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**Sarantos et al.**

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(54) **HEART RATE SENSOR WITH  
HIGH-ASPECT-RATIO PHOTODETECTOR  
ELEMENT**

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6,289,230 B1	9/2001	Chaiken et al.
6,402,690 B1	6/2002	Rhee et al.
6,418,394 B1	7/2002	Puolakanaho et al.
6,583,369 B2	6/2003	Montagnino et al.
6,731,967 B1	5/2004	Turcott
6,997,882 B1	2/2006	Parker et al.
7,539,532 B2	5/2009	Tran
7,720,306 B2	5/2010	Gardiner et al.
8,040,758 B1	10/2011	Dickinson
8,152,745 B2	4/2012	Smith et al.
8,172,761 B1	5/2012	Rulkov et al.
8,211,503 B2	7/2012	Tsao et al.
8,346,328 B2	1/2013	Mannheimer et al.
8,386,042 B2	2/2013	Yudovsky et al.
8,444,578 B2	5/2013	Bourget et al.
8,475,367 B1	7/2013	Yuen et al.

(Continued)

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#### FOREIGN PATENT DOCUMENTS

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CN	101615098 A	12/2009
CN	102389313 A	3/2012

(Continued)

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#### OTHER PUBLICATIONS

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(58) **Field of Classification Search**  
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See application file for complete search history.

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(56) **References Cited**

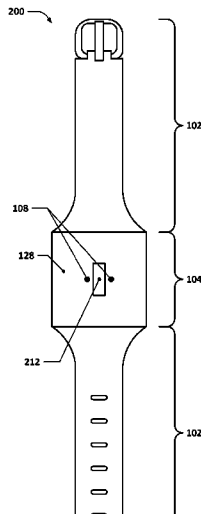
#### U.S. PATENT DOCUMENTS

4,367,752 A	1/1983	Jimenez et al.
4,771,792 A	9/1988	Seale
5,036,856 A	8/1991	Thornton
5,101,831 A	4/1992	Koyama et al.
5,318,597 A	6/1994	Hauck et al.
5,738,104 A	4/1998	Lo et al.
6,076,015 A	6/2000	Hartley et al.
6,131,076 A	10/2000	Stephan et al.
6,241,684 B1	6/2001	Amano et al.

(57) **ABSTRACT**

Heart rate sensors including high-aspect-ratio photodetector elements are discussed herein. Such high-aspect-ratio photodetector elements may provide improved signal-strength-to-power-consumption performance for heart rate sensors incorporating such photodetector elements as compared with heart rate sensors incorporating, for example, square photodetector elements.

**30 Claims, 14 Drawing Sheets**



(56)

**References Cited****U.S. PATENT DOCUMENTS**

8,579,827 B1 11/2013 Rulkov et al.  
 8,792,981 B2 7/2014 Yudovsky et al.  
 8,868,377 B2 10/2014 Yuen et al.  
 8,920,332 B2 12/2014 Hong et al.  
 8,945,017 B2 2/2015 Venkatraman et al.  
 8,948,832 B2 2/2015 Hong et al.  
 8,954,135 B2 2/2015 Yuen et al.  
 8,956,303 B2 2/2015 Hong et al.  
 8,998,815 B2 4/2015 Venkatraman et al.  
 9,005,129 B2 4/2015 Venkatraman et al.  
 9,042,971 B2 5/2015 Brumback et al.  
 9,044,149 B2 6/2015 Richards et al.  
 9,044,150 B2 6/2015 Brumback et al.  
 9,049,998 B2 6/2015 Brumback et al.  
 9,089,760 B2 7/2015 Tropper et al.  
 9,113,794 B2 8/2015 Hong et al.  
 9,113,795 B2 8/2015 Hong et al.  
 9,237,855 B2 1/2016 Hong et al.  
 2001/0044588 A1 11/2001 Mault  
 2003/0163710 A1 8/2003 Ortiz et al.  
 2004/0236227 A1 11/2004 Gueissaz  
 2005/0054940 A1 3/2005 Almen  
 2005/0245793 A1 11/2005 Hilton et al.  
 2006/0195020 A1 8/2006 Martin et al.  
 2007/0213020 A1 9/2007 Novac  
 2007/0265533 A1 11/2007 Tran  
 2008/0097221 A1 4/2008 Florian  
 2009/0012433 A1 1/2009 Fernstrom et al.  
 2009/0132197 A1 5/2009 Rubin et al.  
 2009/0163783 A1 6/2009 Mannheimer et al.  
 2009/0292332 A1 11/2009 Li et al.  
 2009/0318779 A1 12/2009 Tran  
 2010/0106044 A1 4/2010 Linderman  
 2010/0152600 A1 6/2010 Droitcour et al.  
 2010/0204550 A1 8/2010 Heneghan et al.  
 2010/0249633 A1 9/2010 Droitcour et al.  
 2010/0274100 A1 10/2010 Behar et al.  
 2010/0292568 A1 11/2010 Droitcour et al.  
 2010/0298650 A1 11/2010 Moon et al.  
 2010/0298651 A1 11/2010 Moon et al.  
 2010/0298653 A1 11/2010 McCombie et al.  
 2010/0298661 A1 11/2010 McCombie et al.  
 2010/0331145 A1 12/2010 Lakovic et al.  
 2010/0331657 A1 12/2010 Mensinger et al.  
 2011/0009727 A1 1/2011 Mensinger et al.  
 2011/0032105 A1 2/2011 Hoffman et al.  
 2011/0066010 A1 3/2011 Moon et al.  
 2011/0112442 A1 5/2011 Meger et al.  
 2011/0118621 A1 5/2011 Chu  
 2012/0083705 A1 4/2012 Yuen et al.  
 2012/0083714 A1 4/2012 Yuen et al.  
 2012/0083715 A1 4/2012 Yuen et al.  
 2012/0083716 A1 4/2012 Yuen et al.  
 2012/0084053 A1 4/2012 Yuen et al.  
 2012/0084054 A1 4/2012 Yuen et al.  
 2012/0123232 A1 5/2012 Najarian et al.  
 2012/0150074 A1 6/2012 Yanev et al.  
 2012/0172733 A1 7/2012 Park  
 2012/0226471 A1 9/2012 Yuen et al.  
 2012/0226472 A1 9/2012 Yuen et al.  
 2012/0232432 A1 9/2012 Kahn et al.  
 2012/0245439 A1 9/2012 Andre et al.  
 2012/0253486 A1 10/2012 Niemimaki  
 2012/0255875 A1 10/2012 Vicente et al.  
 2012/0274508 A1 11/2012 Brown et al.  
 2012/0316471 A1 12/2012 Rahman et al.  
 2013/0009779 A1 1/2013 Wittling et al.  
 2013/0073254 A1 3/2013 Yuen et al.  
 2013/0073255 A1 3/2013 Yuen et al.  
 2013/0077826 A1 3/2013 Cowperthwaite et al.  
 2013/0080113 A1 3/2013 Yuen et al.  
 2013/0106684 A1 5/2013 Weast et al.  
 2013/0151196 A1 6/2013 Yuen et al.

2013/0211265 A1 8/2013 Bedingham et al.  
 2013/0218053 A1 8/2013 Kaiser et al.  
 2014/0073486 A1 3/2014 Ahmed et al.  
 2014/0074431 A1 3/2014 Modi  
 2014/0099614 A1 4/2014 Hu et al.  
 2014/0107493 A1 4/2014 Yuen et al.  
 2014/0135631 A1 5/2014 Brumback et al.  
 2014/0142403 A1 5/2014 Brumback et al.  
 2014/0241626 A1 8/2014 Sull et al.  
 2014/0275821 A1 9/2014 Beckman  
 2014/0275852 A1 9/2014 Hong et al.  
 2014/0275854 A1 9/2014 Venkatraman et al.  
 2014/0276119 A1 9/2014 Venkatraman et al.  
 2014/0278139 A1 9/2014 Hong et al.  
 2014/0288390 A1 9/2014 Hong et al.  
 2014/0288391 A1 9/2014 Hong et al.  
 2014/0288392 A1 9/2014 Hong et al.  
 2014/0288435 A1 9/2014 Richards et al.  
 2014/0288436 A1 9/2014 Venkatraman et al.  
 2014/0288438 A1 9/2014 Venkatraman et al.  
 2014/0303523 A1 10/2014 Hong et al.  
 2014/0378786 A1 12/2014 Hong et al.  
 2014/0378787 A1 12/2014 Brumback et al.  
 2014/0378872 A1 12/2014 Hong et al.  
 2015/0025393 A1 1/2015 Hong et al.  
 2015/0025394 A1 1/2015 Hong et al.  
 2015/0196256 A1 7/2015 Venkatraman et al.  
 2015/0201853 A1 7/2015 Hong et al.  
 2015/0201854 A1 7/2015 Hong et al.  
 2015/0223708 A1 8/2015 Richards et al.  
 2015/0230761 A1 8/2015 Brumback et al.  
 2016/0034634 A9 2/2016 Hong et al.

**FOREIGN PATENT DOCUMENTS**

CN 103093420 A 5/2013  
 EP 1 721 237 8/2012

**OTHER PUBLICATIONS**

U.S. Appl. No. 14/724,750, filed May 28, 2015, Sarantos et al.  
 US Office Action, dated Aug. 4, 2014, issued in U.S. Appl. No. 13/924,784.  
 US Notice of Allowance, dated Nov. 19, 2014, issued in U.S. Appl. No. 13/924,784.  
 US Office Action, dated Oct. 22, 2014, issued in U.S. Appl. No. 14/290,884.  
 US Notice of Allowance, dated Feb. 6, 2015, issued in U.S. Appl. No. 14/290,884.  
 US Office Action, dated Jun. 22, 2015, issued in U.S. Appl. No. 14/693,710.  
 US Notice of Allowance, dated Jul. 27, 2015, issued in U.S. Appl. No. 14/693,710.  
 US Notice of Allowance, dated Sep. 23, 2014, issued in U.S. Appl. No. 14/292,669.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Oct. 14, 2014, issued in U.S. Appl. No. 14/292,669.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Dec. 31, 2014, issued in U.S. Appl. No. 14/292,669.  
 US Notice of Allowance, dated Oct. 14, 2014, issued in U.S. Appl. No. 14/295,144.  
 US Notice of Allowance, dated Dec. 3, 2014, issued in U.S. Appl. No. 14/295,144.  
 US Notice of Allowance, dated Sep. 26, 2014, issued in U.S. Appl. No. 14/295,158.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Dec. 31, 2014, issued in U.S. Appl. No. 14/295,158.  
 US Office Action, dated Jan. 23, 2015, issued in U.S. Appl. No. 14/507,184.  
 US Final Office Action, dated May 11, 2015, issued in U.S. Appl. No. 14/507,184.  
 US Notice of Allowance, dated Aug. 11, 2015, issued in U.S. Appl. No. 14/507,184.

(56)

**References Cited****OTHER PUBLICATIONS**

US Notice of Allowance, dated Apr. 14, 2015, issued in U.S. Appl. No. 14/295,161.  
 US Notice of Allowance, dated Jul. 28, 2015, issued in U.S. Appl. No. 14/295,161.  
 US Office Action, dated May 11, 2015, issued in U.S. Appl. No. 14/673,630.  
 US Office Action, dated Jan. 27, 2015, issued in U.S. Appl. No. 14/507,173.  
 US Notice of Allowance, dated Apr. 17, 2015, issued in U.S. Appl. No. 14/507,173.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Jul. 16, 2015, issued in U.S. Appl. No. 14/507,173.  
 US Office Action, dated Jun. 8, 2015, issued in U.S. Appl. No. 14/673,634.  
 US Office Action, dated Aug. 5, 2014, issued in U.S. Appl. No. 14/292,673.  
 US Notice of Allowance, dated Dec. 8, 2014, issued in U.S. Appl. No. 14/292,673.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Mar. 5, 2015, issued in U.S. Appl. No. 14/292,673.  
 US Office Action, dated Sep. 18, 2014, issued in U.S. Appl. No. 14/295,059.  
 US Notice of Allowance, dated Jan. 28, 2015, issued in U.S. Appl. No. 14/295,059.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Mar. 11, 2015, issued in U.S. Appl. No. 14/295,059.  
 US Office Action, dated Dec. 24, 2014, issued in U.S. Appl. No. 14/295,076.  
 US Final Office Action, dated Apr. 15, 2015, issued in U.S. Appl. No. 14/295,076.  
 US Office Action, dated Jul. 31, 2014, issued in U.S. Appl. No. 14/295,122.  
 US Notice of Allowance, dated Nov. 24, 2014, issued in U.S. Appl. No. 14/295,122.  
 US Notice of Allowance (Corrected Notice of Allowability), dated Jan. 5, 2015, issued in U.S. Appl. No. 14/295,122.  
 US Office Action, dated Mar. 14, 2014, issued in U.S. Appl. No. 14/154,009.  
 US Office Action, dated Sep. 29, 2014, issued in U.S. Appl. No. 14/154,009.  
 US Notice of Allowance, dated Jan. 21, 2015, issued in U.S. Appl. No. 14/154,009.  
 US Office Action, dated Nov. 25, 2014, issued in U.S. Appl. No. 14/154,019.  
 US Notice of Allowance, dated Mar. 20, 2015, issued in U.S. Appl. No. 14/154,019.  
 US Notice of Allowance (Corrected Notice of Allowability), dated May 14, 2015, issued U.S. Appl. No. 14/154,019.  
 US Office Action, dated Dec. 10, 2014, issued in U.S. Appl. No. 14/484,104.  
 US Notice of Allowance, dated Mar. 19, 2015, issued in U.S. Appl. No. 14/484,104.  
 US Notice of Allowance (Corrected Notice of Allowability), dated May 6, 2015, issued in U.S. Appl. No. 14/484,104.  
 US Office Action, dated Dec. 4, 2014, issued in U.S. Appl. No. 14/216,743.  
 US Final Office Action, dated Apr. 8, 2015, issued in U.S. Appl. No. 14/216,743.  
 US Office Action, dated Mar. 12, 2015, issued in U.S. Appl. No. 14/481,020.  
 US Final Office Action, dated Jul. 7, 2015, issued in U.S. Appl. No. 14/481,020.  
 US Office Action, dated Aug. 22, 2014, issued in U.S. Appl. No. 14/250,256.  
 US Final Office Action, dated Nov. 21, 2014, issued in U.S. Appl. No. 14/250,256.

US Office Action, dated Oct. 7, 2014, issued in U.S. Appl. No. 14/481,762.  
 US Final Office Action, dated Dec. 19, 2014, issued in U.S. Appl. No. 14/481,762.  
 US Office Action, dated Jul. 7, 2015, issued in U.S. Appl. No. 14/481,762.  
 Chinese First Office Action (no translation) dated Aug. 7, 2015 issued in CN 201410243180.6.  
 "Activator is One of the Best Cydia iPhone Hacks | Control your iPhone with Gestures," *iphone-tips-and-advice.com*, [retrieved on Jul. 9, 2013 at <http://www.iphone-tips-and-advice.com/activation.html>], 10 pp.  
 Chudnow, Alan (Dec. 3, 2012) "Basis Wristband Make Its Debut," *The Wired Self, Living in a Wired World*, published in Health [retrieved on Jul. 22, 2013 at <http://thewiredself.com/health/basis-wrist-band-make-its-debut/>], 3pp.  
 Cooper, Daniel (Aug. 16, 2013) *Withings Pulse review*, <http://www.engadget.com/2013/08/16/withings-pulse-review/>, 8 pages.  
 DesMarais, Christina (posted on Sep. 3, 2013) "Which New Activity Tracker is Best for You?" *Health and Home, Health & Fitness, Guides & Reviews*, [Retrieved on Sep. 23, 2013 at <http://www.techlicious.com/guide/which-new-activity-tracker-is-right-for-you/>] 4 pp.  
 Empson, Rip, (Sep. 22, 2011) "Basis Reveals an Awesome New Affordable Heart and Health Tracker You Can Wear on Your Wrist," [retrieved on Sep. 23, 2013 at <http://techcrunch.com/2011/09/22/basis-reveals-an-awesome-new-...>], 3 pp.  
 Fitbit User's Manual, Last Updated Oct. 22, 2009, 15 pages.  
 Forerunner® 201 personal trainer owner's manual, (Feb. 2006) Garmin Ltd., 48 pp.  
 Forerunner® 301 personal trainer owner's manual, (Feb. 2006) Garmin Ltd., 66 pp.  
 Forerunner® 50 with ANT+Sport™ wireless technology, Owner's Manual, (Nov. 2007) Garmin Ltd., 44 pp.  
 Forerunner® 205/305 Owner's Manual, GPS-enabled trainer for runners, (2006-2008), Garmin Ltd., 80 pp.  
 Forerunner® 405CX Owner's Manual, "GPS-Enabled Sports Watch With Wireless Sync," (Mar. 2009), Garmin Ltd., 56 pp.  
 Forerunner® 110 Owner's Manual, (2010) "GPS-Enabled Sport Watch," Garmin Ltd., 16 pp.  
 Forerunner® 210 Owner's Manual, (2010) "GPS-Enabled Sport Watch," Garmin Ltd., 28 pp.  
 Forerunner® 410 Owner's Manual, (Jul. 2012) "GPS-Enabled Sport Watch with Wireless Sync," Garmin Ltd., 52 pp.  
 Forerunner® 10 Owner's Manual (Aug. 2012), Garmin Ltd., 10 pp.  
 Forerunner® 310XT Owner's Manual, Multisport GPS Training Device, (2009-2013), Garmin Ltd., 56 pp.  
 Forerunner® 405 Owner's Manual, (Mar. 2011) "GPS-Enabled Sport Watch with Wireless Sync," Garmin Ltd., 56 pp.  
 Forerunner® 910XT Owner's Manual, (Jan. 2013) Garmin Ltd., 56 pp.  
 Garmin Swim™ Owner's Manual (Jun. 2012), 12 pp.  
 Larklife, User Manual, (2012) *Lark Technologies*, 7 pp.  
 Lark/Larkpro, User Manual, (2012) "What's in the box," *Lark Technologies*, 7 pp.  
 LIFETRNR, User Manual (2003, specific date unknown), NB new balance®, Implus Footcare, LLC, 3 pages.  
 Nike+ FuelBand GPS Manual, User's Guide (Product Release Date Unknown, downloaded Jul. 22, 2013), 26 pages.  
 Nike+SportBand User's Guide, (Product Release Date Unknown, downloaded Jul. 22, 2013), 36 pages.  
 Nike+SportWatch GPS Manual, User's Guide, Powered by TOMTOM, (Product Release Date Unknown, downloaded Jul. 22, 2013), 42 pages.  
 "Parts of Your Band," (Product Release Date Unknown, downloaded Jul. 22, 2013) Jawbone UP Band, 1 page.  
 Polar WearLink® + Coded Transmitter W.I.N. D. User Manual, Polar® Listen to Your Body, *Manufactured by Polar Electro Oy*, 11 pages.  
 Rainmaker, (Jun. 25, 2012, updated Feb 16, 2013) "Garmin Swim watch In-Depth Review," [retrieved on Sep. 9, 2013 at <http://www.>

(56)

**References Cited**

OTHER PUBLICATIONS

Rainmaker, (Jul. 25, 2013) "Basis B<sub>1</sub> Watch In-Depth Review," [retrieved on Feb. 4, 2014 at <http://www.dcrainmaker.com/2013/07/basis-b1-review.html>], 56 pp.

"Withings pulse, Quick Installation Guide" (Jul. 24, 2013) Withings Pulse QIG, v 1.3, withings.com/pulse, 16 pages.

Zijlstra, Wiebren, (2004) "Assessment of spatio-temporal parameters during unconstrained walking," *Eur J Appl Physiol*, 92:39-44.

Duun et al., "A Novel Ring Shaped Photodiode for Reflectance Pulse Oximetry in Wireless Applications," IEEE Sensors Conference 2007, 4 pp.

U.S. Appl. No. 14/954,753, filed Nov. 30, 2015, Richards et al.

US Notice of Allowance (Corrected Notice of Allowability), dated Dec. 18, 2015, issued in U.S. Appl. No. 14/507,184.

US Notice of Allowance, dated Nov. 25, 2015, issued in U.S. Appl. No. 14/673,630.

US Final Office Action, dated Nov. 4, 2015, issued in U.S. Appl. No. 14/673,634.

US Office Action, dated Oct. 22, 2015, issued in U.S. Appl. No. 14/295,076.

US Office Action, dated Oct. 2, 2015, issued in U.S. Appl. No. 14/216,743.

US Final Office Action, dated Feb. 8, 2016, issued in U.S. Appl. No. 14/216,743.

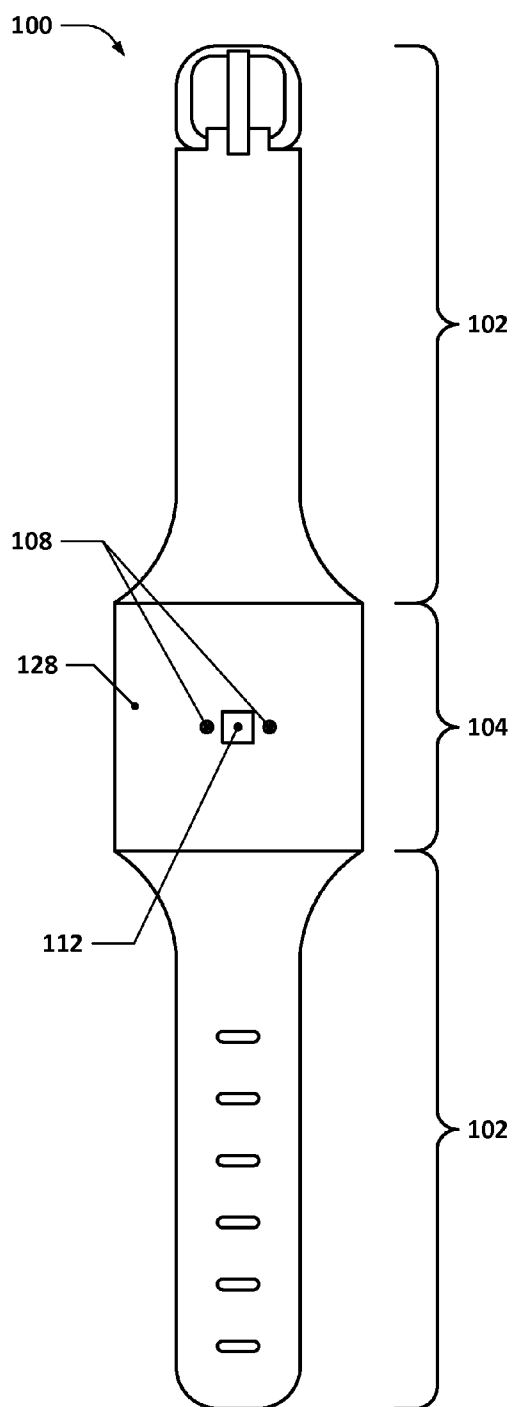
US Office Action, dated Oct. 27, 2015, issued in U.S. Appl. No. 14/481,020.

US Final Office Action, dated Oct. 23, 2015, issued in U.S. Appl. No. 14/250,256.

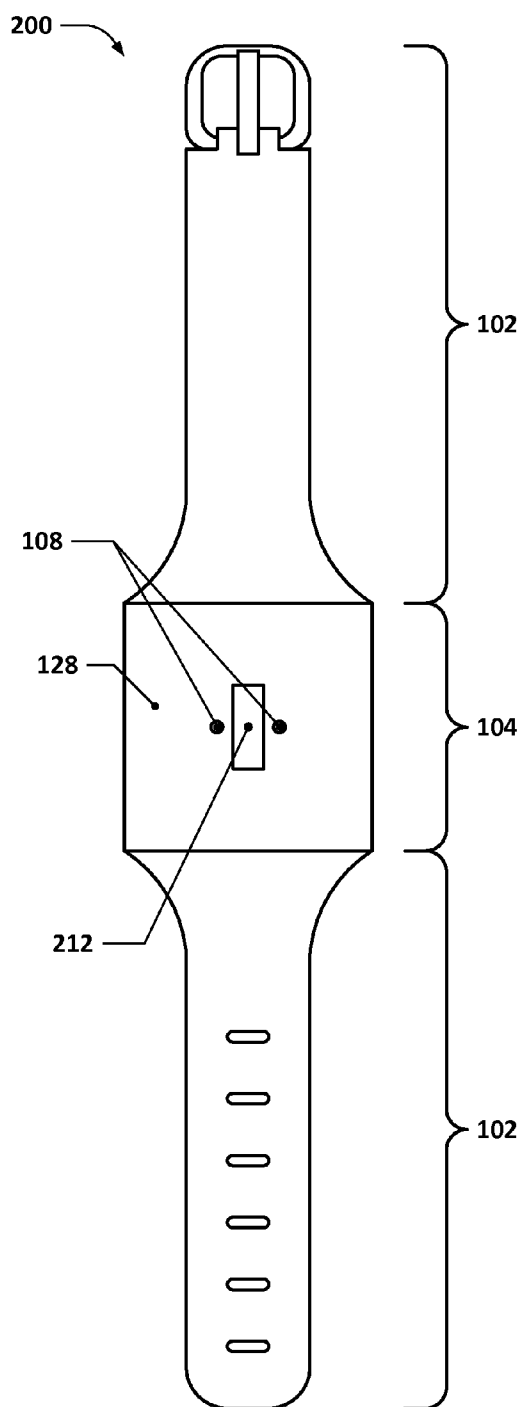
US Final Office Action, dated Nov. 5, 2015, issued in U.S. Appl. No. 14/481,762.

Litigation Document—"Complaint for Patent Infringement," filed Oct. 29, 2015, in U.S. District Court of Delaware [Re: U.S. Pat. No. 8,868,377, 8,920,332, and 9,089,760].

Litigation Document—"Report on the Filing or Determination of an Action Regarding a Patent or Trademark," filed Oct. 29, 2015, in U.S. District Court of Delaware [Re: U.S. Pat. No. 8,868,377, 8,920,332, and 9,089,760].



**FIG. 1**  
(Prior Art)



**FIG. 2**

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