QUINN EMANUEL URQUHART & SULLIVAN, LLP
Charles K. Verhoeven (Bar No. 170151)
charlesverhoeven@quinnemanuel.com
50 California Street, 22nd Floor
San Francisco, California 94111
Telephone: (415) 875-6600
Facsimile: (415) 875-6700

Kevin P.B. Johnson (Bar No. 177129)
kevinjohnson@quinnemanuel.com
Victoria F. Maroulis (Bar No. 202603)
victoriamaroulis@quinnemanuel.com
555 Twin Dolphin Dr., 5th Floor
Redwood Shores, California 94065
Telephone: (650) 801-5000
Facsimile: (650) 801-5100

Michael T. Zeller (Bar No. 196417)
michaelzeller@quinnemanuel.com
865 S. Figueroa St., 10th Floor
Los Angeles, California 90017
Telephone: (213) 443-3000
Facsimile: (213) 443-3100

Attorneys for SAMSUNG ELECTRONICS CO., LTD., SAMSUNG ELECTRONICS AMERICA, INC., and SAMSUNG TELECOMMUNICATIONS AMERICA, LLC

UNITED STATES DISTRICT COURT

NORTHERN DISTRICT OF CALIFORNIA, SAN JOSE DIVISION

APPLE INC., a California corporation,

Plaintiff,

vs.

SAMSUNG ELECTRONICS CO., LTD., a Korean business entity; SAMSUNG ELECTRONICS AMERICA, INC., a New York corporation; SAMSUNG TELECOMMUNICATIONS AMERICA, LLC, a Delaware limited liability company,

Defendants.

CASE NO. 11-cv-01846-LHK

DECLARATION OF WOODWARD YANG, PH.D. IN SUPPORT OF SAMSUNG'S OPPOSITION TO APPLE'S MOTION FOR SUMMARY JUDGMENT OF NON-INFRINGEMENT OF U.S. PATENT NO. 7,362,867 AND INVALIDITY OF U.S. PATENT NOS. 7,456,893 AND 7,577,460

DECLARATION OF WOODWARD YANG, PH.D.

I, Woodward Yang, declare:

1. I have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I submit this declaration in support of Samsung's Opposition to Apple's Motion for Summary Judgment of Non-Infringement of U.S. Patent No. 7,362,867 ("the '867 patent") and Invalidity of U.S. Patent Nos. 7,456,893 ("the '893 patent") and 7,577,460 ("the '460 patent"). If asked at hearings or trial, I am prepared to testify regarding the matters I discuss in this declaration.

I. BACKGROUND

3. I am presently the Gordon McKay Professor of Electrical Engineering and Computer Science in the School of Engineering and Applied Science at Harvard University, where I have taught and pursued research endeavors since 1990. I have taught classes related generally to the design and analysis of microelectronic circuits and Very Large Scale Integration ("VLSI") systems: the process of creating integrated circuits by combining thousands of transistors into a single chip. VLSI began in the 1970s when complex semiconductor and communication technologies were being developed. The microprocessors typically used in smartphones are an example of a VLSI device. I have also taught graduate and undergraduate level courses in computer architecture, computing hardware, digital logic design, mixed signal circuit design, circuit theory, and engineering design. My research pursuits have been directed to the development of advanced computing and memory systems for high performance image processing and computer vision applications, data encryption, error correcting codes, and integrated sensor and computing systems.

4. Since 2008, I have also served as the Harvard Business School ("HBS") University Fellow and teach courses at HBS as a Visiting Professor. In this capacity, I have conducted research and taught business school courses on the commercialization of new technologies, technological innovation, and industry architecture.

5. I have over 25 years of experience in the field of electrical engineering and computer science, during which time I have published many peer-reviewed papers in the field and have been extensively involved in the development and commercialization of several important mobile phone technologies. These technologies, which are now common in mobile phones, include CMOS image sensors and pseudo-SRAM. Over the course of my career, I have been a named inventor on at least 9 patents.

6. I graduated with a Bachelor of Science degree in Electrical Engineering and Computer Science from the University of California, Berkeley in 1984. During my undergraduate studies, I also pursued research in the university's Electronic Research Laboratory, where I researched the measurement and analysis of hot electron degradation in MOS ("metal oxide semiconductor") transistors.

7. I received a Master's of Science degree in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology in 1987. While pursuing my Masters degree, I served as a research assistant in the Microsystems Technology Laboratory, where I assisted in developing and characterizing low pressure ammonia and oxygen annealing processes that improve the reliability of scaled MOS transistors.

8. I received my Ph.D. in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology in 1990. My doctoral thesis concerned "The Architecture and Design of CCD Processors for Computer Vision." While pursuing my doctorate, I served as research assistant in the university's Artificial Intelligence Laboratory, where I contributed to the development, design, and implementation of analog VLSI hardware in computer vision systems.

9. From approximately 1990-2000, I taught and pursued advanced research at Harvard in the general areas of high performance VLSI computing systems and computer architecture, and also worked as a consultant in the area of advanced image sensors based on both CCD and CMOS technology. The culmination of a large portion of this work was the successful commercialization of CMOS image sensors into miniature cameras that were integrated into computer and mobile phones.

10. In 2000, I founded a company called Silicon7. The company designed, developed, manufactured, and marketed advanced memory components and systems for mobile communication devices and platforms. These advanced memory components and systems were optimized for the distinct requirements of mobile communication devices.

11. Over the course of my career, I have received various honors and fellowships. In 1984, I received both the National Science Foundation Fellowship and Hertz Foundation Fellowship. In 1992, I received both the Army Research Office Young Investigator Award and the National Science Foundation Young Investigator Award. I have also served as an IEEE Distinguished Lecturer in the areas of CMOS Image Sensors and High Performance VLSI Systems.

12. I have previously been qualified as an expert witness in the field of electrical engineering and computer science in the matter of Certain Electronic Devices, Including Mobile Phones, Portable Music Players, and Computers, ITC Investigation No. 337-TA-701.

13. Attached as **Appendix A** to this report is my curriculum vitae, which contains a complete listing of my education, my professional experience, the publications that I have authored, and the cases in which I have testified as an expert at trial or in depositions during the previous four years.

II. OPINIONS

A. U.S. Patent No. 7,456,893

14. The '893 patent is directed to a method and apparatus for "bookmarking" an image in a digital photo album. The claimed invention for controlling a digital image processing system returns a user to the same bookmarked image in a digital image photo album even after capturing new images. The invention marks a departure from the default mode on digital cameras practiced in the art, which always returned a user to the last image captured upon returning to a digital photo album. This default mode resulted in users losing their place in a digital image photo album, forcing the user to tediously scroll back to their place in a digital image photo album. As explained in the Background of the Invention: "…when a user temporarily switches from the

stored-image display mode to another operating mode (e.g., a photographing mode), the user has to again sequentially display files that were already displayed to find his or her most recently viewed stored image." The invention of the '893 patent was to enable the user of a camera-phone to quickly and conveniently find "his or her most recently viewed stored image," even after switching between the viewing and photographing modes.

15. The asserted claims of the '893 patent are directed to an apparatus with a digital bookmarking function: claims 10 and 12. In particular, this claimed apparatus must be a "digital image processing apparatus," i.e., a device containing a digital camera. According to claim 10, this device must include a digital camera, memory that stores digital images, and a display. The device claimed in claim 10 must further include a controller that is used in camera mode to take pictures and store them in memory and in display mode to view images which have been previously photographed, captured, and/or stored. Finally claim 10 requires that the device switches back and forth between camera mode and display mode but displays the last viewed image rather than the last captured image in the display mode.

16. Claim 12 of the '893 patent, which is dependent on claim 10, requires that the identifying step in claim 10 means setting the index value of the last image displayed in memory.

17. I understand that Apple contends that claims 10 and 12 of the '893 patent are invalid as indefinite. Specifically, I understand Apple to contend that independent claim 10 covers both an apparatus and a method for using the apparatus and is therefore insolubly ambiguous.

18. I disagree with Apple's contention. By its clear terms, claim 10 is directed to an apparatus with a recited structure, including an "optical system," a "photoelectric conversion module," a "recording medium," a "display screen," and a "controller." This apparatus performs a specific function upon returning to a reproduction mode after capturing new photos in a photographing mode: first displaying the last image displayed in the reproduction mode. Claim 10 is, therefore, directed to an apparatus capable of performing this recited function.

19. I also understand that Apple contends that claim 10 requires user action to practice the claim. In addition, I understand that Apple contends that I agree that claim 10 requires user action to practice the claim.

20. I disagree with Apple's contentions. Claim 10 states, in part, "upon a user performing a mode-switching operation …." That phrase is immediately followed with a description of what the apparatus's controller is to do if the user performs a mode-switching operation, that is, if the user flips a switch. It is my understanding that this claim language is describing how the apparatus is to function ***if*** the user flips a switch. This does not mean that the claim ***requires*** the user to flip a switch (or to do anything, for that matter). Rather, it is simply describing how the apparatus must function if the user does, in fact, flip a switch.

21. I further understand that the sole basis for Apple's contention that I agree that claim 10 requires user action to practice the claim is the following testimony from my deposition:

> Q. I'm asking is your understanding of this language, does the "wherein, upon a user performing a mode switching operation," does that require some action by the user?
>
> MR. STRETCH: Same objection.
>
> A. There's clearly the implication that the user is going to do – flip a switch, going to switch something; and then it's describing – the remainder of that is describing what that – what has – what the device has to do –
>
> Q. Thank you.
>
> A. – but that's initiated by the user.

(Yang Deposition Transcript, Stake Decl. Ex. 14 at 80:25-81:9.)

22. I disagree with Apple's contention that my testimony requires user action to practice the claim. Prior to the exchange that Apple cites to above, I had testified as follows:

> Q. Would you agree with me that in claim 10, the last clause starts where – "wherein, upon a user performing," that that – to practice the claim that's – the language of that – of claim 10 requires the user to take some action?
>
> MR. STRETCH: Objection. Calls for a legal conclusion.
>
> A. Well, I'm not really a lawyer and I'm not that familiar with the law, but let me try to describe it this way. It's like a switch. Mode switching is a switch. So you flip a switch, and then it's describing how the device has – or the apparatus has to operate or behave. So it's really talking about there's a switch; if you flip the switch, this is what's going to happen. So I think it's an apparatus.

(Yang Deposition Transcript, Stake Decl. Ex. 14 at 80:2-21.)

This testimony, as well as the testimony that Apple cites, is consistent with my understanding that the language of claim 10 is describing how the apparatus is to function if the user flips a switch. If Apple is asserting that I testified that claim 10 requires user action, that it is incorrect and is taking my testimony out of context.

23. As a person of skill in the art, I readily understand the language of claims 10 and 12 of the '893 Patent. In addition, I readily understand the scope of claims 10 and 12. Because claims 10 and 12 claim an apparatus and not any user action, it is my understanding that infringement occurs when one creates an apparatus that meets all of the limitations in claims 10 and 12.

B. U.S. Patent No. 7,577,460

24. Claim 1 of the ‘460 patent is clear and unambiguous. Claim 1 is reproduced below, with the claim’s steps labeled [a] to [e]:

> 1. A data transmitting method for a portable composite communication terminal which functions as both a portable phone and a camera, comprising the steps of:
>
> [a] entering a first E-mail transmission sub-mode upon user request for E-mail transmission while operating in a portable phone mode, the first e-mail transmission sub-mode performing a portable phone function;
>
> [b] entering a second E-mail transmission sub-mode upon user request for E-mail transmission while operating in a display sub-mode, the second e-mail transmission sub-mode displaying an image most recently captured in a camera mode;
>
> [c] sequentially displaying other images stored in a memory through the use of scroll keys;
>
> [d] transmitting the address of the other party and a message received through a user interface in the first E-mail transmission sub-mode;
>
> [e] and transmitting the address of the other party and the message received through the user interface and the image displayed on the display as an E-mail in the second E-mail transmission sub-mode.

25. Claim 1 is directed to the performance of three core functions on a camera phone. Specifically, steps [a] and [d] claim the transmission of an email displaying a message only (i.e.,

without any image). Steps [b] and [e] claim the transmission of an email displaying an image and a message. Step [c] claims displaying images stored on the device in sequence.

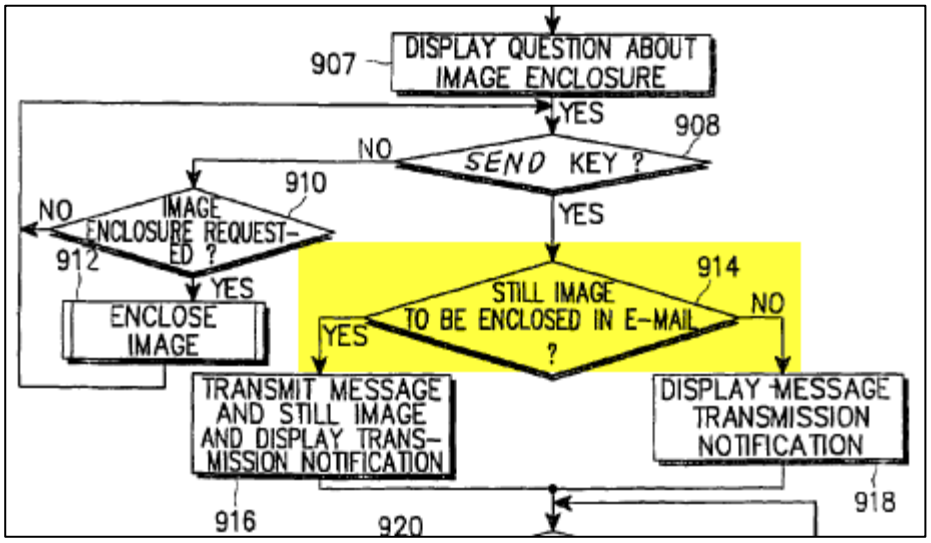
26. A user interface for entering an email address and a text message is also specified in Claim 1. More specifically, claim 1 requires transmission of e-mail through two distinct transmission "sub-modes": a "first e-mail transmission sub-mode" and a "second e-mail transmission sub-mode." The device enters this first e-mail transmission sub-mode from a "portable phone mode," in which phone calls may be placed or received. This first sub-mode transmits text-only e-mail. The device enters the second e-mail transmission sub-mode from a "display sub-mode," in which images stored on the phone may be reviewed. This second sub-mode transmits e-mails enclosing a stored image and a text message. Claim 1 further requires that the user can sequentially display images stored on the device through the use of scroll keys.

27. The specification of the '460 patent teaches each of the three core functions claimed by the claim 1. The specification discloses sequentially displaying photos stored on a camera phone, stating: "Upon user pressing the volume up/down key 312 in a play sub-mode of the camera mode, an image previous or next to a current image is displayed.") ('460 patent, col. 5: 9-12.) The specification further discloses that distinct e-mail functionalities are available when a user requests to send an e-mail in "play sub-mode" (i.e., image review mode) rather than in "portable phone mode" (i.e., phone standby mode):

> Meanwhile, upon entry of the send key in step 908, the portable phone controller 32 determines whether there is any still image to be enclosed in the E-mail. If the E-mail transmission sub-mode is selected in the play sub-mode of the camera mode, ***this implies that image data to be enclosed in the E-mail exists.*** If the image enclosure operation is implemented in the E-mail transmission sub-mode selected in the portable phone mode, as in step 912, this implies that image data to be enclosed in the E-mail exists. However, if only the E-mail transmission sub-mode is selected in the portable phone mode, ***this implies that no image data enclosed in the E-mail exists.***

('460 patent, col. 12:30-41; see also col. 10:65-11:12; figs. 6, 9.) Specifically, the specification teaches that the user can send an email with message only when the user requests to send an e-mail in "portable phone mode." ('460 patent, col. 12:38-41 ("However, if only the E-mail transmission sub-mode is selected in the portable phone mode, this implies that no image data enclosed in the

E-mail exists."); Figs. 6, 9.) In contrast, the user can send an e-mail displaying an image and a message by requesting e-mail transmission while reviewing images. ('460 Patent, col. 11: 9-11 ("By selecting the E-mail transmission sub-mode in the play sub-mode, the user can transmit an E-mail with a still image enclosed therein."); Figs. 8, 9.) The specification teaches that this request to send an e-mail in the play sub-mode "implies that image data to be enclosed in the E-mail exists." ('460 patent, col. 12:33-35; figs. 8, 9.) Viewed in light of the specification, Figure 9 of the patent illustrates that image enclosure results from requesting e-mail transmission in play sub-mode:



(Fig. 9; col. 12:30-51 (discussion of labels 914-918).)

28. The specification's discussion of two distinct states on a camera phone with distinct e-mail functionalities supports claim 1's requirement of a "first E-mail transmission sub-mode" and a "second E-mail transmission sub-mode." As I explained in my expert report, a "mode" is a "specific state of the device in which certain functions are available to the user," while a "sub-mode" is "another specific state in which another set of functions are available to the user upon subselection from the current 'mode.'" A camera phone with distinct states with distinct e-mail functionalities, therefore, has a "first" and a "second E-mail transmission sub-mode."

29. The prosecution history of the '460 patent further confirms that claim 1 is directed to the performance of three core functions on a camera phone. The '460 patent claims priority to

U.S. Application No. 09/540,830 (the "'830 application"). Claim 20 of the '830 application was similar to claim 1 but omitted "sequentially displaying other images stored in a memory through the use of scroll keys" (step [c]). (Stake Decl. Ex. 4 at APLNDC-WH-A0000014309-10.)

30. The Patent Office initially rejected claim 20 as obvious in view of the combination of the Wagner, Suso, and Dawson patents, all U.S. patents. (Stake Decl. Ex. 5 at APLNDC-WH-A0000014263.) The Patent Office asserted that the Wagner patent disclosed a device that:

> [F]unctions as a portable phone comprising the steps of **entering a first E-mail transmission sub-mode** upon user request for E-mail transmission while operating in a portable phone mode, the first E-mail transmission sub-mode performing a portable phone function, **and transmitting** the address of the other party and a message received through a user interface **in the first E-mail transmission sub-mode**.

(*Id.* at APLNDC-WH-A0000014263-64.) (emphasis added.) The Patent Office further asserted that the Dawson patent disclosed an "e-mail system" having distinct e-mail transmission sub-modes for sending text-only e-mails and for sending e-mails with an image and a message:

> Dawson teaches an audio-visual e-mail system having a **first E-mail transmission mode for transmitting a text-only email message** and a second E-mail transmission sub-mode upon user request for E-mail transmission, wherein the **second E-mail sub-mode displays an image captured by a digital camera and transmits the address of the other party and the message received through the user interface and the image display on the display**

(*Id.* at APLNDC-WH-A0000014264.) In its first Office Action, the Patent Office therefore readily understood that claim 20 claimed sending separate emails through two distinct sub-modes.

31. Samsung responded to the initial rejection of claim 20 by amending it to claim "sequentially displaying other images stored in a memory through the use of scroll keys." (Stake Decl. Ex. 6 at APLNDC-WH-A0000014254.) Samsung contended that its amendment distinguished claim 20 from the asserted patents. (*Id.* at APLNDC-WH-A0000014251.)

32. In two subsequent Office Actions, the Patent Office rejected claim 20 over the Harris, Hull, and Sugiyama patents. (Stake Decl. Ex. 7 at APLNDC-WH-A0000014238-39; Stake Decl. Ex. 8 at APLNDC-WH-A0000014156-58.) The Patent Office contended that these references, in combination, rendered claim 20 obvious by disclosing the three core functions of the '460 patent. The Patent Office contended that the Harris patent disclosed a "portable phone and

camera" that sent text-only email, that the Hull patent disclosed sending e-mails with an image and a message, and that the Sugiyama patent disclosed the use of scroll keys to sequentially display images. (*Id.*)

33. The Patent Office ultimately allowed claim 1 of the '460 patent to issue after Samsung demonstrated that none of these three patents disclosed a device "capable of operating in a first and a second E-mail transmission sub-mode." (Stake Decl. Ex. 9 at APLNDC-WH-A0000014122.) Samsung specifically contended that "[e]ach of the references can only operate in one of the two modes, not both." (*Id.*) The Patent Office issued no further anticipation or obviousness rejections of pending claim 20 in either the '830 application or in Divisional Application No. 11/493,754, from which the '460 patent issued on August 18, 2009.

34. I disagree with Apple's contention that the '460 patent is invalid as indefinite. In its Motion, Apple contends that claim 1 fails to clarify whether the claim requires: (a) "sending two separate email messages from two separate email transmission sub-modes"; (b) "sending one email message from the 'first E-mail transmission sub-mode' if the E-mail does not have an image attachment and sending one email message from the 'second E-mail transmission submode' if the email has an image attachment"; or (c) "sending one email message from the 'second E-mail transmission sub-mode' only, whereby the email is created by transmitting the address of the other party and a message received through a user interface in the 'first E-mail transmission sub-mode' to the 'second E-mail transmission sub-mode.'" To the extent I understand these alternate interpretations, I disagree that claim 1 is ambiguous. The specification and figures of the '460 patent only supports Apple's first interpretation of claim 1. As I explained in my expert report, claim 1 of the '460 patent is infringed if a camera phone performs—in any sequence—three claimed functions: (1) transmitting text-only e-mails in a first e-mail transmission sub-mode, entered through a portable phone mode; (2) transmitting e-mails enclosing both an image and a textual message in a second e-mail transmission sub-mode, entered through a display sub-mode; and (3) sequentially displaying images stored on the phone through the use of scroll keys. Notably, Apple's second and third interpretations of claim 1 do not require performance of all claimed functions, and are, therefore, incorrect.

I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct. Executed on May 31, 2012, in Bangkok, Thailand.

Woodward Yang

APPENDIX A

Expert Report of Woodward Yang
Appendix A

Woodward Yang

Home Address
14 Fox Run Lane
Lexington, MA 02420
(781) 863-1371
(617) 512-0296 cell

Work Address
Maxwell-Dworkin 325
School of Engineering and Applied Sciences
Harvard University
Cambridge, MA 02138
Tel: (617) 495-3987
Fax: (617) 495-9837

Education:

Massachusetts Institute of Technology — August 1990
Ph.D. in Electrical Engineering and Computer Science
Thesis: ``The Architecture and Design of CCD Processors for Computer Vision''

Massachusetts Institute of Technology — January 1987
S.M. in Electrical Engineering and Computer Science
Thesis: ``Low Pressure Nitrided Oxide in MOS Capacitors''

University of California, Berkeley — May 1984
B.S. in Electrical Engineering and Computer Science

Research and Professional Experience:

Professor of Electrical Engineering and Computer Science
School of Engineering and Applied Sciences, Harvard University
- Gordon McKay Professor — September 1997 - present
- Associate Professor — September 1994 - 1997
- Assistant Professor — September 1990 - 1994

Analysis, design and implementation of microelectronic circuits and VLSI systems.
Teaching and curriculum planning in electrical engineering and computer science.

HBS University Fellow and Visiting Professor — September 2008 - present
Harvard Business School
Research and teaching in technology innovation and industry evolution.

Founder — March 2000 – March 2008
Silicon7, Incorporated
Seongnam-si, Kyoungki-do, KOREA
Application Specific Memory products for mobile communications and computing platforms.

Science and Technology Board Member — June 1998 – June 2001
Polaroid Corporation, Cambridge, Massachusetts
Evaluation of research and technology developments.

Consultant and Senior Fellow — August 1995 – March 2000
Hyundai Electronics Industries, Ichon, Korea

Development of high performance CMOS image sensor technology for embedded image sensing and processing applications. Research on advanced DRAM design and merged memory logic (MML) technology for advanced computer systems.

Consultant — December 1993 - June 1998
Hamamatsu Photonics K.K., Hamamatsu City, Japan
Development of smart image sensors and CCD/CMOS analog charge-domain circuitry.

Consultant — June 1991 - December 1993
Istituto per la Ricerca Scientifica e Tecnologica (IRST), Trento, Italy
Research and development of advanced CMOS/CCD technology and circuitry.

Consultant — June 1988 - August 1990
M.I.T. Lincoln Laboratory, Dr. Alice M. Chiang, Advisor
Design and implementation of CCD image sensors and analog signal processors.

Research Assistant — September 1987 - August 1990
M.I.T. Artificial Intelligence Laboratory, Professor Tomaso Poggio, Advisor
Implementation of analog VLSI hardware for computer vision.

Research Assistant — September 1984 - August 1987
M.I.T. Microsystems Technology Laboratory, Professor Charles G. Sodini, Advisor
Development and characterization of low pressure ammonia and oxygen annealing process for improved reliability of scaled MOS transistors.

Research Assistant — January 1983 - May 1984
U.C. Berkeley Electronic Research Laboratory, Professor Chenming Hu, Advisor
Measurement and analysis of hot electron degradation in MOS transistors.

Honors and Awards:

National Science Foundation Young Investigator Award	1992
Army Research Office Young Investigator Award	1992
Hertz Foundation Fellowship	1984 – 1990
National Science Foundation Fellowship	1984
University of California Alumni Scholarship	1980 - 1984
Phi Beta Kappa, Eta Kappa Nu, Tau Beta Pi	1984

Patents:

Method and Charge--Coupled Apparatus for Algorithmic Computations, Woodward Yang, May 12, 1992, U.S. Patent No. 5,113,365.

Image Sensor Array With Threshold Voltage Detectors and Charged Storage Capacitors, Woodward Yang, May 25, 1993, U.S. Patent No. 5,214,274.

Error Correcting Sigma-Delta Modulation Decoding, Philip Steiner and Woodward Yang, November 17, 1998, U.S. Patent No. 5,838,272.

CMOS image sensor with equivalent potential diode, Woodward Yang, Ju Il Lee and Nan Yi Lee, February 26, 1999, US Patent No. 6,180,969.

CMOS image sensor with equivalent potential diode and method for fabricating the same, Woodward Yang, Ju Il Lee and Nan Yi Lee, February 26, 1999, US Patent No. 6,184,055.

CMOS image sensor with testing circuit for verifying operation thereof, Oh Bong Kwon, Woodward Yang, Suk Joong Lee, and Gyu Tae Hwang, February 26, 1999, US Patent No. 6,633,335.

Antifuse circuitry for post-package DRAM repair, Woodward Yang, et al., January 10, 2000, US Patent No. 6,240,033.

Image sensor with analog-to-digital converter that generates a variable slope ramp signal, Kang Jin Lee, Chan Ki Kim, Jae Won Eom and Woodward Yang, February 8, 2001, US Patent No. 6,545,624.

Error-correcting circuit for high density memory, Elaine Ou and Woodward Yang, June 9, 2009, US Patent No. 7,546,517.

Selected Presentations, Interviews and Invited Lectures:

“Chip Industry must learn not to overshoot,” EE Times cover page, interview and commentary, June 6, 2006.

“Disruptive Innovation,” Keynote Speaker at Consumer Electronics Show, January 2006.

“Using DRAM Technology to Make SRAM,” The Weekly Economist interview, September 24, 2002.

“Silicon7 8-Mbit SRAM sports single-transistor cell,” EE Times interview, September 2001.

“Hyundai modifies DRAM process to produce CMOS image sensors,” EE Times interview, March 1999.

“Merged Memory Logic," W. Yang, IEEE Solid-State Circuits Society Distinguished Lecturer, Hanyang University, Korea, March 1999.

``The Dawn of Billion Transistor Chips," W. Yang, 1998 Korea - U.S. Science and Technology Symposium: Computing and Telecommunication, Chicago, April 1998.

``Innovation in Microelectronic Manufacturing," W. Yang, National Research Council Workshop on the Electronics Industry, November 1997.

``The Smart Access Memory: An Intelligent RAM for Nearest Neighbor Database Searching," A. Lipman and W. Yang, Workshop on Mixing Logic and DRAM at the 24th International Symposium on Computer Architecture, http://iram.cs.berkeley.edu/isca97-workshop, June 1997.

``Using MML to Simulate Multiple Dual-Ported SRAMs: Parallel Routing Lookups in an ATM Switch Controller," A. Brown, D. Chian, N. Mehta, Y. Papaefstathiou, J. Simer, T. Blackwell, M.D. Smith, and W. Yang, Workshop on Mixing Logic and DRAM at the 24th International Symposium on Computer Architecture, http://iram.cs.berkeley.edu/isca97-workshop, June 1997.

``Trends in Electronic Image Sensing and Processing," IEEE Laser and Electro Optical Society, Lincoln, MA, March 1996.

``VLSI Systems for Machine Vision," LG Industrial Systems, Anyang, Korea, August 1996.

``An Embedded Processor-Memory Architecture," Samsung Electronics, Kiheung, Korea, June 1996.

``VLSI Hardware for Example-Based Learning," IBM T.J. Watson Laboratories, Hawthorne, NY, October 1995.

``Intelligent VLSI Systems," Hyundai Electronics, Ichon, Korea, December 1994.

``Bidirectional Delay Line" and ``Pulse-based Photodetector," NSF Workshop on Neuromorphic Analog VLSI Systems, Telluride, CO, July 1994.

Depositions and Trial Testimonies:

In the matter of CERTAIN ELECTRONIC DEVICES, INCLUDING MOBILE PHONES, PORTABLE MUSIC PLAYERS, AND COMPUTERS (ITC, Investigation No. 337-TA-701, deposition and trial) – retained by Nokia

Publications:

"Science and Technology Entrepreneurship for Greater Societal Benefit: Ideas for Curricular Innovation," Fleming, Lee, Woodward Yang, and John Golden in **Spanning Boundaries and Disciplines: University Technology Commercialization in the Information Age**, edited by Gary D. Libecap, Marie Thursby and Sherry Hoskinson, Emerald Group Publishing Limited, 2010.

"The New Economics of Semiconductor Manufacturing," Clayton Christensen, Steve King, Matt Verlinden and Woodward Yang, **IEEE Spectrum**, vol. 45, issue 5, pp. 24-29 May 2008.

"Energy Consumption Model for Power Management in Wireless Sensor Networks," Qin Wang and Woodward Yang, *IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks SECON 2007*, June 2007.

"A Realistic Power Consumption Model for Wireless Sensor Network Devices," Qin Wang, Mark Hempstead and Woodward Yang, *IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks SECON 2006*, September 2006.

"Fast Error-Correcting Circuits for Fault-Tolerant Memory," E. Ou and W. Yang, *IEEE International Workshop on Memory Technology, Design and Testing*, pp. 8-12, August 2004.

"A Low-Power 256-Mb SDRAM with an On-Chip Thermometer and Biased Reference Line Sensing Scheme," J.P. Kim, W. Yang, and H.-Y. Tan, **IEEE Journal of Solid-State Circuits**, vol. 38, no. 2, pp. 329-337, February 2003.

"An Antifuse EPROM Circuitry Scheme for Field-Programmable Repair in DRAM," J.K. Wee, W. Yang, E.K. Ryou, J.S. Choi, S.H. Ahn, J.Y. Chung and S.C. Kim, **IEEE Journal of Solid-State Circuits**, vol. 35, no. 10, pp. 1408-1414, October 2000.

"An Embeddable Low Power SIMD Processor Bank," S.-H. Hong and W. Yang, *Digest of Technical Papers of IEEE International Solid--State Circuits Conference*, pp. 192-193, February 2000.

"Antifuse EPROM Circuit for Field Programmable DRAM," J.-S. Choi, J.-K. Wee, P.-J. Kim, J.-K. Oh, C.-H. Lee, H.-Y. Cho, J.-Y. Chung, S.-C. Kim and W. Yang, *Digest of Technical Papers of IEEE International Solid--State Circuits Conference*, pp. 406-407, February 2000.

"An Improved Digital CMOS Imager," O.-B. Kwon, K.-N. Park, D.-Y. Lee, K.-J. Lee, S.-C. Jun, C.-K. Kim, Y.-B. Lee and W. Yang*, IEEE Workshop on Charged-Coupled Devices and Advanced Image Sensors*, Nagano, Japan, June 1999.

"A Linear-Response, High-Dynamic Range CMOS Imager Suitable for Spectroscopic Applications," D. Qian and W. Yang, *IEEE Workshop on Charged-Coupled Devices and Advanced Image Sensors*, Nagano, Japan, June 1999.

"New Self Refresh Scheme Using Cell Leakage Monitoring Circuit," Y.-H. Seol, H.-Y. Cho, J.-K. Wee, D.-H. Ryu, J.-G. Oh, J.-S. Choi, J.-J. Lee, J.-H. Lee, and W. Yang, (in Korean) *Proceedings of the 6th Korean Conference on Semiconductors*, pp. 377-378, Seoul, Korea, February 1999.

"High Voltage Circuitry for Post Package DRAM Repair," P.-J. Kim, J.-G. Oh, J.-K. Wee, D.-H. Ryu, Y.-H. Seol, H.-Y. Cho, J.-S. Choi, J.-H. Han, J.-H. Lee, and W. Yang, (in Korean) *Proceedings of the 6th Korean Conference on Semiconductors*, pp. 385-386, Seoul, Korea, February 1999.

``An Integrated 800 x 600 CMOS Imaging System,'' W. Yang, O.-B. Kwon, J.-I. Lee, G.-T. Hwang and S.-J. Lee, *Digest of Technical Papers of IEEE International Solid--State Circuits Conference*, pp. 304-305, February 1999.

``VLSI Hardware for Example-Based Learning,'' A. Lipman and W. Yang, **IEEE Transactions on VLSI Systems**, vol. 5, no. 3, pp. 320-328, September 1997.

``A Reconfigurable VLSI Coprocessing System for the Block Matching Algorithm,'' A. Bugeja and W. Yang, **IEEE Transactions on VLSI Systems**, vol. 5, no. 3, pp. 329-337, September 1997.

``A CCD/CMOS Image Sensor Array with Integrated A/D Conversion,'' M. Gottardi and W. Yang, *Proceedings of the IEEE International Symposium on Circuits and Systems*, Vol. III, pp. 1908-1911, June 1997.

``Circuit integration pushes image sensor performance,'' W. Yang, **Laser Focus World**, Penwell Publishing, pp. 129-139, February 1997.

``A Framework for Analysis of High Order Sigma-Delta Modulators,'' P. Steiner and W. Yang, **IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing**, vol. 44, no. 1, pp. 1-12, January 1997.

``Competitive learning algorithms for channel optimized vector quantizers,'' D. Martinez and W. Yang, *The 1996 IEEE International Conference on Neural Networks*, pp. 1462-1467, June 1996.

``Stability of High Order Sigma-Delta Modulators,'' P. Steiner and W. Yang, *Proceedings of IEEE International Symposium on Circuits and Systems*, Vol. III, pp. 52-57, May 1996.

``Simple Pulse Asynchronous State Machines,'' J. Miller and W. Yang, *Proceedings of IEEE International Symposium on Circuits and Systems*, Vol. III, pp. 405-409, May 1996.

``Neuromorphic CMOS Circuitry for Active Bidirectional Delay Lines,'' W. Yang, *Proceedings of IEEE International Symposium on Circuits and Systems*, Vol. III, pp. 473-476, May 1996.

``A Robust Backward Adaptive Quantizer,'' D. Martinez and W. Yang, *Proceedings of IEEE Workshop on Neural Networks for Signal Processing V*, pp. 531-540, August 1995.

``A Real-Time Face Recognition System Using Machine Vision Techniques,'' W. Yang, invited paper, *CardTech/SecurTech Conference Proceedings*, pp. 179-193, April 1995.

``Stability Analysis of the Second Order Sigma-Delta Modulator,'' P. Steiner and W. Yang, *Proceedings of IEEE International Symposium on Circuits and Systems*, Vol. V, pp. 365-368, June 1994.

``An Interline CCD Imaging Array with On-Chip A/D Conversion,'' D. J. Friedman and W. Yang, *Proceedings of SPIE, Charge--Coupled Devices and Solid State Optical Sensors IV*, vol. 2172, pp. 54-63, February 1994.

``A Wide Dynamic Range, Low Power Photosensor Array,'' W. Yang, *Digest of Technical Papers of IEEE International Solid--State Circuits Conference*, pp. 230-231, February 1994.

``A Real--Time Face Recognition System Using Custom VLSI Hardware,'' J.M. Gilbert and W. Yang, *Proceedings of IEEE Workshop on Computer Architectures for Machine Perception*, pp. 58-66, December 1993.

``A CCD/CMOS Image Motion Sensor,'' M. Gottardi and W. Yang, *Digest of Technical Papers of IEEE International Solid—State Circuits Conference*, pp. 194-195, February 1993.

``Analog CCD Processors for Image Filtering,'' W. Yang, *Proceedings of SPIE, Visual Information Processing: From Neurons to Chips*, vol. 1473, pp. 114-127, April 1991.

``The MIT Vision Chip Project: Analog VLSI Systems for Fast Image Acquisition and Early Vision Processing,'' J.L. Wyatt, D.L. Standley, and W. Yang, *Proceedings of the International Conference on Robotics and Automation*, vol. 2, pp. 1330-1335, April 1991.

``A Full Fill--Factor CCD Imager with Integrated Signal Processors,'' W. Yang and A.M. Chiang, *Digest of Technical Papers of International Solid--State Circuits Conference*, pp. 218-219, February 1990.

``A Charge--Coupled Device Architecture for On Focal Plane Image Signal Processing,'' W. Yang, *Proceedings of International Symposium on VLSI Technology, Systems, and Applications*, pp. 266-270, May 1989.

``Optical Flow: Computational Properties and Networks, Biological and Analog,'' Tomaso Poggio, Woodward Yang, and Vincent Torre, **The Computing Neuron**, R. Durbin, C. Maill, and G. Mitchison (editors), pp. 255-370, Addison--Wesley, New York, 1989.

``Optimization of Low Pressure Nitridation/Oxidation of SiO_2 for Scaled MOS Devices,'' W. Yang, R. Jayaraman, and C.G. Sodini**, IEEE Transactions on Electron Devices**, vol. ED-35, no. 7, pp. 935-944, July 1988.

``Radiation Effects in Low Pressure Reoxidized Nitrided Oxide Gate Dielectrics,'' G. Dunn, R. Jayaraman, W. Yang, and C.G. Sodini, **Applied Physics Letters**, vol. 52, no. 20, pp 1713-1715, May 1988.

``The MIT Vision Machine,'' T. Poggio, J. Little, E. Gamble, W. Gillet, D. Geiger, D. Weinshall, M. Villalba, N. Larson, T. Cass, H. Bulthoff, M. Drumheller, P. Oppenheimer, W. Yang, and A. Hurlbert, *DARPA Image Understanding Workshop*, pp. 177-198, April 1988.

``MOS Electrical Characteristics of Low Pressure Re—oxidized Nitrided Oxide,'' R. Jayaraman, W. Yang, and C.G. Sodini, *Technical Digest of International Electron Devices Conference*, pp. 668-671, December 1986.

``Hot Carriers Induced Degradation in Thin Gate Oxide MOSFET's,'' M--S. Liang, C. Chang, W. Yang, C. Hu, and R.W. Brodersen, *Technical Digest of International Electron Devices Conference*, pp. 186-189, December 1983.