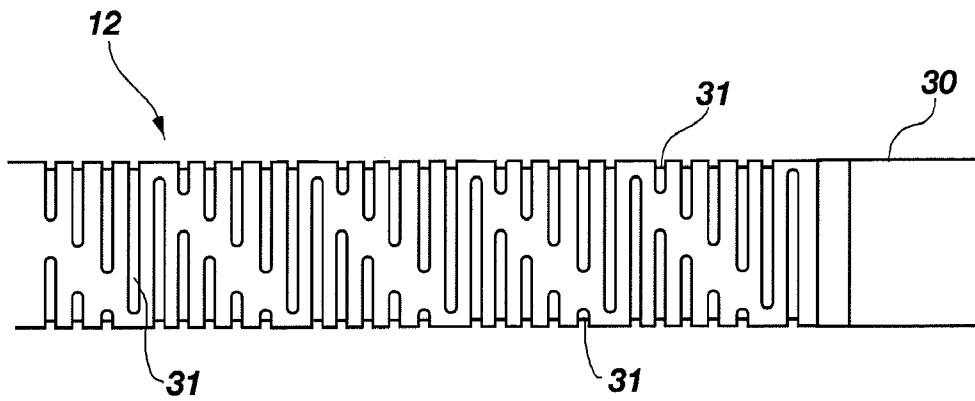


FIG. 2

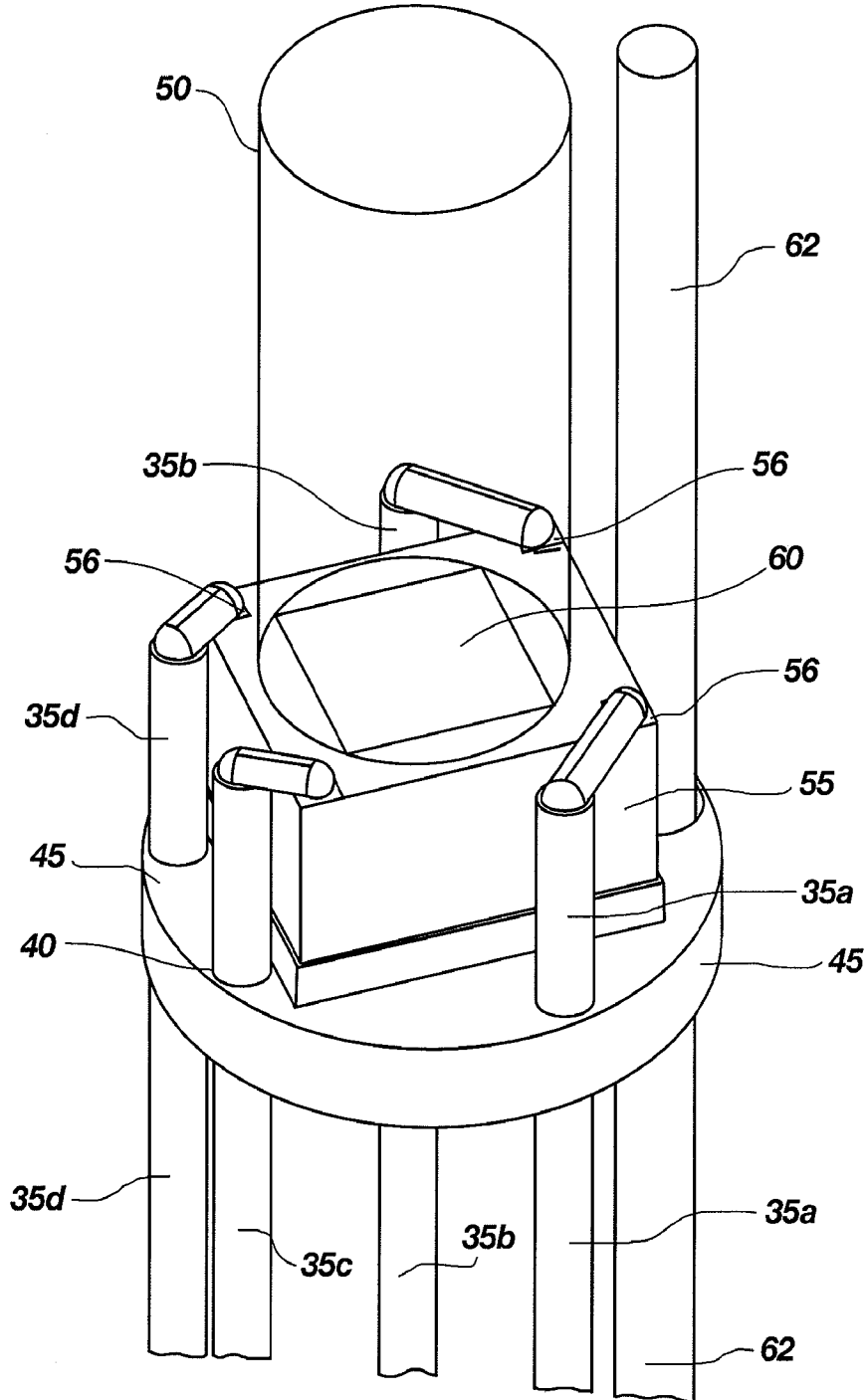


FIG. 3

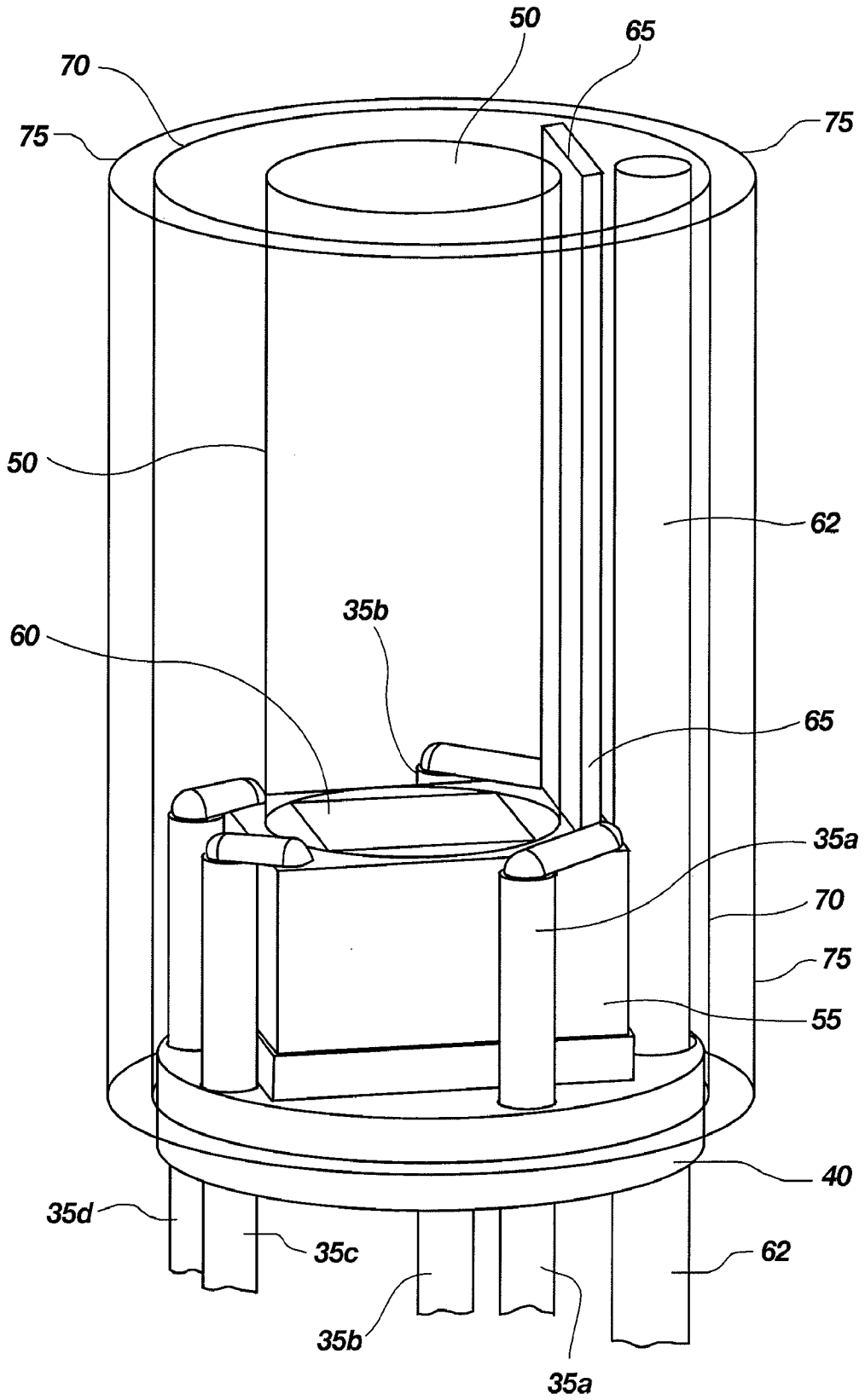


FIG. 4

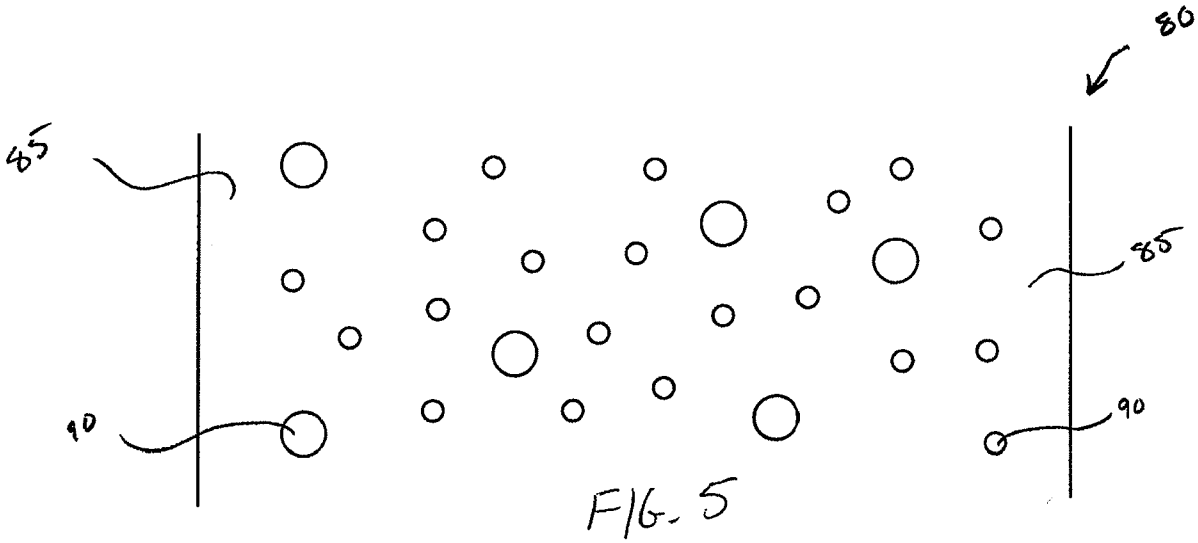


FIG. 5



FIG. 7

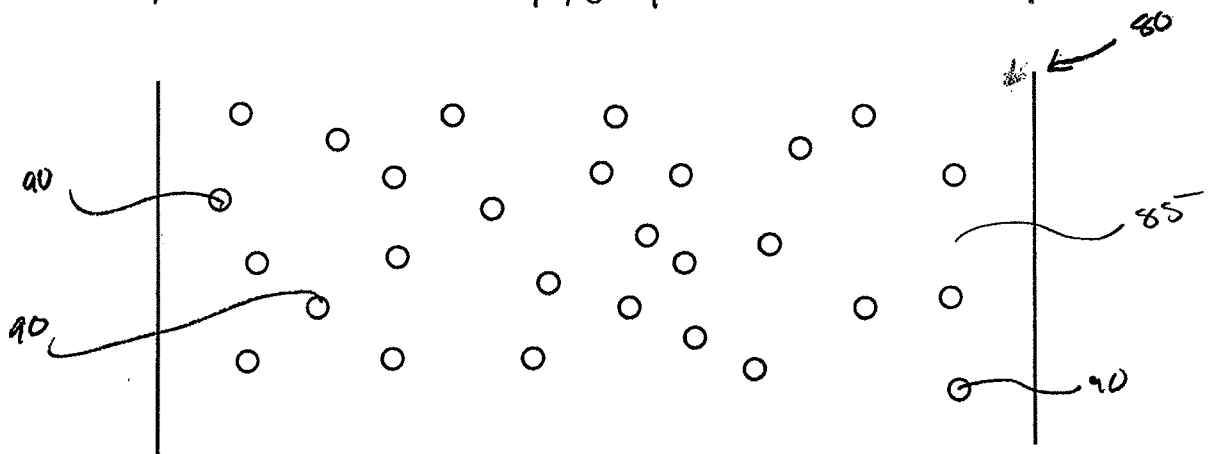


FIG. 6

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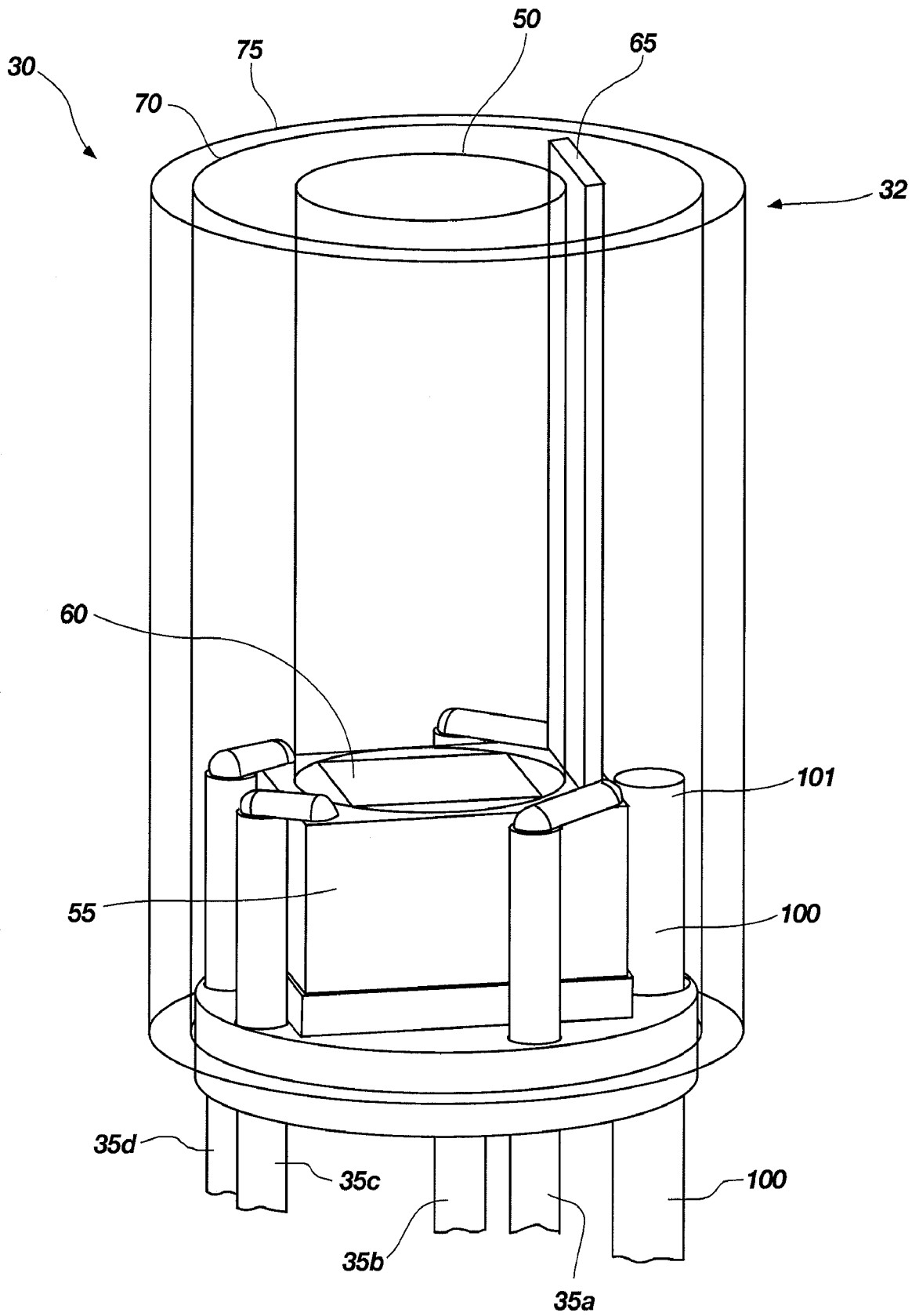


FIG. 8

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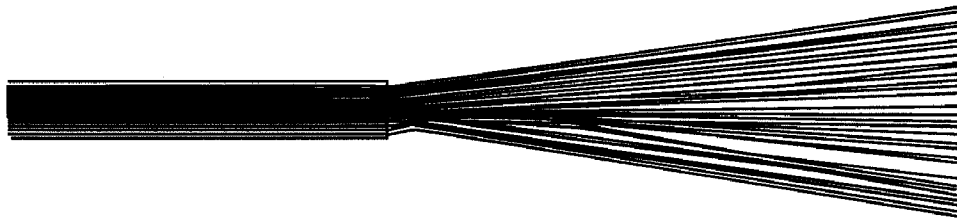


FIG. 8a

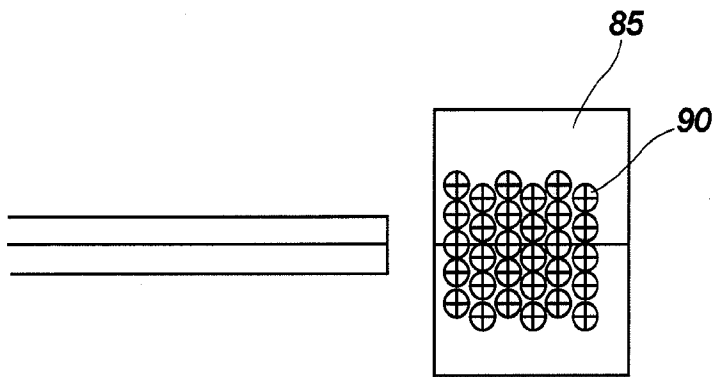


FIG. 8b

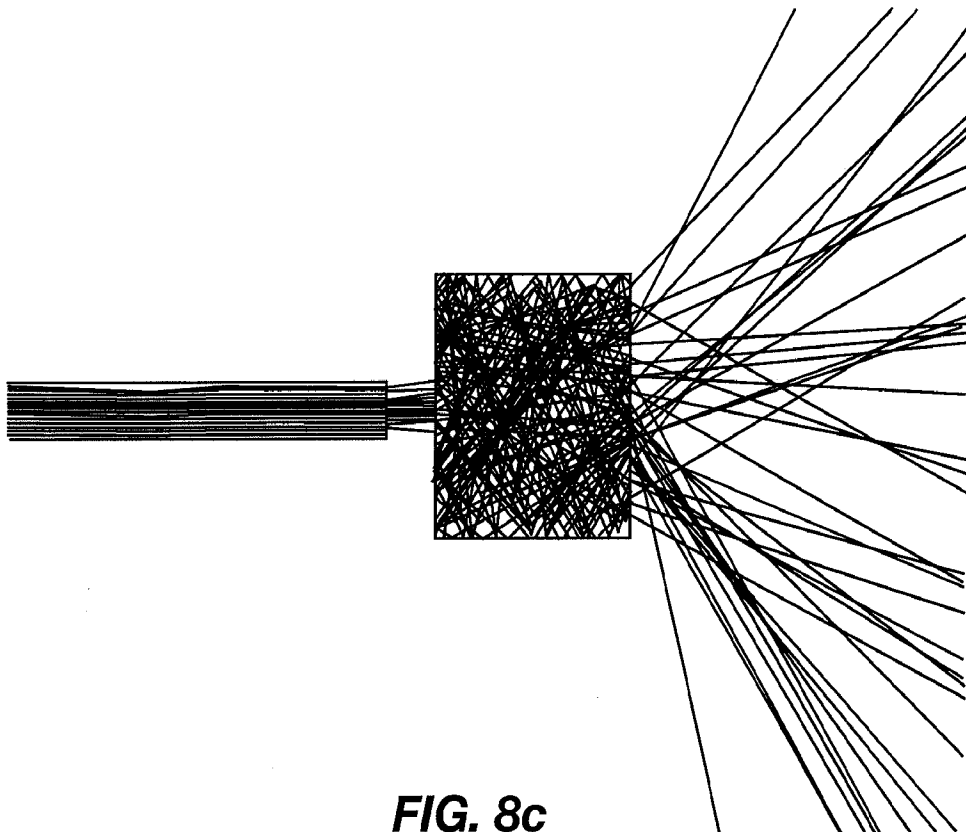


FIG. 8c

717

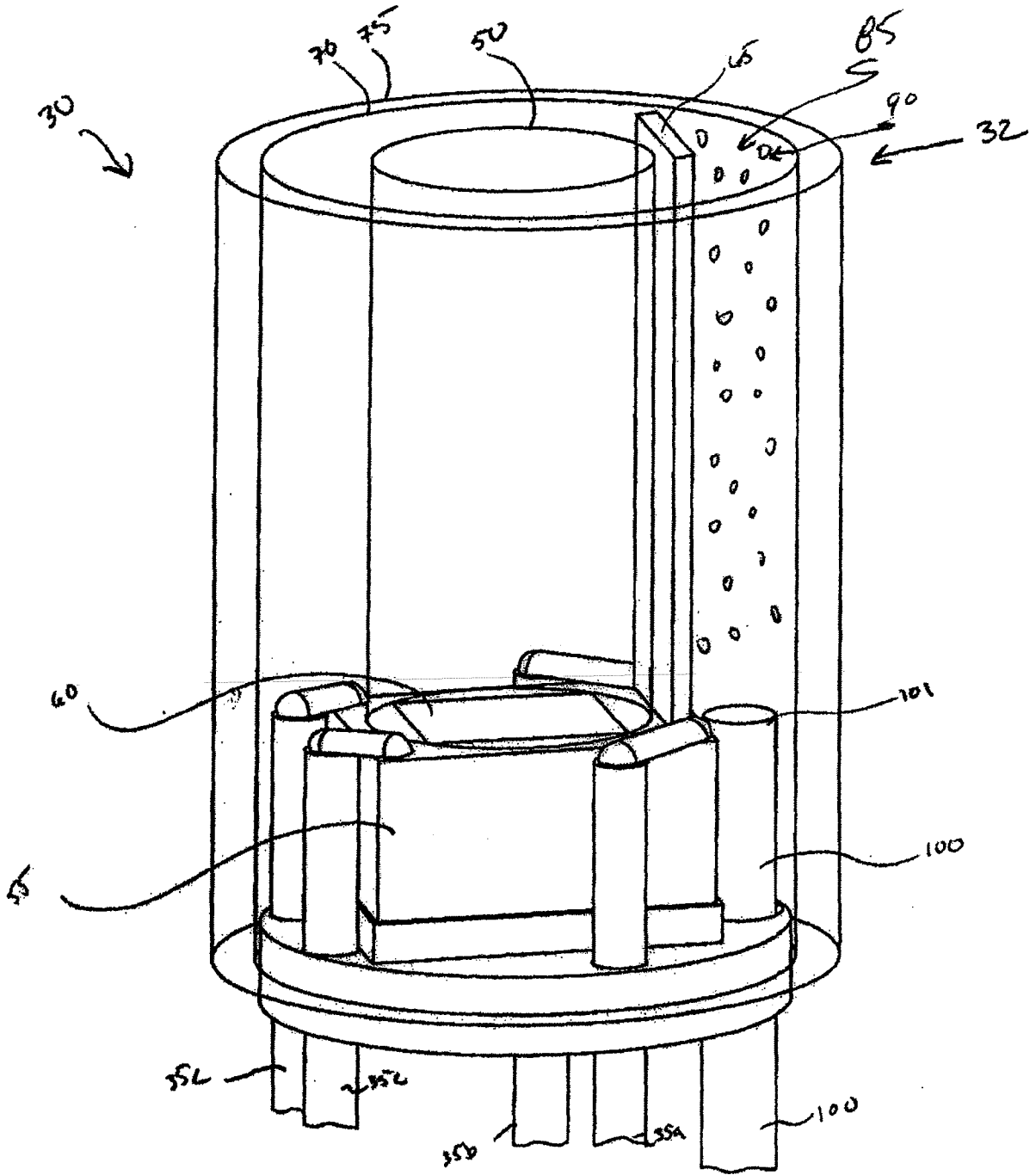


FIG. 9