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(54) **LUMENALLY-ACTIVE DEVICE**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

3,391,697 A 7/1968 Greatbatch
3,802,417 A 4/1974 Lang
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2 426 746 A1 5/2002
CA 2 433 147 A1 7/2002
(Continued)

OTHER PUBLICATIONS

Christensen, Bill; "Propulsion System for 'Fantastic Voyage' Robot"; Technovelgy.com; pp. 1-4; Technovelgy.com; located http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=811, printed on Jan. 4, 2007.
(Continued)

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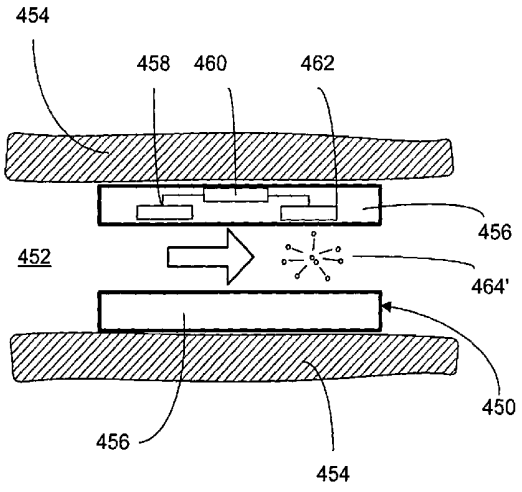
(57) **ABSTRACT**

Embodiments of a lumenally-active system and method of use and control thereof are disclosed. According to various embodiments, a lumenally-active device is positioned in a body lumen of an organism, where the device may sense a parameter of a fluid in the body lumen and perform an action on the fluid. Control logic and/or circuitry may be located on the device, or the system may include a separate control module. Liquid or gaseous fluids may be treated by embodiments of the device. Actions may include, for example, modification of a body fluid by addition or removal of a material, or by modification of a property of a body fluid or a component thereof.

18 Claims, 19 Drawing Sheets



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(56) **References Cited**

U.S. PATENT DOCUMENTS

3,821,469	A	6/1974	Whetstone et al.
3,837,339	A	9/1974	Aisenberg et al.
3,941,127	A	3/1976	Froning
3,983,474	A	9/1976	Kuipers
4,054,881	A	10/1977	Raab
4,119,900	A	10/1978	Kremnitz
4,202,349	A	5/1980	Jones
4,262,306	A	4/1981	Renner
4,267,831	A	5/1981	Aguilar
4,314,251	A	2/1982	Raab
4,317,078	A	2/1982	Weed et al.
4,339,953	A	7/1982	Iwasaki
4,367,741	A	1/1983	Michaels
4,396,885	A	8/1983	Constant
4,403,321	A	9/1983	Krüger
4,418,422	A	11/1983	Richter et al.
4,431,005	A	2/1984	McCormick
4,583,190	A	4/1986	Salb
4,585,652	A	4/1986	Miller et al.
4,628,928	A	12/1986	Lowell
4,638,798	A	1/1987	Shelden et al.
4,642,786	A	2/1987	Hansen
4,651,732	A	3/1987	Frederick
4,658,214	A	4/1987	Petersen
4,714,460	A	12/1987	Calderon
4,717,381	A	1/1988	Papantonakos
4,733,661	A	3/1988	Palestrant
4,750,488	A	6/1988	Wuchinich et al.
4,763,667	A	8/1988	Manzo
4,769,006	A	9/1988	Papantonakos
4,771,772	A	9/1988	DeWitt
4,785,806	A	11/1988	Deckelbaum
4,795,434	A	1/1989	Kujawski
4,800,898	A	1/1989	Hess et al.
4,805,615	A	2/1989	Carol
4,817,601	A	4/1989	Roth et al.
4,871,351	A	10/1989	Feingold
4,889,526	A	12/1989	Rauscher et al.
4,905,689	A	3/1990	Stack et al.
4,943,296	A	7/1990	Funakubo et al.
4,944,659	A	7/1990	Labbe et al.
4,962,453	A	10/1990	Pong et al.
4,981,138	A	1/1991	Deckelbaum et al.
4,994,071	A	2/1991	MacGregor
5,019,372	A	5/1991	Folkman et al.
5,031,109	A	7/1991	Gloton
5,042,494	A	8/1991	Alfano
5,046,501	A	9/1991	Crilly
5,051,906	A	9/1991	Evans, Jr. et al.
5,078,140	A	1/1992	Kwoh
5,086,401	A	2/1992	Glassman et al.
5,115,137	A	5/1992	Andersson-Engels et al.
5,153,827	A	10/1992	Coutre et al.
5,165,064	A	11/1992	Mattaboni
5,176,638	A	1/1993	Don Michael
5,188,111	A	2/1993	Yates et al.
5,204,814	A	4/1993	Noonan et al.
5,234,457	A	8/1993	Andersen
5,269,303	A	12/1993	Wernicke et al.
5,275,594	A	1/1994	Baker et al.
5,279,607	A	1/1994	Schentag et al.
5,289,557	A	2/1994	Sheinis et al.
5,293,872	A	3/1994	Alfano et al.
5,310,404	A	5/1994	Gyory et al.
5,313,835	A	5/1994	Dunn
5,314,451	A	5/1994	Mulier
5,321,614	A	6/1994	Ashworth
5,331,966	A	7/1994	Bennett et al.
5,335,657	A	8/1994	Terry, Jr. et al.
5,337,732	A	8/1994	Grundfest et al.
5,338,625	A	8/1994	Bates et al.
5,339,051	A	8/1994	Koehler et al.
5,350,375	A	9/1994	Deckelbaum et al.
5,353,807	A	10/1994	DeMarco
5,374,285	A	12/1994	Vaiani et al.
5,381,786	A	1/1995	Spears
5,386,741	A	2/1995	Rennex
5,395,390	A	3/1995	Simon et al.
5,398,670	A	3/1995	Ortiz et al.
5,403,311	A	4/1995	Abele et al.
5,411,551	A	5/1995	Winston et al.
5,437,660	A	8/1995	Johnson et al.
5,476,450	A	12/1995	Ruggio
5,497,147	A	3/1996	Arms et al.
5,502,638	A	3/1996	Takenaka
5,507,287	A	4/1996	Palcic et al.
5,522,394	A	6/1996	Zurbrügg
5,551,953	A	9/1996	Lattin et al.
5,554,914	A	9/1996	Miyazawa
5,569,968	A	10/1996	Lal et al.
5,574,347	A	11/1996	Neubauer
5,589,932	A	12/1996	García-Rubio et al.
5,593,434	A	1/1997	Williams
5,599,324	A	2/1997	McAlister et al.
5,604,531	A	2/1997	Iddan et al.
5,610,488	A	3/1997	Miyazawa
5,624,398	A	4/1997	Smith et al.
5,632,754	A	5/1997	Farley et al.
5,634,920	A	6/1997	Hohla
5,643,296	A	7/1997	Hundertmark et al.
5,662,587	A	9/1997	Grundfest et al.
5,669,874	A	9/1997	Feiring
5,670,329	A	9/1997	Oberhardt
5,674,276	A	10/1997	Andersen et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,688,269 A 11/1997 Newton et al.
5,695,457 A 12/1997 St. Goar et al.
5,697,967 A 12/1997 Dinh et al.
5,702,432 A 12/1997 Chen et al.
5,705,293 A 1/1998 Hobson
5,728,089 A 3/1998 Lal et al.
5,735,276 A 4/1998 Lemelson
5,737,279 A 4/1998 Carter
5,758,298 A 5/1998 Guldner
5,782,798 A 7/1998 Rise
5,804,563 A 9/1998 Still et al.
5,807,395 A 9/1998 Mulier et al.
5,819,736 A 10/1998 Avny et al.
5,827,190 A 10/1998 Palcic et al.
5,830,179 A 11/1998 Mikus et al.
5,830,207 A 11/1998 Leeb et al.
5,831,012 A 11/1998 Nilsson et al.
5,833,603 A 11/1998 Kovacs et al.
5,843,139 A 12/1998 Goedeke et al.
5,855,801 A 1/1999 Lin et al.
5,865,754 A 2/1999 Sevick-Muraca et al.
5,865,828 A 2/1999 Jeng
5,873,835 A 2/1999 Hastings et al.
5,908,027 A 6/1999 Butterfield et al.
5,921,982 A 7/1999 Lesh et al.
5,931,788 A 8/1999 Keen et al.
5,947,119 A 9/1999 Reznick
5,951,600 A 9/1999 Lemelson
5,954,675 A 9/1999 Dellagatta
5,964,773 A 10/1999 Greenstein
6,004,269 A 12/1999 Crowley et al.
6,016,449 A 1/2000 Fischell et al.
6,019,729 A 2/2000 Itoigawa et al.
6,022,316 A 2/2000 Eppstein et al.
6,053,873 A 4/2000 Govari et al.
6,058,932 A * 5/2000 Hughes 128/200.24
6,086,528 A 7/2000 Adair
6,102,845 A 8/2000 Woodard et al.
6,108,597 A 8/2000 Kirchner et al.
6,111,520 A 8/2000 Allen et al.
6,128,538 A 10/2000 Fischell et al.
6,134,474 A 10/2000 Fischell et al.
6,149,603 A * 11/2000 Parker 600/532
6,159,230 A 12/2000 Samuels
6,164,284 A 12/2000 Schulman et al.
6,165,170 A 12/2000 Wynne et al.
6,170,488 B1 1/2001 Spillman, Jr. et al.
6,175,757 B1 1/2001 Watkins et al.
6,179,789 B1 1/2001 Tu et al.
6,185,452 B1 2/2001 Schulman et al.
6,186,986 B1 2/2001 Berg et al.
6,187,599 B1 2/2001 Asher et al.
6,197,013 B1 3/2001 Reed et al.
6,219,577 B1 4/2001 Brown, III et al.
6,221,099 B1 4/2001 Andersen et al.
6,240,312 B1 * 5/2001 Alfano et al. 600/476
6,240,316 B1 5/2001 Richmond et al.
6,248,345 B1 6/2001 Goldenheim et al.
6,249,076 B1 6/2001 Madden et al.
6,255,361 B1 7/2001 Rajagopalan et al.
6,255,793 B1 7/2001 Peless et al.
6,258,576 B1 7/2001 Richards-Kortum et al.
6,263,245 B1 7/2001 Snell
6,278,379 B1 8/2001 Allen et al.
6,280,386 B1 8/2001 Alfano et al.
6,289,270 B1 9/2001 Baumgarten
6,290,668 B1 * 9/2001 Gregory et al. 604/22
6,295,990 B1 10/2001 Lewis et al.
6,296,638 B1 10/2001 Davison et al.
6,322,532 B1 11/2001 D'Sa et al.
6,337,997 B1 1/2002 Rise
6,372,248 B1 4/2002 Qin et al.
6,383,162 B1 5/2002 Sugarbaker
6,384,741 B1 5/2002 O'Leary, Sr.
6,385,472 B1 5/2002 Hall et al.
6,398,280 B1 6/2002 Parker et al.
6,400,980 B1 6/2002 Lemelson
6,402,678 B1 6/2002 Fischell et al.
6,409,674 B1 6/2002 Brockway et al.
6,417,641 B2 7/2002 Peless et al.
6,431,171 B1 8/2002 Burton
6,436,120 B1 8/2002 Meglin
6,442,413 B1 8/2002 Silver
6,450,937 B1 9/2002 Mercereau et al.
6,453,199 B1 9/2002 Kobozev
6,464,687 B1 10/2002 Ishikawa et al.
6,475,639 B2 11/2002 Shahinpoor et al.
6,490,483 B2 12/2002 Willis
6,491,618 B1 12/2002 Ganz
6,493,607 B1 12/2002 Bourne et al.
6,497,714 B1 12/2002 Ishikawa et al.
6,500,174 B1 12/2002 Maguire et al.
6,512,940 B1 1/2003 Brabec et al.
6,512,949 B1 1/2003 Combs et al.
6,512,950 B2 1/2003 Li et al.
6,514,237 B1 2/2003 Maseda
6,530,950 B1 3/2003 Alvarado et al.
6,547,723 B1 4/2003 Ouchi
6,547,825 B1 4/2003 Shimizu et al.
6,548,982 B1 4/2003 Papanikolopoulos et al.
6,554,798 B1 4/2003 Mann et al.
6,564,106 B2 5/2003 Guck et al.
6,575,969 B1 6/2003 Rittman, III et al.
6,584,352 B2 6/2003 Combs et al.
6,585,763 B1 7/2003 Keilman et al.
6,591,137 B1 7/2003 Fischell et al.
6,592,567 B1 7/2003 Levin et al.
6,597,954 B1 7/2003 Pless et al.
6,607,553 B1 8/2003 Healy et al.
6,612,982 B1 9/2003 Ouchi
6,616,676 B2 9/2003 Bashiri et al.
6,623,519 B2 9/2003 Edwin et al.
6,631,290 B1 10/2003 Guck et al.
6,632,216 B2 10/2003 Houzego et al.
6,638,273 B1 10/2003 Farley et al.
6,648,908 B2 11/2003 Dobak, III et al.
6,666,860 B1 12/2003 Takahashi
6,669,683 B2 12/2003 Santini, Jr. et al.
6,673,042 B1 1/2004 Samson et al.
6,673,363 B2 1/2004 Luo et al.
6,679,893 B1 1/2004 Tran
6,709,388 B1 3/2004 Mosse et al.
6,711,423 B2 3/2004 Colvin, Jr.
6,712,835 B2 3/2004 Mazzocchi et al.
6,719,684 B2 4/2004 Kim et al.
6,723,092 B2 4/2004 Brown et al.
6,733,485 B1 5/2004 Whitehurst et al.
6,735,474 B1 5/2004 Loeb et al.
6,735,475 B1 5/2004 Whitehurst et al.
6,743,211 B1 6/2004 Prausnitz et al.
6,754,536 B2 6/2004 Swoyer et al.
6,755,802 B2 6/2004 Bell
6,755,803 B1 6/2004 Le et al.
6,764,441 B2 7/2004 Chiel et al.
6,770,071 B2 8/2004 Woloszko et al.
6,773,429 B2 8/2004 Sheppard, Jr. et al.
6,776,165 B2 8/2004 Jin
6,797,522 B1 9/2004 Still et al.
6,802,811 B1 10/2004 Slepian
6,816,632 B1 11/2004 Slice
6,817,998 B2 11/2004 LaHaye
6,824,508 B2 11/2004 Kim et al.
6,824,510 B2 11/2004 Kim et al.
6,824,561 B2 11/2004 Soykan et al.
RE38,670 E 12/2004 Asah et al.
6,834,118 B2 12/2004 Kim
6,849,183 B2 2/2005 Gorsuch et al.
6,855,115 B2 2/2005 Fonseca et al.
6,860,867 B2 3/2005 Seward et al.
6,861,001 B2 3/2005 Lee et al.
6,866,626 B2 3/2005 Long et al.
6,869,430 B2 3/2005 Balbierz et al.
6,875,209 B2 4/2005 Zvuloni et al.
6,882,881 B1 4/2005 Lesser et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,889,091 B2 5/2005 Hine et al.
6,890,303 B2 5/2005 Fitz
6,898,464 B2 5/2005 Edell et al.
6,911,004 B2 6/2005 Kim et al.
6,911,496 B2 6/2005 Rhee et al.
6,920,359 B2 7/2005 Meadows et al.
6,921,413 B2 7/2005 Mahadevan-Jansen et al.
6,925,357 B2 8/2005 Wang et al.
6,929,636 B1 8/2005 Von Alten
6,936,003 B2 8/2005 Iddan
6,939,290 B2 9/2005 Iddan
6,939,376 B2 9/2005 Shulze et al.
6,950,707 B2 9/2005 Whitehurst
6,953,589 B1 10/2005 Trautman et al.
6,958,034 B2 10/2005 Iddan
6,959,215 B2 10/2005 Gliner et al.
6,960,227 B2 11/2005 Jones et al.
6,963,792 B1 11/2005 Green
6,984,205 B2 1/2006 Gazdzinski
6,984,952 B2 1/2006 Peless et al.
6,991,617 B2 1/2006 Hektner et al.
7,003,352 B1 2/2006 Whitehurst
7,013,177 B1 3/2006 Whitehurst et al.
7,020,231 B1 3/2006 Frey et al.
7,027,134 B1 4/2006 Garcia-Rubio et al.
7,037,343 B2 5/2006 Imran
7,039,453 B2 5/2006 Mullick et al.
7,042,184 B2 5/2006 Oleynikov et al.
7,044,911 B2 5/2006 Drinan et al.
RE39,133 E 6/2006 Clayton et al.
7,060,793 B2 6/2006 Tsien et al.
7,066,180 B2 6/2006 Aylsworth et al.
7,066,879 B2 6/2006 Fowler et al.
7,083,578 B2 8/2006 Lewkowicz et al.
7,101,386 B2 9/2006 Dobak, III
7,115,109 B2 10/2006 Gerdts et al.
7,118,531 B2 10/2006 Krill
7,125,382 B2 10/2006 Zhou et al.
7,131,979 B2 11/2006 DiCarlo et al.
7,160,258 B2 1/2007 Imran et al.
7,171,285 B2 1/2007 Kim et al.
7,181,261 B2 * 2/2007 Silver et al. 600/345
7,194,063 B2 3/2007 Dilmanian et al.
7,195,641 B2 3/2007 Palmaz et al.
7,212,110 B1 5/2007 Martin et al.
7,214,182 B2 5/2007 Shimizu et al.
7,228,162 B2 6/2007 Ward et al.
7,236,821 B2 * 6/2007 Cates et al. 607/2
7,244,232 B2 7/2007 Connelly et al.
7,245,954 B2 7/2007 Glukhovsky
7,297,113 B1 11/2007 Russell et al.
7,341,577 B2 3/2008 Gill
7,359,574 B2 4/2008 Lennon et al.
7,365,509 B2 4/2008 Park et al.
7,365,614 B2 4/2008 McCorquodale et al.
7,383,071 B1 6/2008 Russell et al.
7,398,734 B1 7/2008 Jean
7,451,537 B2 11/2008 Liu et al.
7,486,967 B2 2/2009 Pan et al.
7,510,699 B2 3/2009 Black et al.
7,572,228 B2 * 8/2009 Wolinsky et al. 600/486
7,596,403 B2 9/2009 Horn
7,625,338 B2 12/2009 Gilad et al.
7,684,840 B2 3/2010 Palti
7,713,196 B2 5/2010 Baker, Jr.
7,736,300 B2 6/2010 Ziegler et al.
7,744,542 B2 * 6/2010 Piaget et al. 600/529
7,801,626 B2 * 9/2010 Moser 607/126
7,840,271 B2 * 11/2010 Kieval et al. 607/44
7,857,767 B2 12/2010 Ferren et al.
7,894,882 B2 * 2/2011 Mullick et al. 600/476
7,967,016 B2 6/2011 Anderson et al.
8,019,413 B2 9/2011 Ferren et al.
8,024,036 B2 9/2011 Ferren et al.
8,036,731 B2 10/2011 Kimchy et al.
8,055,329 B2 11/2011 Kimchy et al.
8,140,141 B2 3/2012 McGreevy et al.
8,180,436 B2 5/2012 Boyden et al.
8,294,333 B2 10/2012 Salomon et al.
8,317,688 B2 11/2012 Glozman et al.
8,323,263 B2 12/2012 Wood, Jr.
2001/0029348 A1 10/2001 Willis
2001/0039385 A1 * 11/2001 Ellenz 600/524
2001/0051766 A1 12/2001 Gazdzinski
2002/0026188 A1 2/2002 Balbierz et al.
2002/0049370 A1 4/2002 Laufer et al.
2002/0065509 A1 5/2002 Lebel et al.
2002/0068080 A1 6/2002 Lerner
2002/0077369 A1 * 6/2002 Noolandi et al. 514/958
2002/0090388 A1 7/2002 Humes et al.
2002/0103417 A1 8/2002 Gazdzinski
2002/0107573 A1 8/2002 Steinberg
2002/0111601 A1 8/2002 Thompson
2002/0116029 A1 8/2002 Miller et al.
2002/0116034 A1 8/2002 Miller et al.
2002/0120263 A1 8/2002 Brown et al.
2002/0123674 A1 9/2002 Plicchi et al.
2002/0123770 A1 9/2002 Combs et al.
2002/0147480 A1 10/2002 Mamayek
2002/0156462 A1 10/2002 Stultz
2002/0165592 A1 11/2002 Glukhovsky et al.
2002/0169436 A1 11/2002 Gurm et al.
2002/0171385 A1 11/2002 Kim et al.
2002/0183721 A1 12/2002 Santini, Jr. et al.
2002/0188323 A1 12/2002 Penner et al.
2002/0193679 A1 12/2002 Malave et al.
2002/0193874 A1 12/2002 Crowley
2002/0198470 A1 12/2002 Imran et al.
2002/0198521 A1 12/2002 Maguire
2002/0198604 A1 12/2002 Schulman et al.
2003/0004403 A1 * 1/2003 Drinan et al. 600/301
2003/0023150 A1 1/2003 Yokoi et al.
2003/0024534 A1 2/2003 Silvestri et al.
2003/0040704 A1 2/2003 Dorros et al.
2003/0060723 A1 3/2003 Joo et al.
2003/0065250 A1 4/2003 Chiel et al.
2003/0065358 A1 4/2003 Frecker et al.
2003/0069475 A1 4/2003 Banik et al.
2003/0069523 A1 4/2003 Williams et al.
2003/0078485 A1 4/2003 Hartlep
2003/0093031 A1 5/2003 Long et al.
2003/0097082 A1 5/2003 Purdy et al.
2003/0151524 A1 8/2003 Clark
2003/0152823 A1 8/2003 Heller
2003/0153866 A1 8/2003 Long et al.
2003/0158584 A1 8/2003 Cates et al.
2003/0163177 A1 8/2003 Eggers et al.
2003/0167000 A1 9/2003 Mullick et al.
2003/0171738 A1 9/2003 Konieczynski et al.
2003/0191430 A1 10/2003 D'Andrea et al.
2003/0214579 A1 11/2003 Iddan
2003/0214580 A1 11/2003 Iddan
2004/0008853 A1 1/2004 Pelrine et al.
2004/0018508 A1 1/2004 Friedman
2004/0019374 A1 1/2004 Hojeibane et al.
2004/0034332 A1 2/2004 Uhland
2004/0044332 A1 3/2004 Stergiopulos
2004/0049240 A1 3/2004 Gerber et al.
2004/0064093 A1 4/2004 Hektner et al.
2004/0073177 A1 4/2004 Hickle
2004/0073190 A1 4/2004 Deem et al.
2004/0092825 A1 5/2004 Madar et al.
2004/0097805 A1 5/2004 Verard et al.
2004/0097819 A1 5/2004 Duarte
2004/0098030 A1 5/2004 Makower et al.
2004/0111019 A1 6/2004 Long
2004/0133147 A1 7/2004 Woo
2004/0138517 A1 7/2004 Osorio et al.
2004/0147939 A1 7/2004 Rabkin et al.
2004/0148034 A1 7/2004 Kagan et al.
2004/0152988 A1 8/2004 Weirich
2004/0162469 A1 8/2004 Imran
2004/0162501 A1 8/2004 Imran
2004/0176664 A1 9/2004 Iddan

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0193010	A1	9/2004	Fujimori et al.	
2004/0193235	A1*	9/2004	Altshuler et al.	607/88
2004/0199246	A1	10/2004	Chu et al.	
2004/0220552	A1	11/2004	Heruth et al.	
2004/0225325	A1	11/2004	Bonutti	
2004/0225326	A1	11/2004	Weiner et al.	
2004/0230182	A1	11/2004	Heruth et al.	
2004/0260278	A1	12/2004	Anderson et al.	
2004/0260391	A1	12/2004	Santini, Jr. et al.	
2004/0267240	A1	12/2004	Gross et al.	
2005/0004474	A1	1/2005	Iddan	
2005/0004553	A1	1/2005	Douk	
2005/0021023	A1	1/2005	Guglielmi et al.	
2005/0027236	A1	2/2005	Douk	
2005/0043583	A1	2/2005	Killmann et al.	
2005/0058701	A1	3/2005	Gross et al.	
2005/0062562	A1	3/2005	Ries	
2005/0065592	A1	3/2005	Holzer	
2005/0069925	A1	3/2005	Ford et al.	
2005/0079132	A1	4/2005	Wang et al.	
2005/0096712	A1	5/2005	Abraham-Fuchs et al.	
2005/0107870	A1	5/2005	Wang et al.	
2005/0113460	A1	5/2005	Glick	
2005/0113745	A1	5/2005	Stultz	
2005/0121411	A1	6/2005	Cohen	
2005/0126916	A1	6/2005	Lockard et al.	
2005/0137577	A1	6/2005	Heruth et al.	
2005/0149170	A1	7/2005	Tassel et al.	
2005/0151524	A1	7/2005	Sae-Ueng et al.	
2005/0171418	A1	8/2005	Lin	
2005/0171434	A1	8/2005	Madden et al.	
2005/0177223	A1	8/2005	Palmaz	
2005/0177239	A1	8/2005	Steinberg	
2005/0182482	A1	8/2005	Wang et al.	
2005/0197701	A1	9/2005	Steinberg	
2005/0203613	A1	9/2005	Arney et al.	
2005/0215911	A1	9/2005	Alfano et al.	
2005/0216074	A1	9/2005	Sahatjian et al.	
2005/0221529	A1	10/2005	Bang et al.	
2005/0228259	A1	10/2005	Glukhovsky et al.	
2005/0234393	A1	10/2005	Wood, Jr.	
2005/0234440	A1	10/2005	Wood, Jr.	
2005/0238689	A1	10/2005	Carpenter et al.	
2005/0272806	A1	12/2005	Falotico et al.	
2005/0272974	A1	12/2005	Iddan	
2005/0277839	A1	12/2005	Alderman et al.	
2005/0277912	A1	12/2005	John	
2005/0278020	A1	12/2005	Wang et al.	
2006/0004395	A1	1/2006	Chiel et al.	
2006/0009810	A1	1/2006	Mann et al.	
2006/0015146	A1	1/2006	Girouard et al.	
2006/0037617	A1*	2/2006	Walke et al.	128/207.15
2006/0042631	A1	3/2006	Martin et al.	
2006/0058647	A1	3/2006	Strommer et al.	
2006/0074479	A1	4/2006	Bailey et al.	
2006/0119304	A1	6/2006	Farritor et al.	
2006/0152309	A1	7/2006	Mintchev et al.	
2006/0167339	A1	7/2006	Gilad et al.	
2006/0169294	A1	8/2006	Kaler et al.	
2006/0173444	A1	8/2006	Choy et al.	
2006/0195015	A1	8/2006	Mullick et al.	
2006/0235275	A1	10/2006	Rabinovitz et al.	
2006/0241577	A1	10/2006	Balbierz et al.	
2006/0241717	A1	10/2006	Whitehurst et al.	
2006/0252987	A1	11/2006	Hasegawa et al.	
2007/0010868	A1	1/2007	Ferren et al.	
2007/0066929	A1	3/2007	Ferren et al.	
2007/0083099	A1	4/2007	Henderson et al.	
2007/0088334	A1	4/2007	Hillis et al.	
2007/0100398	A1	5/2007	Sloan	
2007/0156211	A1	7/2007	Ferren et al.	
2007/0213613	A1*	9/2007	Ishida et al.	600/439
2007/0213698	A1	9/2007	Altshuler et al.	
2007/0225634	A1	9/2007	Ferren et al.	
2007/0270782	A1	11/2007	Miesel et al.	
2008/0063703	A1	3/2008	Gross et al.	
2008/0066929	A1	3/2008	Costa et al.	
2008/0103440	A1	5/2008	Ferren et al.	
2008/0121054	A1	5/2008	Goldenberg et al.	
2008/0241847	A1	10/2008	Hoon et al.	
2008/0243056	A1	10/2008	Hillis et al.	
2008/0266106	A1	10/2008	Lim et al.	
2009/0062646	A1	3/2009	Creighton, IV et al.	
2009/0069821	A1	3/2009	Farritor et al.	
2009/0082652	A1	3/2009	Koh et al.	
2009/0182388	A1	7/2009	Von Arx et al.	
2009/0306728	A1	12/2009	Wright et al.	
2010/0022947	A1	1/2010	Hassidov et al.	
2010/0041951	A1	2/2010	Glozman et al.	
2010/0145143	A1	6/2010	Salomon et al.	
2010/0204546	A1	8/2010	Hassidov et al.	
2010/0249505	A1	9/2010	Shoham et al.	
2011/0112549	A1	5/2011	Neubach et al.	
2011/0158244	A1	6/2011	Long et al.	
2013/0274658	A1*	10/2013	Steinke et al.	604/96.01
2013/0304446	A1	11/2013	Rabinovitz et al.	

FOREIGN PATENT DOCUMENTS

CN	99810271.7		10/2001
EP	1 245 201	A1	10/2002
EP	1 464 362	A1	10/2004
EP	1 618 831	A2	1/2006
EP	1 345 653	B1	7/2006
EP	1 331 878	B1	11/2006
EP	1 331 970	B1	8/2007
EP	2 163 206	A1	3/2010
JP	H06505662 (A)		6/1994
JP	2001-506871		3/1998
JP	10-099261		4/1998
JP	2002-010990		1/2002
JP	2002-153569		5/2002
JP	2003-111720	A	4/2003
JP	2005-74229		3/2005
KR	2002-0010990	A	2/2002
WO	WO 92/17240		10/1992
WO	WO 96/39999		12/1996
WO	WO 98/09582		3/1998
WO	WO 98/14243		4/1998
WO	WO 99/20335		4/1999
WO	WO 99/44665		9/1999
WO	WO 00/69515		11/2000
WO	WO 01/08548	A1	2/2001
WO	WO 01/24731	A1	4/2001
WO	WO 02/34332	A1	5/2002
WO	WO 02/051497	A2	7/2002
WO	WO 03/072157	A1	9/2003
WO	WO 03/090618	A2	11/2003
WO	WO 03/106966	A2	12/2003
WO	WO 2004/028335	A2	4/2004
WO	WO 2004/058041	A2	7/2004
WO	WO 2004/086958	A1	10/2004
WO	WO 2005/067792	A1	7/2005
WO	WO 2005/082248	A1	9/2005
WO	WO 2006/066099	A1	6/2006
WO	WO 2011/158244	A2	12/2011

OTHER PUBLICATIONS

Mohseni, Kamran; "Biomimetic & Bio-Inspired Aerial and Underwater Vehicles"; bearing a date of Sep. 23, 2006; pp. 1-10; printed on Jan. 4, 2007; located at http://enstrophy.colorado.edu/~mohseni/MicroVehicles1.html#UUV1#UUV1.

Murthy, S. Narasimha; Hiremath, Shobha Rani R; "Physical and Chemical Permeation Enhancers in Transdermal Delivery of Terbutaline Sulphate"; AAPS PharmSciTech; bearing a date of 2001; pp. 1-5; vol. 2001, 2(1); Technical Note 1; located at http://www.pharmscitech.com/.

"Researchers: Squid-Inspired Vortex Generators Could Mean Better Propulsion for Unmanned Underwater Vehicles"; UnderwaterTimes.com; Dec. 12, 2006; pp. 1-2; UnderwaterTimes.com; printed on Jan. 4, 2007; located at http://www.underwatertimes.com/print.php?article_id=51030782641.

(56) **References Cited**

OTHER PUBLICATIONS

Senel, Sevda; Hincal, A. Atilla; "Drug permeation enhancement via buccal route: possibilities and limitations"; Journal of Controlled Release; bearing a date of 2001; pp. 133-144; vol. 72 (2001); Elsevier; located at www.elsevier.com/locate/jconrel.

UK Intellectual Property Office Combined Search and Examination Report Under Sections 17 & 18(3); App. No. GB1016383.0; Nov. 1, 2010; pp. 1-4.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821519.6; Nov. 12, 2009; 1-4.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821526.1; Nov. 11, 2009; 1-5.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0706802.6; Nov. 23, 2009; pp. 1-2.

U.S. Appl. No. 12/928,455, Wood, Jr., Lowell L.

UK Examination Report Under Section 18(3); App. No. GB0821524.6; bearing a date of May 6, 2010 (received by our Agent on May 7, 2010); pp. 1-3.

U.S. Appl. No. 11/478,368, Ferren et al.

U.S. Appl. No. 11/485,619, Hillis et al.

U.S. Appl. No. 11/417,898, Hillis et al.

U.S. Appl. No. 10/949,186, Hillis et al.

U.S. Appl. No. 12/075,480, Hillis et al.

U.S. Appl. No. 10/827,572, Wood, Jr., Lowell L.

U.S. Appl. No. 10/827,576, Wood, Jr., Lowell L.

U.S. Appl. No. 10/827,578, Wood, Jr., Lowell L.

U.S. Appl. No. 10/827,390, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,333, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,355, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,334, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,356, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,573, Wood, Jr., Lowell L.

U.S. Appl. No. 11/891,371, Wood, Jr., Lowell L.

"001_08 Comparison of Capsule Cameras: M2A (Given Imaging) vs. NORIKA3 (RF System lab)" RF System lab; bearing dates of 2001-2004; pp. 1-2; located at http://www.rfnorika.com/eng/system/sys_008.html; printed on May 4, 2006.

"A Hydrogel-based CO2 sensor"; BIOS—The lab on a chip group; bearing a date of Aug. 29, 2005; pp. 1-2; located at: http://bios.ewi.utwente.nl/research/analysissystemssenors/ahydrogelbased.doc/index.html; printed on Apr. 25, 2006; University of Twente; the Netherlands.

"Agile new plastics change shape with heat"; MIT News Office; Nov. 20, 2006; pp. 1-4; Massachusetts Institute of Technology; printed on Nov. 22, 2006; located at http://web.mit.edu/newsoffice/2006/triple-shape.html.

"Agile new plastics change shape with heat"; MIT Tech Talk; Nov. 22, 2006; p. 5 (1 page).

Ananthaswamy, Anil; "First robot moved by muscle power"; bearing a date of Feb. 27, 2004; pp. 1-3; New Scientist; located at http://www.newscientist.com/article.ns?id=dn4717; printed on Sep. 12, 2006.

Asari, Vijayan K.; Kumar, Sanjiv; Kassim, Irwan M.; "A Fully Autonomous Microrobotic Endoscopy System"; Journal of Intelligent and Robotic Systems; bearing a date of 2000; pp. 325-341; vol. 28; Kluwer Academic Publishers.

Behkam, Bahareh; Sitti, Metin; "Towards Hybrid Swimming Microrobots: Bacteria Assisted Propulsion of Polystyrene Beads"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates of Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 2421-2424; IEEE.

Berlinger, Norman T.; "Robotic Surgery—Squeezing into Tight Places"; New England Journal of Medicine; bearing dates of May 17, 2006, May 18, 2006, and 2006; pp. 2099-2101; Massachusetts Medical Society; located at www.nejm.org.

Costamagna; Guido M.D.; "PillCam™ SB Capsule Endoscopy"; Given Imaging.com; bearing dates of 2001-2006; pp. 1-4; located at http://www.givenimaging.com/Cultures/en-US/Given/English/Products/CapsuleEndoscopy/; printed on May 4, 2006.

Christensen, Bill; "Musclebot: Microrobot with a Heart"; Technovelgy.com; pp. 1-2; bearing a date of Feb. 27, 2004; located at http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=46, printed on Sep. 12, 2006.

Dario, P.; Carrozza, M.C.; Lencioni, L.; Magnani, B.; D'Attanasio, S.; "A Micro Robotic System for Colonoscopy"; Proceedings of the 1997 IEEE International Conference on Robotics and Automation; bearing dates of Apr. 1997 and 1997; pp. 1567-1572; IEEE.

Dongxiang, Chi; Guozheng, Yan; "An earthworm based miniature robot for intestinal inspection"; Proceedings of SPIE; bearing dates of Nov. 7, 2001-Nov. 9, 2001; pp. 396-400; vol. 4601; SPIE.

Freitas Jr., Robert A.; "8.2.1.2 Arteriocenous Microcirculation"; "9.4.3.5 Legged Ambulation"; "9.4.3.6. Tank-Tread Rolling"; "9.4.3.7 Amoeboid Locomotion"; "9.4.3.8 Inchworm Locomotion"; "Nanomedicine vol. I: Basic Capabilities"; bearing a date of 1999; pp. 211-214, pp. 316-318; Landes Bioscience; Georgetown, Texas, USA.

Høeg, H.D.; Slatkin, A.B.; Burdick, J.W.; Grundfest, Dr. Warren S.; "Biomechanical Modeling of the Small Intestine as Required for the Design and Operation of a Robotic Endoscope"; Proceedings ICRA '00 IEEE International Conference on Robotics and Automation; Apr. 24, 2000-Apr. 28, 2000; pp. 1-8; vol. 2.

Ikeuchi, K.; Yoshinaka, K.; Hashimoto, S.; Tomita, N.; "Locomotion of Medical Micro Robot with Spiral Ribs Using Mucus"; Seventh International Symposium on Micro Machine and Human Science; bearing a date of 1996; pp. 217-222; IEEE.

Kassim, Irwan; Phee, Louis; Ng, Wan S.; Gong, Feng; Dario, Paolo; Mosse, Charles A.; "Locomotion Techniques for Robotic Colonoscopy"; IEEE Engineering in Medicine and Biology Magazine; bearing dates of May/Jun. 2006 and 2006; pp. 49-56; IEEE.

Krueger, Curtis; "New light on blood testing"; Oct. 20, 2006; pp. 1-2; St. Petersburg Times; printed on Oct. 24, 2006; located at http://www.sptimes.com/2006/10/20news_pf/Tampabay/New_light_on_blood_te.shtml.

Lu, Zhao; Martel, Sylvain; "Preliminary Investigation of Bio-carriers Using Magnetotactic Bacteria"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates of Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 3415-3418; IEEE.

Mangan, Elizabeth V.; Kingsley, Dan A.; Quinn, Roger D.; Chiel, Hillel J.; "Development of a Peristaltic Endoscope"; IEEE International Conference on Robotics & Automation 2002; pp. 1-6; located at http://biorobots.cwru.edu/publications/ICRA02_Mangan_Endoscope.pdf.

Martel, Sylvain; "Towards MRI-Controlled Ferromagnetic and MC-1 Magnetotactic Bacterial Carriers for Targeted Therapies in Arteriolocapillar Networks Stimulated by Tumoral Angiogenesis"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates of Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 3399- 3402; IEEE.

Mathieu, J-B.; Martel, S.; Yahia, L'H.; Soulez, G.; Beaudoin, G.; "MRI Systems as a Mean of Propulsion for a Microdevice in Blood Vessels"; bearing a date of 2003; pp. 3419-3422; IEEE.

Meier, P.; Oberthür, S.; Lang, M.; "Development of a compliant device for minimally invasive surgery"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates of Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 331-334; IEEE.

"MEMS at the cutting edge®, Patent Pending"; VERIMETRA; pp. 1-2; located at http://www.verimetra.com/flow.htm; printed on May 4, 2006.

Menciassi, A.; Park, Jong H.; Lee, S.; Gorini, S.; Dario, P.; Park, Jong-Oh; "Robotic Solutions and Mechanisms for a Semi-Autonomous Endoscope"; Proceedings of the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems; bearing a date of 2002; pp. 1379-1384; IEEE.

Mosse, Charles; Mills, Tim; Appleyard, Mark; Swain, Paul; "Electrostimulation to move endoscopes in the small bowel"; Proceedings of SPIE; bearing a date of 2001; pp. 24-28; vol. 4158.

Nyitrai, Zsolt; Illyefalvi-Vitéz, Zsolt; Pinkola, János; "Preparing Stents with Masking & Etching Technology"; 26th International Spring Seminar on Electronics Technology; bearing dates of May 8, 2003-May 11, 2003 and 2003; pp. 321-324; IEEE.

Patronik, N.A.; Ota, T.; Zenati, M.A.; Riviere, C.N.; "Improved Traction for a Mobile Robot Traveling on the Heart"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates of Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 339-342; IEEE.

(56) **References Cited**

OTHER PUBLICATIONS

"Remote-Control Electrostimulation Capsule"; Popular Science; bearing dates of 2002 and 2003; pp. 1-2; located at http://www.popsci.com/popsci/brown/2003/article/0,18881,537028,00.html; printed on May 4, 2006.

Rice, Mike; "Implantable Neurostimulation Device Market Poised for Explosive Growth"; Future Fab International; Jan. 7, 2006; pp. 1-4; printed on Oct. 6, 2006; located at http://www.future-fab.com/documents.asp?d_ID=3725.

Rice, Mike; "New Products, Emphasis on Miniaturization Driving Medical Device Innovation"; bearing a date Aug. 23, 2006; pp. 1-3; Advantage Business Media; located at http://www.mdtmag.com/scripts/ShowPR.asp?PUBCODE=046&ACCT=0006109&ISSUE=0603&RELTYPE=PR&PRODCODE=0790&PRODLETT=A; printed on Aug. 23, 2006.

Saltzman, John R.; "Endoscopic Advances—A View Toward the Future"; bearing dates of May 4, 2006, May 17, 2005, and 2005; pp. 1-4; Medscape; located at http://www.medscape.com/viewarticle/505100; printed on May 4, 2006.

Shahinpoor, Mohsen; Kim, Kwang J.; Ionic polymer-metal composites: IV. Industrial and medical applications; Smart Materials and Structures; 2005; pp. 197-214; vol. 14; Institute of Physics Publishing.

Smith, Michael; "PAS: Nasal Spray Flu Vaccine Seems Safe and Effective in Young"; May 2, 2006; pp. 1-2; MedPage Today, LLC; bearing dates of 2004-2006; printed on May 4, 2006; located at http://www.medpagetoday.com/tbprint.cfm?tbid=3213.

"Trying to control pain can be a double-edged sword, say scientists"; PhysOrg.com; printed on Nov. 2, 2006; pp. 1-2; located at http://www.physorg.com/printnews.php?newsid=81599312.

Tummala, R. Lal; Mukherjee, R.; Aslam, D.; Xi, Ning; Mahadevan, S.; Weng, J.; "Reconfigurable Adaptable Micro-robot"; IEEE; bearing a date of 1999; pp. 687-691.

"Zyvex NanoEffector Microgrippers"; Nanotechnology at Zyvex; printed on Dec. 7, 2006; pp. 1-2; located at http://www.zyvex.com/Products/Grippers_Features.html.

"Zyvex NanoEffector Microgrippers"; Zyvex.com; bearing a date of 2006; pp. 1-2; Zyvex Corporation.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821524.6; Aug. 9, 2010 (received by our Agent on Aug. 10, 2010); pp. 1-2.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821519.6; Aug. 9, 2010 (received by our Agent on Aug. 10, 2010); pp. 1-3.

U.S. Appl. No. 11/726,031, Ferren et al.

U.S. Appl. No. 11/726,025, Ferren et al.

U.S. Appl. No. 11/725,982, Ferren et al.

U.S. Appl. No. 11/651,946, Ferren et al.

U.S. Appl. No. 11/645,358, Ferren et al.

U.S. Appl. No. 11/645,357, Ferren et al.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0706802.6; bearing a date of Dec. 1, 2008; pp. 1-2.

U.S. Appl. No. 11/541,492, Jung et al.

U.S. Appl. No. 11/541,452, Jung et al.

U.S. Appl. No. 11/541,448, Jung et al.

Bialek, William; Rieke, Fred; De Ruyter Van Steveninck, Rob R.; Warland, David; "Reading a Neural Code"; Science; bearing a date of Jun. 28, 1991; pp. 1854-1857; vol. 252.

Bucher, Volker; Graf, Michael; Stelzle, Martin; Nisch, Wilfried; "Low-Impedance Thin-Film Polycrystalline Silicon Microelectrodes for Extracellular Stimulation and Recording"; Biosensors and Bioelectronics; bearing a date of 1999; pp. 639-649; vol. 14; Elsevier Science S.A.; located at: www.elsevier.com/locate/bios.

Butson, Christopher R.; McIntyre, Cameron C.; "Role of Electrode Design on the Volume of Tissue Activated During Deep Brain Stimulation"; Journal of Neural Engineering; bearing a date of 2006; vol. 3; pp. 1-8; IOP Publishing Ltd.

Chang, Suk Tai; Paunov, Vesselin N.; Petsev, Dimiter N.; Velev, Orlin D.; "Articles: Remotely Powered Self-Propelling Particles and Micropumps Based on Miniature Diodes"; Nature Materials; bearing a date of 2007; pp. 1-6; Nature Publishing Group; located at: www.nature.com/naturematerials.

U.S. Appl. No. 11/541,378, Jung et al.

U.S. Appl. No. 11/541,377, Jung et al.

U.S. Appl. No. 11/526,203, Jung et al.

U.S. Appl. No. 11/526,201, Jung et al.

U.S. Appl. No. 11/526,144, Jung et al.

U.S. Appl. No. 11/526,089, Jung et al.

U.S. Appl. No. 11/455,010, Jung et al.

U.S. Appl. No. 11/454,343, Jung et al.

Cui, Xinyan; Hetke, Jamille F.; Wiler, James A.; Anderson, David J.; Martin, David C.; "Electrochemical Deposition and Characterization of Conducting Polymer Polypyrrole/PPS on Multichannel Neural Probes"; Sensors and Actuators A Physical; bearing a date of 2001; pp. 8-18; vol. 93; Elsevier Science B.V.; located at: www.elsevier.com/locate/sna.

Dillier, Norbert; Lai, Wai Kong; Almqvist, Bengt; Frohne, Carolin; Müller-Deile, Joachim; Stecker, Matthias; Von Wallenberg, Ernst; "Measurement of the Electrically Evoked Compound Action Potential Via a Neural Response Telemetry System"; Annals of Otology Rhinology and Laryngology; bearing a date of May 2002; pp. 407-414; vol. 111, No. 5; Annals Publishing Company.

Donoghue, John P.; "Review: Connecting Cortex to Machines: Recent Advances in Brain Interfaces"; Nature Neuroscience Supplement; bearing a date on Nov. 2002; pp. 1085-1088; vol. 5; Nature Publishing Group; located at: http://www.nature.com/natureneuroscience.

Fang, Zi-Ping; Mortimer, J. Thomas; "Selective Activation of Small Motor Axons by Quasitrapezoidal Current Pulses"; IEEE Transactions on Biomedical Engineering; bearing a date of Feb. 1991; pp. 168-174; vol. 38, No. 2; IEEE.

Fiaccabrino, G.C.; Tang, X.-M.; Skinner, N.; De Rooij, N.F.; Koudelka-Hep, M.; "Electrochemical Characterization of Thin-Film Carbon Interdigitated Electrode Arrays"; Analytica Chimica Acta; bearing a date of 1996; pp. 155-160; vol. 326; Elsevier Science B.V.

Gitter, Alfred H.; Fromm, Michael; Schulzke, Jörg-Dieter; "Impedance Analysis for the Determination of Epithelial and Subepithelial Resistance in Intestinal Tissues"; Journal of Biochemical and Biophysical Methods, bearing a date of 1998; pp. 35-46; vol. 37; Elsevier Science B.V.

Goda, Yukiko; Colicos, Michael A.; "Protocol: Photoconductive Stimulation of Neurons Cultured on Silicon Wafers"; Nature Protocols; bearing a date of 2006; pp. 461-467; vol. 1, No. 1; Nature Publishing Group; located at: http://www.nature.com/natureprotocols.

Gozani, Shai N.; Miller, John P.; "Optimal Discrimination and Classification of Neuronal Action Potential Waveforms from Multiunit, Multichannel Recordings Using Software-Based Linear Filters"; IEEE Transactions on Biomedical Engineering; bearing a date of Apr. 1994; pp. 358-372; vol. 41, No. 4; IEEE.

Gray, Charles M.; Maldonado, Pedro E.; Wilson, Mathew; McNaughton, Bruce; "Tetrodes Markedly Improve the Reliability and Yield of Multiple Single-Unit Isolation from Multi-Unit Recordings in Cat Striate Cortex"; Journal of Neuroscience Methods; bearing a date of 1995; pp. 43-54; vol. 63; Elsevier Science B.V.

Hodgkin, A.L.; Huxley, A.F.; "A Quantitative Description of Membrane Current and its Application to Conduction and Excitation in Nerve"; Journal of Physiology; bearing a date of 1952; pp. 500-544; vol. 117.

Hofmann, U.G.; Folkers, A.; Mösch, F.; Höhl, D.; Kindlundh, M.; Norlin, P.; "A 64(128)-Channel Multisite Neuronal Recording System"; bearing a date of 2002; pp. 1-4.

Inmann, Andreas; Haugland, Morten; Haase, Jens; Biering-Sørensen, Fin; Sinkjaer, Thomas; "NeuroReport: Signals from Skin Mechanoreceptors used in Control of a Hand Grasp Neuroprosthesis"; Motor Systems; bearing a date of Sep. 17, 2001; pp. 2817-2819; vol. 12, No. 13; Lippincott Williams & Wilkins.

Janders, M.; Egert, U.; Stelze, M.; Nisch, W.; "Novel Thin Film Titanium Nitride Micro-Electrodes with Excellent Charge Transfer Capability for Cell Stimulation and Sensing Applications"; IEEE Engineering in Medicine and Biology Society; bearing a date of 1996; pp. 245-247; IEEE.

(56) **References Cited**

OTHER PUBLICATIONS

"Japanese Researchers Unveil Medical Mini Robot"; Yahoo! News; bearing a date of Mar. 8, 2007; pp. 1-2; Yahoo! Inc.; located at: http://news.yahoo.com/s/afp/20070308/hl_afp/a4plifestyleshealthscience; printed on Mar. 8, 2007.

Ji, Jin; Najafi, Khalil, Wise, Kensall D.; "A Low-Noise Demultiplexing System for Active Multichannel Microelectrode Arrays"; IEEE Transactions of Biomedical Engineering; bearing a date of Jan. 1991; pp. 77-81; vol. 38, No. 1; IEEE.

Kennedy, P.R.; Bakay, R.A.E.; Moore, M.M.; Adams, K.; Goldwaithe, J.; "Direct Control of a Computer from the Human Central Nervous System"; IEEE Transactions on Rehabilitation Engineering; bearing a date of Jun. 2000; pp. 198-202; vol. 8, No. 2; IEEE.

Kobetic, Rudi; Triolo, Ronald J.; Uhlir, James P.; Bieri, Carole; Wibowo, Michael; Polando, Gordie; Marsolais, E. Byron; Davis Jr., John A.; Ferguson, Kathleen A.; Sharma, Mukut; "Implanted Functional Electrical Stimulation System for Mobility in Paraplegia: A Follow-Up Case Report"; IEEE Transactions on Rehabilitation Engineering; bearing a date of Dec. 1999; pp. 390-398; vol. 7, No. 4; IEEE.

Loeb, Gerald E.; Peck, Raymond A.; Moore, William H.; Hood, Kevin; "BION System for Distributed Neural Prosthetic Interfaces"; Medical Engineering and Physics; bearing a date of 2001; pp. 9-18; vol. 23; Elsevier Science Ltd.; located at: www.elsevier.com/locate/medengphy.

Loeb, G.E.; Peck, R.A.; Martyniuk, J.; "Toward the Ultimate Metal Microelectrode"; Journal of Neuroscience Methods; bearing a date of 1995; pp. 175-183; vol. 63; Elsevier Science B.V.

Marks, William B.; Loeb, Gerald E.; "Action Currents, Internodal Potentials, and Extracellular Records of Myelinated Mammalian Nerve Fibers Derived from Node Potentials"; Biophysical Journal; 1976; pp. 655-668; vol. 16.

Martel, Sylvain; Mathieu, Jean-Baptiste; Felfoul, Ouajdi; Chanu, Arnaud; Aboussouan, Eric; Tamaz, Samer; Pouponneau, Pierre; "Automatic Navigation of an Untethered Device in the Artery of a Living Animal using a Conventional Clinical Magnetic Resonance Imaging System"; Applied Physics Letters; 2007; pp. 114105-1-114105-3; vol. 90, No. 114105; American Institute of Physics.

Matsui, Takemi; Matsumura, Kouji; Hagisawa, Kousuke; Ishihara, Masayuki; Ishizuka, Toshiaki; Suzuki, Minoru; Kurita, Akira; Kikuchi, Makoto; "A Novel Ferromagnetic Thermo-Stent for Plaque Stabilization That Self-Regulates the Temperature"; IEEE Transactions on Biomedical Engineering; bearing dates of Jun. 2002 and 2002; pp. 621-623; vol. 49, No. 6; IEEE.

McNeal, Donald R.; "Analysis of a Model for Excitation of Myelinated Nerve"; IEEE Transactions on Biomedical Engineering; bearing a date of Jul. 1976; pp. 329-337; vol. BME-23, No. 4.

Naqvi, Nasir H.; Rudrauf, David; Damasio, Hanna; Bechara, Antoine; "Damage to the Insula Disrupts Addiction to Cigarette Smoking"; Science; bearing a date of Jan. 26, 2007; pp. 531-534; vol. 315, No. 531; located at: www.sciencemag.org; printed on Jan. 25, 2007.

Olsson III, R.H.; Gulari, M.N.; Wise, K.D.; "Poster 114: Silicon Neural Recording Arrays with On-Chip Electronics for In-Vivo Data Acquisition"; Microtechnologies in Medicine and Biology; bearing dates of May 2, 2002-May 4, 2002; pp. 237-240; IEEE.

Oweiss, Karim G.; Anderson, David J.; "A New Technique for Blind Source Separation Using Subband Subspace Analysis in Correlated Multichannel Signal Environments"; bearing a date of 2001; pp. 2813-2816; IEEE.

Peckham, P. Hunter; Knutson, Jayme S.; "Functional Electrical Stimulation for Neuromuscular Applications"; Annual Review Biomedical Engineering; bearing a date of 2005; pp. 327-360; vol. 7; Annual Reviews.

Rattay, F.; "The Basic Mechanism for the Electrical Stimulation of the Nervous System"; Neuroscience; 1999; pp. 335-346; vol. 98. No. 2; Elsevier Science Ltd; printed on Mar. 15, 2007.

Rattay, Frank; "Analysis of Models for Extracellular Fiber Stimulation"; IEEE Transactions on Biomedical Engineering; bearing a date of Jul. 1989; pp. 676-682; vol. 36, No. 7; IEEE.

Rattay, Frank, Aberham, Matthias; "Modeling Axon Membranes from Functional Electrical Stimulation"; IEEE Transactions on Biomedical Engineering; bearing a date of Dec. 1993; pp. 1201-1209; vol. 40, No. 12; IEEE.

Riedmüller, J.; Bolz, A.; Rebling, H.; Schaldach, M.; "Improvement of Stimulation and Sensing Performance of Bipolar Pacemaker Leads"; IEEE Eng. Med. Biol. Soc.; 1992; pp. 2364-2365; IEEE.

Robinson, David A.; "The Electrical Properties of Metal Microelectrodes"; Proceedings of the IEEE; bearing a date of Jun. 1968; pp. 1065-1071; vol. 56, No. 6.

Rousche, Patrick J.; Pellinen, David S.; Pivin, David P.; Williams, Justin C.; Vetter, Rio J.; Kipke, Daryl R.; "Flexible Polyimide-Based Intracortical Electrode Arrays with Bioactive Capability"; IEEE Transactions on Biomedical Engineering; bearing a date Mar. 2001; pp. 361-371; vol. 48, No. 3; IEEE.

Rutten, Wim; Mouveroux, Jean-Marie; Buitenweg, Jan; Heida, Ciska; Ruardij, Teun; Marani, Enrico; Lakke, Egbert; "Neuroelectronic Interfacing with Cultured Multielectrode Arrays Toward a Cultured Probe"; Proceedings of the IEEE; bearing a date of Jul. 2001; pp. 1013-1029; vol. 89, No. 7; IEEE.

Schoonhoven, R.; Stegeman, D.F.; "Models and Analysis of Compound Nerve Action Potentials"; Critical Reviews in Biomedical Engineering; bearing a date of 1991; pp. 47-111; vol. 19, No. 1; CRC Press, Inc.

Serruya, Mijail D.; Hatsopoulos, Nicholas G.; Paninski, Liam; Fellows, Matthew R.; Donoghue, John P.; "Brief Communications: Instant Neural Control of a Movement Signal"; Nature; bearing a date of Mar. 14, 2002; pp. 141-142; vol. 416; Macmillan Magazines Ltd; located at: www.nature.com.

Snoek, GJ; Ijzerman, MJ; In 'T Groen, Facg; Stoffers, TS; Zilvold, G; "Use of the NESS Handmaster to Restore Handfunction in Tetraplegia: Clinical Experiences in Ten Patients"; Spinal Cord; bearing a date of 2000; pp. 244-249; vol. 38; International Medical Society of Paraplegia.

Struijk, Johannes Jan; "The Extracellular Potential of a Myelinated Nerve Fiber in an Unbounded Medium and in Nerve Cuff Models"; Biophysical Journal; bearing a date of Jun. 1997; pp. 2457-2469; vol. 72; Biophysical Society.

Taylor, Dawn M.; Helms Tillery, Stephen I.; Schwartz, Andrew B.; "Research Article: Direct Cortical Control of 3D Neuroprosthetic Devices"; Science; bearing a date of Jun. 7, 2002; pp. 1829-1832; vol. 296; located at: www.sciencemag.org.

"Tiny Robot Reduces Need for Surgery"; Pink Tentacle; bearing a date of Feb. 26, 2007; p. 1; located at: http://www.pinktentacle.com/2007/02/tiny-robot-reduces-need-for-surgery; printed on Mar. 8, 2007.

Twardoch, U.M.; "Integrity of Ultramicro-Stimulation Electrodes Determined from Electrochemical Measurements"; Journal of Applied Electrochemistry; bearing a date of 1994; pp. 835-857; vol. 24; Chapman & Hall.

Warland, David K.; Reinagel, Pamela; Meister, Markus; "Decoding Visual Information from a Population of Retinal Ganglion Cells"; bearing a date of 1997; pp. 2336-2350; The American Physiological Society.

Weis, Rolf; Müller, Bernt; Fromherz, Peter; "Neuron Adhesion on a Silicon Chip Probed by an Array of Field-Effect Transitors"; Physical Review Letters; bearing a date of Jan. 8, 1996; pp. 327-330; vol. 76, No. 2; The American Physical Society.

Wessberg, Johan; Stambaugh, Christopher R.; Kralik, Jerald D.; Beck, Pamela D.; Laubach, Mark; Chapin, John K.; Kim, Jung; Biggs, S. James; Srinivasan, Mandayam A.; Nicolelis, Miguel A.L.; "Letters to Nature: Real-Time Prediction of Hand Trajectory by Ensembles of Cortical Neurons in Primates"; Nature; bearing a date of Nov. 16, 2000; pp. 361-365; vol. 408; Macmillan Magazines Ltd; located at: www.nature.com.

White, Dave; "Mini Robot Explores, Gives you Medicine from Within"; Mobile Magazine; bearing a date of Feb. 27, 2007; p. 1; located at: http://www.mobilemag.com/content/100/313/C11869/; printed on Mar. 8, 2007.

(56) **References Cited**

OTHER PUBLICATIONS

UK Intellectual Property Office Examination Report Under Section 18(3), App. No. GB0821523.8; Jul. 2, 2009; pp. 1-2.

UK Intellectual Property Office Examination Report under Section 18(3); App. No. GB0821521.2; Jan. 12, 2011 (received by our agent on Jan. 13, 2011); 4 pages.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821519.6; Oct. 19, 2010 (received by our Agent on Oct. 19, 2010); 1 page.

Yavari, Nazila; "Optical spectroscopy for tissue diagnostics and treatment control"; Doctoral Thesis; Department of Physics and Technology; University of Bergen; bearing a date of Apr. 2006; 130 pages.

Bezrouk, A.; Hanuš, J.; Záhora, J.; "Temperature Characteristics of Nitinol Spiral Stents"; Scripta Medica (BRNO); bearing dates of Aug. 2005, Oct. 2005; pp. 219-226; vol. 78, No. 4.

Chen, Ting; Barton, Scott Calabrese, Binyamin, Gary; Gao, Zhiqiang; Zhang, Yongchao, Kim, Hyug-Han; Heller, Adam; "A Miniature Biofuel Cell"; Journal of the American Chemical Society; Aug. 11, 2001; pp. 8630-8631; vol. 123; 2001 American Chemical Society.

Hagleitner, C.; Hierlemann, A.; Lange, D.; Kummer, A.; Kerness, N.; Brand, O.; Baltes, H.; "Smart single-chip gas sensor microsystem"; Nature; Nov. 15, 2001; pp. 293-296; vol. 414; Macmillan Magazines Ltd.; www.nature.com.

Hanna, Darrin M.; Oakley, Barbara A.; Stryker, Gabrielle A.; "Using a System-on-Chip Implantable Device to Filter Circulating Infected Cells in Blood or Lymph"; IEEE Transactions on Biomedical Engineering; bearing dates of Jan. 25, 2003, Mar. 2003; pp. 6-13; vol. 2, No. 1; IEEE.

Matsui, Takemi; Matsumura, Kouji; Hagisawa, Kousuke; Ishihara, Masayuki; Ishizuica, Toshiaki; Suzuki, Minoru; Kurita, Akira; Kikuchi, Makoto; "A Novel Ferromagnetic Thermo-Stent for Plaque Stabililzation That Self-Regulates the Temperature"; IEEE Transactions on Biomedical Engineering; bearing dates of Jun. 2002 and 2002; pp. 621-623; vol. 49, No. 6; IEEE.

Nakayama, Yasuhide; Ji-Youn, Kim; Nishi, Shogo; Ueno, Hikaru; Matsuda, Takehisa; "Development of high-performance stent: gelatinous photogel-coated stent that permits drug delivery and gene transfer"; J Biomed Mater Res; bearing dates of Nov. 13, 2000, Apr. 23, 2001, May 10, 2001 and 2001; pp. 559-566; vol. 57; John Wiley & Sons, Inc.

Neto, A.M. Figueiredo; Godinho, M.H.; Toth-Katona, T.; Palffy-Muhoray, P.; "Optical, Magnetic and Dielectric Properties of Non-Liquid Crystalline Elastomers Doped with Magnetic Colloids"; Brazilian Journal of Physics; Bearing a date of Mar. 2005; pp. 184-189; vol. 35, No. 1.

"New Medical Device Combines Wireless and MEMS Technology"; Georgia Institute of Technology; pp. 1-4; PhysOrg.com; located at: http://www.physorg.com/printnews.php?newsid=10533; printed on Feb. 20, 2006.

Nieuwenhuizen-Berkovits, P.; "lubrelastic medical appliances,"; Lubrelastic Medical Appliances; pp. 1-4; located at: http://www.xs4all.nl/~plien070/caeng.html; printed on Feb. 20, 2006.

Schmidt, W.; Behrens, P.; Behrend, D.; Schmitz, K.-P.; Andresen, R.; "Experimental Study of Peripheral, Balloon-expandable Stent Systems"; Progress in Biomedical Research; bearing a date of May 2001; pp. 246-255.

Serruys, Patrick W.; Kutryk, Michael J.B.; Ong, Andrew T.L.; "Coronary-Artery Stents"; The New England Journal of Medicine; bearing dates of Feb. 2, 2006 and Feb. 15, 2006; pp. 483-495; vol. 354;5; Massachusetts Medical Society.

Shabalovskaya, Svetlana, A.; "Surface, corrosion and biocompatibility aspects of Nitinol as an implant material"; Bio-Medical Materials and Engineering; bearing dates of Apr. 4, 2001, and 2002; pp. 69-109; vol. 12; IOS Press.

Snow, E.S.; Perkins, F.K.; Houser, E.J.; Badescu, S.C.; Reinecke, T. L.; "Chemical Detection with a Single-Walled Carbon Nanotube Capacitor"; Science; Mar. 25, 2005; pp. 1942-1945; vol. 307; www.sciencemag.org.

Stoeckel, Dieter; Pelton, Alan; Duerig, Tom; "Self-expanding nitinol stents: material and design considerations"; European Radiology; bearing dates of Jan. 28, 2003, May 22, 2003, Jul. 1, 2003, Sep. 3, 2003, Feb. 2004 and 2004; pp. 292-301(1-2); vol. 14, No. 2; Springer-Verlag GmbH-SpringerLink—Article; located at: http://www.springerlink.com/(1begg455gtgjfseqqptyb43m)/app/home/contribution.asp?referrer=parent&backto=issue,17,26;journal,27,147;browsepublicationsresults,444,1551; printed on Feb. 22, 2006.

Strauss, Bradley H., M.D., Ph.D.; Li, Chris, M.D.; Whittingham, Heather A., M.Sc; Tio, Fermin O., M.D.; Kutryk, Michael J.B., M.D., Ph.D.; Janicki, Christian, Ph.D.; Sparkes, John, D., M.Sc.; Turnlund, Todd, B.Sc.; Sweet, William L., M.D.; "Late Effects of Low-Energy Gamma-Emitting Stents in a Rabbit Iliac Artery Model"; Int. J. Radiation Oncology Biol. Phys.; bearing dates of Oct. 23, 2001, May 13, 2002 and May 15, 2002 and 2002; pp. 551-561; vol. 54, No. 2; Elsevier Science Inc.

Yusa, Go; Muraki, Koji; Takashina, Kei; Hashimoto, Katsushi; Hirayama, Yoshiro; "Controlled multiple quantum coherences of nuclear spins in a nanometre-scale device"; Nature; Apr. 21, 2005; pp. 1001-1005; vol. 434; 2005 Nature Publishing Group; www.nature.com/nature.

UK Intellectual Property Office Examination Report Under Section 18(3); App. No. GB0821530.3; Aug. 27, 2010 (received by our Agent on Sep. 3, 2010); pp. 1-6.

Mosby's Dictionary of Medicine, Nursing & Health Professions; "endoscopy"; 2009; Credo Reference. Web. Jun. 29, 2011; 1 page; Elsevier Health Sciences.

U.S. Appl. No. 13/135,696, filed Jul. 12, 2011, Ferren et al.

U.S. Appl. No. 13/135,694, filed Jul. 12, 2011, Ferren et al.

Arkin, Ronald C.; "Towards the Unification of Navigational Planning and Reactive Control"; Working Notes of the AAAI Spring Symposium on Robot Navigation; bearing dates of Mar. 20-28, 1989; pp. 1-6.

Arleo et al.; "Spatial Cognition and Neuro-Mimetic Navigation: A Model of Hippocampal Place Cell Activity"; bearing a date of Oct. 28, 1999; pp. 1-13.

Balakrishnan et al.; "Spatial Learning and Localization in Rodents: A Computational Model of the Hippocampus and its Implications for Mobile Robots"; Adaptive Behavior; bearing a date of 1999; pp. 173-216 plus cover page; vol. 7, No. 2; SAGE Publications.

Bellin et al.; "Polymeric triple-shape materials"; PNAS; bearing dates of Nov. 18, 2006 and 2006; pp. 18043-18047; vol. 103, No. 48; The National Academy of Sciences of the USA; located at www.pnas.org/cgi/doi/10.1073/pnas.0608586103.

Berman et al.; "Decentralized Autonomous AGV System for Material Handling"; iFirst; bearing a date of Oct. 2002; pp. 3995-4006 (Only the Abstract is being provided); vol. 40, No. 15; located at: http://www.informaworld.com/smpp/content~content=a713846479~db=ai; printed on Apr. 24, 2007.

Bianco et al.; "Carbon Nanotube-based Vectors for Delivering Immunotherapeutics and Drugs"; Nanotechnologies for the Live Sciences: Nanomaterials for Medical Diagnosis and Therapy; bearing a date of 2007; Chapter 3; pp. 85-142.; vol. 10; Wiley-VCH Verlag GmbH & Co. KGaA; Weinheim.

Breslin et al.; "Autofluorescence and Diffuse Reflectance Properties Malignant and Benign Breast Tissues"; Annals of Surgical Oncology; bearing dates of 2003 and 2004; pp. 65-70; vol. 11, No. 1; Lippincott Williams & Wilkin.

Bright et al.; "Automated Pipe Inspection Robot"; Industrial Robot: An International Journal; bearing a date of Aug. 1997; pp. 285-289 (Only the Abstract is being provided); vol. 24, No. 4; located at: http://www.emeraldinsight.com/10.1108/01439919710176372; printed on Apr. 23, 2007.

Brinn, David; "A incredible journey from an Israeli robotics team"; ISRAEL21c: A Focus Beyond; bearing a date of Nov. 12, 2006; pp. 1-3; ISRAEL21c.org.

Brown et al.; "Performance Test Results of an Integrated GPS/MEMS Inertial Navigation Package"; Proceedings of ION GNSS 2004, bearing a date of Sep. 2004; pp. 1-8.

Budgett et al.; "Novel technology for the provision of power to implantable physiological devices"; Journal of Applied Physiology; bearing dates of Jan. 27, 2006, Jan. 5, 2007, and 2007; pp. 1658-1663; vol. 102; The American Physiological Society.

(56) **References Cited**

OTHER PUBLICATIONS

Bullitt et al.; "Analysis of Time-Varying Images Using 3D Vascular Models"; Proceedings 30th Applied Imagery Pattern Recognition Workshop; bearing a date of Apr. 2001; pp. 9-14; IEEE Computer Society; Piscataway, NJ.

Burke et al.; "Towards a single-chip, implantable RFID system: is a single-cell radio possible?"; Biomed Microdevices; bearing a date of 2009; pp. 1-8; Springer.

Cady et al.; "Optimized linkage and quenching strategies for quantum dot molecular beacons"; Molecular and Cellular Probes; bearing dates of Jul. 5, 2006, Sep. 7, 2006, Sep. 17, 2006, 2006, and 2007; pp. 116-124; vol. 21; Elsevier Ltd.

Cavalcanti et al.; "Autonomous Multi-Robot Sensor-Based Cooperation for Nanomedicine"; Nanotechnology Special Edition; bearing a date of Aug. 2002; pp. 1-4; International Journal of Nonlinear Science and Numerical Stimulation.

Chen et al.; "Review on the Achievements in Simultaneous Localization and Map Building for Mobile Robot" CSA Illumina; bearing a date of Jun. 2005; pp. 455-460 (Only the Abstract is being provided); vol. 22, No. 3; ProQuest-CSA LLC; located at: http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=TRD&recid=A056354818AH&recid=2005134422784EA&q=Review+on+the+Achievements+in+Simultaneuous+Localization+and+Map+Building+for+Mobile+Robot&uid=790366044&setcookie=yes.

Chiyo et al.; "Effective detection of bronchial preinvasive lesions by a new autofluorescence imaging bronchovideoscope system"; Lung Cancer; bearing dates of May 12, 2004, Nov. 17, 2004, Nov. 23, 2004, 2004, and 2005; pp. 307-313; vol. 48; Elsevier Ireland Ltd.

Chung et al.; "Advanced Optical Imaging Requiring No Contrast Agents—A New Armamentarium for Medicine and Surgery"; Current Surgery; bearing dates of May/Jun. 2005 and 2005; pp. 365-370; vol. 62, No. 3; Elsevier Inc.

Dacosta et al.; "Autofluorescence characterisation of isolated whole crypts and primary cultured human epithelial cells from normal, hyperplastic, and adenomatous colonic mucosa"; Journal of Clinical Pathology; bearing dates of 2004 and 2005; pp. 766-774; vol. 58.

Degani et al.; "Minimalistic, Dynamic, Tube Climbing Robot"; 2010 IEEE International Conference on Robotics and Automation; bearing dates of May 3-8, 2010 and 2010; pp. 1100-1101; IEEE.

Desouza et al.; "Vision for Mobile Robot Navigation: A Survey"; IEEE Transactions on Pattern Analysis and Machine Intelligence; bearing a date of Feb. 2002; pp. 237-267 (Only the Abstract is being provided); vol. 24, No. 2; located at: http://csdl2.computer.org/persagen/DLAbsToc.jsp?resourcePath=/dl/trans/tp/&toc=comp/trans/tp/2002/02/i2toc.xml&DOI=10.1109/34.982903; printed on Apr. 23, 2007.

Diard et al.; "A theoretical comparison of probabilistic and biomimetic models of mobile robot navigation"; Proceedings of the 2004 IEEE International Conference on Robotics & Automation; bearing dates of Apr. 2004 and 2004; pp. 933-938; IEEE.

Dweik et al.; "Exhaled breath analysis: the new frontier in medical testing"; Journal of Breath Research; bearing a date of 2008; pp. 1-3; vol. 2; IOP Publishing Ltd; UK.

Edwards, Lin; "Spider pill to seek out disease"; PhysOrg.com; bearing dates of Oct. 16, 2009 and 2009; p. 1.

Eker et al.; "Clinical spectral characterisation of colonic mucosal lesions using autofluorescence and δ aminolevulinic acid sensitization"; Gut; bearing dates of 1998 and 1999; pp. 511-518; vol. 44.

Eulenstein et al.; "Ultrasound-Based Navigation System Incorporating Preoperative Planning for Liver Surgery"; International Congress Series CARS 2004—Computer Assisted Radiology and Surgery, Proceedings of the 18th International Congress and Exhibition; bearing a date of 2004; pp. 758-763; vol. 1268.

Filliat et al.; "Map Based Navigation in Mobile Robots: I. A Review of Localization Strategies"; Science Direct-Cognitive Systems Research; bearing dates of Feb. 12, 2003 and Dec. 2003; pp. 1-58; vol. 4, No. 4; Elsevier Science.

Foxlin et al.; "Miniature 6-DOF inertial system for tracking HMDs"; Helmet and Head-Mounted Displays III, AeroSense 98; bearing dates of Apr. 13-14, 1998; pp. 1-15; vol. 3362; SPIE.

Gabrecht et al.; "Detection of early bronchial cancer by autofluorescence: results in patients with H&N cancer"; Diagnostic Optical Spectroscopy in Biomedicine IV, Proc. SPIE-OSA Biomedical Optics; bearing a date of 2007; pp. 1-8; vol. 6628; SPIE-OSA.

Gao et al., "A Micro Sensing Probe for Detecting Individual Biological Cells"; Proceedings of the 25th Annual International Conference of the IEEE EMBS; bearing dates of Sep. 17-21, 2003 and 2003; pp. 3348-3351; IEEE.

Gillenwater et al.; "Noninvasive Diagnosis of Oral Neoplasia Based on Fluorescence Spectroscopy and Native Tissue Autofluorescence"; Archives of Otolaryngology-Head & Neck Surgery; bearing a date of Nov. 1998 and 1998; pp. 1251-1258; vol. 124.

Grifantini, Kristina; "Voyage of the Bacteria Bots"; Technology Review; bearing a date of Oct. 31, 2008; pp. 1-4; Technology Review.

Groothuis et al.; "The entry of antiviral and antiretroviral drugs into the central nervous system"; Journal of NeuroVirology; bearing a date of 1997; pp. 387-400; vol. 3; Journal of NeuroVirology, Inc.

"Guessing Robots Predict Their Environments, Navigate Better"; PhysOrg.com; printed on Sep. 16, 2008; pp. 1-2; original story found at www.phyorg.com/news100887209.html.

Gur, Amir; "The Nanobots are Coming"; TFOT; bearing a date of Jul. 9, 2007; pp. 1-2; The Future of Things.

Hattori, Kevin; "Robot Can Crawl Through Human Body"; American Technion Society; bearing a date of Jul. 7, 2009; pp. 1-2; American Technion Society; located at http://www.ats.org/site/News2?page=NewsArticle&id=6063&news_iv_ctrl=1161&printer_friendly=1.

Herth et al.; "Successful Bronchoscopic Placement of Tracheobronchial Stents Without Fluoroscopy"; Chest; bearing a date of Jun. 2001; pp. 1910-1912; vol. 119, No. 6; American College of Chest Physicians.

Hertzberg et al.; "Landmark-Based Autonomous Navigation in Sewerage Pipes"; Proceedings of EUROBOT; bearing a date of 1996; pp. 68-73; IEEE.

Hirsch et al.; "A new device with PZT ultrasonic transducers in MEMS technology"; Journal of Physics: Conference Series 34, International MEMS Conference 2006; bearing a date of 2006; pp. 475-480; IOP Publishing Ltd.

Hollings et al.; "Diagnostic imaging of lung cancer"; European Respiratory Journal; bearing a date of 2002, pp. 722-742; vol. 19; ERS Journals Ltd.

Hornyak, Tim; "RFID Powder"; Scientific American Magazine; bearing dates of Feb. 2008 and 2008; pp. 68-71; Scientific American, Inc.

Hosseini-Khayat, Saied; "A Lightweight Security Protocol for Ultra-low Power ASIC Implementation for Wireless Implantable Medical Devices"; 2011 Symposium on Medical Information and Communication Technology (ISMICT); bearing dates of 2011 and Mar. 27-30, 2011; pp. 6-9; IEEE.

Howell et al.; "Practical Mobile Robot Self-Localization"; Proceedings of the IEEE International Conference on Robotics and Automation, 2000; bearing dates of Apr. 24-28, 2000; pp. 3485-3492; vol. 4.

Jaiswal et al.; "Long-term multiple color imaging of live cells using quantum dot bioconjugates"; Nature Biotechnology; bearing dates of Jan. 2003 and 2003; pp. 47-51; vol. 21; Nature Publishing Group.

Jovanov et al.; "A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation"; Journal of NeuroEngineering and Rehabilitation; bearing dates of Mar. 1, 2005, Jan. 28, 2005, Mar. 1, 2005, and 2005; pp. 1-10; vol. 2, No. 6; BioMed Central Ltd.

Karino et al.; "Flow Patterns in Vessels of Simple and Complex Geometries"; Annals of the New York Academy of Sciences; bearing a date of 1987; pp. 422-441; vol. 516.

Kawaguchi et al.; "Internal Pipe Inspection Robot"; IEEE Xplore; bearing dates of May 21, 1995-May 27, 1995 and 2005; pp. 857-862 (Only the Abstract is being provided); vol. 1; IEEE; located at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?rnumber=525390; printed on Apr. 23, 2007.

(56) **References Cited**

OTHER PUBLICATIONS

Kharitonov et al.; "Exhaled Markers of Pulmonary Disease"; American Journal of Respiratory and Critical Care Medicine; bearing dates of Sep. 5, 2000, Jan. 24, 2001, and 2001; pp. 1693-1722; vol. 163.

Kim et al.; "Inchworm-Like Microbot for Capsule Endoscope"; Proceedings of the 2004 IEEE International Conference on Robotics and Biomimetics; bearing dates of Aug. 22-26, 2004 and 2004; pp. 458-463; IEEE.

Kim et al.; "Ultrasensitive carbon nanotube-based biosensors using antibody-binding fragments"; Analytical Biochemistry; bearing a date of 2008; pp. 193-198; vol. 381; Elsevier Inc.

Kirchner et al.; "A Prototype Study of an Autonomous Robot Platform for Sewerage System Maintenance"; Autonomous Robots; bearing a date of 1997; pp. 319-331; vol. 4; Kluwer Academic Publishers.

Kitaoka et al.; "A three-dimensional model of the human airway tree"; Journal of Applied Physiology; bearing a date of 1999; pp. 2207-2217; vol. 87; The American Physiological Society.

Kitching, John; "Time for a Better Receiver: Chip-Scale Atomic Frequency References"; GPS World; bearing a date of Nov. 2007; pp. 52-57.

Knappe, Svenja; "Emerging Topics: MEMS Atomic Clocks"; Comprehensive Microsystems; bearing a date of 2007; pp. 571-612; vol. 3; Elsevier B.V.; Netherlands.

Koenig et al.; "Laser-Induced Autofluorescence for Medical Diagnosis"; Journal of Fluorescence; bearing a date of 1994, pp. 17-40; vol. 4, No. 1; Plenum Publishing Corporation.

Kuipers et al.; "A Robot Exploration and Mapping Strategy Based on a Semantic Hierarchy of Spatial Representations"; Robotics and Autonomous Systems; bearing a date of 1981; pp. 47-63; vol. 8; Elsevier Science Publishers B.V.

Kuntze et al.; "Experiences With the Development of a Robot for Smart Multisensoricpipe Inspection"; IEEE Xplore; bearing dates of May 16, 1998-May 20, 1998 and 2005; pp. 1773-1778 (Only the Abstract is being provided); vol. 2; IEEE; located at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?rnumber=677423; printed on Apr. 23, 2007.

Latombe, Jean-Claude; "Chapter 1: Introduction and Overview"; Robot Motion Planning; bearing a date of 1991; 11 pages total, pp. 12-20; Kluwer Academic Publishers.

Laumond et al.; "Robot Motion Planning and Control"; bearing a date of 1998; pp. 1-343 plus cover page, foreword and table of contents (353 total pages); Springer.

Leong et al.; "Tetherless thermobiochemically actuated microgrippers"; PNAS; bearing dates of Jan. 20, 2009 and 2009; pp. 703-708; vol. 106, No. 3; The National Academy of Sciences of the USA; located at www.pnas.org_cgi_doi_10.1073_pnas.0807698106.

Luckevich, Mark, "MEMS microvalves: the new valve world"; Valve-World; bearing a date of May 2007; pp. 79-83.

Lynch et al.; "Design of Piezoresistive MEMS-Based Accelerometer for Integration with Wireless Sensing Unit for Structural Monitoring"; Journal of Aerospace Engineering; bearing a date of Jul. 2003; pp. 108-114; vol. 3; ASCE.

Machado et al., "Detection of Lung Cancer by Sensor Array Analyses of Exhaled Breath"; American Journal of Respiratory and Critical Care Medicine; bearing a date of 2005; pp. 1286-1291; vol. 171.

Marcu et al.; "In vivo detection of macrophages in a rabbit atherosclerotic model by time-resolved laser-induced fluorescence spectroscopy"; Atherosclerosis; bearing a date of 2005, pp. 295-303; vol. 181; Elsevier Ireland Ltd.

Martel, Sylvain; "Fundamental Principles and Issues of High-speed Piezoactuated Three-legged Motion for Miniature Robots Designed for Nanometer-scale Operations"; The International Journal of Robotics Research; bearing dates of Jul. 2005 and 2005; pp. 575-588; vol. 24, No. 7; Sage Publications.

Mataric, Maja J.; "Integration of Representation into Goal-Driven Behavior-Based Robots"; IEEE Transactions on Robotics and Automation; bearing dates of Jun. 1992 and 1992; pp. 304-312; vol. 8, No. 3; IEEE.

Mattley et al.; "Blood Characterization using uv/vis Spectroscopy"; Advances in Fluorescence Sensing Technology II (Proceedings Volume); bearing a date of 1995; pp. 462-470; vol. 2388; SPIE.

Mehmood et al.; "Autonomous Navigation of Mobile Agents Using RFID-Enabled Space Partitions"; ACMGIS '08; bearing dates of Nov. 5-7, 2008 and 2008; pp. 1-10; ACM.

Menciassi et al.; "Towards Active Capsular Endoscopy: Preliminary Results on a Legged Platform"; Proceedings of the 28th IEEE EMBS Annual International Conference; bearing dates Aug. 30, 2006-Sep. 3, 2006 and 2006; pp. 2215-2218; IEEE.

Meyer et al.; "Map-Based Navigation in Mobile Robots: II. A Review of Map-Learning and Path-Learning Strategies"; Science Direct-Cognitive Systems Research; bearing dates of Feb. 12, 2003 and Dec. 4, 2003; pp. 1-51; vol. 4, No. 4; Elsevier Science.

Mohan et al., "Bokode: Imperceptible Visual tags for Camera Based Interaction from a Distance"; ACM Transactions on Graphics (Proceedings of SIGGRAPH 2009); bearing dates of Aug. 3-7, 2009; pp. 1-8.

Mok et al.; "Recent Progress in Nucleic Acid Aptamer-Based Biosensors and Bioassays"; Sensors; bearing a date of 2008; pp. 7050-7084; vol. 8.

Morrison et al., "Clinical Applications of Micro- and Nanoscale Biosensors"; Biomedical Nanostructures; bearing a date of 2008; Chapter 17; pp. 433-454; John Wiley & Sons, Inc.

Motomiya et al.; "Flow Patterns in the Human Carotid Artery Bifurcation"; Stroke; bearing dates of Jan.-Feb. 1984; pp. 50-56; vol. 15, No. 1.

Nehmzow et al.; "Robot Navigation in the Real World: Experiments with Manchester's FortyTwo in Unmodified, Large Environments"; Robotics and Autonomous Systems; bearing a date of 2000; pp. 223-242; vol. 33; Elsevier Science B.V.

Nguyen, Clark T.-C.; "MEMS Technology for Timing and Frequency Control"; IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Controls; bearing dates of Feb. 2007 and 2007; pp. 251-270; vol. 54, No. 2; IEEE.

Nordstrom et al.; "Identification of Cervical Intraepithelial Neoplasia (CIN) Using UV-Excited Fluorescence and Diffuse-Reflectance Tissue Spectroscopy"; Lasers in Surgery and Medicine; bearing a date of 2001; pp. 118-127; vol. 29; Wiley-Liss, Inc.

Nowinski et al.; "Three-dimensional Atlas of the Brain Anatomy and Vasculature"; RadioGraphics; bearing dates of Jan.-Feb. 2005 and 2005; pp. 263-271; vol. 25, No. 1; RSNA.

Pan et al.; "A magnetically driven PDMS micropump with ball check-valves"; Journal of Micromechanics and Microengineering; bearing a date of 2005, pp. 1021-1026; vol. 15; IOP Publishing Ltd.

Pavlidis, N.; "The diagnostic and therapeutic management of leptomeningeal carcinomatosis"; Annals of Oncology; bearing a date of 2004; pp. iv285-iv291; vol. 15 (Supp. 4); European Society for Medical Oncology.

Peng et al.; "Ultraviolet light-emitting diodes operating in the 340 nm wavelength range and application to time-resolved fluorescence spectroscopy"; Applied Physics Letters; bearing dates of Aug. 23, 2004 and 2004; pp. 1436-1438; vol. 85, No. 8; American Institute of Physics.

Pfister et al.; "Weighted Line Fitting Algorithms for Mobile Robot Map Building and Efficient Data Representation"; Proceedings of the 2003 IEEE International Conference on Robotics and Automation; bearing a date of Sep. 14-19, 2003; pp. 1-8.

"Philips develops "intelligent pill""; Reuters; bearing a date of Nov. 11, 2008; p. 1; Thomson Reuters.

"Philips' intelligent pill targets drug development and treatment for digestive tract diseases"; PhysOrg.com; bearing a date of Nov. 11, 2008; pp. 1-3; located at http://www.physorg.com/news145640874.html.

Phillips et al.; "Detection of Lung Cancer With Volatile Markers in the Breath"; Chest; bearing dates of Jun. 2003 and 2003; pp. 2115-2123; vol. 123, No. 6; American College of Chest Physicians.

Pisupati et al.; "A Central Axis Algorithm for 3D Bronchial Tree Structures"; Proceedings of the International Symposium on Computer Vision; bearing a date of 1995; pp. 259-264; IEEE.

Psathakis et al.; "8-Isoprostane, a Marker of Oxidative Stress, Is Increased in the Expired Breath Condensate of Patients With Pulmo-

(56) **References Cited**

OTHER PUBLICATIONS

nary Sarcoidosis"; Chest; bearing dates of Mar. 2004 and 2004, pp. 1005-1011; vol. 125, No. 3; American College of Chest Physicians.
Quaglia et al.; "An endoscopic capsule robot: a meso-scale engineering case study"; Journal of Micromechanics and Microengineering; bearing a date of 2009; pp. 1-11; vol. 19; IOP Publishing Ltd.
Quirini et al.; "Design of a Pill-Sized 12-legged Endoscopic Capsule Robot"; 2007 IEEE International Conference on Robotics and Automation; bearing dates of Apr. 10-14, 2007 and 2007; pp. 1856-1862; IEEE.
Raman et al.; "In Vivo Atherosclerotic Plaque Characterization Using Magnetic Susceptibility Distinguishes Symptom-Producing Plaques"; JACC: Cardiovascular Imaging; bearing dates of Jan. 2008 and 2008; pp. 49-57; vol. 1, No. 1; Elsevier.
Rasmussen et al.; "Proximity-based Access Control for Implantable Medical Devices"; CCS '09, Proceedings of the 16th ACM Conference on Computer and Communications Security; bearing dates of Nov. 9-13, 2009 and 2009; pp. 1-10.
"Remote-controlled capsule endoscope safely examines the stomach"; PhysOrg.com; bearing a date of Jan. 18, 2011; pp. 1-2; located at http://www.physorg.com/news-2011-01-remote-controlled-capsule-endoscope-safely-stomach.html.
"Researchers Create Tiny, Self-Propelled Devices"; PhysOrg.com; printed on Feb. 12, 2007; pp. 1-3; located at: http://www.physorg.com/printnews.php?newsid=90521279.
Roh et al.; "Strategy for Navigation Inside Pipelines With Differential-Driveinpipe Robot"; IEEE Xplore; 2002 and 2005; pp. 2575-2580 (Only the Abstract is being provided); vol. 3; IEEE; located at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1013619; printed on Apr. 23, 2007.
Roh et al.; "Actively Steerable In-Pipe Inspection Robots for Underground Urban Gas Pipelines"; IEEE Xplore; bearing dates of 2001 and 2005; pp. 761-766 (Only the Abstract is being provided); vol. 1; IEEE; located at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=932642; printed on Apr. 23, 2007.
Rolfe, Brigitte; "Toward Nanometer-Scale Sensing Systems: Natural and Artificial Noses as Models for Ultra-Small, Ultra-Dense Sensing Systems"; Advances in Computers; bearing dates of Nov. 2004, 2004, and 2007; pp. 11-46; vol. 71; Elsevier, B.V.
Schertler et al.; "Effects of ECG Gating and Postprocessing Techniques on 3D MDCT of the Bronchial Tree"; AJR; bearing a date of Jul. 2004; pp. 83-89; vol. 183; American Roentgen Ray Society.
Schnakenberg et al.; "Intravascular pressure monitoring system"; Sensors and Actuators A: Physical; bearing a date of 2004; pp. 61-67; vol. 110; Elsevier B.V.
Schwartz, John; "In the Lab: Robots That Slink and Squirm"; The New York Times: Science; bearing a date of Mar. 27, 2007; pp. 1-4; The New York Times Company; located at: http://www.nytimes.com/2007/03/27/science/27robo.html?ex=1332648000&en=d4541141c174b454&ei=5124&partner=digg&exprod=digg; printed on Mar. 27, 2007.
"Spider pill to seek out diseases"; PhysOrg.com; bearing a date of Oct. 16, 2009 and 2009; p. 1; located at http://www.physorg.com/news174893082.html.
Sun et al.; "A Miniature RF Communication System for Micro Gastrointestinal Robots"; Journal of Medical Engineering & Technology; bearing a date of 2003; pp. 160-163; vol. 27.
Suzumori et al.; "Micro Inspection Robot for 1-in Pipes"; IEEE/ASME Transactions on Mechatronics; bearing dates of Sep. 1999 and 1999; pp. 286-292; vol. 4, No. 3; IEEE.
Tang et al.; "Cerebral Vascular Tree Matching of 3D-RA Data Based on Tree Edit Distance"; Medical Imaging and Augmented Reality; bearing a date of 2006; pp. 116-123.
The Biomedical Engineering Handbook, Second Edition; bearing a date of 2000; pp. IV-1-43-31; vol. I; CRC Press LLC.
The Biomedical Engineering Handbook, Second Edition; bearing a date of 2000; pp. V-1-51-9; vol. I; CRC Press LLC.
Thrun, Sebastian; "Learning Metric-Topological Maps for Indoor Mobile Robot Navigation"; Artificial Intelligence; bearing a date of 1998; pp. 21-71; vol. 99; Elsevier Science B.V.
Thrun, Sebastian; "Probabilistic Algorithms in Robotics"; AI Magazine; bearing dates of Winter 2000 and 2000; pp. 93-109; vol. 21, No. 4; American Association for Artificial Intelligence.
Thrun, Sebastian; "Robotic Mapping: A Survey"; Exploring Artificial Intelligence in the New Millenium; bearing a date of Feb. 2002; pp. 1-29 (31 total pages); Morgan Kaufmann.
Thrun et al.; "A Real-Time Algorithm for Mobile Robot Mapping With Applications to Multi-Robot and 3D Mapping"; IEEE International Conference on Robotics and Automation; bearing a date of Apr. 2000; pp. 1-8.
Thrun et al.; "Integrating Topological and Metric Maps for Mobile Robot Navigation: A Statistical Approach"; pp. 1-7.
Tomatis et al.; "Simultaneous Localization and Map Building: A Global Topological Model with Local Metric Maps"; Robotics Autonomous Systems; bearing a date of 2003; pp. 1-6; vol. 44.
Tsuruta et al.; "Control Circuit in an In-Pipe Wireless Micro Inspection Robot"; IEEE Xplore; bearing dates of 2000 and 2005; pp. 59-64 (Only the Abstract is being provided); IEEE; located at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=903290; printed on Apr. 23, 2007.
Ulrich et al.; "Appearance-Based Place Recognition for Topological Localization"; IEEE International Conference on Robotics and Automation; bearing a date of Apr. 2000; pp. 1023-1029.
Verheye et al.; "Selective Clearance of Macrophages in Atherosclerotic Plaques by Autophagy"; Journal of the American College of Cardiology; bearing dates of Feb. 13, 2007 and 2007; pp. 706-715; vol. 49, No. 6; Elsevier Inc.
Wacharasindhu et al.; "Radioisotope microbattery based on liquid semiconductor"; Applied Physics Letters; bearing dates of Dec. 11, 2008, Jun. 9, 2009, Jul. 6, 2009, Dec. 8, 2009 and 2009; pp. 014103-1-014103-3; vol. 95; American Institute of Physics.
Wakimoto et al.; "A Micro Snake-Like Robot for Small Pipe Inspection"; International Symposium on Micromechatronics and Human Science; bearing a date of 2003; pp. 303-308; IEEE.
Wang et al.; "A MEMS-based Air Flow Sensor with a Free-standing Micro-cantilever Structure"; Sensors; bearing dates of Aug. 27, 2007, Oct. 10, 2007, Oct. 17, 2007, and 2007; pp. 2389-2401; vol. 7; MDPI.
Watson et al.; "Piezoelectric ultrasonic resonant motor with stator diameter less than 250 μm: the Proteus motor"; Journal of Micromechanics and Microengineering; bearing dates of Sep. 25, 2008, Nov. 18, 2008, Jan. 20, 2009, and 2009; pp. 1-5; vol. 19; IOP Publishing Ltd.
Weingandt et al.; "Autofluorescence spectroscopy for the diagnosis of cervical intraepithelial neoplasia"; BJOG: an International Journal of Obstetrics and Gynaecology; bearing dates of Aug. 2002 and 2002; pp. 947-951; vol. 109; RCOG.
Xi et al.; "Self-assembled microdevices driven by muscle"; Nature Materials; bearing dates of Feb. 2005 and 2005; pp. 180-184 (10 pages total); vol. 4; Nature Publishing Group.
Yang et al.; "Power generation with laterally packaged piezoelectric fine wires"; Nature Nanotechnology; bearing dates of Nov. 9, 2008, Jan. 2009, and 2009; pp. 34-39; vol. 4; Macmillan Publishers Limited.
Yang et al.; "Converting Biomechanical Energy into Electricity by a Muscle-Movement-Driven Nanogenerator"; Nano Letters; bearing dates of Dec. 25, 2008, Jan. 31, 2009, and 2009; pp. 1201-1205; vol. 9, No. 3; American Chemical Society.
Yu et al.; "System for the analysis and visualization of large 3D anatomical trees"; Computers in Biology and Medicine; bearing dates of Oct. 6, 2006, May 31, 2007, Jun. 4, 2007, and 2007; pp. 1802-1820; vol. 37; Elsevier Ltd.
Zhao et al.; "Physicist Develops Natural Motor Technique"; PhysOrg.com; bearing dates of Apr. 21, 2007 and 2007; 1 page; United Press International; located at: http://www.physorg.com/news96357975.html; printed on Apr. 23, 2007.
Zheng et al.; "Design and Fabrication of a Micro Coulter Counter with Thin Film Electronics"; Proceedings of 2006 International Conference on Microtechnologies in Medicine and Biology; bearing dates of May 9-12, 2006 and 2006; pp. 16-19; IEEE.
Zhu et al.; "Flattening Maps for the Visualization of Multibranched Vessels"; IEEE Transactions on Medical Imaging; bearing dates of Feb. 10, 2004, Sep. 27, 2004, Feb. 2005, and 2005; pp. 191-198; vol. 24, No. 2; IEEE.

(56) **References Cited**

OTHER PUBLICATIONS

Zrimec et al.; "3D Modelling and Visualization of the Human Lung"; Proceedings of the 2nd International Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT'04); bearing a date of 2004; pp. 110-115; IEEE.

Zyga, Lisa; "Microswimmer Propels Itself With Near-Zero Friction"; PhysOrg.com; bearing dates of Jun. 4, 2007 and 2007; pp. 1-2; PhyOrg.com; located at: http://www.physorg.com/news100176842.html; printed on Jun. 6, 2007.

Agarwal, Abhishek K.; Atencia, Javier; Beebe, David J.; Jiang, Hongrui; "Magnetically-driven temperature-controlled microfluidic actuators"; printed on Apr. 12, 2006; pp. 1-5; located at: http://www.unl.im.dendai.ac.jp/INSS2004/INSS2004_papers/OralPresentations/C2.pdf.

Chen, Haitao; Ebner, Armin D.; Ritter, James A.; Kaminski, Michael D.; Rosengart, Axel J.; "Sequestration of Blood-Borne Magnetic Drug Carrier Particles Using Magnetizable Intravascular Stents"; Collaborative Investigators for Applied Nanotechnology in Medicine; printed on Apr. 12, 2006; pp. 1; Chicago, Illinois.

Japanese Office Action; Japanese App. No. 2007-533572; Sep. 22, 2010 (received by our Agent on Sep. 28, 2010); pp. 1-3; (English translation).

Martel, Sylvain; "Fundamentals of high-speed piezo-actuated three-legged motion for miniature robots designed for nanometer-scale operations"; printed on Oct. 24, 2008; pp. 1-8.

U.S. Appl. No. 12/930,916, Wood, Jr., Lowell.

U.S. Appl. No. 13/136,680, Ferren et al.

U.S. Appl. No. 13/136,679, Ferren et al.

U.S. Appl. No. 13/136,677, Ferren et al.

U.S. Appl. No. 13/136,676, Ferren et al.

U.S. Appl. No. 13/136,675, Ferren et al.

U.S. Appl. No. 13/136,678, Ferren et al.

U.S. Appl. No. 13/136,674, Ferren et al.

Hammer-Wilson et al.; "Fluorescence Diagnostics of *Helicobacter pylori*-Infected Human Gastric Mucosa: Establishing Technique and Validity"; Scandinavian Journal of Gastroenterology; bearing a date of 2007, accepted Jan. 2, 2007; pp. 941-950; vol. 42; Taylor& Francis.

So, Peter TC; "Two-Photon Fluorescence Light Microscopy"; Encyclopedia of Life Sciences; bearing a date of 2002; pp. 1-5; Macmillan Publishers Ltd, Nature Publishing Group; located at: http://web.mit.edu/solab/Documents/Assets/So-2PF%20light%20microscopy.pdf.

Thomas et al.; "Detection and Analysis of Tumor Fluorescence Using a Two-Photon Optical Fiber Probe"; Biophysical Journal; bearing a date of Jun. 2004; 7 pages (3959-3965); vol. 86, No. 6.

Korean Intellectual Property Office (KIPO); Notice of Office Action; App. No. 10-2007-7009231; Jun. 8, 2012; pp. 1-5 (translation provided, 2 pages).

European Patent Office, Supplementary European Search Report, Pursuant to Rule 62 EPC; App. No. EP 08795525; Jan. 21, 2015 (received by our Agent on Jan. 16, 2015); pp. 1-7.

* cited by examiner

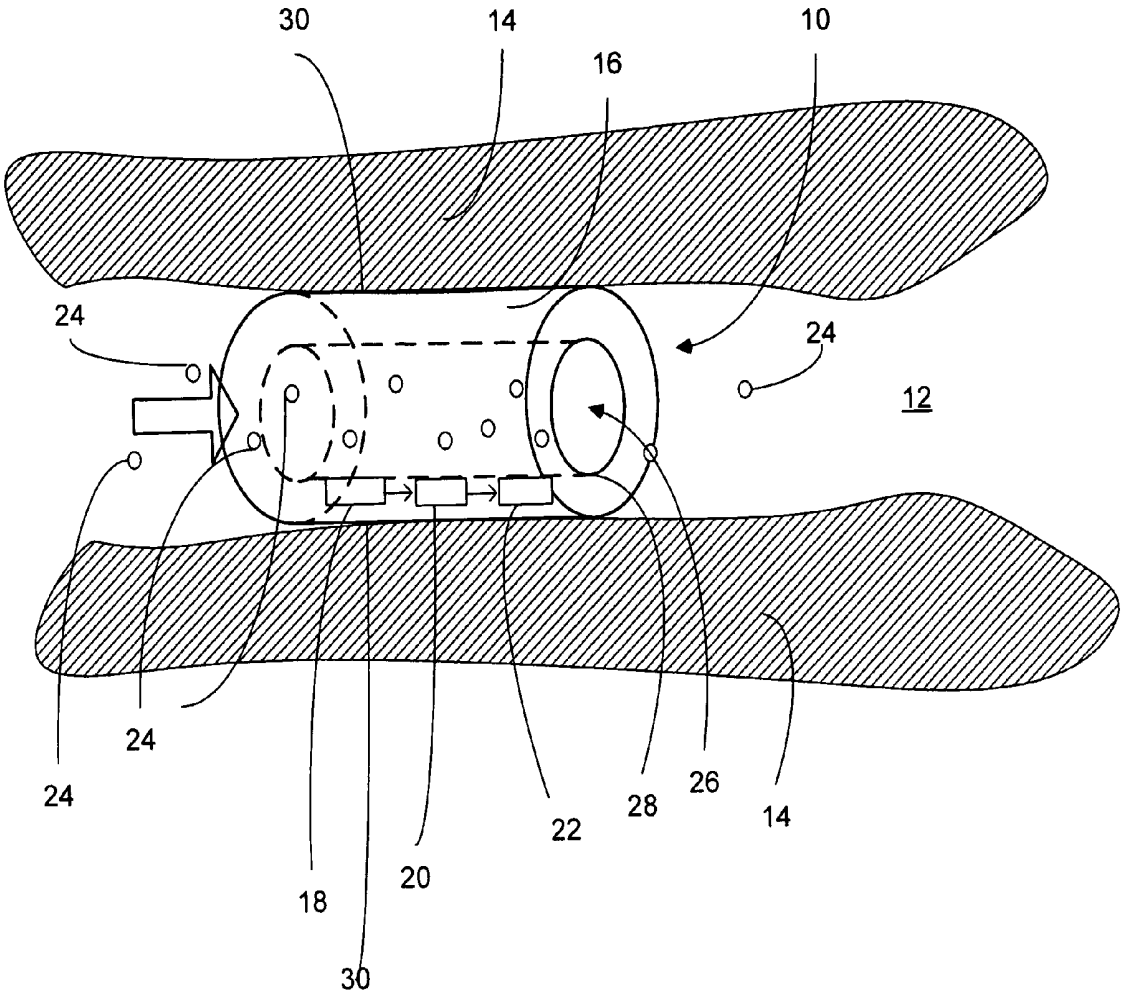

FIG. 1

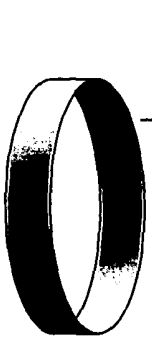

FIG. 2A

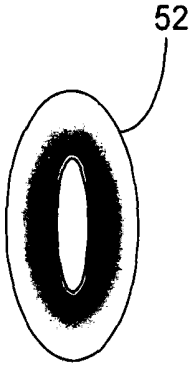

FIG. 2B

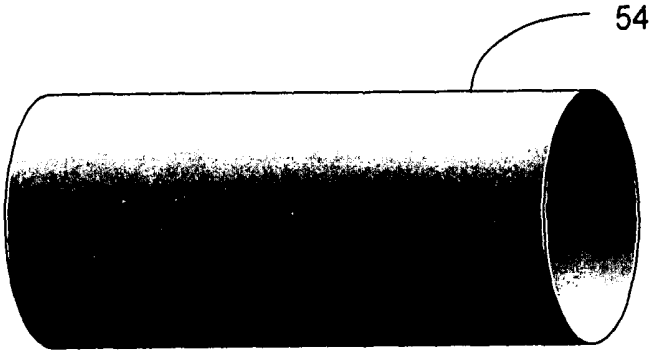

FIG. 2C

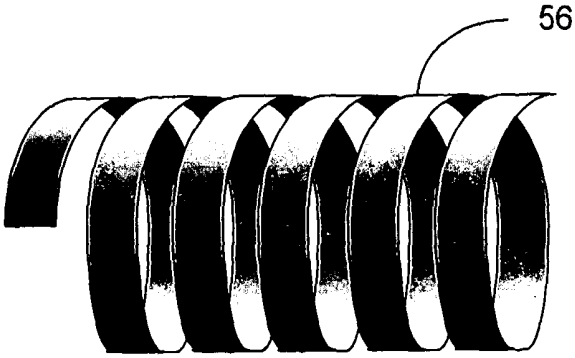

FIG. 2D

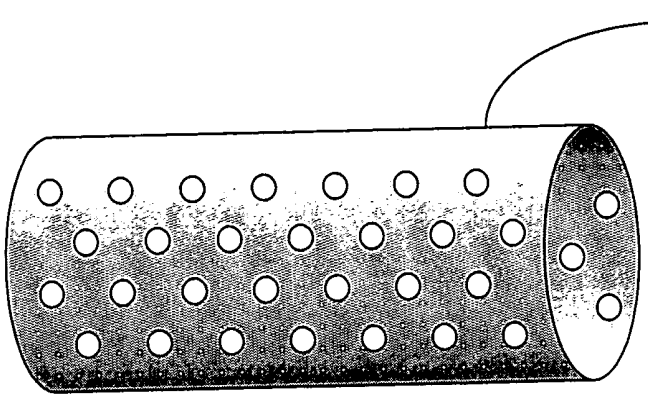

FIG. 3A

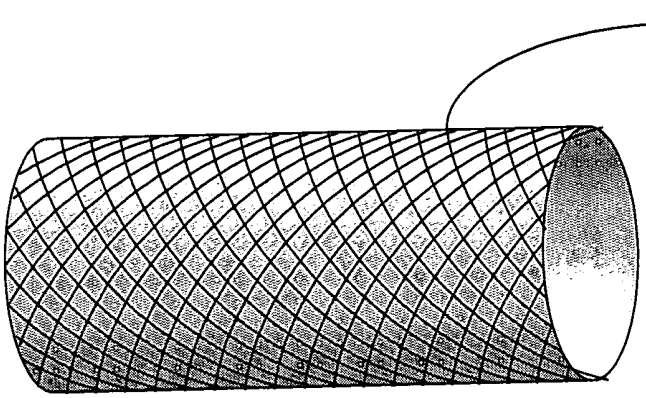

FIG. 3B

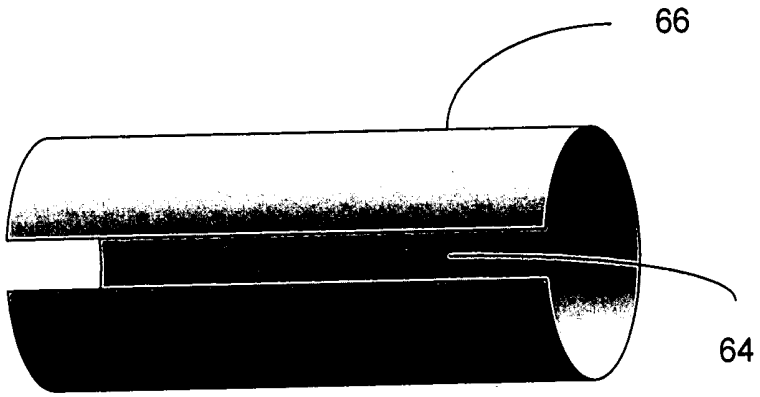

FIG. 3C

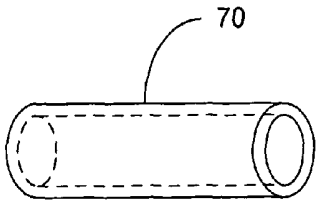

FIG. 4A

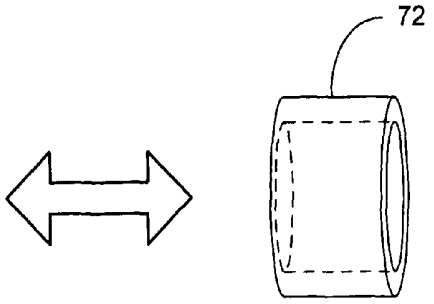

FIG. 4B

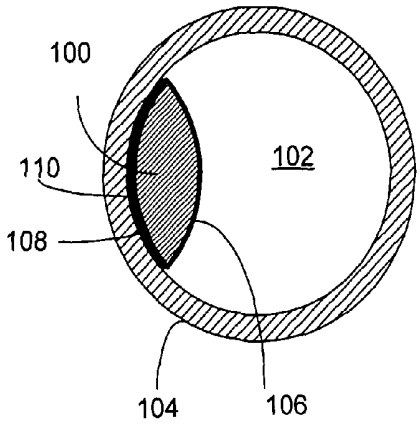

FIG. 5A

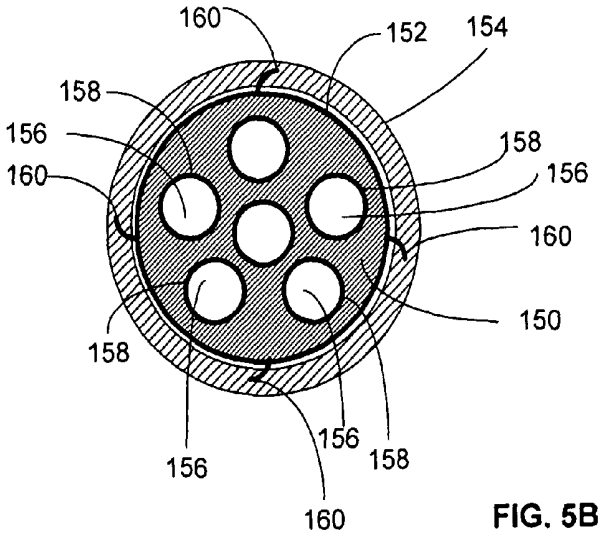

FIG. 5B

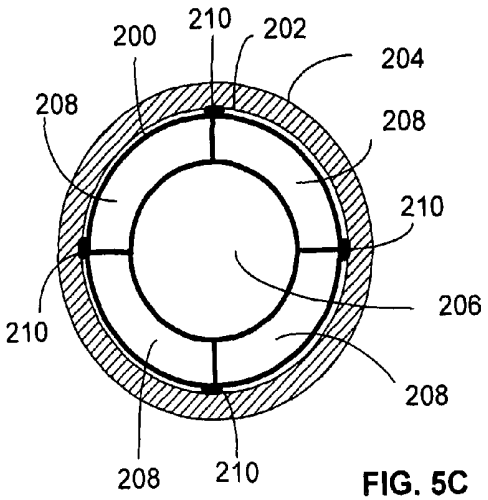

FIG. 5C

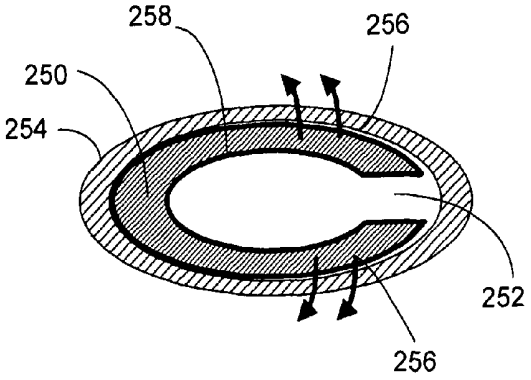

FIG. 5D

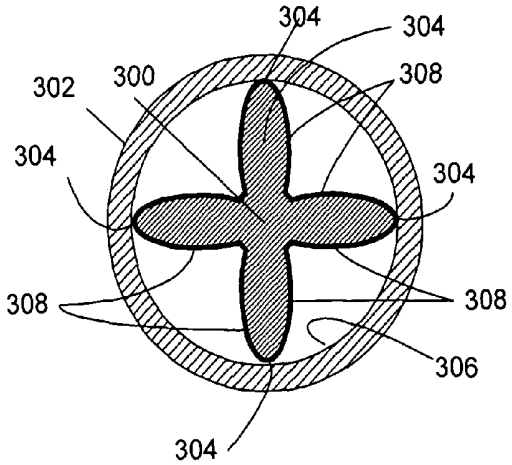

FIG. 5E

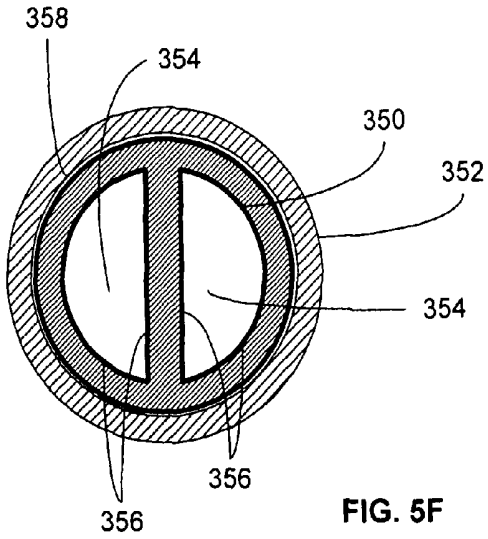

FIG. 5F

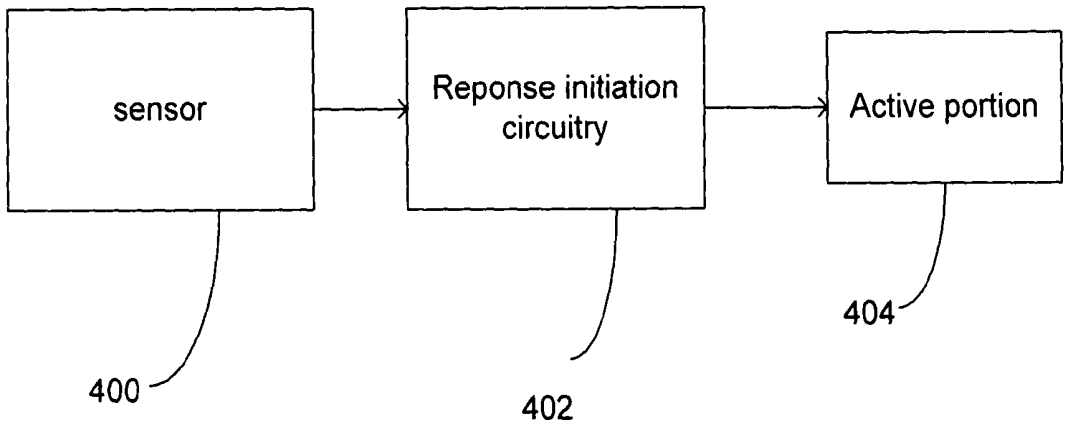
sensor
Reponse initiation circuitry
Active portion
400
402
404

FIG. 6

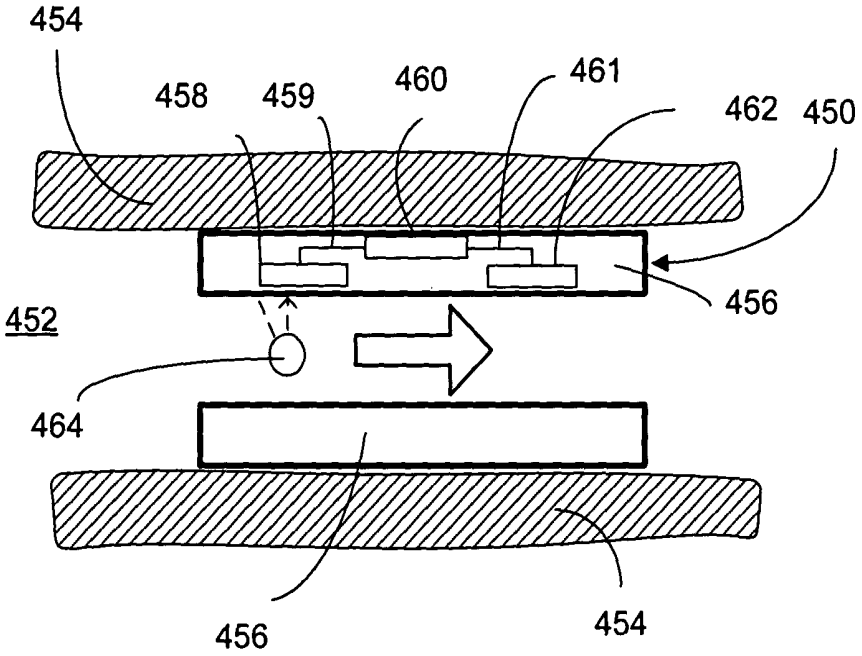
454
458
459
460
461
462
450
456
452
464
456
454

FIG. 7A

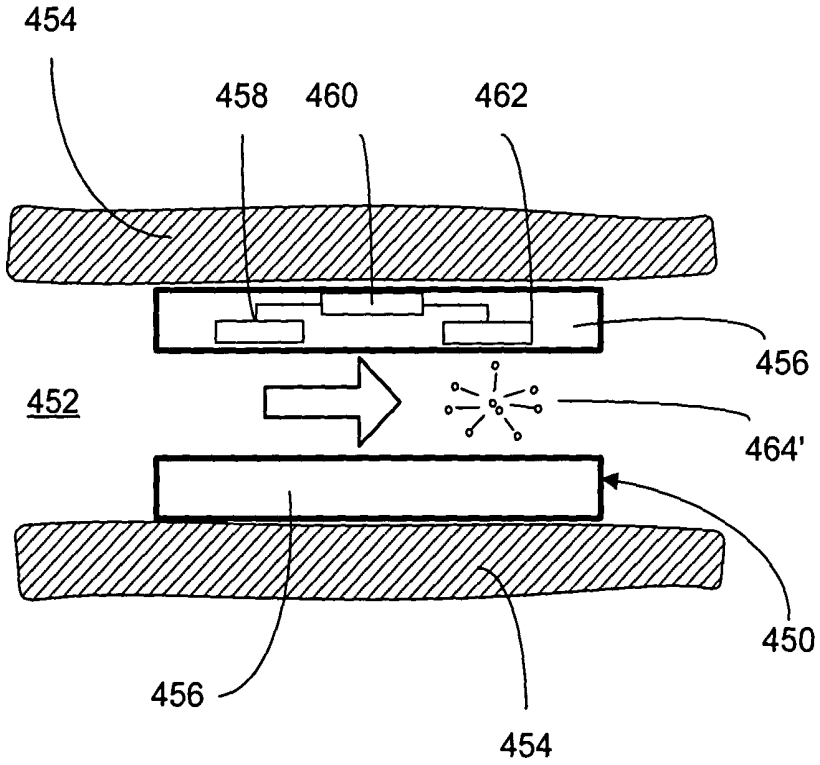
454
458
460
462
456
452
464'
450
456
454

FIG. 7B

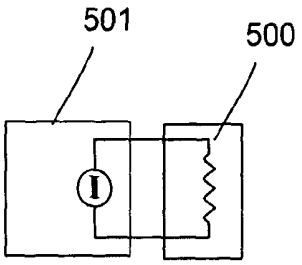

FIG. 8A

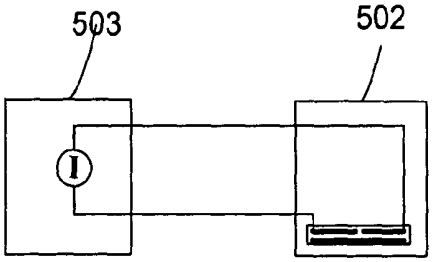

FIG. 8B

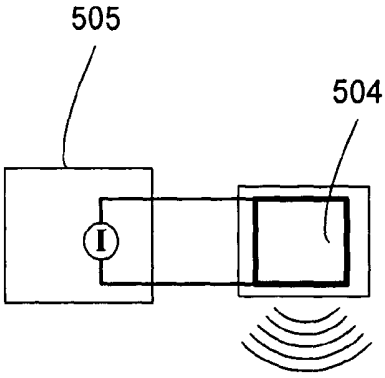

FIG. 8C

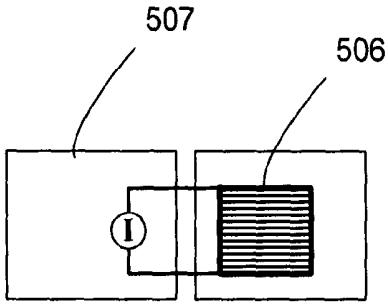

FIG. 8D

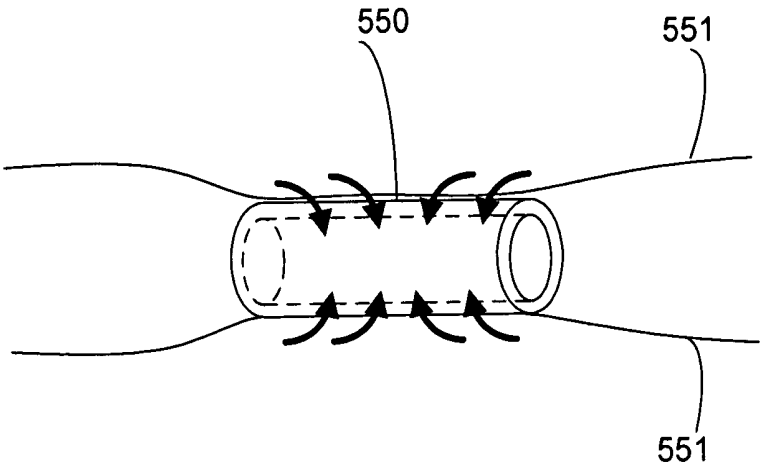

FIG. 9A

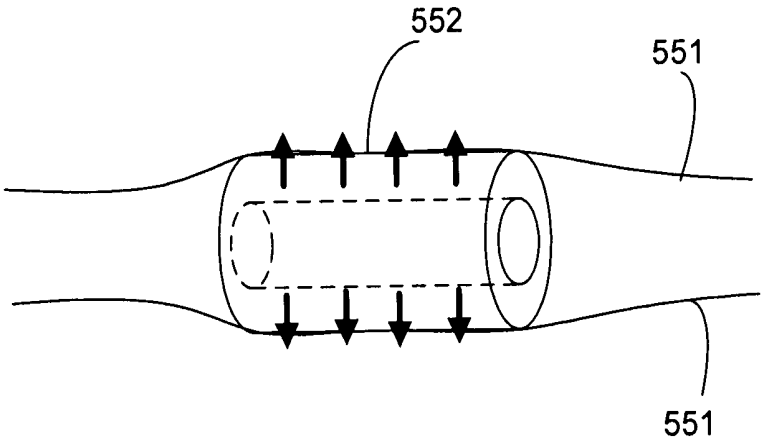

FIG. 9B

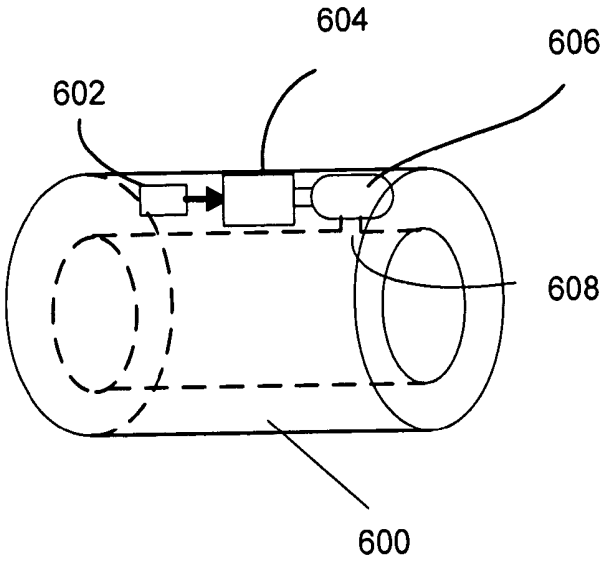

FIG. 10

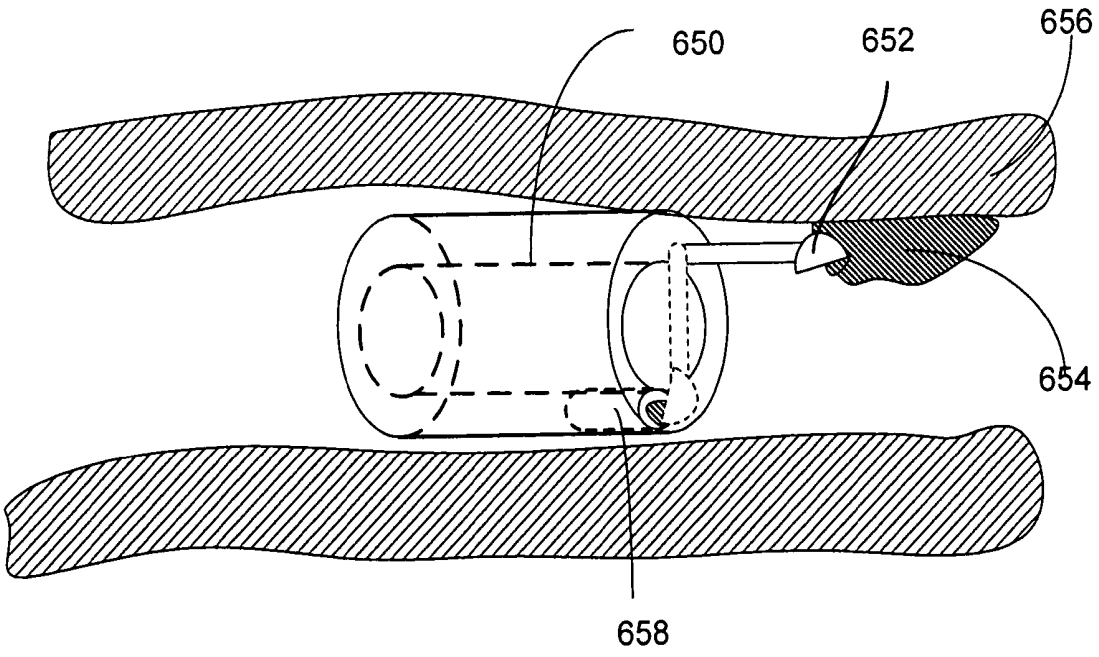

FIG. 11

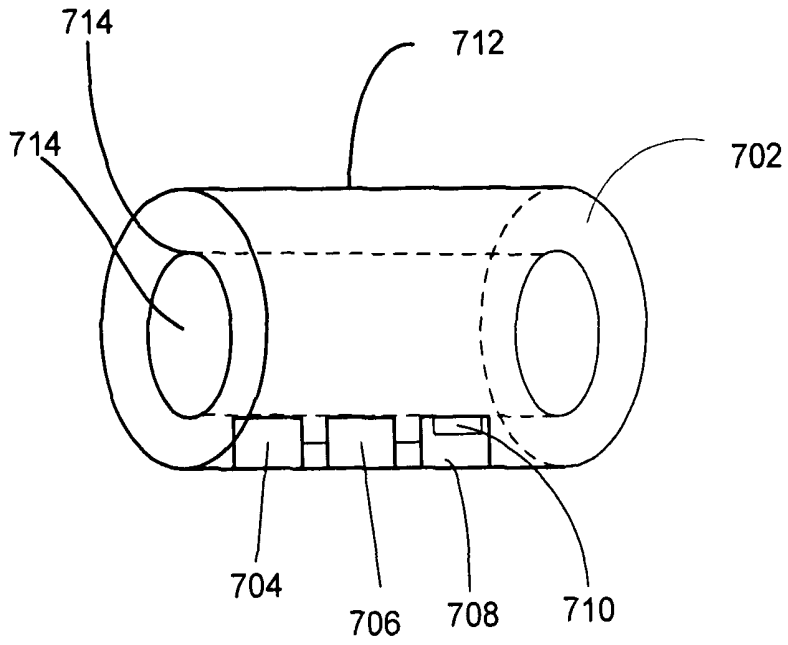

FIG. 12

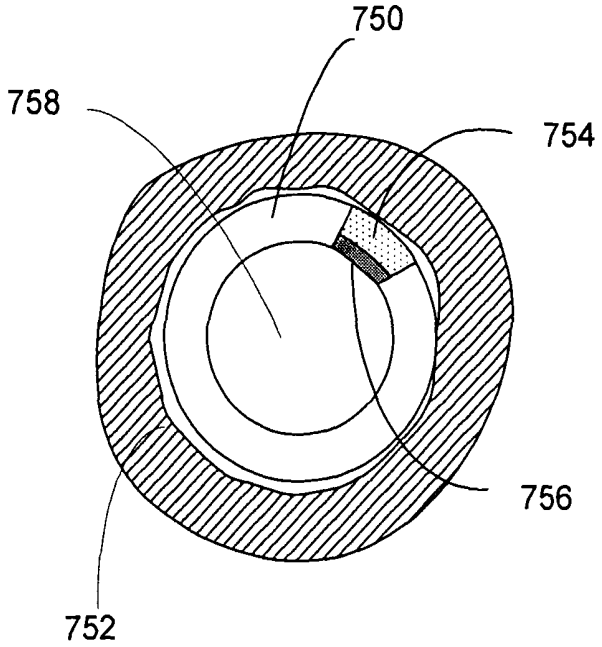

FIG. 13

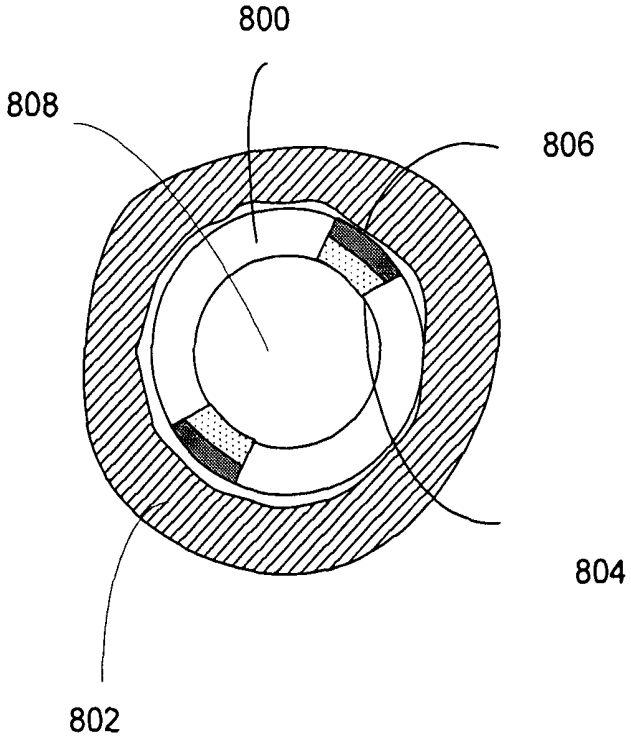

FIG. 14

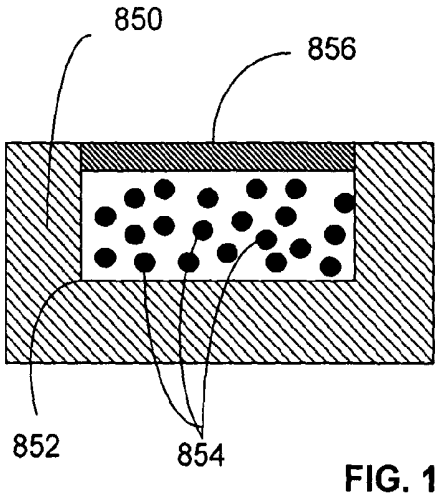

FIG. 15A

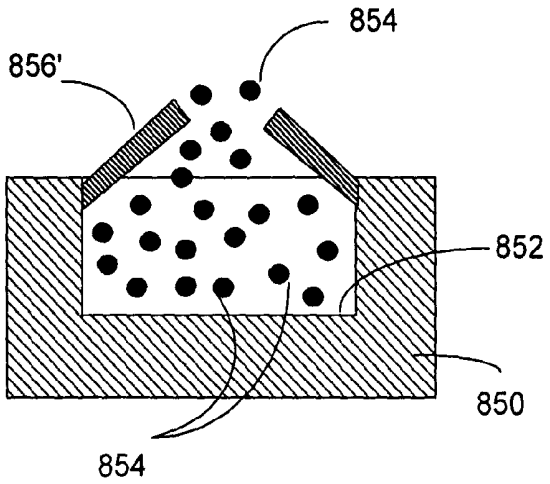

FIG. 15B

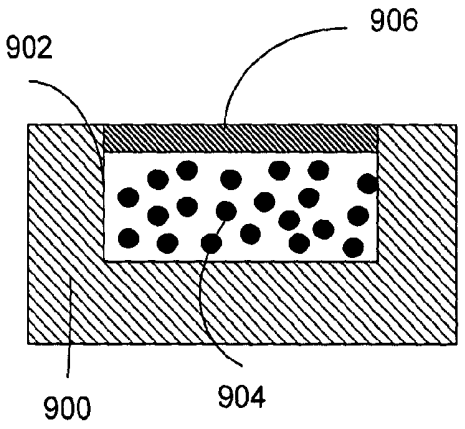

FIG. 16A

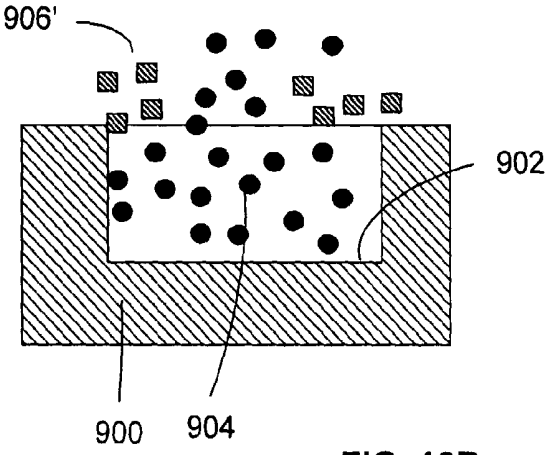

FIG. 16B

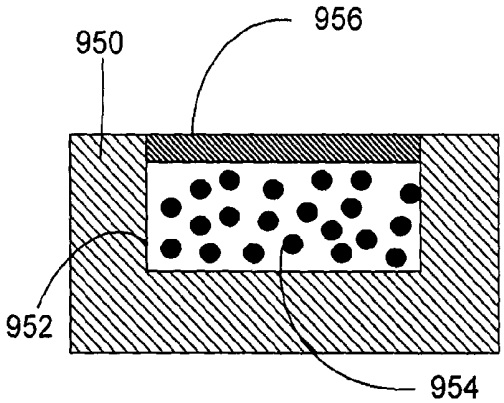

FIG. 17A

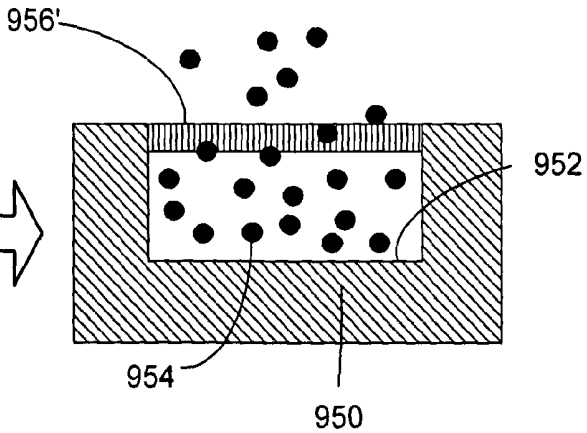

FIG. 17B

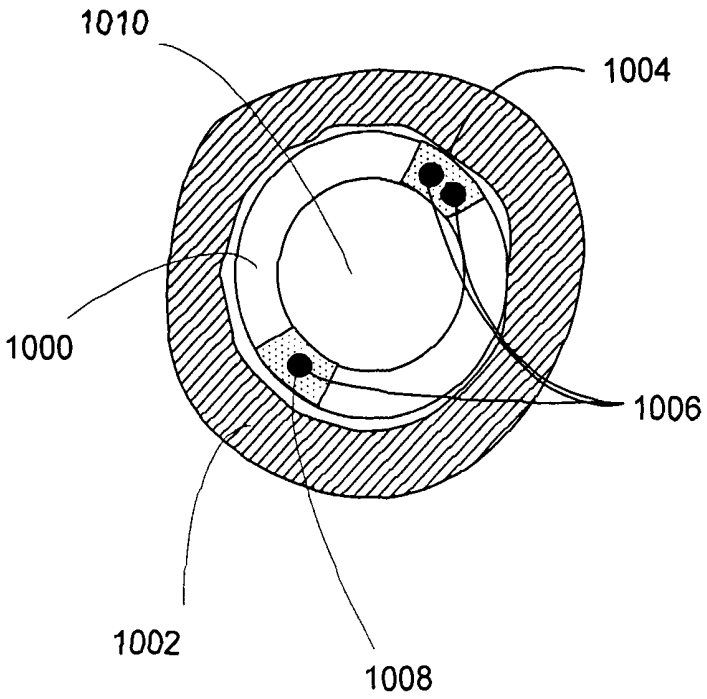

FIG. 18

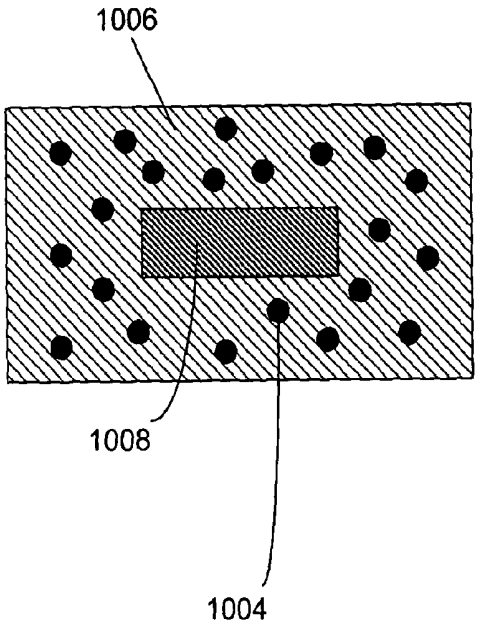

FIG. 19A

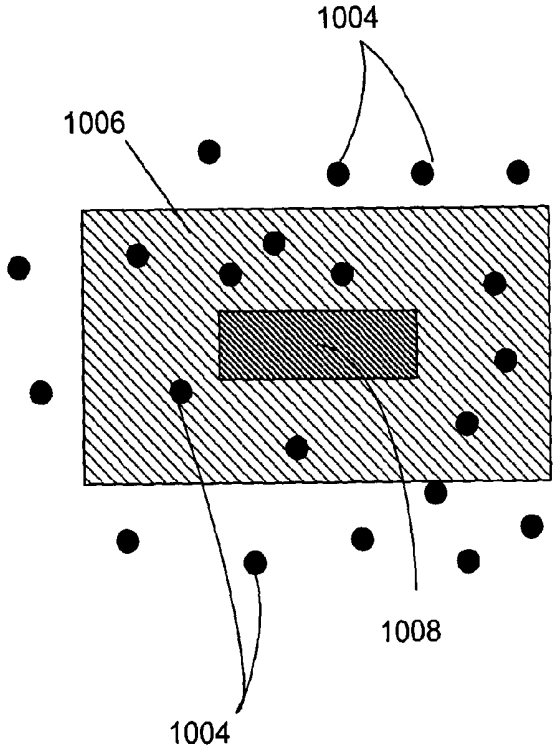

FIG. 19B

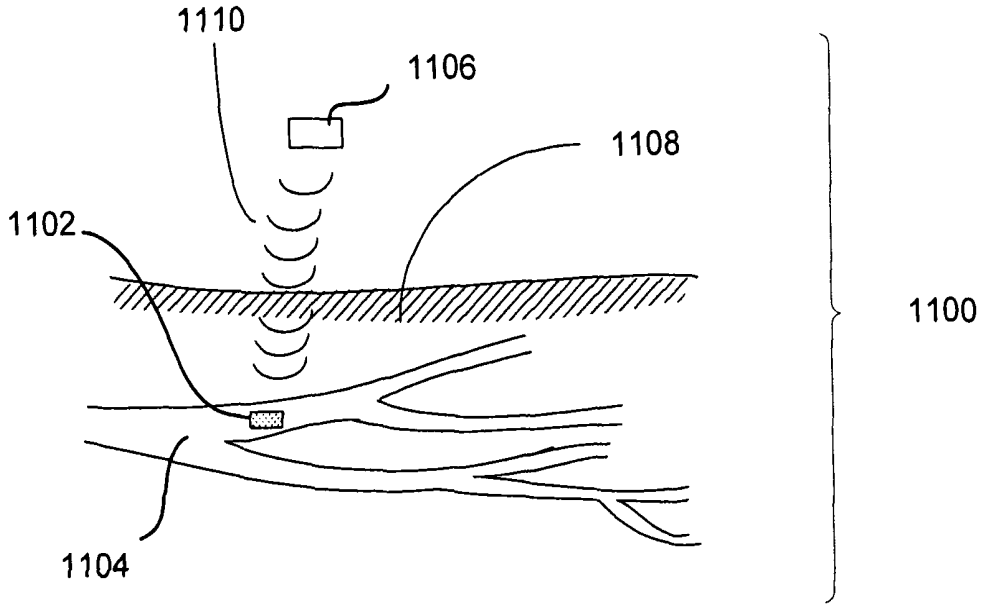

FIG. 20

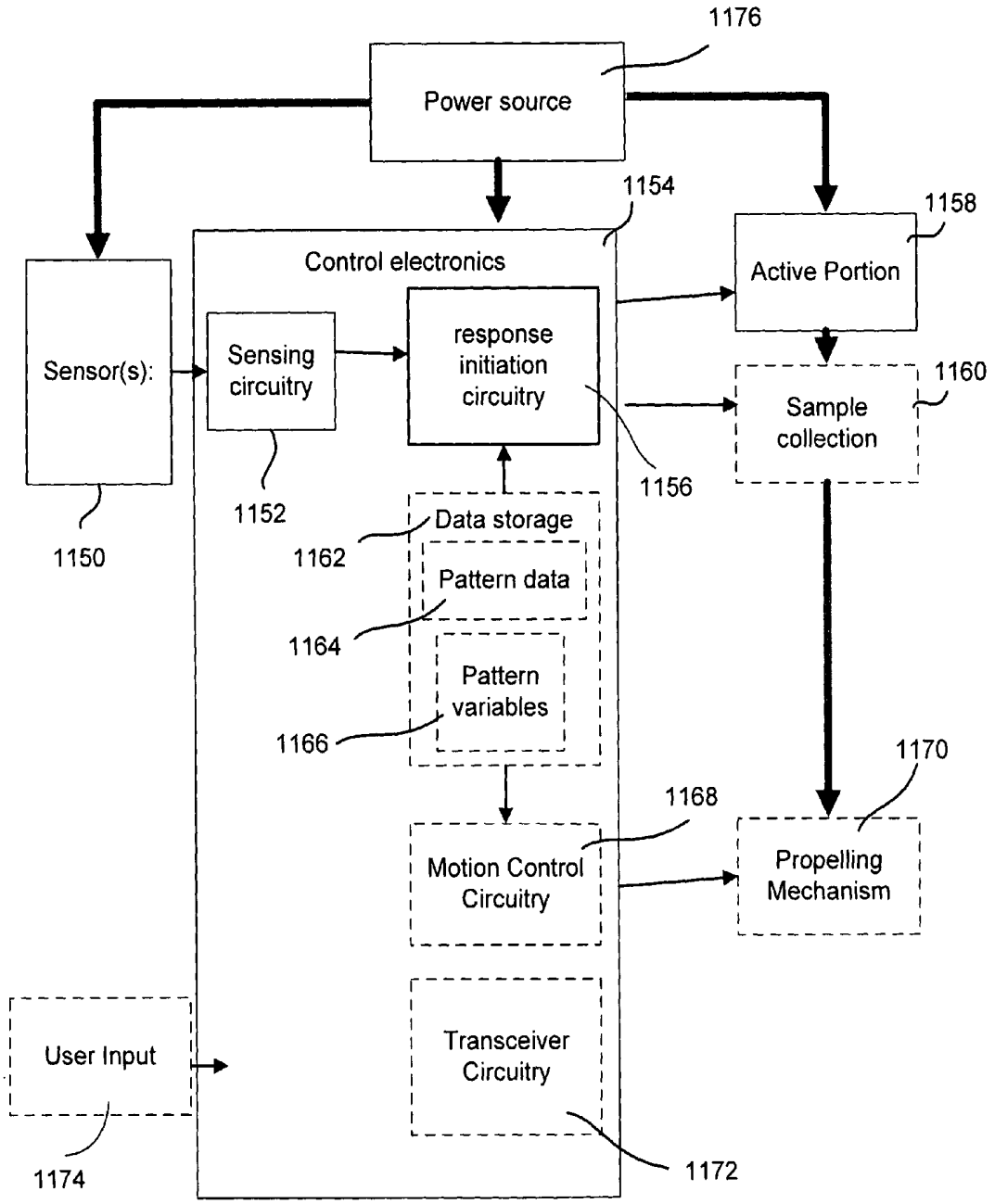
1176
Power source
1154
1158
Control electronics
Active Portion
Sensor(s):
Sensing circuitry
response initiation circuitry
1160
Sample collection
1156
1152
1150
Data storage
1162
Pattern data
1164
Pattern variables
1166
1170
1168
Motion Control Circuitry
Propelling Mechanism
User Input
Transceiver Circuitry
1174
1172

FIG. 21

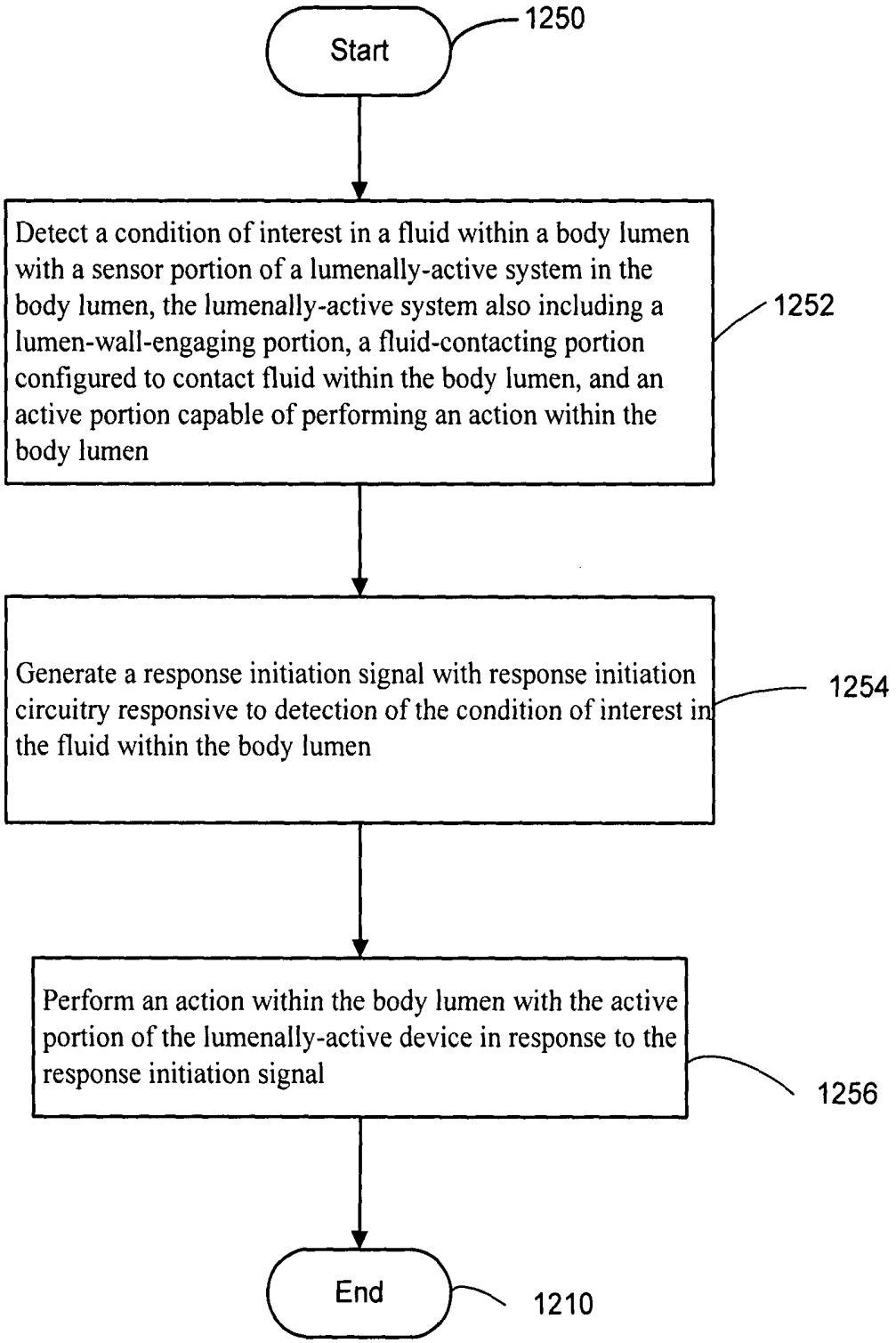
Start
1250
Detect a condition of interest in a fluid within a body lumen with a sensor portion of a lumenally-active system in the body lumen, the lumenally-active system also including a lumen-wall-engaging portion, a fluid-contacting portion configured to contact fluid within the body lumen, and an active portion capable of performing an action within the body lumen
1252
Generate a response initiation signal with response initiation circuitry responsive to detection of the condition of interest in the fluid within the body lumen
1254
Perform an action within the body lumen with the active portion of the lumenally-active device in response to the response initiation signal
1256
End
1210

FIG. 22

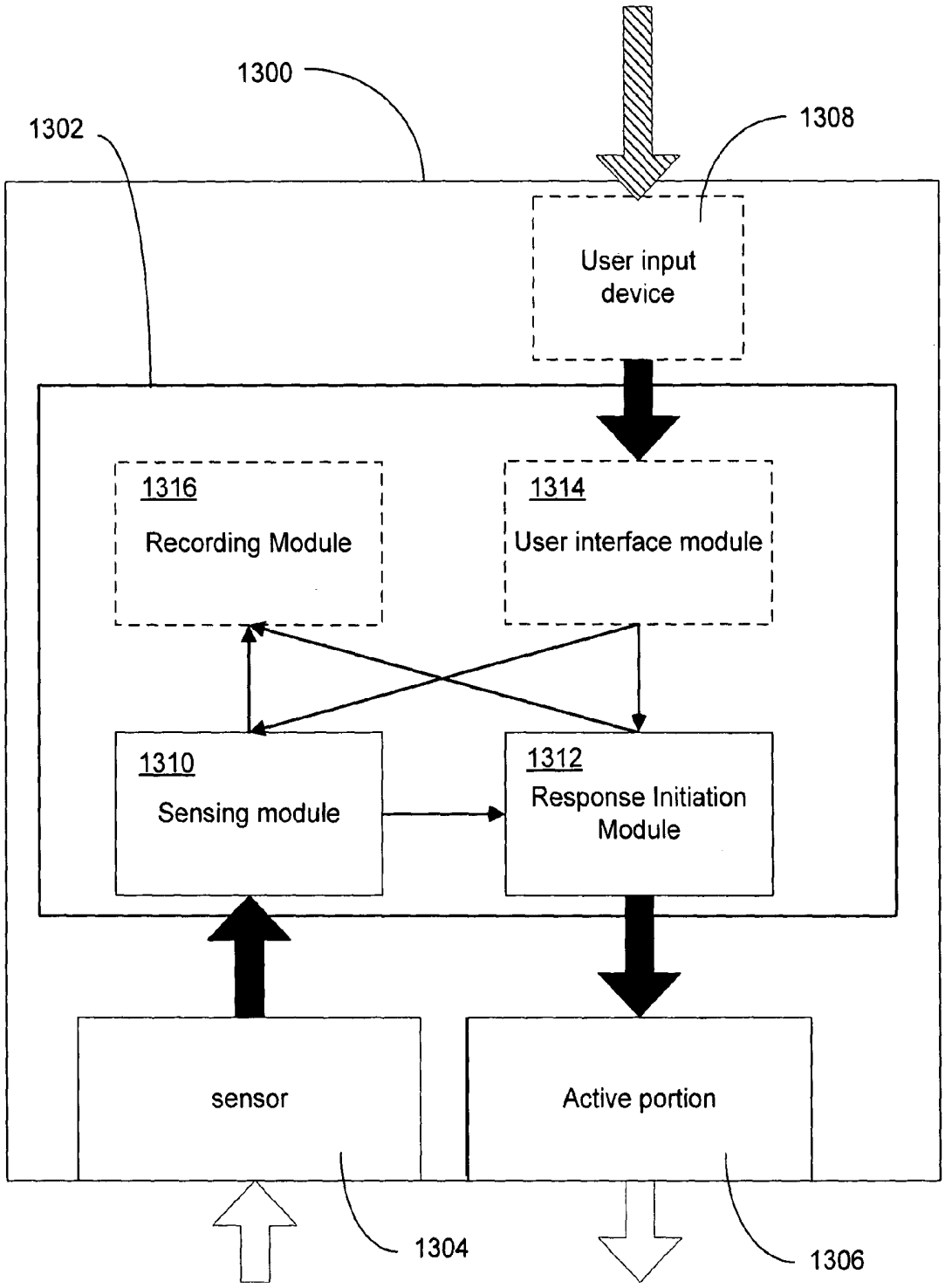
1300
1302
1308
User input device
1316
Recording Module
1314
User interface module
1310
Sensing module
1312
Response Initiation Module
sensor
Active portion
1304
1306

FIG. 23

LUMENALLY-ACTIVE DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is related to and claims the benefit of the earliest available effective filing date(s) from the following listed application(s) (the "Related Applications") (e.g., claims earliest available priority dates for other than provisional patent applications or claims benefits under 35 USC §119(e) for provisional patent applications, for any and all parent, grandparent, great-grandparent, etc. applications of the Related Application(s)).

RELATED APPLICATIONS

For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 10/949,186, entitled A CILIATED STENT-LIKE SYSTEM, naming Richa Wilson, Victoria Y. H. Wood, W. Daniel Hillis, Clarence T. Tegreene, Muriel Y. Ishikawa, and Lowell L. Wood, Jr. as inventors, filed 24 Sep. 2004 now U.S. Pat. No. 8,092,549, which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 10/827,576, entitled A SYSTEM FOR PERFUSION MANAGEMENT, naming Lowell L. Wood, Jr. as inventor, filed 19 Apr. 2004 now U.S. Pat. No. 8,337,482, which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 10/827,578, entitled A SYSTEM WITH A SENSOR FOR PERFUSION MANAGEMENT, naming Lowell L. Wood, Jr. as inventor, filed 19 Apr. 2004, which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date. For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 10/827,572, entitled A SYSTEM WITH A RESERVOIR FOR PERFUSION MANAGEMENT, naming Lowell L. Wood, Jr. as inventor, filed 19 Apr. 2004 now U.S. Pat. No. 7,850,676, which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 10/827,390, entitled A TELESCOPING PERFUSION MANAGEMENT SYSTEM, naming Lowell L. Wood, Jr. as inventor, filed 19 Apr. 2004 now U.S. Pat. No. 8,361,013, which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date. The United States Patent Office (USPTO) has published a notice to the effect that the USPTO's computer programs require that patent applicants reference both a serial number and indicate whether an application is a continuation or continuation-in-part. Stephen G. Kunin, *Benefit of Prior-Filed Application*, USPTO Official Gazette Mar. 18, 2003, available at http://www.uspto.gov/web/offices/com/sol/og/2003/week11/patbene.htm. The present applicant entity has provided above a specific reference to the application(s) from which priority is being claimed as recited by statute. Applicant entity understands that the statute is unambiguous in its specific reference language and does not require either a serial number or any characterization, such as "continuation" or "continuation-in-part," for claiming priority to U.S. patent applications. Notwithstanding the foregoing, applicant entity understands that the USPTO's computer programs have certain data entry requirements, and hence applicant entity is designating the present application as a continuation-in-part of its parent applications as set forth above, but expressly points out that such designations are not to be construed in any way as any type of commentary and/or admission as to whether or not the present application contains any new matter in addition to the matter of its parent application(s).

All subject matter of the Related Applications and of any and all parent, grandparent, great-grandparent, etc. applications of the Related Applications is incorporated herein by reference to the extent such subject matter is not inconsistent herewith.

BACKGROUND

Devices and systems have been developed for use in various body lumens, particularly in the cardiovascular system, digestive, and urogenital tract. Catheters are used for performing a variety of sensing and material delivery tasks. Stents are implanted in blood vessels for the purpose of preventing stenosis or restenosis of blood vessels. Capsules containing sensing and imaging instrumentation that may be swallowed by a subject and which travel passively through the digestive tract have also been developed. Robotic devices intended to move through the lower portion of the digestive tract under their own power are also under development.

SUMMARY

The present application describes devices, systems, and related methods for treatment of fluid in a body lumen. Embodiments of lumenally-active devices for placement in body lumens are disclosed. In one aspect, a system includes but is not limited to a sensor, response initiation circuitry, and an active portion capable of performing an action. In addition to the foregoing, other system aspects are described in the claims, drawings, and text forming a part of the present disclosure.

In one aspect, a method includes but is not limited to detecting a condition of interest in a fluid within a body lumen, generating a response initiation signal with response initiation circuitry, and performing an action within the body lumen with the active portion of the lumenally-active device. In addition to the foregoing, other method aspects are described in the claims, drawings, and text forming a part of the present disclosure.

Various aspects of the operation of such lumenally-active devices may be performed under the control of hardware, software, firmware, or a combination thereof. In one or more various aspects, related systems include but are not limited to circuitry and/or programming for effecting the herein-referenced method aspects; the circuitry and/or programming can be virtually any combination of hardware, software, and/or firmware configured to effect the herein-referenced method aspects depending upon the design choices of the system

designer. Software for operating a lumenally-active device according to various embodiments is also described.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is an illustration of an embodiment of a lumenally-active device;

FIGS. **2**A-**2**D are illustrations of several embodiments of lumenally-active device structures;

FIGS. **3**A-**3**C are illustrations of several embodiments of materials for lumenally-active device structures;

FIGS. **4**A and **4**B are illustrations of a device structure having a variable length and diameter;

FIGS. **5**A-**5**F are cross-sectional views of a number of embodiments of lumenally-active device structures;

FIG. **6** is a schematic diagram of a lumenally-active device;

FIGS. **7**A and **7**B are longitudinal cross-sectional views of the treatment of a fluid flowing through a lumenally-active device;

FIGS. **8**A-**8**D are illustrations of several embodiments of lumenally-active device active portions;

FIGS. **9**A and **9**B are illustrations of several further embodiments of lumenally-active device active portions;

FIG. **10** is a depiction of a lumenally-active device including a fluid structure;

FIG. **11** is a depiction of a lumenally-active device including a material collection structure;

FIG. **12** is an illustration of a device including stored deliverable material;

FIG. **13** is a cross-sectional view of an embodiment of a device including a stored deliverable material and a barrier release mechanism;

FIG. **14** is a cross-sectional view of another embodiment of a device including a stored deliverable material and a barrier release mechanism;

FIGS. **15**A and **15**B are depictions of the release of a stored deliverable material from a reservoir via a rupturable barrier;

FIGS. **16**A and **16**B are depictions of the release of a stored deliverable material from a reservoir via a degradable barrier;

FIGS. **17**A and **17**B are depictions of the release of a stored deliverable material from a reservoir via a barrier having controllable permeability;

FIG. **18** is a cross-sectional view of another embodiment of a device including a stored deliverable material;

FIGS. **19**A and **19**B are depictions of the release of a stored deliverable material from a carrier material;

FIG. **20** is an illustration of a lumenally-active system that includes an external control portion;

FIG. **21** is a block diagram of a device depicting various alternative and/or optional components;

FIG. **22** is a flow diagram of a method of treating a body fluid; and

FIG. **23** is schematic diagram of a system including software modules.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here.

According to various embodiments described herein, a lumenally-active system may include a structural element configured to fit within at least a portion of a body lumen, the structural element including a lumen-wall-engaging portion and a fluid-contacting portion configured to contact fluid within the body lumen; a sensor capable of detecting a condition of interest in the fluid; response initiation circuitry operatively connected to the sensor and configured to generate a response initiation signal upon detection of the condition of interest in the fluid by the sensor; and an active portion operatively connected to the response initiation circuitry and capable of producing a response upon receipt of the response initiation signal.

FIG. **1** depicts a first embodiment of a lumenally-active device **10** positioned in a body lumen **12**. Body lumen **12** is defined by wall portions **14**, which may be the walls of a blood vessel or other lumen-containing structure within the body of an organism. Lumenally-active device **10** includes structural element **16**, sensor **18**, response initiation circuitry **20**, and active portion **22**. In this example, a body fluid flows through lumen **12** in the direction indicated by the arrow. Body fluid components **24**, which may be, for example, cells, cellular fractions or components, collections or aggregations of cells, bacterial, viral or fungal species, ions, molecules, gas bubbles, dissolved gas, suspended particles, or a variety of other materials that may be present in the body fluid, are also indicated. Body fluid components may be materials that are normally present in the body fluid, materials that are naturally derived but not normally present in the body fluid, or foreign materials that have entered or been introduced to the body fluid (including but not limited to pathogens, toxins, pollutants, or medications, for example). Fluid flows through the central opening **26** of structural element **16**, with the interior surface of structural element **16** forming fluid-contacting surface **28**. In the embodiment of FIG. **1**, sensor **18** and active portion **22** may be located at a fluid-contacting surface **28**. In the embodiment of FIG. **1**, outer surface **30** of structural element **16** functions as a lumen-wall engaging portion, providing a frictional fit with wall portions **14**. In other embodiments of lumenally-active devices, other structures and methods for engaging the lumen wall may be employed.

Embodiments of the lumenally-active system may be configured for use in various different body lumens of an organism including, for example, a nostril or nasal cavity, the respiratory tract, the cardiovascular system (e.g., a blood vessel), the lymphatic system, the biliary tract, the urogenital tract, the oral cavity, the digestive tract, the tear ducts, a glandular system, a reproductive tract, the cerebral ventricles, spinal canal, and other fluid-containing structure of the nervous system of an organism. Other fluid-containing lumens within the body may be found in the auditory or visual system, or in interconnections thereof, e.g., the Eustachian tubes. Although many of the devices and systems described herein may be used in body lumens through which fluid flows, it is not intended that such devices or systems are limited to use in tubular lumen-containing structures containing moving fluid; in some applications a lumenally-active device may be placed in a body lumen containing relatively unmoving, or intermittently moving fluid. Wherever a lumenally-active device or system is to be used, the dimensions and mechanical properties (e.g., rigidity) of the lumenally-active system, and particularly of the structural element of the lumenally-active

system, may be selected for compatibility with the location of use, in order to provide for reliable positioning of the device and to prevent damage to the lumen-containing structure including the body lumen.

FIGS. **2**A-**2**D depict a number of possible configurations for structural elements of lumenally-active devices for use in body lumens. Structural elements may have the form of a short cylinder **50**, as shown in FIG. **2**A; an annulus **52**, as shown in FIG. **2**B; a cylinder **54**, as shown in FIG. **2**C; or a spiral **56**, as shown in FIG. **2**D. Elongated forms such as cylinder **54** or spiral **56** may be suitable for use in tubular lumen-containing structures such as, for example, blood vessels. Structural elements may be formed from various materials, including metals, polymers, fabrics, and various composite materials, including ones of either inorganic or organic character, the latter including materials of both biologic and abiologic origin, selected to provide suitable biocompatibility and mechanical properties.

As shown in FIGS. **3**A-**3**C, the basic form of a structural element may be subject to different variations, e.g., by perforations, as shown in structural element **60** in FIG. **3**A; a mesh structure, as shown in structural element **62** in FIG. **3**B; or the inclusion of one or more slots **64** in structural element **66** in FIG. **3**C. Slot **64** runs along the entire length of structural element **66**; in other embodiments, one or more slots (or mesh or perforations) may be present in only a portion of the structural element. By using spiral, mesh, or slotted structural elements (as in FIGS. **2**D, **3**B, and **3**C) formed from resilient, elastic, springy or self-expanding/self-contracting structural elements may be formed. A self expanding or contracting structural element may facilitate positioning of the structural element within a body lumen of an organism. In some embodiments, flexible material having adjustable diameter, taper, and length properties may be used. For example, some materials may change from a longer, narrower configuration **70** as shown in FIG. **4**A, to a shorter, wider configuration **72** as shown in FIG. **4**B, or may taper over their length. Structural elements that may exhibit this type of expansion/contraction property may include mesh structures formed of various metals or plastics, and some polymeric materials, for example.

The exemplary embodiments depicted in FIGS. **2**A-**2**C, **3**A-**3**C, and **4**A and **4**B are substantially cylindrical, and hollow and tubular in configuration, with a single central opening. Thus, the exterior of the cylindrical structural element may contact and engage the wall of the body lumen, and the interior of the structural element (within the single central opening) may form the fluid-contacting portion of the structural element. Lumenally-active devices according to various embodiments are not limited to cylindrical structural elements having a single central opening, however.

FIGS. **5**A through **5**F depict a variety of cross-sectional configurations for structural elements of lumenally-active devices. In FIG. **5**A, a lumenally-active device **100** is positioned in lumen **102** of lumen-containing structure **104**. In this embodiment, fluid-contacting portion **106** may be the surface of structural element **100** that faces lumen **102**, while the lumen-wall engaging portion **108** may be a layer of tissue adhesive on surface **110** of structural element **100**.

FIG. **5**B depicts in cross-section a further embodiment of a structural element **150** in lumen **152** of lumen-containing structure **154**. Structural element **150** includes multiple openings **156**, each of which includes an interior surface **158** that forms a fluid-contacting portion. Structural element **150** may include one or more barb-like structures **160** that serve as lumen-wall engaging portions that maintain structural element **150** in position with respect to lumen-containing structure **154**.

FIG. **5**C depicts in cross-section an embodiment of a structural element **200** in lumen **202** of lumen-containing structure **204**. Structural element **200** includes a large central opening **206** and multiple surrounding openings **208**. The interior surface of each opening **206** or **208** serves as a fluid-contacting portion, while projections **210** function as lumen-wall engaging portions, which may engage frictionally or may project slightly into the interior of the wall of lumen-containing structure **204**.

FIG. **5**D depicts a further embodiment in which structural element **250** has a substantially oval cross-section and includes a slot **252**. Lumen-containing structure **254** may be generally oval in cross section, or may be flexible enough to be deformed to the shape of structural element **250**. Structural element **250** may be a compressed spring-like structure that produces outward forces as indicated by the black arrows, so that end portions **256** of structural element **250** thus press against and engage the lumen wall. Interior surface **258** of structural element **250** serves as the fluid-contacting portion of structural element **250**.

FIG. **5**E is a cross-sectional view of a structural element **300** in a lumen-containing structure **302**. Structural element **300** includes multiple projecting arms **304** which contact lumen wall **306** of lumen-containing structure **302**, and function as lumen-wall engaging portions. Inner surfaces **308** of arms **304** function as fluid-contacting portions of structural element **300**.

FIG. **5**F depicts (in cross-section) another example of a structural element **350** positioned within a lumen-containing structure **352**. Structural element **350** includes two openings **354**. The interior surfaces **356** of openings **354** function as fluid-contacting portions, while the outer surface **358** of structural element **350** serves as a lumen-wall engaging portion.

The structural elements depicted in FIGS. **2**-**5** are intended to serve as examples, and are in no way limiting. The choice of structural element size and configuration appropriate for a particular body lumen may be selected by a person of skill in the art. Structural elements may be constructed by a variety of manufacturing methods, from a variety of materials. Appropriate materials may include metals, ceramics, polymers, and composite materials having suitable biocompatibility, sterilizability, mechanical, and physical properties, as will be known to those of skill in the art. Examples of materials and selection criteria are described, for example, in *The Biomedical Engineering Handbook*, Second Edition, Volume 1, J. D. Bronzino, Ed., Copyright 2000, CRC Press LLC, pp. IV-1-43-31. Manufacturing techniques may include injection molding, extrusion, die-cutting, rapid-prototyping, etc., and will depend on the choice of material and device size and configuration. Sensing and active portions of the lumenally-active device as well as associated electrical circuitry (not depicted in FIGS. **2**-**5**) may be fabricated on the structural element using various microfabrication and/or MEMS techniques, or may be constructed separately and subsequently assembled to the structural element, as one or more distinct components.

The term fluid, as used herein, may refer to liquids, gases, and other compositions, mixtures, or materials exhibiting fluid behavior. The fluid within the body lumen may include a liquid, or a gas or gaseous mixtures. As used herein, the term fluid may encompass liquids, gases, or mixtures thereof that also include solid particles in a fluid carrier. Liquids may include mixtures of two or more different liquids, solutions, slurries, or suspensions. Examples of liquids present within body lumens include blood, lymph, serum, urine, semen, digestive fluids, tears, saliva, mucous, cerebro-spinal fluid,

intestinal contents, bile, epithelial exudate, or esophageal contents. Liquids present within body lumens may include synthetic or introduced liquids, such as blood substitutes or drug, nutrient, or buffered saline solutions. Fluids may include liquids containing dissolved gases or gas bubbles, or gases containing fine liquid droplets or solid particles. Gases or gaseous mixtures found within body lumens may include inhaled and exhaled air, e.g. in the nasal or respiratory tract, or intestinal gases.

FIG. **6** is a schematic diagram of a lumenally-active device, including sensor **400**, response initiation circuitry **402**, and active portion **404**. Sensor **400** may be used to detect a condition of interest in the fluid, which may include, for example, detecting pressure, temperature, fluid flow, presence of a cell of interest, or concentration of a chemical or chemical species (including ionic species) of interest. Sensor **400** may sense a wide variety of physical or chemical properties. In some embodiments, detecting a condition of interest may include detecting the presence (or absence) of a material or structure of interest in the fluid. Sensor **400** may include one or more of an optical sensor, an imaging device, an acoustic sensor, a pressure sensor, a temperature sensor, a flow sensor, a viscosity sensor, or a shear sensor for measuring the effective shear modulus of the fluid at a frequency or strain-rate, a chemical sensor for determining the concentration of a chemical compound or species, a biosensor, or an electrical sensor, for example. An optical sensor may be configured to measure the optical absorption, optical emission, fluorescence, or phosphorescence of at least a portion of the fluid of the fluid, for example. Such optical properties may be inherent optical properties of all or a portion of the fluid, or may be optical properties of materials added or introduced to the fluid, such as tags or markers for materials of interest within the fluid. A biosensor may detect materials including, but not limited to, a biological marker, an antibody, an antigen, a peptide, a polypeptide, a protein, a complex, a nucleic acid, a cell (and, in some cases, a cell of a particular type, e.g. by methods used in flow cytometry), a cellular component, an organelle, a gamete, a pathogen, a lipid, a lipoprotein, an alcohol, an acid, an ion, an immunomodulator, a sterol, a carbohydrate, a polysaccharide, a glycoprotein, a metal, an electrolyte, a metabolite, an organic compound, an organophosphate, a drug, a therapeutic, a gas, a pollutant, or a tag. A biosensor may include an antibody or other binding molecule such as a receptor or ligand. Sensor **400** may include a single sensor or an array of sensors, and is not limited to a particular number or type of sensors. Sensor **400** might comprise in part or whole, a gas sensor such as an acoustic wave, chemiresistant, or piezoelectric sensor, or perhaps an electronic nose. Sensor **400** may be very small, comprising a sensor or array that is a chemical sensor (Chemical Detection with a Single-Walled Carbon Nanotube Capacitor E. S. Snow, 2005 Science Vol. 307; 1942-1945), a gas sensor (Smart single-chip gas sensor microsystem Hagleitner, C. et al. 2001 NATURE VOL 414 p. 293-296.), an electronic nose, a nuclear magnetic resonance imager ("Controlled multiple quantum coherences of nuclear spins in a nanometer-scale device", Go Yusa, 2005, Nature 343: 1001-1005). Further examples of sensors are provided in The Biomedical Engineering Handbook, Second Edition, Volume I, J. D. Bronzino, Ed., Copyright 2000, CRC Press LLC, pp. V-1-51-9, and U.S. Pat. No. 6,802,811, both of which are incorporated herein by reference. A sensor may be configured to measure various parameters, including, but not limited to, the electrical resistivity of the fluid, the density or sound speed of the fluid, the pH, the osmolality, or the index of refraction of the fluid at at least one wavelength. The selection of a suitable sensor for a particular application or use site is considered to be within the capability of a person having skill in the art.

FIGS. **7**A and **7**B illustrate the treatment of a fluid flowing through a lumenally-active device similar to that shown in FIG. **1**. Body lumen **452** is defined by wall portions **454**. In FIG. **7**A, component **464** of fluid flowing through body lumen **452** is detected by sensor **458** in structural element **456** of lumenally-active device **450**. Upon detection of component **464** by sensor **458**, a sense signal **459** is sent to response initiation circuitry **460**, which generates a response initiation signal **461**. Response initiation signal **461** is sent to active portion **462**. As shown in FIG. **6**B, upon receipt of response initiation signal **461**, active portion **462** produces a response or action, which in this example is a pulse of energy (e.g. acoustic energy) to destroy or component **464** (indicated following destruction by reference number **464'**). For example, a pulse of acoustic energy may be used to modify a kidney stone in the urinary tract, or to modify another object in another body fluid.

In some applications, detecting a condition of interest in the fluid within the body lumen may include detecting the presence of a material of interest in the fluid within the body lumen. A material of interest in a fluid may include, for example, an object such as a blood clot, a thrombus, an embolus, a plaque, a lipid, a kidney stone, a dust particle, a pollen particle, an aggregate, a cell, a specific type of cell, a cellular component, an organelle, a collection or aggregation of cells or components thereof, a gamete, a pathogen, or a parasite.

In connection with detection of the presence of a material of interest in the fluid within the body lumen, the active portion of the lumenally-active system may be capable of removing, modifying, or destroying the material of interest. Modification or destruction of the material of interest may be accomplished by the release of a suitable material (e.g. an anti-coagulant for destroying a blood clot, complement to coat a parasite for recognition by the immune system, or by the release of an anti-inflammatory, biomimetic or biologic to bind to and inactivate an inflammatory mediator such as TNFα, by the delivery of suitable energy (e.g., acoustic energy for modifying a kidney stone, electromagnetic energy such as light to cause a photoreaction, break bonds in a molecule, produce heating, etc., or by delivery of heat or cold or other chemo-physical change (e.g. ambient pressure, pH, osmolality, toxic material introduction/generation) for tissue modification, as in ablation of circulating tumor cells or plaque or temperature-induced modification of sperm as it passes through the vas deferens.

The lumenally-active device may include an active portion capable of producing a response upon receipt of the response initiation signal. FIGS. **8**A-**8**D, **9**A and **9**B, and **10** and **11** provide examples of different active portions which may be included in a lumenally-active device. The active portion may include a heating element **500** as depicted in FIG. **8**A, operatively coupled to the response initiation circuitry **501** and configured to produce heating in response to detection of the condition of interest. The heating element may be a resistive element that produces heat when current is passed through it, or it may be a magnetically active material that produces heat upon exposure to an electromagnetic field. Examples of magnetically active materials include permanently magnetizable materials, ferromagnetic materials such as iron, nickel, cobalt, and alloys thereof, ferrimagnetic materials such as magnetite, ferrous materials, ferric materials, diamagnetic materials such as quartz, paramagnetic materials such as silicate or sulfide, and antiferromagnetic materials such as

canted antiferromagnetic materials which behave similarly to ferromagnetic materials; examples of electrically active materials include ferroelectrics, piezoelectrics and dielectrics. Alternatively, the active portion may include a cooling element **502** as depicted in FIG. **8**B, operatively coupled to the response initiation circuitry **503** and configured to produce cooling in response to detection of the condition of interest. Cooling may be produced by a number of mechanisms and/or structures. For example, cooling may be produced by an endothermic reaction (such as the mixing of ammonium nitrate and water) initiated by opening of a valve or actuation of a container in response to a control signal. Other methods and/or mechanisms of producing cooling may include, but are not limited to, thermoelectric (Peltier Effect) and liquid-gas-vaporization (Joule-Thomson) devices.

In some embodiments, the active portion may include an electromagnetic radiation source **504** as depicted in FIG. **8**C, operatively coupled to the response initiation circuitry **505** and configured to emit electromagnetic radiation in response to detection of the condition of interest. Electromagnetic radiation sources may include light sources, for example, such as light emitting diodes and laser diodes, or sources of other frequencies of electromagnetic energy or radiation, radio waves, microwaves, ultraviolet rays, infra-red rays, optical rays, terahertz beams, and the like. In some embodiments, the active portion may include an electric field source or a magnetic field source. As another alternative, the active portion may include an acoustic energy source **506** (e.g., a piezoelectric crystal) as depicted in FIG. **8**D, operatively coupled to the response initiation circuitry **507** and configured to emit acoustic energy in response to detection of the condition of interest. The active portion may include a pressure source operatively coupled to the response initiation circuitry and configured to apply pressure to a portion of the body lumen in response to detection of the condition of interest. Pressure source may include materials that expand through absorption of water, or expand or contract due to generation or consumption of gas or conformation changed produced by chemical reactions or temperature changes, electrically-engendered Maxwell stresses, osmotic stress-generators, etc. FIG. **9**A depicts a negative pressure source **550** capable of applying negative pressure (in this example, substantially radially-inward force) to lumen walls **551**, while FIG. **9**B depicts a positive pressure (expanding or expansion) source **552**, capable of applying positive pressure (in this example, a substantially radially-outward force) to lumen walls **551**.

Alternatively, or in addition, in some embodiments the active portion may include a capture portion operatively coupled to the response initiation circuitry and configured to capture the detected material of interest. FIG. **10** depicts a device **600** including a fluid capture portion **606**. Lumenally-active device **600** includes sensor **602**, response initiation circuitry **604**, and fluid capture portion **606**. Fluid enters fluid capture portion **606** via inlet **608**. Fluid capture portion **606** may be a reservoir, for example, into which fluid is drawn by capillary action. Alternatively, fluid may be pumped into capture portion **606**. Captured fluid may be treated and released, or simply stored. In some applications, stored fluid may be subjected to analysis.

FIG. **11** depicts lumenally-active device **650** including a sample collection structure **652** capable of collecting a solid sample **654**. In the example depicted in FIG. **11**, solid sample **654** is a solid material found upon or immediately under the surface of the lumen-defining wall **656** (an arterial plaque, for example). Solid sample **654** placed in storage reservoir **658** by sample collection structure **652**. In a related alternative embodiment, a lumenally-active device may include a filter or selective binding region to remove materials from fluid moving past or through the lumenally-active device.

In other embodiments, the active portion of a lumenally-active device may include a material release structure operatively coupled to the response initiation circuitry and configured to release a material in response to detection of a condition of interest.

FIG. **12** depicts a lumenally-active device **700** including a structural element **702**, sensor **704**, response initiation circuitry **706**, and material release structure **708** including release mechanism **710**. Structural element **702** includes external surface **712**, configured to fit within a body lumen, and internal surface **714** defining central opening **716**, through which a fluid may flow. Upon sensing of a condition of interest in the fluid by sensor **704**, response initiation circuitry **706** may cause release of material from material release structure **708** by activating release mechanism **710**. Release mechanism **710** may include a variety of different types of release mechanisms.

FIG. **13** illustrates, in cross sectional view, a structural element **750** of a lumenally-active device positioned in a lumen-containing structure **752**. A reservoir **754** contains stored deliverable material. Barrier **756** is a controllable barrier that control the release of the stored deliverable material into central opening **758**, and thus into a fluid that fills and/or flows through lumen-containing structure **752**.

FIG. **14** illustrates an embodiment similar to that depicted in FIG. **13**, including a structural element **800** of a lumenally-active device positioned in a lumen-containing structure **802**. A reservoir **804** contains stored deliverable material. Barrier **806** is a controllable barrier that controls the release of the stored deliverable material. In the embodiment of FIG. **14**, activation of barrier **806** causes release of the stored deliverable material toward the lumen wall of lumen-containing structure **802**, rather than into central opening **808**.

FIGS. **15**A, **15**B, **16**A, **16**B, **17**A and **17**B, illustrate several alternative embodiments of material release structures that include controllable barriers. In FIGS. **15**A and **15**B, release structure **850** includes reservoir **852** containing stored deliverable material **854**. As shown in FIG. **15**A, while rupturable barrier **856** is intact, stored deliverable material **854** is contained within reservoir **852**. As shown in FIG. **15**B, when rupturable barrier **856** has been ruptured (as indicated by reference number **856'**), deliverable material **854** may be released from reservoir **852**. Rupturable barrier **856** may be ruptured by an increase of pressure in reservoir **852** caused by heating, for example, which may be controlled by response initiation circuitry. In another alternative shown in FIGS. **16**A and **16**B, release structure **900** includes reservoir **902** containing stored deliverable material **904**. As shown in FIG. **16**A, while degradable barrier **906** is intact, stored deliverable material **904** is contained within reservoir **902**. As shown in FIG. **16**B, degradation of degradable barrier **906** to degraded form **906'** causes stored deliverable material **904** to be released from reservoir **904**. FIGS. **17**A and **17**B depict release structure **950** including reservoir **952** containing stored deliverable material **954**. FIG. **17**A, shows barrier **956**, which has a controllable permeability, in a first, impermeable state, while FIG. **17**B shows barrier **956** in a second, permeable state (indicated by reference number **956'**). Stored deliverable material **954** passes through barrier **956'**, when it is in its permeable state, and is released. Rupturable barriers as described above may be formed from a variety of materials, including, but not limited to, metals, polymers, crystalline materials, glasses, ceramics, semiconductors, etc. Release of materials through rupture or degradation of a barrier is also

described in U.S. Pat. No. 6,773,429, which is incorporated herein by reference. Semipermable barriers having variable permeability are described, for example, in U.S. Pat. No. 6,669,683, which is incorporated herein by reference. Those of skill in the art will appreciate that barriers can be formed and operated reversibly through multiple release cycles, in addition to the single-release functionality available from a rupturable barrier.

FIG. **18** depicts another embodiment of a lumenally-active device **1000** in a lumen containing structure **1002**. Lumenally-active device **1000** includes stored deliverable material **1004** dispersed in a carrier material **1006**. Stored deliverable material **1004** may be released from carrier material **1006** by release mechanism **1008** upon activation of release mechanism **1008**. Released deliverable material **1004** may be released into central opening **1010** of lumenally-active device **1000**, as well as into the volume defining the outermost portion of the lumen. FIGS. **19**A and **19**B depict in greater detail the release of stored deliverable material from the carrier material. In FIG. **19**A, deliverable material **1004** is stored in carrier material **1006**. Carrier material **1006** may be, for example, a polymeric material such as a hydrogel, and deliverable material is dispersed or dissolved within carrier material **1006**. Release mechanism **1008** may be a heating element, for example a resistive element connected directly to response initiation circuitry, or an electrically or magnetically responsive material that may be caused to move, vibrate, heat, by an externally applied electromagnetic field, which in turn causes release of deliverable material **1004** from carrier material **1006**, as shown in FIG. **19**B. See, for example, U.S. Pat. Nos. 5,019,372 and 5,830,207, which are incorporated herein by reference. In some embodiments, an electrically or magnetically active component may be heatable by an electromagnetic control signal, and heating of the electrically or magnetically active component may cause the polymer to undergo a change in configuration. An example of a magnetically responsive polymer is described, for example, in Neto, et al, "Optical, Magnetic and Dielectric Properties of Non-Liquid Crystalline Elastomers Doped with Magnetic Colloids"; Brazilian Journal of Physics; bearing a date of March 2005; pp. 184-189; Volume 35, Number 1, which is incorporated herein by reference. Other exemplary materials and structures are described in Agarwal et al., "Magnetically-driven temperature-controlled microfluidic actuators"; pp. 1-5; located at: http://www.unl.im.dendai.ac.jp/INSS2004/INSS2004_papers/OralPresentations/C2.pdf or U.S. Pat. No. 6,607,553, both of which are incorporated herein by reference.

In some embodiments of lumenally-active devices or systems, a lumenally-active device may be a self-contained device that may be positioned in a body lumen and that includes all functionalities necessary for operation of the device. In other embodiments, as illustrated in FIG. **20**, a lumenally-active system **1100** may include a lumenally-active device **1102** that may be placed in a body lumen **1104**, and a remote portion **1106** that includes a portion of the functionalities of the lumenally-active system. In some embodiments, all functionalities essential for the operation of the lumenally-active device may be located on the lumenally-active device, but certain auxiliary functions may be located in remote portion **1106**. For example, remote portion **1106** may provide for monitoring of the operation of the lumenally-active device or data collection or analysis. The remote portion may be located within the body of the subject at a distance from the lumenally-active device, or outside the body **1108** of the subject, as depicted in FIG. **20**. Data and/or power signals may be transmitted between lumenally-active device **1102** and remote portion **1106** with the use of electromagnetic or acoustic signals **1110**, or, in some embodiments, may be carried over electrical or optical links. In general, the remote portion may be placed in a location where there is more space available than within the body lumen, that is more readily accessible, and so forth. It is contemplated that a portion of the electrical circuitry portion of the lumenally-active system (which may include hardware, firmware, software, or any combination thereof) may be located in a remote portion. Methods of distributing functionalities of a system between hardware, firmware, and software at located at two or more sites are well known to those of skill in the art. The electrical circuitry portion of the lumenally-active system may include, but is not limited to, electrical circuitry associated with the sensor, response initiation circuitry, and electronics associated with the active portion. While the response initiation circuitry has been discussed within the context of electrical circuitry, it will be appreciated that in some embodiments other types of logic/circuitry may be used in place of or in addition to electrical circuitry, and the response initiation circuitry and other circuitry described herein is not limited to electrical circuitry. For example, fluid circuitry, chemo-mechanical circuitry, and other types of logic/circuitry may provide equivalent functionality and may be used in certain embodiments.

FIG. **21** is a block diagram illustrating in greater detail various electrical circuitry components of a lumenally-active system. As discussed herein, the electrical circuitry components may be located entirely on the structural element of a lumenally-active device, or may be distributed between the lumenally-active device and a remote portion as depicted in FIG. **19**. The lumenally-active system may include one or more sensors **1150** for measuring or detecting a condition of interest. Sensing circuitry **1152** may be associated with sensors **1150**. The lumenally-active system may include various control electronics **1154**, including response initiation circuitry **1156**. Response initiation circuitry **1156** provides response initiation signal to active portion **1158**. In some embodiments, response initiation circuitry **1156** may also control sample collection portion **1160**. Control electronics **1154** may also include data storage portion **1162**, which may, for example, be used to store pattern data **1164** or pattern variables **1166**. In some embodiments, control electronics **1154** may include motion control circuitry **1168** for controlling propelling mechanism **1170**. Control electronics may include transceiver circuitry **1172**, which provides for the transmission and reception of data and/or power signals between the lumenally-active device and a remote portion. A user input portion **1174** may provide for the input of user instruction, parameter, etc. to control electronics **1154**. Finally, one or more power source **1176** may provide power to electrical components of the lumenally-active system.

Lumenally-active devices and systems according to various embodiments as described herein may include a power source, such as one or more batteries located on the lumenally-active device, possibly a microbattery like those available from Quallion LLC (http://www.quallion.com) or designed as a film (U.S. Pat. Nos. 5,338,625 and 5,705,293), which are incorporated herein by reference. Alternatively, the power source **1176** could be one or more fuel cell such as an enzymatic, microbial, or photosynthetic fuel cell or other biofuel cell (US20030152823A1; WO03106966A2 Miniature Biofuel cell; Chen T et al. J. Am. Chem. Soc. 2001, 123, 8630-8631, A Miniature Biofuel Cell, all of which are incorporated herein by reference), and could be of any size, including the micro- or nano-scale. In some embodiments, the power source may be a nuclear battery. The power source may

be an energy-scavenging device such as a pressure-rectifying mechanism that utilizes pulsatile changes in blood pressure, for example, or an acceleration-rectifying mechanism as used in self-winding watches. In some embodiments, the power source may be an electrical power source located remote from the structural element and connected to the structural element by a wire, or an optical power source located remote from the structural element and connected to the structural element by a fiber-optic line or cable. In some embodiments, the power source may be a power receiver capable of receiving power from an external source, acoustic energy from an external source, a power receiver capable of receiving electromagnetic energy (e.g., infrared energy) from an external source.

The response initiation circuitry may include at least one of hardware, software, and firmware; in some embodiments the response initiation circuitry may include a microprocessor. The response initiation circuitry may be located in or on the structural element in some embodiments, while in other embodiments the response initiation circuitry may be at a location remote from the structural element.

As shown in FIG. **22**, a method of treating a body fluid using a lumenally-active device may include: detecting a condition of interest in a fluid within a body lumen with a sensor portion of a lumenally-active system in the body lumen, the lumenally-active system also including a lumen-wall-engaging portion, a fluid-contacting portion configured to contact fluid within the body lumen, and an active portion capable of performing an action within the body lumen, at step **1252**; generating a response initiation signal with response initiation circuitry responsive to detection of the condition of interest in the fluid within the body lumen, at step **1254**; and performing an action within the body lumen with the active portion of the lumenally-active device in response to the response initiation signal, at step **1256**.

Detecting a condition of interest in a body fluid in the body lumen may include detecting a temperature, detecting a pressure, detecting a fluid flow, detecting an optical absorption, optical emission, fluorescence, or phosphorescence, detecting an index of refraction at at least one wavelength, detecting an acoustic signal, detecting an electrical resistivity, detecting a density or sound speed, detecting a pH, detecting an osmolality, detecting the presence of an embolism, detecting the presence (or absence) of an object (such as a blood clot, a thrombus, an embolus, a plaque, a lipid, a kidney stone, a dust particle, a pollen particle, a gas bubble, an aggregate, a cell, a specific type of cell, a cellular component or fragment, a collection of cell, a gamete, a pathogen, or a parasite), or detecting the presence (or absence) of a substance such as a biological marker, an antibody, an antigen, a peptide, a polypeptide, a protein, a complex, a nucleic acid, a cell (and, in some cases, a cell of a particular type, e.g. by methods used in flow cytometry), a cellular component, an organelle, a gamete, a pathogen, a lipid, a lipoprotein, an alcohol, an acid, an ion, an immunomodulator, a sterol, a carbohydrate, a polysaccharide, a glycoprotein, a metal, an electrolyte, a metabolite, an organic compound, an organophosphate, a drug, a therapeutic, a gas, a pollutant, or a tag, for example.

The step of performing an action within the body lumen with the active portion of the lumenally-active device in response to the response initiation signal may include activating a heating element, activating a cooling element, activating a material release portion, activating a material retrieval or sequestering portion, activating an analytic portion, activating an electromagnetic radiation source, activating an acoustic energy source, activating a pressure-generating element, activating a traction-generating element, activating a flow-modulating element capable of modulating the flow of fluid through at least a portion of the body lumen, activating a separator capable of at least partly removing specific components from at least a portion of the fluid, activating a catalytic portion to expose a catalytic surface to at least a portion of the fluid, activating an electric field source to apply an electric field to the fluid, activating a magnetic field source to apply a magnetic field to the fluid removing, modifying, or destroying at least a portion of the material of interest, or capturing at least a portion of the material of interest. In some embodiments, the presence of the material of interest may be desired, and if the absence (or a deficiency) of the material of interest is detected, performing an action within the body lumen with the active portion of the lumenally-active device may include adding the material of interest.

Lumenally-active devices and systems as described herein may be operated under the control of software. FIG. **23** illustrates in schematic form a lumenally-active device **1300**. Components of lumenally-active device **1300** within box **1302** may be operated in whole or in part under software control. Lumenally-active device **1300** also includes components that may be primarily hardware-based, e.g., sensor **1304**, active portion **1306**, and, optionally, user input device **1308**. Hardware-based devices may include components that are electrical, mechanical, chemical, optical, electromechanical, electrochemical, electro-optical, and are not limited to the specific examples presented herein. For example, software for operating a lumenally-active device may include a sensing module **1310** capable of receiving and processing a sense signal from a sensor portion **1304** of a lumenally-active system in a body lumen, the lumenally-active system also including a lumen-wall-engaging portion, a fluid-contacting portion configured to contact fluid within the body, lumen, and an active portion **1306** capable of performing an action within the body lumen, and producing as output one or more sense parameters; and a response initiation module **1312** capable of receiving as input the one or more sense parameters and generating as output a response initiation signal to cause the performance of an action within the body lumen with the active portion **1306** of the lumenally-active system.

The sensing module **1310** may be configured to receive the sense signal from the sensor **1304** substantially continuously, or the sensing module **1310** may include software code for controlling polling of the sense signal from the sensor portion to detect the presence of a condition of interest in the body lumen. In another alternative, the sensing module **1310** includes interrupt-driven software code responsive to an interrupt signal from the sensor portion to begin receipt and processing of the sense signal.

The sensing module **1310** may be configured to process the sense signal to determine the presence of the condition of interest. For example, the sensing module may be configured to process the sense signal by any of various signal processing methods, including, for example, filtering, signal amplification, windowing, noise reduction, clutter reduction, signal averaging, feature detection, time-domain analysis, frequency-domain analysis, feature extraction, comparison, sorting, reduction, and endpoint determination to determine the presence of the condition of interest. The sensing module **1310** may be configured to detect a critical value in the sense signal, the critical value indicative of the presence of a condition of interest in the body lumen.

The response initiation module **1312** may be configured to calculate the response initiation signal based at least in part upon at least one of the one or more sense parameters, or the response initiation module **1312** may be configured to generate the response initiation signal from a stored function. In some embodiments, the response initiation module may be

configured to calculate the response initiation signal based at least in part upon at least one or more stored constants.

In some embodiments, the software may include a user interface module **1314** configured to receive user input of one or more user-enterable parameters from a user interface device **1308**. In some embodiments, the software may include a recording module **1316** configured to record one or more values from the lumenally-active device over a recording interval. Recording module **1316** may also perform some processing of the information. In some embodiments, at least a portion of the one or more values may be sense signal values from sensor **1304**. At least a portion of the one or more values may be sense parameter values. In some embodiments, at least a portion of the one or more values may be values corresponding to the action performed by the active portion of the lumenally-active system. In some embodiments, at least a portion of the one or more values may be response initiation signal values, corresponding to the response or action that is to be produced by active portion **1306**. In some embodiments, a signal from active portion **1306** corresponding to the action produced by active portion **1306** may be recorded by recording module **1316**. At least a portion of the one or more values may be response initiation signal values.

If the software includes a recording module, the response initiation module may be configured to generate the response initiation signal based at least in part upon one or more values received from the recording module. If the software includes a user-interface module, the response initiation may be is configured to generate the response initiation signal based at least in part upon one or more user-enterable parameters received from the user interface module.

Those having skill in the art will recognize that the state of the art has progressed to the point where there is little distinction left between hardware and software implementations of aspects of systems; the use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. Those having skill in the art will appreciate that there are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; alternatively, if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware. Hence, there are several possible vehicles by which the processes and/or devices and/or other technologies described herein may be effected, none of which is inherently superior to the other in that any vehicle to be utilized is a choice dependent upon the context in which the vehicle will be deployed and the specific concerns (e.g., speed, flexibility, or predictability) of the implementer, any of which may vary. Those skilled in the art will recognize that optical aspects of implementations will typically employ optically-oriented hardware, software, and or firmware.

The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

In a general sense, those skilled in the art will recognize that the various embodiments described herein can be implemented, individually and/or collectively, by various types of electromechanical systems having a wide range of electrical components such as hardware, software, firmware, or virtually any combination thereof; and a wide range of components that may impart mechanical force or motion such as rigid bodies, spring or torsional bodies, hydraulics, and electro-magnetically actuated devices, or virtually any combination thereof. Consequently, as used herein "electromechanical system" includes, but is not limited to, electrical circuitry operably coupled with a transducer (e.g., an actuator, a motor, a piezoelectric crystal, etc.), electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment), and any non-electrical analog thereto, such as optical or other analogs. Those skilled in the art will recognize that electromechanical as used herein is not necessarily limited to a system that has both electrical and mechanical actuation except as context may dictate otherwise. Non-electrical analogs of electrical circuitry may include fluid circuitry, electromechanical circuitry, mechanical circuitry, and various combinations thereof.

In a general sense, those skilled in the art will recognize that the various aspects described herein which can be imple-

mented, individually and/or collectively, by a wide range of hardware, software, firmware, or any combination thereof can be viewed as being composed of various types of "electrical circuitry." Consequently, as used herein "electrical circuitry" includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

One skilled in the art will recognize that the herein described components (e.g., steps), devices, and objects and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are within the skill of those in the art. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar herein is also intended to be representative of its class, and the non-inclusion of such specific components (e.g., steps), devices, and objects herein should not be taken as indicating that limitation is desired.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations are not expressly set forth herein for sake of clarity.

The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

While particular aspects of the present subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of the subject matter described herein. Furthermore, it is to be understood that the invention is defined by the appended claims. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A lumenally-active device, comprising:

a structural element configured to fit entirely within a body lumen, wherein the body lumen is at least a portion of a nostril, nasal cavity, respiratory tract, or oral cavity of an

organism, the structural element including: a lumen wall engaging portion and a fluid contacting portion configured to contact fluid within the body lumen;

a sensor on the structural element, the sensor configured to fit entirely within the body lumen and capable of detecting a presence of a material of interest that is at least one of dissolved or suspended in the fluid;

response initiation circuitry on the structural element, the response initiation circuitry configured to fit entirely within the body lumen and operatively connected to the sensor and configured to generate a response initiation signal upon detection of the presence of a material of interest in the fluid by the sensor; and

an active portion on the structural element, the active portion configured to fit entirely within the body lumen and operatively connected to the response initiation circuitry and capable of producing a response upon receipt of the response initiation signal, the response including releasing energy to modify or destroy the material of interest within the fluid.

2. The device of claim **1**, wherein the fluid includes a gas or gaseous mixture.

3. The device of claim **2**, wherein the gas or gaseous mixture is at least one of an inhaled gas or gaseous mixture or an expired gas or gaseous mixture.

4. The device of claim **1**, wherein the active portion further includes a capture portion operatively coupled to the response initiation circuitry and configured to capture at least a portion of the detected material of interest.

5. The device of claim **1**, wherein the active portion includes at least one of a heating element operatively coupled to the response initiation circuitry and configured to produce heating in response to detection of the presence of the material of interest, a cooling element operatively coupled to the response initiation circuitry and configured to produce cooling in response to detection of the presence of the material of interest, an electromagnetic radiation source operatively coupled to the response initiation circuitry and configured to emit electromagnetic radiation in response to detection of the presence of the material of interest, an acoustic energy source operatively coupled to the response initiation circuitry and configured to emit acoustic energy in response to detection of the presence of the material of interest, an electric field source operatively connected to the response initiation circuitry and configured to apply an electric field to the fluid in response to detection of the presence of the material of interest, or a magnetic field source operatively connected to the response initiation circuitry and configured to apply a magnetic field to the fluid in response to detection of the presence of the material of interest.

6. The device of claim **1**, wherein the sensor is selected from an optical sensor, an imaging device, an acoustic sensor, a pressure sensor, a temperature sensor, a flow sensor, a viscosity sensor, a shear sensor, a chemical sensor, a biosensor, or an electrical sensor.

7. A method of treating a body fluid, comprising:

detecting a presence of a material of interest that is at least one of dissolved or suspended in a fluid within a body lumen with a sensor portion of a lumenally-active device, wherein the body lumen is at least a portion of a nostril, nasal cavity, respiratory tract, or oral cavity of an organism, the lumenally-active device positioned entirely within the body lumen, the lumenally-active device also including a lumen-wall-engaging portion, a fluid containing portion configured to contact fluid within the body lumen, and an active portion capable of performing an action within the body lumen;

generating a response initiation signal with response initiation circuitry on the lumenally-active device responsive to detection of the presence of the material of interest in the fluid within the body lumen, the response initiation circuitry positioned entirely within the body lumen; and

performing an action within the body lumen with the active portion of the lumenally-active device in response to the response initiation signal, including releasing energy to modify or destroy the material of interest.

8. The method of claim **7**, wherein detecting the presence of the material of interest that is at least one of dissolved or suspended in the body fluid in the body lumen includes detecting the presence of one or more substance, chemical compound, or chemical species that is at least one of dissolved or suspended the body fluid in the body lumen.

9. The method of claim **8**, wherein the one or more substance, chemical compound or chemical species includes at least one of a biological marker, an antibody, an antigen, a peptide, a polypeptide, a protein, a complex, a nucleic acid, a cell, a cellular component or organelle, a gamete, a pathogen, a lipid, a lipoprotein, an alcohol, an acid, an ion, an immunomodulator, a sterol, a carbohydrate, a polysaccharide, a glycoprotein, a metal, an electrolyte, a metabolite, an organic compound, an organophosphate, a drug, a therapeutic, a gas, a pollutant, or a tag.

10. The method of claim **7**, wherein detecting the presence of the material of interest that is at least one of dissolved or suspended in the fluid within the body lumen includes processing a sense signal from the sensor portion of the lumenally-active device by at least one of filtering, signal amplification, windowing, noise reduction, clutter reduction, signal averaging, feature detection, time-domain analysis, frequency-domain analysis, spectral analysis, spectrophotometric analysis, feature extraction, comparison, sorting, reduction, or endpoint determination to determine the presence of the material of interest.

11. The method of claim **7**, wherein detecting the presence of the material of interest that is at least one of dissolved or suspended in the fluid within the body lumen includes detecting the presence of at least one of an object, an embolus, a plaque, a lipid, a lipoprotein, a dust particle, a pollen particle, an aggregate, a cell, a specific type of cell, a cellular component, a collection of cells, an organelle, a gamete, a pathogen, or a parasite.

12. The method of claim **7**, wherein performing an action within the body lumen with the active portion of the lumenally-active device includes at least one of activating a heating element, activating an electromagnetic radiation source, activating an acoustic energy source, activating an electric field source to apply an electric field to at least a portion of the fluid, or activating a magnetic field source to apply a magnetic field to at least a portion of the fluid.

13. A lumenally-active device, comprising:

a structural element configured to fit entirely within a body lumen, wherein the body lumen is at least a portion of a nostril, nasal cavity, respiratory tract, or oral cavity of an organism, the structural element including: a lumen wall engaging portion and a fluid contacting portion configured to contact fluid within the body lumen;

a sensor on the structural element, the sensor configured to fit entirely within the body lumen and capable of detecting a presence of a material of interest that is at least one of dissolved or suspended in the fluid;

response initiation circuitry on the structural element, the response initiation circuitry configured to fit entirely within the body lumen and operatively connected to the

sensor and configured to generate a response initiation signal upon detection of the presence of a material of interest in the fluid by the sensor; and

an active portion on the structural element and operatively connected to the response initiation circuitry, the active portion configured to fit entirely within the body lumen and capable of delivering energy sufficient to modify or destroy the material of interest within the fluid upon receipt of the response initiation signal.

14. The device of claim **13**, wherein the active portion is an electromagnetic radiation source.

15. The device of claim **13**, wherein the active portion is an acoustic energy source.

16. A method of treating a body fluid, comprising:

detecting a presence of a material of interest that is at least one of dissolved or suspended in a fluid within a body lumen with a sensor portion of a lumenally-active device, wherein the body lumen is at least a portion of a nostril, nasal cavity, respiratory tract, or oral cavity of an organism, the lumenally-active device positioned entirely within the body lumen, the lumenally-active device also including a lumen-wall-engaging portion, a fluid containing portion configured to contact fluid within the body lumen, and an active portion capable of performing an action within the body lumen;

generating a response initiation signal with response initiation circuitry on the lumenally-active device responsive to detection of the presence of the material of interest in the fluid within the body lumen, the response initiation circuitry positioned entirely within the body lumen; and

delivering energy with the active portion of the lumenally-active device in response to the response initiation signal, the energy sufficient to modify or destroy the detected material of interest, the active portion positioned entirely within the body lumen.

17. The method of claim **16**, wherein delivering energy includes delivering electromagnetic radiation.

18. The method of claim **16**, wherein delivering energy includes delivering acoustic energy source.

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申请(专利权)人(译)	SEARETE有限责任公司，特拉华州的有限责任公司		
当前申请(专利权)人(译)	SEARETE LLC		
[标]发明人	FERREN BRAN HILLIS W DANIEL HYDE RODERICK A ISHIKAWA MURIEL Y JUNG EDWARD K Y MYHRVOLD NATHAN P SWEENEY ELIZABETH A TEGREENE CLARENCE T WILSON RICHA WOOD JR LOWELL L WOOD VICTORIA Y H		
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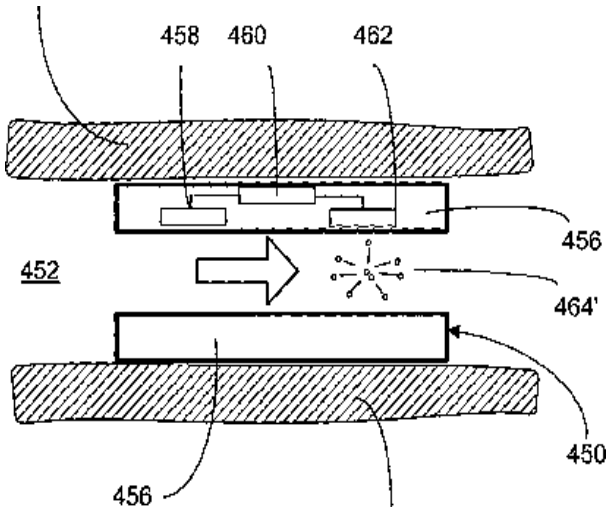
其他公开文献	US20070066929A1		
外部链接	Espacenet USPTO		

摘要(译)

公开了腔内活动系统的实施例及其使用和控制方法。根据各种实施例，腔内活动装置定位在生物体腔中，其中该装置可以感测体腔中的流体参数并对流体执行动作。控制逻辑和/或电路可以位于设备上，或者系统可以包括单独的控制模块。液体或气体流体可以通过装置的实施方案处理。动作可以包括，例如，通过添加或去除材料来改变体液，或者通过改变体液或其组分的性质。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