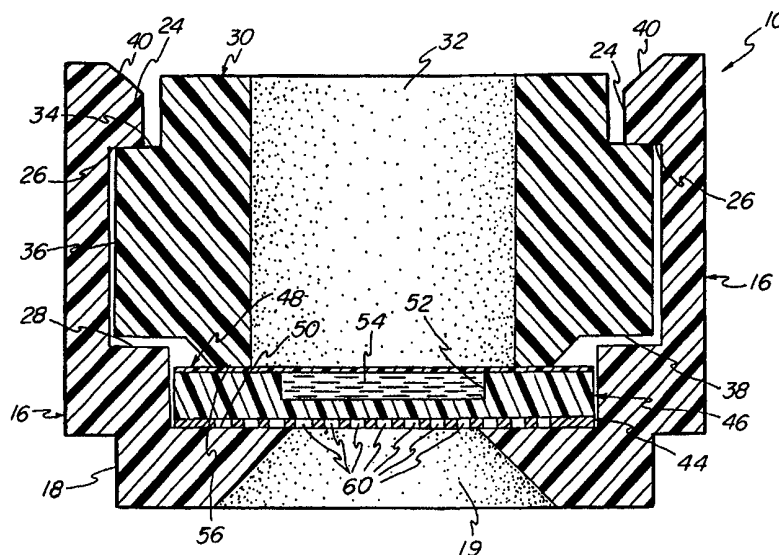




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/US99/25506</p> <p>(22) International Filing Date: 29 October 1999 (29.10.99)</p> <p>(30) Priority Data: 60/106,528 31 October 1998 (31.10.98) US</p> <p>(71) Applicant (for all designated States except US): YELLOW SPRINGS OPTICAL CO. PLL. [US/US]; 1725 Brannum Lane, P.O. Box 279, Yellow Springs, OH 45387 (US).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): CORDONNIER, Michael, J. [US/US]; 4461 Rascule Bridge #711, Beavercreek, OH 45440 (US). WU, H., Ping [US/US]; 4196 Chalmette Drive, Beavercreek, OH 45440 (US). SPOKANE, Robert, B. [US/US]; 1715 Garry Drive, Bellbrook, OH 45305 (US). LUSSIER, Jamie, N. [US/US]; 7218 Chatlake Drive, Huber heights, OH 45424 (US).</p> <p>(74) Agents: PEACOCK, Bruce, E. et al.; Biebel & French, 35 East First Street, Dayton, OH 45402 (US).</p>		<p>(81) Designated States: CA, JP, MX, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</p> <p>Published With international search report.</p>

(54) Title: SENSOR CAPSULE FOR CO₂ SENSOR



(57) Abstract

A sensor capsule (10) to facilitate positioning of an analyte sensitive element such as a CO₂ sensor at the end of a fiber optic probe, which discloses a dye layer defined by a dye well (52), fluorescent dye solution (54) and apertures (32, 19) formed in a silicone sensor membrane (46). A Teflon covering membrane (48) is positioned over the silicone membrane to retain the dye layer within the well, and perforated metal disc (44) is positioned beneath the silicone membrane (48) to provide support and resist swelling of the dye layer. The perforated metal disc, silicone membrane and Teflon membrane define a sandwich sensor structure which is positioned within an outer housing (16). An insert member (30) is positioned over the sandwich sensor structure and is snap fit into outer housing (16) to provide a sensor capsule (10) which may be removeably positioned/replaced in association with a probe tip used for forming the fiber optic CO₂ sensor.

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SENSOR CAPSULE FOR CO₂ SENSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates generally to instruments for measuring the concentration of a gas in a fluid, and more particularly relates to an improved sensor including a sensor capsule for facilitating positioning an analyte sensitive element at the end of an optical fiber probe.

10 2. Description of Related Art

 Various forms of analyte measuring instruments have been designed and developed for use in numerous medical and industrial applications. Among these devices are those that rely on optical properties of a sensing element containing a dye which is responsive to a particular analyte. When the dye interacts with the
15 analyte, the dye undergoes an optical change, such as a change of fluorescence, which is measurable and is directly related to the concentration of the analyte contained in the medium being sampled.

 The analyte sensitive substance or indicator is located in a sensor element typically including a permeable membrane allowing the analyte to permeate
20 and interact with the indicator. The indicator, typically a dye solution, has in prior devices been held trapped between the permeable membrane and an optical sensing surface, for example, the end of a probe, and has required a dye retaining mesh. A recognized need in the use of these sensors is the ability to interchange the element containing the indicator. It is desirable to change the element containing the
25 indicator for various reasons, including to avoid transfer of contamination when the sensor probe is applied to different sensing locations, or due to the dye leaching out of the sensor, or for other reasons which make it desirable to interchange sensor elements.

SUMMARY OF THE INVENTION

The present invention provides a sensor capsule for use in combination with a fiber optic sensor. In particular, the present invention is specifically designed for use in a carbon dioxide sensor.

5 The sensor capsule comprises a two-piece snap together cap including an outer housing portion and an inner insert portion which fits within the housing portion. The housing and insert portions cooperate to retain a perforated metal disc, a sensor membrane, a covering membrane and a sandwiched dye layer at a predetermined position within the sensor capsule.

10 The sensor membrane comprises a silicone membrane positioned in engagement with the perforated metal disc and includes an indentation defining a dye well containing an indicator dye solution. The covering membrane comprises a Teflon membrane positioned over the silicone membrane to retain the dye solution within the dye well.

15 The snap together design of the sensor capsule assembly holds the sandwiched dye layer in a rigid structure which facilitates attachment to and detachment from a sensor probe while protecting the dye layer.

 Therefore, it is an object of the present invention to provide a sensor capsule for facilitating mounting of an indicator element to a sensor probe.

20 It is a further object of the invention to provide a sensor capsule which includes sandwiched layers for retaining a dye solution.

 It is yet another object of the invention to provide a sensor capsule which provides a rigid housing for enclosing a sandwiched dye layer.

25 Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an exploded perspective view showing a probe assembly incorporating the sensor capsule of the present invention;

30 Fig. 2 is an exploded perspective view of the sensor capsule; and

Fig. 3 is a cross-sectional elevational view of the assembled sensor

capsule.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring initially to Fig. 1, the present invention provides a sensor capsule 10 which is adapted to fit on a probe housing 12 where it is held in place by a probe cap 14 positioned over the sensor capsule 10 and mounted to the housing 12. The probe housing 12 is of the type which is used with a fiber optic sensor system wherein fiber optic elements are used to transmit and detect light to and from a fluorescent dye indicator for measuring the concentration of an analyte, such as carbon dioxide.

Referring further to Figs. 2 and 3, the present invention is particularly directed to a self-contained structure defined by the sensor capsule 10 whereby the indicator or sensor dye may be conveniently brought into association with the probe housing 12 or interchanged with a different sensor capsule 10. The sensor capsule 10 comprises an outer housing 16 formed with a circular base portion 18 defining a base aperture 19, and four axially extending side walls 20 which are separated by slots 22. The distal ends of each of the side walls 20 includes a radially inwardly extending detent portion 24 having lower sides 26 located in axially spaced relation to an annular ledge 28 defined on the annular base portion 18 adjacent to a proximal end of the side walls 20.

The sensor capsule 10 further includes a cylindrical, inner insert member 30 defining an aperture 32 therethrough. In addition, an annular grooved or recessed area 34 is defined at one end of the insert member 30 extending radially inwardly from an outer surface 36 of the insert member 30. The insert member 30 is adapted to be positioned within the outer housing 16, with an annular lower surface 38 of the insert member 30 located adjacent to ledge 28 and the recessed area 34 engaged by the lower surfaces 26 of the detent portions 24. Further, it should be noted that the outer housing 16 is formed such that the side walls 20 will flex outwardly as the insert member 30 is inserted, and the detent portions 24 will snap over the recessed 34 when the insert member 30 reaches its final position to thereby positively retain the insert member 30 within the outer housing 16. Also, in order to

facilitate insertion of the insert member 30, the upper surfaces of the detent portions 24 are provided with inwardly and downwardly angled portions 40 which facilitate outward flexing of the side walls 20.

The outer housing 16 and insert member 30 cooperate to hold a
5 sandwiched sensor structure 42 comprising a perforated metal disc 44, a silicone sensor membrane 46 and a Teflon covering membrane 48. The perforated metal disc 44 is supported on a ledge 50 inside the outer housing 16, and the silicone membrane 46 is supported on top of the perforated disc 44. The silicone membrane 46 includes a dye well 52 containing a fluorescent dye solution 54. The Teflon membrane 48
10 acts to retain the dye solution 54 within the dye well 52.

When the perforated metal disc 44, silicone membrane 46, dye solution 54 and Teflon membrane 48 are positioned within the outer housing 16, and the insert member 30 is snapped into place, a lower end 56 of the insert member 30 engages the Teflon membrane 48 and rigidly retains the sandwiched sensor structure
15 42 in position at the lower end of the outer housing 16 whereby the dye solution 54 is physically retained between the silicone membrane 46 and Teflon membrane 48 through cooperation of the outer housing 16 and insert member 30.

When placed on the probe housing 12, a tip 58 of the probe housing 12 extends through the aperture 32 of the insert member 30 to the Teflon membrane
20 48, and the dye well 52 defines the optical path for the sensor. This optical path structure is in contrast to the typical prior art sensors which generally require a dye retaining mesh and wherein the dye solution may be trapped between a membrane and the optical sensing surface itself. Plus, the present invention retains the dye solution 54 in such a way that it may be positioned adjacent to the sensor surface at
25 the tip 58, or easily removed for use in combination with a different probe housing 12 or to be replaced by a different sensor capsule 10. It should also be understood that compression of the silicone membrane 46 is independent of the tolerances of the fit between the probe housing 12 and the probe cap 14 in that a shoulder 60 of the probe tip 58 rests in engagement with the distal ends of the side walls 20, and the
30 boundaries of the dye layer formed by the dye solution 54 within the dye well 52 are defined between the perforated metal disc 44 and the end of the probe tip 58

positioned at the Teflon membrane 48. In this manner, it is possible to construct the sensor capsule 10 such that the compression of the silicone membrane 30 is consistent from one sensor to another.

In a specific embodiment of the present invention, the outer housing 5 16 and insert member 30 are formed of PEEK, which is a steam sterilizable USP Class VI plastic. The perforated metal disc is made of 0.005" thick 316 stainless steel having perforation holes 60 with a diameter of 0.010" and spaced apart with 0.015" on-center spacing. The silicone membrane 46 is injection molded with a wall thickness of 0.025" and a well thickness or depth of 0.010", and is preferably black to 10 prevent transmission of light therethrough. The Teflon membrane 48 is formed 0.002" thick, and the dye solution constrained between the Teflon membrane 48 and the silicone membrane 46 is a measured amount of photo-reactive HPTS dye in a buffered solution. The perforated metal disc 44 serves as a mechanical constraint for swelling of the dye layer 54 as well as providing a short diffusion path for dissolved 15 CO₂ to penetrate through. Further, the present design reduces the length of the diffusion path by 80% in comparison to prior art sensors, which feature helps to reduce the response time of the sensor.

From the above description, it should be apparent that the present invention provides certain advantages over prior art sensors including:

- 20 1. A sandwiched dye layer in a dye well;
2. A dye well defining the optical path of the sensor and eliminating the need for a dye retaining mesh;
3. A perforated metal support for the outer or silicone membrane wherein the perforated metal and the probe tip provide two 25 solid surfaces confining the boundaries of the sandwiched dye layer;
4. A snap together cap design which facilitates assembly and which eliminates the need for O-ring seals found in prior art sensors wherein the snap together design holds the sandwiched 30 dye layer assembly in a rigid structure;
5. A structure providing membrane compression which is

independent of the geometric tolerances of the probe housing containing the probe tip and the probe cap wherein the outer housing of the sensor capsule rests against the shoulder of the probe tip; and

- 5 6. The provision of a sensor capsule which is interchangeable for mounting on multiple probe housings.

While the form of apparatus herein described constitutes a preferred embodiment of this invention, it is to be understood that the invention is not limited to this precise form of apparatus, and that changes may be made therein without
10 departing from the scope of the invention which is defined in the appended claims.

--CLAIMS--

1. A sensor for measuring the concentration of an analyte in a solution, the sensor comprising:
 - a sensor membrane diffusible to an analyte to be measured;
 - an indentation defining a well in said sensor membrane;
 - 5 a photo-reactive dye solution located in said well and defining a dye layer; and
 - a covering membrane positioned over said well to retain said dye solution.

2. The sensor of claim 1 further including a thin perforated element supporting said sensor membrane, said thin perforated element defining a diffusion path for passage of said analyte to said sensor membrane.

3. The sensor of claim 2 further including a housing and an insert member wherein said covering membrane, sensor membrane, dye layer and thin perforated element are located within said housing and sandwiched between said insert member and said housing.

4. The sensor of claim 3 wherein said insert member cooperates with said housing in a snap fit to retain said insert within said housing.

5. The sensor of claim 3 wherein said insert member includes an aperture for receiving a tip of a fiber optic probe therein.

6. The sensor of claim 2 wherein said thin perforated element comprises a stainless steel member having a plurality of perforations.

7. The sensor of claim 1 wherein said sensor membrane comprises silicone.

8. The sensor of claim 1 wherein said covering membrane comprises Teflon.

9. The sensor of claim 1 wherein said dye solution comprises photo-reactive HPTS dye.

FIG -1

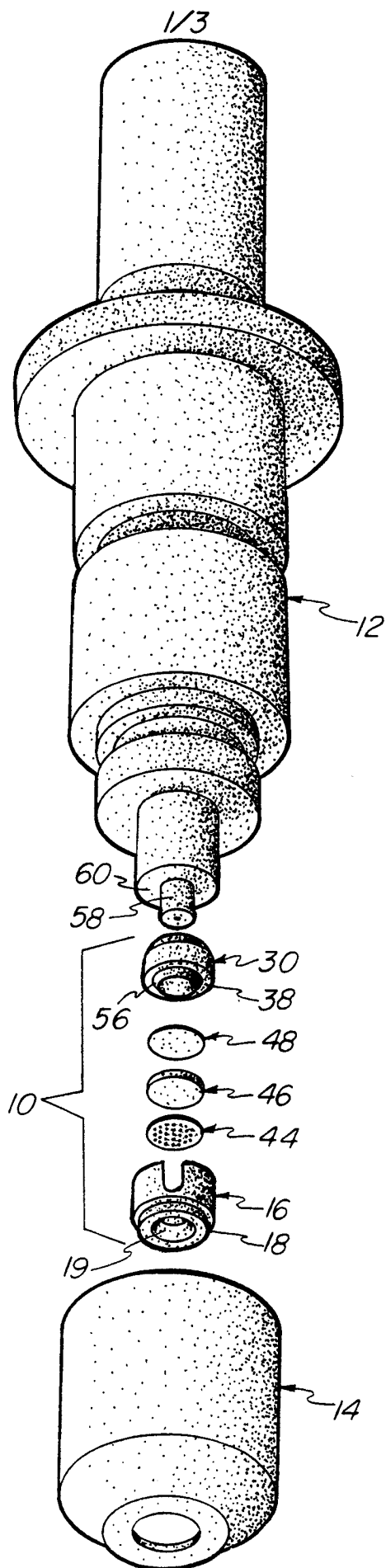
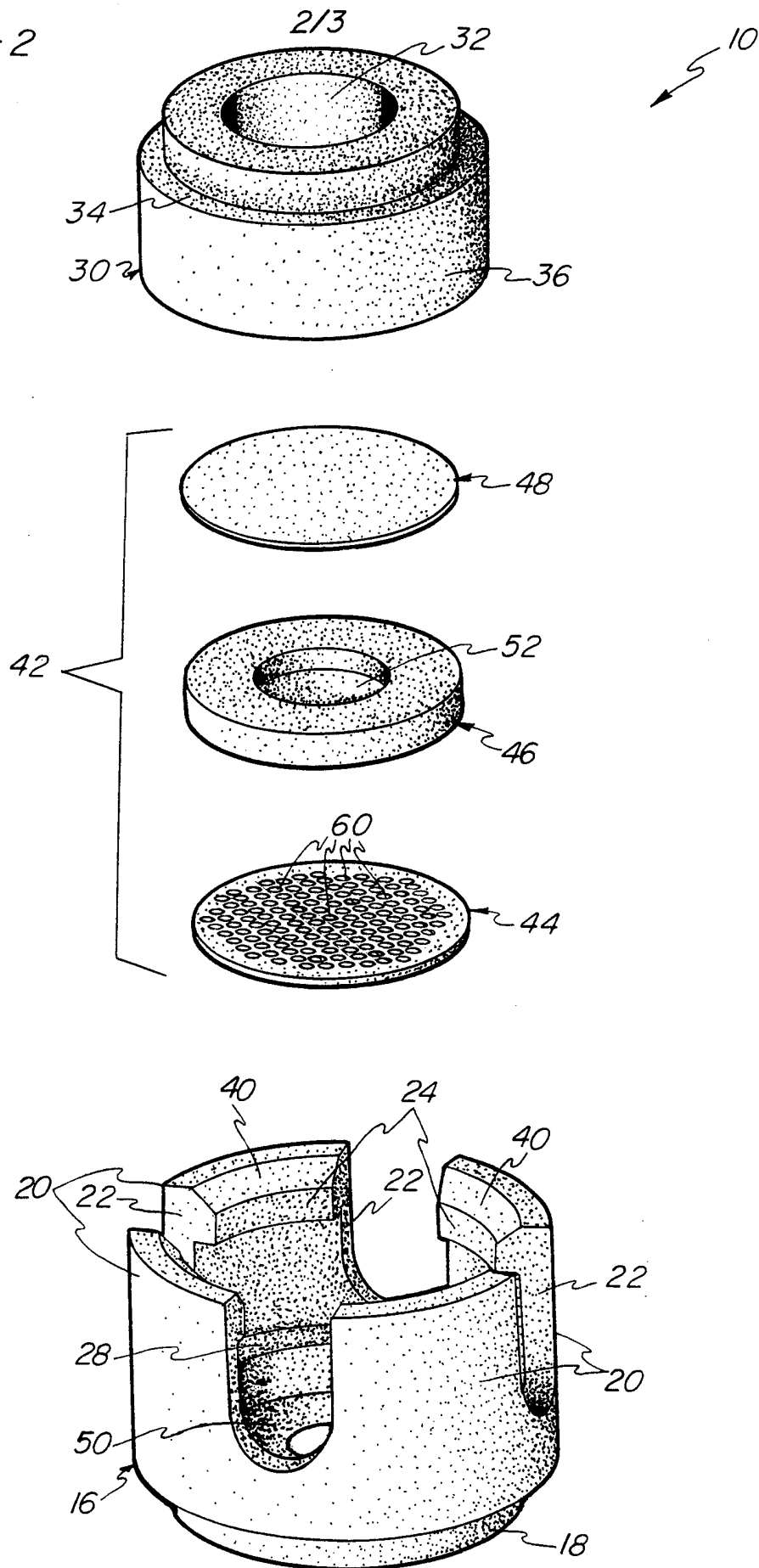


FIG-2



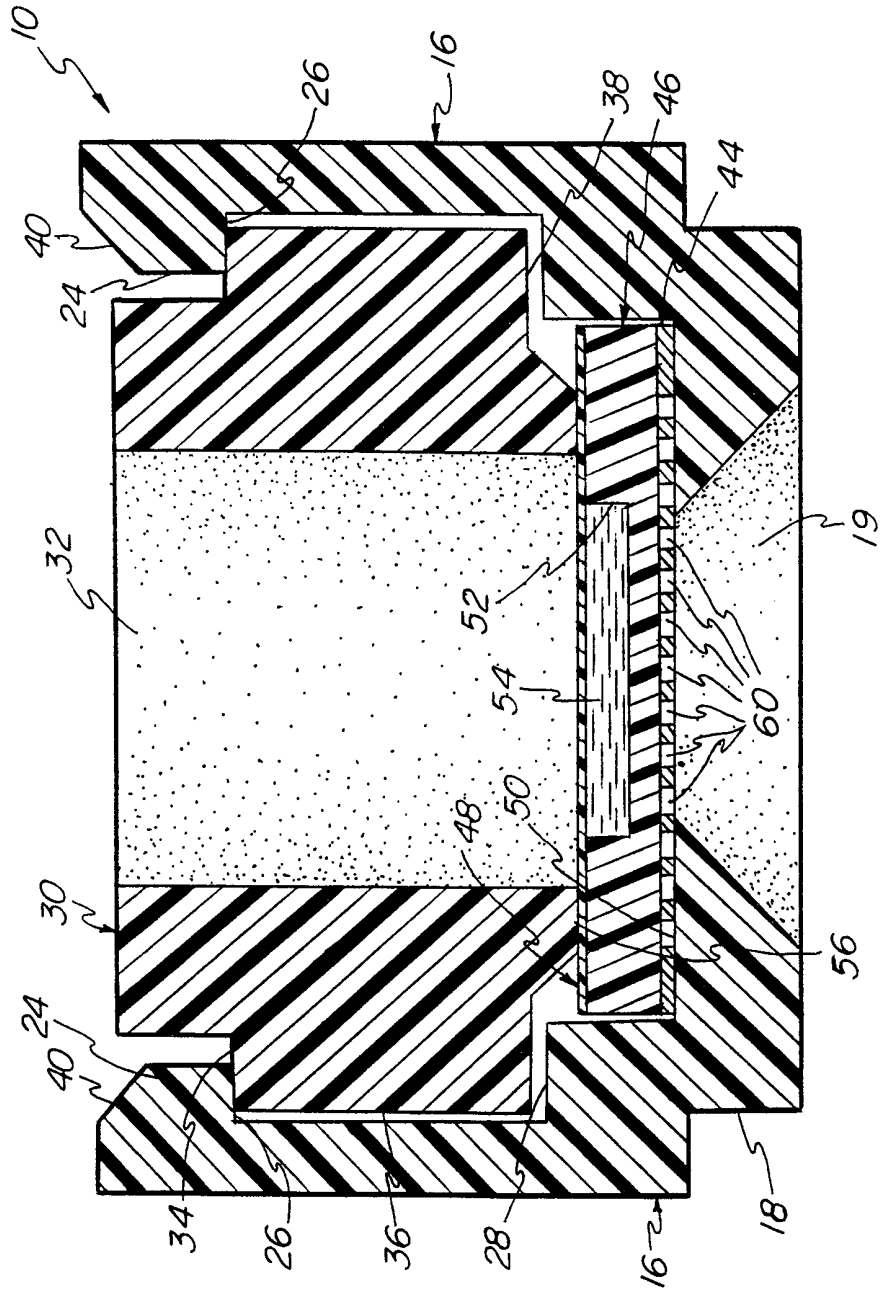


FIG - 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT:US99-25506

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G01N 27/06, 31/06, 33/00, 33/553; G01L 07/08; A61B 05/00
US CL : Please See Extra Sheet.

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)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
None

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

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,343,768 A (KIMURA) 10 August 1982 (10.08.82) all	1-9
A	US 4,198,851 A (JANATA) 22 April 1980 (22.04.80) all	1, 7 and 8
Y	US 5,506,148 A (MUNKHOLM) 09 April 1996 (09.04.96), Col. 17, line 8 - Col. 19, line 56 and Col. 13, line 7 - Col. 14, line 47.	1, 5, 8 & 9
A	US 5,244,636 A (WALT et al.) 14 September 1993 (14.09.93) all	1-2, 5 & 8
A	US 5,252,494 A (WALT) 12 October 1993 (12.10.93) all	1, 5 and 8
A	US 4,422,129 A (BRIANT et al.) 20 December 1983 (20.12.83) all	1 and 7

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

* Special categories of cited documents.	*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
A document defining the general state of the art which is considered to be of particular relevance	*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
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/25506

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,557,900 A (HEITZMANN) 10 December 1985 (10.12.85), Col. 1, line 23 - Col. 3, line 56, Col. 3, line 2 - Col. 4, line 63 along with Figures 1-2 & 4.	1-2, 4-5 and 7-8
A,P	US 5,856,175 A (THORPE et al.) 05 January 1999 (05.01.99).	1-8
Y	US 5,608,167 A (HALE et al.) 04 March 1997 (04.03.97), Col. 5, line 1 - Col. 6, line 50, Col. 7, lines 2-55, Col. 1, lines 12-54, and Column 3, line 2 - Col. 4, line 41 along with Figure 1.	1-4, 6 & 8
A,P	US 5,866,433 A (SCHALKHAMMER et al.) 02 February 1999 (02.02.99) all	1, 2 and 5
A	US 5,710,012 A (NIKOLYUKIN et al.) 20 January 1998 (20.01.98) all	1
A,P	US 5,889,195 A (KANEBLEI) 30 March 1999 (30.03.99) all	1-2, 5 & 8
Y	US 5,141,873 A (STEUDLE et al.) 25 August 1992 (25.08.92), Col. 12, lines 7-66, Col. 9, line 16 - Col. 10, line 11 and Col. 1, lines 9-67 along with Figure 3.	1-4, 6 & 8
A	US 4,003,707 A (LUBBERS et al.) 18 January 1977 (18.01.77) all	1-3, 5-6 and 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/25506

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

073/19.12, 19.01, 64.47, 61.71, 61.48, 64.56; 422/86.00, 82.09, 82.05

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

073/19.12, 19.01, 19.10, 53.01, 31.05, 64.47, 61.71, 61.48, 64.56, 61.41, 61.63, 61.72, 61.73; 422/86.00, 82.09, 82.05, 85.00, 88.00, 82.09, 82.07, 68.10

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

WEST/EAST computer database search terms: analyte, contaminant, particle, particulate, solute, species; sensor, detector, analyzer, probe, gauge; solution, suspension, solvent, mixture, fluid, liquid, water; membrane, filter, barrier; osmosis, diffusion, permeable, permeate, charge transfer, kinetic transfer; indentation, recess, well, trench, foxhole, pool, valley, depression; dye, color-change, photometric, photo-reaction, litmus, bleach, fluorescence, phosphorescence, photo-sensitive; layer, covering, coating, film