

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Bilal Muhsin, et al.
U.S. Patent No.: 10,736,507 Attorney Docket No. 50095-0135IP2
Issue Date: August 11, 2020
Appl. Serial No.: 15/880,071
Filing Date: January 25, 2018
Title: PHYSIOLOGICAL MONITOR WITH MOBILE COMPUTING
 DEVICE CONNECTIVITY

DECLARATION OF DR. THOMAS W. KENNY

I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of the Title 18 of the United States Code.

Dated: December 11, 2023

By: 
Thomas W. Kenny, Ph.D.

TABLE OF CONTENTS

I.	QUALIFICATIONS AND BACKGROUND INFORMATION.....	4
II.	OVERVIEW OF CONCLUSIONS FORMED	12
III.	LEVEL OF ORDINARY SKILL IN THE ART	14
IV.	THE '507 PATENT	15
A.	Overview	15
V.	PRIOR ART ANALYSIS.....	18
A.	[GROUND 1A] – CLAIMS 13-15 AND 19 ARE ANTICIPATED BY BAILEY	18
1.	Bailey describes a system for monitoring physiological parameters having a sensor, a processing board, and a mobile computing device that acts as a display device	18
2.	Application of Bailey to Claims 13-15 and 19	27
B.	[GROUND 1B] – CLAIMS 16, 18, AND 20 ARE OBVIOUS OVER BAILEY AND TRAN.....	52
1.	Tran describes a physiological sensing system that outputs alerts allows users to set reminders.....	52
2.	The combination of Bailey and Tran	54
3.	Application of Bailey and Tran to Claims 16, 18, and 20	62
C.	[GROUND 1C] – CLAIMS 14 AND 17 ARE OBVIOUS OVER BAILEY AND KIANL	70
1.	Kianl describes a physiological monitoring system that performs and displays a trend analysis and provides charts of SpO₂ measurements	70
2.	The combination of Bailey and Kianl.....	73
3.	Application of Bailey and Kianl to Claims 14 and 17	76
D.	[GROUND 1D] – CLAIMS 1-2, 5, 7, 9, 12-15, 17, AND 19 ARE OBVIOUS OVER BAILEY AND D'ANGELO	82
1.	D'Angelo describes a user interface for a smartphone having multiple physiological parameter views and touchscreen user inputs for a physiological monitoring system and describes using the smartphone to provide power to a processing board.....	82
2.	The combination of Bailey and D'Angelo.....	88
3.	Application of Bailey and D'Angelo to Claims 1-2, 5, 7, 9, 12-15, 17-19	94
E.	[GROUND 1E] – CLAIM 3 IS OBVIOUS OVER BAILEY, D'ANGELO, AND ORDING	120
1.	Ording describes narrowing or expanding a display in response to a user using a pinch gesture via a touch-sensitive display. 120	

2.	The combination of Bailey, D’Angelo, and Ording	121
3.	Application of Bailey, D’Angelo, and Ording to Claim 3.....	124
F.	[GROUND 1F] – CLAIMS 4-6, 8, 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, D’ANGELO, AND TRAN	125
G.	[GROUND 1G] – CLAIMS 2, 7, 14, AND 17 ARE OBVIOUS OVER BAILEY, D’ANGELO, AND KIANL	128
H.	[GROUND 1H] – CLAIM 3 IS OBVIOUS OVER BAILEY, D’ANGELO, KIANL, AND ORDING	131
I.	[GROUND 1I] – CLAIMS 10 AND 11 ARE OBVIOUS OVER BAILEY, D’ANGELO, AND GOLDSMITH	132
1.	Goldsmith discloses a display device for a physiological monitoring system implemented as a wearable wristwatch. ..	132
2.	The Combination of Bailey, D’Angelo, and Goldsmith.....	134
3.	Application of Bailey, D’Angelo, and Goldsmith to Claims 10 and 11	138
J.	[GROUND 2A] – CLAIMS 13-15 AND 19 ARE OBVIOUS OVER BAILEY AND MOON	140
1.	Moon describes reduction and/or correction of motion artifacts caused by user motion.....	141
2.	The combination of Bailey and Moon	144
3.	Application of Bailey and Moon to Claims 13, 15, and 18-19	148
K.	[GROUND 2B] – CLAIMS 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, MOON, AND TRAN	152
L.	[GROUND 2C] – CLAIMS 14 AND 17 ARE OBVIOUS OVER BAILEY, MOON, AND KIANL	152
M.	[GROUND 2D] – CLAIMS 1-2, 5, 7, 9, 12-15, 17, AND 19 ARE OBVIOUS OVER BAILEY, MOON, AND D’ANGELO.....	153
N.	[GROUND 2E] – CLAIM 3 IS OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND ORDING	153
O.	[GROUND 2F] – CLAIMS 4-6, 8, 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND TRAN.....	153
P.	[GROUND 2G] – CLAIMS 2, 7, 14, AND 17 ARE OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND KIANL	154
Q.	[GROUND 2H] – CLAIM 3 IS OBVIOUS OVER BAILEY, MOON, D’ANGELO, KIANL, AND ORDING	154
R.	[GROUND 2I] – CLAIMS 10 AND 11 ARE OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND GOLDSMITH	155
VI.	CONCLUSION.....	155

I. QUALIFICATIONS AND BACKGROUND INFORMATION

1. My education and experience are described more fully in my curriculum vitae, attached as Appendix A to this declaration. For ease of reference, I have highlighted certain information below.

2. My academic and professional background is in Physics, Mechanical Engineering, Sensing, and Robotics, with a research specialization focused on microfabricated physical sensors, and I have been working in those fields since the completion of my Ph.D. more than 30 years ago. The details of my background and education and a listing of all publications I have authored in the past 35 years are provided in my curriculum vitae, attached as Appendix A. Below I provide a short summary of my education and experience which I believe to be most pertinent to the opinions that I express here.

3. I received a B.S. in Physics from University of Minnesota, Minneapolis in 1983, and a Ph.D. in Physics from University of California at Berkeley in 1989. I was educated as a Physicist specializing in sensors and measurement. My Physics Ph.D. thesis involved measurements of the heat capacity of monolayers of atoms on surfaces, and relied on precision measurements of temperature and power using time-varying electrical signals, and also on the design and construction of miniature sensor components and associated electrical circuits for conditioning and conversion to digital format.

4. After completion of my Ph.D. in Physics at U.C. Berkeley in 1989, I joined the Jet Propulsion Laboratory (JPL) in Pasadena, CA, as a staff scientist, and began working on miniature sensors and instruments for small spacecraft. This work involved the use of silicon microfabrication technologies for miniaturization of the sensors, and served as my introduction to the field of micro-electromechanical systems (MEMS), or the study of very small mechanical sensors powered by electricity and used for detection of physical and chemical signals.

5. While at JPL, we developed accelerometers, uncooled infrared sensors, magnetometers, seismometers, force and displacement sensors, soil chemistry sensors, miniature structures for trapping interstellar dust, and many other miniature devices. Some of these projects led to devices that were launched with spacecraft headed for Mars and for other interplanetary missions. Much of this work involved the use of physical sensors for detection of small forces and displacements using micromechanical sensors.

6. I am presently the Richard Weiland Professor at the Department of Mechanical Engineering at Stanford University, where I have taught for the past 29 years. I am also currently the Senior Associate Dean of Engineering for Student Affairs at Stanford.

7. For almost all of these 29 years, I have taught courses on Sensors and Mechatronics at Stanford University. The “Introduction to Sensors” course is a

broad overview of all sensing technologies, from thermometers, to inertial sensors, ultrasound devices, flow sensors, optical and IR sensors, chemical sensors, pressure sensors, and many others, and has included sensors based on changes in capacitance, resistance, piezoelectricity. This course specifically included different mechanisms for sensing heart rate, blood pressure, blood chemistry, cardiovascular blood flow and pressure drops, intraocular pressure and other physiological measurements, as well as activity monitoring (step counting, stair-counting, etc). I first taught this course at Stanford in the Spring of 1994, and I offered this course at least annually until 2016, when my duties as Senior Associate Dean made this impractical, yet have continued to offer this course periodically since, including these last two years.

8. The “Introduction to Mechatronics” course is a review of the mechanical, electrical and computing technologies necessary to build systems with these contents, which include everything from cars and robots to cellphones and other consumer electronics devices. In this class, we routinely use IR, LEDs, and photosensors as a way of detecting proximity to objects in the space around miniature robots. We also use inertial sensors to detect movement, and a number of sensors, such as encoders to measure changes in position and trajectory. I was one of the instructors for the first offering of this course in 1995, and this course has been offered at least once each year ever since, except for the pandemic year of

2021. The 2023 offering was highly-successful with 80 undergraduate and graduate students from many engineering and science disciplines.

9. I am co-author of a textbook titled “Introduction to Mechatronic Design,” which broadly covers the topic of integration of mechanical, electronic and computer systems design into “smart products.” This textbook includes chapters on Microprocessors, Programming Languages, Software Design, Electronics, Sensors, Signal Conditioning, and Motors, as well as topics such as Project Management, Troubleshooting, and Synthesis.

10. My research group at Stanford has focused on the area of microsensors and microfabrication—a domain in which we design and build micromechanical sensors using silicon microfabrication technologies. The various applications for these technologies are numerous.

11. I have advised 75 Ph.D. students that have completed Ph.D. degrees and many more M.S. and B.S. students in Engineering during my time at Stanford.

12. I have published over 250 technical papers in refereed journals and conferences in the field of sensors, MEMS, and measurements. I have further presented numerous conference abstracts, posters, and talks in my field. I am a named inventor on 50 patents in my areas of work.

13. From 2020 to 2022 I served as CEO of Applaud Medical, a startup that I co-founded in 2015. Applaud is developing improved methods for treatment

of kidney stones, and during my time as CEO, we initiated a FDA-regulated pivotal clinical trial on our first product, concluded an Australian clinical study on our second product, and positioned the company for on-boarding of an experienced CEO with resources to guide the company through all remaining trials and to a successful outcome.

14. I received the Office of the Secretary of Defense Award for Exceptional Public Service in 2010, the IEEE Sensors Council Technical Achievement Award in 2011, and was named Fellow of the ASME in 2014. I was awarded the 2018 IEEE Daniel Noble Award for Emerging Technologies. In 2022, I was elected to the National Academy of Engineering.

15. I have previously served as an expert on a patent infringement case involving the mounting and use of pressure sensors on guidewire catheters for cardiovascular procedures that included a number of sensing aspects, such as recording static and dynamic pressure signals, and compensating for electrical and mechanical errors. I have also previously served as an expert on a patent infringement case involving the design and use of miniature inertial sensors. That case involved the design and operations of micromechanical sensors, and particularly the use of inertial sensors for detection of states of movement and rest. I have also served as an expert in a patent infringement case involving the use of sensors on athletic shoes for determining athletic performance. More recently, I

served as an expert in a patent infringement case involving optical proximity sensors in smartphones. My CV, Appendix A, includes a full listing of all cases in which I have testified at deposition or trial in the preceding several years.

16. I have been retained on behalf of Apple Inc. to offer technical opinions relating to U.S. Patent No. 10,736,507 (“the ’507 Patent”) and prior art references relating to its subject matter. I have reviewed the ’507 Patent, and relevant excerpts of the prosecution history of the ’507 Patent. Based on my experience and education, and the acceptance of my publications and professional recognition by societies in my field, I believe that I am qualified to offer opinions as to the knowledge and level of skill of one of ordinary skill in the art at the time of the alleged invention of the ’507 patent (which I further describe below).

17. In addition to any materials cited in the present declaration, I have also reviewed the following references:

- APPLE-1004: Brian Bailey, et al., Development of a Remote Pulse Oximeter, the University of Arizona, May 2010 (“Bailey”)
- APPLE-1005: U.S. Patent Application Pub. No. 2008/0004904 to Tran (“Tran”)
- APPLE-1006: U.S. Patent No. 6,658,276 to Kianl et al. (“Kianl”)
- APPLE-1007: Lorenzo T. D’Angelo, et al., A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine, 33rd Annual International Conference of the IEEE EMBS

Boston, Massachusetts USA, August 30 - September 3, 2011
("D'Angelo")

- APPLE-1008: U.S. Patent No. 7,812,826 to Ording et al. ("Ording")
- APPLE-1009: U.S. Patent Application Pub. No. 2007/0093786 to Goldsmith et al. ("Goldsmith")
- APPLE-1010: U.S. Patent Application Pub. No. 2010/0324387 to Moon et al. ("Moon")
- APPLE-1011: Y. Mendelson, et al., A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring, Proceedings of the 28th IEEE EMBS Annual International Conference New York City, USA, Aug 30-Sept 3, 2006.
- APPLE-1012 Leslie R. Martin, et al., The Challenge of Patient Adherence, 1(3) Therapeutics Clinical Risk Mgmt. 189 (Sep. 2005)
- APPLE-1013 Jimmy Beena, et al., Patient Medication Adherence: Measures in Daily Practice, 26(3) Oman MED. J. 155 (May 2011)
- APPLE-1014 U.S. Patent Application Pub. No. 2009/0247850 to Charles E. Porges
- APPLE-1015 Pulse Oximetry: An Essential Tool for the Busy Med-Surg Nurse, AMERICAN NURSE (Nov. 11, 2009), available at <https://www.myamericannurse.com/pulse-oximetry-an-essential-tool-for-the-busy-med-surg-nurse/> (retrieved July 29, 2023)

- APPLE-1016 U.S. Patent Application Pub. No. 2013/0245408 to Porges (“Porges”)
- APPLE-1018 U.S. Patent No. 8,626,255 to Ammar Al-Ali, et al. (“Al-Ali”)
- APPLE-1019 U.S. Patent No. 8,666,467 to Lawrence A. Lynn (“Lynn”)
- APPLE-1020 U.S. Patent No. 8,195,848 to Zach Jones (“Jones”)
- APPLE-1023 U.S. Patent No. 8,515,979 to Japan A. Mehta
- APPLE-1024 U.S. Patent No. 8,310,492 to Rex McCrary, et al.

18. I have also reviewed various supporting references and other documentation as further noted in my opinions below.

19. Counsel has informed me that I should consider these materials through the lens of one of ordinary skill in the art related to the ’507 Patent at the time of the earliest possible priority date of the ’507 Patent, and I have done so during my review of these materials. The ’507 Patent claims the benefit of priority to a provisional application filed September 20, 2012 (“the Critical Date”). Counsel has informed me that the Critical Date represents the earliest possible priority date to which the challenged claims of ’507 Patent are entitled, and I have therefore used that Critical Date in my analysis below.

20. I have no financial interest in the parties or in the outcome of this proceeding. I am being compensated for my work as an expert on an hourly basis. My compensation is not dependent on the outcome of these proceedings or the content of my opinions.

21. In writing this declaration, I have considered the following: my own knowledge and experience, including my work experience in the fields of mechanical engineering, computer science, biomedical engineering, and electrical engineering; my experience in teaching those subjects; and my experience in working with others involved in those fields. In addition, I have analyzed various publications and materials, in addition to other materials I cite in my declaration.

22. My opinions, as explained below, are based on my education, experience, and expertise in the fields relating to the '507 Patent. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art as of the Critical Date, or before. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the '507 Patent and the prior art discussed below.

II. OVERVIEW OF CONCLUSIONS FORMED

23. This declaration explains the conclusions that I have formed based on my analysis. To summarize those conclusions, based upon my knowledge and experience and my review of the prior art publications listed above, I believe that:

- Claims 13-15 and 19 are obvious over Bailey;
- Claims 16, 18, and 20 are obvious over Bailey and Tran.
- Claims 14 and 17 are obvious over Bailey and Kianl
- Claims 1-2, 5, 7, 9, and 12 are obvious over Bailey and D'Angelo
- Claim 3 is obvious over Bailey, D'Angelo, and Ordning
- Claims 4-6 and 8 are obvious over Bailey, D'Angelo, and Tran
- Claims 2 and 7 are obvious over Bailey, D'Angelo, and Kianl
- Claim 3 is obvious over Bailey, D'Angelo, Kianl, and Ordning
- Claims 10-11 are obvious over Bailey, D'Angelo, and Goldsmith
- Claims 13-15 and 19 are obvious over Bailey and Moon;
- Claims 16, 18, and 20 are obvious over Bailey, Moon, and Tran.
- Claims 14 and 17 are obvious over Bailey, Moon, and Kianl
- Claims 1-2, 5, 7, 9, and 12 are obvious over Bailey, Moon, and
D'Angelo
- Claim 3 is obvious over Bailey, Moon, D'Angelo, and Ordning
- Claims 4-6 and 8 are obvious over Bailey, Moon, D'Angelo, and Tran
- Claims 2 and 7 are obvious over Bailey, Moon, D'Angelo, and Kianl
- Claim 3 is obvious over Bailey, Moon, D'Angelo, Kianl, and Ordning
- Claims 10-11 are obvious over Bailey, Moon, D'Angelo, and
Goldsmith

III. LEVEL OF ORDINARY SKILL IN THE ART

24. In my opinion, a person of ordinary skill in the art as of the Critical Date of the '507 Patent (hereinafter a "POSITA") would have been a person with a working knowledge of physiological monitoring technologies. The person would have had at least a bachelor's degree in electrical engineering, mechanical engineering, biomedical engineering, computer engineering, physics, or a related field, and would have had at least two years of relevant work experience with physiological monitoring technologies and devices, including user interfaces and capture and processing of physiological information, or equivalents thereof. Alternatively, the person could have also had a Master of Science degree in a relevant academic discipline to compensate for less related work experience in the same discipline or vice versa.

25. Based on my experiences, I have a good understanding of the capabilities of one of ordinary skill. Indeed, I have taught, participated in organizations, and worked closely with many such persons over the course of my career. Based on my knowledge, skill, and experience, I have an understanding of the capabilities of one of ordinary skill. For example, from my industry experience, I am familiar with what an engineer would have known and found predictable in the art. From teaching and supervising my post-graduate students, I

also have an understanding of the knowledge that a person with this academic experience possesses. Furthermore, I possess those capabilities myself.

IV. THE '507 PATENT

A. Overview

26. The system described by the '507 Patent is said to include, in one embodiment, “a physiological sensor and a mobile computing device [that] can be connected via a cable or cables, and a processing board can be connected between the sensor and the mobile computing device to conduct advanced signal processing on the data received from the sensor before the data is transmitted for display on the mobile computing device.” APPLE-1001, Abstract. The system is arranged “such that board or card handles advanced signal processing and the smartphone displays parameter data.” FIG. 1A shows an example arrangement of the physiological sensor (sensor 110), processing board (processing module 130), and mobile computing device (smartphone 160) in which the processing module 130 receives sensor data from the sensor 110 and then “appl[ies] noise filtering and signal processing techniques described below to provide output data for display on the smartphone 160.” APPLE-1001, 3:57-62, 4:65-4.

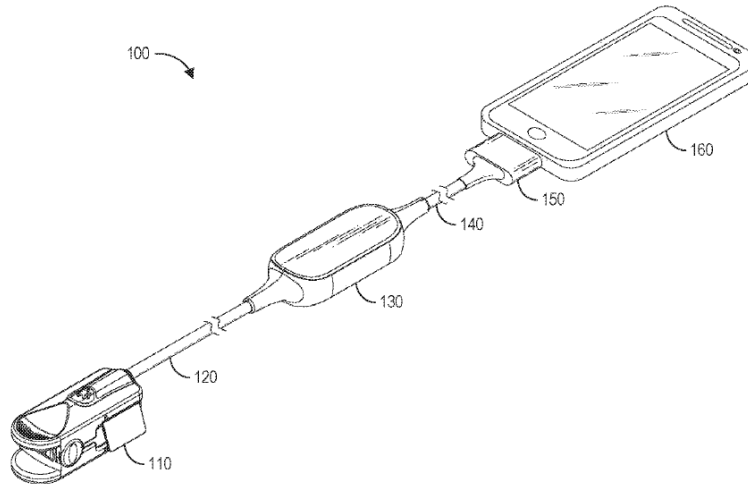


FIG. 1A

APPLE-1001, FIG. 1A. The '507 describes that the sensor 110 can be “a pulse oximeter capable of being secured to a digit such as a finger.” *Id.*, 4:9-10.

Furthermore, a number of devices can serve as the display device, including a smartphone, laptop, tablet computer, netbook, PDA, media player, mobile game console, wristwatch, [or] wearable computing device. *Id.*, 3:65-4:4.

27. The '507 Patent describes that “[t]he processing module 130 processes the raw detected signals to determine a physiological measurement” such as “SpO₂ and pulse rate.” APPLE-1001, 6:1-22. The processing module 130 then “provide[s] output data for display on the smartphone 160.” *Id.*, 4:65-10. The '507 also describes issuing alerts via the smartphone 160:

The smartphone 160 can also be able to alert the user and/or a physician or other care provider to an abnormal data reading. For

example, an abnormally low or high blood oxygen saturation reading can cause the smartphone 160 to buzz, vibrate or otherwise notify the user of an abnormal reading, or to transmit a notification to a physician via a network.

APPLE-1001, 5:52-58.

28. As shown in FIG. 4A, the smartphone 160 includes a display “an application configured to manage output measurement data from the processing module 130.” APPLE-1001, 5:25-27. For example, the display includes physiological information for the patient, including numerical values for the blood oxygen (SpO₂) level, heart rate, and perfusion index, and a plethysmographic waveform, along with options for interacting with the display application:

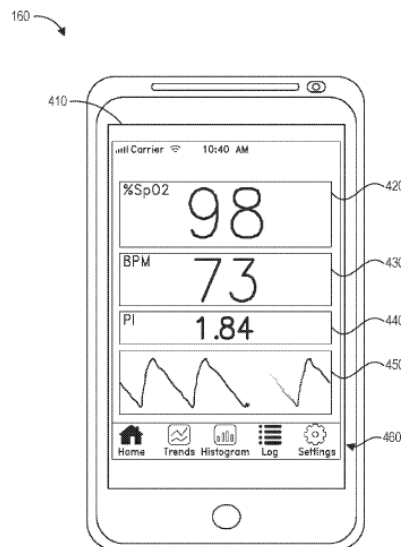


FIG. 4A

APPLE-1001, FIG. 4A, 13:22-43.

29. The claimed inventions recited in the ‘507 patent, which were disclosed at the priority date of September 20, 2012, include combinations of established fingertip-mounted transmission pulse oximeters with peripheral devices, such as PDAs, wearable devices and early-generation smartphones, which were also well-established at the time of this disclosure. By 2012, it was well known that applications developed for peripheral devices could perform important and useful functions in the capture, processing, analysis, display, and distribution of data and information related to physiological parameters, and that these devices could be connected and used in a variety of ways to meet patient needs.

V. PRIOR ART ANALYSIS

A. [GROUND 1A] – CLAIMS 13-15 AND 19 ARE ANTICIPATED BY BAILEY

30. The sections below provide a brief introduction to the Bailey reference.

1. Bailey describes a system for monitoring physiological parameters having a sensor, a processing board, and a mobile computing device that acts as a display device

31. The Bailey reference is a thesis that was submitted in May 2010 by a team of undergraduate students reporting on a project completed to fulfill the requirements for a Bachelors degree as part of the Interdisciplinary Engineering Design Program at the University of Arizona, and was sponsored by Texas Instruments Inc. APPLE-1004, Abstract. The student team members that

produced this report were all at a stage in their education that is below the training expected for a POSITA in this proceeding, and therefore, their appreciation and understanding of the basic ideas and opportunities for design of a pulse oximeter system represent what would have been obvious to any other POSITA at the time of the '507.

32. Bailey describes its system design for “a pulse oximeter geared toward consumer use that could wirelessly transmit data to a portable device, such as a smartphone, for convenient, remote monitoring of oxygen saturation.”

APPLE-1004, Abstract, 8. The goal of the team of undergraduates working together on Bailey’s project was “to develop an intimate knowledge base of the considerations, components, and overall design of a pulse oximeter in order to better assist their customers. The creation of the pulse oximeter reference design was inspired by thorough research on the scientific principles underlying pulse oximetry as well as existing pulse oximeter technologies.” APPLE-1004, Abstract, 8.

33. Among other things, Bailey describes:

The project entailed the design of a pulse oximeter intended primarily for consumer use. This requirement meant that the device needed to be user-friendly and as small and unobtrusive as possible. Pulse oximeters for consumer use have been on the market for a number of years now; however, the novelty of this project was mostly in the

remote monitoring capability of the oxygen saturation data. TI [Texas Instruments] wanted a device that could incorporate and demonstrate some of the wireless technology it has developed, so the decision was made to have a pulse oximeter with the ability to communicate data to a smartphone or other portable device. This potentially made the device smaller by not needing to incorporate a display and user interface on the oximeter itself. It also lent itself to situations such as remote monitoring of an infant's oxygen levels during sleep to warn of dangerously low oxygen conditions that may be associated with Sudden Infant Death Syndrome (SIDS) or suffocation. However, the ultimate goal of the project was to develop a working oximeter prototype so TI could use it as a reference design. TI could then use the design and the knowledge accumulated throughout its development to better address the needs of their customers.

APPLE-1004, 8.

34. As such, the Bailey system includes a “remotely monitored pulse oximeter, a device that measures blood oxygen saturation.” APPLE-1004, 8. In particular, Bailey describes:

Typical pulse oximeters utilize two light emitting diodes (LEDs), one red and one infrared, to measure relative levels of HbO₂ and Hb as blood is pumped through the body. The LEDs are positioned on one side of an extremity of the body, usually a finger, ear or toe, and a photodetector is placed on the opposite side, as in Figure 1.

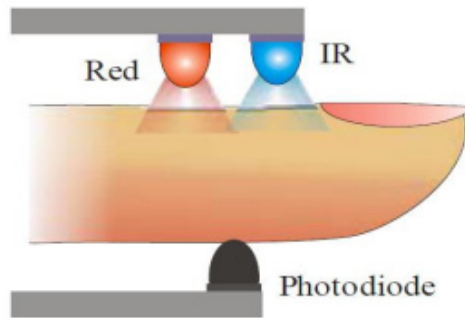


Figure 1: Typical pulse oximeter configuration [4]

APPLE-1004, Figure 1.

35. Bailey further describes:

In operation the LEDs are pulsed alternately, with one off while the other is on, allowing the photodetector to measure the transmitted light intensity at each wavelength separately. The transmitted light intensity differs greatly at each wavelength and can be attributed to the attenuation as it travels through the body, which results from a combination of reflection, scattering, and absorption by tissue and bone, venous blood, and arterial blood in the region. These values are then also related to the absorption of light by the oxyhemoglobin and deoxyhemoglobin molecules. Figure 2 shows the absorption of each molecule and its dependence on wavelength.

APPLE-1004, 11.

36. In describing its final design, Bailey states:

The operation of the ear oximeter was to closely follow that of standard pulse oximeters currently on the market. Therefore, it would consist of a red and an infrared LED placed on one side of the ear and

opposite a photodiode. The LEDs would be pulsed, with one being on while the other is off and continually alternating in that fashion, at a combined rate of 100 Hz. Light would reach the photodiode, causing it to output a signal, which would then be amplified, processed, and the ratio of the two signals would be mathematically related to the actual oxygen saturation of the user. Afterward, the device would transmit the oxygen saturation as well as the pulsatile signal to an iPhone or iPod Touch and be displayed on a user interface that would allow the data to be monitored and stored.

APPLE-1004, 22.

37. Bailey’s pulse oximeter includes “three main systems: the LED driver control, analog signal processing, and digital signal processing systems.” APPLE-1004, 22. The “digital signal processing system” is in data communication with the “LED driver control” and “analog signal processing” and further in data communication with a smartphone (e.g., iPhone). APPLE-1004, 23, 8, Figure 7. In Figure 7, Bailey illustrates that the LED driver control system, the analog signal processing system, and the digital signal processing system are included in the “ear-oximeter housing.” APPLE-1004, 23, Figure 7.

38. Although Bailey illustrates the “ear-oximeter housing” as a single device, it would have been obvious to implement the LED driver control system, the analog signal processing system, and the digital signal processing system in multiple separate devices. Further, it would have been obvious to configure and

arrange the components of the LED driver control system, the analog signal processing system, and the digital signal processing system within multiple devices in various manners. In fact, Bailey describes that its “pulse oximeter housing” is “divided into two main parts: the main circuitry housing and the sensor housing.” APPLE-1004, 24. “The main housing contained a LED driver circuit, temperature sensor, microcontroller circuit, antenna, and battery, while the sensor housing contained the LEDs, photodiode, and signal amplifier circuit.” APPLE-1004, 24, Figure 11 (below).



APPLE-1004, Figure 11 (annotated).

39. In Bailey, components (e.g., LEDs) of the LED driver control system and components (e.g., photodiode and signal amplifier circuit) of the analog signal processing system are contained in the sensor housing. APPLE-1004, 24, Figure 11. Further, components (e.g., LED driver circuit and temperature sensor) of the LED driver control system and components (e.g., microcontroller circuit and

antenna) of the digital signal processing system are contained in the main circuitry housing. APPLE-1004, 24, Figure 11.



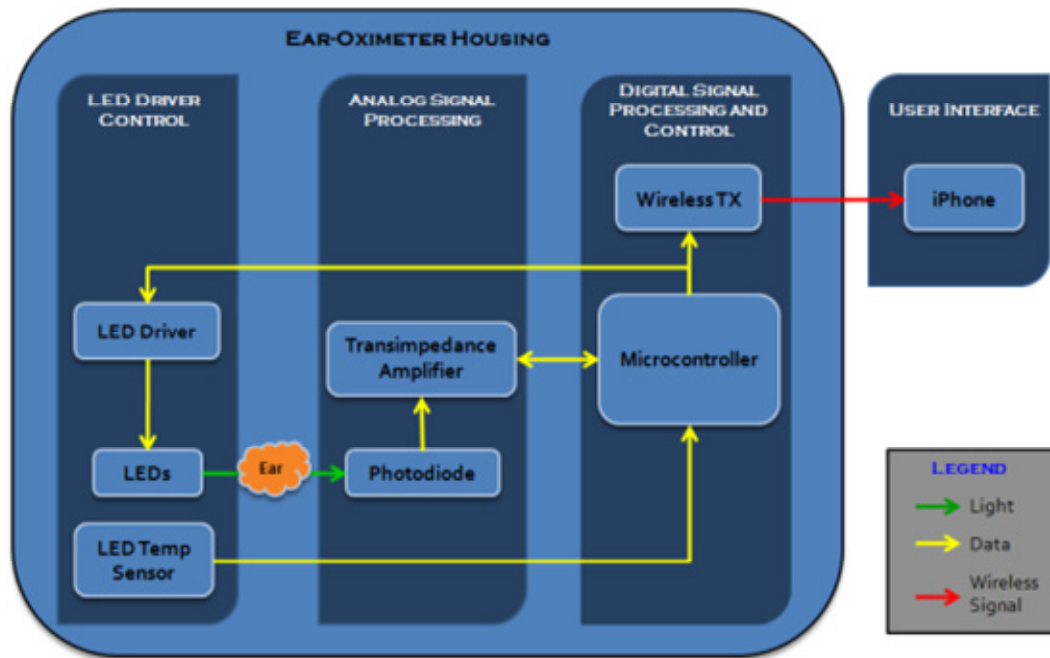
APPLE-1004, Figure 11 (annotated).

40. LEDs “produce a consistent and accurate light output,” and “[t]he photodiode senses the optical power (light) present on the other side of the sample (the ear in this case) and proportionally produces a current. This signal, in the form of an electrical current, is then sent to the transimpedance amplifier where it is converted into a voltage and amplified.” APPLE-1004, 23, Figure 7 (below).

“The amplified signal is sent to the microcontroller where the signal data is processed and then sent to the wireless transmitter.” APPLE-1004, 23. The processed signals are “mathematically related to the actual oxygen saturation of the user.” APPLE-1004, 22.

41. Bailey’s “digital signal processing system,” which is contained in the main circuitry housing, includes a microcontroller that receives amplified signal from the analog signal processing system that is contained in the sensor housing.

APPLE-1004, 23, Figure 7. Bailey's digital signal processing system includes a wireless transmitter that "communicates with the application on the iPhone to send and display the data on the user interface." APPLE-1004, 22-23.



APPLE-1004, Figure 7.

42. The mobile device (e.g., iPhone), which is in data communication with the "digital signal processing system" (contained in the main circuitry housing), runs an application and includes a display. APPLE-1004, 23, 47-48, Figure 32. Bailey describes that "the user interface [is] implemented for an iPhone" to "display the recorded data from the microcontroller via wireless interface." APPLE-1004, 47. Further, Bailey's graphical user interface has a plurality of display portions, as illustrated in Figure 32 (below). APPLE-1004, 48. Bailey's mobile device displays at least a SpO2 value and a heart rate. APPLE-

1004, 48. Further, the SpO2 and the heart rate are displayed in respective display portions, as shown in Figure 32. APPLE-1004, 48. For example, SpO2 is represented as a numerical value (%) as well as a graph. APPLE-1004, 48. Bailey's mobile phone also displays the results of the trend analysis in one of the display portions. APPLE-1004, 14.



APPLE-1004, Figure 32.

43. As shown in Figure 32, Bailey's mobile device displays a user-selectable "Options" menu where the user can select several options including "O2 Alert Threshold," "Volume," and "File Name," which are displayed in respective display portions. APPLE-1004, Figure 32. These options are configured to allow

the user to interact with the display portions or the application. For example, by adjusting the “Volume,” the user can interact with the application that generates a sound. APPLE-1004, Figure 32. Moreover, the display shows “Save” and “Upload” buttons, by which the user can interact with the application to save or upload the information provided by the user. APPLE-1004, Figure 32. By adjusting the “O2 Alert Threshold,” the user can interact with the display portion that outputs an alert of low O2 levels, and the user interface on the mobile device is designed to “sound an alarm when a low oxygen level was reached.” APPLE-1004, 47, 62, 8, 14, Figure 32.

2. Application of Bailey to Claims 13-15 and 19

(i) Claim 13

[13pre] A computer-implemented method of informing a user of mobile measurement of oxygen saturation (“SpO2”), the computer-implemented method comprising:

44. To the extent that the preamble is limiting, Bailey describes a “remotely monitored pulse oximeter, a device that measures blood oxygen saturation.” APPLE-1004, 8. Based on my review, Bailey’s pulse oximeter is designed for ***mobile measurement of oxygen saturation***. For example, Bailey’s pulse oximeter design is “intended primarily for consumer user” and provides “the ability to communicate data to a smartphone or other portable device” so that the device can be made “smaller by not needing to incorporate a display and user interface on the oximeter itself.” APPLE-1004, 8. Further, Bailey’s pulse

oximeter is “intended to be worn by a person” and “needed to be durable enough to handle the daily rigors of being worn by an adult or child.” APPLE-1004, 14.

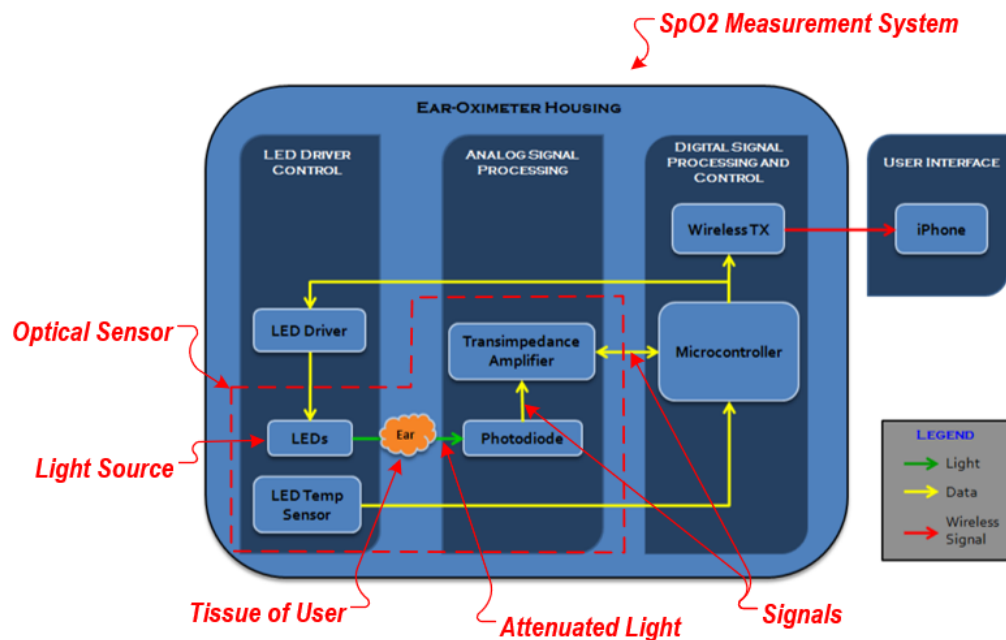
Bailey’s pulse oximeter system needs to be “as small and as lightweight as possible.” APPLE-1004, 27. Due to its small form factor and portable nature, it would have been apparent and obvious that Bailey’s pulse oximeter is adapted for mobile measurement of oxygen saturation.

45. Further, Bailey’s system includes a mobile device (e.g., iPhone), which is in data communication with the “digital signal processing system,” runs an application and includes a display, thereby implementing a ***computer-implemented method***. APPLE-1004, 23, 47-48, Figure 32. Bailey’s mobile device implements a user interface to “display the recorded data from the microcontroller via wireless interface.” APPLE-1004, 47. Further, Bailey’s mobile device is designed to “warn of dangerously low oxygen conditions.” APPLE-1004, 47. Therefore, Bailey teaches ***a computer-implemented method of informing a user of mobile measurement of SpO₂***.

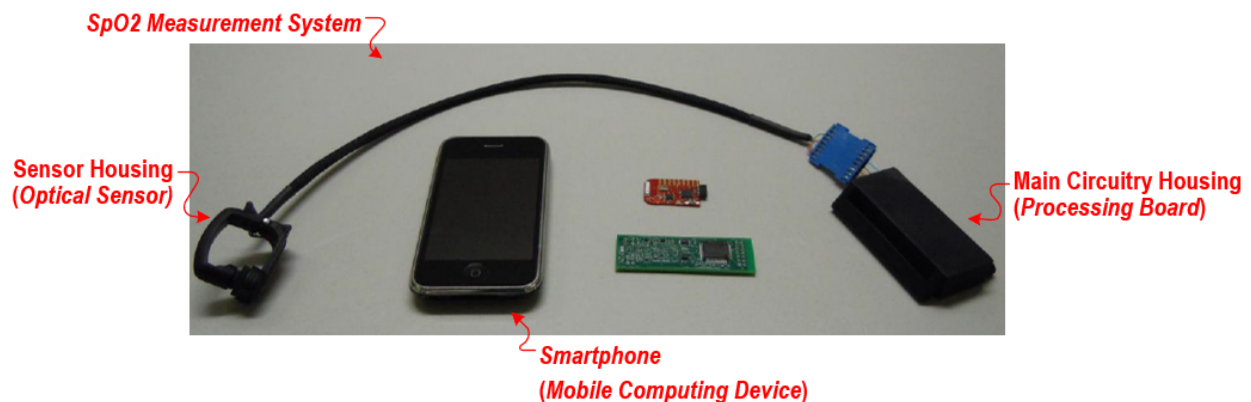
[13a] outputting, from an optical sensor of an SpO₂ measurement system, one or more signals responsive to light from a light source attenuated by tissue of the user at a measurement site, said one or more signals responsive to an oxygen saturation of said tissue; and

46. Referring to Figures 7 and 11 (below), Bailey’s device “measures blood oxygen saturation,” thereby teaching a ***SpO₂ measurement system***. APPLE-1004, 22. In particular, as illustrated in Figure 7, Bailey’s device includes “the

LED driver control, analog signal processing, and digital signal processing systems.” APPLE-1004, 22, Figures 7 and 11. In an example implementation discussed in Bailey, components (e.g., LEDs) of the “LED driver control system” and components (e.g., photodiode and transimpedance amplifier) of the “analog signal processing system” are contained in the sensor housing, as illustrated in Figure 7, thereby implementing an *optical sensor*. APPLE-1004, 23-24.

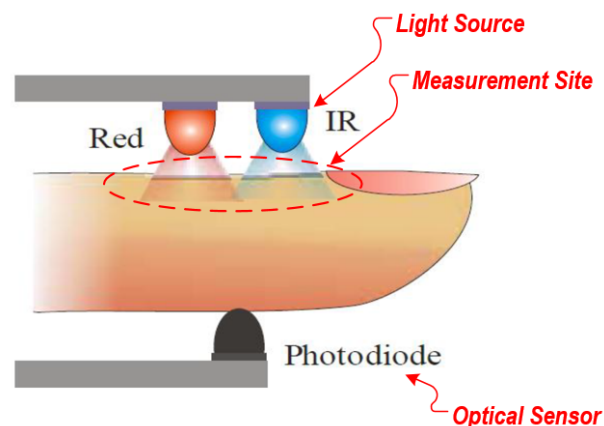


APPLE-1004, Figure 7 (annotated).



APPLE-1004, Figure 11.

47. Bailey's system (*SpO₂ measurement system*) employs the well-known basic elements of "[t]ypical pulse oximeters" that "utilize two light emitting diodes (LEDs), one red and one infrared, to measure relative levels of HbO₂ and Hb as blood is pumped through the body." APPLE-1004, 10, Figure 1 (below). "The LEDs are positioned on one side of an extremity of the body, usually a finger, ear or toe, and a photodetector is placed on the opposite side, as in Figure 1," thereby serving a *light source* for the system. APPLE-1004, 9.



APPLE-1004, Figure 1.

48. Based on my review of the detailed descriptions of the operation of the embodiments presented by Bailey and my knowledge and experience in the field, the optical sensor as illustrated in Figures 1 and 7 above is configured to produce signals associated with light that is attenuated by tissue of the user at a measurement site, such as a finger in these illustrated examples.

49. Specifically, Bailey describes that “[i]n operation the LEDs are pulsed alternately, with one off while the other is on, allowing the photodetector to measure the transmitted light intensity at each wavelength separately. The transmitted light intensity differs greatly at each wavelength and can be attributed to the attenuation as it travels through the body, which results from a combination of reflection, scattering, and absorption by tissue and bone, venous blood, and arterial blood in the region. These values *[signals]* are then also related to the absorption of light by the oxyhemoglobin and deoxyhemoglobin molecules.” APPLE-1004, 11, 27-28.

50. As noted above, Bailey’s “LED driver control” and “analog signal processing” systems are at least partially contained in the sensor housing (*optical sensor*). APPLE-1004, 23-24. LEDs in the LED driver control system “produce[s] a consistent and accurate light output,” and “[t]he photodiode senses the optical power (light) present on the other side of the sample (the ear in this case) and proportionally produces a current. This *signal*, in the form of an electrical current, is then sent to the transimpedance amplifier where it is converted into a voltage and amplified.” APPLE-1004, 23. Further, the “amplified *signal* is sent to the microcontroller where the signal data is processed and then sent to the wireless transmitter.” APPLE-1004, 23.

51. As such, Bailey’s sensor housing (*optical sensor*) outputs *signals*, including the signal produced by the photodiode and the signal amplified by the transimpedance amplifier, which are responsive to light that is produced by the LED driver control system and the LEDs (*light source*) and *attenuated by tissue of the user at a measurement site* as the light travels through the user’s body.

APPLE-1004, 9-11, 23-24, 27-28. Further, as noted above, the above signals are *responsive to an oxygen saturation of the tissue*. APPLE-1004, 9-11, 23-24, 27-28.

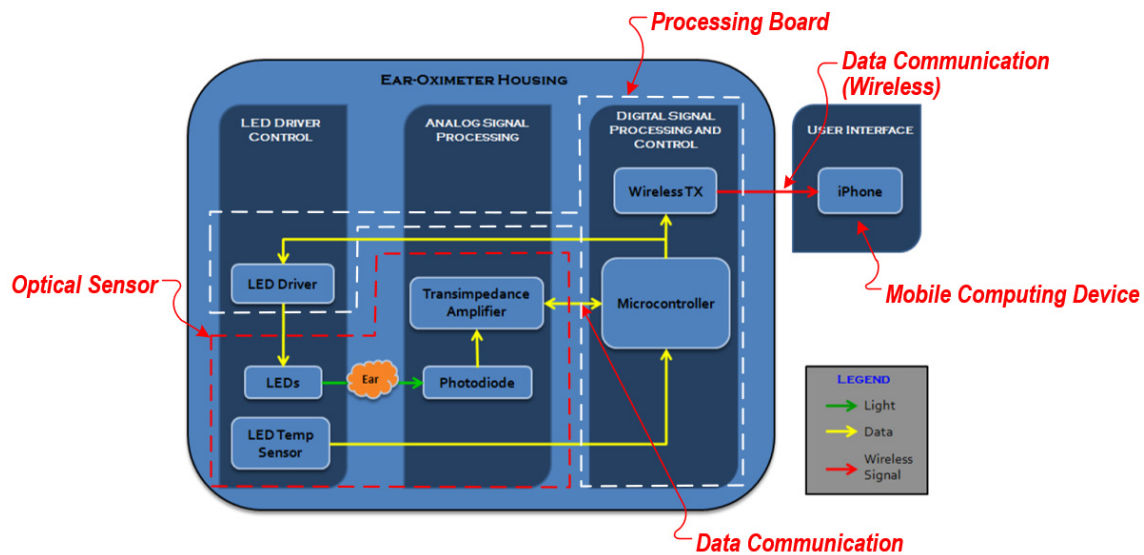
[13b] via a processing board of the SpO2 measurement system, the processing board in data communication with the optical sensor and a mobile computing device including a display:

52. Again, Bailey’s pulse oximeter includes “three main systems: the LED driver control, analog signal processing, and digital signal processing systems.” APPLE-1004, 22. Based on my review of the record, Bailey’s “digital signal processing system” (or “digital signal processing and control” in Figure 7), either itself or with other components as implemented in the main circuitry housing (APPLE-1004 at 24, Figure 11), corresponds to the *processing board* in [13b].

53. As illustrated in Figure 7 below, the “digital signal processing system” (as implemented in the main circuitry housing) (*processing board*) is *in data communication with* the components of the “LED driver control” and “analog signal processing” systems (as implemented in the sensor housing)

(*optical sensor*, see [13a] above) through a cable shown in Figure 11 below.

APPLE-1004, 24. Further, the digital signal processing system (as implemented in the main circuitry housing) (*processing board*) is *in data communication with* a smartphone (e.g., iPhone in Figure 7) (*mobile computing device*) through a wireless connection. APPLE-1004, 24.



APPLE-1004, Figure 7 (annotated).



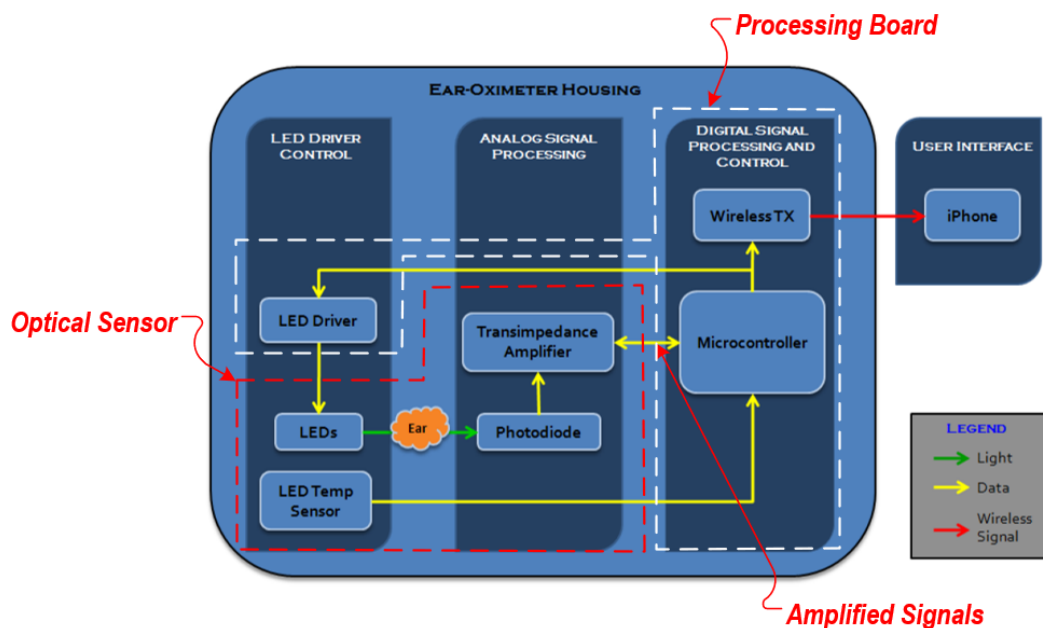
APPLE-1004, Figure 11.

54. Further, as shown in Figure 11 above, Bailey’s smartphone (e.g., iPhone) includes a *display*. APPLE-1004, 48, Figure 32.

55. Based on my review, claim 13 does not require the “processing board” to be separate from the “optical sensor” or “mobile computing device.” However, if the processing board were to be a component physically separate from the optical sensor and the mobile computing device, Bailey’s main circuitry housing, which corresponds to the *processing board*, is separate from the sensor housing (*optical sensor*). APPLE-1004, 23-24, Figure 11. As diagrammatically illustrated in Figure 7, Bailey’s “pulse oximeter housing” is “divided into two main parts: the main circuitry housing and the sensor housing. The main housing contained the LED driver circuit, temperature sensor, microcontroller circuit, antenna, and battery, while the sensor housing contained the LEDs, photodiode, and signal amplifier circuit.” APPLE-1004, 24, Figure 7 (above). In Figure 11, Bailey shows that the sensor housing (*optical sensor*) is separate from, but connected via a cable to, the main housing (*processing board*), and the main housing is separate from, and in wireless communication with, the smartphone (Figure 7). Therefore, a POSITA would have understood and found obvious that Bailey’s “main circuitry housing” would correspond the *processing board*, separate from Bailey’s “sensor housing” and the mobile device.

[13c] receiving said one or more signals from the optical sensor;

56. Referring to Figure 7, Bailey’s “digital signal processing system” (*processing board*) includes a “microcontroller” that receives “amplified *signal*” from the “analog signal processing system” contained in the sensor housing (*optical sensor*). APPLE-1004, 23. Therefore, it would have been apparent and obvious that Bailey’s digital signal processing system (*processing board*) receives the signals that are output from the sensor housing (*optical sensor*), as discussed above with respect to [13a].

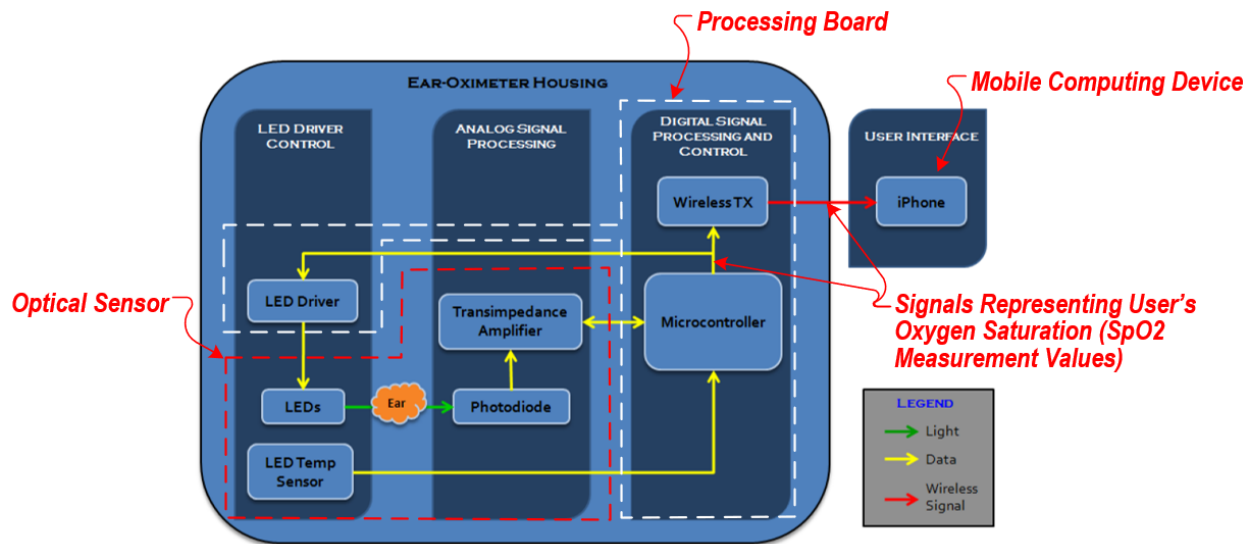


APPLE-1004, Figure 7 (annotated).

[13d] processing said one or more signals to generate the SpO2 measurement values; and

57. Referring to Figure 7, Bailey describes that “[t]he amplified signal is sent to the microcontroller where the signal data is processed and then sent to the

wireless transmitter.” APPLE-1004, 23. This “amplified, processed” signals are “mathematically related to the actual oxygen saturation of the user.” APPLE-1004, 22. As such, Bailey’s digital signal processing system (*processing board*), which includes the microcontroller, *processes the signals*, which was output from the sensor housing (*optical sensor*, see [13a] above), such that the processed signals represent the actual oxygen saturation of the user (*generate the SpO2 measurement values*).



APPLE-1004, Figure 7 (annotated).

[13e] outputting the SpO2 measurement values to the mobile computing device; and

58. Referring to Figure 7 above, Bailey’s digital signal processing system (*processing board*) includes the wireless transmitter that “communicates with the application on the iPhone to send and display the data [*SpO2 measurement values* shown in [13d]] on the user interface.” APPLE-1004, 23, 22 (“Afterward, the

device would transmit the oxygen saturation as well as the pulsatile signal to an iPhone or iPod Touch and be displayed on a user interface that would allow the data to be monitored and stored.”).

[13f] via an application configured to execute commands on the mobile computing device:

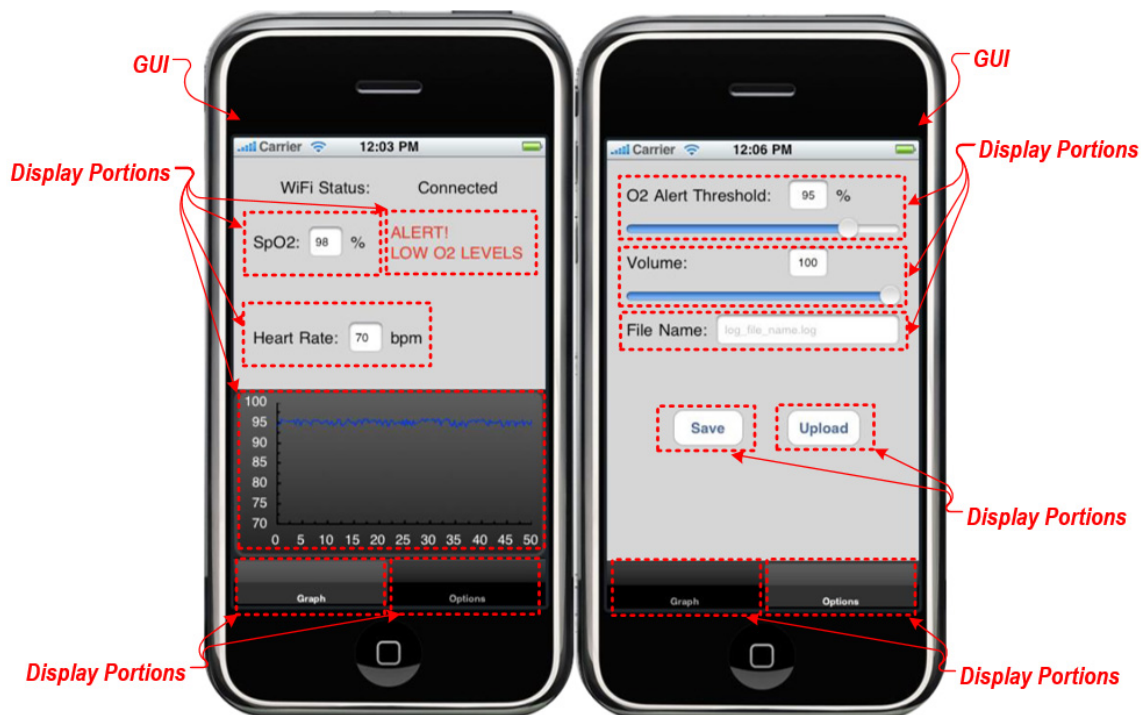
59. Bailey describes that the mobile device (e.g., iPhone) runs an ***application***. APPLE-1004, 23 (“The transmitter wirelessly communicates with the application on the iPhone to send and display the data on the user interface.”), 47 (“TI also had a separate requirement that the user interface be implemented for an iPhone. This was attainable because Apple makes a software development kit (SDK) available for the public to develop software for the iPhone OS.”).

60. Further, it would have been apparent and obvious that an application running on a mobile device like Bailey’s iPhone is configured to ***execute commands*** to perform various functions at the mobile device, including the display functions and other operations described in the ’507 patent. *See, e.g.*, APPLE-1023, Abstract (“The user device generates, based on the user query, commands to be executed by each of the potential applications.”); APPLE-1024, 7:49-53 (“For example, during execution of application such as a game application numerous graphics related commands are executed in order to perform various graphics related tasks including the rendering of images on a display.”). For example, Bailey’s iPhone executes a program for operating the user interface to “manage[]

the WiFi connection, listens for data, verifies the data, updates the GUI, and manages the alert sound.” APPLE-1004, 49, Figure 33. With these teachings, a POSITA would have understood and found obvious that the code running at the iPhone includes a series of commands consistent with the elements of the program flow shown in Bailey’s Figure 33.

[13g] generating a graphical user interface having a plurality of display portions;

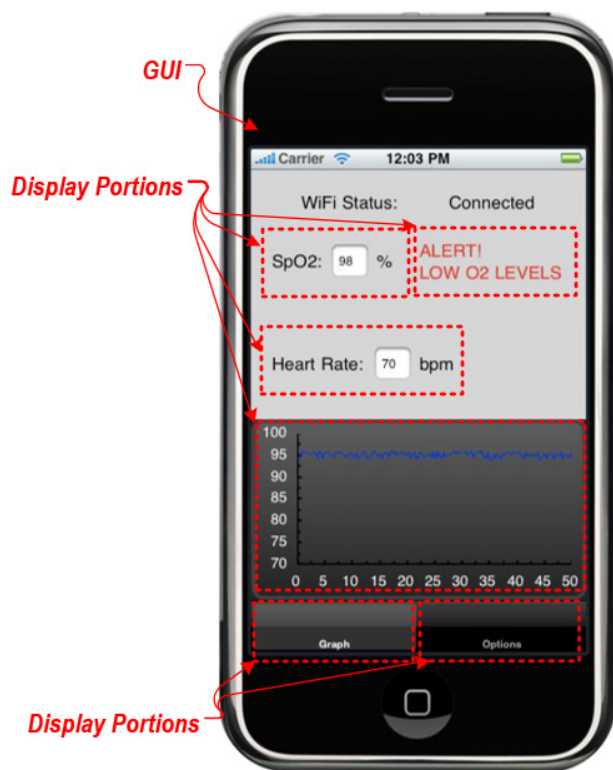
61. Bailey describes that “the user interface [is] implemented for an iPhone” to “display the recorded data from the microcontroller via wireless interface.” APPLE-1004, 47 (“an LCD to display the GUI”). Further, Bailey’s GUI (*graphical user interface*) has *a plurality of display portions*, as illustrated in Figure 32 below. APPLE-1004, Figures 32-33.



APPLE-1004, Figure 32 (annotated).

[13h] displaying, in at least one portion of the plurality of display portions, a representation of a physiological parameter of a plurality of physiological parameters comprising at least the SpO2 measurement values;

62. As shown in Figure 32 below, Bailey's mobile device displays at least a SpO2 value and a heart rate (***a plurality of physiological parameters comprising at least the SpO2 measurement values***). APPLE-1004, Figure 32. Further, the display of Bailey's mobile device have different ***display portions*** used for displaying different pieces of information. As illustrated in Figure 32, the SpO2 and the heart rate are displayed in respective ***display portions***. In the illustrated example, Bailey's SpO2 is represented as a numerical value (%) as well as a graph (***a representation of a physiological parameter***). Similarly, Bailey's heart rate is indicated as a numerical value.

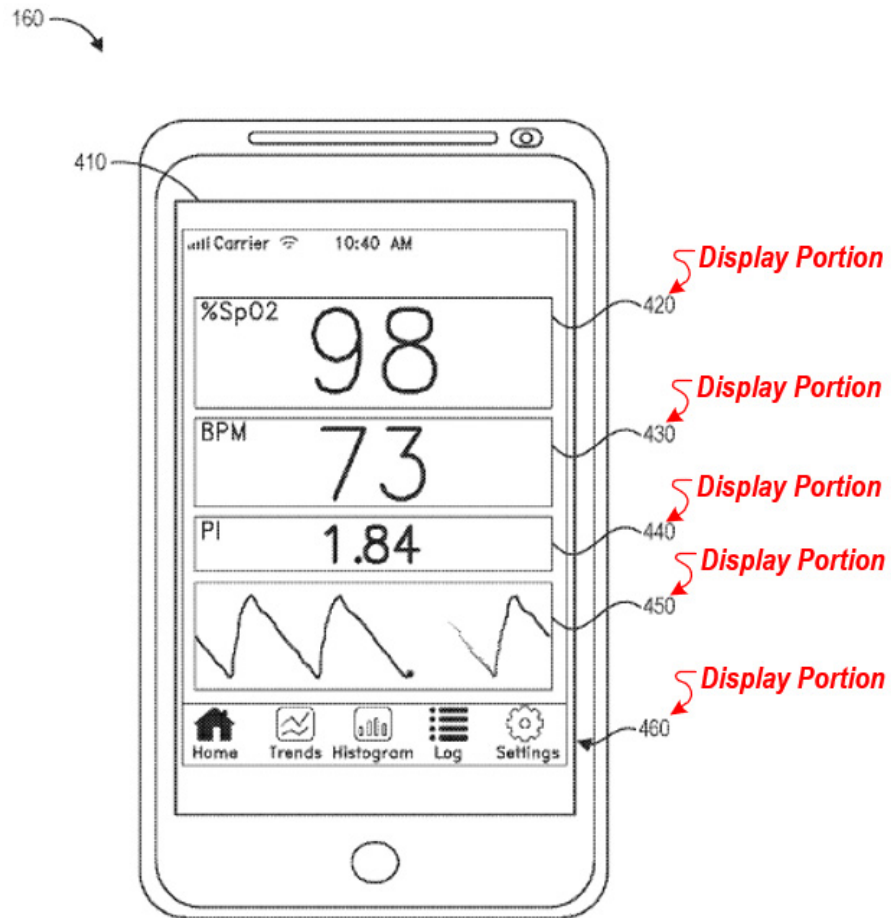


APPLE-1004, Figure 32 (partial) (annotated).

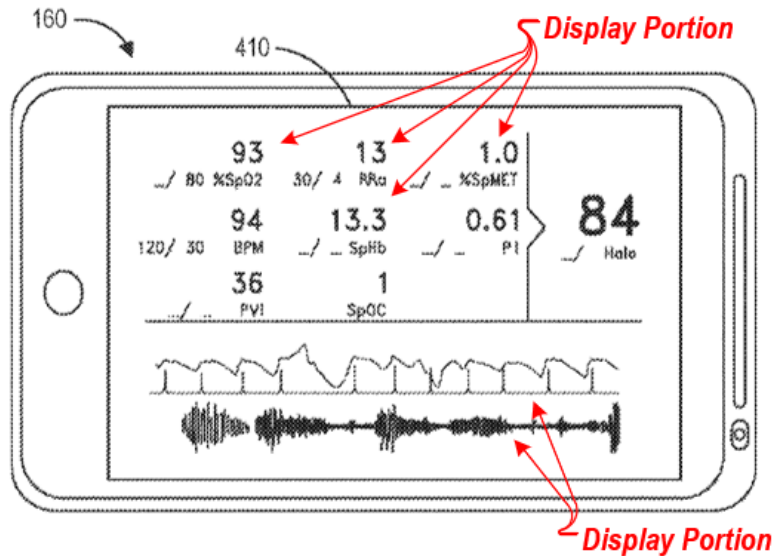
63. Bailey’s teaching of display portions are consistent with the ’507 patent’s disclosure. For example, the ’507 patent describes that “[t]he application can include a plurality of display portions in which a plurality of physiological parameters can be displayed, such as SpO2 display 420, heart rate display 430, perfusion index display 450, or plethysmographic waveform display 450.”

APPLE-1001, 13:26-31, 13:44-46, Figure 4A. The ’507 patent further describes “[t]he configuration of these various display portions is meant for illustrative purposes, and one skilled in the art would appreciate that the parameter displays could be rearranged relative to one another, displayed alone, or the user interface could be modified to include other parameter display portions.” APPLE-1001,

13:33-38. The '507 patent describes “[a]nother example of a variety of display portions” in Figure 4B. APPLE-1001, 13:38-43.



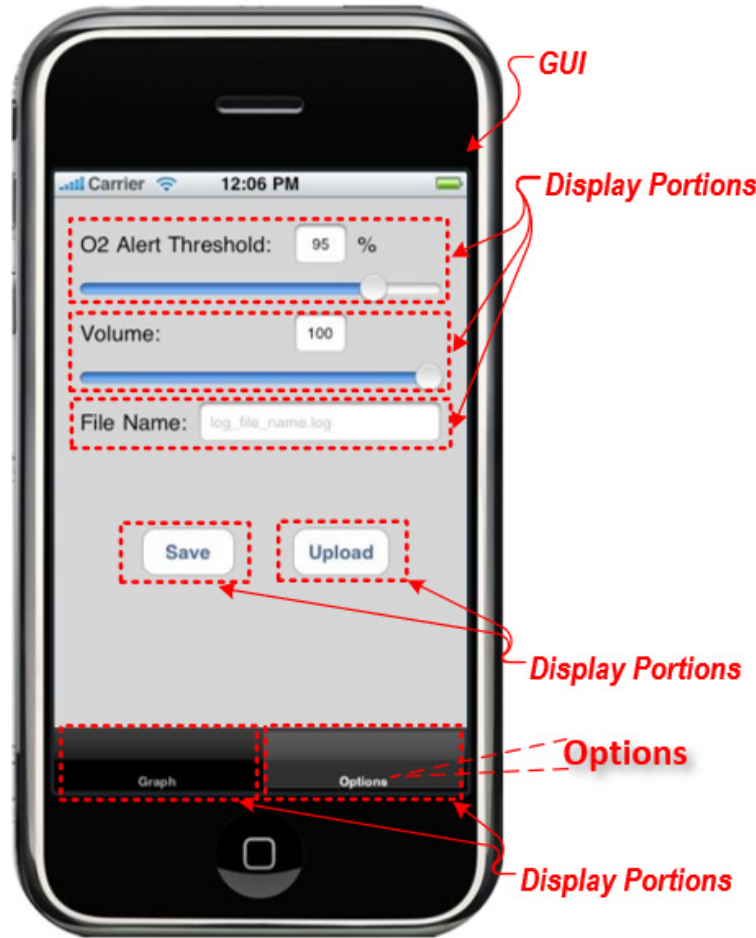
APPLE-1001, Figure 4A (annotated).



APPLE-1001, Figure 4B (annotated).

[13i] displaying, in a different portion of the plurality of portions, a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application.

64. As shown in Figure 32 below, Bailey's mobile device display a user-selectable "Options" menu where the user can select several options or control elements including "O2 Alert Threshold," "Volume," and "File Name" (***a plurality of user inputs***), which are displayed in respective ***display portions***. APPLE-1004, Figure 32.



APPLES-1004, Figure 32 (annotated).

65. It would have been understood and obvious that these options or control elements (*user inputs*) are *configured to allow the user to interact with the display portions or the application*. For example, in the illustrated example of Figure 32, the “O2 Alert Threshold” display portion includes a slider (or marker, scale bar, etc.) that a user can manipulate, or a text box to which the user can enter a value, to set the alert threshold. Through this user interaction with the display, the user is able to determine the threshold O2 level will trigger an alert of low O2 levels. APPLE-1004, Figure 32. Such user manipulation and entry of a value

allow the user to interact with the display portion or the application that displays the display portion and receives and processes the entered value.

66. Similarly, in the above example, the “Volume” display portion includes a slider (or marker, scale bar, etc.) that a user can manipulate, or a text box to which the user can enter a value, to control the sound level associated with an alert or other events, thereby allowing the user to interact with the application. Moreover, the display includes display portions that contain “Save” and “Upload” buttons, by which the user can interact with the application to save or upload the information provided by the user. APPLE-1004, Figure 32.

(ii) Claim 14

[14pre] The computer-implemented method of claim 13, further comprising, via the application:

67. As discussed above with respect to [13f], Bailey describes the ***application*** running on the mobile computing device.

[14a] performing a trend analysis on received SpO2 measurement values; and

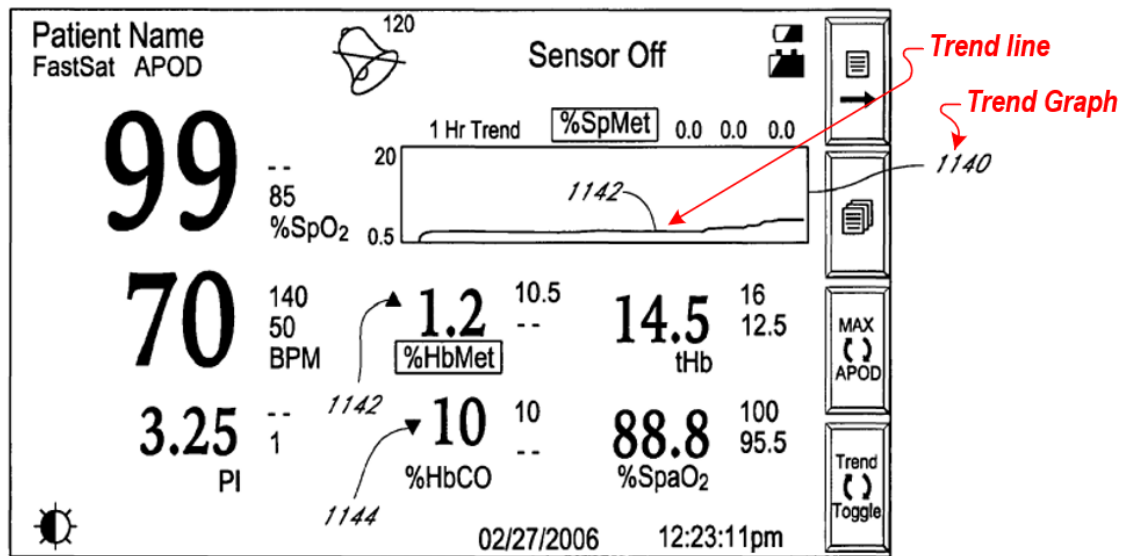
68. Bailey’s mobile device is configured to perform a trend analysis on the SpO2 measurement values received from the digital signal processing system (***processing board***, see [13c] above). In particular, Bailey’s system includes “a means to record and store data” to “monitor trends in the blood oxygen saturation of the user.” APPLE-1004, 14. Bailey’s mobile device is configured to receive “continuous oxygen saturation data” collected over a certain period of time, and

store the data in a format that is “accessible and readable using common software.” APPLE-1004, 14 (“[a] metric of one week’s worth of continuous oxygen saturation data” or “over long period of time”), 55, Table 7 (“Data Logging – ability to continuously monitor data for specified time period”). For example, Bailey’s mobile device can “output a file that was easily accessible and readable using common software, such as Microsoft Excel, so that both the user and medical personnel alike could easily read and analyze the recorded blood oxygen levels over long periods of time.” APPLE-1004, 14. With these teachings, a POSITA would have understood and found obvious that a record of the blood oxygen levels over a long period of time would provide the data to look for trends in the blood oxygen measurement values. With access to a record of the blood oxygen levels over a long period of time, the process of performing a trend analysis by the application running on Bailey’s mobile device would have been straightforward and obvious to a POSITA. For example, it would have been obvious to modify Bailey’s mobile device (or the application thereof) to display the data with a graph of measured blood oxygen level as a function of time for known benefits, such as allowing a user to look at the data and visualize the trend. Alternatively, a POSITA would have found it obvious to implement code (or the application) on the mobile device to execute known data analysis methods (e.g., simple least-square fitting) on the data to look for increasing or decreasing trends.

69. Through these teachings, a POSITA would have understood and found obvious that Bailey's mobile device *performs a trend analysis on received SpO2 measurement values* by receiving and storing the oxygen saturation data over a course of days and compile the data into the "file" for output to the user, as taught by Bailey. APPLE-1004, 14.

70. In fact, it was well-known to provide a display of the record of the data over a period of time at a mobile device, enabling a user to visualize the trend of oxygen saturation values or other physiological parameters, as evidenced in several references before the Critical Date. For example, Al-Ali describes displaying "parameter trend data" using color coding. APPLE-1018, 3:39-53 ("parameter trend data may also be displayed using the same or similar color coding, especially when multiple trends are displayed on one or more display graphs."), 5:38-55 ("a parameter display may switch to a trend graph in the same or different color, line weight, flash, flash rate, intensity, size, or the like."), 6:49-54 ("When connected to the computing device, the processing board 104 may upload various stored data for, for example, off-line analysis and diagnosis. The stored data may comprise trend data for any one or more of the measured parameter data, plethysmograph waveform data acoustic sound waveform, or the like."), 11:18-23 ("Additionally, the monitor 200 may be capable of storing and outputting historical parameter data, display trend traces or data, or the like."),

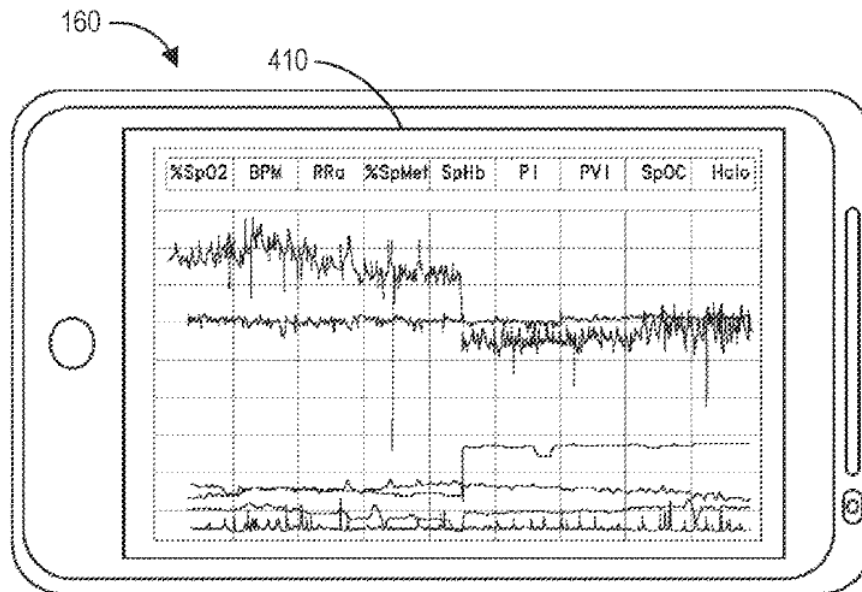
14:1-10 (“the monitor 200 may include output functionality that outputs, for example, trend perfusion data, such that a caregiver can monitor measured values of perfusion over time. Alternatively or additionally, the monitor 200 may display historical trace data on an appropriate display indicating the measured values of perfusion over time.”), 17:29-19:51, Figures 11A-11H.



APPLE-1018, Figure 11C.

71. Further, as described in Lynn, it was well-known to provide information extracted from such data, such as the maximum and minimum values of the oxygen saturation, as well as information about the rate of change in the oxygen saturation during portions of the record. APPLE-1019, 1:36-41, 2:18-42, 4:43-49, 6:8-34, 8:30-50, 11:35-40, 12:22-26, 12:53-58, 15:1-16:20, 21:21-27, 23:7-15, 29:65-30:38, 45:14-34, 56:3-38, 61:27-60, 65:55-63, 69:55-67, 70:29-39, 72:10-19, 72:48-54, 79:10-24, 82:19-33, 84:27-85:35, 86:47-87:25.

72. Bailey's above teachings aligns the '507 patent's disclosure of "trend analysis." The '507 patent describes a "trend analysis" as one of several application functions, stating that this function allows users "to manipulate the data to visualize trends in the data." APPLE-1001, 5:25-35, 5:50-52. The '507 specifies that "the user can choose to view trends in the data, as illustrated in FIG. 4C." APPLE-1001, 13:44-56.



APPLE-1001, Figure 4C.

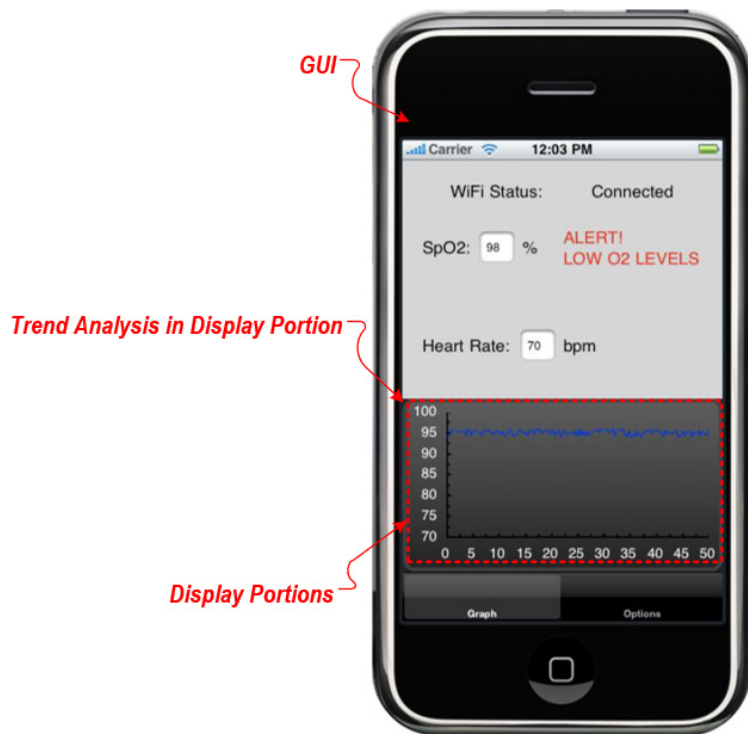
73. The '507 patent includes additional descriptions of allowing a user to zoom in and out on the graph view of the physiological parameters and printing the trend information. APPLE-1001, 13:54-63. There are no other descriptions in the '507 patent specification of viewing trends or of "trend analysis." Based on these descriptions in the '507 patent specification, a POSITA would have

recognized that displaying a graph of SpO₂ information collected and plotted over time in one of the display portions satisfies this element.

[14b] displaying results of the trend analysis in at least one portion of the plurality of display portions.

74. Referring to Figure 7 below, Bailey's mobile device displays a graph of SpO₂ values over time in a portion of the GUI display. APPLE-1004, 48.

Through this and above teachings, a POSITA would have understood and found obvious that Bailey's mobile device displays the ***results of the trend analysis*** in one of the ***display portions***.



APPLE-1004, Figure 32 (partial).

(iii) Claim 15

[15] The computer-implemented method of claim 13, further comprising, via the application, outputting one or more alarms associated with SpO2 measurement values that are above or below threshold SpO2 measurement values.

75. As discussed above with respect to [13g], Bailey's mobile device generates the user interface, via the ***application*** running on the mobile device, and implements "an alarm in the event that the blood oxygen level of the user fell below a safe level." APPLE-1004, 14, 47, 62. For example, Bailey's mobile device can "sound an alarm when a low oxygen level [***threshold SpO2 measurement values***] was reached." APPLE-1004, 47. Further, Bailey's mobile device can output the alarm on the display, as shown in Figure 32 below.

Additionally, Bailey's mobile device provides an option for a user to set up the "O2 Alert Threshold," as shown in Figure 32. Therefore, Bailey describes or renders obvious ***outputting, via the application, an alarm associated with SpO2 measurement values that are above or below threshold SpO2 measurement values.***



APPLE-1004, Figure 32.

(iv) Claim 19

[19] The computer-implemented [method of] claim 13, further comprising wirelessly transmitting the SpO2 measurement values from the SpO2 measurement system to the mobile computing device.

76. As discussed above in [13b], Bailey’s *SpO2 measuring system* includes the digital signal processing system (*processing board*), which is in data communication with the mobile device, such as iPhone (*mobile computing device*), via the wireless transmitter. APPLE-1004, 22, Figure 7. Further, as discussed above in [13e], Bailey’s digital signal processing system (*processing board*) “communicates with the application on the iPhone to send and display the data [*SpO2 measurement values* shown in [13d]] on the user interface.” APPLE-1004, 23. Therefore, Bailey discloses or render obvious *wirelessly transmitting*

the SpO2 measurement values from its *SpO2 measurement system to the mobile computing device*. Again, it is worth noting that the work presented in Bailey is the work of a team of undergraduate students that do not meet the standard of a POSITA for this declaration, and yet this team fully anticipates all elements of these claims of the '507 patent more than 2 years before the filing of the '507 patent.

B. [GROUND 1B] – CLAIMS 16, 18, AND 20 ARE OBVIOUS OVER BAILEY AND TRAN

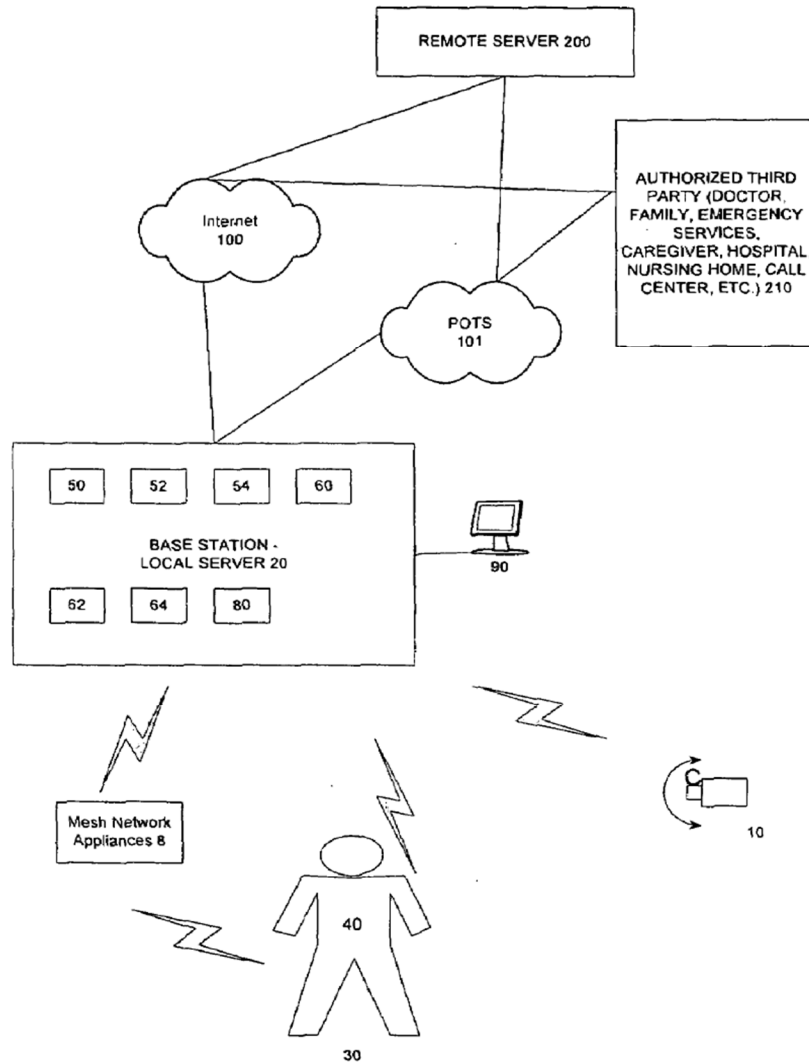
77. The sections below provide a brief introduction to Tran and its combination with Bailey.

1. Tran describes a physiological sensing system that outputs alerts allows users to set reminders

78. Tran describes a “patient monitoring system.” APPLE-1005, [0054]. The system can include multiple physiological sensors, including “a blood pressure monitor, heart rate monitor, weight scale, thermometer, spirometer, single or multiple lead electrocardiograph (ECG), a pulse oxymeter, a body fat monitor, a cholesterol monitor, a signal from a medicine cabinet, a signal from a drug container, a signal from a commonly used appliance such as a refrigerator/stove/oven/washer, or a signal from an exercise machine, such as a heart rate.” APPLE-1005, [0054]. For example, the system can include “a blood oxygen saturation monitor, using an infra-red or laser source, to alert the user if the

patient's blood in the brain or some brain region is deoxygenated.” APPLE-1005, [0335], [0057] (describing detecting “blood-oxygen levels and pulse rate.”).

79. Figure 1A shows an example system for monitoring physiological parameters of a user via body worn sensors.



APPLE-1005, Figure 1A.

80. Tran describes allowing users to “set up alerts or reminders that are triggered when one or more reading meet a certain set of conditions, depending on

parameters defined by the user.” APPLE-1005, [0255]. When the system determines that a physiological parameter (such as blood oxygen level) exceeds a predetermined value, the system can issue an alert to a caregiver. APPLE-1005, [0260]. A user can designate authorized individuals, such as clinicians or caregivers, to receive alerts and set reminders and alerts. APPLE-1005, [0257], [0261].

81. Interestingly, in Fig. 6A and 6B, Tran shows an example of a wristwatch-based device and a wireless mesh network that would work with the wristwatch to capture signals from the sensor module and transmit information to the internet, including to third parties, which could include hospitals, caregivers and others. APPLE-1005, [0280]-[0307], [0367]-[0399].

2. The combination of Bailey and Tran

82. There are multiple reasons that would have prompted a POSITA to apply the detailed implementation examples provided in the teachings of Tran to the physiological monitoring system of Bailey. Furthermore, a POSITA would have recognized several particular teachings of Tran that would have been beneficially applied to Bailey to improve the resulting system. A first teaching of Tran that a POSITA would have been compelled to apply to Bailey’s physiological monitoring system would have been Tran’s teaching to issue reminders to the user (or a caregiver) to take SpO₂ measurements. A POSITA also would have been

compelled to modify Bailey based on the teachings of Tran to allow the user to set such reminders to take future measurements. A POSITA also would have predictably applied the teachings of Tran to Bailey to beneficially output an alert via a network to a designated physician or other care provider in response to abnormal SpO₂ readings.

83. A first reason that would have compelled a POSITA to apply Tran to Bailey is that implementing Bailey's physiological monitoring system to output reminders, including reminders to take SpO₂ measurements, would have led to a system that better ensures that the user's SpO₂ levels are being monitored at regular intervals so that SpO₂ values outside of preset thresholds can be identified and appropriate action can be taken in response. Bailey is clear about the importance of issuing "an alarm in the event that the blood oxygen level of the user fell below a safe level." APPLE-1004, 14, 47, 52, 62. Taking such measurements is an integral part of Bailey's goal of "ensur[ing] that the wearer's ability to transport oxygen to the cells in his or her body has not been compromised." APPLE-1004, 9.

84. Tran teaches that "users may set up alerts or reminders" that occur according to a user specified "time duration in units such as hours, days, weeks or months." APPLE-1005, [0255]. Such reminders could be included in a "to do list" displayed to the user. APPLE-1005, [0418]. A POSITA would have recognized

that applying Tran’s teaching to set reminders in a physiological monitoring system to Bailey’s system, which stresses the importance of identifying when SpO₂ and heart rate readings are abnormal would have improved the overall system by ensuring that the user is checking physiological parameters, including SpO₂, at regular intervals such that problems can be readily identified and addressed. A POSITA would have recognized that applying Tran to Bailey in this manner would have been particularly beneficial in the use cases of Bailey in which the user is monitoring their own vital signs rather than the vital signs being monitored by a remote care giver.

85. As a second reason, a POSITA would have been prompted to apply the teachings of Tran to Bailey’s oximeter system to further conserve power in the monitoring system. That is, a POSITA would have recognized that configuring Bailey’s oximeter system to issue reminders to periodically check physiological parameters, including SpO₂ and heart rate, would have provided a configuration in which the user did not need to continually monitor such parameters, in at least some scenarios. Bailey is clear that one of the main objectives of the system is to ensure that the oximeter operates on battery power for an extended period of time (e.g., “for at least 12 hours”). APPLE-1004, 15 (“low power consumption”), 21 (“Power Consumption” in Table 2), 28 (“in an attempt to reduce the overall power consumption of the device”). That is, Bailey considers reducing power

consumption to extend battery life as a “functional requirement” for oximeters and selects “the electronic design and components” “to result in low power consumption in order to meet the requirement.” APPLE-1004, 15 (“the oximeter needed to operate solely on battery power for at least 12 hours”). Configuring Bailey’s system, based on the teachings of Tran, to allow for an operation mode in which the system issues reminders to periodically check physiological parameters, including SpO₂ and heart rate, rather than continuously monitoring such parameters would have furthered these power saving goals of Bailey. Such a configuration would have allowed for options to continually monitor physiological parameters in other scenarios. A POSITA would have recognized that allowing for a configuration in which the system does not continually monitor SpO₂ levels in at least some scenarios while providing the user with reminders to make such measurements, as taught by Tran, would have increased the power savings and therefore extended battery longevity while ensuring that SpO₂ measurements are still collected at sufficient intervals, thus providing both a sufficient level of patient monitoring while also extending battery life.

86. As a third reason, a POSITA would have recognized that applying Tran’s teachings to Bailey’s pulse oximeter system to “set up alerts or reminders” according to “parameters defined by the user” would have beneficially improved the system by ensuring that the reminders to take future SpO₂ measurements are

provided to the user at proper intervals to ensure that any abnormal readings are properly captured and addressed. APPLE-1005, [0255]. As would have been recognized by a POSITA, implementing such user set parameters for measurement reminders in Bailey's system, as suggested by Tran, would have allowed for flexibility such that the user is reminded to take the physiological measurements at a time that is most convenient to them (such as when the user is awake, not likely to be engaged in another activity, not in the shower, etc.), to ensure proper compliance with taking such measurements and improve health outcomes. A POSITA also would have recognized that allowing greater control of when the reminders are issued would have increased overall usability of the system and user satisfaction.

87. As a fourth reason, a POSITA would have recognized that applying Tran's teachings to Bailey's physiological monitoring system to send alerts to a designated physician or other care provider in response to detection of an abnormal SpO₂ reading (or abnormal reading of another monitored physiological parameter) would have led to more attentive health care, quicker responses to potentially dangerous health conditions, and better overall health outcomes by quickly alerting one or more care providers to such abnormal readings. Bailey's overall disclosures stress the importance of allowing remote monitoring of vital signs (including SpO₂) by caregivers (like parents or medical providers) and the

importance of issuing alerts to “to warn of dangerously low oxygen conditions” of users. APPLE-1004, 8 (“the novelty of this project was mostly in the remote monitoring capability of the oxygen saturation data”; “remote monitoring of an infant’s oxygen levels during sleep to warn of dangerously low oxygen conditions that may be associated with Sudden Infant Death Syndrome (SIDS) or suffocation”), 14 (“One of the novel aspects of the remote pulse oximeter design was the implementation of an alarm in the event that the blood oxygen level of the user fell below a safe level.”).

88. Tran adds additional details to these disclosures of Bailey to facilitate remote monitoring and trigger alerts in response to abnormal vital sign readings, describing that issuing alerts in response to abnormal vital sign readings (including SpO₂) to remote care providers beneficially alerts the “remote healthcare provider[s]” to sudden changes in physiological parameters that can “indicate a problem” to allow such healthcare providers to quickly and accurately respond to the healthcare event, thus improving overall health outcomes for the user wearing the physiological monitor. APPLE-1005, [0028], [0129], [0260]. Tran teaches that the user or caretaker can beneficially “choose[] the condition that they would like to be alerted to and [provide] the parameters (e.g. threshold value for the reading) for alert generation.” APPLE-1005, [0255]. Applying this additional level of control for alerts to Bailey’s system would have allowed the user or healthcare

provider to ensure that they are only alerted to physiological parameter readings (including abnormal SpO₂) when such a reading is concerning for that particular patient. Such individual customization of the alert limits would have improved the overall functionality of the system by providing monitoring that is tailored to each user.

89. As a fifth reason, a POSITA would have recognized that applying Tran's teachings to Bailey's physiological monitoring system allowed for a wider variety of uses for the resulting system. Tran's very effective initial demonstration system provides an opportunity for a POSITA to appreciate the opportunity to leverage communication via the Internet to expand the features and customize operations of the Bailey system. A POSITA would appreciate that the addition of the features disclosed by Tran to the system disclosed by Bailey would require only straightforward modifications to software for interfacing with facilities and other users through the internet, and that the result of these modifications would provide the simple and clear additive benefit of these features from Tran to the system of Bailey. The result would have been a physiological parameter monitoring system (e.g., pulse oximeter system) with a wider range of utility, including for monitoring users who have recently been discharged from a hospital or other medical setting.

90. As a sixth reason, a POSITA would have been prompted to implement Bailey's oximeter system to output reminders to the user to take SpO₂ measurements, allow the user to set such reminders to take future measurements, and to output an alert via a network to a designated physician or other care provider in response to abnormal SpO₂ readings (as suggested by Tran) because doing so would be merely the application of a known technique to a known system (e.g., Bailey's oximeter system) ready for improvement to yield predictable results. Here, Tran provides straightforward evidence of known techniques for allowing a user to set alerts and reminders and for alerting remote care providers in the context of a physiological monitoring system, and Bailey's teaching provides a known system that would have been improved by application of Tran's suggested technique for at least the reasons described above.

91. Based upon my knowledge and experience in this field and my review of Bailey and Tran, I am confident a POSITA would have recognized that such a modification would have yielded predictable results, and these modifications would have been within the ordinary level of skill of a POSITA at the time of the '507 disclosure. In fact, between 2006 (the date of Tran) and 2011 (date before the disclosure of the '507 patent), there was rapid expansion of many example uses of wireless data and information transmission, and the use of networks and the internet to aggregate and share information. The use of wireless signal

transmission with handheld PDAs together with networks and the internet was well-within the capabilities of the undergraduate students that produced the Bailey reference in 2010. A POSITA would have been aware of the rapid growth in availability of miniature, lightweight, low-power and easy to use components that could be used to build a working system based on the disclosures of Tran and Bailey.

92. Thus, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying Tran's teachings to Bailey's system.

3. Application of Bailey and Tran to Claims 16, 18, and 20

(i) Claim 16

[16] The computer-implemented method of claim 13, further comprising, via the application, outputting one or more reminders to use the optical sensor to take measurements of SpO₂ measurement values at predetermined times or cycles.

93. As I discussed with respect to Ground 1A, above, Bailey discloses an oximeter system for monitoring physiological parameters including SpO₂ and heart rate. APPLE-1004, 15 ("The digital interface also includes the wireless transmitter that sends data to the user interface. The user interface is the means by which the user can monitor his heart rate and oxygen saturation levels."), 50-51, 61-62, 63 ("In terms of functionality, the oximeter was able to output the user's SpO₂ level, with an accuracy comparable with commercial-grade sensors, in addition to dynamically calculating and displaying the user's heart rate."). As such, Bailey's

mobile device (e.g., iPhone) runs the application ([13f]) configured to generate the user interface ([13g]) for outputting various pieces of information and menus for user interaction. Tran provides similar disclosure regarding monitoring physiological parameters, disclosing a “patient monitoring system” having multiple physiological sensors, including “a blood pressure monitor, heart rate monitor, weight scale, thermometer, spirometer, single or multiple lead electrocardiograph (ECG), a pulse oxymeter, a body fat monitor, a cholesterol monitor, a signal from a medicine cabinet, a signal from a drug container, a signal from a commonly used appliance such as a refrigerator/stove/oven/washer, or a signal from an exercise machine, such as a heart rate.” APPLE-1005, [0054]. Similar to Bailey, Tran discloses “a blood oxygen saturation monitor, using an infra-red or laser source, to alert the user if the patient’s blood in the brain or some brain region is deoxygenated.” APPLE-1005, [0335], [0057].

94. Tran additionally demonstrates that the combination of Bailey and Tran provides that the application outputs one or more reminders to use the optical sensor to take measurements of SpO2 measurement values at predetermined times or cycles. For example, in the predictable combination, according to Tran, “users may set up alerts or *reminders*” that occur at certain “interval[s]” which can be “a time duration in units such as hours, days, weeks or months” based on “parameters defined by the user.” APPLE-1005, [0255]. A POSITA would have understood

that such reminders would have been beneficially applied to “one or more reading[s]” including the SpO₂ and heart rate readings disclosed by both Bailey and Tran. APPLE-1005, [0255]. As I discussed above, a POSITA would have recognized that configuring Bailey’s system to issue reminders to periodically check physiological parameters, including SpO₂ and heart rate, would have provided a configuration in which the user did not need to continually monitor such parameters, in at least some scenarios, thereby providing additional power savings. A POSITA also would have been aware that in applying Tran’s teachings to include such reminders in Bailey’s system, it would have been obvious to implement the reminders to be output via the application and user interface. Bailey describes that the application for the user interface (GUI) “manages the WiFi connection, listens for data, verifies the data, updates the GUI, and manages the alert sound.” APPLE-1004, 48-49, 52. Further, Bailey describes that the implementation of the user interface is attainable using a publicly-available “software development kit (SDK). APPLE-1004, 47. Therefore, using Bailey’s application for the user interface and other available SDKs to implement and issue the reminders would have been the most straightforward way to implement Tran’s teachings in Bailey’s system. APPLE-1004, 47-48.

95. In addition to the reasons discussed above, a POSITA would have been further motivated and found it obvious to modify Bailey’s mobile device to

output reminders for ensuring consistent data collection so that users and caregivers can identify SpO₂ trends. APPLE-1005, [0023] (“Data measured several times each day provide a relatively comprehensive data set compared to that measured during medical appointments separated by several weeks or even months. This allows both the patient and medical professional to observe trends in the data, such as a gradual increase or decrease in blood pressure, which may indicate a medical condition.”). Regular SpO₂ measurements would allow users and caretakers to better manage users’ health. APPLE-1005, [0007] (“Advantages of the system may include one or more of the following. The system empowers people with the information they need to better manage their health and the health of their loved ones. The interoperability enables disparate industries to work together to combine their products and services through connectivity standards and provide millions of people with the tools they need to better manage their health and the health of their families. The system can perform chronic disease management, monitoring the health and healthcare needs of aging people and proactive health and fitness. The interoperable system can address the data storage requirements for health and wellness management, chronic disease management or patient recovery, medication management, and fitness and workout tracking.”). Further, the reminders at the Bailey-Tran mobile device would address the problems of users forgetting to take SpO₂ measurements as needed, thereby

providing “effective medical treatment.” APPLE-1012, 189 (“A significant barrier to effective medical treatment, however, is the patient’s failure to follow the recommendations of his or her physician or other healthcare provider.”).

Moreover, the reminders would improve users’ adhering to measurement schedules. APPLE-1013, 156-57 (“A systematic approach that could be instituted in improving medication adherence is as follows: . . . Use medication adherence improving aids. Provide medication calendars or schedules that specify the time to take medications, drug cards, medication charts or medicine related information sheets or specific packaging’s such as pill boxes, ‘unit-of-use’ packaging, and special containers indicating the time of dose. . . One of the major reasons that patients become non adherent is because they forget to take their medications.”).

(ii) Claim 18

[18] The computer-implemented method of claim 13, further comprising, via the application, outputting an alert, via a network to a designated physician or other care provider, regarding abnormal SpO2 readings.

96. As I discussed above, Bailey describes “remote monitoring of an infant’s oxygen levels during sleep to warn of dangerously low oxygen conditions that may be associated with Sudden Infant Death Syndrome (SIDS) or suffocation.” APPLE-1004, 8. Therefore, it would have been apparent and obvious that Bailey’s system is configured to output an alert to a parent or other care providers regarding abnormal SpO2 readings. APPLE-1004, 13-14, 47, 49,

52, 55, 62. Bailey’s mobile device also transmits SpO2 data wirelessly via a network, such as WiFi and Bluetooth. APPLE-1004, 47.

97. Tran provides additional details that demonstrate that the Bailey-Tran combination provides that the application outputs an alert, via a network to a designated physician or other care provider, regarding abnormal SpO2 readings. Tran provides that in the predictable combination, “users may *set up alerts* or reminders that are triggered when one or more *reading meet a certain set of conditions*, depending on parameters defined by the user” including when readings, such as blood oxygen level meet a “threshold value for the reading.” APPLE-1005, [0255], [0252], [0054], [0246], [0335], [0417]. Tran goes on to describe that “[t]he user chooses the destination where the alert may be sent.” APPLE-1005, [0255]. A POSITA would have understood that such alerts would have beneficially applied to “one or more reading[s]” including the SpO₂ and heart rate readings disclosed by both Bailey and Tran so that care givers could be promptly alerted to abnormal conditions. APPLE-1005, [0255]. This includes “alert[ing] caretakers to out-of-the-ordinary” readings to allow such caretakers to take proper action for the patient. APPLE-1005, [0129], [0252], [0260], [0320]. Tran teaches that “[t]he remote healthcare provider may receive alerts over the Internet” which a POSITA would have recognized as an example of a network. APPLE-1005, [0028], [0005], [0009]. A POSITA also would have been aware that

in applying Tran’s teachings to include such alerts in Bailey’s system, it would have been obvious to implement the reminders to be output via the application. Bailey describes that the implementation of the user interface can be achieved using a publicly-available “software development kit (SDK) and, therefore, using Bailey’s application for the user interface and other available SDKs to implement and issue the reminders would have been the most straightforward way to implement Tran’s teachings in Bailey’s system. APPLE-1004, 47-48.

98. In addition to the reasons discussed above, several known advantages would have further prompted a POSITA to modify Bailey’s mobile device to communicate with systems via a network that are accessible by physicians and caregivers and output an alert to them regarding abnormal SpO2 readings. For example, the alert mechanism in the Bailey-Tran system would allow patients, doctors and caretakers to monitor and manage health more easily. APPLE-1005, [0003], [0008] (“However, at present, each device is designed to stand alone as an island. It is difficult to bring together multiple devices into interoperable (inter-connected) systems to improve patient care and avoid unnecessary accidents. . . By enabling a network of readily connected health and medical devices, people with diabetes or other chronic diseases will be able to share vital sign information such as blood pressure and glucose level with their doctors. Adult children will be able to remotely watch over their aging parents and proactively help them manage

safely in their own homes.”). Further, the combined system would “alert clinicians to patterns or trends that give early warning of respiratory decompensation,” and help predict serious health events such as respiratory failure. APPLE-1015, 4.

(iii) Claim 20

[20] The computer-implemented method of claim 13, further comprising, via the application, enabling the user to set reminders to take future measurements.

99. Tran demonstrates that in the combination of Bailey with Tran, the user is enabled to use the application to set reminders to take future measurements. Tran describes that in the predictable combination, “***users may set*** up alerts or ***reminders***” that occur at certain “interval[s]” which can be “a time duration in units such as hours, days, weeks or months” based on “***parameters defined by the user.***” APPLE-1005, [0255]. Tran gives another example in which “[a]n authorized person could set the reminders and alerts parameters.” APPLE-1005, [0257]. The reminder can be part of a “to do list.” APPLE-1005, [0418]. A POSITA would have understood that such reminders would have beneficially applied to “one or more reading[s]” including the SpO₂ and heart rate readings disclosed by both Bailey and Tran and that such reminders to take readings are reminders to take future measurements. APPLE-1005, [0255]. A POSITA also would have been aware that in applying Tran’s teachings to include functionality to set reminders in Bailey’s system, it would have been obvious to implement this functionality to be part of the application. Bailey describes that the

implementation of the user interface can be achieved using a publicly-available “software development kit (SDK) and, therefore, using Bailey’s application for the user interface and other available SDKs to provide the functionality for setting reminders would have been the most straightforward way to implement Tran’s teachings in Bailey’s system. APPLE-1004, 47-48.

C. [GROUND 1C] – CLAIMS 14 AND 17 ARE OBVIOUS OVER BAILEY AND KIANL

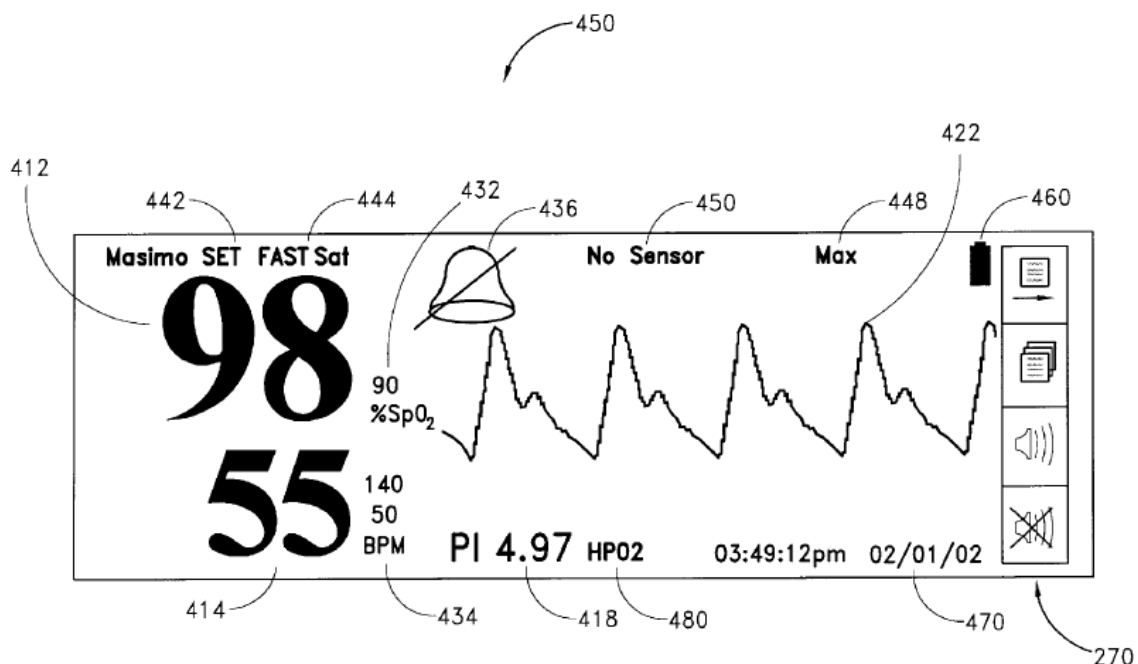
100. The sections below provide a brief introduction to Kianl and its combination with Bailey.

1. Kianl describes a physiological monitoring system that performs and displays a trend analysis and provides charts of SpO₂ measurements

101. Kianl describes a blood oxygen saturation measurement system that includes “[a] pulse oximetry user interface ha[ving] a display and a plurality of views each configured to occupy the display.” APPLE-1006, Abstract. Kianl describes the various views for displaying the pulse oximetry information, describing that “[o]ne of the views is a pleth view that presents a pulse waveform. ***Another one of the views is a trend view that presents a trend graph.*** At least one of the icons can be selected so as to switch the display between the pleth view and the trend view.” APPLE-1006, Abstract. Kianl describes that “[e]ach of the views are adapted to present data responsive to a physiological signal. A plurality of icons are configured to occupy a portion of the views and adapted to designate the

content of the views.” APPLE-1006, 2:18-23. Specifically, “[a]t least one of the icons can be selected so as to *switch the display between the pleth view and the trend view.*” APPLE-1006, 2:29-31.

102. Kianl provides many examples of display configurations that include a variety of arrangements of different combinations of numerical and graphical displays, which can be applied to other instruments. For example, FIG. 4 shows a user interface that includes a chart of SpO₂ readings, a numeric value for SpO₂, and input keys for switching between the views.

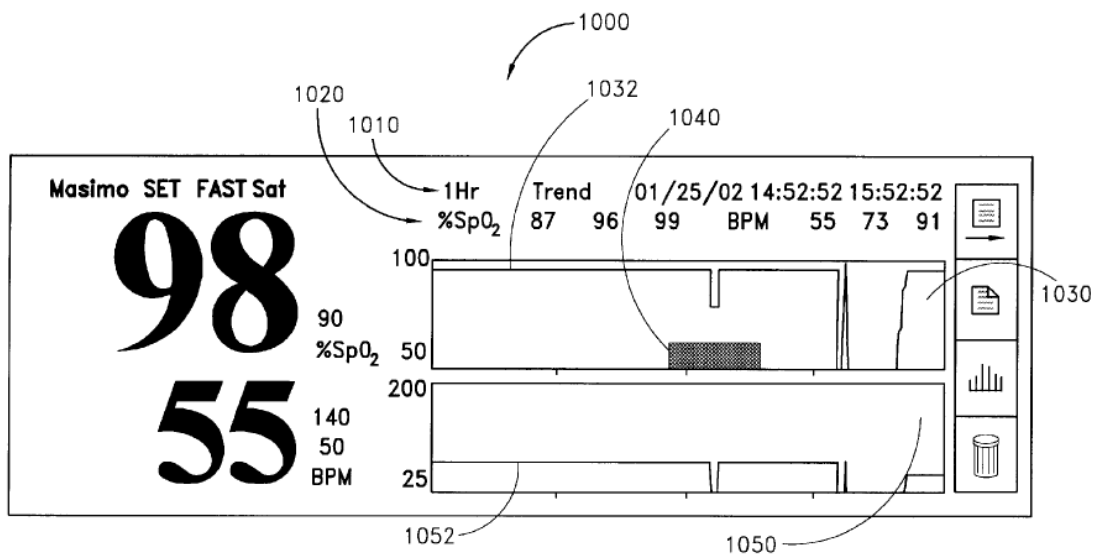


APPLE-1006, FIG. 4.

103. In describing FIG. 4, Kianl describes that “[t]he oxygen saturation 412 displays a functional arterial hemoglobin oxygen saturation measurement in units

of percentage SpO₂.” APPLE-1006, 6:1-3. The display also includes a “pulse waveform 422” of blood oxygen level. APPLE-1006, 6:10-15.

104. FIG. 10 shows another example display that includes “*a pulse rate trend graph 1050*” along with blood oxygen trend information over time. APPLE-1006, 11:6-49, 12:18-26.



APPLE-1006, FIG. 10.

105. Kianl further describes a trend setup menu with respect to FIG. 19 that allows the user to identify which trend analyses should be performed on the SpO₂ data. APPLE-1006, 15:10-56. As Kianl describes “FIG. 19 illustrates a *trend setup menu* 1900 having %SpO₂ max and min 1910, BPM max and min 1920, default view 1930, trend action 1940 and trend period 1950 items.” APPLE-1006, 15:10-56. Kianl describes that the trend analysis is customizable describing that “[t]he trend setup menu 1900 allows the user to set the default trend settings and to

clear the trend data or download the trend data to the serial port.” APPLE-1006, 15:10-56. Kianl also describes printing trend data and other data collected and generated by the system in various analog charts, including “printing” such information to various “trend views” of the system displayed on the user device, as shown, for example, in FIG. 10. APPLE-1006, 15:10-56.

2. The combination of Bailey and Kianl

106. There are multiple reasons that would have prompted a POSITA to apply the many examples provided by the teachings of Kianl to the oximeter system of Bailey. On it’s own, Bailey’s system includes “a means to record and store data” to “monitor trends in the blood oxygen saturation of the user.” APPLE-1004, 14. A POSITA would have predictably applied Kianl to Bailey to beneficially include specific functionality to conduct a trend analysis on received SpO₂ data (and other physiological measurements), to display the results of the trend analysis, and to display SpO₂ measurement values in a plurality of graphical representations including charts.

107. As a first reason, a POSITA would have recognized that “calculating a data trend” of measured SpO₂ data would have provided easier to digest information to healthcare providers to allow them to more easily identify abnormal patterns, conditions, and other health concerns based on the analyzed physiological data, such as blood oxygen saturation data. APPLE-1006, 2:32-41. This would

have beneficially led to easier identification of potentially dangerous health conditions thereby leading to quicker and/or better treatment in at least some scenarios, which would have led to improved health outcomes for patients.

108. As a second reason, a POSITA would have recognized that applying Kianl's teachings to Bailey's oximeter system to allow users (including the user being monitored, caregivers, and affiliated healthcare providers) to easily switch between various views for the physiological measurements, including SpO₂ measurements, such as trend analysis, real-time measurement values, and scrolling waveforms, would have provided the most complete information for healthcare providers and users to allow for consideration of all such relevant information when assessing the patient's condition. Such functionality would have allowed each user to view the physiological information in a preferred format, thereby increasing the overall usability of the resulting system.

109. As a third reason, a POSITA would have recognized that applying Kianl's teachings to Bailey's oximeter system to provide multiple different graphical representations of SpO₂ values would have allowed users to more easily mentally process such information, leading to quicker and more accurate responsiveness to potential health conditions indicated by such information. Providing additional options for viewing physiological measurement information would have improved overall usability of the resulting system.

110. As a fourth reason, a POSITA would have recognized that applying Kianl's teachings to Bailey's oximeter system to provide touchscreen user interface options for switching between the various views would have made the resulting system easy and intuitive to use. Notably, Bailey represents the work of a team of undergraduate students, and that the development of a GUI with well-formatted displays would have represented a predictable effort by the team. For example, Bailey's mobile device can "output a file that was easily accessible and readable using common software, such as Microsoft Excel, so that both the user and medical personnel alike could easily read and analyze the recorded blood oxygen levels over long periods of time." APPLE-1004, 14. Therefore, a POSITA would appreciate that developing a GUI with a graphical display of such data would be straightforward and provide the obvious benefit of providing this display to the user for visual analysis.

111. As a fifth reason, a POSITA would have been prompted to implement Bailey's oximeter system to conduct a trend analysis on received SpO₂ data (and other physiological measurements), to display the results of the trend analysis, and to display SpO₂ measurement values in a plurality of graphical representations including charts (as suggested by Kianl) because doing so would be merely the application of a known technique to a known system (e.g., Bailey's oximeter system) ready for improvement to yield predictable results. Here, Kianl provides

straightforward examples of known techniques for performing trend analyses on physiological measurement data, including SpO₂ measurement data and providing various different views for the information, including in chart form, and Bailey's teaching provides a known system that would have been improved by application of Kianl's suggested technique for at least the reasons described above.

112. Based upon my knowledge and experience in this field and my review of Bailey and Kianl, I am confident a POSITA would have recognized that such a modification would have yielded predictable results, and implementation of these modifications would have been within the ordinary level of skill of a POSITA. Thus, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying Kianl's teachings to Bailey's system.

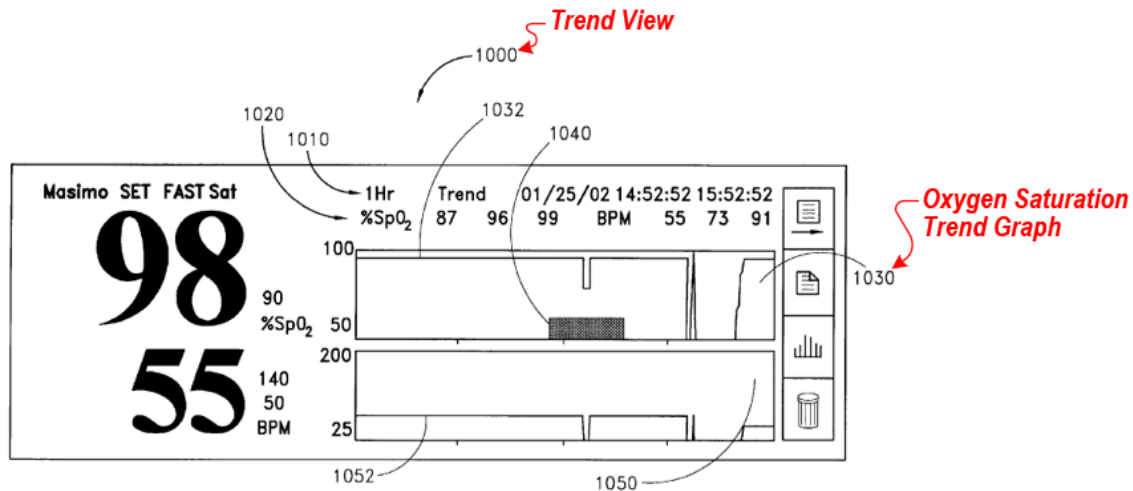
3. Application of Bailey and Kianl to Claims 14 and 17

(i) Claim 14

[14] The computer-implemented method of claim 13, further comprising, via the application: performing a trend analysis on received SpO₂ measurement values; and displaying results of the trend analysis in at least one portion of the plurality of display portions.

113. The combination of Bailey with Kianl provides an application that performs a trend analysis on received SpO₂ measurement values and displays results of the trend analysis in at least one portion of the plurality of display portions. Kianl describes a system that "calculat[es] a data trend responsive to the

physiological signal and provid[es] the pulse waveform in a first display view” as part of “a pulse oximetry user interface.” APPLE-1006, 2:32-36.

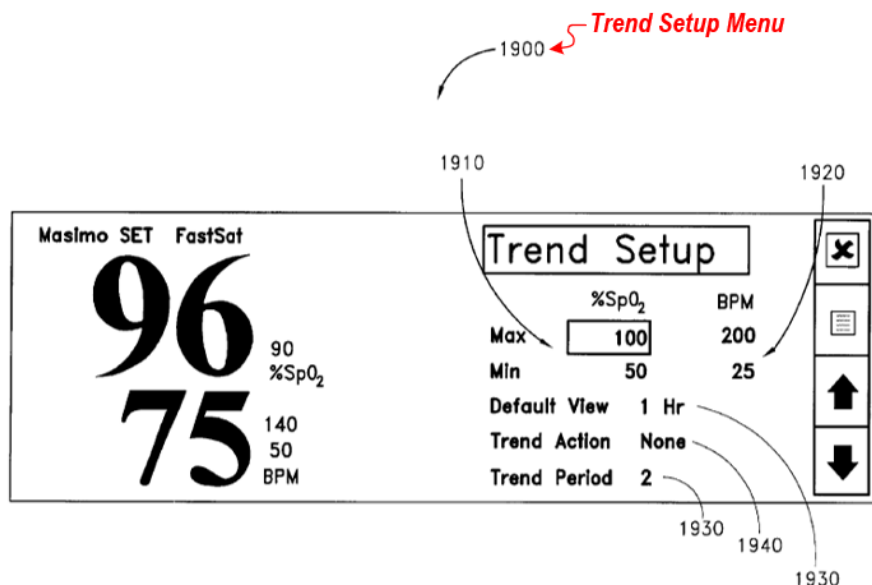


APPLE-1006, Figure 10.

114. As shown in FIG. 10, the displayed trend analysis includes an analysis of received SpO₂ measurement values. These examples from Kianl would be easily implemented in the system of Bailey, simply by revising the format and content of the displays described by Bailey to include the additional details and features described by Kianl. A POSITA would have been able to appreciate the benefits of the examples in Kianl, and make revisions to the displays in Bailey as needed to incorporate those benefits into the combined system.

115. As I previously discussed, Kianl describes a “trend setup menu 1900 having %SpO₂ max and min 1910, BPM max and min 1920, default view 1930, trend action 1940 and trend period 1950 items” to allow users to customize the trend analysis performed by the system. APPLE-1006, 15:10-56.

FIG. 10 shows “a trend view 1000” that includes “an oxygen saturation trend graph 1030.” APPLE-1006, 11:6-31.

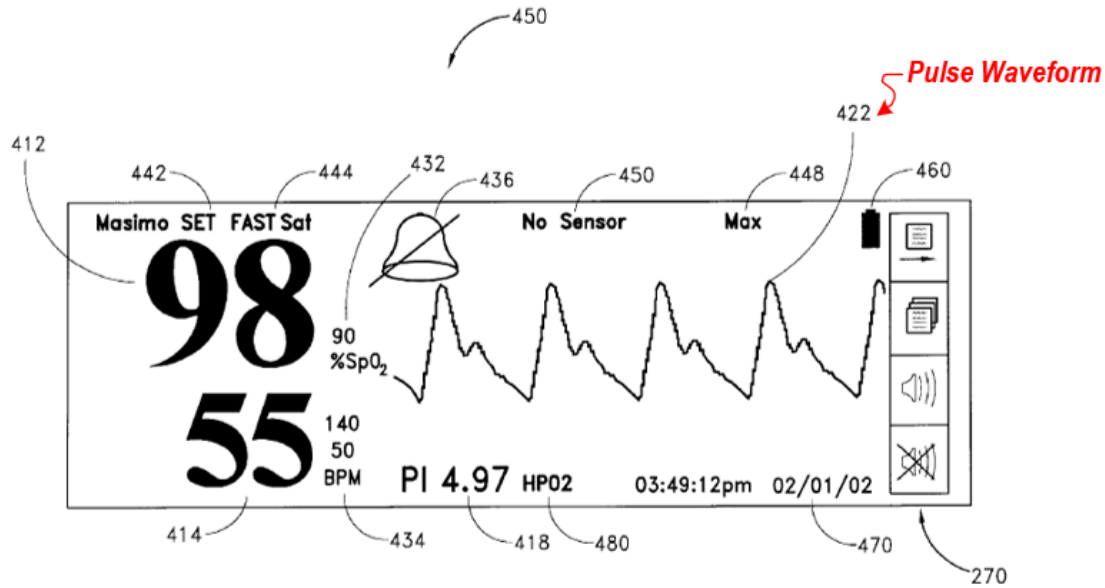


APPLE-1006, Figure 19.

(ii) Claim 17

[17] The computer-implemented method of claim 13, further comprising, via the application, updating the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts.

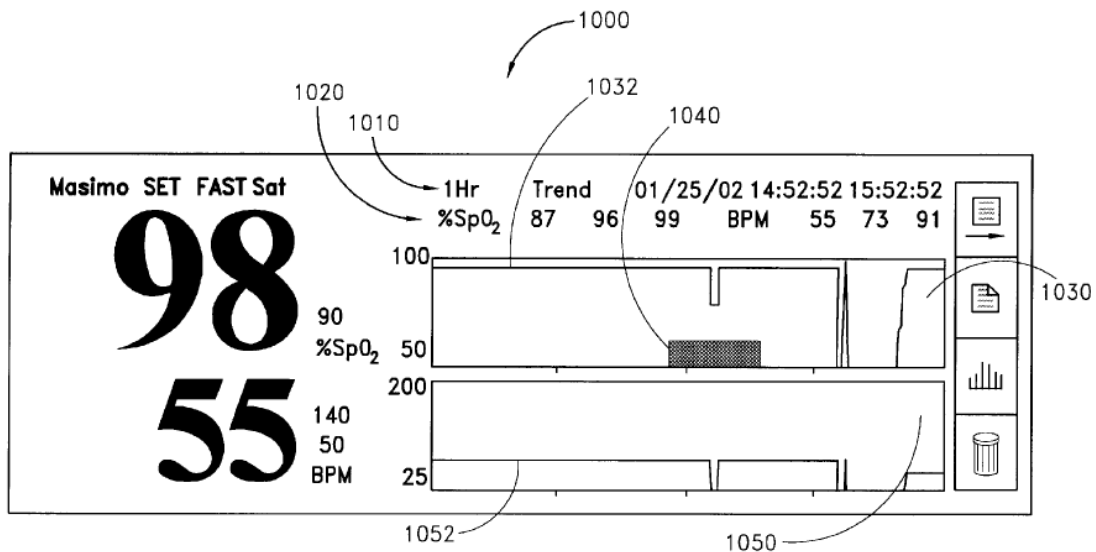
116. The combination of Bailey and Kianl provides a plurality of graphical representations of the SpO₂ measurement values via the application. For example, FIG. 4 from Kianl shows that a display that includes at least two graphical representations of the SpO₂ measurement value: a scrolling waveform showing the SpO₂ trend over time and a numerical value of the current SpO₂ value.



APPLE-1006, Figure 4.

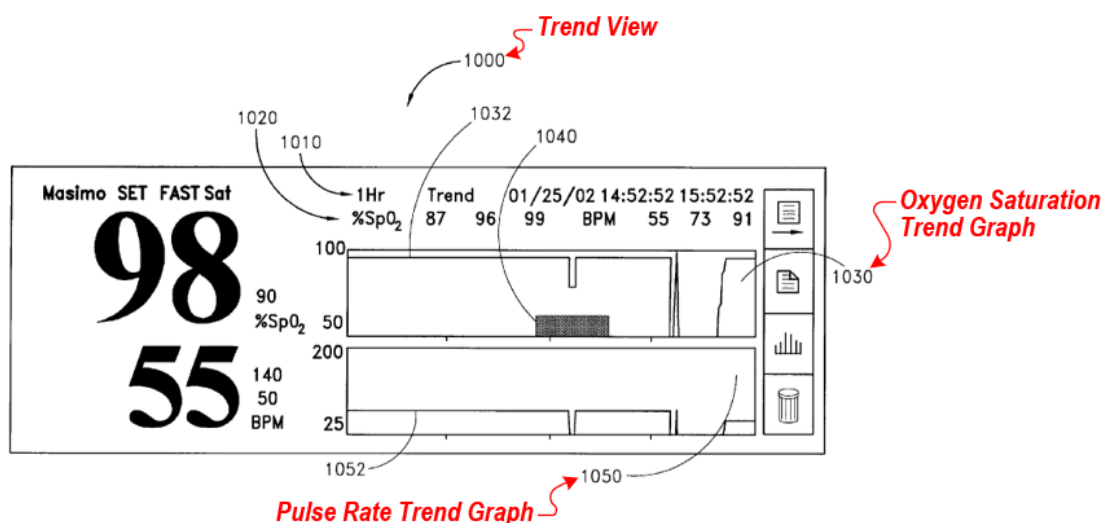
117. Kianl describes that GUI provides a plurality of graphical representations of the SpO_2 measurement values including “a pleth view that presents a pulse waveform” and “a trend view that presents a trend graph.”

APPLE-1006, 2:18-31, 1:33-37. FIG. 10 shows the “trend view 1000” including “oxygen saturation trend graph 1030.” APPLE-1006, 11:6-49.



APPLE-1006, FIG. 10.

118. Kianl describes that “[t]he oxygen saturation 412 displays a functional arterial hemoglobin oxygen saturation measurement in units of percentage SpO₂.” APPLE-1006, 6:1-3. The display also includes a “pulse waveform 422” of blood oxygen level. APPLE-1006, 6:10-15. FIG. 10 includes “a pulse rate trend graph 1050” along with blood oxygen trend information over time. APPLE-1006, 11:6-49, 12:18-26.



APPLE-1006, Figure 10.

119. Kianl describes that these trends are plotted over time and therefore a POSTIA would have recognized that the display of these different representations of SpO₂ measurement data are updated with each new measurement. APPLE-1006, 11:6-49, 14:18-30. Kianl further discloses a “trend setup menu 1900” that allows the user to specify what trends are calculated and displayed based on the SpO₂

measurement data. APPLE-1006, 15:10-56. As Kianl describes “FIG. 19 illustrates a trend setup menu 1900 having %SpO₂ max and min 1910, BPM max and min 1920, default view 1930, trend action 1940 and trend period 1950 items.” APPLE-1006, 15:10-56. The setup menus described with respect to FIG. 19 include an option to output the measured SpO₂ data as an “analog dump” including “an analog chart” of the data. APPLE-1006, 15:10-56. While Kianl describes these charts as being “print[ed],” a POSITA would have recognized that it would have been beneficial to include this chart as displayed data on Bailey’s user interface (GUI) in addition to or in place of printing such information to more readily provide the information “so that both the user and medical personnel alike could easily read and analyze the recorded blood oxygen levels over long periods of time,” as described in Bailey. APPLE-1004, 14. Displaying such information on the interface rather than in print would have negated the need for a printer which would have been beneficial “for consumer use” in such remote settings outside of a healthcare facility. APPLE-1004, 8, 13, 15. These examples from Kianl would be easily implemented in the system of Bailey, simply by revising the format and content of the displays described by Bailey to include the additional details and features described by Kianl. A POSITA would have been able to appreciate the benefits of the examples in Kianl, and make revisions to the displays in Bailey as needed to incorporate those benefits into the combined system.

**D. [GROUND 1D] – CLAIMS 1-2, 5, 7, 9, 12-15, 17, AND 19
ARE OBVIOUS OVER BAILEY AND D’ANGELO**

120. The sections below provide a brief introduction to D’Angelo and its combination with Bailey.

1. D’Angelo describes a user interface for a smartphone having multiple physiological parameter views and touchscreen user inputs for a physiological monitoring system and describes using the smartphone to provide power to a processing board

121. D’Angelo is a paper that was presented at the 33rd IEEE EMBS Annual International Conference in Boston, MA and published in the collected proceedings of the conference. The conference took place from August 30th to September 3, 2011. I was (and still am) a member of IEEE during the relevant time frame. As I described above with respect to the Bailey reference, I know from my personal experience as both an IEEE member and as a regular attendee of various IEEE conferences that practitioners interested in the area of engineering in medicine and biology (which includes the subfield of physiological monitoring) would have been aware of and attended conferences such as the annual IEEE EMBS International Conference. Furthermore IEEE members would have had access to the archives of the proceeding papers, and an opportunity to search for and read papers of direct interest to them. This would have been particularly true of practitioners interested in developments and research related to ways to develop instruments that can provide improvements in measurements of physiological

parameters. Through IEEE membership, it would have been very easy to search for and read papers of interest based on keyword searching the proceeding archives. Those papers are all archived and easily found today and this was also the general practice of the IEEE at the time. I am confident that a POSITA working on developing a pulse oximeter would have been aware of the proceedings from this conference, and would have known how to look for and access papers from the conference.

122. D'Angelo describes a physiological monitoring system to facilitate mobile telemedicine that includes “a new concept for interfacing sensor network nodes (motes) and smartphones.” APPLE-1007, Abstract, 1528.

The presented system allows receiving and storing data continuously using a mote and visualizing or sending it on the go using the smartphone as user interface only when desired. Thus, the processes of data reception and storage run on a safe system consuming less energy and the smartphone's potential along with its battery are not demanded continuously. Both, system concept and realization with an Apple iPhone are presented.

APPLE-1007, Abstract.



APPLE-1007, Figure 4.

123. D’Angelo describes that its physiological measurement system includes a pulse oximeter for measuring SpO₂. APPLE-1007, 1529. Similar to Bailey, D’Angelo’s system “employs a dedicated device, called management device, which is part of the sensor network used to acquire health information and a smartphone. The management device can receive data from a variety of sensors, e.g. the Eventlogger presented in [12] for behavior recognition, the sensor unit described in [13] for car-embedded vital parameter acquisition or the garment described in [14] for fall detection.” APPLE-1007, 1529. D’Angelo describes that “[t]he continuous processes, e.g. data acquisition, processing and time-stamped storage, run on the management device.” APPLE-1007, 1529. The smartphone

acts as the user interface for displaying the physiological parameters calculated by the management device and for receiving user inputs for interacting with the system. APPLE-1007, 1529-31.

124. Figure 1 of D'Angelo shows interactions between the various sensors, the management device and the smartphone:

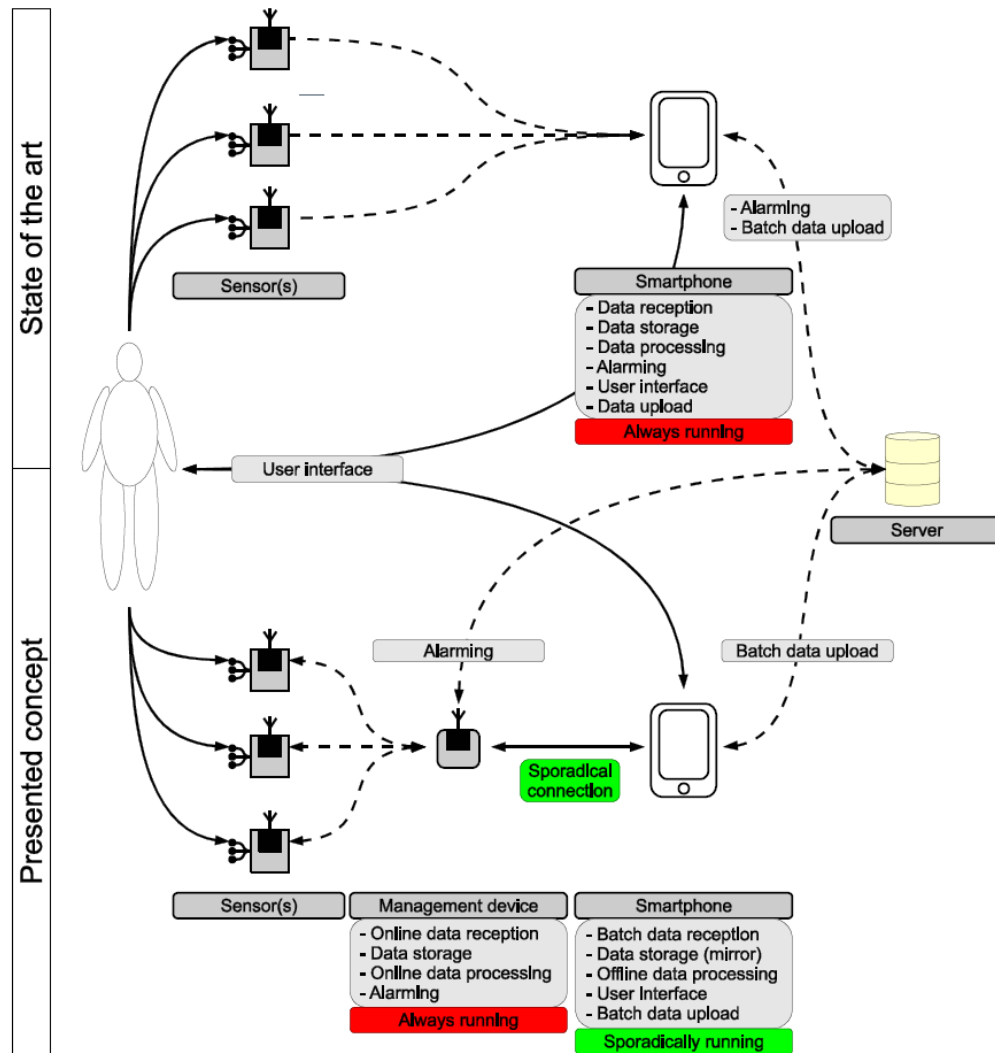


Fig. 1 Comparison between presented concept (bottom) and state of the art (top) in mobile telemedicine systems with smartphone-based visual user interface.

APPLE-1007, Fig. 1.

125. D’Angelo goes on to describe “a connection between the smartphone’s power output pin and the management device’s charging pin, allowing to read out the management device with the smartphone even when its battery is empty.” APPLE-1007, 1530. “The management device has a built-in connector which is compatible with the Apple Dock Connector. In addition to this, some pins can be used to program and debug the management device’s microcontroller using the Joint Test Action Group (JTAG) interface.” APPLE-1007, 1530.

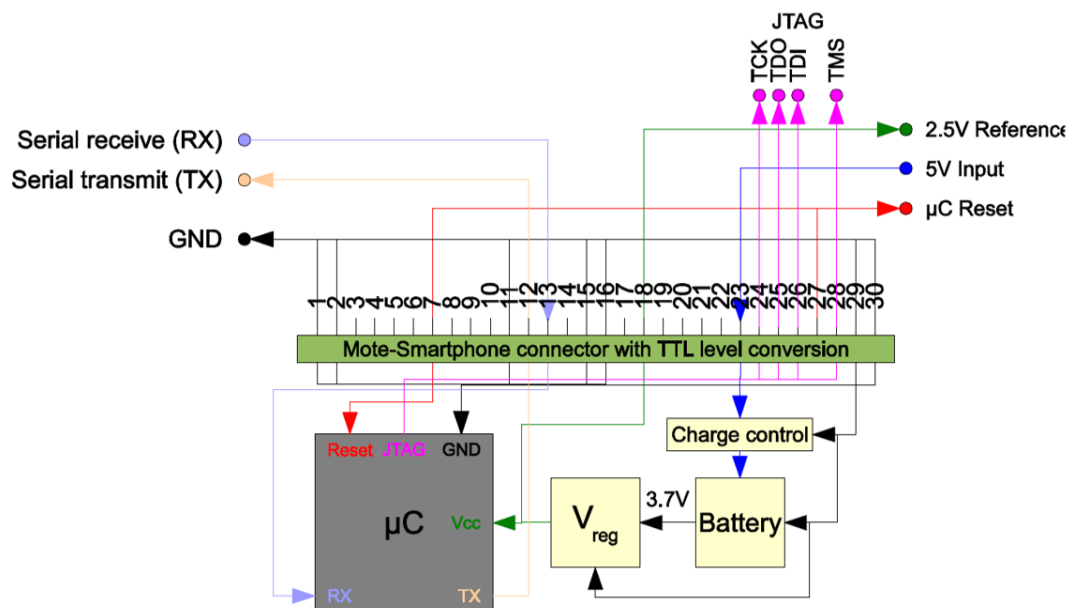


Fig. 3 Pin assignment of the mote-smartphone connector.

APPLE-1007, Figure 3.

126. D’Angelo describes two configurations for how the management device interacts with the smartphone (in this implementation, an iPhone 3G):

The management device has been built in two variants; the first one enables continuous connection between iPhone and management device. The second one is an adapter transforming the Eventlogger presented in [12] into a management device just during the connection with the iPhone, i.e. containing the additional components needed to use the Eventlogger as a management device. Prototypes of both devices are shown in Fig. 4.

APPLE-1007, 1530.

127. D'Angelo describes a user interface displayed by the smartphone that includes multiple views for displaying measured physiological parameters including numerical values for each variable along with “upper and lower limits” for the variables, a “graph view” which shows multiple rows associated with various variables, and an “options view” that allows the user to set upper and lower limits for each variable using a picker wheel. APPLE-1007, 1530-31.

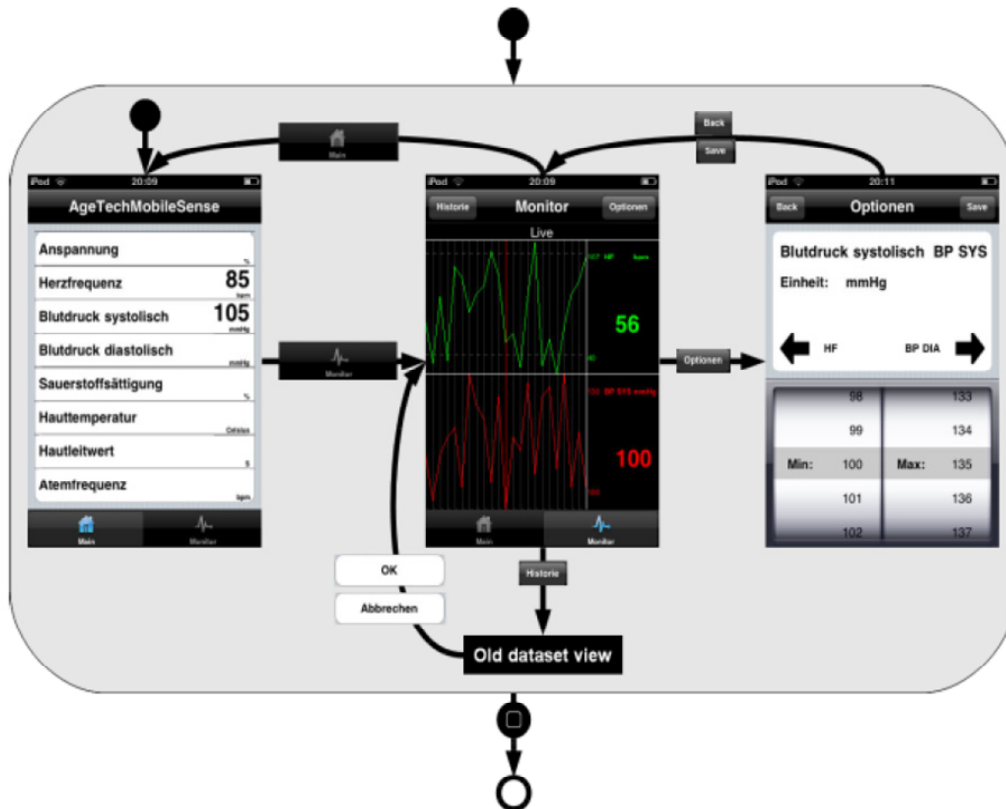


Fig. 5 Screenshots of the iPhone application visualizing acquired vital parameters live and previously recorded datasets.

APPLE-1007, Figure 5. The graph view allows users to view minimum and maximum recorded values and “scroll through current and older values.” APPLE-1007, 1530-31. The measured values include SpO₂. APPLE-1007, 1529.

2. *The combination of Bailey and D’Angelo*

128. There are multiple reasons that would have prompted a POSITA to apply the teachings of D’Angelo to the physiological monitoring system of Bailey. A POSITA would have predictably applied D’Angelo to Bailey to beneficially implement Bailey’s smartphone (e.g., iPhone, APPLE-1004 at 14, 20, 22-23, 47) to include a configuration that allows Bailey’s digital signal processing system

(APPLE-1004 at 22-23, Figure 7) or main circuitry housing (APPLE-1004, 24, 26, Figure 11) (equivalent to D'Angelo's management device) to draw power from the smartphone in at least some scenarios, and to include various user interface screens for displaying physiological data and receiving user input as described by D'Angelo in addition to or in place of the user interface screens described by Bailey.

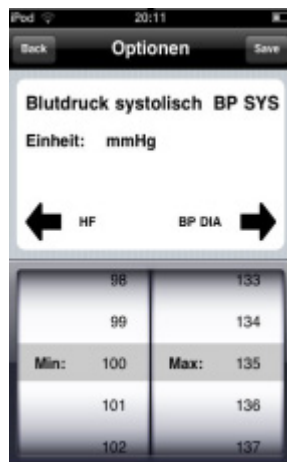
129. As a first reason, a POSITA would have recognized that applying D'Angelo's teachings to Bailey's oximeter system would implement Bailey's smartphone to provide an improved user interface that expand the features and customize operations of the Bailey system as taught by D'Angelo. A POSITA would appreciate that the addition of the features disclosed by D'Angelo to the system disclosed by Bailey would require only straightforward modifications to software for interfacing with facilities and other users through the internet, via the cellular connection of the smartphone, and that the result of these modifications would provide the simple and clear additive benefit of these features from D'Angelo to the system of Bailey to facilitate Bailey's remote monitoring functionality.

130. As a second reason, a POSITA would have recognized that applying D'Angelo's teachings to Bailey's oximeter system to configure Bailey's main circuitry housing to be able to draw power from the smartphone in at least some

scenarios would have provided the additional and beneficial functionality for the measured SpO₂ and physiological data to be read from the main circuitry housing “even when its battery is empty.” APPLE-1007, 1530; APPLE-1004, 24 (“The main housing contained ... battery”). Such a modification to Bailey’s system based on the straightforward teachings of D’Angelo would have provided crucial backup functionality for collecting important physiological data, including SpO₂ readings, even in scenarios in which the main circuitry housing of Bailey has lost power, which could facilitate potentially lifesaving interventions based on the physiological data read from the main circuitry housing.

131. As a third reason, a POSITA would have been prompted to apply D’Angelo’s teachings to Bailey’s oximeter system to include the multiple measured physiological data views disclosed by D’Angelo because such a modification would have improved the overall functionality and user experience of the resulting system. A POSITA would have recognized that including the additional graphical views for collected physiological information, including SpO₂ readings, disclosed by D’Angelo in the GUI of Bailey would have helped users to more readily understand the recorded information, including by “scroll[ing] through current and older values.” APPLE-1007, 1529-31. D’Angelo beneficially teaches multiple views for SpO₂ readings which would have provided more information

132. As a fourth reason, a POSITA would have been prompted to apply D'Angelo's teachings to Bailey's oximeter system to include the various different user interface screens in addition to or in place of the user interface screens disclosed by Bailey because the user interface described by D'Angelo would have allowed the users of the resulting system to more easily set alarm limits for physiological parameters, including SpO₂. APPLE-1007, 1531. For example, Figure 5 of D'Angelo shows a straightforward, intuitive user interface screen for setting minimum and maximum values for physiological parameters that will cause the resulting system to issue an alert if the measured physiological parameter is outside of the set threshold values:



APPLE-1007, Fig. 5. As D'Angelo describes "[i]n the options view, the user can set the upper and lower limits for each variable using a picker wheel. A screenshot of all three views is shown in Fig. 5." APPLE-1007, 1531. These limits can, for example, be used to "alarm relatives or clinicians." APPLE-1007, 1528, 1529

(“Should a safety-critical function like alarming also be needed, the management device must also contain a module for this function, e.g. a GSM module.”). Bailey recognizes the importance of alerting the user or a caregiver when SpO₂ values are outside of threshold values and D’Angelo provides a user interface screen that allows those values to be easily and intuitively set for each specific user according to their specific care needs and health scenario. APPLE-1004, 14, 47, 52, 62; APPLE-1007, 1531.

133. As a fifth reason, a POSITA would have been prompted to apply D’Angelo’s teachings to Bailey’s oximeter system to include the various different user interface screens in addition to or in place of the user interface screens disclosed by Bailey because such a modification would have increased the overall utility of the system resulting from the application of D’Angelo to Bailey. Bailey describes the application executing on the smartphone that provides a user interface to “display the recorded data from the microcontroller via wireless interface” and “sound an alarm when a low oxygen level was reached.” APPLE-1004, 47-50. D’Angelo provides additional details that allow users to easily switch between the various user interface views to control aspects of the system including by setting alarm limits and viewing the recorded physiological information in different formats including graphically, numerically (in charts), and as scrollable waveforms. APPLE-1007, 1530-1531. A POSITA would have recognized that

such additional functionality and flexibility in the GUI would have increased the overall utility of the system, thus making it easier for users to accurately use the system to monitor important vital sign information.

134. As a sixth reason, a POSITA would have been prompted to implement Bailey's oximeter system to include a configuration that allows Bailey's main circuitry housing (equivalent to D'Angelo's management device) to draw power from the smartphone in at least some scenarios, and to include various user interface screens for displaying physiological data and receiving user input as described by D'Angelo in addition to or in place of the user interface screens described by Bailey (all features suggested by D'Angelo) because doing so would be merely the application of a known technique to a known system (e.g., Bailey's oximeter system) ready for improvement to yield predictable results. Here, D'Angelo provides straightforward evidence of known techniques for powering a processing board from the smartphone and providing additional user interface screens for a physiological data monitoring system, and Bailey's teaching provides a known system that would have been improved by application of D'Angelo's suggested techniques for at least the reasons described above.

135. Based upon my knowledge and experience in this field and my review of Bailey and D'Angelo, I am confident a POSITA would have recognized that a modification of Bailey based on the examples provided by D'Angelo would have

yielded predictable results, and these modifications would have been within the predictable and ordinary level of skill of a POSITA. Thus, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying D’Angelo’s teachings to Bailey’s system.

3. *Application of Bailey and D’Angelo to Claims 1-2, 5, 7, 9, 12-15, 17-19*

(i) Claim 1

[1pre] A mobile pulse oximetry system for informing a user of mobile measurement of oxygen saturation (“SpO₂”), the mobile pulse oximetry system comprising:

136. To the extent the preamble is deemed to be limiting, Bailey discloses a mobile pulse oximetry system for informing a user of mobile measurement of oxygen saturation (“SpO₂”).

137. Bailey describes a “remotely monitored pulse oximeter, a device that measures blood oxygen saturation.” APPLE-1004, 8. Based on my review, Bailey’s pulse oximeter is designed for ***mobile measurement of oxygen saturation***. For example, Bailey’s pulse oximeter design is “intended primarily for consumer user” and provides “the ability to communicate data to a smartphone or other portable device” so that the device can be made “smaller by not needing to incorporate a display and user interface on the oximeter itself.” APPLE-1004, 8. Further, Bailey’s pulse oximeter is “intended to be worn by a person” and “needed to be durable enough to handle the daily rigors of being worn by an adult or child.”

APPLE-1004, 14. Due to its small form factor and portable nature, it would have been apparent and obvious that Bailey's pulse oximeter is adapted for mobile measurement of oxygen saturation, thereby providing a *mobile pulse oximetry system*.

138. Further, Bailey's pulse oximeter is in data communication with a mobile device (e.g., iPhone), which runs an application and includes a display, thereby implementing a mobile pulse oximetry *system*. APPLE-1004, 23, 47-48, Figure 32. Bailey's mobile device implements an user interface to "display the recorded data from the microcontroller via wireless interface." APPLE-1004, 47. Further, Bailey's mobile device is designed to "warn of dangerously low oxygen conditions." APPLE-1004, 47. Therefore, Bailey teaches *a mobile pulse oximetry system for informing a user of mobile measurement of SpO₂*.

139. D'Angelo similarly describes a mobile pulse oximetry system for informing a user of mobile measurement of SpO₂. D'Angelo describes that its physiological measurement system includes a pulse oximeter for measuring SpO₂. APPLE-1007, 1529. Similar to Bailey, D'Angelo's system "employs a dedicated device, called management device, which is part of the sensor network used to acquire health information and a smartphone. The management device can receive data from a variety of sensors, e.g. the Eventlogger presented in [12] for behavior recognition, the sensor unit described in [13] for car embedded vital parameter

acquisition or the garment described in [14] for fall detection.” APPLE-1007, 1529. D’Angelo describes that “[t]he continuous processes, e.g. data acquisition, processing and time-stamped storage, run on the management device.” APPLE-1007, 1529. The smartphone acts as the user interface for displaying the physiological parameters calculated by the management device and for receiving user inputs for interacting with the system. APPLE-1007, 1529-31.

[1a] an SpO₂ measurement system including:

140. Bailey discloses an SpO₂ measurement system including “the LED driver control, analog signal processing, and digital signal processing systems” for the reasons I discussed with respect to claim 13 (specifically elements [13a]-[13d]) in Ground 1A, above. APPLE-1004, 9-11, 22-24, 27-28 Figures 1, 7, 11, and 32.

[1b] an optical sensor configured to output one or more signals responsive to light from a light source attenuated by tissue of the user at a measurement site, said one or more signals responsive to an oxygen saturation of said tissue; and

141. Bailey discloses an optical sensor configured to output one or more signals responsive to light from a light source attenuated by tissue of the user at a measurement site, said one or more signals responsive to an oxygen saturation of said tissue for the reasons I discussed with respect to claim 13 (specifically element [13a]) in Ground 1A, above. APPLE-1004, 9-11, 22-24, 27-28, Figures 1, 7 and 11.

[1c] a processing board in data communication with the optical sensor and a mobile computing device including a display and cellular communication, wherein the processing board is configured to:

142. Bailey discloses a processing board in data communication with the optical sensor and a mobile computing device including a display and cellular communication for the reasons I discussed with respect to claim 13 (specifically element [13b]) in Ground 1A, above. APPLE-1004, 22-24, 48, Figures 7 and 11.

143. Again, as I explained above, Bailey's oximeter system uses a smartphone (e.g., iPhone) as the mobile computing device. APPLE-1004, 14, 20, 22, 23, 47, 62, Figures 7 and 45. A POSITA would have been well aware that by the year 2012, iPhones and other smart phones communicated using cellular communication, including both voice and data communication over such cellular networks. APPLE-1005, [0010], [0018], [0108]; APPLE-1009, [0016]-[0018], [0047]; APPLE-1010, [0136].

[1d] receive said one or more signals from the optical sensor;

144. Bailey discloses that the processing board receives said one or more signals from the optical sensor for the reasons I discussed with respect to claim 13 (specifically element [13c]) in Ground 1A, above. APPLE-1004, 23, Figure 7.

[1e] process said one or more signals to generate SpO₂ measurement values; and

145. Bailey discloses that the processing board processes said one or more signals to generate SpO₂ measurement values for the reasons I discussed with

respect to claim 13 (specifically element [13d]) in Ground 1A, above. APPLE-1004, 22-23, Figure 7.

[1f] output the SpO2 measurement values to the mobile computing device; and

146. Bailey discloses that the processing board outputs the SpO₂ measurement values to the mobile computing device for the reasons I discussed with respect to claim 13 (specifically element [13e]) in Ground 1A, above.

APPLE-1004, 22-23.

[1g] one or more hardware processors of the mobile computing device configured to execute an application, the application configured to execute commands to:

147. Bailey discloses that the mobile computing device is configured to execute an application that is configured to execute commands for the reasons I discussed with respect to claim 13 (specifically element [13f]) in Ground 1A, above. APPLE-1004, 23, 47, 49, Figure 33.

148. Further, a POSITA would have recognized that portable devices such as iPod or iPhone disclosed by Bailey and the smartphones described in D'Angelo, including the iPhone 3G in D'Angelo's primary embodiment, include one or more processors for executing software applications, such as the "application on the iPhone" and "user interface [] implemented for an iPhone" described by Bailey and the software application that provides the graphical user interface described in D'Angelo. APPLE-1004, 14, 20, 22, 23, 47, 49, 62, Figures 7, 33, and 45;

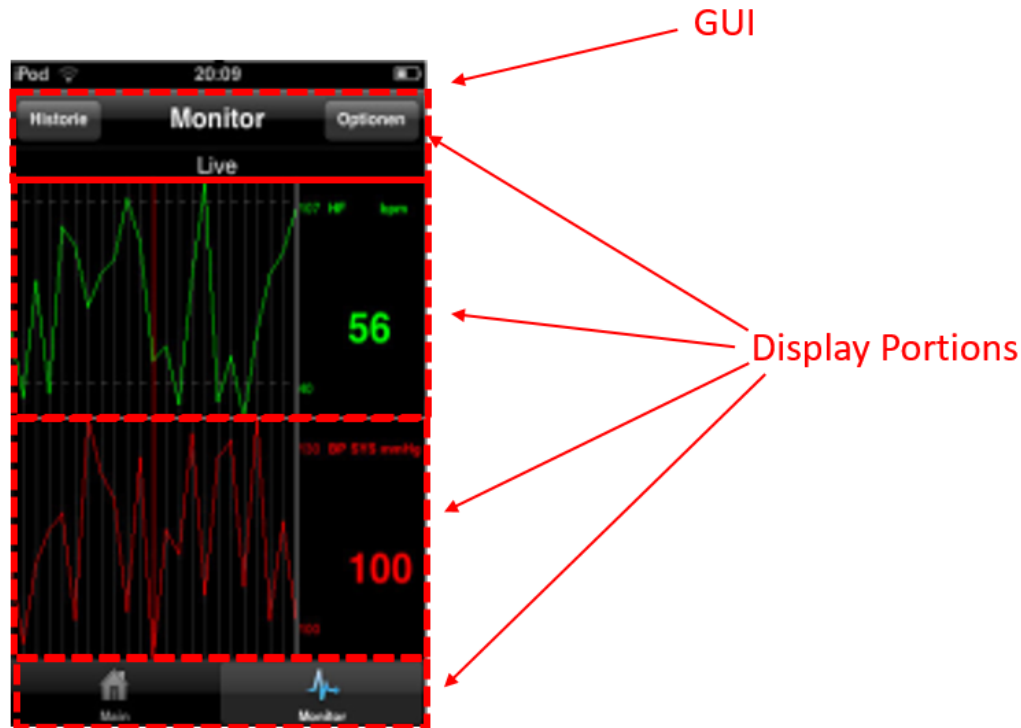
APPLE-1007, 1528-29. For Example, D'Angelo describes the smartphone as performing "processing," which a POSITA would have recognized as processing performed by one or more hardware processors of the smartphone to execute the application. APPLE-1007, 1528-29. In the predictable combination of Bailey with D'Angelo that I have described above, a POSITA would have recognized that the one or more hardware processors of the smartphone execute the application disclosed by Bailey (as modified based on D'Angelo), which executes commands to perform the described functions. APPLE-1004, 23, 49, Figure 33.

[1h] generate a graphical user interface having a plurality of display portions;

149. Bailey discloses that the application executes commands to generate a graphical user interface having a plurality of display portions for the reasons I discussed with respect to claim 13 (specifically element [13g]) in Ground 1A, above. APPLE-1004, 47, Figures 32-33.

150. Alternatively, D'Angelo also discloses that, in the predictable combination of Bailey with D'Angelo, the resulting application executes commands to generate a graphical user interface having a plurality of display portions. As I discussed above, a POSITA would have recognized that it would have been beneficial to add one or more of the display screens disclosed by D'Angelo to the application of Bailey in addition to or in place of the GUI screens

described by Bailey. This includes the “Graph view” screen described by D’Angelo and shown in Figure 5, which includes multiple display portions:



APPLE-1007, Figure 5, 1530-31.

[1i] display, in at least one portion of the plurality of display portions, a representation of a physiological parameter of a plurality of physiological parameters comprising at least the SpO2 measurement values; and;

151. Bailey discloses that the application executes commands to display, in at least one portion of the plurality of display portions, a representation of a physiological parameter of a plurality of physiological parameters comprising at least the SpO₂ measurement values for the reasons I discussed with respect to claim 13 (specifically element [13h]) in Ground 1A, above. APPLE-1004, Figure 32.

152. Alternatively, D’Angelo also discloses that, in the predictable combination of Bailey with D’Angelo, the resulting application executes commands to display, in at least one portion of the plurality of display portions, a representation of a physiological parameter of a plurality of physiological parameters comprising at least the SpO₂ measurement values. Specifically, D’Angelo describes a “Graph view” that is “structured as a table in which each row is associated to a variable.” APPLE-1007, 1530. D’Angelo describes displaying the physiological parameters in display portions:

Values are displayed in a graph on the left side of the screen. New values are added scrolling the graph automatically. On the right side, the value is shown as a number along with the corresponding unit and current maximum and minimal value measured. The graph height adapts to these values. Tapping and wiping on the left side, the automatic scrolling can be stopped and the user can scroll through current and older values. Older data sets can also be loaded and displayed. With a double tap, the graph scrolls back to show current values on the right end and the automatic scrolling is reactivated.

APPLE-1007, 1530-31.

153. D’Angelo also confirms Bailey’s disclosure that in the resulting combination, one of the displayed physiological parameters is blood oxygen saturation (SpO₂). APPLE-1007, 1529. As shown in Figure 5, multiple scrolling graphs along the left of the GUI show multiple measured physiological parameters

while for each “the value is shown as a number along with the corresponding unit and current maximum and minimal value measured” for the parameter. APPLE-1007, 1530-31.

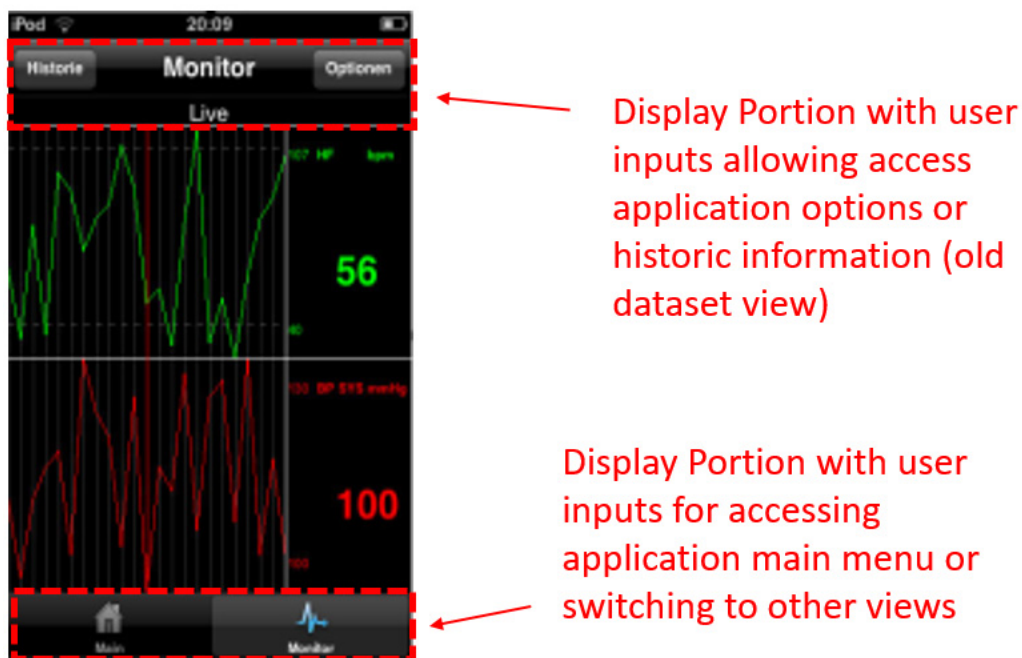


APPLE-1007, Figure 5.

[1j] display, in a different portion of the plurality of display portions, a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application;

154. Bailey discloses that the application executes commands to display, in a different portion of the plurality of display portions, a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application for the reasons I discussed with respect to claim 13 (specifically element [13i]) in Ground 1A, above. APPLE-1004, Figure 32.

155. Alternatively, D’Angelo also discloses that, in the predictable combination of Bailey with D’Angelo, the resulting application executes commands to display, in a different portion of the plurality of display portions, a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application. Specifically, D’Angelo’s “Graph view” that displays measured physiological parameters in both “a graph on the left side of the screen” and in numerical values also includes a number of display portions that include a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application, as shown in Figure 5:



APPLE-1007, Figure 5, 1530-31.

156. As a first example, a display portion near the top of the GUI includes multiple user inputs allowing access to application options or historic information. APPLE-1007, 1530-31. As a second example, a display portion near the bottom of the GUI includes multiple user inputs that allow the user to access a “Main view” or switch to other views of the GUI, such as the currently displayed “Graph view.” APPLE-1007, 1530-31. In yet another example, D’Angelo also describes receiving user input on the touchscreen so that “the user can scroll through current and older values.” APPLE-1007, 1531. A POSITA would have recognized that each of these examples individually or collectively provide this claim element as these are all examples of interactions with the application.

[1k] wherein the processing of the one or more signals to generate SpO₂ measurement values is performed only on the processing board, thereby freeing up memory available to the mobile computing device; and

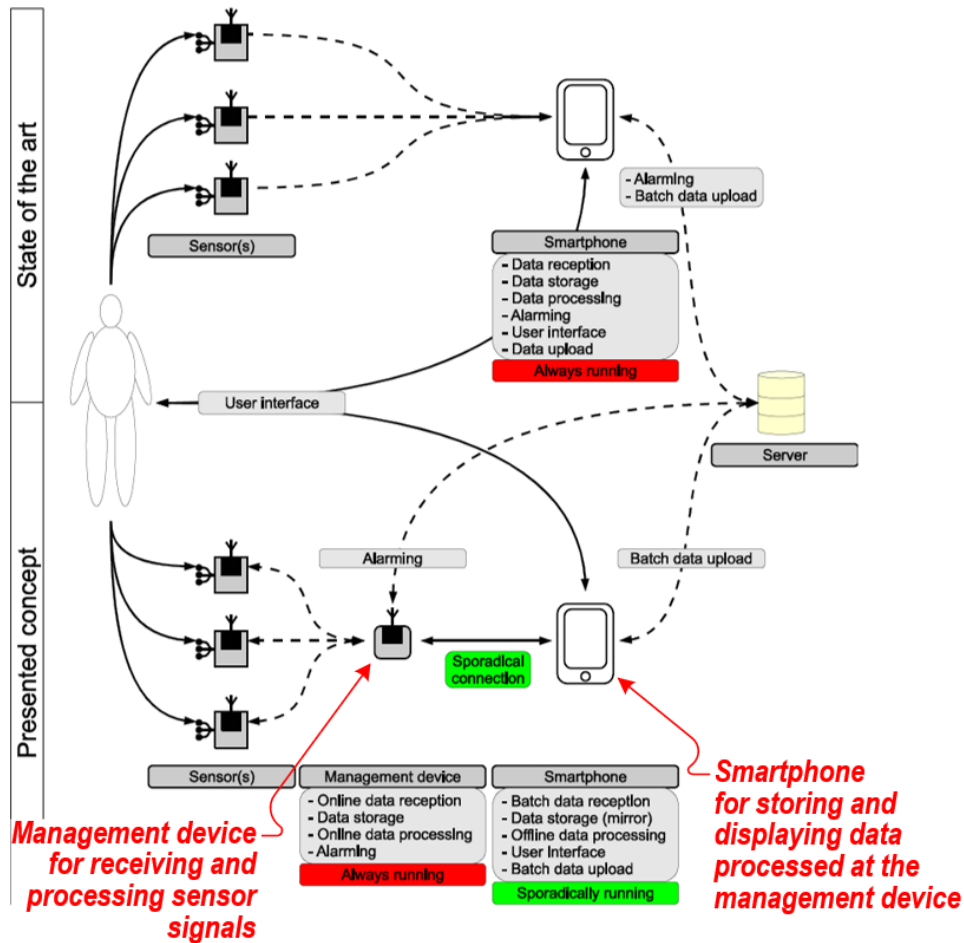
157. Bailey reveals that the predictable combination of Bailey with D’Angelo provides that the processing of the one or more signals to generate SpO₂ measurement values is performed only on the processing board, thereby freeing up memory available to the mobile computing device. As discussed above, Bailey’s “digital signal processing system” (or “digital signal processing and control” in Figure 7), which corresponds to or is included in the ***processing board***, processes the signals from the “analog signal processing system,” to generate SpO₂ measurement values. APPLE-1004, 22-24, 48, Figures 7 and 32. As also noted

above, Bailey's "digital signal processing system" then transmits the processed signals to the mobile device (e.g., iPhone) for displaying on the user interface. APPLE-1004, 22-23. Therefore, a POSITA would have understood that, in Bailey's system, the processing of the signals from the optical sensor is performed only on the "digital signal processing system" (*processing board*), which would naturally unload or free up memory and processing capability of the mobile device for use by other processes (*thereby freeing up memory available to the mobile computing device*).

158. For example, U.S. Patent No. 8,195,848 to Jones ("Jones") confirms the knowledge of a POSITA that off loading this processing of received physiological signals to a processing device distinct from the display device would have freed up memory available to the display device. Jones describes that when processing is done by a separate computing device, the "host processing system may be automatically repurposed with the medical operating system communicated from a memory location...of the medical component when it may be determined that the medical operating system is optimized to operate with the host processing system 100 and the medical component." APPLE-1020, 8:10-22. A POSITA would have been well aware that off loading such processing functions to a separate device (e.g., Bailey's digital signal processing system) would have freed up memory and processing capabilities of the display device to be used for other

purposes and/or to improve the processing speed and power consumption of the mobile device as described in Bailey.

159. In addition, D'Angelo clearly supports the POSITA's understanding and discloses that, in the predictable combination of Bailey with D'Angelo, the resulting application executes commands to process one or more signals to generate SpO2 measurement values only on the processing board, thereby freeing up memory available to the mobile computing device. A POSITA would have been motivated to modify Bailey's 'yste' based on D'Angelo's teachings for several known or predictable benefits. In fact, D'Angelo provides the same three-component architecture as Bailey's system. In particular, D'Angelo includes "a dedicated device, called management device," which "receive[s] data from a variety of sensors" (e.g., SpO2 and ECG sensors) and is "connected to a mobile phone or smartphone" to exchange data therebetween. APPLE-1007, 1529. D'Angelo's management device is configured for "continuous critical processes" ("time-critical or safety-critical processes") by running "[t]he continuous processes, e.g. data acquisition, processing and time-stamped storage" on behalf of the mobile phone. APPLE-1007, 1529, 1531, Figure 1 (below). D'Angelo's mobile phone only performs "sporadic processes like user interaction or data visualization." APPLE-1007, 1529, 1531.



APPLE-1007, Figure 1 (annotated).

160. Several reasons would have prompted a POSITA to modify Bailey's system to implement D'Angelo's teaching of "separating continuous critical processes and sporadic processes" between Bailey's "digital signal processing system" (*processing board*) and its mobile device. APPLE-1007, 1531. For example, a POSITA would have recognized that the Bailey-D'Angelo combination would enhance security and stability in processing and managing the SpO2 data because it needs not rely on "a mobile phone for reception, processing and

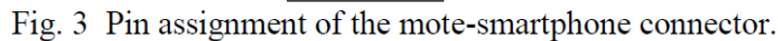
transmission of private medical data and for time-critical or safety-critical processes,” which “can be very risky, especially considering that modern mobile phones are getting more and more complex.” APPLE-1007, 1529. Further, a POSITA would have recognized that Bailey-D’Angelo’s system would benefit from “the processes of data reception and storage run on a safe system [“management device,” corresponding to the *processing board*] consuming less energy” so that “the smartphone’s potential along with its battery are not demanded continuously.” APPLE-1007, Abstract.

[11] wherein the processing board is configured to draw power for operation from the mobile computing device.

161. Similarly to Bailey’s pulse oximeter, D’Angelo’s “management device” is battery-operated so that “the smartphone’s potential along with its battery are not demanded continuously.” APPLE-1007, Abstract, 1530. Further, D’Angelo’s management device is designed to be able to *draw power for operation from* the connected mobile device. APPLE-1007, 1530.

162. As I discussed above, a POSITA would have been compelled to beneficially apply the teachings of D’Angelo to Bailey’s system such that in the resulting system, Bailey’s “digital signal processing system” (*processing board*) is configured to draw power for operation from the mobile computing device. D’Angelo specifically describes “a connection between the smartphone’s *power output pin* and the management device’s *charging pin*, allowing to read out the

APPLE-1007, 1530. The blue connection in figure 3 (shown below) corresponds to the connection between the smartphone’s power output pin (labelled as the “5V input”) and the management device’s charging pin (shown as the connection to the “charge control” element).



163. As would have been recognized by a POSITA, D’Angelo’s “management device” is equivalent to Bailey’s “digital signal processing system” in that they are both computing devices that are in communication with both physiological sensors and the smartphone and they both perform signal processing to determine physiological parameters based on physiological parameter signals received from the sensors. APPLE-1007, 1529-1530; APPLE-1004, 22-24.

Therefore, when applying these teachings of D’Angelo to Bailey, a POSITA would

have implemented Bailey's digital signal processing system to be configured to draw power for operation from the mobile computing device.

164. In addition to the advantages of the Bailey-D'Angelo combination above, additional benefits would have motivated a POSITA to modify Bailey's system to be capable of drawing power for operation from a mobile device, as taught by D'Angelo. For example, a POSITA would have recognized that the Bailey-D'Angelo combination would allow Bailey's pulse oximeter to continue to run even when it is out of battery. APPLE-1016, [0006] ("there still exists a problem that the batteries in such pulse oximeters regularly die and need to be replaced. When this occurs in situations where replacement batteries are not readily available, these pulse oximeters become similarly disadvantaged as the traditional plug-in pulse oximeters"). Further, using power from a mobile device would eliminate the need for an outlet, thereby making the entire pulse oximeter system to be completely portable. Relatedly, the oximeter system in the Bailey-D'Angelo combination would offer ease of use for users who do not have a steady power supply or cannot afford regularly buy new disposable batteries.

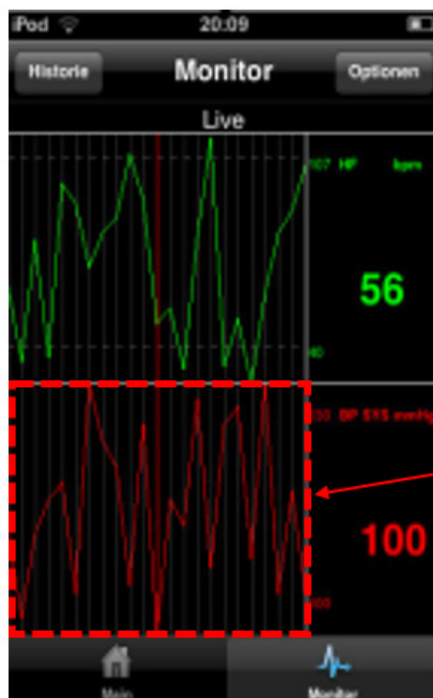
(ii) Claim 2

[2pre]-[2b] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to: perform a trend analysis on received SpO2 measurement values; and display results of the trend analysis in at least one portion of the plurality of display portions.

165. Bailey discloses that the application is configured to execute commands to: perform a trend analysis on received SpO2 measurement values and display results of the trend analysis in at least one portion of the plurality of display portions for the reasons I discussed with respect to claim 14 (specifically elements [14pre]-[14b]) in Ground 1A, above. APPLE-1004, 14, 55, Table 7. As I discussed with respect to claim 14, abundant evidence supports such well-known functionalities of displaying the record of the data over a period of time at a mobile device, enabling a user to visualize the trend of oxygen saturation values or other physiological parameters. APPLE-1018 (Al-Ali), 3:39-53, 5:38-55, 6:49-54, 11:18-23, 14:1-10, 17:29-19:51, Figures 11A-11H; APPLE-1019 (Lynn), 1:36-41, 2:18-42, 4:43-49, 6:8-34, 8:30-50, 11:35-40, 12:22-26, 12:53-58, 15:1-16:20, 21:21-27, 23:7-15, 29:65-30:38, 45:14-34, 56:3-38, 61:27-60, 65:55-63, 69:55-67, 70:29-39, 72:10-19, 72:48-54, 79:10-24, 82:19-33, 84:27-85:35, 86:47-87:25.

166. In addition, the predictable combination of Bailey with D'Angelo provides that the application is configured to execute commands to: perform a trend analysis on received SpO2 measurement values and display results of the trend analysis in at least one portion of the plurality of display portions. As I

discussed in the analysis of claim 14, the '507 patent provides a limited disclosure of “trend analysis.” APPLE-1001, 5:25-35, 5:50-52, 13:44-63, Figure 4C. Given the '507's disclosure, a POSITA would have recognized that displaying a graph of SpO₂ information collected and plotted over time in one of the display portions satisfies this element. D'Angelo discloses this element and therefore the combination of Bailey with D'Angelo renders this claim obvious. Specifically, D'Angelo describes that the “Graph view” that is one of the display screens of D'Angelo's GUI displays determined physiological parameters in an automatically scrolling graph that depicts changes in the measured value over time. APPLE-1007, 1530-31.



APPLE-1007, Fig. 5. D'Angelo is consistent with the disclosures of Bailey that SpO₂ values are one of the values displayed as part of the graph view in the resulting combination. APPLE-1004, 50, 52 (Table 5), Figures 31-32; APPLE-1007, 1529.

(iii) Claim 5

[5] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to output one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values.

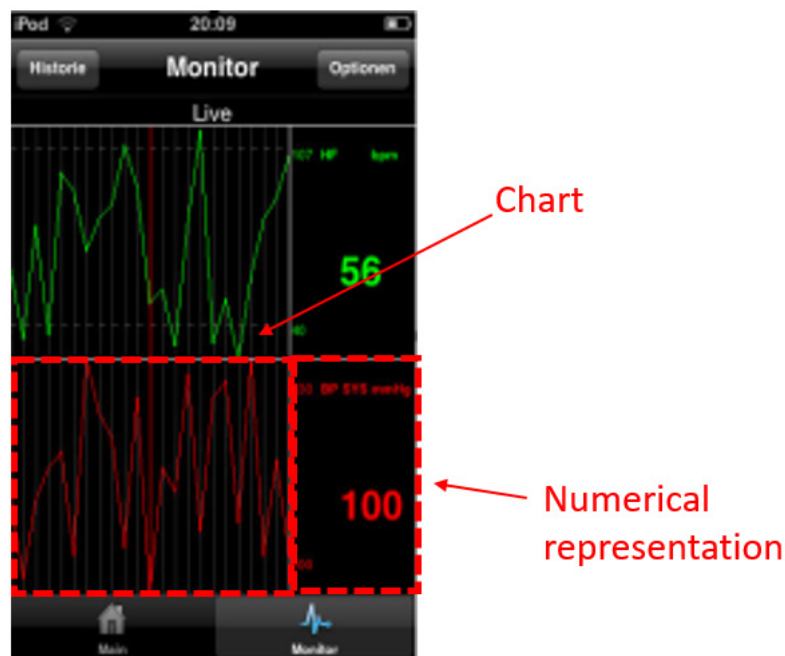
167. Bailey discloses that the application is configured to execute commands to output one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values for the reasons that I discussed with respect to claim [15] in Ground 1A, above. APPLE-1004, 14, 47, 62, Figure 32.

(iv) Claim 7

[7] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to update the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts.

168. The predictable combination of Bailey with D'Angelo provides an application that is configured to execute commands to update the representation of the physiological parameter, comprising one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical

representations comprising at least one of bar graphs or charts. This is shown, for example, by Figure 5 of D'Angelo which shows each of the multiple physiological parameters are displayed in a plurality of graphical representations including a chart showing values plotted over time that updates over time such that “[n]ew values are added scrolling the graph automatically” and also as a numerical value in a second graphical representation. APPLE-1007, 1530-31.



APPLE-1007. Fig. 5.

169. D'Angelo is consistent with the disclosures of Bailey that SpO₂ values are one of the values displayed as part of the graph view in the resulting combination. APPLE-1004, 50, 52 (Table 5), Figures 31-32; APPLE-1007, 1529. Notably, Bailey's iPhone executes a program for operating the user interface to “manage[] the WiFi connection, listens for data, verifies the data, updates the GUI,

and manages the alert sound.” APPLE-1004, 49, Figure 33. A POSITA would have recognized that the various graphical displays of SpO₂ values (both the numerical representation and the chart) would have been performed by executing commands of the modified application or program in the resulting combination.

(v) Claim 9

[9] The mobile pulse oximetry system of claim 1, wherein the mobile computing device comprises a smartphone.

170. Bailey describes a smartphone like iPhone. APPLE-1004, 14, 20, 22, 23, 47, 62-63. D’Angelo demonstrates that the predictable combination of Bailey with D’Angelo provides that the mobile computing device comprises a smartphone such as an iPhone 3G. APPLE-1007, 1-2.

(vi) Claim 12

[12] The mobile pulse oximetry system of claim 1, wherein the SpO₂ measurement system is configured to wirelessly transmit the SpO₂ measurement values to the mobile computing device.

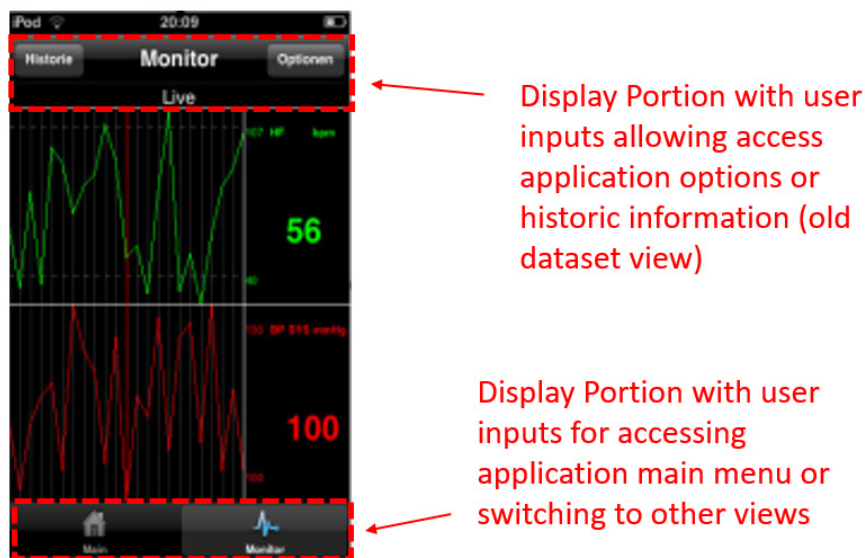
171. Bailey discloses that the SpO₂ measurement system is configured to wirelessly transmit the SpO₂ measurement values to the mobile computing device for the reasons that I discussed with respect to claim [19] in Ground 1A, above. APPLE-1004, 22-23, Figure 7.

(vii) Claim 13

172. As I discussed above in Ground 1A, a POSITA would have recognized that Bailey discloses all elements of claim 13. Alternatively, to the

extent that element [13i] is interpreted narrowly such that it is believed that Bailey alone does not disclose displaying, in a different portion of the plurality of portions, a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application, the predictable combination of Bailey with D'Angelo included such functionality. Specifically, the “Graph view” of D'Angelo includes multiple examples which meet this claim element.

173. For example, D'Angelo's “Graph view” that displays measured physiological parameters in both “a graph on the left side of the screen” and in numerical values also includes a number of display portions that include a plurality of user inputs configured to allow the user to interact with at least one of the plurality of display portions or the application, as shown in Figure 5:



APPLE-1007, Figure 5, 1530-31.

174. As a first example, a display portion near the top of the GUI includes multiple user inputs allowing access to application options or historic information. APPLE-1007, 1530-31. As a second example, a display portion near the bottom of the GUI includes multiple user inputs that allow the user to access a “Main view” or switch to other views of the GUI, such as the currently displayed “Graph view.” APPLE-1007, 1530-31. In yet another example, D’Angelo also describes receiving user input on the touchscreen so that “the user can scroll through current and older values.” APPLE-1007, 1531. A POSITA would have recognized that each of these examples individually or collectively provide this claim element as these are all examples of interactions with the application.

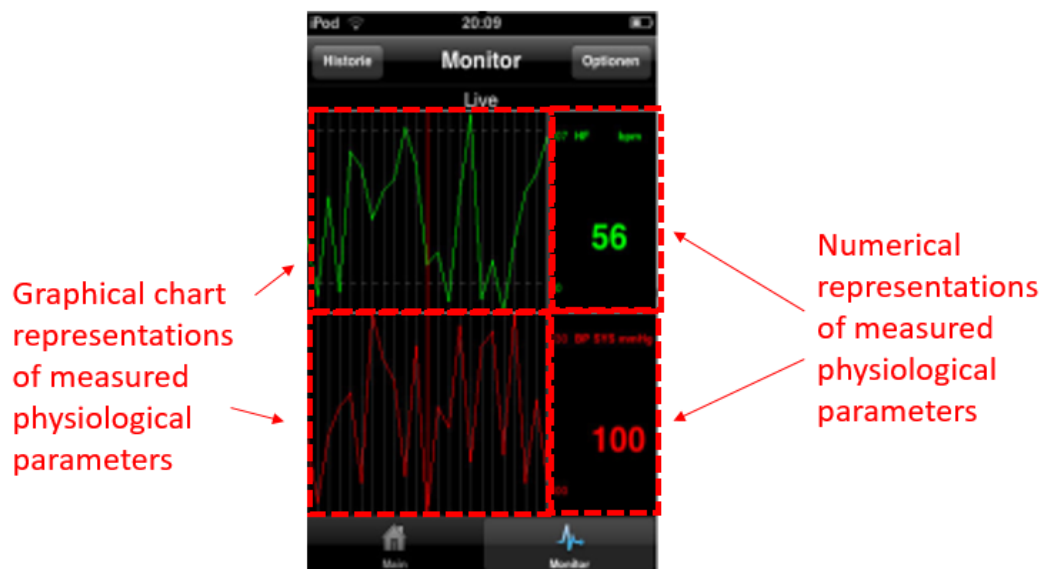
175. Furthermore, with respect to element [13g], as I previously described with respect to element [1i], the predictable combination of Bailey with D’Angelo displays a “Graph view” that is “structured as a table in which each row is associated to a variable.” APPLE-1007, 1530. D’Angelo describes displaying the physiological parameters in display portions:

Values are displayed in a graph on the left side of the screen. New values are added scrolling the graph automatically. On the right side, the value is shown as a number along with the corresponding unit and current maximum and minimal value measured. The graph height adapts to these values. Tapping and wiping on the left side, the automatic scrolling can be stopped and the user can scroll through current and older values. Older data sets can also be loaded and

displayed. With a double tap, the graph scrolls back to show current values on the right end and the automatic scrolling is reactivated.

APPLE-1007, 1530-31.

176. D'Angelo is consistent with Bailey's disclosure that in the resulting combination, one of the displayed physiological parameters is blood oxygen saturation (SpO_2). APPLE-1007, 1529. As shown in Figure 5, multiple scrolling graphs along the left of the GUI show multiple measured physiological parameters while for each "the value is shown as a number along with the corresponding unit and current maximum and minimal value measured" for the parameter. APPLE-1007, 1530-31.



APPLE-1007, Fig. 5.

177. All other elements of claim 13 are provided by Bailey for the reasons I discussed in Ground 1A, above.

(viii) Claim 14

[14] The computer-implemented method of claim 13, further comprising, via the application: performing a trend analysis on received SpO₂ measurement values; and displaying results of the trend analysis in at least one portion of the plurality of display portions.

178. Bailey in view of D'Angelo provides that the application performs a trend analysis on received SpO₂ measurement values and displays results of the trend analysis in at least one portion of the plurality of display portions for the reasons that I discussed with respect to claim [2] in Ground 1D, above.

(ix) Claim 15

[15] The computer-implemented method of claim 13, further comprising, via the application, outputting one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values.

179. Bailey in view of D'Angelo provides that the application outputs one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values for the reasons that I discussed with respect to claim [15] in Ground 1A, above.

(x) Claim 17

[17] The computer-implemented method of claim 13, further comprising, via the application, updating the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts.

180. Bailey in view of D'Angelo provides that the application updates the representation of the physiological parameter to comprise one or more of a

plurality of graphical representations of the SpO2 measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts for the reasons that I discussed with respect to claim [7] in Ground 1D, above.

(xi) Claim 19

[19] The computer-implemented [method of] claim 13, further comprising wirelessly transmitting the SpO2 measurement values from the SpO2 measurement system to the mobile computing device.

181. Bailey in view of D’Angelo provides wirelessly transmitting the SpO2 measurement values from the SpO2 measurement system to the mobile computing device for the reasons that I discussed with respect to claim [19] in Ground 1A, above.

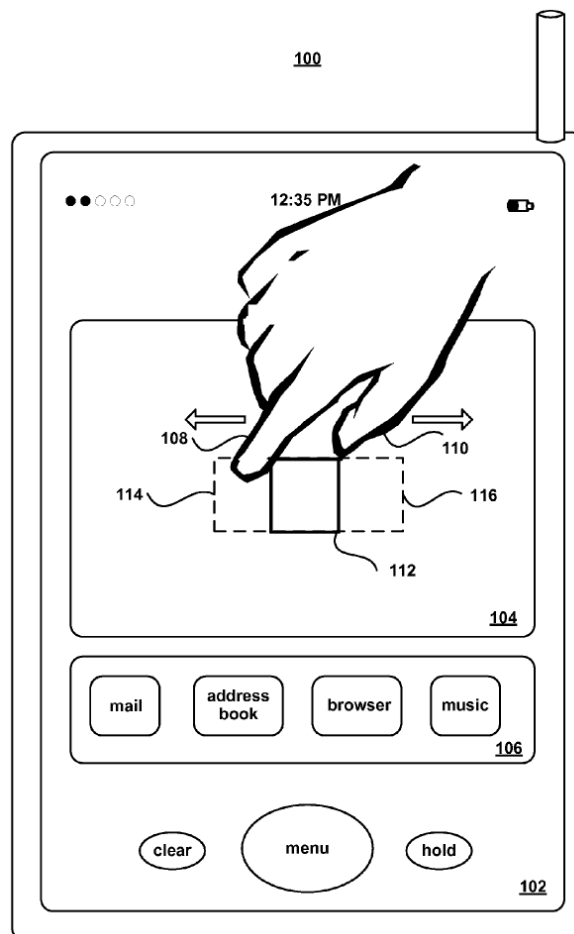
E. [GROUND 1E] – CLAIM 3 IS OBVIOUS OVER BAILEY, D’ANGELO, AND ORDING

182. The sections below provide a brief introduction to Ording and its combination with Bailey and D’Angelo.

1. Ording describes narrowing or expanding a display in response to a user using a pinch gesture via a touch-sensitive display.

183. Ording describes a “portable communication device” having a touchscreen that includes “multi-touch input” that detects “one or more multi-touch contacts and motions” to perform various operations on objects displayed on the screen. APPLE-1008, Abstract. These various multi-touch user inputs include

an input in which a user uses their index finger 108 and thumb 110 to make a “pinch” or “de-pinch” motion with respect to one or more displayed objects that causes the user interface to change the dimension of the object such as by zooming the displayed view in or out. APPLE-1008, 4:40-47, 7:63-64, 8:2-3. Figure 1 shows an example of such a gesture (in this case a de-pinching gesture):



APPLE-1008, Figure 1.

2. The combination of Bailey, D’Angelo, and Ording

184. There are multiple reasons that would have prompted a POSITA to apply the teachings of Ording to the pulse oximeter system of Bailey (as modified

by D'Angelo). A POSITA would have predictably applied Ording to the system of Bailey and D'Angelo to beneficially include multi-touch gesture detection to allow users to beneficially and intuitively zoom in and out of various displays of the resulting GUI.

185. Ording's disclosed method for expanding or compressing a display was disclosed well before the time of the '507 patent, and introduced to consumers as a feature in the iPhone, the iPod, the iPad and in other smartphones and displays. APPLE-1004, 22 ("iPod Touch"), 26, 47, 48. A POSITA at the time of the '507 would certainly have been aware of this invention, and would probably also have had significant direct personal experience with this function.

186. As a first reason, a POSITA would have recognized that smartphones, such as the iPhone disclosed by Bailey and D'Angelo included touchscreen interfaces for detecting user input via contact with the screen. APPLE-1007, 1530; APPLE-1004, 14, 20, 22, 23, 26, 47, 48, 55, and 62-63. Furthermore, Ording describes additional details on how to use a touchscreen interface to manipulate displayed information and navigate GUIs and therefore a POSITA would have turned to Ording to add additional beneficial functionality to the resulting system. APPLE-1008, 1:56-60, 4:14-47, 7:61-67, 8:2-3.

187. As a second reason, a POSITA would have recognized that providing functionality to allow users to zoom in and out by performing a de-pinching or

pinching gesture, as described by Ording, would have provided a quick and easy way for users to view the displayed physiological parameter information in a desired way (e.g., by looking at a zoomed in detailed portion of Bailey's and D'Angelo's graphs, or zooming out to see a trend over a larger time period). This would have been especially helpful for users with vision problems or with out of date glasses prescriptions, thereby increasing the overall utility of the resulting system.

188. As a third reason, a POSITA would have known that by 2012, touchscreen smart phones were in common use and therefore the additional touch-based GUI functionality described by Ording would have been straightforward and familiar to users. De-pinching and pinching to perform zoom in and out functions would have been an intuitive action for many users, thereby increasing ease of use of the resulting system.

189. As a fifth reason, a POSITA would have been prompted to implement the SpO2 and physiological parameter monitoring system of Bailey and D'Angelo to include additional touchscreen user interface functionality, including de-pinching and pinching gestures to zoom in and zoom out (as suggested by Ording) because doing so would be merely the application of a known technique to a known system (e.g., Bailey's pulse oximeter system as modified by D'Angelo) ready for improvement to yield predictable results. Here, Ording provides

straightforward evidence of known techniques for receiving user input via a touchscreen to manipulate a GUI display, and the combination of Bailey and D'Angelo provides a known system having a touchscreen display device that would have been improved by application of Ording's suggested technique for at least the reasons described above.

190. Based upon my knowledge and experience in this field and my review of Bailey, D'Angelo, and Ording, I am confident a POSITA would have recognized that such a modification would have yielded predictable results, and these modifications would have been within the predictable and ordinary level of skill of a POSITA. Thus, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying Ording's teachings to the system of Bailey and D'Angelo.

3. Application of Bailey, D'Angelo, and Ording to Claim 3

(i) Claim 3

[3] The mobile pulse oximetry system of claim 2, wherein the display is touch-sensitive, and wherein the application is configured to execute commands to narrow or expand the displayed results of the trend analysis in response to the user using a pinch gesture.

191. Bailey in view of D'Angelo and Ording provides that the display is touch-sensitive, and wherein the application is configured to execute commands to narrow or expand the displayed results of the trend analysis in response to the user using a pinch gesture. Both Bailey and D'Angelo disclose that the resulting

mobile device (Bailey's smartphone, as disclosed alone or modified by D'Angelo's teachings) includes "a touch display" and that the resulting device is configured to receive touch input ("[t]aping and wiping") that allows users to interact with the displayed physiological parameter information, including the graph of SpO₂ values over time. APPLE-1007, 1530-31; APPLE-1004, 14, 20, 22, 23, 26, 47, 48, 55, and 62-63.

192. Ording provides the additional details that the resulting mobile device (smartphone) would have included functionality for zooming in and out using de-pinching and pinching touch inputs. APPLE-1008, 4:14-47, 7:61-67, 8:2-3, 9:24-29. A POSITA would have applied Ording to the combination of Bailey with D'Angelo for the reasons described above to allow for zooming in and out (narrow and expand) the displayed graph of SpO₂ values included in Bailey's GUI or D'Angelo's Graph view using a pinch gesture in the resulting combination. A POSITA would have recognized that such zooming in or out provides narrowing or expanding the displayed results of the trend analysis in response to the user using a pinch gesture.

F. [GROUND 1F] – CLAIMS 4-6, 8, 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, D'ANGELO, AND TRAN

193. I provided an overview of Tran and described how a POSITA would have applied the teachings of Tran to Bailey above. A POSITA would have applied the teachings of Tran to the combination of Bailey with D'Angelo in the

same manor and for the same reasons as I discussed in Ground 1B. The resulting combination renders claims 4-6, 8, 16, 18, and 20 obvious.

(i) Claim 4

[4] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to set reminders to take future measurements.

194. Bailey in view of D'Angelo and Tran provides that the application is configured to execute commands to set reminders to take future measurements for the reasons that I discussed with respect to claims [16] and [20] in Ground 1B, above.

(ii) Claim 5

[5] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to output one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values.

195. Bailey in view of D'Angelo and Tran provides that the application is configured to execute commands to output one or more alarms associated with SpO₂ measurement values that are above or below threshold SpO₂ measurement values for the reasons that I discussed with respect to claim [15] in Ground 1A, above.

(iii) Claim 6

[6] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to output one or more reminders to use the optical sensor to take measurements of SpO₂ measurement values at predetermined times or cycles.

196. Bailey in view of D'Angelo and Tran provides that the application is configured to execute commands to output one or more reminders to use the optical sensor to take measurements of SpO₂ measurement values at predetermined times or cycles for the reasons that I discussed with respect to claim [16] in Ground 1B, above.

(iv) Claim 8

[8] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to output an alert, via a network to a designated physician or other care provider, regarding abnormal SpO₂ readings.

197. Bailey in view of D'Angelo and Tran provides that the application is configured to execute commands to output an alert, via a network to a designated physician or other care provider, regarding abnormal SpO₂ readings for the reasons that I discussed with respect to claim [18] in Ground 1B, above.

(v) Claim 16

[16] The computer-implemented method of claim 13, further comprising, via the application, outputting one or more reminders to use the optical sensor to take measurements of SpO₂ measurement values at predetermined times or cycles.

198. Bailey in view of D'Angelo and Tran provides that the application outputs one or more reminders to use the optical sensor to take measurements of

SpO₂ measurement values at predetermined times or cycles for the reasons that I discussed with respect to claim [16] in Ground 1B, above.

(vi) Claim 18

[18] The computer-implemented method of claim 13, further comprising, via the application, outputting an alert, via a network to a designated physician or other care provider, regarding abnormal SpO₂ readings.

199. Bailey in view of D'Angelo and Tran provides that the application outputs an alert, via a network to a designated physician or other care provider, regarding abnormal SpO₂ readings for the reasons that I discussed with respect to claim [18] in Ground 1B, above.

(vii) Claim 20

[20] The computer-implemented method of claim 13, further comprising, via the application, enabling the user to set reminders to take future measurements.

200. Bailey in view of D'Angelo and Tran provides that the application enables the user to set reminders to take future measurements for the reasons that I discussed with respect to claim [20] in Ground 1B, above.

**G. [GROUND 1G] – CLAIMS 2, 7, 14, AND 17 ARE
OBVIOUS OVER BAILEY, D'ANGELO, AND KIANL**

201. I provided an overview of Kianl and described how a POSITA would have applied the teachings of Kianl to Bailey above. A POSITA would have applied the teachings of Kianl to the combination of Bailey with D'Angelo in the same manor and for the same reasons as I discussed in Ground 1C. The resulting combination renders claims 2, 7, 14, and 17 obvious.

(i) Claim 2

[2] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to: perform a trend analysis on received SpO₂ measurement values; and display results of the trend analysis in at least one portion of the plurality of display portions.

202. Bailey in view of D'Angelo and Kianl provides that the application is configured to execute commands to perform a trend analysis on received SpO₂ measurement values and display results of the trend analysis in at least one portion of the plurality of display portions for the reasons that I discussed with respect to claim [14] in Ground 1A and Ground 1C, above.

(ii) Claim 7

[7] The mobile pulse oximetry system of claim 1, wherein the application is configured to execute commands to update the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts.

203. Bailey in view of D'Angelo and Kianl provides that the application is configured to execute commands to update the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts for the reasons that I discussed with respect to claim [17] in Ground 1C, above.

(iii) Claim 14

[14] The computer-implemented method of claim 13, further comprising, via the application: performing a trend analysis on received SpO₂ measurement values; and displaying results of the trend analysis in at least one portion of the plurality of display portions.

204. Bailey in view of D'Angelo and Kianl provides that the application is configured to perform a trend analysis on received SpO₂ measurement values and display results of the trend analysis in at least one portion of the plurality of display portions for the reasons that I discussed with respect to claim [14] in Ground 1A and Ground 1C, above.

(iv) Claim 17

[17] The computer-implemented method of claim 13, further comprising, via the application, updating the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts.

205. Bailey in view of D'Angelo and Kianl provides that the application is configured to update the representation of the physiological parameter to comprise one or more of a plurality of graphical representations of the SpO₂ measurement values, the plurality of graphical representations comprising at least one of bar graphs or charts for the reasons that I discussed with respect to claim [17] in Ground 1C, above.

**H. [GROUND 1H] – CLAIM 3 IS OBVIOUS OVER BAILEY,
D’ANGELO, KIANL, AND ORDING**

206. I provided an overview of Ording and described how a POSITA would have applied the teachings of Ording to the combination of Bailey and D’Angelo above. A POSITA would have applied the teachings of Ording to the combination of Bailey with D’Angelo and Kianl in the same manor and for the same reasons as I discussed in Ground 1E. The resulting combination renders claim 3 obvious.

(i) Claim 3

[3] The mobile pulse oximetry system of claim 2, wherein the display is touch-sensitive, and wherein the application is configured to execute commands to narrow or expand the displayed results of the trend analysis in response to the user using a pinch gesture.

207. Bailey in view of D’Angelo and Kianl provides that the display is touch-sensitive, and wherein the application is configured to execute commands to narrow or expand the displayed results of the trend analysis in response to the user using a pinch gesture for the reasons that I discussed with respect to claim [3] in Ground 1E, above. Specifically, a POSITA would have applied Ording to the predictable combination of Bailey with D’Angelo and Kianl to allow zooming in and out of Kianl’s trend analysis views displaying various views of SpO₂ information (as discussed in Ground 1C, *supra*) using a pinch gesture (as disclosed by Ording) to achieve the same benefits that I previous discussed in Ground 1E, above, with respect to Bailey’s graph and D’Angelo’s Graph view. APPLE-1008,

4:14-47, 7:61-67, 8:2-3, 9:24-29. A POSITA therefore would have recognized that the predictable combination of Bailey with D’Angelo, Kianl, and Ording provides claim 3.

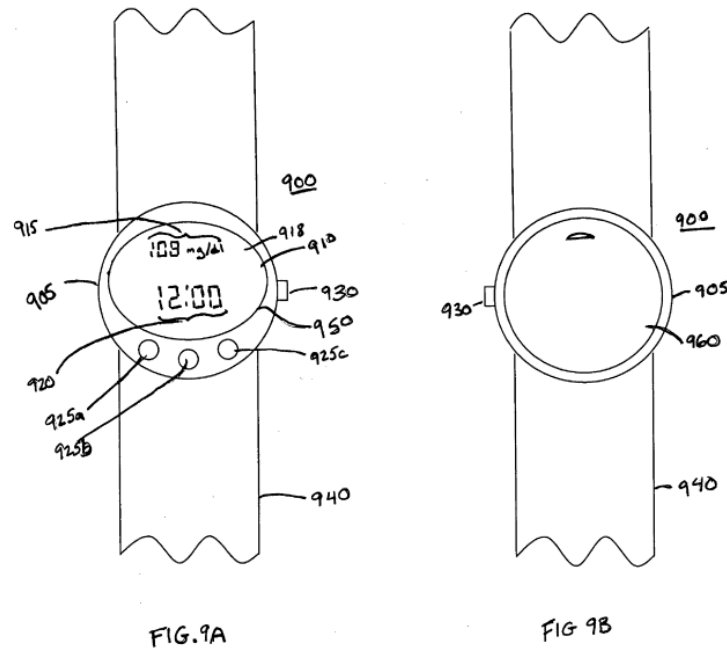
I. [GROUND 1I] – CLAIMS 10 AND 11 ARE OBVIOUS OVER BAILEY, D’ANGELO, AND GOLDSMITH

208. The sections below provide a brief introduction to Goldsmith and its combination with Bailey and D’Angelo.

1. Goldsmith discloses a display device for a physiological monitoring system implemented as a wearable wristwatch.

209. Goldsmith generally describes an infusion system that includes “a watch controller device and a communication system to transmit the communications from the watch controller device” and an infusion system.

APPLE-1009, Abstract. The watch controller provides “convenient ***monitoring*** and control” of the infusion system. *Id.* For example, Goldsmith describes a medical watch controller device 900. APPLE-1009, [0085], [0095], [0098], [0104], [0010], claim 6, FIGS. 9A, 9B.



APPLE-1009, Figures 9A and 9B.

210. As illustrated in Goldsmith's Figures 9A and 9B reproduced above, the wrist watch display device 900 can be "used with any number of...diagnostic devices" and sensors to obtain various physiological measurements, such as user oxygen level. APPLE-1009, [0037], [0038]. The controller device 900 includes a wrist band 940 that enables it to be worn "like a watch." APPLE-1009, [0082]-[0085], [0095], claims 25, 26, 27.

211. In more detail, Goldsmith's device 900 includes a display 910 for displaying data "received from a sensor transmitter on the patient's skin," from "any number of therapy/diagnostic devices," and/or from user input. APPLE-1009, [0082], [0087], [0095], [0102]. Goldsmith's device can, for example, conveniently monitor and display "concentration, levels, or quantities

of...oxygen.” APPLE-1009, [0014], [0037], [0038]. A POSITA would have recognized this disclosure of monitoring the concentration of oxygen in a user’s blood as indicating measurement and monitoring of blood oxygenation levels (SpO₂) such as through pulse oximetry.

2. The Combination of Bailey, D’Angelo, and Goldsmith.

212. There are multiple reasons that would have prompted a POSITA to apply the teachings of Goldsmith to the pulse oximeter system of Bailey (as modified by D’Angelo). A POSITA would have predictably applied Goldsmith to the system of Bailey and D’Angelo to beneficially implement the display device (Bailey’s smartphone alone or as modified by D’Angelo’s teachings) as a wearable wristwatch.

213. As a first reason, a POSITA would have recognized that implementing the display device of the system resulting from the combination of Bailey with D’Angelo as a wristwatch would have made the display device easier to carry and thus increased portability of the display device. Bailey discloses that its system is intended for use in monitoring physiological parameters of users in motion. For example, Bailey’s pulse oximeter is “intended to be worn by a person” and “needed to be durable enough to handle the daily rigors of being worn by an adult or child.” APPLE-1004, 14, 8. A POSITA would have recognized that implementing the display device as a wrist watch (worn either by users or other

monitored users such as child) would have made the resulting display device easier to transport and therefore easier to use in emergency scenarios and situations involving motion of the user.

214. As a second reason, implementing the display device of the system resulting from the combination of Bailey with D'Angelo as a wristwatch would have freed up the user's hands for performing other tasks. Having the display device on the user's wrist would have meant that the user would not need to use one or both hands to hold the display device. Freeing up the user's hands to perform other tasks would have been especially helpful in the case of parents or other caregivers who would need to perform other care tasks during the measurement described by Bailey.

215. As a third reason, implementing the display device of the system resulting from the combination of Bailey with D'Angelo as a wristwatch would have made the display device always out and available. Therefore, the user would not need to retrieve the display device from a pocket, backpack, or bag to view the display physiological parameters. This would have increased the ease of use of the resulting system.

216. As a fourth reason, a POSITA would have known that smart watches were increasing in wide-spread use by 2012 and therefore implementing the display device of the system resulting from the combination of Bailey with

D'Angelo as a wristwatch would have added extra functionality to devices already owned by many consumers, therefore increasing the utility of such devices.

217. As a fifth reason, a POSITA would have been prompted to implement Bailey's pulse oximeter system (as modified by D'Angelo) to implement the display device as a wristwatch (as suggested by Goldsmith) because doing so would be merely the application of a known technique to a known system (e.g., Bailey's pulse oximeter system as modified by D'Angelo) ready for improvement to yield predictable results. Here, Goldsmith provides straightforward evidence of known techniques for implementing a display device in a physiological monitoring system as a wristwatch, and Bailey's teaching provides a known system that would have been improved by application of Goldsmith's suggested technique for at least the reasons described above.

218. Based upon my knowledge and experience in this field and my review of Bailey, D'Angelo, and Goldsmith, I am confident a POSITA would have recognized that such a modification would have yielded predictable results, and these modifications would have been within the predictable and ordinary level of skill of a POSITA. For example, Goldsmith describes that its controller device (which can be implemented as a wristwatch) displays data "received from a sensor transmitter on the patient's skin," and "any number of therapy/diagnostic devices," and/or from user input. APPLE-1009, [0082]-[0087], [0095], [0102]. This includes

monitoring and displaying “concentration, levels, or quantities of...oxygen.”

APPLE-1009, [0014], [0037], [0038]. Goldsmith’s controller further includes “a touchscreen display.” APPLE-1009, [0086]. Goldsmith also describes “giving the controller device cellular telephone or pager capabilities” and therefore the wristwatch implementation for the display device in the resulting system would have had all of the cellular capabilities (and the resulting benefits) that I discussed above with respect to the application of D’Angelo to Bailey. APPLE-1009, [0016], [0068]. Based on these various disclosures of Goldsmith, a POSITA would have recognized that Goldsmith is fully compatible with the system resulting from the combination of Bailey with D’Angelo that I described in Ground 1D.

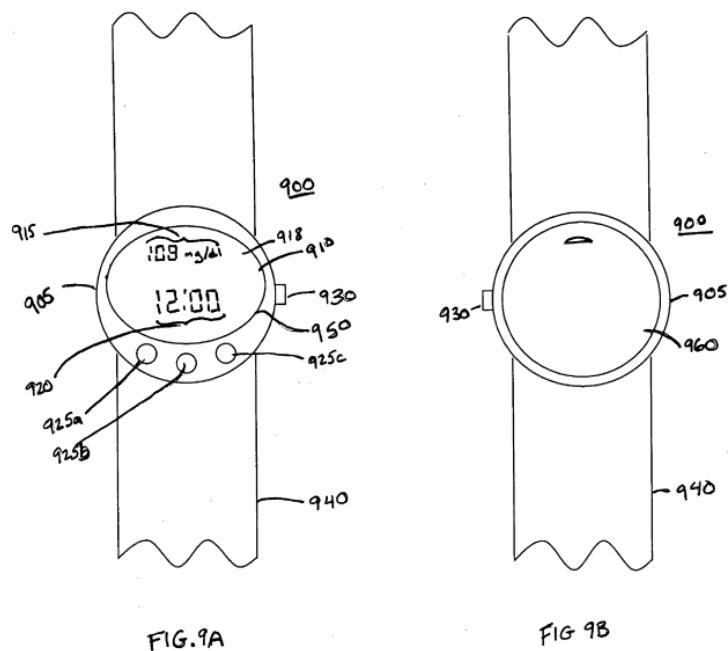
Furthermore, a POSITA would have recognized that implementing the wristwatch display device described by Goldsmith to provide a power output pin for the digital signal processing system/management device (*processing board*) would have achieved the same benefits of allowing read out even when the digital signal processing system’s battery is empty that I discussed in Ground 1D. APPLE-1007, 1530. Therefore, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying Goldsmith’s teachings to the system of Bailey and D’Angelo.

3. Application of Bailey, D’Angelo, and Goldsmith to Claims 10 and 11

(i) Claim 10

[10] The mobile pulse oximetry system of claim 1, wherein the mobile computing device comprises a wearable computing device.

219. In the predictable combination of Bailey, D’Angelo, and Goldsmith, the mobile computing device “may be a wrist-worn device, such as a watch. The controller device may also be a watch that can be carried on other parts of the body or clothing, such as the ankle, neck (e.g., on a chain), pocket, or ankle.” APPLE-1009, [0010]. In another example, Goldsmith discloses that the “remote display” can be a “watch remote[.]” APPLE-1009, [0050]. Goldsmith describes that “[a] watch may be considered a more socially acceptable embodiment of a controller device, because it is common for people to wear watches, making it less noticeable that a user is using an infusion pump and/or analyte monitor. Because watches beep or otherwise alarm, it is less noticeable when a watch alarms to indicate high or low glucose, infusion pump occlusion, or other alarm occurrences.” APPLE-1009, [0085]. The watch is configured to display blood oxygen concentration. APPLE-1009, [0037]-[0038].



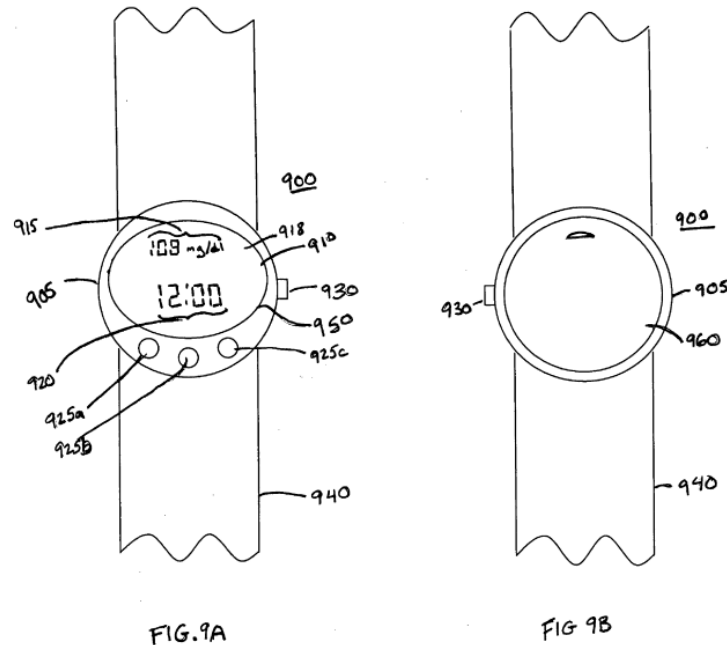
APPLE-1009, Figures 9A and 9B.

(ii) Claim 11

[11] The mobile pulse oximetry system of claim 1, wherein the mobile computing device comprises a wristwatch.

220. In the predictable combination of Bailey, D'Angelo, and Goldsmith, the mobile computing device “may be a wrist-worn device, such as a watch.” APPLE-1009, [0010]. In another example, Goldsmith discloses that the “remote display” can be a “watch remote[.]” APPLE-1009, [0050]. Goldsmith describes that “[a] watch may be considered a more socially acceptable embodiment of a controller device, because it is common for people to wear watches, making it less noticeable that a user is using an infusion pump and/or analyte monitor. Because watches beep or otherwise alarm, it is less noticeable when a watch alarms to indicate high or low glucose, infusion pump occlusion, or other alarm

occurrences.” APPLE-1009, [0085]. The watch is configured to display blood oxygen concentration. APPLE-1009, [0037]-[0038].



APPLE-1009, Figures 9A and 9B.

J. [GROUND 2A] – CLAIMS 13-15 AND 19 ARE OBVIOUS OVER BAILEY AND MOON

221. As I discussed above in Grounds 1A-1I, I believe that all claims of the '507 patent are either anticipated or rendered obvious by the various reference combinations that I described in Grounds 1A-1I. However, I have been asked to review each combination from Grounds 1A-1I in additional combination with Moon (APPLE-1010) with respect to each of the claims. It is my opinion that each of the combinations described with respect to Grounds 2A-2I, which rely on Bailey in view of Moon (and one or more additional references for Grounds 2B-2I) render obvious each of the claims of the '507 patent.

222. Specifically, to the extent that the preambles of independent claims 1 and 13 are interpreted such that the term “mobile measurement of oxygen saturation (‘SpO₂’)” is believed to require active reduction and/or correction of motion artifacts caused by user motion, Moon provides this additional disclosure and would have been predictably and beneficially added to the previously discussed prior art combinations to achieve resulting systems that provide each of the challenged claim elements.

1. Moon describes reduction and/or correction of motion artifacts caused by user motion

223. Moon describes “a body-worn system that continuously measures pulse oximetry and blood pressure, along with motion, posture, and activity level, from an ambulatory patient.” APPLE-1010, Abstract. Moon describes that “pulse oximetry can be extremely sensitive to a patient’s motion. Activities such as walking, finger tapping, falling, and convulsing can result in a number of artifacts that distort both the AC and DC components of waveforms measured with the oximeter’s optical system.” APPLE-1010, [0011]. Moon’s system includes motion-detecting sensors, such as accelerometers to monitor movement of the patient. APPLE-1010, [0015]. Moon describes that this monitored patient motion is “processed and used to exclude certain noise-corrupted artifacts from the SpO₂ calculation.” APPLE-1010, [0015]. Removal of these noise-corrupted artifacts

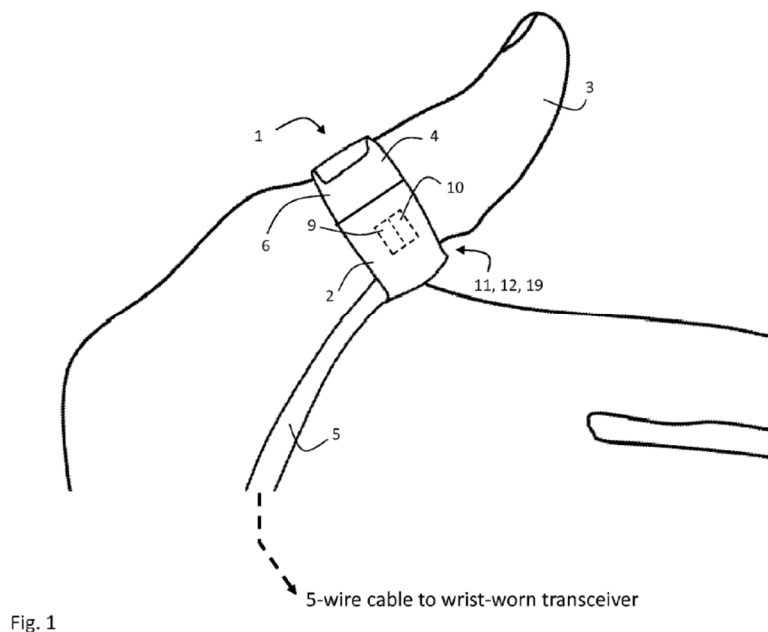
“can greatly enhance the accuracy” of measurements taken by the system. APPLE-1010, [0015].

224. Similar to the pulse oximetry system of Bailey, Moon’s pulse oximetry sensor system “features a first sensor with two radiation sources that emit optical radiation at first and second wavelengths, and a photodetector configured to detect the radiation after it passes through a portion of the patient.” APPLE-1010, [0018]. The system uses both the signals from the photodetector and signals from a motion sensor to determine SpO₂ and other “physiological propert[ies] of the patient’s blood.” APPLE-1010, [0018]. Moon describes various examples in which the system filters the PPG and PTT waveforms using detected motion of the patient to more accurately determine SpO₂. APPLE-1010, [0025], [0073]-[0074], [0089]-[0092]. Moon describes that “[t]he filter, for example, can be a matched filter, described in detail below.” APPLE-1010, [0025]. Moon goes on to describe that “if “motion is determined to be present, the algorithm proceeds to analyze both RED/IR(PPG) waveforms to determine if they are distorted in any way.” APPLE-1010, [0073].

225. If “a pulse is corrupted by noise” due to movement, the system “deploys a ‘matched filter’ to process both the RED/IR(PPG) waveforms to maximize signal-to-noise ratios of the pulses therein.” APPLE-1010, [0089]. This allows Moon’s system to “determine accurate SpO₂ and cNIBP values even when

motion-related noise is present.” APPLE-1010, [0089]. Moon then goes on to provide a detailed description of how to correct for such motion induced noise. APPLE-1010, [0089]-[0092]. Moon’s motion correction techniques allow for “motion [to] be detected and accounted for during pulse oximetry measurements to minimize the occurrence of false alarms and, additionally, make accurate readings in the presence of motion.” APPLE-1010, [0082], [0089], [0102]-[0103].

226. Moon’s sensor includes secure straps 2 and 4 and a flexible cable 5 to “minimize[] motion relative to the measurement site.” APPLE-1010, [0060].



APPLE-1010, FIG. 1. While FIG. 1 shows a finger worn sensor, Moon explains that its system and techniques “can be modified to attach to other conventional sites for measuring SpO₂, such as the ear, forehead, and bridge of the nose.” APPLE-1010, [0138]. Moon further discusses using digital communication between

the system components to further reduce signal noise caused by motion. APPLE-1010, [0130].

2. The combination of Bailey and Moon

227. There are multiple reasons that would have prompted a POSITA to apply the teachings of Moon to the pulse oximeter system of Bailey to correct for the effects of motion on vital sign readings, including SpO₂ and to filter out noise caused by user motion from such readings.

228. As a first reason, a POSITA would have recognized that in user worn pulse oximetry systems, “[a]ctivities such as walking, finger tapping, falling, and convulsing can result in a number of artifacts that distort both the AC and DC components of waveforms measured with the oximeter’s optical system.” APPLE-1010, [0011]. Moon explains that this motion of the patient can cause motion artifacts in sensed signals which “can cause the pulse oximeter to generate inaccurate values and false alarms.” APPLE-1010, [0011], [0078]. As I’ve previously discussed, Bailey discloses that its system is intended for use in monitoring physiological parameters of users in motion. For example, Bailey’s pulse oximeter is “intended to be worn by a person” and “needed to be durable enough to handle the daily rigors of being worn by an adult or child.” APPLE-1004, 14, 8. A POSITA therefore would have recognized that the teachings of Moon would have been beneficially applied to Bailey’s system to both reduce the

effects of motion on the measured signals and to filter noise caused by such motion to “greatly enhance the accuracy” of the detected vital signs. APPLE-1010, [0015], [0065]-[0066] (“...maximizes accuracy of the SpO2 calculation”), [0070], [0072], [0083], [0088]-[0089]. A POSITA would have therefore recognized that in the resulting system “the body-worn monitor can determine accurate SpO2 and cNIBP values even when motion-related noise is present.” APPLE-1010, [0089].

229. As a second reason, a POSITA would have recognized that pulse oximetry systems that only function accurately “when a patient is sedentary...are impractical for ambulatory patients...making it difficult to provide true continuous monitoring.” APPLE-1010, [0012]. As discussed above, Bailey’s system is intended for users in motion. APPLE-1004, 14, 8. A POSITA therefore would have recognized that applying Moon’s teachings to Bailey to account for noise caused by user motion would have allowed for “true continuous monitoring” of such users in motion. APPLE-1010, [0025], [0073]-[0074], [0082], [0089]-[0092], [0102]-[0103].

230. As a third reason, a POSITA would have recognized that applying Moon’s teachings to Bailey to reduce motion artifacts and account for signal noise caused by motion of the user would “minimize the occurrence of false alarms and, additionally, make accurate readings in the presence of motion.” APPLE-1010, [0082]. As Moon describes, such techniques can “greatly enhance the accuracy of

alarms/alerts.” APPLE-1010, [0015], [0076]. One of the features of Bailey is that the system issues “an alarm in the event that the blood oxygen level of the user fell below a safe level” and therefore increasing the accuracy of alerts would have improved the resulting system. APPLE-1004, 14, 47.

231. As a fourth reason, Bailey expressly discusses using “filters” for the measured sensor signals “[t]o limit the noise in the system.” APPLE-1004, 40, 18, 20, 22, 34-44. A POSITA would have recognized that Bailey expressly contemplates the well-known pulse oximetry principle where “two light emitting diodes (LEDs), one red and one infrared” are used to determine SpO₂. APPLE-1004, 10, 15-19, 22, 27-28, 31, 34, 45, 58, 59. Further, Bailey considers “reduc[ing] the signal noise due to motion artifact” within the measured waveforms and thus “increasing the detection accuracy” as one of the important goals. APPLE-1004, 22, 21 (Table 2 describing “Noise” and “Accuracy” as the most important characteristics), 37-42, 18. Therefore a POSITA would have looked to other references that disclose techniques for improving the accuracy of the signals from the LEDs by filtering noise. Moon describes that “the oximeter processes PPG waveforms measured with red (RED(PPG)) and infrared (IR(PPG)) wavelengths to determine time-dependent AC signals and time-independent DC signals,” and provides just such a teaching for filtering noise from the PPG waveforms caused by motion of the user. APPLE-1010, [0007], [0102]; APPLE-

1004, 50 (“the AC and DC components of the pulsatile waveform” in the measured signal). A POSITA therefore would have beneficially applied Moon to Bailey because Moon provides additional details on how to filter noise as contemplated by Bailey.

232. As a fifth reason, a POSITA would have been prompted to implement Bailey’s pulse oximeter system to correct for motion induced artifacts and signal noise (as described by Moon) because doing so would be merely the application of a known technique to a known system (e.g., Bailey’s pulse oximeter system) ready for improvement to yield predictable results. Here, Moon provides straightforward evidence of known techniques for correcting for motion induced artifacts and noise in a body-worn pulse oximetry system and Bailey’s teaching provides a known system that would have been improved by application of Moon’s suggested techniques for at least the reasons described above.

233. As a sixth reason, at the time of the ‘507 patent, a POSITA would have been aware of the availability of miniature, low-power and low-cost accelerometers being widely used in consumer electronic devices for monitoring motion. Additionally, a POSITA would have appreciated that addition of such an accelerometer to the system of Bailey would have been straightforward, and provided the benefits described by Moon without compromising the features described by Bailey.

234. Based upon my knowledge and experience in this field and my review of Bailey and Moon, I am confident a POSITA would have recognized that such a modification would have yielded predictable results, and these modifications would have been within the predictable and ordinary level of skill of a POSITA. Thus, a POSITA would have had a reasonable expectation of success in implementing such a combined system based on applying Moon's teachings to Bailey's system.

3. *Application of Bailey and Moon to Claims 13, 15, and 18-19*

(i) Claim 13

235. As I discussed in Ground 1A, Bailey provides all elements of claim 13. However, to the extent that the preamble of claim 13 is interpreted such that the term "mobile measurement of oxygen saturation ('SpO₂') " is believed to require active reduction and/or correction of motion artifacts caused by user motion, the predictable combination of Bailey and Moon provides the preamble [13pre]. The preamble of claim 13 recites:

A computer-implemented method of informing a user of mobile measurement of oxygen saturation ("SpO₂"), the computer-implemented method comprising:

236. Moon demonstrates that in the system resulting from the combination of Bailey with Moon, the pulse oximetry system includes "motion-detecting

sensors” to track various aspects of the patient’s motion. APPLE-1010, [0015].

This detected motion can “be processed and used to exclude certain noise-corrupted artifacts from the SpO₂ calculation” to “greatly enhance the accuracy” of vital sign measurements. APPLE-1010, [0015].

237. Both Moon and Bailey utilize an SpO₂ sensor that includes a photodetector to detect emitted light after it passes through a portion of the patient. APPLE-1004, 10-12, 15-20, 22-25, 27-34, 45-46, 52, 58-59, and 61; APPLE-1010, [0018]. Bailey and Moon also both contemplate that the sensor can be worn at the patient’s finger, ear, and other body extremity. APPLE-1004, 10, 24, 27, 53; APPLE-1010, [0010], [0138]. A POSITA would have applied the teachings of Moon to Bailey so that the processing performed by Bailey’s main circuitry housing (*processing board*) includes the motion correction techniques taught by Moon. In the resulting combination, Bailey’s digital signal processing system (as housed in the main circuitry housing), which processes the signals to generate the SpO₂ values, would have been configured to include a miniature accelerometer, and to use both the signals from the photodetector and signals from an accelerometer to determine SpO₂ and other “physiological propert[ies] of the patient’s blood.” APPLE-1010, [0018]. Moon goes on to describe filtering the PPG and PTT waveforms using detected motion of the patient to more accurately determine SpO₂. APPLE-1010, [0025], [0073]-[0074], [0089]-[0092].

238. Moon's described techniques allow for "motion [to] be detected and accounted for during pulse oximetry measurements to minimize the occurrence of false alarms and, additionally, make accurate readings in the presence of motion." APPLE-1010, [0082]. In one example, if "a pulse is corrupted by noise" due to movement the system "deploys a 'matched filter' to process both the RED/IR(PPG) waveforms to maximize signal-to-noise ratios of the pulses therein" to allow the system to "determine accurate SpO2 and cNIBP values even when motion-related noise is present." APPLE-1010, [0088]-[0089]. Moon further describes a weighted average signal processing technique when "profound motion is present" that "would likely yield a SpO2 value with suitable accuracy." APPLE-1010, [0088]-[0089]. Paragraph 75 of Moon provides another example of a technique for determining SpO2 even when the user is in motion. APPLE-1010, [0075].

239. In yet another example, a "wrist-worn accelerometer" measures user motion and collected data is "analyzed to estimate the effects of specific motions and activities on the ECG and PPG waveforms, and then deconvolute these factors using known mathematical techniques to *effectively remove any motion-related artifacts*." APPLE-1010, [0102]. These "deconvoluted ECG and PPG waveforms can then be used to calculate vital signs." *Id.* For example, PPG waveforms are "used to determine SpO2." APPLE-1010, [0121]; APPPLE-1004, 10, 22-23.

240. As I previously discussed at Ground 1A, Bailey's pulse oximeter design is "intended primarily for consumer user" and provides "the ability to communicate data to a smartphone or other portable device" so that the device can be made "smaller by not needing to incorporate a display and user interface on the oximeter itself." APPLE-1004, 8. Further, Bailey's pulse oximeter is "intended to be worn by a person" and "needed to be durable enough to handle the daily rigors of being worn by an adult or child." APPLE-1004, 14. Bailey's pulse oximeter system needs to be "as small and as lightweight as possible." APPLE-1004, 27. Due to its small form factor and portable nature, it would have been apparent and obvious that Bailey's pulse oximeter is adapted for mobile measurement of oxygen saturation.

241. Further, Bailey's system includes a mobile device (e.g., iPhone), which is in data communication with the "digital signal processing system," runs an application and includes a display, thereby implementing a ***computer-implemented method***. APPLE-1004, 23, 47-48, Figure 32. Bailey's mobile device implements an user interface to "display the recorded data from the microcontroller via wireless interface." APPLE-1004, 47. Further, Bailey's mobile device is designed to "warn of dangerously low oxygen conditions." APPLE-1004, 47. Therefore, Bailey in view of Moon provides a computer-implemented method of informing a user of mobile measurement of SpO₂.

242. All other elements of claims 13 are provided by the combination of Bailey with Moon for the reasons that I discussed with respect to claim 13 in Ground 1A, above.

(ii) Claims 14, 15, and 19

243. All additional elements of claims 14, 15, and 19 are provided by the combination of Bailey with Moon for the reasons that I discussed in Ground 1A, above.

K. [GROUND 2B] – CLAIMS 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, MOON, AND TRAN

244. A POSITA would have been prompted to apply the teachings of Tran to the combination of Bailey and Moon in the same manner and for the same reasons discussed with respect to Ground 1B, above. The predictable combination of Tran with Bailey and Moon provides all additional elements of claims 16, 18, and 20 for the reasons discussed in Ground 1B.

L. [GROUND 2C] – CLAIMS 14 AND 17 ARE OBVIOUS OVER BAILEY, MOON, AND KIANL

245. A POSITA would have been prompted to apply the teachings of Kianl to the combination of Bailey and Moon in the same manner and for the same reasons discussed with respect to Ground 1C, above. The predictable combination of Kianl with Bailey and Moon provides all additional elements of claims 14 and 17 for the reasons discussed in Ground 1C.

M. [GROUND 2D] – CLAIMS 1-2, 5, 7, 9, 12-15, 17, AND 19 ARE OBVIOUS OVER BAILEY, MOON, AND D’ANGELO

246. A POSITA would have been prompted to apply the teachings of D’Angelo to the combination of Bailey and Moon in the same manner and for the same reasons discussed with respect to Ground 1D, above. The predictable combination of D’Angelo with Bailey and Moon provides all additional elements of claims 1-2, 5, 7, 9, 12-15, and 17-19 for the reasons discussed in Ground 1D.

N. [GROUND 2E] – CLAIM 3 IS OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND ORDING

247. A POSITA would have been prompted to apply the teachings of Ording to the combination of Bailey, Moon, and D’Angelo in the same manner and for the same reasons discussed with respect to Ground 1E, above. The predictable combination of Ording with Bailey, Moon, and D’Angelo provides all additional elements of claim 3 for the reasons discussed in Ground 1E.

O. [GROUND 2F] – CLAIMS 4-6, 8, 16, 18, AND 20 ARE OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND TRAN

248. A POSITA would have been prompted to apply the teachings of Tran to the combination of Bailey, Moon, and D’Angelo in the same manner and for the same reasons discussed with respect to Grounds 1B and 1F, above. The predictable combination of Tran with Bailey, Moon, and D’Angelo provides all

additional elements of claims 4-6, 8, 16, 18, and 20 for the reasons discussed in Grounds 1B and 1F.

P. [GROUND 2G] – CLAIMS 2, 7, 14, AND 17 ARE OBVIOUS OVER BAILEY, MOON, D’ANGELO, AND KIANL

249. A POSITA would have been prompted to apply the teachings of Kianl to the combination of Bailey, Moon, and D’Angelo in the same manner and for the same reasons discussed with respect to Grounds 1C and 1G, above. The predictable combination of Kianl with Bailey, Moon, and D’Angelo provides all additional elements of claims 2, 7, 14, and 17 for the reasons discussed in Grounds 1C and 1G.

Q. [GROUND 2H] – CLAIM 3 IS OBVIOUS OVER BAILEY, MOON, D’ANGELO, KIANL, AND ORDING

250. A POSITA would have been prompted to apply the teachings of Ording to the combination of Bailey, Moon, D’Angelo, and Kianl in the same manner and for the same reasons discussed with respect to Grounds 1E and 1H, above. The predictable combination of Ording with Bailey, Moon, D’Angelo, and Kianl provides all additional elements of claim 3 for the reasons discussed in Grounds 1E and 1H.

**R. [GROUND 2I] – CLAIMS 10 AND 11 ARE OBVIOUS
OVER BAILEY, MOON, D’ANGELO, AND
GOLDSMITH**

251. A POSITA would have been prompted to apply the teachings of Goldsmith to the combination of Bailey, Moon, and D’Angelo in the same manner and for the same reasons discussed with respect to Ground 1I, above. The predictable combination of Goldsmith with Bailey, Moon, and D’Angelo provides all additional elements of claims 10 and 11 for the reasons discussed in Ground 1I.

VI. CONCLUSION

252. I reserve the right to supplement my opinions to address any information obtained, or positions taken, based on any new information introduced throughout this proceeding.

253. I declare under penalty of perjury that the foregoing is true and accurate to the best of my ability.

APPENDIX A

Thomas W. Kenny

Department of Mechanical Engineering, Stanford University, Stanford, CA 94305-4021

Home : 2820 Greenwich St #2, San Francisco, CA 94123

(415) 725-3805 kenny@cdr.stanford.edu

Education

- University of California, Berkeley
Ph D Physics June 1989
- University of Minnesota, Minneapolis
BS Physics March 1983

Experience

Senior Associate Dean of Engineering for Student Affairs, Stanford. 7/15-present.

Director, Founder, recent CEO, BoD Member, Applaud Medical 11/14-present.

- Non-invasive therapy for Kidney Stones using unfocused energy and Acoustic Enhancer
- Appointed as CEO 2/2020, leading effort to launch Pivotal FDA Clinical Trial.

Founder, Member, Board of Directors, Chair of Technical Advisory Board, SiTime 8/04-11/14

- CMOS-Compatible MEMS Resonators for Electronic Products.
- SITM on Nasdaq, >\$2B Market Cap, World-leading supplier of MEMS-based oscillators

CTO and Founder Cooligy, 6/02-3/05

- Liquid cooling of microprocessors and other high power-density electronic devices.

Program Manager, DARPA Microsystems Technology Office, 10/06-10/10

- Launched \$250M program on Nanotechnology, Thermal Management and Nanomanufacturing.

Professor, Department of Mechanical Engineering, Stanford University, 1/94-Present

- Leading Micromechanical Systems Research Group, with emphasis on development of high-performance microsensors, and measurements of fundamental properties of microstructures.
- Active research in Micromechanical Resonators for Time References, Encapsulated Inertial Sensors, Optimal Design of MEMS Structures, Wafer-Scale Packaging of MEMS Devices.
- Teaching Mechatronics, Sensors and Measurement, and others

Staff Scientist, Technical Group Leader, Jet Propulsion Laboratory, 7/89-1/94.

- Led the design, construction, and characterization of novel micromachined Si infrared detectors magnetometers and accelerometers based on a novel displacement transducer.
- Participated in development of meteorological instrumentation (pressure, wind, temperature, humidity,...), seismological instrumentation, deformable optical elements, instrumented neurological probes, soil chemistry apparatus, calibration parts for space telescopes,...

Research Assistant, Physics Department, University of California, Berkeley. 1/84-7/89.

- Measured of the heat capacity of ^4He submonolayers on metallic films, showing them to be in a 2-dimensional Bose gas phase, in contradiction to similar measurements on other substrates.

Honors

- | | | |
|-------------|---|--------------|
| • Recipient | Elected to the National Academy of Engineering | 2/22 |
| • Recipient | Stanford Presidential Award for Excellence in Diversity | 6/19 |
| • Recipient | Tau Beta Pi Teaching Honor Roll | 6/19 |
| • Recipient | IEEE Daniel Noble Award for Emerging Technologies | 9/18 |
| • Recipient | IEEE Sensors Council Technical Achievement Award | 9/11 |
| • Winner | Coed Ultimate Frisbee National and World Champion | 11/98, 11/99 |
| • Recipient | NSF CAREER Award | 7/95 |
| • Recipient | R+D 100 Award | 5/93 |
| • Recipient | Distinguished Teaching Award | 6/89 |
| • Recipient | AT&T Bell Laboratories Fellowship | 8/86-6/89 |

Litigation Experiences

- 2022 retained as Expert Witness by Apple to prepare IPR responses and declarations for patents related to noise cancellation. Two of these cases has been instituted for IPR, and others are pending decision. There have been reports, settlements and joinders involving multiple parties, with the current clients being Sony, Meta and LG.
- 2021 retained as Expert Witness by Apple for IPR challenge of a pair of patents describing use of inertial sensors for monitoring of posture and movement of humans for diagnostics and training. Reports were prepared, and the board recently ruled all claims of both patents invalid.
- 2020 retained as Expert Witness by Apple in multiple patents related to design of optical physiological monitors. IPRs were initially instituted against all thirteen challenged patents. Subsequent work included preparation and submission of reports and responses, and numerous depositions. In a string of final written decisions that issued from February through May 2022, the patent board invalidated all but one challenged claim of the thirteen patents, subsequent appeals were recently resolved. There is ongoing work here related to more recent patent challenges by both sides.
- 2019 retained as Expert witness in case related to wearable baby monitors, including motion and temperature sensors. Case settled during drafting of expert infringement report.
- 2018, retained as Expert witness by attorneys representing Apple in a case related to algorithms for sensing motion and other physiological parameters in wearable devices,. Case settled after going on hold for IPR evaluation of IP.
- 2016, Expert Witness in case involving optical proximity sensors in smartphones. I was retained by HTC America and Capella, who were defendants in the case. I was compensated by defendants for work involving Invalidity and Non-Infringement reports, and was deposed after expert reports on invalidity and non-infringement. This case settled just a few weeks before trial in march 2017. This was Case Action No. 2:15-cv-1524-JRG in Marshall Texas.
- 2015, Expert Witness in Mayfonk –vs- Nike patent infringement suit brought by Mayfonk. I prepared expert reports on validity and non-infringement. The case settled just before depositions were taken. I was compensated by Nike for this work. This was case # Civil No.3:14-cv-00423-MO in the District of Oregon.
- 2013-2014, Expert Witness in ST Microelectronics –vs- Invensense patent infringement suit brought in the ITC by ST. I assisted in claim construction, prepared expert reports on claim construction, validity and infringement, and provided deposition testimony. This case settled after opening statements. I was compensated by Invensense for this work. This was ITC Investigation # 337-TA-876.
- 2011-2012, Expert Witness in St. Jude Medical-vs-Volcano Corp patent infringement suit and counter suit. Assisted in claim construction, prepared expert reports, provided deposition testimony and trial testimony. I was compensated by Volcano Corporation for this work.
- 2011, Retained by Maxim Integrated Systems to examine documents and prepare opinions as to the value of certain documents in the possession of former employees of ST Microelectronics. I was compensated by Maxim for this work. This was Italian proceeding Rg. 50253/2011.

Books :

J.E. Carryer, M.Ohline and T.W. Kenny, “Introduction to Mechatronic Design”, Pearson (2011).

Refereed Journal Publications:

1. J. Sun, S. Yu, H. Zhang, D. Chen, X. Zhou, C. Zhao, **D.D. Gerrard, H-K Kwon, G. Vukasin**, D. Xiao, T.W. Kenny, X. Wu, A. Seshia, “Generation and Evolution of Phononic Frequency Combs via Coherent Energy Transfer Between Mechanical Modes”, Physical Review Applied 19, 014031 (2023)
2. G. Margiani, S. Guerrero, T.L Heugel, C. Marty, R. Pachlatko, T. Gisler, **G.D. Vukasin, H-K. Kwon, J.M.L. Miller, N.E. Bousse**, T.W. Kenny, O. Zilberberg, D. Sabonis, A. Eichler, “Extracting the Lifetime of a Synthetic 2-Level System”, Applied Physics Letters 121, 164101 (2022).
3. **N.E. Bousse**, S.E. Kuenstner, **J.M.L. Miller, H-K. Kwon, G.D. Vukasin**, J.D. Teufel, and T.W. Kenny, “Dispersive Readout of a High-Q Micromechanical Resonator”, Applied Physics Letters 121, 73503 (2022).
4. **J.M.L. Miller, G.D. Vukasin**, Z. Zhang, **H-K. Kwon**, A. Majumdar, T.W. Kenny, and S.W. Shaw, “Effect of Remote Boundary Conditions on Clamping Loss in Micromechanical Resonators”, JMEMS 3, 204 (2022).
5. **J.M.L. Miller, A. Gomez-Franco, D.D. Shin, H-K Kwon**, and T.W. Kenny, “Amplitude stabilization of micromechanical oscillators using engineered nonlinearity” Physical Review Research 3, 033268 (2021).
6. S. Shin, **H-K Kwon, G.D. Vukasin**, T.W.Kenny and F. Ayazi, “A temperature compensated biaxial eFM accelerometer in Epi-seal process” Sensors and Actuators A 330, 112860 (2021).
7. Y. Wang, Y.W. Lin, **J. Glaze, G.D. Vukasin, D.D. Shin, Hyun-Keun Kwon, D.B. Heinz, Y. Chen, D.D. Gerrard**, T.W. Kenny, Andrei M Shkel, “Quantification of Energy Dissipation Mechanisms in Toroidal Ring Gyroscope”, JMEMS 30, 193 (2021).
8. J.S. Katz, C. Zhang, M.T. Barako, **H.J.K. Kim**, M. Asheghi, T.W. Kenny, and K.E. Goodson, “Bicontinuous Mesoporous Metal Foams with Enhanced Conductivity and Tunable Pore Size and Porosity via Electrodeposition for Electrochemical and Thermal Systems”, ACS Appl. Nano Mater. 2020, 3, 12, 12408 (2020)
9. V. Zega, G. Gattere, **S. Koppaka, A. Alter, G.D. Vukasin**, A. Frangi, and T.W. Kenny, “Numerical Modelling of Non-Linearities in MEMS Resonators”, JMEMS 29, 1443 (2020).
10. **A.L. Alter, I.B. Flader, Y. Chen, L.C. Ortiz, D.D. Shin**, and T.W. Kenny, “Characterization of Accelerated Fatigue in Thick Epi-Polysilicon Vacuum Encapsulated MEMS Resonators”, JMEMS 29, 1483 (2020).
11. J.S. Katz, C. Zhang, M.T. Barako, **H.J.K. Kim**, M. Asheghi, T.W. Kenny, and K.E. Goodson, “Bicontinuous Mesoporous Metal Foams with Enhanced Conductivity and Tunable Pore Size and Porosity via Electrodeposition for Electrochemical and Thermal Systems”, ACS Appl. Nano Mater. 2020, 3, 12, 12408 (2020)
12. V. Zega, G. Gattere, **S. Koppaka, A. Alter, G.D. Vukasin**, A. Frangi, and T.W. Kenny, “Numerical Modelling of Non-Linearities in MEMS Resonators”, JMEMS 29, 1443 (2020).

13. **A.L. Alter, I.B. Flader, Y. Chen, L.C. Ortiz, D.D. Shin,** and T.W. Kenny, “Characterization of Accelerated Fatigue in Thick Epi-Polysilicon Vacuum Encapsulated MEMS Resonators”, JMEMS 29, 1483 (2020).
14. **J.M.L. Miller, H. Zhu, S. Sundaram, G.D. Vukasin, Y. Chen, I.B. Flader, D.D. Shin,** and T.W. Kenny, “Limits to Thermal-Piezoresistive Cooling in Silicon Micromechanical Resonators”, JMEMS 29, 677 (2020).
15. **H.K. Kwon, G.D. Vukasin, N.E. Bousse,** and T.W. Kenny, “Crystal Orientation Dependent Dual Frequency Ovenized MEMS Resonator With Temperature Stability and Shock Robustness”, JMEMS 29, 1130 (2020).
16. **G.D. Vukasin, V.K. Sanchez, J. Glaze, N.E. Bousse, N. Bissel, D.D. Shin, H.K. Kwon, D. Heinz,** E.T-T Yen, and T.W. Kenny, “Anchor Design Affects Dominant Energy Loss Mechanism in a Lamé Mode MEM Resonator”, JMEMS 29, 860 (2020).
17. **J.M.L. Miller, D.D. Shin, H.K. Kwon,** S.W. Shaw, and T.W. Kenny, “Spectral narrowing of parametrically pumped thermomechanical noise”, Applied Physics Letters 117, 033504 (2020).
18. **A.L. Alter, I.B. Flader, Y. Chen, D.D. Shin,** and T.W. Kenny, “Nonlinear Dissipation in Epitaxial SCS and Polysilicon MEMS Driven at Large Amplitudes”, JMEMS 29, 1118 (2020).
19. **N.E. Bousse, J.M.L. Miller, A.L. Alter, C.P. Cameron, H.K. Kwon, G.D. Vukasin,** and T.W. Kenny, “Negative Nonlinear Dissipation in Microelectromechanical Beams”, JMEMS 29, 954 (2020).
20. **A.L. Alter, D.D. Gerrard, H.K. Kwon, G.D. Vukasin,** and T.W. Kenny, “Quality Factor Extraction and Enhancement Across Temperature in Ring Resonators”, JMEMS 29, 1124 (2020).
21. Z. Mohammadi, T.L. Heugel, **J.M.L. Miller, D.D. Shin, H.K. Kwon,** T.W. Kenny, R. Chitra, Oded Zilberberg, and L.G. Villanueva, “On the effect of linear feedback and parametric pumping on a resonators frequency stability”, arXiv preprint arXiv:2006.00650 (2020).
22. **L.C. Ortiz, H.K. Kwon, J. Rodriguez, Y. Chen, G.D. Vukasin, D.B. Heinz, D.D. Shin,** and T.W. Kenny, “Low-Power Dual Mode MEMS Resonators With PPB Stability Over Temperature”, JMEMS 29, 190 (2020).
23. **N.E. Bousse, J.M.L. Miller, H.K. Kwon, G.D. Vukasin,** and T.W. Kenny, “Quality factor tuning of micromechanical resonators via electrical dissipation”, Applied Physics Letters 116, 023506 (2020).
24. X. Zhou, C. Zhao, D. Xiao, J. Sun, G. Sobreviola, **D.D. Gerrard, Y. Chen, I. Flader,** T.W. Kenny, X. Wu, and A.A. Seshia, “Dynamic modulation of modal coupling in microelectromechanical gyroscopic ring resonators”, Nature Communications 10, 1 (2019).
25. **J.M.L. Miller, D.D. Shin, H.K. Kwon,** S.W. Shaw, and T.W. Kenny, “Phase Control of Self-Excited Parametric Resonators”, Physical Review Applied 12 (4), 044053 (2019).

26. **J.M.L. Miller, N.E. Bousse, D.B. Heinz, H.J. Kim, H.K. Kwon, G.D. Vukasin** and T.W. Kenny, “Thermomechanical-Noise-Limited Capacitive Transduction of Encapsulated MEM Resonators”, JMEMS 28, 965 (2019).
27. Y. A. Pishchalnikov, W. M. Behnke-Parks, K. Schmidmayer, K. Maeda, T. Colonius, T.W. Kenny, D.J. Laser, “High-speed video microscopy and numerical modeling of bubble dynamics near a surface of urinary stone”, The Journal of the Acoustical Society of America 146, 516 (2019).
28. **I.B. Flader, Y. Chen, Y. Yang, E.J. Ng, D.D. Shin, D.B. Heinz, L. Comenencia Ortiz, A.L. Alter, W. Park, K.E. Goodson, T.W. Kenny**, “Micro-Tethering for Fabrication of Encapsulated Inertial Sensors with High Sensitivity”, JMEMS 28, 372 (2019).
29. **H.J. Kim, K. Kaplan, P. Schindler, S. Xu, M.M. Winterkorn, D. Heinz, T. English, J. Provine, F.B. Prinz, T. Kenny**, “Electrical Properties of Ultrathin Platinum Films by Plasma Enhanced Atomic Layer Deposition”, ACS Applied Materials and Interfaces, 11, 9594 (2019).
30. **J. Rodriguez, S.A.Chandorkar, C.A. Watson, G.M, Glaze, C.H. Ahn, E.J. Ng, Y. Yang, T.W. Kenny**, “Direct Detection of Akhiezer Damping in a Silicon MEMS Resonators”, Scientific Reports 9, 2244 (2019).
31. **J.M.L. Miller, A. Ansari, D.B. Heinz, Y. Chen, I.B. Flader, D.D. Shin, L.G. Villanueva** and T.W. Kenny, “Effective Quality Factor Tuning Mechanisms in Micromechanical Resonators”, Applied Physics Reviews 5, 041307 (2018).
32. **J.M.L. Miller, H. Zhu, D.B. Heinz, Y. Chen, I.B. Flader, D.D. Shin, J.E-Y. Lee, T.W. Kenny**, “Thermal-Piezoresistive Tuning of the Effective Quality Factor of a MicroMechanical Resonator”, Physical Review Applied, 10, 044055 (2018).
33. **J. Rodriguez, S.A.Chandorkar, G.M, Glaze, D.D. Gerrard, Y. Chen, D.B. Heinz, I.B. Flader, T.W. Kenny**, “Direct Detection of Anchor Damping in MEMS Tuning Fork Resonators”, JMEMS 27, 1 (2018).
34. M. Mellema, W. Behnke-Parks, A. Luong, M. Hopcroft, Claire Mills, S. Ho, R. Hsi, D. Laser, T. Kenny, R. Grubbs, M. Stoller, “Absence of Ureteral/Renal Injury Following Low-Intensity Extracorporeal Acoustic Energy Lithotripsy with Stone-Targeting Microbubbles in an in-vivo Swine Model”, The Journal of Urology 199,4 pe479, (2018).
35. **L. Comenencia Ortiz, D.B. Heinz, I.B. Flader, A.L. Alter, D.D. Shin, Y. Chen** and T.W. Kenny, “Assessing failure in epitaxially encapsulated micro-scale sensors using micro and nano x-ray computed tomography”, MRS Communications 8, 275 (2018).
36. M.T. Barako, **T.S. English, S. Roy-Panzer, T.W. Kenny** and Kenneth E Goodson, “Dielectric barrier layers by low-temperature plasma-enhanced atomic layer deposition of silicon dioxide”, Thin Solid Films 649, 24 (2018).
37. **Y. Chen, I.B. Flader, D.D. Shin, C.H. Ahn, J. Rodriguez** and T.W. Kenny, “Robust Method of Fabricating Epitaxially Encapsulated MEMS Devices with Large Gaps”, JMEMS 26, 1235 (2017).
38. W. Park, **D.D. Shin, S.J. Kim, J.S. Katz, J. Park, C.H. Ahn, T. Kodama, M. Asheghi, T.W. Kenny, K.E. Goodson**, “Phonon Conduction in Silicon Nanobeams”, Appl. Phys. Lett. 110, 213102 (2017).
39. F. Purkl, A.Daus, **T. English, J. Provine, A. Feyh, G. Urban, T. Kenny**, “Measurement of Young's modulus and residual stress of atomic layer deposited Al₂O₃ and Pt thin films”, J. Micromech. Microeng. 27, 085008 (2017)

40. G.Agarwal, T. Kazior, T. Kenny, D. Weinstein, “Modeling and analysis for thermal management in Gallium Nitride HEMTs using microfluidic cooling”, Journal of Electronic Packaging 139, 11001 (2017).
41. J. Atalaya, T.W. Kenny, M.L Roukes, M.I Dykman, “Nonlinear damping and dephasing in nanomechanical systems”, Physical Review B, 94, 15440 (2016).
42. O. Shoshani, **D. Heywood, Y. Yang**, T.W. Kenny, and S.W. Shaw, “Phase Noise Reduction in an MEMS Oscillator Using a Nonlinearly Enhanced Synchronization Domain”, JMEMS 25 (2016).
43. **Y. Yang, E.J. Ng**, P.M. Polunin, **Y.Chen, I.B. Flader**, S.W. Shaw, M.I. Dykman, and T.W. Kenny, “Nonlinearity of Degenerately Doped Bulk-Mode Silicon MEMS Resonators”, JMEMS 25, 859 (2016).
44. **T.S. English**, J Provine, A.F. Marshall, A.L. Koh, T.W. Kenny, “Parallel preparation of plan-view transmission electron microscopy specimens by vapor-phase etching with integrated etch stops”, Ultramicroscopy 166, 39 (2016).
45. **Y. Yang, E.J. Ng, Y. Chen, I.B. Flader**, T.W. Kenny, “A Unified Epi-Seal Process for Fabrication of High-Stability Microelectromechanical Devices”, JMEMS 25, 489 (2016).
46. **D.B. Heinz, V.A. Hong, C.H. Ahn, E.J. Ng, Y. Yang**, and T.W. Kenny, “Experimental Investigation into Stiction Forces and Dynamic Mechanical Anti-Stiction Solutions in Ultra-Clean Encapsulated MEMS Devices”, JMEMS 25, 469 (2016)
47. P.M. Polunin, **Y. Yang**, M.I. Dykman, T.W. Kenny, and S.W. Shaw, “Characterization of MEMS Resonator Nonlinearities Using the Ringdown Response”, JMEMS 25, 297 (2016).
48. **C.H. Ahn, E.J Ng, V.A Hong, J. Huynh, S. Wang**, and T.W. Kenny, “Characterization of Oxide-Coated Polysilicon Disk Resonator Gyroscope Within a Wafer-Scale Encapsulation Process”, JMEMS 24, 1687 (2015).
49. B.W. Soon, Y. Qian, **E.J. Ng, V.A. Hong, Y. Yang, C.H. Ahn**, T.W. Kenny, and C. Lee, “Investigation of a Vacuum Encapsulated Si-to-Si Contact Microswitch Operated From– 60° C to 400° C”, JMEMS 24 1906, (2015).
50. **Y. Won**, Y. Gao, R. Guzman de Villoria, B.L. Wardle, R. Xiang, S. Maruyama, T.W. Kenny, and K.E. Goodson, “Nonhomogeneous morphology and the elastic modulus of aligned carbon nanotube films”, Journal of Micromechanics and Microengineering 25, 115023 (2015).
51. M.T Barako, S. Roy-Panzer, T.S. English, T. Kodama, M. Asheghi, T.W. Kenny, and K.E. Goodson, “Thermal Conduction in Vertically Aligned Copper Nanowire Arrays and Composites”, ACS Applied Materials and Interfaces, 34, 19251 (2015).
52. V. Zega, S.H. Nitzan, M. Li, **C.H. Ahn, E. Ng, V. Hong, Y. Yang**, T.W. Kenny, A. Corigliano, and D.A. Horsley, “Predicting the closed-loop stability and oscillation amplitude of nonlinear parametrically amplified oscillators_{SEP}”, Appl. Phys. Lett. 106, 233111 (2015).
53. S.H. Nitzan, V. Zega, M. Li, **C.H. Ahn**, A. Corigliano, T.W. Kenny and D.A. Horsley, “Self-Induced Parametric Amplification arising from Nonlinear Elastic Coupling in a Micromechanical Resonating Disk Gyroscope”, Scientific Reports 5:9036 (2015)
54. **C.H. Ahn, E.J. Ng, V.A. Hong, Y. Yang, B. Lee, I. Flader** and T.W. Kenny, “Mode-Matching of Wineglass-Mode Disk Resonator Gyroscope in (100) Single Crystal Silicon”, JMEMS 24, 343 (2015).

55. **V.A. Hong, S. Yoneoka, M.W. Messana, A.B. Graham, J.C. Salvia, T.T. Branchflower, E.J. Ng** and T.W. Kenny, “Fatigue Experiments on Single-Crystal Silicon in an Oxygen-Free Environment”, JMEMS 24, 351 (2015).
56. **E.J. Ng, V.A. Hong, Y. Yang, C.H. Ahn, C.L.M. Everhart** and T.W. Kenny, “Temperature Dependence of the Elastic Constants of Doped Silicon”, JMEMS 24 730, (2015)
57. C.L. Roozeboom, B.E. Hill, **V.A. Hong, C.H. Ahn, E.J. Ng, Y. Yang**, T.W. Kenny, M.A. Hopcroft and B.L. Pruitt, “Multifunctional Integrated Sensors for MultiParameter Monitoring Applications”, JMEMS 24, (2015).
58. **S. Ghaffari, E.J. Ng, C.H. Ahn, Y. Yang, S. Wang, V.A. Hong**, and T.W. Kenny, “Accurate Modeling of Quality Factor Behavior of Complex MEMS Resonators”, JMEMS 24, 276 (2015)
59. **C.H. Ahn, S. Nitzan, E.J. Ng, V.A. Hong, Y. Yang, T. Kimbrell, D.A. Horsley**, and T.W. Kenny, “Encapsulated High Frequency (235 kHz), High-Q (100k) Disk Resonator Gyroscope with Electrostatic Parametric Pump”, Applied Physics Letters, 105, 243504 (2014).
60. B.W. Soon, **E.J. Ng, V.A. Hong, Y. Yang, C.H. Ahn**, Y. Quan, T.W. Kenny and C. Lee, “Fabrication and Characterization of a Vacuum-Encapsulated Curved Beam Switch for Harsh Environment Application”, JMEMS 23, 1121 (2014).
61. Y. Won, Y. Gao, M.A. Panzer, R. Xiang, S. Maruyama, T.W. Kenny, W. Cai, and K.E. Goodson, “Zippering, entanglement, and the Elastic Modulus of Aligned Single-Walled Carbon Nanotube Films”, Proceedings of the National Academy of Sciences, 110, 20426 (2013).
62. **M.A. Philippine**, H. Zareie, O. Sigmund, G.M. Rebeiz, and T.W. Kenny, “Experimental Validation of Topology Optimization for RF MEMS Capacitive Switch Design”, JMEMS 22, 1296 (2013).
63. **S. Ghaffari, S.A. Chandorkar, S. Wang, E.J. Ng, C.H. Ahn, V. Hong, Y. Yang**, and T.W. Kenny, “Quantum Limit of Quality Factor in Silicon Micro and Nano Mechanical Resonators”, Scientific Reports, 3:3244 (2013).
64. M. Li, **E.J. Ng, V.A. Hong, C.H. Ahn, Y. Yang**, T.W. Kenny and D.A. Horsley, “Lorentz Force Magnetometer using a Micromechanical Oscillator”, Appl. Phys. Lett 103, (2013)
65. **H.K. Lee, R. Melamud, B. Kim, S. Chandorkar, J.C. Salvia** and T.W. Kenny, “The effect of Temperature-Dependent Nonlinearities on the Temperature Stability of Micromechanical Resonators”, J. Appl. Phys. 114, (2013)
66. R.G. Hennessy, M.M. Shulaker, **M. Messana, A.B. Graham**, N. Klewa, J. Provine, T.W. Kenny and R.T. Howe, “Vacuum Encapsulated Resonators for Humidity Measurement”, Sensors and Actuators B-Chemical 185, 575 (2013)
67. **S. Ghaffari, C.H. Ahn, E.J. Ng, S. Wang** and T.W. Kenny, “Crystallographic Effects in Modeling Fundamental behavior in MEMS Silicon Resonators”, Microelectronics Journal 44, 586 (2013)
68. **E. Ng, H-K Lee, C-H Ahn, R. Melamud** and T.W. Kenny, “Stability of Silicon Microelectromechanical Systems Resonant Thermometers”, IEEE Sensors 13, (2013).
69. **M.A. Philippine**, O. Sigmund, G.M. Rebeiz, and T.W. Kenny, “Topology Optimization of Stressed Capacitive RF MEMS Switches,” JMEMS 22, 206 (2013).

70. J.C. Duda, **T.S. English**, E.S. Piekos, T.E. Beechem, T.W. Kenny and P.E. Hopkins, “Bidirectionality tuning Kapitza conductance through the inclusion of Substitutional Impurities”, J. Appl. Phys 112, (2012).
71. **S. Yoneoka**, J. Lee, M. Liger, G. Yama, T. Kodama, M. Gunji, R.T. Howe, K.E. Goodson and T.W. Kenny, “Electrical and Thermal Conduction in Atomic Layer Deposition Nanobridges down to 7nm Thickness”, NanoLett, 12 (2) 683 (2012).
72. **Y. Won**, J.Lee, M. Asheghi, T.W. Kenny, and K.E. Goodson “Phase and thickness dependent modulus of Ge₂Sb₂Te₅ films down to 25 nm thickness”, Appl. Phys. Lett 100, 161905 (2012).
73. **Y. Won**, Y. Gao, M.A. Panzer, S. Dogbe, L. Pan, T.W. Kenny, and K.E. Goodson, “Mechanical Characterization of Aligned Multi-Walled Carbon Nanotube Films using Microfabricated Resonators”, Carbon 50, 347 (2012)
74. **H.K. Lee, R. Melamud, S. Chandorkar, J.G. Salvia, S. Yoneoka** and T.W. Kenny, “Stable Operation of MEMS Oscillators Far Above the Critical Vibration Amplitude in the Nonlinear Regime”, JMEMS Letters 20,1228 (2011).
75. K.P. Bloschock, A.R. Schofield, and T.W. Kenny, “Tip-Based Nanofabrication : An Approach to True Nanotechnology”, Proceedings of the SPIE 8031, 803102 (2011).
76. **H.K. Lee, R. Melamud, B. Kim, M.A. Hopcroft, J.G. Salvia**, and T.W. Kenny, “Electrostatic Tuning to Achieve Higher Stability Micromechanical Composite Resonators”, JMEMS 20, 1355 (2011).
77. **G. Bahl, S. Wang, J.C. Salvia, R. Melamud**, R.T. Howe and T.W. Kenny, “AC Polarization for Charge-Drift Elimination in Resonant Electrostatic MEMS and Oscillators”, IEEE JMEMS 20, 355-364 (2011).
78. **H.K. Lee, B. Kim, R. Melamud, M.A. Hopcroft, J.C. Salvia** and T.W. Kenny, “Influence of the Temperature-Dependent Nonlinearities on the Performance of Micromechanical Resonators”, Appl. Phys. Lett 99, 194102 (2011).
79. **Y. Won, E.N. Wang**, K.E. Goodson and T.W. Kenny, “3-D Visualization of Flow in Microscale Jet Impingement Systems”, International Journal of Thermal Sciences, 50, 325 (2011).
80. **K-L. Chen, S. Wang, J.C. Salvia, R. Melamud** R.T. Howe and T.W. Kenny, “Wafer-Level Epitaxial Silicon Packaging for Out-of Plane RF MEMS Resonators with Integrated Actuation Electrodes”, IEEE Transactions on Components, Packaging and Manufacturing Technology Vol 1, 310-317 (2011).
81. **G. Hill, D. Soto**, A. Peattie, R.J. Full, T.W. Kenny, “Orientation angle and the adhesion of single gecko setae”, Journal of the Royal Society Interface, Vol 8 926-933 (2011).
82. **S. Yoneoka, J.C. Salvia, G. Bahl, R. Melamud, S.A. Chandorkar**, and T.W. Kenny, “Active Electrostatic Compensation of Micromechanical Resonators under Random Vibrations”, IEEE JMEMS 19, 1270 (2010).
83. A.R. Schofield, K,P. Bloschock, and T.W. Kenny, “Tip-Based Nanofabrication : An Approach to True Nanotechnology”, Proceedings of the SPIE 7637, 76371 (2010).
84. **D. Soto, G. Hill**, A. Parness, N. Esparza, M. Cutkosky, and T. Kenny, “Effect of Fibril Shape on Adhesive Properties”, Appl. Phys Lett 97, 153701 (2010).

85. **M.A. Hopcroft**, W.D. Nix, T.W. Kenny, "What is the Young's Modulus of Silicon?", IEEE JMEMS 19, 229 (2010).
86. **S. Yoneoka**, C.S. Roper, **R.N. Candler**, **S.A. Chandorkar**, **A.B. Graham**, J. Provine, R. Maboudian, R.T. Howe, and T.W. Kenny, "Characterization of Encapsulated Micromechanical Resonators Sealed and Coated with Polycrystalline SiC", IEEE JMEMS 19, 357 (2010).
87. **A.B. Graham**, **M.W. Messana**, P.G. Hartwell, J. Provine, **S. Yoneoka**, **R. Melamud**, **B. Kim**, R.T. Howe and T.W. Kenny, "A Method for Wafer-Scale Encapsulation of Large Lateral-Deflection MEMS Devices", IEEE JMEMS 19, 28 (2010).
88. **G. Bahl**, **R. Melamud**, **B. Kim**, **S.A. Chandorkar**, **J.C. Salvia**, **M.A. Hopcroft**, D. Elata, R.G. Hennessy, R.N. Candler, R.T. Howe and T.W. Kenny, "Model and Observations of Dielectric Charge in Thermally-Oxidized Silicon Resonators", IEEE JMEMS 19, 162, (2010).
89. **J.C. Salvia**, **R. Melamud**, **S.A. Chandorkar**, **S.F. Lord** and T.W. Kenny, "Real-Time Temperature Compensation of MEMS Oscillators using an Integrated Micro-Oven and a Phase-Locked Loop", IEEE JMEMS 19, 192 (2010).
90. **R. Melamud**, **S.A. Chandorkar**, **B. Kim**, **HK Lee**, **J. Salvia**, **G. Bahl**, **MA Hopcroft**, and TW Kenny, "Temperature-Insensitive Composite Micromechanical Resonators", IEEE JMEMS 18, 1409 (2009).
91. **V. Ayanoor-Vitikkate**, **K-L Chen**, **W.T. Park**, T.W. Kenny, "Development of Wafer-Scale Encapsulation Process for Large Displacement Piezoresistive MEMS Device", Sensors and Actuators A 156, 275 (2009).
92. **K-L Chen**, **J. Salvia**, R. Potter, R.T. Howe, and T.W. Kenny, "Performance evaluation and equivalent model of silicon interconnects for fully-encapsulated RF MEMS devices", IEEE Transactions on Advanced Packaging 32, p. 402-9 (2009).
93. **S.A. Chandorkar**, **R.N. Candler**, **A. Duwel**, **R. Melamud**, **M. Agarwal**, K.E. Goodson, T.W. Kenny, "Multimode thermoelastic dissipation", Journal of Applied Physics 105, P 043505 (13 pp.) (2009).
94. **B. Kim**, **R.N. Candler**, **R. Melamud**, **M.A. Hopcroft**, **S. Yoneoka**, **H-K Lee**, **M. Agarwal**, **S.A. Chandorkar**, G. Yama, and T.W. Kenny, "Hermeticity and diffusion investigation in polysilicon film encapsulation for microelectromechanical systems", Journal of Applied Physics 105 pp. 013514 (10 pp.), (2009).
95. **C.M. Jha**, **J. Salvia**, **S.A. Chandorkar**, **R. Melamud**, E. Kuhl, T.W. Kenny, "Acceleration insensitive encapsulated silicon microresonator", Applied Physics Letters 93 P. 234103 (3 pp.) (2008)
96. **B. Kim**, **M.A. Hopcroft**, **R.N. Candler**, **C.M. Jha**, **M. Agarwal**, **R. Melamud**, **S.A. Chandorkar**, G. Yama, T.W. Kenny, "Temperature Dependence of Quality Factor in MEMS Resonators", JMEMS 17, 755 (2008).
97. **M. Agarwal**, **SA Chandorkar**, **H. Mehta**, **RN Candler**, **B. Kim**, **MA Hopcroft**, **R. Melamud**, TW Kenny, and B. Muhrmann, "A Study of Electrostatic Force nonlinearities in Resonant Microstructures", Appl. Phys Lett. 92, 104 (2008).
98. **M. Swartwout**, C Kitts, R. Twiggs, T.W. Kenny, B.R. Smith, R. Lu, K. Stattenfield, F. Pranajaya, "Mission Results for a Student-Built Satellite", ACTA Astronautica 62, 521 (2008).

99. **C.M. Jha, M.A. Hopcroft, S.A. Chandorkar, J.C. Salvia, M. Agarwal, R.N Candler, R. Melamud, B. Kim,** and T.W. Kenny, “Thermal Isolation of Encapsulated MEMS Resonators”, JMEMS 17, 175 (2008).
100. **W.T. Park, K.N. O’Connor, K.L. Chen, J.R. Mallon, T. Maetani, P. Dalal, R.N. Candler, V. Ayanoor-Vitikkate, J.B. Roberson, S. Puria,** and T.W. Kenny, “Ultraminiature Encapsulated Accelerometers as a Fully-Implantable Sensors for Implantable Hearing Aids”, Biomedical MicroDevices 9, 939 (2007).
101. **M. Bartsch, W. Federle, R.J. Full** and T.W. Kenny, “A Multi-Axis Force Sensor for the Study of Insect Biomechanics”, JMEMS 16, 709 (2007).
102. **M. Agarwal, H. Mehta, R.N. Candler, S.A. Chandorkar, B. Kim, M.A. Hopcroft, R. Melamud, G. Bahl, G. Yama²,** T. W. Kenny and B. Murmann, “Scaling of A-f nonlinearities in electrostatically transduced microresonators”, Journal of Applied Physics 102, 74903 (2007).
103. **B. Kim, R.N. Candler, M.A. Hopcroft; M. Agarwal, WT Park,** T.W. Kenny, “Frequency stability of wafer-scale film encapsulated silicon based MEMS resonators ” Sensors and Actuators A (Physical), 136, 125 (2007).
104. **M.A. Hopcroft, B. Kim, S. Chandorkar, R. Melamud, M. Agarwal, C.M. Jha, G. Bahl, J. Salvia, H. Mehta, H.K. Lee, R.N. Candler,** T.W. Kenny, “Using the Temperature Dependence of Resonator Quality Factor as a Thermometer”, Appl. Phys. Lett. **91**, 13505 (2007).
105. **J. Bower, C. Mehls, N. Vora, R. Torii,** and T. Kenny, “Effect of Surface Roughness on Thin Film Niobium Coatings”, IEEE Transactions on Applied Superconductivity 2, 768 (2007).
106. **O. Ajakaiye, J. Grade, C. Shin,** and T. Kenny, “Wafer-Scale Fabrication of Infrared Detectors based on Tunneling Displacement Transducers”, Sensors and Actuators A (Physical) 134, 575 (2007).
107. **C. M. Jha, G. Bahl, R. Melamud, S. A. Chandorkar, M. A. Hopcroft, B. Kim, M. Agarwal, J. Salvia, H. Mehta,** and T. W. Kenny, “High Resolution microresonator-based digital temperature sensor”, Appl. Phys. Lett 91, 74101 (2007).
108. **R. Melamud, B. Kim, S.A. Chandorkar, M.A. Hopcroft, M. Agarwal, C.M. Jha** and T.W. Kenny, “Temperature Compensated High-Stability Silicon Resonators”, Appl. Phys. Lett. **90**, 244107 (2007).
109. **C.M. Jha, M.A. Hopcroft, S.A. Chandorkar, J. Salvia, M. Agarwal, R.N. Candler, R. Melamud, B. Kim,** and Thomas W. Kenny, “Thermal Isolation of Encapsulated MEMS Resonators” Accepted with Minor Revision JMEMS (2007).
110. **M. Agarwal, K.K. Park, S.A. Chandorkar, R.N. Candler, B. Kim, M.A. Hopcroft, R. Melamud,** T.W. Kenny, and B. Murmann, “Acceleration sensitivity in beam-type electrostatic microresonators”, Appl. Phys. Lett. 90, 14103 (2007).
111. **M. Agarwal, S.A. Chandorkar, R.N. Candler, B. Kim, M.A. Hopcroft, R. Melamud, C.M. Jha,** T.W. Kenny and B. Murmann “Optimal drive condition for nonlinearity reduction in electrostatic MEMS resonators”, Appl. Phys. Lett., 89, (2006)
112. **R.N. Candler, M.A. Hopcroft, B. Kim, W.-T. Park, R. Melamud, M. Agarwal, G. Yama, A. Partridge, M. Lutz,** and T.W. Kenny, “Long-Term and Accelerated Life Testing of a Novel Single-Wafer Vacuum Encapsulation for MEMS Resonators”, JMEMS 15, 1446 (2006).

113. **E.N. Wang**, S. Devasenathipathy, H. Lin, C.H. Hidrovo, J.G. Santiago, K.E. Goodson, and T.W. Kenny, "A Hybrid Method for Bubble Geometry Reconstruction in Two-Phase Microchannels", *Experiments in Fluids* 40, 847 (2006).
114. C.H. Hidrovo, T.A. Kramer, **E.N. Wang**, S. Vigneron, **J.E. Steinbrenner**, J.M. Koo, F.M. Wang, **D.W. Fogg**, **R.D. Flynn**, E.S. Lee, C.H. Cheng, T.W. Kenny, J.K. Eaton, and K.E. Goodson, "Two-Phase Microfluidics for Semiconductor Circuits and Fuel Cells," *Heat Transfer Engineering*, 27, 53 (2006).
115. T.W. Kenny, K.E. Goodson, J.G. Santiago, **E.N. Wang**, J-M Koo, L. Jiang, E. Pop, S. Sinha, **L. Zhang**, D. Fogg, S. Yao, R. Flynn, CH Chang, C.H. Hidrovo, "Advanced Cooling Technologies for Microprocessors", *International Journal of High Speed Electronics and Systems*, 15, 301 (2006).
116. A. Duwel, **R.N. Candler**, T.W. Kenny, M. Varghese, "Engineering MEMS Resonators with Low Thermoelastic Damping", *IEEE JMEMS* 15, 1437 (2006).
117. **R.N. Candler**, A. Duwel, M. Varghese, **S. Chandorkar**, **M. Hopcroft**, **W.T. Park**, **B. Kim**, G. Yama, A. Partridge, M. Lutz, and T.W. Kenny, "Impact of Geometry on Thermoelastic Dissipation in Micromechanical Resonant Beams", *IEEE JMEMS* 15, 927 (2006).
118. **W.T. Park**, A. Partridge, **R.N. Candler**, **V. Ayanoor-Vitikkate**, G. Yama, M. Lutz, and T.W. Kenny, "Encapsulated Sub-Millimeter Piezoresistive Accelerometers", *JMEMS* 15, 507 (2006).
119. **E.N. Wang**, S. Devasenathipathy, J.G. Santiago, K.E. Goodson, and T.W. Kenny, "Nucleation and Growth of Vapor Bubbles in a Heated Silicon Microchannel," *ASME Journal of Heat Transfer*, Vol. 128, p. 497. (2004)
120. B.W. King, T.W. Kenny, and K.E. Goodson, "Comparison of Thermal and Piezoresistive Sensing Approaches for Atomic Force Microscopy Topography Measurements", *Appl. Phys. Lett.* 85, 2086 (2004).
121. **E.N. Wang**, **L. Zhang**, L. Jiang, J.M. Koo, J.G. Maveety, E.A. Sanchez, K.E. Goodson, and T.W. Kenny, "Micromachined Jets for Liquid Impingement Cooling of VLSI Chips", *JMEMS* 13, 833 (2004).
122. **L. Zhang**, **E.N. Wang**, K.E. Goodson, and T.W. Kenny, "Phase Change Phenomena in Silicon Microchannels", *International Journal of Heat and Mass Transfer* 48, 1572 (2005).
123. E.N. Renuart, **A.M. Fitzgerald**, T.W. Kenny, R. H. Dauskardt, "Fatigue Crack Growth in Micromachined Single Crystal Silicon", *Journal of Materials Research* 19, 2635 (2004).
124. J.P. Lynch, A. Sundararajan, K.H. Law, A.S. Kiremidjian, T. Kenny and S. Carryer, "Embedment of structural monitoring algorithms in a wireless sensing unit", *Structural Engineering and Mechanics*, 15, 285-97 (2003).
125. **R.N. Candler**, **W.T. Park**, **H.M. Li**, G. Yama, A. Partridge, M. Lutz, and T.W. Kenny, "Single Wafer Encapsulation of MEMS Devices", *IEEE Transactions on Advanced packaging* 26, 227 (2003).
126. **J.P. Lynch**, **A. Partridge**, K.H. Law, T.W. Kenny, A.S. Kiremidjian, E. Carryer, "Design of Piezoresistive MEMS-based Accelerometer for Integration with Wireless Sensing Unit for Structural Monitoring", *Journal of AeroSpace Engineering*, 16, 108 (2003).
127. **Y. Hishinuma**, T. Geballe, B. Moyzhes, and T.W. Kenny, "Measurements of Cooling by Room-Temperature Thermionic Emission across a Nanometer Gap" *Journal of Applied Physics* 94, 4690 (2003).

128. **E.M. Chow, A. Partridge**, V. Chandrasekaran, M. Sheplak, C.F. Quate, and T.W. Kenny, “Process-Compatible Polysilicon-Based Through-Wafer Interconnects in Silicon Substrates”, JMEMS, 11,631 (2002).
129. K. Autumn, M. Sitti, **Y.A. Liang**, A.M. Peattie, W.R. Hansen, S. Sponberg, T.W. Kenny, R. Fearing, J.N. Israelachvili, and R.J. Full, “Evidence for van der Waals adhesion in gecko setae”, Proceedings of the National Academy of Science, 99, 12252 (2002).
130. K.E. Goodson, J.G. Santiago, T.W. Kenny, L. Jiang,, S. Zeng, J.M. Koo, **L. Zhang**, S. Yao, and **E.N. Wang**, “Electroosmotic Microchannel Cooling System for Microprocessors,” *Electronics Cooling*, Vol. 8, No. 4, pp. 46-47. (2002)
131. **A.M. Fitzgerald**, T.W. Kenny, and R.H Dauskardt, “Stress wave interference effects during fracture of silicon micromachined specimens,” IEEE Special Issue on Experimental Mechanics 43,317, (2003).
132. **B.L. Pruitt, W.-T. Park**, T. Kenny. Measurement System for Low Force and Small Displacement Contacts.” *Journal of Micro-electro-mechanical Systems*. 13, 220 (2004).
133. W.P. King, T.W. Kenny, K.E. Goodson, G.L.W. Cross, M. Despont, U.T. Dürig, H. Rothuizen, G.K. Binnig, and P. Vettiger, “Design of Atomic Force Microscope Cantilevers For Combined Thermomechanical Writing and Thermal Reading in Array Operation,” *Journal of MicroElectroMechanical Systems* 11, 765 (2002).
134. **A.E. Herr, J.I. Molho**, K.A. Drouvalakis, J.C. Mikkelsen, P.J. Utz, J.G. Santiago, and T.W. Kenny, “On-Chip Coupling of Isoelectric Focusing and Free Solution Electrophoresis for Multi-Dimensional Separations”, Analytical Chemistry 75, 1180 (2003)
135. Jiang, L., Mikkelsen J., Koo J.-M., Huber D., Yao S., **Zhang L.**, Zhou P., Maveety J.G., Prasher R., Santiago J.G., Kenny T.W., & Goodson K.E., “Closed-loop electroosmotic microchannel cooling system for VLSI circuits”, IEEE Transactions on Components & Packaging Technologies 25, 347 (2002).
136. **Y. Hishinuma**, B.Y. Moyzhes, T.H. Geballe, and T.W. Kenny, “Vacuum Thermionic Refrigeration with a Semiconductor Heterojunction Structure”, Appl. Phys. Lett. 81, 4242 (2002).
137. **B.L. Pruitt**, T. Kenny. “Piezoresistive Cantilevers and Measurement System for Low Force Electrical Contact Measurements.” *Sensors and Actuators, A* 104, 68 (2003).
138. **J.Grade**, H. Jerman, and T.W. Kenny, Design and Characterization of Large Displacement Electrostatic Actuators, JMEMS, 12, 335 (2003).
139. **E.M. Chow**, G. Yaralioglu, C.F. Quate, and T.W. Kenny, Characterization of a Two-Dimensional Cantilever Array with Through-Wafer Electrical Interconnects, Appl. Phys Lett. 80, 664 (2002).
140. B.C. Stipe, H.J. Mamin, C.S. Yannoni, **T.D. Stowe**, T.W. Kenny and D. Rugar “Electron Spin Relaxation near a Micron-Sized Ferromagnet”, Phys. Rev. Lett. 87, 2776 (2001).
141. B.C. Stipe, H.J. Mamin, **T.D. Stowe**, T.W. Kenny and D. Rugar, Non-contact friction and force fluctuations between closely spaced bodies, Phys. Lett. Rev. 8709, 6801 (2001).
142. Rugar, B.C. Stipe, H.J. Mamin, C.S. Yannoni, **T.D. Stowe, K.Y. Yasumura** and T.W. Kenny Adventures in Attonewton Force Detection, Applied Physics A 72 [Suppl] S3-S10 (2001).

143. B. C. Stipe, H.J. Mamin, **T.D. Stowe**, T.W. Kenny and D. Rugar, Magnetic dissipation and fluctuations in individual nanomagnets measured by ultrasensitive cantilever magnetometry, Phys. Rev. Lett. 86 2874 (2001)
144. **L. Zhang**, J.M. Koo, L. Jiang, K.E. Goodson, J.G. Santiago, and T.W. Kenny, Measurements and Modeling of Two-Phase Flow in Microchannels with Nearly-Constant Heat Flux Boundary Conditions, JMEMS 11,12 (2002).
145. B.W. King, T.W. Kenny, K.E. Goodson, G. Cross, M. Despont, U. Durig, H. Rothuizen, G.K. Binnig, and P. Vettiger, Atomic Force Microscope Cantilevers for Combined Thermomechanical Data Writing and Reading, Appl. Phys. Lett. 78, 1300 (2001).
146. T.W. Kenny, Nanometer-Scale Force Sensing with MEMS Devices, Invited Review, IEEE Sensors 1,148 (2001).
147. **J.A. Harley** and T.W. Kenny, A High-Stiffness Axial Resonant Probe for Atomic Force Microscopy, JMEMS 10, 434 (2001)
148. **Y. Hisunuma**, T.H. Geballe, B.Y. Mozyzhes, and T.W. Kenny, Refrigeration by Combined Tunneling and Thermionic Emission in Vacuum: Use of Nanometer Scale Design, Appl. Phys. Lett. 78, 2572 (2001).
149. **J.I. Molho**, **A.E. Herr**, B.P. Mosier, J.G. Santiago, T.W. Kenny, R.A. Brennen, G.B. Gordon, B. Mohammadi, Optimization of Turn Geometries for On-Chip Electrophoresis, Analytical Chemistry 73, 1350 (2001).
150. **A.M. Fitzgerald**, R.S. Iyer, R.H. Dauskardt, and T.W. Kenny, Sub-Critical Crack Growth in Single Crystal Silicon Using Micromachined Specimens, Journal of Materials Research 17, 683 (2002).
151. **C.H. Liu**, and T.W. Kenny, A High-Precision, Wide-Bandwidth Micromachined Tunneling Accelerometer, JMEMS, 10,425 (2001)
152. K. Autumn, **Y. Liang**, W.P. Chan, T. Hsieh, R. Fearing, T.W. Kenny, and R. Full, Dry Adhesive Force of a Single Gecko Foot-Hair, Nature. 405: 681-685 (2000).
153. **A.E. Herr**, **J.I. Molho**, J.G. Santiago, M.G. Mungal, T.W. Kenny, and M.G. Garguilo, Electroosmotic Capillary Flow with Non-Uniform Surface Potential, Analytical Chemistry 72, 1053-1057 (2000).
154. **E.M. Chow**, H.T. Soh, H.C. Lee, J.D. Adams, S.C. Minne, G. Yaralioglu, A. Atalar, C.F. Quate, and T.W. Kenny, Integration of Through-Wafer Interconnects with a Two-Dimensional Cantilever Array, Sensors and Actuators 83, 118-123 (2000).
155. **K.Y. Yasumura**, **T.D. Stowe**, **E.M. Chow**, T.E. Pfafman, T.W. Kenny, B. Stipe, and D. Rugar, Quality Factors in Micron- and Submicron-Thick Cantilevers, JMEMS 9, 117-125 (2000).
156. **J.K. Reynolds**, D.C. Catling, R.C. Blue, N. Maluf, T.W. Kenny, Packaging a piezoresistive pressure sensor for pressure and temperature stability in a Martian environment, Sensors and Actuators 83, 142-149 (2000).
157. **R. G. Rudnitsky**, **E.M. Chow**, and T.W. Kenny, High-Speed Biological Screening with Magnetic Force Microscope Cantilever Arrays, Sensors and Actuators 83, 256-262 (2000).
158. **A.M. Fitzgerald**, T.W. Kenny, S. Iyer, R. Dauskard, Fracture Toughness and Crack-Growth Phenomena of Plasma-Etched Single Crystal Silicon, Sensors and Actuators 83, 194-199 (2000)

159. **J.A. Harley** and T.W. Kenny, Design and Process Optimization of Piezoresistive Cantilevers, JMEMS 9, 226-235 (2000).
160. **T.D. Stowe**, T.W. Kenny, D.J. Thompson, and D. Rugar, Silicon Dopant Imaging by Dissipation Force Microscopy, Appl. Phys Lett, 75, 2785-2787 (1999).
161. **A. Partridge, J.K. Reynolds, B.W. Chui, E.M. Chow, A.M. Fitzgerald, L. Zhang, N.I. Maluf**, and T.W. Kenny, A High-Performance Planar Piezoresistive Accelerometer JMEMS 9, 58-66 (2000).
162. **J.A. Harley**, and T.W. Kenny, High Sensitivity Piezoresistive Cantilevers under 1000Å Thick, Appl. Phys. Lett. 75, 289-291 (1999).
163. **B.W. Chui, M. Asheghi, Y.S. Ju**, K.E. Goodson, T.W. Kenny and H.J. Mamin, Intrinsic-Carrier Thermal Runaway in Silicon Microcantilevers, Microscale Thermophysical Engineering 3, 217-228 (1999).
164. G. Binnig, M. Despont, U. Drechsler, W. Haberle, M. Lutwyche, P. Vettiger, H.J. Mamin, **B.W. Chui**, and T.W. Kenny, High-Density Data Read, Write, and Erase using Heated Atomic Force Microscopy Cantilevers, Appl. Phys Lett, 74 1329-1331 (1999)
165. **A. Partridge, J.K. Reynolds, J.D. Grade**, B.J. Kane, N.I. Maluf, G.T.A. Kovacs, and T.W. Kenny, An Integrated Controller for Tunnel Sensors, J. Solid State Circuits 34, 1099-1107 (1999).
166. T.E. Pfafman, **A.M. Fitzgerald** and T.W. Kenny, A Micromachined Calorimeter for Spacecraft Exposure Monitoring, J. Vac. Sci. Technol., In review (8/99).
167. **B.W. Chui**, T.W. Kenny, H.J. Mamin, B.D. Terris, and D. Rugar, Independent Detection of Vertical and Lateral Forces with a Sidewall-Implanted Dual-Axis Piezoresistive Cantilever, Appl. Phys Lett. 72, 1388-1390 (1998).
168. **C.H. Liu, A.M. Barzilai, J.K. Reynolds, A. Partridge**, T.W. Kenny, **J.D. Grade** and H.K. Rockstad, Characterization of a High-Sensitivity Micromachined Tunneling Accelerometer with Micro-g Resolution, J. MicroElectroMechanical Systems 7, 235-244 (1998).
169. **A.M. Barzilai**, T.R. VanZandt, T. Kenny, Measurement of the Noise of a Geophone in the Presence of Large Background Signals, Rev. Sci. Instrum. 69, 2767-2772 (1998).
170. **B.W. Chui, T.D. Stowe**, Y.S. Ju, K.E. Goodson, T.W. Kenny, H.J. Mamin, B.D. Terris, R.P. Ried, and D. Rugar, Low-stiffness Silicon Cantilevers with Integrated Heaters and Piezoresistive Sensors for High-Density AFM Thermomechanical Data Storage, IEEE Journal of MicroElectroMechanical Systems, 7, 69-78 (1998).
171. **T.D. Stowe, K. Yasumura**, T. Pfafman, T. Kenny, D. Botkin, and D. Rugar, Attonewton Force Detection using Ultrathin Silicon Cantilevers, Appl. Phys. Lett. 71, 288-290 (1997).
172. R.A. Brennen, M.H. Hecht, D.V. Wiberger, S.J. Manion, W.D. Bonivert, J.M. Hruby, **M.L. Scholz, T.D. Stowe**, T.W. Kenny, K.H. Jackson, and C.K. Malek, Fabrication of Collimating Grids for an X-Ray Solar Telescope using LIGA Methods, Microsystem Technologies 3, 91-96 (1997).
173. D. Dilella, L.J. Whitman, R.J. Colton, T.W. Kenny, W.J. Kaiser, E.C. Vote, J.A. Podosek, and L.M. Miller, A Micromachined Magnetic-Field Sensor based on an Electron Tunneling Displacement Transducer, Sensors and Actuators A, 86, 8 (2000).

174. **B.W. Chui, T.D. Stowe, T.W. Kenny, H.J. Mamin, B.D. Terris, and D. Rugar,** Low-Stiffness Silicon Cantilevers for Thermal Writing and Piezoresistive Readback with the Atomic Force Microscope, Appl. Phys. Lett., 69, 2767-2769 (1996).
175. H.K. Rockstad, T.K. Tang, **J.K. Reynolds, T.W. Kenny, W.J. Kaiser, and T.B. Gabrielson,** A Miniature, High-Sensitivity, Electron Tunneling Accelerometer, Sensors and Actuators A53, 227-231 (1996).
176. T.W. Kenny, **J.K. Reynolds, J.A. Podosek, E.C. Vote, L.M. Miller, H.K. Rockstad, and W.J. Kaiser,** Micromachined Infrared Sensors using Tunneling Displacement Transducers, Rev. Sci. Instrum. 67, 112-128 (1996).
177. T.W. Kenny, W.J. Kaiser, H.K. Rockstad, J.K. Reynolds, J.A. Podosek, and E.C. Vote, Wide-Bandwidth Mechanical Elements for Tunneling Transducers, J. MicroElectroMechanical Systems 3, 97-104 (1994).
178. R.E. Stalder, S. Boumsellek, T.R. VanZandt, T.W. Kenny, M.H. Hecht and F.E. Grunthaner, Micromachined Array of Electrostatic Energy Analyzers for Charged Particles, J. Vac. Sci. Technol. A12, 2554-2558 (1994).
179. H.K. Rockstad, T.W. Kenny, J.K. Reynolds, W.J. Kaiser, and T.B. Gabrielson, A Miniature High-Sensitivity Broad-Band Accelerometer Based on Electron Tunneling Transducers, Sensors and Actuators A 43, 107-114 (1994).
180. T.W. Kenny, W.J. Kaiser, J.A. Podosek, H.K. Rockstad, J.K. Reynolds, and E.C. Vote, Micromachined Tunneling Displacement Transducers for Physical Sensors, J. Vac. Sci. Technol. A11, 797-803 (1993).
181. T.W. Kenny, W.J. Kaiser, J.K. Reynolds, J.A. Podosek, H.K. Rockstad, E.C. Vote, and S.B. Waltman, Electron Tunnel Sensors, J. Vac. Sci. Technol. A 10(4), 2114-2118 (1992).
182. T.W. Kenny, W.J. Kaiser, S.B. Waltman, J.K. Reynolds, A Novel Infrared Detector Based on a Tunneling Displacement Transducer, Appl. Phys. Lett. 59, 1820-1822 (1991).
183. T.W. Kenny, S.B. Waltman, J.K. Reynolds, and W.J. Kaiser, A Micromachined Silicon Tunnel Sensor for Motion Detection, Appl. Phys. Lett. 58, 100-102 (1991).
184. T.W. Kenny and P.L. Richards, Heat Capacity and Sticking Probability Measurements of ^4He Submonolayers Adsorbed on Evaporated Ag Films: Bose Statistics in Two Dimensions, Phys. Rev. Lett. 64, 2386-2389 (1990).
185. T.W. Kenny and P.L. Richards, AC Calorimeter for Measurements of Adsorbed Gases on Metal Films at ^4He Temperatures, Rev. Sci. Instr. 61, 822-829 (1990).
186. T.W. Kenny, P.L. Richards, I.S. Park, E.E. Haller, and J.W. Beeman, Bias Induced Nonlinearities in Neutron Transmutation Doped Germanium at ^4He Temperatures, Phys. Rev. B 39, 8476-8482 (1989).
187. M. Berg, C.B. Harris, T.W. Kenny, and P.L. Richards, Generation of Intense Tunable Picosecond Pulses in the Far-Infrared, Appl. Phys. Lett. 47, 206-208 (1985).
188. U. Frick, T.W. Kenny, R.O. Pepin, "The Irradiation History of Lunar Breccia 79035", Meteoritics 17, 216 (1982).

Refereed Symposia and Conference Proceedings:

1. C.H. Hidrovo, T.A. Kramer, **E.N. Wang**, S. Vigneron, J.E. Steinbrenner, J.-M. Koo, F.-M. Wang, D. Fogg, R. Flynn, E.S. Lee, C.-H. Cheng, T.W. Kenny, J.K. Eaton, K.E. Goodson, "Two-phase Microfluidics for Semiconductor Circuits and Fuel Cells," 3rd International Conference on Microchannels & Minichannels, Toronto, Canada, June 13-15, ICMM2005-75085. 2005
2. **E.N. Wang**, J.G. Santiago, K.E. Goodson, T.W. Kenny. "Microjet Impingement Cooling with Phase Change," ASME International Mechanical Engineering Congress & Exposition, November 13-19, Anaheim, CA, USA, IMECE2004-62176. 2004.
3. **E.N. Wang**, S. Devasenathipathy, C.H. Hidrovo, D.W. Fogg, J.-M. Koo, J.G. Santiago, K.E. Goodson, T.W. Kenny. "Liquid Velocity Fields in Two-Phase Microchannel Convection," 3rd International Symposium on Two-Phase Flow Modelling and Experimentation, September 22-24, 2004, Pisa, Italy.
4. **E.N. Wang**, S. Devasenathipathy, J.G. Santiago, K.E. Goodson, T.W. Kenny. "Nucleation and Growth of Vapor Bubbles in a Heated Silicon Microchannel," ASME International Mechanical Engineering Congress & Exposition, Washington, D.C., USA, Nov. 15-21, 2003.
5. Koo, J.-M., Jiang, L., Bari, A., **Zhang, L., Wang, E.**, Kenny, W., Goodson, K.E., and Santiago, J.G., "Convective Boiling in Microchanenl Heat Sinks with Spatially-varying Heat Flux", *ITHERM 2002*, San Diego, CA, USA, May, 2002.
6. Jiang, L., Koo, J.-M., Bari, A., **Wang, E.**, Prasher, R.S., Maveety, J., Kenny, T.W., Goodson, K.E., and Santiago J.G., "Cross-linked Microchannels for VLSI Hotspot Cooling", *2002 ASME International Mechanical Engineering Congress & Exposition*, New Orleans, USA, Nov.17-22, 2002.
7. Koo, J.-M., Im, S., Goodson, K.E., Cho, E., Prashe,r R.S., **Wang, E.**, Jiang, L., Bari, A., Champion, D., Fogg, D., Kim, M., Kenny, T.W., and Santiago, J.G., "VLSI Hotspot Cooling Using Two-phase Microchannel Convection", *2002 ASME International Mechanical Engineering Congress & Exposition*, New Orleans, USA, Nov. 17-22, 2002.
8. Jiang, L., Mikkelsen, J., Koo, J-M, **Zhang, L.**, Huber, D., Yao, S., Bari, A., Zhou, P., Santiago, J., and Kenny, T.W. and Goodson, K.E., "Transient and Sub-atmospheric Performance of A Closed-loop Electroosmotic Microchannel Cooling System", *Proceeding of Thermal Challenges in Next Generation Electronic Systems, THERMES 2002*, Santa Fe, New Mexico, USA, pp. 133-139, Jan. 13-16, 2002.
9. J.M. Koo, S. Im., S.S. Banerjee, D. Fogg, **E.N. Wang, L. Zhang**, L. Jiang, A. Bari, T.W. Kenny, K.E. Goodson, and J.G. Santiago, "Two-phase Microchannel Heat Sinks for Sub-100nm High Performance VLSI," *Proc. ISLPED*. 2002.
10. L. Jiang, J.M. Koo S. **L. Zhang., S. Banerjee**, P. Zhou. J.G, T.W. Kenny, K.E. Goodson,, "An Electrokinetic Closed-Loop Micro Cooler for High-Power VLSI Chips," presented at SEMI-THERM, San Jose, CA, USA, March. 2001.
11. R.M. Zeighami, **D. Laser**, P. Zhou, M. Asheghi., S. Devasenathipathy, T.W. Kenny, J.G. Santiago and K.E. Goodson, "Experimental Investigation of Flow Transition in Microchannels using Micron Resolution Particle Image Velocimetry," *Proc. ITHERM*, Las Vegas, Nevada, May. 2000.
12. **C.H.Liu**, T.W. Kenny and H.K. Rockstad, Robust Controller Design via μ -synthesis for High-Performance Micromachined Tunneling Accelerometers, 1999 American Controls Conference Digest (1999)

13. W.P. King, J.G. Santiago, T.W. Kenny, and K.E. Goodson, "Modeling and Simulation of Sub-Micrometer Heat Transfer in AFM Thermomechanical Data Storage," ASME MEMS-Vol. 1, pp. 583-588. 1999.
14. **J.I. Molho, A.E. Herr**, T.W. Kenny, M.G. Mungal, M.G. Garguilo, P.H. Paul, M. Desphande, J.R. Gilbert, P.M. St.John, T.M. Woudenberg, and C. Connell, Fluid Transport Mechanisms in MicroFluidic Devices, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 69 (1998).
15. S.M. Kumar, W.C. Reynolds, and T.W. Kenny, MEMS Based Actuators for Boundary Layer Control, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 103 (1998).
16. **J.A. Harley, E.M Chow**, and T.W. Kenny Design of Resonant Beam Force Transducers; An Axial Force Probe for Atomic Force Microscopy, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 247 (1998).
17. **Y. Liang** and T.W. Kenny, Mechanical Optimization of a Dual-Axis Piezoresistive Force Sensor, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 389 (1998).
18. **A.M. Fitzgerald**, R.S. Iyer, R.H. Dauskardt, and T.W. Kenny, Fracture and Sub-Critical Crack Growth Behavior of Micromachined Single Crystal Silicon Structures, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 395 (1998).
19. **J.K. Reynolds**, D.C Catling, R.C. Blue, N.I. Maluf, and T.W. Kenny Packaging and Instrumentation of a Commercial Pressure Sensor for a High-G Impact and the Martian Environment, Proceedings 1998 ASME Winter Meeting DSC Vol 66, 401 (1998).
20. **B.W. Chui**, T.W. Kenny, H.J. Mamin, B.D. Terris, and D. Rugar, A Novel AFM Cantilever with Independent Piezoresistive Sensors for Simultaneous Lateral and Vertical Force Detection, ASME Winter Exposition 1997.
21. **C.H. Liu, A. Barzilai, J.K. Reynolds, J. Grade**, H.K. Rockstad, T.W. Kenny, Feedback Control Strategies for High-Sensitivity Micromachined Tunneling Accelerometer, ASME Winter Exposition 1997.

Non-Refereed Symposia and Conference Publications:

1. **C.P. Cameron, T. Imamura, C. Devmalya, G. Vukasin, A. Alter**, T.W. Kenny, "Design Comparison and Survivability of Epitaxially Encapsulated MEMS Disc Resonating Gyroscopes at High Shock (>27,000g)", Proceedings 2019 International Symposium on Inertial Sensors and Systems, (2020).
2. **K.E. Kaplan**, M.W. Winterkorn, **H.J.K Kim, C.L.M. Everhart**, F.B. Prinz, and T.W. Kenny, "Thermal Accelerometer Performance Enhancements through AC Biasing Schemes", Proceedings 2020 IEEE MEMS (2020).
3. J. Yu, **H.K. Kwon, G.D. Vukasin**, T.W. Kenny, and Hanna Cho, "Frequency Stabilization in an Encapsulated High-Q Micromechanical Resonator via Internal Resonance", Proceedings 2020 IEEE MEMS (2020).
4. V. Zega, A. Opreni, G. Mussi, **H.K. Kwon, G. Vukasin**, G. Gattere, G. Langfelder, A. Frangi, and T.W. Kenny, "Thermal Stability of DETF MEMS Resonators: Numerical Modelling and Experimental Validation", Proceedings 2020 IEEE MEMS (2020).

5. J. Sun, H. Zhang, D. Chen, M. Pandit, G. Sobreviela, D. Xiao, M. Zhuo, **D.D. Gerrard, R. Kwon, G. Vukasin**, T.W. Kenny, and Ashwin Seshia, “Nonlinear Modal Interactions and Internal Resonance in a Micromachined Disk Resonator”, Proceedings 2020 IEEE MEMS (2020).
6. D.A. Kassie, **I.B. Flader**, S. Shmulevich, **H.K. Kwon**, T.W. Kenny, and D. Elata, “An Epi-Seal Encapsulated Franklin Oscillator Sustaining More Than 200,000,000 Electric Switching Cycles”, Proceedings 2020 IEEE MEMS (2020).
7. **J.M.L. Miller**, Z. Zhang, **N.E. Bousse**, D. Coso, S. Sadat, **H.K. Kwon, G.D. Vukasin**, A. Majumdar, and T.W. Kenny, “Temperature Hysteresis in Piezoresistive Microcantilevers”, Proceedings 2020 IEEE MEMS (2020).
8. S. Shin, H. Wen, **H.K. Kwon, G.D. Vukasin**, T.W. Kenny, and F. Ayazi, “A Dual-Axis Resonant Accelerometer Based on Electrostatic Stiffness Modulation in Epi-Seal Process”, Proceedings 2019 IEEE Sensors (2019).
9. **J.M.L. Miller, N.E. Bousse, D.D. Shin, H.K. Kwon**, and T.W. Kenny, “Signal Enhancement in MEM Resonant Sensors Using Parametric Suppression”, 2019 20th International Conference on Solid-State Sensors, Actuators and Microsystems and Eurosensors XXXIII, (2019).
10. **S. Koppaka, A.L. Alter, G.D. Vukasin, D.D. Shin, I.B. Flader, Y. Chen**, and T.W. Kenny, “Nonlinearity of Degenerately Doped Flexural Mode Silicon Micromechanical Resonators”, 2019 20th International Conference on Solid-State Sensors, Actuators and Microsystems and Eurosensors XXXIII, (2019).
11. **H.K. Kwon, L.C. Ortiz, G.D. Vukasin, Y.Chen, D.D. Shin**, and T.W. Kenny, “An Oven-Controlled MEMS Oscillator (OCMO) With Sub 10mw, ± 1.5 PPB Stability Over Temperature”, 2019 20th International Conference on Solid-State Sensors, Actuators and Microsystems and Eurosensors XXXIII, (2019).
12. **G.D. Vukasin, V.K. Sanchez, C.P. Cameron, H.K. Kwon, J. Rodriguez, I.B. Flader, Y. Chen**, and T.W. Kenny, “Effect of Substrate Thickness on Anchor Damping in MEMS Devices”, 2019 20th International Conference on Solid-State Sensors, Actuators and Microsystems and Eurosensors XXXIII, (2019).
13. **A.L. Alter, G.D. Vukasin, I.B. Flader, H.J. Kim, Y. Chen, D.D. Shin**, and T.W. Kenny, “Experimentally Observed Nonlinear Dissipation Linked to Contributions from Gas Damping and TED in Mems Flexural Mode Resonators”, 2019 20th International Conference on Solid-State Sensors, Actuators and Microsystems and Eurosensors XXXIII, (2019).
14. I.P. Prikhodko, J.A. Gregory, **D. Shin, R. Kwon**, T.W. Kenny, and M.W. Judy, “Pseudo-Extensional Mode MEMS Ring Gyroscope”, 2019 International Symposium on Inertial Sensors and Systems, (2019).
15. Y.A. Pishchalnikov, W. Behnke-Parks, K. Maeda, T. Colonius, M. Mellema, M. Hopcroft, A. Luong, S. Wiener, M.L. Stoller, T. Kenny, D.J. Laser, “Experimental observations and numerical modeling of lipid-shell microbubbles with calcium-adhering moieties for minimally-invasive treatment of urinary stones”, Proceedings Meetings on Acoustics. 35, 020008 (2018).

16. M.H. Asadian, S. Askari, **I.B. Flader, Y. Chen, D.D. Gerrard, D.D. Shin, H.K. Kwon,** T.W. Kenny, and A.M. Shkel, “High Quality Factor Mode Ordered Dual Foucault Pendulum Gyroscope”, 2018 IEEE Inertial Sensors (2018).
17. **J. Rodriguez, G.D. Vukasin,** G.M. Glaze, M.A. Hopcroft, **L.C. Ortiz, C.H. Ahn, E. Ng,** W. Park, T.W. Kenny, and C.A. Watson, “Investigation of Orientation Dependence of the Thermal Expansion Coefficient in Silicon MEMS Resonators” 2018 International Frequency Control Symposium, Olympic Valley, CA. Pg 1-4. (2018).
18. **L.C. Ortiz, H-K. Kwon, J. Rodriguez, D.B. Heinz, Y. Chen, G.D. Vukasin, D.D. Shin** and T.W. Kenny, “A New Low-Power MEMS Dual-Mode Clock with PPB Stability over Temperature”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
19. **A.L. Alter, I.B. Flader, Y. Chen, L.C. Ortiz, D.D. Shin, D.B. Heinz** and T.W. Kenny, “First Fatigue Measurements on Thick Epi-Polysilicon MEMS in Ultra-Clean Environment”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
20. **L.C. Ortiz, D.D. Gerrard, I.B. Flader, G.D. Vukasin, D.B. Heinz, J. Rodriguez, S. Koppaka, D.D. Shin, H-K Kwon,** S. Chandorkar, and T.W. Kenny, “Enhancing Micro-Oven Power and Stiffness in Encapsulated Devices for Timing Reference Applications”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
21. **J.M.L. Miller,** A. Ansari, **D.B. Heinz, Y. Chen, I.B. Flader, D.D. Shin,** L.G. Villanueva, and T.W. Kenny, “What is Effective Quality Factor?”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
22. Y. Wang, Y-W, Lin, **J. Rodriguez, G.D. Vukasin, D.D. Shin, H-K. Kwon, D.B. Heinz, Y. Chen, D.D. Gerrard,** T.W. Kenny and A.M. Shkel, “On Decoupled Quantification of Energy Dissipation Mechanisms in Toroidal Ring Gyroscopes”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
23. **H-K. Kwon, D.B. Heinz, D.D. Shin, Y. Chen, L.C. Ortiz, G.D. Vukasin** and T.W. Kenny, “Precise Local Temperature Measurement of Fully-Encapsulated Ovenized MEMS Devices”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
24. E. Cook, M. Tomaino-Iannucci, J. Bernstein, M. Weinberg, J. Choy, K. Hobart, L. Luna, M. Tadjer, R. Myers-Ward, F. Kub, **Y. Yang, E. Ng, I. Flader, Y. Chen,** and T. Kenny, “A High-Mass, Eight-Fold Symmetric Silicon Carbide MEMS Gyroscope”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
25. **G.D. Vukasin, J. Rodriguez, L.C. Ortiz,** G.M. Glaze, **D.D. Gerrard, C.H. Ahn, Y. Yang,** J. Lake, R.N. Candler and T.W. Kenny, “Direct Measurement of Anchor Damping in Pressure-Limited Ring Resonators”, Proceedings 2018 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2018).
26. **D.D. Shin, D.B. Heinz, K-K. Kwon, Y. Chen,** and T.W. Kenny, “Lateral Diffusion Doping of Silicon for Temperature Compensation of MEMS Resonators”, 2018 IEEE International Symposium on Inertial Sensors and Systems, (2018).

27. **K.E. Kaplan, M.W. Winterkorn, C.L.M. Everhart, D.D. Shin, G.J. O'Brien, F.B. Prinz and T.W. Kenny**, "Active Temperature Compensation of Thermal Accelerometer for Improved Stability", 2018 IEEE International Symposium on Inertial Sensors and Systems (2018).
28. **J. Rodriguez, D.D. Gerrard, G.M. Glaze, S. Chandorkar, L. Comenecia, Y. Chen, I.B. Flader, T.W. Kenny**, "Direct Measurement of Anchor Damping in MEMS Resonators", Proceedings IEEE Sensors P.1, October 29, 2017, Glasgow, Scotland (2017).
29. **I.B. Flader, Y. Chen, C.C. Shin, A.L. Alter, J. Rodriguez, and T.W. Kenny**, "Epitaxial Encapsulation of Fully-Differential Electrodes and Large Transduction Gaps for MEMS Resonant Structures", IEEE MEMS Glasgow 483 (2018).
30. **V. Maiwald, I.B. Flader, M. Muller, Y. Chen, S. Lluss, D.D. Shin, C. Roman, D.B. Heinz, T.W. Kenny and C. Hierold**, "Experimental Fractal-Like Instability Bands in Resonant Silicon-Silicon Contact Pull-In Vibration Detector", IEEE MEMS Glasgow 984 (2018).
31. **L.C. Ortiz, I.B. Flader, G.D. Vukasin, D.D. Gerrard, S.A. Chandorkar, J. Rodriguez, D.D. Shin, R. Kwon, D.B. Heinz, Y. Chen, W. Park, K.E. Goodson and T.W. Kenny**, "Thermal Effects of Ovenized Clocks on Epitaxial Encapsulated Inertial Measurement Units", IEEE MEMS Glasgow 980 (2018).
32. **J. Rodriguez, D.D. Gerrard, G.M. Glaze, S. Chandorkar, Y. Chen, I.B. Flader, D.D. Shin and T.W. Kenny**, "Unanticipated Results in the First Direct Measurements of Anchor Damping in MEMS Resonators", IEEE MEMS Glasgow 543 (2018).
33. **C.L.M. Everhart, K.E. Kaplan, M.W. Winterkorn, H. Kwon, J. Provine, M. Asheghi, K.E. Goodson, F.B. Prinz, and T.W. Kenny**, "High-Stability Thermal Accelerometer based on UltraThin Platinum ALD Nanostructures", IEEE MEMS Glasgow 976 (2018).
34. **D.D. Shin, Y. Chen, I.B. Flader and T.W. Kenny**, "Temperature Compensation of Resonant Accelerometer via Nonlinear Operation", IEEE MEMS Glasgow 1012 (2018).
35. **M. Bauer, T. Ebefors, M.M. Visser Taklo, S. Moe, P. Pickering, C. Twanow, D. Spicer, S. Nasiri, S. Winkler, R. Ramadoss, A. Luque, C. Aracil, J. Rodriguez, T.W. Kenny, M. Esashi, S. Tanaka, Y-C. Su, H-A. Yang, C-W. Lin, W. Fang, Y.T. Cheng, Y.C. Su, L.Lin, E.M. Chow, C.L. Chua, C-M. Huang, A. Sai S. Vasan, Y. Huang, R. Doraiswami, M. Osterman, M. Pecht, Y.C. Lee, Y-T. Cheng**, "Silex's TSV Technology: Overview of Processes and MEMS Applications", MEMS Packaging 5, 31 (2018).
36. **J. Rodriguez, D.D. Gerrard, G.M. Glaze, S. Chandorkar, L.C. Ortiz, Y. Chen, I.B. Flader and T.W. Kenny**, "Direct Measurements of Anchor Damping in MEMS Resonators", IEEE Sensors Belfast (2017).
37. **S.Sonmezoglu, I.B. Flader, Y. Chen, D. D Shin, T.W. Kenny, and D.A. Horsley**, "Dual-resonator MEMS magnetic sensor with differential amplitude modulation", Proceedings, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 814 (2017).
38. **I.B. Flader, Y. Chen, D.D. Gerrard, and T.W. Kenny**, "Wafer-scale encapsulation of fully differential electrodes for multi-axis inertial sensing", Proceedings, 2017 International

Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 591 (2017).

39. **J.M.L. Miller, D.B. Heinz, I.B. Flader, Y. Chen, D.D. Shin, T.W. Kenny**, “Effective quality factor and temperature dependence of self-oscillations in a thermal-piezoresistively pumped resonator”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 1907 (2017).
40. **D.D. Gerrard, Y. Chen, S.A. Chandorkar, G.Yu, J.Rodriguez, I.B. Flader, D.D. Shin, C.D. Meinhart, O.Sigmund, T.W. Kenny**, “Topology optimization for reduction of thermo-elastic dissipation in MEMS resonators”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 794 (2017).
41. **D.B.Heinz, I.B. Flader, Y. Chen, G.D. Vukasin, L.C. Ortiz, T.W. Kenny**, “Direct comparison of stiction properties of oxide coated polysilicon and smooth single crystal silicon”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 1203 (2017).
42. **J. Rodriguez, D.D. Gerrard, S. Chandorkar, Y. Chen, G.M. Glaze, I.B. Flader, C.H. Ahn, E.J. Ng, T.W. Kenny**, “Wide-range temperature dependence studies for devices limited by thermoelastic dissipation and anchor damping”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 1100 (2017).
43. **D.D. Shin, Y. Chen, I.B. Flader, T.W. Kenny**, “Epitaxially encapsulated resonant accelerometer with an on-chip micro-oven”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 595 (2017).
44. **V. Maiwald, Y. Chen, M. Müller, I.B. Flader, C. Roman, D.B. Heinz, D.D. Shin, T.W. Kenny, C. Hierold**, “Transfer function tuning of a broadband shoaling mechanical amplifier near the electrostatic instability”, 2017 International Conference on Solid-State Sensors, Actuators and Microsystems, June 18-22, 2017, Kaohsiung, Taiwan, P. 802 (2017).
45. **D.D. Shin, C.H. Ahn, Y. Chen, V.A. Hong, E.J. Ng, Y. Yang, T.W. Kenny**, “Electrostatic tuning of temperature coefficient of frequency of anisotropic disk-shaped resonators”, 2017 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), Kauai, Hawaii, P. 264 (2017).
46. **A. Efimovskaya, Y. Yang, E. Ng, Y. Chen, I. Flader, T.W. Kenny, A.M. Shkel**, “Compact roll-pitch-yaw gyroscope implemented in wafer-level Epitaxial Silicon Encapsulation process”, 2017 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), Kauai, Hawaii, P. 1 (2017).
47. **S.Sonmezoglu, I.B. Flader, Y. Chen, D.D. Shin, T.W. Kenny, D.A. Horsley**, “Dual-resonator MEMS Lorentz force magnetometer based on differential frequency modulation”, 2017 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), Kauai, Hawaii, P. 160 (2017).
48. **Y.Chen, I.B. Flader, D.D. Shin, C.H. Ahn, L.C. Ortiz, T.W. Kenny**, “Fabrication of wide and deep cavities for silicon MEMS devices without wafer bonding”, 2017 IEEE International Symposium on Inertial Sensors and Systems (INERTIAL), Kauai, Hawaii, P. 113 (2017).

49. P.Taheri-Tehrani, M.Defoort, **Y. Chen, I. Flader, D.D. Shin**, T.W. Kenny, D.A. Horsley, “Epitaxially-encapsulated quad mass resonator with shaped comb fingers for frequency tuning”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 1111. (2017).
50. **D.B. Heinz, V.A. Hong, Y. Yang, C.H. Ahn**, T.W. Kenny, “High-G (> 20,000 g) inertial shock survivability of epitaxially encapsulated silicon MEMS devices”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 1122. (2017).
51. **D.D. Shin, C.H. Ahn, Y. Chen, D.L. Christensen, I.B. Flader**, T.W. Kenny, “Environmentally robust differential resonant accelerometer in a wafer-scale encapsulation process”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 17. (2017).
52. **I.B Flader, Y. Chen, Dongsuk D. Shin, D.B. Heinz, L.C. Ortiz, A.L. Alter**, W. Park, K.E. Goodson, T.W. Kenny, “Micro-tethering for in-process stiction mitigation of highly compliant structures”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 675. (2017).
53. **Y. Chen, D.D. Shin, I.B. Flader**, T.W. Kenny, “Tri-mode operation of highly doped silicon resonators for temperature compensated timing references”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 1158. (2017).
54. A. Efimovskaya, Y.W. Lin, **Y. Yang, E. Ng, Y. Chen, I. Flader, C.H. Ahn, V. Hong**, T.W. Kenny, A.M. Shkel, “On cross-talk between gyroscopes integrated on a folded MEMS IMU Cube”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 1142. (2017).
55. **D.D. Gerrard, J. Rodriguez, L.C. Ortiz, S.A. Chandorkar, I.B. Flader, Y. Chen, D.D. Shin**, T.W. Kenny, “Manipulation of heat flux paths in thermo-elastically damped resonators for Q optimization”, Proceedings 2017 IEEE MEMS, January 22-25, 2017, Las Vegas, NV, P 1130. (2017).
56. **C.H Ahn, D.L Christensen, D.B Heinz, V.A Hong, E.J Ng, J. Rodriguez, Y. Yang, G. O'Brien**, T.W. Kenny, “Encapsulated Inertial Systems”, 2016 IEEE International Electron Devices Meeting (IEDM), San Francisco, CA (2016).
57. **D.B. Heinz, V.A. Hong, C.H. Ahn. Y. Yang** and T.W. Kenny, “Stiction at High Temperature (>205C) in Encapsulated MEMS Devices for Harsh Environment Applications”, Proceedings 2016 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2016).
58. P. Polunin, **Y. Yang**, S. Shaw, T.W. Kenny and M. Dykman, “Revealing and Characterizing Noise Sources in MEMS Resonators”, Proceedings 2016 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2016).
59. O. Shoshani, **D. Heywood, Y. Yang**, T.W. Kenny and S. Shaw, “Phase Noise Reduction in a MEMS Oscillator using a Nonlinearity-Enhanced Synchronization Domain”, Proceedings 2016 Hilton Head Workshop on Solid State Sensors and Actuators, Hilton Head (2016).
60. **I.B. Flader, C.H. Ahn, D.D. Gerrard, E.J. Ng, Y Yang, V.A. Hong**, M. Pavone, T.W. Kenny, “Autonomous calibration of MEMS disk resonating gyroscope for improved sensor

performance”, 2016 American Control Conference, P. 5803 (2016).

61. I.P. Prikhodko, J.A. Gregory, W.A. Clark, J.A. Geen, M.W. Judy, **C.H. Ahn**, and T.W. Kenny, “Mode-matched MEMS Coriolis vibratory gyroscopes: Myth or reality?”, 2016 Position, Location and Navigation Symposium (PLANS) (2016).
62. **V.A. Hong, D.B. Heinz, D.L. Christensen, D.D. Shin, Y. Chen, C.H. Ahn, Y. Yang, E.J. Ng, I.B. Flader**, and T.W. Kenny, “Overcoming Stiction Forces with Resonant Over-Travel Stops”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 47-50.
63. **Y. Chen, E.J. Ng, D.D. Shin, C.H. Ahn, Y. Yang, I.B. Flader, V.A. Hong** and T.W. Kenny, “Ovenized Dual-Mode Clock (ODMC) based on Highly-Doped Single-Crystal Silicon Resonators”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 91-94.
64. S. Wisher, P. Shao, A. Norouzpour-Shirazi, **Y. Yang, E. Ng, I. Flader, Y. Chen, D. Heinz**, T. Kenny, and F. Ayazi, “A High-Frequency Epitaxially-Encapsulated Single-Drive Quad-Mass Tri-Axial Resonant Tuning Fork Gyroscope”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 930-933.
65. **C.H. Ahn, D.D. Shin, V.A. Hong, Y. Yang, E.J. Ng, Y. Chen, I.B. Flader**, and T.W. Kenny, “Encapsulated Disk Resonator Gyroscope with Differential Internal Electrodes”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 962-969.
66. P. Taheri-Tehrani, M. Kline, I. Izyumin, B. Eminoglu, Y-C- Yeh, **Y. Yang, Y. Chen, I. Flader, E.J. Ng**, T.W. Kenny, B.E. Boser, and D.A. Horsley, “Epitaxially-Encapsulated Quad Mass Gyroscope with Nonlinearity Compensation”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 966-969.
67. **D.D. Gerrard, C.H. Ahn, I.B. Flader, Y. Chen, E.J. Ng, Y. Yang**, and T.W. Kenny “Q-Factor Optimization in Disk Resonator Gyroscopes via Geometric Parameterization”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 994-997.
68. **I.B. Flader, C.H. Ahn, E.J. Ng, Y. Yang, V.A. Hong**, and T.W. Kenny, “Stochastic Method for Disk Resonating Gyroscope Mode Matching and Quadrature Nulling”, Proceedings 2016 IEEE MEMS, January 24-27, 2016, Shanghai China, p. 998-1001.
69. **C. H. Ahn, V.A. Hong, W. Park, T. Yang, Y. Chen, E. Ng, J. Huynh**, A.D. Challoner, K.E Goodson and T.W. Kenny, “On-Chip Ovenization of Encapsulated Disk Resonator Gyroscope (DRG)”, Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 39-42 (2015).
70. **V.A. Hong, J. Stehle, C.H. Ahn, D.B. Heinz**, G. Yama, B. Kim, G.J. O’Brien and T.W. Kenny, “Capacitive Sensor Fusion : Co-Fabricated X/Y and Z axis Accelerometers, Pressure Sensor and Thermometer”, Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 295-298 (2015).
71. **Y. Yang, E.J. Ng, Y. Chen, I.B. Flader, C.H. Ahn, V.A. Hong** and T.W. Kenny, “A Unified Epi-Seal Process for Resonators and Inertial Sensors”, Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 1326-1329 (2015).
72. **D.D. Gerrard, E.J. Ng, C.H. Ahn, V.A. Hong, Yushi Yang**, and T.W. Kenny, “Modeling

the Effect of Anchor Geometry on the Quality Factor of Bulk-Mode Resonators", Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 1997-2000 (2015).

73. **J. Rodriguez, Y. Yang, C.H. Ahn, Y. Chen, E.J. Ng, V.A. Hong, S. Ghaffari, and T.W. Kenny**, "Damping Mechanisms in Light and Heavy-Doped Dual-Ring and Double-Ended Tuning Fork Resonators (DETF)", Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 2005-2009 (2015).
74. B.W. Soon, Y. Qian, **E.J. Ng**, T.W. Kenny and C. Lee, "Silicon-to-Silicon Microswitch with Wide Operation Temperature Range", Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 2105-2108 (2015).
75. P. Polunin, **Y. Yang**, J. Atalaya, **E. Ng**, S. Strachan, O. Shoshani, M. Dykman, S. Shaw and T.W. Kenny, "Characterizing MEMS Nonlinearities Directly : The Ring-Down Measurements", Proceedings, 2015 International Conference on Solid-State Sensors, Actuators and Microsystems, June 23-27, 2015, Anchorage, AK, p 2176-2179 (2015).
76. **C. H. Ahn, E. Ng, V.A. Hong, J. Huynh**, T.W. Kenny and **S. Wang**, "Oxide-coated Polysilicon Disk Resonator Gyroscope (DRG) within the Wafer-Scale Encapsulation Process", Proceedings 2nd IEEE International Symposium on Inertial Sensors and Systems, P. 127 (2015).
77. P.Taheri-Tehrani, O. Izyumin, **C.H. Ahn, E.J. Ng, V.A. Hong, Y. Yang**, T.W. Kenny, B.E. Bozer, D.A. Horsley, "Disk Resonator Gyroscope with Whole-Angle Mode Operation", Proceedings 2nd IEEE International Symposium on Inertial Sensors and Systems, P. 9 (2015).
78. **E. Ng, Y. Yang, V.A. Hong, C.H. Ahn, D.B. Heinz, I. Flader, Y. Chen, C.L.M. Everhart, B. Kim, R. Melamud, R.N. Candler, M.A. Hopcroft, J.C. Salvia, S. Yoneoka, A.B. Graham, M. Agarwal, M.W. Messana, K.L. Chen, H.K. Lee, S. Wang, G. Bahl, V. Qu, C.F. Chiang**, and T.W. Kenny, A. Partridge, M. Lutz, G. Yama, and G.J. O'Brien, "The Very Long Path from MEMS Resonators to Timing Products", Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.1 (2015).
79. D. Senkal, **E.J. Ng, V.A Hong, Y. Yang, C.H. Ahn**, T.W. Kenny and A.M. Shkel, "Parametric Drive of a Toroidal MEMS Rate Integrating Gyroscope Demonstrating <20PPM Scale Factor Stability", Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.33 (2015).
80. I.I. Izuymin, M.H. Kline, Y-C. Yeh, B. Eminoglu, **C.H. Ahn. V.A. Hong, Y. Yang, E.J. Ng**, T.W. Kenny and B.E. Bozer, "A 7PPM 6d/HR Frequency-Output MEMS Gyroscope", Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.1 (2015).
81. **D.B. Heinz, V.A. Hong, T.S. Kimbrell, J. Stehle, C.H. Ahn, E.J. Ng, Y. Yang**, G. Yama, G.J. O'Brien and T.W. Kenny, "Stiction Forces and Reduction by Dynamic Contact in Ultra-Clean Encapsulated MEMS Devices", Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.393 (2015).
82. **Y. Chen, E.J. Ng, Y. Yang, C.H. Ahn, I. Flader** and T.W. Kenny, "In-Situ Ovenization of Lamé-Mode Silicon Resonators for Temperature Compensation", Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.809 (2015).

83. **Y. Yang, E.J. Ng, P. Polunin, Y. Chen, S. Strachan, V.A. Hong, C.H. Ahn, O. Shoshani, S. Shaw, M. Dykman and T.W. Kenny**, “Experimental Investigation on Mode Coupling of Bulk-Mode Silicon MEMS Resonators”, Proceedings 2015 IEEE MEMS Conference, Estoril Portugal, P.1008 (2015).
84. **Yushi Yang, Eldwin J. Ng, Vu A. Hong, Chae Hyuck Ahn, Yunhan Chen, Elia Ahadi, Mark Dykman, and Thomas W. Kenny**, “Measurement of the Nonlinear Elasticity of Doped Bulk-Mode MEMS Resonators”, Proceedings 2014 Solid State Sensors and Actuators Workshop, 285-288, Hilton Head, SC (2014).
85. **Eldwin J. Ng, Yushi Yang, Yunhan Chen, and Thomas W. Kenny**, “An Etch Hole-Free Process for Temperature-Compensated, High-Q Encapsulated Resonators”, Proceedings 2014 Solid State Sensors and Actuators Workshop, 99-100, Hilton Head, SC (2014).
86. **J. Stehle, V.A. Hong, A. Feyh, G.J. O’Brien, G. Yama, O. Ambacher, B. Kim, and T.W. Kenny**, “Silicon Migration of Through-Holes in Single and Poly-Crystalline Silicon Membranes”, Proceedings 2014 Solid State Sensors and Actuators Workshop, 32-35, Hilton Head, SC (2014).
87. **M. Li, S. Sonmezoglu, E.J. Ng, V.A. Hong, C. H. Ahn, Y. Yang, T.W. Kenny and D.A. Horsley**, “Lorentz Force magnetometer with Quadrature Frequency Modulation”, Proceedings 2014 Solid State Sensors and Actuators Workshop, 52-55, Hilton Head, SC (2014).
88. **T.S. English, F. Purkl, A. Daus, J. Provine, Y. Won, G. Yama, A. Feyh, G. O’Brien, K.E. Goodson, O. Ambacher, and T.W. Kenny**, “Atomic Layer Deposited Platinum as a Sensor Material: Uniformity, 1/F Noise and Young’s Modulus”, Proceedings 2014 Solid State Sensors and Actuators Workshop, 44-47, Hilton Head, SC (2014).
89. **S. Nitzan, T-H. Su, C. Ahn, E. Ng, V. Hong, Y. Yang, T. Kenny, and D.A. Horsley**, “Impact of Gyroscope Operation Above the Critical Bifurcation Threshold on Scale Factor and Bias Instability”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 749-752 (2014).
90. **David B. Heinz, Vu A. Hong, Eldwin J. Ng, Chae Hyuck Ahn, Yushi Yang, Thomas W. Kenny**, “Characterization of Stiction Forces in Ultra-Clean Encapsulated MEMS Devices”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 588-591 (2014).
91. **Mo Li, Eldwin J. Ng, Vu A. Hong, Chae H. Ahn, Yushi Yang, Thomas W. Kenny and David A. Horsley** “Single-Structure 3-Axis Lorentz Force Magnetometer with Sub-30 nT/ $\sqrt{\text{Hz}}$ Resolution”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 80-83 (2014).
92. **Eldwin J. Ng, Kimberly L. Harrison, Camille L. Everhart, Vu A. Hong, Yushi Yang, Chae Hyuck Ahn, David B. Heinz, Roger T. Howe and Thomas W. Kenny**, “Stable Charge-Biased Capacitive Resonators with Encapsulated Switches”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 1277-1280 (2014).

93. **Eldwin J. Ng, Yushi Yang, Vu A. Hong, Chae Hyuck Ahn, David L. Christensen,** Brian A. Gibson, Kamala R. Qalandar, Kimberly L. Turner, Thomas W. Kenny, “Stable Pull-In Electrodes for Narrow Gap Actuation”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 1281-1284 (2014).
94. D. Senkal, S. Askari, M.J. Ahamed, **E.J. Ng, V. Hong, Y. Yang, C.H. Ahn,** T.W. Kenny, A.M. Shkel, “100K Q-Factor Torodial Ring Gyroscope Implemented in Wafer-Level Epitaxial Silicon Encapsulation Process”, Proceedings 2014 IEEE 27th International Conference on Micro Electro Mechanical Systems (MEMS), San Francisco, 24-27 (2014).
95. **E.J. Ng, C.H. Ahn, Y. Yang, V.A. Hong, C-F. Chiang, E. Ahadi, M.W. Ward** and T.W. Kenny, “Localized, Degenerately-Doped Epitaxial Silicon for Temperature Compensation of Resonant Microsystems”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 2419-2422.
96. **E.J. Ng, C-F. Chiang, Y. Yang, V.A. Hong, C.H. Ahn** and T.W. Kenny, “Ultra-High Aspect Ratio Trenches in Single Crystal Silicon with Epitaxial Gap Tuning”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 182-185.
97. **Y. Yang, E.J. Ng, C.H. Ahn, V.A. Hong, E. Ahadi** and T.W. Kenny, “Mechanical Coupling of Dual Breath-Mode Ring Resonator”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 502-505.
98. **C.H. Ahn, E.J. Ng, V.A. Hong, Y. Yang, B.J. Lee, M.W. Ward,** and T.W. Kenny, “Geometric Compensation of (100) Single Crystal Silicon Disk Resonating Gyroscope for Mode-Matching”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 1723-1726.
99. **V.A. Hong, B.J. Lee, D.L Christensen, E.J. Ng, C.H. Ahn, Y. Yang** and T.W. Kenny, “X-Y and Z-Axis Capacitive Accelerometers Packaged in an Ultra-Clean Hermetic Environment”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 618-621
100. **D.L. Christensen, C.H. Ahn, V.A. Hong, E.J. Ng, Y. Yang, B.J. Lee** and T.W. Kenny, “Hermetically-Encapsulated Differential Resonant Accelerometer”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 606-609.
101. **M.A. Philippine,** H. Zareie, O. Sigmund, G.M. Rebeiz and T.W. Kenny, “Topology Optimized RF MEMS Switches”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 2477-2480.
102. **F. Purkl, T.S. English,** G. Yama, J. Provine, A.K. Samaro, A. Feyh, B. Kim, G. O’Brien, O. Ambacher, R.T. Howe and T.W. Kenny, “Serpentine Geometry for Enhanced Performance of Nanometer-Thin Platinum Bolometers”, Proceedings, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, June 16-20, 2013, Barcelona. Spain, p 1507-1510
103. **C-F Chiang, A.B. Graham, B.J. Lee, C-H Ahn, E. Ng, G.J. O’Brien** and T.W. Kenny “Resonant pressure sensor with on-chip temperature and strain sensors for error correction”, Proceedings 2013 IEEE 26th International Conference on Micro Electro Mechanical Systems (MEMS), Taipei, Taiwan 45-48 (2013).

104. S. Nitzan, **C-H Ahn**, T-H Su, **E. Ng**, **S. Wang**, G. O'Brien, B.E. Boser, T.W. Kenny and D.A Horsley, "Epitaxially-encapsulated polysilicon disk resonator gyroscope", Proceedings 2013 IEEE 26th International Conference on Micro Electro Mechanical Systems (MEMS), Taipei, Taiwan 625-628 (2013).
105. F. Purkl, **T. English**, G. Yama, J. Provine, A.K. Samaroo, A. Feyh, G. O'Brien, O. Ambacher, R.T. Howe and T.W. Kenny, "Sub-10 nanometer uncooled platinum bolometers via plasma enhanced atomic layer deposition", Proceedings 2013 IEEE 26th International Conference on Micro Electro Mechanical Systems (MEMS), Taipei, Taiwan 185-188 (2013).
106. Y. Won, Y. Gao, R.G. deVilloria, B.L. Wardle, T.W. Kenny and K.E. Goodson, "Crust Removal and Effective Modulus of Aligned Multi-Walled Carbon Nanotube Films", 13th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomana in Electronic Systems (ITHERM), San Diego, CA PP 1070-1076 (2012).
107. S. Seth, **S. Wang**, T. Kenny, and B. Murmann, "A -131-dBc/Hz, 20-MHz MEMS Oscillator with a 6.9-mW, 69-k Ω , Gain-Tunable CMOS TIA", SSCIRC 2012 - 38th European Solid State Circuits Conference, Bordeaux, France Pages: 249-52 ,(2012).
108. **B. Kim**, **R. Melamud**, **R.A. Candler**, **M.A. Hopcroft**, and T.W. Kenny, "MEMS Packaging for Reliable Resonators and Oscillators", 2012 IEEE/MTT-S International Microwave Symposium - MTT 2012, Montreal Canada (2012).
109. **C-F. Chiang**, **A.B. Graham**, **E.J. Ng**, **C.H. Ahn**, G.J. O'Brien and T.W. Kenny, "A Novel, High-Resolution Resonant Thermometer used for Temperature Compensation of a Cofabricated Pressure Sensor", Proceedings 2012 Solid State Sensors and Actuators Workshop, P54, Hilton Head, SC (2012).
110. **E.J. Ng**, **S. Wang**, **D. Buchman**, **C-F. Chiang**, T.W. Kenny, H. Muenzel, M. Fuertsch, J. Marek, U.M. Gomez, G. Yama and G.O'Brien, "Ultra-Stable Epitaxial Polysilicon Resonators", Proceedings 2012 Solid State Sensors and Actuators Workshop, P271, Hilton Head, SC (2012).
111. **V.A. Hong**, **S. Yoneoka**, **M.W. Messana**, **A.B. Graham**, **J.C. Salvia**, **T.T. Branchflower**, **E.J. Ng** and T.W. Kenny, "High-Stress Fatigue Experiments on Single Crystal Silicon in an Oxygen-Free Environment", Proceedings 2012 Solid State Sensors and Actuators Workshop, P553, Hilton Head, SC (2012).
112. **M.A. Philippine**, O. Sigmund, G.M Rebeiz and T.W. Kenny, "Reduction of Stress-Stiffening by Topology Optimization", Proceedings 2012 Design Test Integration and Packaging Workshop (DTIP 2012), 2012, Cannes France (2012).
113. **C-F. Chiang**, **A.B. Graham**, G.J. O'Brien, and T.W. Kenny, "A single process for building capacitive pressure sensors and timing references with precise control of released area using lateral etch stop", Proceedings IEEE MEMS 2012, P. 519, Paris (2012).
114. **E. Ng**, **H.K. Lee**, **C.H. Ahn**, **R. Melamud**, and T.W. Kenny, "Stability measurements of silicon MEMS resonant thermometers", Proceedings IEEE Sensors 2011, Limerick (2011).
115. **C-F. Chiang**, **A.B. Graham**, **M.W. Messana**, J. Provine, **D.T. Buchman**, G.J. O'Brien, and T.W. Kenny, "Capacitive Absolute Pressure Sensor with Independent Electrode and Membrane Sizes for Improved Fractional Capacitance Change", Proceedings Transducers 2011, P. 894, Beijing (2011).
116. **H.K. Lee**, **R. Melamud**, **S.A. Chandorkar**, **Y.Q. Qu**, **J.C. Salvia**, **B. Kim**, **M.A. Hopcroft**, and T.W. Kenny, "Influence of the A-F Effect on the Temperature Stability of Silicon Micromechanical Resonators", Proceedings Transducers 2011, P. 506, Beijing (2011).

117. **H.K. Lee, P.A. Ward, A.E. Duwel, J.C. Salvia, Y.Q. Qu, R. Melamud, S.A. Chandorkar, M.A. Hopcroft, B. Kim,** and T.W. Kenny, “Verification of the Phase-Noise Model for MEMS Oscillators Operating in the Nonlinear Regime”, Proceedings Transducers 2011, P. 510, Beijing (2011).
118. R.G. Hennessy, M. M. Shulaker, **M. W. Messana, A. B. Graham,** N. Klejwa, J. Provine, T. W. Kenny and R. T. Howe, “Temperature Dependence of Vacuum-Encapsulated Resonators for Humidity Measurement”, Proceedings Transducers 2011, P. 1950, Beijing (2011).
119. **S. Wang, S. A. Chandorkar, A. B. Graham, M. W. Messana, J. Salvia,** and T.W. Kenny, “Encapsulated Mechanically-Coupled Fully-Differential Breathe-Mode Ring Filters with Ultra-Narrow Bandwidth”, Proceedings Transducers 2011, P. 942, Beijing (2011).
120. **H.K. Lee, R. Melamud, S. Chandorkar, Y-Q Qu, J. Salvia** and T.W. Kenny, “Motional Impedance of Resonators in the Nonlinear Regime”, Proceedings IEEE International Frequency Control Conference, 2011, San Francisco (2011).
121. **S. Yoneoka,** M. Liger, G. Yama, R. Schuster, F. Purkl, J. Provine, F.B. Prinz, R.T. Howe and T.W. Kenny, “ALD-Metal Uncooled Bolometer”, Proceedings IEEE MEMS 2011 P. 676, Cancun, MX (2011).
122. J. Provine, N. Ferralis, **A.B. Graham, M.W. Messana,** R. Kant, R. Maboudian, T.W. Kenny, and R.T. Howe, “Time Evolution of Released Hole Arrays into Membranes via Vacuum Silicon Migration”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P344, Hilton Head, SC (2010).
123. **G. Bahl, J. Salvia, H-K. Lee, R. Melamud, B. Kim,** R.T. Howe and T.W. Kenny, “Heterodyned Electrostatic Transduction Oscillators Evade Low-Frequency Noise Aliasing”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P384, Hilton Head, SC (2010).
124. **W.S. Smith,** P.G. Hartwell, R.G. Walmsley, and T.W. Kenny, “Contact Geometry Effects on Friction in MEMS Probe Arrays”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P198, Hilton Head, SC (2010).
125. **M.A. Philippine, C-F. Chang, J. Salvia, C.M. Jha, S. Yoneoka,** and T.W. Kenny, “Material Distribution Design for a Piezoelectric Energy Harvester Displaying Geometric Nonlinearity”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P451, Hilton Head, SC (2010).
126. R.G. Hennessy, M.M. Shulaker, **R. Melamud,** N. Klejwa, **S. Chandorkar, B. Kim,** J. Provine, T.W. Kenny and R.T. Howe, “Vacuum Encapsulated Resonators for Humidity Measurement”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P487, Hilton Head, SC (2010).
127. **H.K. Lee, J.C. Salvia, S. Yoneoka, G. Bahl, Y.Q. Qu, R. Melamud, S. Chandorkar, M.A. Hopcroft, B. Kim** and T.W. Kenny, “Stable Oscillation of MEMS Resonators Beyond the Critical Bifurcation Point”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P70, Hilton Head, SC (2010).
128. **M.W. Messana, A.B. Graham, S. Yoneoka,** R.T. Howe and T.W. Kenny, “Packaging of Large Lateral Deflection MEMS using a Combination of Fusion Bonding and Epitaxial Reactor Sealing”, Proceedings 2010 Solid State Sensors and Actuators Workshop, P336, Hilton Head, SC (2010).

129. **B. Kim, R. Melamud, R.A. Candler, M.A Hopcroft, C.M. Jha, S. Chandorkar,** and T.W. Kenny, “Encapsulated MEMS Resonators – A technology path for MEMS into Frequency Control”, (Invited) Proceedings 2010 International Frequency Control Symposium, 1 Newport Beach, CA, 2010.
130. **G. Bahl, J. Salvia, I. Bargatin, S. Yoneoka, R. Melamud, B. Kim, S. Chandorkar, M.A. Hopcroft,** R. Bahl, R.T. Howe, and T.W. Kenny, “Charge-drift elimination in resonant electrostatic MEMS”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 108 (2010).
131. **S. Wang, C. Chandorkar, J. Salvia, R. Melamud, Y.Q. Qu, H.K. Lee,** and T.W. Kenny, “Nonlinearity of hermetically-encapsulated high-Q double-balanced breathe-mode ring resonator”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 715 (2010).
132. **H.K. Lee, S. Yoneoka, G. Bahl, J. Salvia, Y.Q. Qu, R. Melamud, C. Chandorkar, B. Kim, M.A. Hopcroft,** and T.W. Kenny, “A novel characterization method for temperature compensation of composite resonators”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 743 (2010).
133. **S. Yoneoka, Y.Q. Qu, S. Wang, M.W. Messana, A.B. Graham, J. Salvia, B. Kim, R. Melamud, G. Bahl** and T.W. Kenny, “High-cyclic fatigue experiments on single crystal silicon in an oxygen-free environment”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 224 (2010).
134. **H.K. Lee, J. Salvia, G. Bahl, R. Melamud, S. Yoneoka, Y.Q. Qu, M.A. Hopcroft, B. Kim** and T.W. Kenny, “Influence of the temperature-dependent A-F effect on the design and performance of oscillators”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 699 (2010).
135. **Y.Q. Qu, R. Melamud, S.A. Chandorkar, H.K. Lee** and T.W. Kenny, “Stress relaxation study of sputtered platinum films near room temperature using an ultrasensitive strain gauge”, 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong Kong January 2010, P. 548 (2010).
136. **K.L. Chen, S. Wang, J. Salvia, R.T. Howe,** and T.W. Kenny, “Encapsulated Out-Of-plane Differential Square-Plate Resonator with Integrated Actuation Electrodes”, 15th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers 2009 June, 2009.
137. **C.S. Roper, R. Candler, S. Yoneoka,** T. Kenny, R.T Howe, R. Maboudian, “Simultaneous Wafer-Scale Vacuum-Encapsulation and Microstructure Cladding with LPCVD Polycrystalline 3C-SiC”, 15th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers 2009 June, 2009.
138. **Y.Q. Qu, R. Melamud** and T.W. Kenny, “Using Encapsulated MEMS Resonators to Measure Evolution in Thin Film Stress”, 15th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers 2009 June, 2009.
139. **M. Weinberg, R. Candler, S. Chandorkar,** J Varasnik, T. Kenny, and A. Duwel, “Energy Loss in MEMS Resonators and the Impact on Inertial and RF Devices”, 15th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers 2009 June, 2009.
140. **K.L. Chen, R. Melamud, S Wang** and T.W. Kenny, “An Integrated Solution for Wafer-Level packaging and Electrostatic Actuation of Out-Of Plane Devices”, Proceedings 22nd International Conference on MicroElectro Mechanical Systems (IEEE MEMS), January 2009.

141. **S. Yoneoka, G. Bahl, J. Salvia, K.L. Chen, A.B Graham, H.K. Lee, G. Yama, R.N. Candler** and T.W. Kenny “Acceleration Compensation of MEMS Resonators using Electrostatic Tuning”, Proceedings 22nd International Conference on MicroElectro Mechanical Systems (IEEE MEMS), January 2009.
142. **A.B. Graham, M. Messina, P. Hartwell, J. Provine, S. Yoneoka, B. Kim, R. Melamud, R.T. Howe, and T.W. Kenny**, “Wafer-Scale Encapsulation of Large Lateral Deflection MEMS Structures”, Proceedings 22nd International Conference on MicroElectro Mechanical Systems (IEEE MEMS), January 2009.
143. **J. Salvia, R. Melamud, S Chandorkar, H.K.Lee, Y.Q.Qu, S.F. Lord, B. Muhrmann,** and T.W. Kenny, “Phase Lock Pool-Based Temperature Compensation for MEMS Oscillators”, Proceedings 22nd International Conference on MicroElectro Mechanical Systems (IEEE MEMS), January 2009.
144. **K.L. Chen, H. Chandrahilim, A.B. Graham, S.A. Bhawe, R.T. Howe and T.W. Kenny**, “Epitaxial Silicon Microshell Vacuum-Encapsulated CMOS-Compatible 200 MHz Bulk-Mode Resonator”, Proceedings 22nd International Conference on MicroElectro Mechanical Systems (IEEE MEMS), January 2009.
145. **J. Salvia, M. Messina, M. Ohline, M.A. Hopcroft, R. Melamud, S. Chandorkar, H.K. Lee, G. Bahl, B. Muhrmann, and T.W. Kenny**, “Exploring the limits and practicality of Q-Based Temperature Compensation for Silicon Resonators”, Proceedings 2008 IEDM Meeting, December 2008.
146. **S.A. Chandorkar, M. Agarwal, R. Melamud, R.N. Candler, K.E. Goodson and T.W. Kenny**, “Limits of Quality Factor in Bulk-Mode Micromechanical Resonators”, Proceedings IEEE MEMS Conference, Tucson, AZ (2008).
147. **H.K. Lee, M.A. Hopcroft, R. Melamud, B. Kim, J. Salvia, S. Chandorkar,** and T.W. Kenny, “Electrostatic Tuning of Hermetically-Encapsulated Composite Resonator”, Proceedings 2008 Solid State Sensors and Actuators Workshop, Hilton Head, SC (2008).
148. **G. Bahl, R. Melamud, B. Kim, S. Chandorkar, J. Salvia, M.A. Hopcroft, R.G. Hennessy, S. Yoneoka, C.M. Jha, G. Yama, D. Elata, R.N. Candler, R.T. Howe, and T.W. Kenny**, “Observations of Fixed and Mobile Charge in Composite MEMS Resonators”, Proceedings 2008 Solid State Sensors and Actuators Workshop, Hilton Head, SC (2008).
149. **B. Kim, M.A. Hopcroft, R. Melamud, C.M. Jha, M. Agarwal, S.A. Chandorkar** and T.W. Kenny, “CMOS-Compatible wafer-scale encapsulation with MEMS Resonators”, Proceedings of the ASME InterPACK 2007, 499 (2007).
150. **H-S. Kim, H.O. Song, T.W. Kenny**, “An improved method of thermal resistance measurement for variable thermal resistors”, Proceedings of the ASME InterPACK 2007, 249 (2007).
151. **M.A. Hopcroft, H.K. Lee, B. Kim, R. Melamud, S. Chandorkar, M. Agarwal, C.M. Jha, J. Salvia, G. Bahl, H. Mehta, and T.W. Kenny** “A High-Stability MEMS Frequency Reference”, Proceedings, 14th International Conference on Solid State Sensors Actuators and Microsystems (Transducers '07), 1307 (2007).
152. **Ginel C. Hill, Daniel R. Soto, Stephanie J. Lue, Anne M. Peattie, Robert J. Full, and Thomas W. Kenny**, “Investigating the Role of Orientation Angle on Gecko Setae Adhesion using a Dual-Axis MEMS Force Sensor”, Proceedings, 14th International Conference on Solid State Sensors Actuators and Microsystems (Transducers '07), 2263 (2007).

153. **C. M. Jha, G. Bahl, R. Melamud, S. A. Chandorkar, M. A. Hopcroft, B. Kim, M. Agarwal, J. Salvia, H. Mehta and T. W. Kenny**, “CMOS Compatible Dual Resonator MEMS Temperature Sensor with Milli-degree Accuracy”, Proceedings, 14th International Conference on Solid State Sensors Actuators and Microsystems (Transducers '07), 229 (2007)
154. **B. Kim, M. Hopcroft, C.M Jha, R. Melamud, S. Chandorkar, M. Agarwal, K.L. Chen, W.T. Park, R. Candler, G. Yama² A. Partridge, M. Lutz, T.W. Kenny**, “Using MEMS to Build the Device and the Package”, Invited Talk, Transducers '07 Lyon France (6/7/07)
155. **B. Kim, M.A. Hopcroft, R. Melamud, C.M. Jha. M. Agarwal, S.A. Chandorkar, and T.W. Kenny**, “MEMS Resonators in CMOS Compatible Wafer-Scale Encapsulation”, Proceedings of IPACK2007 (2007).
156. **R. Melamud, B. Kim, M.A. Hopcroft, S.Chandorkar, M.Agarwal, C.M. Jha, and T.W. Kenny**, “Composite Flexural-Mode Resonator with Controllable Turnover Temperature”, Proceedings 2007 International Conference on MEMS, Kobe, Japan (2007).
157. **S. A. Chandorkar¹, H. Mehta¹, M. Agarwal¹, M.A. Hopcroft¹, C. M. Jha¹, R.N. Candler², G.Yama², G. Bahl¹, B. Kim¹, R. Melamud¹, K. E. Goodson¹ and T. W. Kenny¹** “Non-Isothermal Micromechanical Resonators”, Proceedings 2007 International Conference on MEMS, Kobe, Japan (2007).
158. **M.Agarwal , H. Mehta, R.N. Candler, S.A. Chandorkar, B. Kim , M.A. Hopcroft, R. Melamud, G. Bahl, G. Yama, T.W. Kenny and B. Murmann**, “Impact of Miniaturization on the Current Handling of MEMS Resonators”, Proceedings 2007 International Conference on MEMS, Kobe, Japan (2007).
159. **T.Kenny, M. Lutz, A. Partridge, G. Yama, R.N. Candler, W.T. Park, M. Hopcroft, B. Kim, M. Agarwal, S. Chandorkar, R. Melamud, C. Jha**, "Advances in MEMS Integration: MEMS First or MEMS Last?", Proceedings 12th International Micromachine/Nanotech Symposium, Tokyo, Japan 11/06.
160. **T.W.Kenny, A. Partridge, R.N. Candler, W.T. Park, M. Hopcroft, B. Kim, M. Agarwal, S. Chandorkar, R. Melamud, C. Jha, M. Lutz and G. Yama**, "Manufacturable MEMS : Building the MEMS, the Package and the Circuit in the Same Technology" Proceedings, Second International Forum on Micro-nano Hetero System Integration (MHSI'06) and 2nd Fraunhofer Gesellschaft Symposium, Sendai, Japan 11/06.
161. **M. Agarwal, K.K. Park, R.N. Candler, B. Kim, M.A. Hopcroft, S.A. Chandorkar, C.M. Jha, R. Melamud, T.W. Kenny, and B. Murmann**, “Nonlinear Characterization of Electrostatic MEMS Resonators”, 2006 Frequency Control Symposium (2006)
162. **M. Agarwal, K.K. Park, B. Kim, M.A. Hopcroft, S.A. Chandorkar, R.N. Candler, C.M. Jha, R. Melamud, T.W. Kenny and B. Murmann**, “Amplitude Noise Induced Phase Noise in Electrostatic MEMS Resonators”, Proceedings of the 2006 Hilton Head Workshop in Solid State Sensors, Actuators, and Microsystems, p62 (2006).
163. **R Melamud, B. Kim, M.A. Hopcroft, S. Chandorkar, M. Agarwal, C. Jha, S. Bhat, K.K. Park, and T.W. Kenny**, “Composite Flexural Mode Resonators with Reduced Temperature Coefficient of Frequency”, Proceedings of the 2006 Hilton Head Workshop in Solid State Sensors, Actuators, and Microsystems, p90 (2006).
164. **B. Kim, C.M. Jha, T. White, R.N. Candler, M. Hopcroft, M. Agarwal, K.K. Park, R. Melamud, and T.W. Kenny**, “Temperature Dependence of Quality Factor in MEMS Resonators”, Proceedings 2006 International Conference on MEMS, Istanbul, Turkey (2006).

165. **M. Agarwal, K.K. Park, M. Hopcroft, S. Chandorkar, R.N. Candler, B. Kim, R. Melamud, G. Yama, B. Murmann, and T.W. Kenny**, “Effects of Mechanical Vibrations and Bias Voltage Noise on Phase Noise of MEMS Resonator-based Oscillators”, Proceedings 2006 International Conference on MEMS, Istanbul, Turkey (2006).
166. **M.A. Hopcroft, M. Agarwal, K.K. Park, B. Kim, C.M. Jha, R.N. Candler, G. Yama, B. Murmann, and T.W. Kenny**, “Temperature Compensation of a MEMS Resonator using Quality Factor as a Thermometer”, Proceedings 2006 International Conference on MEMS, Istanbul, Turkey (2006).
167. **M. Agarwal, K. Park, R. Candler, M. Hopcroft, C. Jha, R. Melamud, B. Kim, B. Muhrman, and T. Kenny**, “Nonlinearity Cancellation in MEMS Resonators for Improved Power Handling”, 2005 International Electron Devices Meeting (2005).
168. **R. Melamud, M. Hopcroft, C. Jha, B. Kim, S. Chandorkar, R. Candler, T.W. Kenny**, “Effects of Stress on the Temperature Coefficient of Frequency in Double-Clamped Resonators”, Proceedings Transducers '05, 392-395 (2005).
169. **W.T. Park, K.N. O'Connor, J.R. Mallon, T. Maetani, R.N. Candler, V. Ayanoor-Vitikkate, J. Roberson, S. Puria, and T.W. Kenny**, “Sub-Millimeter Encapsulated Accelerometers : A Fully Implantable Sensor for Cochlear Implants”, Proceedings Transducers '05 109-112 (2005).
170. **R.N. Candler, W.T. Park, M. Hopcroft, B. Kim, and T.W. Kenny**, “Hydrogen Diffusion and Pressure Control of Encapsulated MEMS Resonators”, Proceedings, Transducers '05, 597-600 (2005).
171. **R.N. Candler, M. Hopcroft, C.W. Low, S. Chandorkar, B. Kim, M. Varghese, A. Duwel, and T.W. Kenny**, “Impact of Slot Location in Thermoelastic Dissipation in Micromechanical Resonators”, Proceedings, Transducers '05, 920-923 (2005).
172. **B. Kim, R.N. Candler, M. Hopcroft, M. Agarwal, W.T. Park, and T.W. Kenny**, “Frequency Stability of Wafer-Scale Encapsulated MEMS Resonators”, Proceedings, Transducers '05, 1965-1968 (2005).
173. **W.T. Park, R.N. Candler, V.A. Vittikkate, M. Lutz, A. Partridge, G. Yama, T.W. Kenny**, “Fully-Encapsulated Sub-MM Accelerometer”, Proceedings 18th IEEE International Conference on MEMS, 347, Miami, FL (2005), 347-350 (2005).
174. **B. Kim, R.N. Candler, M. Hopcroft, M. Agarwal, W.T. Park, J.T. Li, and T. Kenny**, “Investigation of MEMS Resonator Characteristics for Long-Term Operation and Wide Temperature Variation Condition”, ASME Winter Annual Meeting, Anaheim CA, 2004.
175. **M. Hopcroft, R. Melamud, R.N. Candler, W-T. Park, B. Kim, G. Yama, A. Partridge, M. Lutz, and T.W. Kenny**, “Active Temperature Compensation for Micromachined Resonators”, Proceedings 2004 Solid State Sensors and Actuators Workshop, 364-367 (2004).
176. **E.N. Wang, S. Devasenathipathy, C.H. Hidrovo, D.W. Fogg, J.M. Koo, J.G. Santiago, K.E. Goodson and T.W. Kenny**, “A Quantitative Understanding of Transient Bubble Growth in Microchannels using μ PIV”, Proceedings 2004 Solid State Sensors and Actuators Workshop, 101-102 (2004).
177. **R.N. Candler, M. Hopcroft, W.T. Park, S.A. Chandorkar, G. Yama, K.E. Goodson, M. Varghese, A.E. Duwel, A. Partridge, M. Lutz and T.W. Kenny**, “Reduction in Thermoelastic Dissipation in Micromechanical Resonators by Disruption of Heat Transport”, Proceedings 2004 Solid State Sensors and Actuators Workshop, 45-48 (2004).

178. T.W. Kenny, **Y. Liang, B.L. Pruitt, J.A. Harley, M. Bartsch, and R. Rudnitsky**, “Fundamental Noise in MEMS Force Sensors”, Proceedings 2004 SPIE Conference on Fluctuations and Noise in Sensors and Measurements, Maspalomas Gran Canaria ,143-151 (2004).
179. G. Upadhyaya, P. Zhou, K. Goodson, M. Munch, and T.W. Kenny, “Closed-Loop Cooling Technologies for Microprocessors”, Proceedings 2003 International Electronic Devices Meeting, Washington, 775-778 (2003).
180. **W.T. Park, R.N. Candler, J. Cho, H. Li, H. Li**, M. Lutz, A. Partridge, G. Yama, and T.W. Kenny, “Wafer-Scale Encapsulation of MEMS Devices”, Proceedings InterPACK '03, Kanapaali, HI IPACK 2003-35032 (2003).
181. **W.T. Park, R.N. Candler**, S. Kronmueller, M. Lutz, A. Partridge, G. Yama, and T.W. Kenny, “Wafer-Scale Film Encapsulation of Micromachined Accelerometers”, Proceedings Transducers '03, Boston, 1903-1906 (2003).
182. B.W. Chui, **Y. Hishinuma**, R. Budakian, H.J. Mamin, T.W. Kenny, and D. Rugar, “Mass-Loaded Cantilevers with Suppressed Higher-Order Modes for Magnetic Resonance Force Microscopy”, Proceedings Transducers '03, Boston, 1120-1123 (2003).
183. **M.S. Bartsch**, W. Federle, R.J. Full, and T.W. Kenny, “Small Insect Force Measurements using a Custom MEMS Force Sensor”, Proceedings Transducers '03, Boston, 1035-1038 (2003).
184. **R.N. Candler, H. Li**, M. Lutz, **W.T. Park**, A. Partridge, G. Yama, and T.W. Kenny, “Investigation of Energy Loss Mechanisms in Micromechanical Resonators”, Proceedings Transducers '03, Boston, 332-335 (2003).
185. **D.J. Laser**, A.M. Meyers, S. Yao, K.F. Bell, K.E. Goodson, J.G. Santiago, and T.W. Kenny, “Silicon ElectroOsmotic MicroPumps for Integrated Circuit Thermal Management”, Proceedings Transducers '03, Boston, 151-154 (2003).
186. L. Jiang, J.M. Koo, S. Zheng, J.C. Mikkelsen, **L. Zhang**, J.G. Santiago, T.W. Kenny, K.E. Goodson, “Two-phase microchannel heat sinks for an electrokinetic VLSI chip cooling system” Seventeenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium, (2001).
187. J.M. Koo, L. Jiang, A. Bari, L. Zhang, **E. Wang**, T.W. Kenny, J.G. Santiago, K.E. Goodson, “Convective boiling in microchannel heat sinks with spatially-varying heat generation”, ITherm 2002. Eighth Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, 30 (2002).
188. J.P. Lynch, K.H. Law, A.S. Kiremidjian, E. Carryer, T.W. Kenny, A. Partridge, A. Sundararajan, “Validation of a Wireless Modular Monitoring System for Structures”, Proceedings of the SPIE - The International Society for Optical Engineering 4696, 124 (2002)
189. T.W. Kenny, **R.N. Candler, H.J. Li, W.T. Park, J. Cho, H. Li**, A. Partridge, G. Yama, M. Lutz, “An Integrated Wafer-Scale Packaging Process for MEMS”, 2002 ASME International Mechanical Engineering Congress and Exhibition, New Orleans (2002).
190. Jiang, L., Mikkelsen, J., Koo, J-M, **Zhang, L.**, Huber, D., Yao, S., Bari, A., Zhou, P., Santiago, J., and Kenny, T.W. and Goodson, K.E., “Transient and Sub-atmospheric Performance of A Closed-loop Electroosmotic Microchannel Cooling System”, *Proceeding of Thermal Challenges in Next Generation Electronic Systems, THERMES 2002*, Santa Fe, New Mexico, USA, 133-139, Jan. 13-16, 2002.

191. **A.E. Herr**, J.C. Mikkelsen, J.G. Santiago, and T.W. Kenny , “Two-Dimensional Chip-Based Protein Analysis using Coupled Isoelectric Focusing and Capillary Electrophoresis”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 366-369 (2002).
192. **A. Tewary, K.Y. Yasumura, T.D. Stowe**, T.W. Kenny, and D. Rugar, “Quality Factor Enhancement of in situ Annealing Cantilevers”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 337-340 (2002).
193. **B.L. Pruitt, W.-T. Park**, and T.W. Kenny , “Measurement System for Low Force and Small Displacement Contacts”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head 297-300 (2002)
194. **D.J. Laser**, K.E. Goodson, J.G. Santiago, and T.W. Kenny , “High-Frequency Actuation with Silicon Electroosmotic Micropumps”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 231-235 (2002)
195. **W.P. King**, T.W. Kenny, K.E. Goodson, M. Despont, U. Duerig, M. Lantz, H. Rothuizen, G. Binnig, and P. Vettiger, “Microcantilevers for Thermal NanoImaging and Thermomechanical Surface Modification”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 210-213 (2002)
196. V. Chandrasekaran, **E.M. Chow**, T.W. Kenny, T. Nishida, L.N. Cattafesta, B.V. Sankar, and M. Sheplak, “Thermoelastically Actuated Acoustic Proximity Sensor with Integrated Through-Wafer Interconnects”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 102-105 (2002)
197. T.W. Kenny, **Y. Liang, S-W Ueng, M. Bartsch and R. Rudnitsky**, “Micromechanical Force Sensing with Application to Biology”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 62-65 (2002)
198. **E.N. Wang, L. Zhang**, L. Jiang, J-M. Koo, K.E. Goodson, and T.W. Kenny, “Micromachined Jet Arrays for Liquid Impingement Cooling of VLSI Chips”, Proceedings, 2002 Workshop on Solid State Sensors, Actuators and Microsystems, Hilton Head, 46-49 (2002)
199. **L. Zhang, E.N. Wang**, J-M. Koo, L. Jiang, K.E. Goodson, J.G. Santiago, and T.W. Kenny, “Enhanced Nucleate Boiling in Microchannels”, 2002 IEEE International Conference on MicroElectroMechanical Systems, Las Vegas, 89-92 (2002).
200. **L. Zhang, E.N. Wang**, J. Koch, J.Liu, J-M. Koo, L. Jiang, K.E. Goodson, J.G. Santiago, T.W. Kenny, “Microscale Liquid Impingement Cooling”, 2001 ASME International Mechanical Engineering Congress and Exhibition, New York (2001).
201. **D.J. Laser**, K.E. Goodson, J.G. Santiago, and T.W. Kenny, “Impact of Pumping Surface Separation Distance on Micromachined Silicon Electrokinetic Pump Performance”, 2001 ASME International Mechanical Engineering Congress and Exhibition, New York (2001).
202. **O. Ajakaiye**, and T.W. Kenny, “Performance Characterization of Micromachined Tunneling Infrared Sensors”, 2001 ASME International Mechanical Engineering Congress and Exhibition, New York (2001).
203. T. Kenny **A. Partridge, A. Rice** and M. Lutz, “An Integrated Wafer-Scale Packaging Process for MEMS”, Proceedings IEEE/ASME InterPACK Conference, Kauai (2001).
204. **L. Zhang**, J. Koo, L. Jiang, K. Goodson, J. Santiago, and T.W. Kenny, “Study of Boiling Regimes and Transient Signal Measurements in Microchannels”, Proceedings Transducers '01, Munich Germany, 1514-1517 (2001).

205. **D. Laser**, S.Yao, C-H Chen, J. Mikkelsen, K.E. Goodson, J.Santiago, and T.W. Kenny, "A Micromachined Low-Voltage, Parallel-Plate Electrokinetic Pump", Proceedings Transducers '01, Munich Germany, 930-933 (2001).
206. **Y. Liang, S-W Ueng**, T.W. Kenny, "Performance Characteristics of Ultra-Thin n-Type Piezoresistive Cantilevers", Proceedings Transducers '01, Munich Germany, 998-1001 (2001).
207. **M. Bartsch**, T. Kenny, W. Federle, and R. Full, "Exploring insect Biomechanics with Micromachined Force Sensors", Proceedings Transducers '01, Munich Germany, 1662-1665 (2001).
208. **B. Pruitt**, D. Choi, J. Florando, W. Nix, T. Kenny, R. Martens, S. Wenzel, and C. Reynolds, "Low-Force Electrical Contact Measurements using Piezoresistive MEMS Cantilevers to Characterize Thin Film Metallization", Proceedings Transducers '01, Munich Germany, 1032 –1035 (2001).
209. J.M. Koo, L. Jiang, **L. Zhang**, P. Zhou, **S. Bannerjee**, T.W. Kenny, J.G. Santiago, and K.E. Goodson, "Modeling of Two-Phase Microchannel Heat Sinks for VLSI Chips", Proceedings 2001 IEEE International Conference on MicroElectromechanical Systems, 422-425 (2001)
210. **A. Partridge, A.E. Rice**, T.W. Kenny and M. Lutz, "New Thin Film Epitaxial Polysilicon Encapsulation for Piezoresistive Accelerometers", Proceedings 2001 IEEE International Conference on MicroElectromechanical Systems, 54-57 (2001)
211. **A.E. Herr**, J.C. Mikkelsen, J.G. Santiago, and T.W. Kenny, "Electroosmotic Flow Suppression and its Implications for a Miniaturized Full-Field Detection Approach to Capillary Isoelectric Focusing (cIEF)", Proceedings ASME 2000 Winter Annual Meeting, MEMS Vol. 2, 513 (2000).
212. **M.S. Bartsch, A. Partridge, B.L.. Pruitt**, R.J. Full and T.W. Kenny, "A Three-Axis Piezoresistive Micromachined Force Sensor for Studying Cockroach Biomechanics", Proceedings ASME 200 Winter Annual Meeting, MEMS Vol. 2, 443-448 (2000).
213. **B.L. Pruitt, A. Partridge, M. Bartsch, Y. Liang**, T.W. Kenny, S. Wenzel, and C. Reynolds, "Design of Piezoresistive Cantilevers for Low-Force Electrical Contact Measurements", Proceedings ASME 2000 Winter Annual Meeting, MEMS Vol. 2, 183-188 (2000).
214. **L. Zhang**, J.M. Koo, **L. Jiang, S. Bannerjee**, M. Asheghi, K.E. Goodson, J.G. Santiago, and T.W. Kenny, "Measurements and Modeling of Two-Phase Flow in Microchannels with Nearly-Constant Heat Flux Boundary Conditions", Proceedings ASME 2000 Winter Annual Meeting, MEMS Vol. 2, 129-135 (2000)
215. L. Jiang, J.M. Koo, S. Zeng, J.C. Mikkelsen, **L. Zhang**, P. Zhou, J.G. Santiago, T.W. Kenny, K.E. Goodson, J.G. Maveety, and Q.A. Tran, "An Electrokinetic Closed-Loop MicroCooler for High-Power VLSI Chips", Proceedings 2001 SEMI-Therm Conference.
216. W.P. King, T.W.Kenny, K.E. Goodson, G. Cross, M. Despont, U. Dürig, M. I. Lutwyche, H. Rothuizen, G.K.Binnig, and P. Vettiger, "Design of AFM Cantilevers for Combined Thermomechanical Data Writing and Reading", Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 1-5 (2000).
217. **J.D. Grade**, J.H. Jerman, and T.W. Kenny, "A Large-Deflection Electrostatic Actuator for Optical Switching Applications", Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 97-100 (2000).

218. **J.I. Molho, A.E Herr, B.P. Mosier, J.G. Santiago, and T.W. Kenny**, A Low-Dispersion Turn for Miniaturized Electrophoresis, Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 132-137 (2000).
219. **A.E. Herr, J.I. Molho, J.G. Santiago, T.W. Kenny, D.A. Borkholder, G.J. Kintz, P. Belgrader, and M.A. Northrup**, Optimization of a Miniaturized Capillary Isoelectric Focusing System using a Full-Field Detection Approach, Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 115-119 (2000).
220. **Y. Liang, K. Autumn, S.T. Hsieh, W. Zesch, W.P. Chan, R.S. Fearing, R.J. Full and T.W. Kenny**, Adhesion Force Measurements on Single Gecko Setae, Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 33-38 (2000).
221. **L Zhang, S.S. Banerjee, J.M. Koo, D.S. Laser, M. Asheghi, K.E. Goodson, J.G. Santiago, and T.W. Kenny**, A Micro Heat-Exchanger with Integrated Heaters and Thermometers, Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 275-280 (2000).
222. **E.M. Chow, A. Partridge, C.F. Quate, and T.W. Kenny**, Thru-Wafer Electrical Interconnects Compatible with Standard Semiconductor Processing, Proceedings 2000 Hilton Head Workshop on Sensors and Actuators, 343-346 (2000).
223. **A.M. Fitzgerald, R.H. Dauskardt, T.W. Kenny**, "High-Resolution Measurement of Crack Growth in Micromachined Single Crystal Silicon", 1999 MRS Symposium Proceedings : Materials Science of Microelectromechanical Systems, p. 43-48 (1999)
224. **W.P. King, J.G. Santiago, T.W. Kenny, and K.E. Goodson**, Modeling and Prediction of Sub-Micrometer Heat Transfer during Thermomechanical Data Storage, Proceedings 1999 ASME Winter Meeting (1999).
225. **Y. Liang, J.N. Welch, R.G. Rudnitsky, and T.W. Kenny**, Biological Force Measurements using Micromachined Cantilevers, Proceedings 1999 ASME Winter Meeting (1999).
226. **J.K. Reynolds, T.W. Kenny, D.C. Catling, R.C. Blue, M.H. Hecht, and N.I. Maluf**, Packaging of Micromachined Absolute Pressure Sensors for High-Accuracy Measurements, Proceedings InterPAK '99 137-142 (1999).
227. **K.Yasumura, J.A. Chiaverini, and T.W. Kenny**, Thermoelastic Dissipation in Silicon Nitride Microcantilevers, Proceedings 10th International Conference on Solid State Sensors and Actuators. 564-567 (1999)
228. **T. Stowe, T.W. Kenny, D. Rugar, and D. Thompson**, Dissipation Microscopy based on Electronic Drag, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1208-1211 (1999)
229. **A.M. Fitzgerald, R.H. Dauskardt, and T.W. Kenny**, Fracture Toughness of Plasma-Etched Single-Crystal Silicon and Implications for MEMS Design, Proceedings 10th International Conference on Solid State Sensors and Actuators. 928-931 (1999).
230. **C.H. Liu, A. Barzilai, O. Ajakaiye, H.K. Rockstad, and T.W. Kenny**, Performance Enhancements for the Micromachined Tunneling Accelerometer, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1290-1293 (1999)
231. **J.K. Reynolds, D.C. Catling, R.C. Blue, N. Maluf, and T.W. Kenny**, Packaging and Calibration of a Piezoresistive Pressure Sensor for High-Accuracy at Low Temperatures and Pressures, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1494-1497 (1999)

232. **E.M. Chow**, H.T. Soh, H.C. Lee, J.D. Adams, S.C. Minne, G. Yaralioglu, A. Atalar, C.F. Quate, and T.W. Kenny, Two-Dimensional Cantilever Arrays with Integrated Thru-Wafer Interconnects, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1886-1889 (1999)
233. **R. Rudnitsky**, **E.M. Chow**, and T.W. Kenny, High-Speed Biochemical Screening with Magnetic Force Microscope Cantilever Arrays, Proceedings 10th International Conference on Solid State Sensors and Actuators. 706-709 (1999)
234. **J.A. Harley**, **T.D. Stowe**, and T.W. Kenny, Piezoresistive Cantilevers with Femtonewton Force Resolution, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1628-1631 (1999)
235. **A.E. Herr**, **J.I. Molho**, T.W. Kenny, J.G. Santiago, M.G. Mungal and M.G. Garguilo, Variation of Capillary Wall Potential in Electrokinetic Flow, Proceedings 10th International Conference on Solid State Sensors and Actuators. 710-713 (1999)
236. **B.W. Chui**, M. Asheghi, Y.S. Ju, H.J. Mamin, K.E. Goodson, and T.W. Kenny, Measurement and Modeling of Thermal-Electrical Runaway in Silicon Cantilevers, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1862-1865 (1999)
237. M. Ashegi, W.P. King, **B.W. Chui**, T.W. Kenny, and K.E. Goodson, Thermal Engineering of Doped Single-Crystal Silicon Microcantilevers for High Density Data Storage, Proceedings 10th International Conference on Solid State Sensors and Actuators. 1840-1843 (1999)
238. S.M Kumar, W.C. Reynolds, and T.W. Kenny, MEMS-Based Transducers for Boundary Layer Control, Proceedings 12th International Conference on Micro Electro Mechanical Systems, 135-138 (1999).
239. M.C. Deshpande, C. Ghaddar, J.R. Gilbert, P.M. St. John, T. Woudenberg, C. Connel, **J.I. Molho**, **A.E. Herr**, G. Mungal, and T.W. Kenny, "Numerical Framework for the Modeling of Electrokinetic Flows", Microfluidic Devices and Systems, Proceedings SPIE 217-223 (1998).
240. **K. Yasumura**, **T. Stowe**, **E. Chow**, T. Pfafman, T.W. Kenny, and D. Rugar, A Study of Microcantilever Mechanical Quality Factor, Proceedings 1998 Hilton Head Workshop on Sensors and Actuators, 65-68. (1998).
241. **A. Partridge**, **B.W. Chui**, **J.K. Reynolds**, **E. Chow**, **A.M. Fitzgerald**, **L. Zhang**, **S. Cooper**, T.W. Kenny, and N.I. Maluf, A High-Performance Planar Piezoresistive Accelerometer, Proceedings 1998 Hilton Head Workshop on Sensors and Actuators, 59-61. (1998).
242. **E.M. Chow**, H.T. Soh, **A. Partridge**, **J.A. Harley**, T.W. Kenny, and C.F. Quate, Fabrication of High-Density Cantilever Arrays and Thru-Wafer Interconnects, Proceedings 1998 Hilton Head Workshop on Sensors and Actuators, 220-223. (1998).
243. P.M. St. John, T. Woudenberg, C. Connell, **J. Molho**, **A. Herr**, T.W. Kenny, M.G. Mungal, M. Deshpande, J.R. Gilbert, M. Garguilo, D. Rakestraw, and P. Paul, Metrology and Simulation of Chemical Transport in Microchannels, Proceedings 1998 Hilton Head Workshop on Sensors and Actuators, 106-109. (1998).
244. **B.W. Chui**, T.W. Kenny, H.J. Mamin, B.D. Terris, and D. Rugar, Independent Detection of Vertical and Lateral Forces with a Sidewall-Implanted Dual-Axis Piezoresistive Cantilever, Proceedings of IEEE MicroElectroMechanical Systems Workshop. 12-15 (1998).

245. **Grade, A. Barzilai, K. Reynolds, C.H. Liu, A. Partridge, H. Jerman, and T.W. Kenny,** Wafer-Scale Processing, Assembly, and Testing of Tunneling Infrared Detectors, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators 1241-1244 (1997)
246. **C.H. Liu, J. D. Grade, A. M. Barzilai, J. K. Reynolds, A. Partridge, H. K. Rockstad, and T. W. Kenny ,** Characterization of a High-Sensitivity Micromachined Tunneling Accelerometer, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators Actuators. 471-472 (1997)
247. **J.Grade, C.H. Liu, K. Reynolds, A. Partridge, A. Barzilai, L.Miller, and T.Kenny,** Reducing the Low-Frequency Drift in Tunneling Transducers, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators 871-874 (1997)
248. **T.D. Stowe, K. Yasumura, T. Pfafman, T. Kenny, D. Botkin, and D. Rugar,** Ultrasensitive Torsional Probes Optimized for Higher-Order Mode Suppression, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators, P. 141-144 (1997).
249. **B.W. Chui, T.D. Stowe, T.W. Kenny, H.J., Mamin, B.D. Terris, and D.Rugar,** Micromachined Heaters with 1- μ s Thermal Time Constants for AFM Thermomechanical Data Storage, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators 1085-1088 (1997).
250. **P. Scheeper, J.K. Reynolds, and T.W. Kenny,** Development of a Modal Analysis Accelerometer Based on a Tunneling Displacement Transducer, Proceedings of Transducers '97 - The 9th International Conference on Solid State Sensors and Actuators 867-870 (1997).
251. **P. Graven and T.W. Kenny,** Laboratory (and on-orbit) Magnetometer Calibration without Coil Facilities or Orientation Information, Proceedings 1996 AIAA Small Satellite Conference (1996).
252. **D.S. Clarke, M.T. Hicks, A.M. Fitzgerald, J.J. Suchman, R.J. Twigg, J.A. Randolph, and T.W. Kenny,** Picosat Free Flying Magnetometer Experiment, Proceedings 1996 AIAA Small Satellite Conference (1996).
253. **Grade, A. Barzilai, J.K. Reynolds, C.H. Liu, A. Partridge, T.W. Kenny, T.R. VanZandt, L.M. Miller, and J.A. Podosek,** Progress in Tunnel Sensors, Proceedings 1996 IEEE Solid State Sensors and Actuators Workshop, 80-83 (1996).
254. **B.W. Chui, H.J., Mamin, D. Rugar, B.D. Terris, R. Ried, T.D. Stowe, S.C. Minne, H.T. Soh, C.F. Quate, Y.S.Ju, O.W. Kaeding, K.E. Goodson, and T.W. Kenny,** Improved Cantilevers for AFM Thermomechanical Data Storage, Proceedings 1996 IEEE Solid State Sensors and Actuators Workshop, 219-224 (1996).
255. **T. Stowe, K. Yasumura, T. Kenny, D. Botkin, K. Wago, and D. Rugar,** Ultrasensitive Vertical Force Probe for Magnetic Resonance Force Microscopy, Proceedings 1996 IEEE Solid State Sensors and Actuators Workshop, 225-230 (1996).
256. **L.M. Miller, J.A. Podosek, E. Kruglick, T.W. Kenny, J.A. Kovacich, and W.J. Kaiser,** A μ -Magnetometer Based on Electron Tunneling, Proceedings IEEE MEMS Workshop, 467-470 (1996).
257. **C.H. Liu, J.K. Reynolds, A. Partridge, T.W. Kenny, L.M. Miller, J.A. Podosek, H.K. Rockstad, and W.J. Kaiser,** High-Bandwidth Feedback Control of Micromachined Tunneling Sensors, Proceedings of ASME, DSC-57-2, 1001-1007 (1995).

258. H.K. Rockstad, **J.K. Reynolds**, T.K. Tang, T.W. Kenny, W.J. Kaiser, and T.B. Gabrielson, A Miniature, High-Sensitivity, Electron-Tunneling Accelerometer, Proceedings, Transducers '95, 675-679 (1995).
259. H.K. Rockstad, T.W. Kenny, P.J. Kelly, and T.B. Gabrielson, "A Micro-Fabricated Electron-Tunneling Accelerometer as a Directional Acoustic Sensor", Proceedings of Acoustic Particle Velocity Sensors : Design, Performance and Applications 9/95 Published in AIP Conf. Proc. 368, 57-62 (1996).
260. R.A. Brennen, M.H. Hecht, D.V. Wiberg, T.D. Stowe, T.W. Kenny, K.H. Jackson, C.K. Malek, "Fabricating Sub-Collimating Grids for X-Ray Solar Imaging Spectrometer using LIGA Technique", SPIE Microlithography and Metrology in Micromachining 10/95, SPIE Vol. 2640, 214-217 (1995).
261. A.W. Chen, P.A. Kaaret, T.W. Kenny, "Micromachined Silicon X-Ray Optics", Proceedings SPIE 2279, 298-301 (1994).
262. A.W. Chen, P.A. Kaaret, T.W. Kenny, "Focusing of X-Rays Using Micromachined Silicon Lobster-Eye Lenses", Proceedings SPIE 2011, 227-230 (1994).
263. L.M. Miller, M.L. Agronin, R.K. Bartman, W.J. Kaiser, T.W. Kenny, R.L. Norton, and E.C. Vote, "Fabrication and Characterization of a Micromachined Deformable Mirror for Adaptive Optics Applications", Proceedings SPIE V1945, 421-424 (1993).
264. H.K. Rockstad, T.W. Kenny, J.K. Reynolds, W.J. Kaiser, and T.R. VanZandt, A Miniature High-Resolution Accelerometer Utilizing Electron Tunneling, Proceedings 1992 ASME Winter Meeting, 41-52 (1992).
265. T.W. Kenny, W.J. Kaiser, J.A. Podosek, H.K. Rockstad, and J.K. Reynolds, Micromachined Electron Tunneling Infrared Sensors, Proceedings IEEE Solid State Sensors and Actuators Workshop, 174-177 (1992).
266. T.R. VanZandt, T.W. Kenny and W.J. Kaiser, Novel Position Sensor Technologies for Microaccelerometers, Proceedings of the SPIE 1694, 165-168 (1992).
267. T.W. Kenny and W.J. Kaiser, Electron Tunnel Sensors, Progress in Precision Engineering, 39-49, May, (1991).
268. T.W. Kenny, S.B. Waltman, J.K. Reynolds, and W.J. Kaiser, A Micromachined Silicon Electron Tunnel Sensor, Proceedings 1990 IEEE MEMS Workshop, 192-196 (1990).

DARPA Program Manager Portfolio (10/1/06 – 9/30/10)

DARPA MIATA Program (MicroAntenna Arrays – Technology and Applications).

- \$40M Program Launched by Henryk Temkin in 2005
- Focused on microfabricated antennas for mm-wave radiation sensors, and on integration of antenna, sensor, amplifier and readout circuitry in same structure

DARPA TGP Program (Thermal Ground Plane).

- \$50M Program Launched by Thomas Kenny in 2007
- Focused on microfabricated vapor chamber heat spreaders with reduced dimensions, increased performance, and circuit-compatible materials

DARPA YFA Program (Young Faculty Award).

- \$7M/year Program Launched by Henryk Temkin in 2006, re-run in 2007 and 2008.
- Provided small (\$200K) grants to promising young faculty throughout the US with ideas and interests that could lead to new technologies for the DoD.

DARPA TBN Program (Tip-Based Nanofabrication)

- \$50M Program Launched by Thomas Kenny in 2007
- Focused on controlled nanofabrication, with emphasis on controlling the size, shape, location and other properties of every nanostructure formed on a surface.

DARPA MACE Program (Microtechnologies for Air-Cooled Exchangers).

- \$35M Program Launched by Thomas Kenny in 2008
- Focused on use of microtechnologies in air-cooled heat exchangers

DARPA NTI Program (NanoThermal Interfaces).

- \$30M Program Launched by Thomas Kenny in 2009
- Focused on development of new nanostructured materials for enhanced thermal interfaces for electronics cooling.

DARPA CEE Program (Casimir Effect Enhancement).

- \$10M Program Launched by Thomas Kenny in 2010
- Focused on demonstration of reduced adhesion at the nanoscale through the use of the Casimir effect

DARPA ACM Program (Active Cooling Modules).

- \$30M Program Launched by Thomas Kenny in 2010)
- Focused on development of complete, high-performance cooling modules based on thermoelectric refrigeration, vapor compression refrigeration, and other novel refrigeration concepts.

DARPA NJTT Program (Near-Junction Thermal Transport).

- \$25M Program Formulated by Thomas Kenny in 2010, Launched by Avram Bar-Cohen in 2011
- Program focus is on enhanced thermal conduction in the region immediately beneath the hot spots in high-power electronic devices.

DARPA “Seedlings” (\$250K efforts to prove key initial pieces of technology)

- ~20 projects solicited, launched and managed
- Produced important early results for TGP, TBN, NTI and ACM programs.

Patents (>50 Issued US Patents)

1. Targeting Microbubbles, Robert H Grubbs, Marshall L Stoller, Hoyong Chung, Alissa M Fitzgerald, Thomas W Kenny, Renee M Thomas, **US Patent 10,357,565 (7/23/2019)**, **US Patent 10,149,906B2 ((12/11/2018)**, **EP3375435A1**, **EP2748299B1**, **CN103917637B**, **WO2013028942A1**, **KR102076069**,
2. Composite Mechanical Resonators and Method Therefor, R. Melamud, B. Kim, M. Hopcroft, S. Chandorkar, T. Kenny, **US Patent 7,806,586 (9/5/10)**, **US Patent #7,824,098 (11/2/10)**.
3. Cooling Systems Incorporating Heat Exchangers and Thermoelectric Layers, Thomas W. Kenny, Mark Munch, Peng Zhou, James Gill Shook, Kenneth Goodson, Dave Corbin, Mark McMaster, James Lovette, **US Patent 8,464,781 (6/18/13)**.
4. Pump and Fan Control Concepts in a Cooling System, S. Sinha, M. Munch, K. Goodson, T. Kenny, **US Patent # 7,591,302 (9/22/09)**, **US Patent #8,602,092 (12/10/13)**
5. Remedies to Prevent Cracking in a Liquid System, M. Munch, D. Werner, T. Kenny, K Goodson, **US Patent # 7,077,634 (7/18/06)**, **US Patent # 7,201,214 (4/10/07)**, **US Patent # 7,201,012 (4/10/07)**. **US Patent # 7,278,549 (10/9/07)**, **US Patent#7,344,363 (3/18/08)**, **US Patent # 7,402,029 (7/22/08)**, Pending (US2005/0182845A1, US2005/0183445A1, US2005/0183444A1, US2005/0183443A1, US2005/0016715A1, WO0471139A3, WO04071139A2, US2004/0148959A1)
6. Apparatus for Conditioning Power and Managing Thermal Energy in an Electronic Device, T.W. Kenny, K.E. Goodson, J.G. Santiago.,G. K. Everett **US Patent # 7,061,104 (6/13/06)**
7. Boiling temperature Design in Pumped Microchannel Cooling Loops, P. Zhou, S. Zheng, T. Kenny, M. Munch. G. Upadhya, K. Goodson, J. Santiago, US 2004/0182551A1, WO04083742A2).
8. Method and Apparatus for achieving temperature uniformity and hot-spot cooling in a heat-producing device, K. Goodson, T. Kenny, P. Zhou, G. Upadhya, M. Munch, M. McMaster, J. Hom, **US Patent# 7,104,312 (9/12/06)**, US2004/0112585A1, WO 04042306A3, WO 04042306A2.
9. Hermetic Closed-Loop Fluid System, D. Werner, M.. Munch, and T. Kenny, **US Patent # 7,021,369 (4/4/06)**.
10. Removeable Heat Spreader support mechanism and method of manufacturing thereof, G. Upadhya, M. Munch, P. Zhou, K.E. Goodson and T.W. Kenny, US 2004/0233639A1, WO04070304A3, WO04070304A2,
11. Method and Apparatus for Low-Cost Electrokinetic Pump Manufacturing, J. Lovette, M. Munch, J.G. Shook, S. Zheng, T.W. Kenny, D. Werner, Z. Cichocki, TCE. Lin, 2004/0234378A1, WO04076857A2).
12. Apparatus and Method of Forming Channels in a Heat Exchanging Device, T. Kenny, M. McMaster, J. Lovette, **US Patent # 7,017,654 (3/28/06)**.
13. Boiling Temperature Design in Pumped Microchannel Cooling Loops, P. Zhou, S. Zheng, T. Kenny, M. Munch, G. Upadhya, K. Goodson, J. Santiago, Pending

14. Method and Apparatus for Efficient Vertical Fluid Delivery for Cooling a Heat-Producing Device, T. Kenny, M. Munch, P. Zhou, J. Shook, K. Goodson, D. Corbin, M. McMaster, J. Lovette, **US Patent#7,000,684 (2/21/06)**, US 2004/0206477A1, US 2004/0112571A1, WO04042304A3, WO04042304A2, WO04042297A3, WO04042297A2,
15. Apparatus for Conditioning Power and Managing Thermal Energy in an Electronic Device, K. Goodson, J. Santiago, T. Kenny, and G Everett, **US Patent #6,882,543**, 10/882475, 10/883530, 10/882607
16. Interwoven Manifolds for Pressure Drop Reduction in Microchannel Heat Exchangers, G. Upadhyaya, M. Munch, P. Zhou, G. Shook, T. Kenny, K. Goodson, D. Corbin, **US Patent# 6,986,382 (1/17/06)** US 2004/0104010A1, WO04042303A3, WO04042303A2
17. Method and Apparatus for Flexible Fluid Delivery for cooling desired Hot Spots in a heat-producing device, T. Kenny, J.G. Shook, D. Corbin, M. Munch, K. Goodson, **US Patent# 6,988,534 (1/24/06)**, US2004/0104022A1, WO04042313A1
18. Vapor Escape Microchannel Heat Exchanger, P. Zhou, K. Goodson, T. Kenny, J Santiago, Pending 10/366122.
19. Ultra-Miniature Accelerometers, T.W. Kenny and W.T. Park, **US Patent# 7,104,130, (9/12/06)**, WO0492746A1
20. Method and Apparatus for Removably Coupling a Heat Rejection Device to a Heat Producing Device, T.W. Kenny, K.E Goodson, US 2004/0076408A1.
21. Microfabricated Electrokinetic Pump with On-Frit Electrodes, T. Kenny, J.G. Shook, S. Zeng, D.J. Lenehan, J. Santiago, J. Lovette, **US Patent # 7,086,839 (8/8/06)**
22. Microfabricated Electrokinetic Pump, D. Corbin, K. Goodson, T. Kenny, J. Santiago, and S. Zheng, **US Patent # 6,881,039 (5/27/04)**, US 2005/0042110A1, US200500843385A1, **US Patent # 7,449,122 (11/11/08)**
23. Electroosmotic MicroPump with Planar Features, **D. Laser**, J.G. Santiago, K.E. Goodson, and T.W. Kenny, **US Patent 7,316,543 (1/8/08)**
24. UltraMiniature Pressure Sensor and Probes, **M. Bly**, T.W. Kenny, **S.A. Shaughnessey, M.S. Bartsch**, **US Patent #6,959,608**
25. Method of making a Nanogap for Variable Capacitive Elements, and Device having a NanoGap, M. Lutz, A. Partridge, and T.W. Kenny, WO 04095540A3, WO 04095540A2, **US Patent 7,127,917 (2/6/07)**
26. System Including Power Conditioning Module, T.W. Kenny, K.E. Goodson, J.G. Santiago, C. K, Everett, R. Chaplinsky, J. Kim, **US Patent # 6,678,168**.
27. Power Conditioning Module, T.W. Kenny, K.E. Goodson, J.G. Santiago, C. K, Everett, **Patent # 6,606,251 (8/12/03)**, **US Patent # 7,050,308 (5/23/06)**.
28. Closed-Loop Microchannel Cooling System, K.E. Goodson, **D.E. Huber**, L. Jiang, T.W. Kenny, **J-M Koo**, J.C. Mikkelsen, J.G. Santiago, **E. Wang**, **S. Zheng**, **L. Zhang**, **D. Laser**, **H. Chen**, **US Patent # 7,334,630 (2/26/08)**, US20050205241A1.

29. Electroosmotic Microchannel Cooling System, K.E. Goodson, **D.E. Huber**, L. Jiang, T.W. Kenny, **J-M Koo**, J.C. Mikkelsen, J.G. Santiago, **E. Wang**, **S. Zheng**, **L. Zhang**, **D. Laser**, **H. Chen**, **US Patent # 7,185,697 (3/6/07)**, **US Patent # 7,131,486 (12/7/06)**, **Patent # 6,942,018 (9/13/05)** **US Patent#6,991,024 (1/24/06)**, **US Patent #7,131,486 (11/7/06)** EP1576320A2, US2005/0098299A1, US2004/0089442A2, US2003/0164231A1, WO0302973A3, WO0302973A2, US2003/0062149A1,
30. Adhesive Microstructure and Method of Forming Same, B. Full, K. Autumn, R. Fearing, and T. Kenny, **US Patent # 6,737,160**, **US Patent # 7,011,723 (3/14/06)**, **US Patent # 7,229,865 (7/11/07)**, US20050072509A1, US2004/0005454A1, EP1241930A4, WO0149776C2, EP1241930A2, WO 0149776A3, WO0149776A2.
31. Non-Contact Mechanical Resonance Method for Determining the Near-Surface Carrier Mobility in Semiconductors, **T.D.Stowe**, D. Rugar, and T.W. Kenny, **Patent #6,489,776 (12/3/02)**
32. In-Plane Micromachined Accelerometer and Bridge Circuit having same, **A. Partridge**, **A. M. Fitzgerald**, **B.W. Chui**, **J. K. Reynolds** and T.W. Kenny, **Patent # 6,389,899 (5/21/02)**
33. Method of Making Electrical Elements on the Sidewalls of Micromechanical Structures, **B.W. Chui** and T.W. Kenny, **Patent # 6,025,208 (2/15/00)**.
34. Micromachined Cantilever Structure Providing for Independent Multidimensional Force Sensing Using High Aspect Ratio Beams, **B.W. Chui** and T.W. Kenny, **Patent # 5,959,200 (9/28/99)**.
35. Tunnel Effect Measuring Systems and Particle Detectors, W.J. Kaiser, S.B. Waltman, and T.W. Kenny, **Patent #5,290,102 (3/1/94/94)**, **Patent #5,265,470 (11/30/93)**, **5,293,781 (3/15/94)**.
36. Methods and Apparatus for Improving Sensor Performance, W.J. Kaiser, T.W. Kenny, S.B. Waltman, **J.K. Reynolds** and T.R. VanZandt. **Patent # 5,211,051 (5/18/93)**.
37. Tunnel Effect Wave Energy Detection, W.J. Kaiser, S.B. Waltman, and T.W. Kenny. **Patent # 5,449,909 (9/12/95)**.
38. Uncooled Tunneling Infrared Sensor, T.W. Kenny, W.J. Kaiser, J.A. Podosek, E.C. Vote, H.K. Rockstad, and **J.K. Reynolds**. **Patent # 5,298,748 (3/29/94)**.
39. Uncooled Tunneling Infrared Sensor, T.W. Kenny, W.J. Kaiser, J.A. Podosek, E.C. Vote, R.E. Muller, and P.D. Maker. **Patent # 5,436,452 (7/25/95)**
40. Dual Element Electron Tunneling Accelerometer, W.J. Kaiser, T.W. Kenny, H.K. Rockstad, **J.K. Reynolds**, and T.R. VanZandt. **Patent # 5,563,344 (10/8/96)**
41. High Performance Miniature Hygrometer and Method Thereof, T.R. VanZandt, W.J. Kaiser, and T.W. Kenny, **Patent # 5,364,185 (11/15/94)**.
42. Method and Apparatus for Measuring a Magnetic Field using a Deflectable Energized Loop and a Tunneling Tip, W.J. Kaiser, S.B. Waltman, and T.W. Kenny, **Patent # 5,315,247 (1994)**