OAK RIDGE
NATIONAL LABORATORY

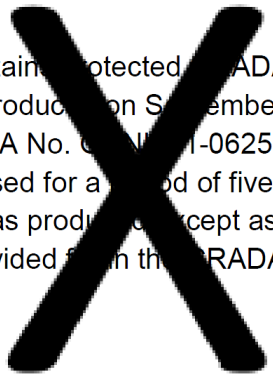
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL 01-0625

Chemical Sciences Division

CRADA Final Report
For
CRADA Number ORNL 01-0625

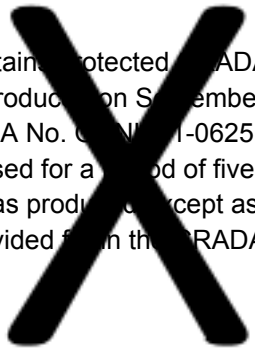
Artificial Retina Project



E. Greenbaum
Oak Ridge National Laboratory

J. Little
Second Sight Medical Products

Prepared by
Oak Ridge National Laboratory
Oak Ridge, TN 37831
managed by
UT-BATTELLE, LLC
for the
U.S. Department of Energy
under contract DE-AC05-00OR22725



UT-BATTELLE

1. Abstract

The U.S. Department of Energy's Artificial Retina Project is a collaborative, multi-institutional effort to develop an implantable microelectronic retinal prosthesis that restores useful vision to people blinded by retinal diseases. The ultimate goal of the project is to restore reading ability, facial recognition, and unaided mobility in people with retinitis pigmentosa and age-related macular degeneration. The project taps into the unique research technologies and resources developed at DOE national laboratories to surmount the many technical challenges involved with developing a safe, effective, and durable product. The research team includes six DOE national laboratories, four universities, and private industry.

2. Statement of Objectives

The technical objectives of the CRADA are to develop, test and qualify an implantable retinal prosthesis with the following attributes:

- Greater than 200+ electrodes Fitting within the eye or eye socket
- Powered wirelessly by an external source
- Capable of both forward (data) and backward (diagnostic) telemetry
- Having an implantable lifetime in excess of 20 years
- Biocompatible
- Provides useful levels of vision that result in a measurable improvement in the quality of life of the patient

3. Benefits to the Funding DOE Office's Mission

"The Department of Energy's national laboratories are incubators of innovation." This quote by Secretary of Energy Steven Chu defines the key benefits to DOE mission. As in many frontier scientific research projects, DOE's Artificial Retina Project has led to cutting-edge innovations as well as several unanticipated discoveries and spinoffs that are increasing the value of these investments. Here's a brief summary of the path-breaking technologies contributed by the DOE artificial retina project.

- **Smart Biodetection Systems** - Lawrence Livermore National Laboratory
- **Electronic-Tissue Interface Devices** - Lawrence Livermore National Laboratory
- **Metabolic Prosthesis for Diabetics** - Oak Ridge National Laboratory and University of Southern California Doheny Eye Institute (USC DEI)
- **From Electrodes to Molecular Photovoltaics** - Oak Ridge National Laboratory
- **Microscale Enablers** - Sandia National Laboratories
- **Vision Simulator Image Processing Software System** - California Institute of Technology
- **Biocompatible Microelectronics** - Lawrence Livermore National Laboratory
- **PET Scans to Measure Light, Electrical Stimulation** - Brookhaven National Laboratory and USC DEI
- **Diamond Coating Technology** - Argonne National Laboratory
- **Microchip Development** - University of California at Santa Cruz

4. Presidential Milestones and Technical Discussion of Work Performed by All Parties

2007 Presidential Milestones

2007	Goal	**Actual**
Oct- Dec 2006 Q1	Further evaluate biocompatibility of 200+ inactive mechanical models	Goal met. Further evaluations of the 200+ "inactive" mechanical models has been completed in animals.
Jan- Mar 2007 Q2	Characterize through bench testing the 200+ electronic subsystems	Goal met. We have characterized through bench testing the 200+ electronic subsystems.
Apr- June 2007 Q3	Evaluate the integration of subsystems of 200+ implant	The multiple subcomponents of the 200 + electrode device have been integrated and have been evaluated
July- Sept 2007 Q4	Test the integration of subsystems of 200+ implant	Tested the integration of subsystems of 200+ implant (Zhou's results).
Annual	Advance blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals.	Annual target met. The design and construction of two 256 electrode arrays was completed, and in vitro and animal non-stimulating tests were initiated. Two implants of 200+ electrode arrays (non-stimulating) were completed on preclinical models. 1. In Oct '06 and Nov '06 a 1-can and 2-can version of the 200+ was delivered to SSMP for post processing (silicone attachment), mechanical model of package attachment, and thermo-forming. The 1-can model was chronically implanted into an animal in Nov'06 at DEI. The mechanical model was removed from the animal and histology was performed. 2. The 200+ was redesigned with the feedback given by these animal experiments and in-vitro (saline soak) testing has been performed on an electrode array to verify the insulation proprieties of the polyimide. The testing was conducted over the summer on a dozen parts. We are currently working with SSMP to design a test structure that can fit into their automated testing station.

2008 Presidential Milestones

2008	Goal	Actual
Oct- Dec 2007 Q1	Refine and optimize 200+ from clinical lessons learned	The strength of device attachment features, the geometry of the electrode array, and the fit of the implant (dimensions) were modified as a result of clinical lessons. LLNL has modified the 200+ design to include the design changes suggested by SSMP in Oct. LLNL has fabricated the TFEA arrays, and thermo-formed them using a mechanical mold fabricated by LLNL. Four arrays were sent to SSMP after Thanksgiving to SSMP for the silicone post-processing. Packaging LLNL has sent a modified Ceramic Substrate design to vendors for quote using W to plug the vias. SSMP have sent back the ceramic carriers with a dummy A60 chip and the discrete components bonded onto them. LLNL will build the mechanical model next year. Insertion Tool LLNL received the insertion tool from SSMP, and the functionality of the device was verified. LLNL developed a excimer laser process to fabricate the silicone washers. The insertion tool and the washers are ready for another test at DEI. LLNL will coordinate with DEI for another test run next year.
Jan- Mar 2008 Q2	Preclinical test of final 200+ mechanical design	We have performed preclinical testing of the final 200+ mechanical design. This design has been fabricated and then implanted in a research animal, demonstrating appropriate physical size and robustness for implantation.
Apr- June 2008 Q3	Final Electronic systems integration testing	The final integration of the electronic system has been tested. Wireless data was sent and received from the external visual processing unit to the internal electronic package which contained the stimulator chip and associated electronics.
July- Sept 2008 Q4	Begin building active 200+ implantable system	The system level integration of the 200+ implant has begun. The 200+ thin film electrode array is being assembled with the electronics system to build the active 200+ artificial retina.

Annual	Optimize the 200+ Artificial Retina Using Data from Clinical Results	The design of the implantable systems including the 200+ thin film electrode array and the electronic package have been optimized based on feedback from the current 60 clinical results.

2009 Presidential Milestones

2009	Goal	Actual
Oct- Dec 2008 Q1	Build electronics module for implantable active A 200+ system	The electronics module for an implantable active 200+ system was assembled and tested. It is a key component required to fabricate the active 200+ prototype system.
Jan- Mar 2009 Q2	Complete fabrication of active 200+ Prototype system	The fabrication of an active 200+ prototype system which includes the electronics package, wireless power and telemetry coil, and the thin film electrode array has been completed.
Apr- June 2009 Q3	Functional characterization of active 200+ system	The functional characterization using the wireless power and telemetry link of an active 200+ prototype system has been completed.
July- Sept 2009 Q4	Final integration of implantable 200+ system	Accomplished by: The final integration of an implantable 200+ prototype system has been completed. The 200+ system has demonstrated wireless power delivery and wireless bi-directional telemetry in an in-vitro setting.
Annual	Advance blind patient sight: Complete bench-top development of implantable 200+ electrode prototype.	Accomplished by: The bench-top development of an implantable 200+ electrode prototype has been completed. All the components of the 200+ electrode prototype have been integrated and characterized.

2010 Presidential Milestones

2010	Goal	Actual
Oct- Dec 2009 Q1	Design Verification of Subsystems for Preclinical 200+ System	The design verification of the subsystems for the preclinical 200+ system has been completed. The thin film electrode array and the demultiplexer which were updated based on the A - 60 clinical trials have been fabricated and successfully tested.
Jan- Mar 2010 Q2	Assembly of Preclinical 200+ Systems	The assembly of the components including the thin film electrode array and the electronics package for a Preclinical 200+ System has been completed. Initial functional testing has verified that wireless power and telemetry was transmitted and received from the Preclinical 200+ System.
Apr- June 2010Q3	Testing and Verification of Preclinical 200+ Systems	A complete preclinical 200+ system was assembled and functionality was verified by the transmission of wireless power and telemetry. The electrode and lifetime parameters were characterized by immersing the preclinical 200+ system in physiological buffered saline. Preliminary results have shown electrode impedances within design parameters and accelerated lifetime greater than one year.
July- Sept 2010 Q4	Implantation of Initial Preclinical 200+ Systems	2 preclinical 200+ systems were surgically implanted into preclinical animal models and functionality was verified by the successful transmission of power and telemetry across the wireless link. The characteristics of more than 200 electrodes were verified to be within the design parameters after the implantation.
Annual	Advance blind patient sight: Initiate preclinical studies of 200+ electrode implantable device. Complete specification for 1000+ pixel device.	Significant progress has been made in the on-going clinical trials of the Argus® II to advance patient sight. The Argus® II has an excellent safety profile and has assisted patients with mobility and orientation. In addition, animal studies of the preclinical 200+ system have been initiated with the first two successful implants of a 200+ system. Finally, the design specifications for a 1000+ system have been completed. The 1000+ system will restore the patient's ability to read and recognize faces.

Doheny Eye Institute

Major Accomplishments

- System engineering of a 200+ electrode retinal prosthesis
- Implantation of 200+mechanical prosthesis in preclinical models 2009
- Implantation of active (electrically functional) 200+ retinal prosthesis in a preclinical model 2010
- Built and validated dynamic mechanical model of force exerted on the retina by an intraocular electrode array
- Measured material properties of ocular tissues as input to mechanical models using both pull testing and nanoindentation
- Experimentally characterized the response of retina and eye tissue to applied pressure
- Tested biocompatibility of novel adhesives attached to silicone and parylene, as a means of attaching the electrode array to the retina
- Established a correlation between increasing electrical stimulation thresholds and decreasing retinal ganglion cell density in animal model of retinal degeneration
- Investigated retinal adaptation in response to continuous stimulation, specifically the rate of response attenuation and response recovery.
- Demonstrated that high rate pulsing for up to 1 hour does not significantly alter retinal architecture in spite of the fact that pulse intensity was above accepted safe limits for platinum, suggesting that the retina is tolerant to epiretinal stimulation
- Used PET imaging to confirm visual cortex activity in response to electrical stimulation of the retina in blind test subjects
- Correlated electrically elicited perceptions from blind test subjects with computational models of current flow in the eye and specific areas of activation in the visual cortex
- Tested biocompatibility of UNCD coatings in the eye

Simultaneously measured electrode impedance, stimulus threshold, and retinelectrode separation, demonstrating that impedance is inversely correlated with separation while threshold is directly correlated with threshold

PATENTS

1. Tai YC, Rodger DC, Li W, Humayun MS, Weiland JD, Ameri H, Tanguay, Jr. AR. *Method of fabricating an integrated intraocular retinal prosthesis device*. United States Patent 7,774,931. Patent Issued: August 17, 2010. (11/414,139)

PATENTS PENDING

1. Humayun MS, Ratner BR, Weiland JD, Tunc M, Cheng X. Reversible Thermo-responsive Adhesives for Implants. United States Patent Application 20080140192. Filed: November 29, 2007.
2. Laude L, Rowley A, Humayun MS, Weiland JD. Nanoscale Surface Activation of Silicone via Laser Processing. United States Patent Application 20080305320. Filed: March 3, 2008.

3. Rowley AP, Laude LD, Humayun MS, Weiland JD, Lotfi A. Biocompatible Implants And Methods Of Making And Attaching The Same. United States Patent Application 20080306611. Filed: March 3, 2008.
4. Ameri H, Humayun MS, Weiland JD. Subchoroidal Retinal Prosthesis. United States Patent Application 20090177245. Filed: July 9, 2009.
5. Tanguay, JR A, Humayun MS. Ocular Imaging System. United States Patent Application 20100026957. Filed: February 4, 2010.

BOOK CHAPTERS

1. Chader GJ, Weiland J, Humayun MS. *Artificial vision: needs, functioning, and testing of a retinal electronic prosthesis.* Prog Brain Res. 2009; 175:317-332.
2. Humayun MS, Morales Martinez Y, Chader G, Santos Garcia A. *Vision artificial: protesis electronica epirretiniana.* Oftalmologica en las Opinion de los Expertos. Ed: Santos, Garcia, A., Garaitia Editores 45-67, 2010
3. Chader G, Horsager A, Weiland J, Humayun MS. *Injury and Repair: Prostheses.* Encyclopedia of the Eye, Eds., Dart, D., Besharse, J., Dana, R. Elsevier Press, Oxford England, vol.2 408-413, 2010

JOURNAL ARTICLES

1. Rodger DC, Fong AJ, Li W, Ameri H, Ahuja AK, Gutierrez C, Lavrov I, Zhong H, Menon PR, Meng E, Burdick JW, Roy RR, Edgerton R, Weiland JD, Humayun MS, Tai YC. *Flexible Parylene-based Multielectrode Array Technology for High-density Neural Stimulation and Recording*. Sensors and Actuators B: Chemical (online), November 12, 2007.
2. Ahuja AK, Behrend MR, Whalen JJ, Humayun MS, Weiland JD. *The dependence of spectral impedance on disc microelectrode radius.* IEEE Trans Biomed Eng. 2008; 55(4):1457-1460.
3. Weiland JD**,** Humayun MS*, Visual Prosthesis*, Proceedings of the IEEE Volume 96, Issue 7, July 2008:1076-1084
4. Ahuja AK, Behrend MR, Kuroda M, Humayun MS, Weiland JD. *An in vitro model of a retinal prosthesis*. IEEE Trans Biomed Eng. 2008; 55(6):1744-1753.
5. Ray A, Colodetti L, Weiland JD**,** Hinton DR, Humayun MS, Lee EJ, *Immunocytochemical analysis of retinal neurons under electrical stimulation*, Brain Research December 9, 2008 DOI 10:1016/brainres.2008.22.089
6. V. Singh, A. Roy, R. Castro, K. McClure, J. Weiland, M. Humayun, and G.Lazzi, *On the Thermal Elevation of a 60-Electrode Epi-Retinal Prosthesis to Restore Partial Vision to the Blind*, IEEE Transactions on Biomedical Circuits and Systems, pp. 289-300, Dec. 2008
7. Behrend MR, Ahuja AK, Humayun MS, Weiland JD, Chow RH. *Selective labeling of retinal ganglion cells with calcium indicators by retrograde loading in vitro.* J Neurosci Methods. 2009; 179(2):166-72. Epub 2009 Jan 31.
8. Ameri H, Ratanapakorn T, Ufer S, Eckhardt H, Humayun MS, Weiland JD. *Toward a wide-field retinal prosthesis*. J Neural Eng. 2009; 6(3):035002. Epub 2009 May 20.
9. V. Singh, A. Roy, R. Castro, K. McClure, J. Weiland, M. Humayun, and G.Lazzi, *Specific Absorption Rate and Current Densities in the Human Eye and Head Induced by the Telemetry Link of a Dual-Unit Epiretinal Prosthesis*, IEEE Transactions on Antennas and Propagation, pp.3110-3118, 2009
10. Basinger BC, Rowley AP, Chen K, Humayun MS, Weiland JD, *Finite element modeling of retinal prosthesis mechanics.* Journal of Neural Engineering 2009 Oct;6(5):55006. Epub 2009 Sep 1

11. Chen K, Rowley AP, Weiland JD, *Elastic properties of porcine ocular posterior soft tissues.* Journal of Biomedical Materials Research Part A, 2010 Vol 93A(2):634-645 DOI.10.1002/jbm.a.32571
12. Ray A, Sun GJ, Chan L, Grzywacz NM, Weiland JD, Lee EJ, *Morphological alterations in retinal neurons in the S334ter-line3 transgenic rat,* Cell Tissue Res. 2010 Mar;339(3):481-91. Epub 2010 Feb 2.PMID: 20127257
13. Chen K, Weiland JD, *Anisotropic and inhomogeneous mechanical characteristics of the retina.*, J Biomech. 2010 May 7;43(7):1417-21. Epub 2010 Feb 8.PMID: 20116062
14. Nayar VT, Weiland JD, Hodge AM, *Characterization of Porcine Sclera using instrumented Nanoindentation*, Materials Science and Engineering Article in Press doi:10:1016/ j.msec. 2011.02.0011
15. Chan L, Lee EJ, Humayun MS, Weiland, JD, *Both Electrical Stimulation Thresholds and SMI-32 Immunoreactive Retinal Ganglion Cell Density Correlate with age in S334ter line 3 Rat Retina*, J Neurophysiol jn.00619.2010; published ahead of print March 16, 2011, doi:10.1152/jn.00619.2010
16. Ray A, Lee EJ, Humayun MS, Weiland, JD, *Continuous electrical stimulation decreases retinal excitability but does not alter retinal morphology,* Journal of Neural Engineering, JNE/383104/SPE/258331 In Press
17. Nayar VT, Weiland JD, Nelson CS, Hodge AM, *Elastic and Viscoelastic Characterization of Agar,* Journal of the Mechanical Behavior of Biomedical Materials 2011 In Press

ABSTRACTS

1. Rowley AP, Basinger BC, Beremesh A, Weiland JD, Humayun MS, *Biomechanics of the Porcine and Humayun Eyewall*, Invest. Ophthalmol. Vis. Sci. 2007 48: E-Abstract 57.
2. Basinger BC, Rowley AP, Beremesh A, Humayun MS, Weiland JD, *Mechanics During Retinal Tracking of an Epiretinal Prosthesis*, Invest. Ophthalmol. Vis. Sci. 2007 48: E-Abstract 2547.
3. Thomas BB, Ray A, Chan L, Humayun MS, Weiland JD, *Electrode Impedance Can Be a Reliable Measurement of Retinal-Electrode Proximity During Epiretinal Electrical Stimulation in Rats,* Invest. Ophthalmol. Vis. Sci. 2007 48: E-Abstract 2551.
4. Lima L, Wang J, Liu W, Weiland JD, Agrawal RN, Humayun MS, *Transretinal Fixation of Polyimide Strips*, Invest. Ophthalmol. Vis. Sci. 2007 48: E-Abstract 2569.
5. Basinger BC, Rowley AP, Humayun MS, Weiland JD, *Modeling Retinal Prosthesis Mechanics*, BMES Annual Fall Meeting, Los Angeles, CA, September 2007
6. Ray A, Lee EJ, Colodetti L, Humayun MS, Weiland JD, *Electrical Stimulation Alters Outer Retina Morphology*, Invest Ophthalmol Vis Sci 2008;49:E-Abstract 1770.
7. Chan L, Lee EJ, Ray A, Thomas BB, Humayun MS, *Correlation of Morphological and Electro-physiological Changes in Degenerated Rat Retina*, Invest Ophthalmol Vis Sci 2008; 49-E-Abstract 3015.
8. Thomas BB, Chan L, Ray A, Humayun MS, Weiland JD, *Spatial Properties of Multi-Electrode Epiretinal Stimulation Evaluated from the Rat*, Invest Ophthalmol Vis Sci 2008; 49:E-Abstract 3021.
9. Thomas BB, Matsuda T, Cholakian D, Young F, Sadda SR, Humayun MS, Weiland JD, *Morphologic Evaluation of the Superior Colliculus in a Retinal Degenerate Rat Model*, Invest Ophthalmol Vis Sci 2009; 50:E-Abstract 1429.
10. Ray A, Lee EJ, Chan L, Humayun MS, Weiland JD, *Effect of High Charge Stimulation on Retinal Morphology*, Invest Ophthalmol Vis Sci 2009: 50:E-Abstract 4572.

11. Rowley AP, Chen K, Basinger BC, Weiland JD, Humayun MS, *Ophthalmology Mechanical Modeling of an Epiretinal Prosthesis*, Invest Ophthalmol Vis Sci 2009; 50:E-Abstract 4592.
12. Thomas BB, Rigas D, Johnston A, Nayak P, Konduru R, Syed T, Wang V, Chen Z, Humayun MS, Weiland JD, *Anatomic Estimation of the Superior Colliculus in Aged Retinal Degenerate Rats*, Invest Ophthalmol Vis Sci 2010; 51-E-Abstract 1059.
13. Gonzalez A, Barbosa JD, Ray A, Morales S, Weiland JD, Humayun MS*, Distance Measurement Between an Electrode and the Retina Using OCT Images*, Invest Ophthalmol Vis Sci 2010; 51:E-Abstract 1788.
14. Rowley AP, Laude L, Lofti A, Kolev K, Swenson S, Markland F, Weiland JD, Humayun MS, *Reversibly Interfacing Biomaterials With the Retina*, Invest Ophthalmol Vis Sci 2010; 51:E-Abstract 3041.
15. Ray A, Lee EJ, Humayun MS, Weiland JD, *Continuous Epiretinal Stimulation Causes Functional and Not Structural Changes*, 2010 Neural Interfaces Conference, Long Beach, CA
16. Nayar VT, Weiland JD, Hodge AM, *Nanoindentation of Porcine Sclera*, 2010 Neural Interfaces Conference, Long Beach, CA
17. Davuluri NS, Weiland JD, *Design of a Microelectrode Array for Chronic Implantation in the Rat's Eye*, 2010 Neural Interfaces Conference, Long Beach, CA
18. Weiland JD, Chan L, Ray A, Humayun MS, *Electrical Stimulation of Degenerated Retina with High Resolution Electrode*, BMES 2010, Austin, Texas
19. Rowley AP, Brant R, Zhang C, Thompson M, Swenson S, Markland F, Weiland JD, Humayun MS, *Interfacing Biomaterials With The Retina In Vivo*, Invest Ophthalmol Vis Sci 2011;52: E-Abstract 5653. ARVO 2011

PEER REVIEWED CONFERENCE PROCEEDINGS

1. Chan LH, Ray A, Thomas BB, Humayun MS, Weiland JD. *In vivo study of response threshold in retinal degenerate model at different degenerate stages.* Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE. Aug. 2008, Pages: 1781 – 1784
2. Chader GJ, Weiland J and Humayun MS. *Artificial Vision: needs, functioning and testing of a retinal electronic prosthesis*. Progress in Brain Research. Amsterdam Brain Research 2009. 175, Pages: 317-332.
3. Parikh NJ, McIntosh BP, Tanguay AR, Humayun MS, Weiland JD. *Biomimetic image processing for retinal prostheses: Peripheral saliency cues.* Conf Proc IEEE Eng Med Biol Soc. 2009; 1:4569-4572.
4. Weiland JD, Humayun MS, Eckhardt H, Ufer S, Laude L, Basinger B, Tai YC. *A comparison of retinal prosthesis electrode array substrate materials.* Conf Proc IEEE Eng Med Biol Soc. 2009; 1:4140-4143.

Chader Invited Lectures

1) *A Retinal Prosthesis for Retinal Degenerative Diseases*, Scientific Advisory Board meeting of AMD Alliance International, 10 April 2008, Toronto, Canada
2) *The Use of a Retinal Prosthesis for Sight Restoration in Retinitis Pigmentosa*, 29 June, 2008, Hong Kong PR China
3) *Visual Performance with Retinal Prostheses*, International Summer School Program of Brain Research, 25-28 August, 2008, Amsterdam, The Netherlands

4) *Artificial Vision: Sight Restoration in Retinal Degenerative Diseases*, 9 October, 2008, Brisbane, Australia
5) *Sight Restoration in Retinal Degenerations*, AMD Alliance International Global Congress, 15 April, 2009, Sao Paulo, Brazil
6) *Fundamentals of Retinal Physiology, Retinal Degeneration and RD Treatment*, Pan American Advanced Study Institute: Science & Technology for Advanced Neural Prostheses,3-10 August, 2009, Pilar, Buenos Aires, Argentina
7) *Artificial Vision and Future Treatments for AMD*, AMD Alliance International Global Congress 16 April, 2010 Vienna, Austria
8) *Perspectives in Inherited Retinal Degenerations*, 16th Retina International World Congress, 26-27 June 2010 Stresa, Italy
9) *Artificial Vision in Retinitis Pigmentosa*, XXXIX Nordic Congress of Ophthalmology, 6-7 August 2010, Reykjavik, Iceland

Yow Invited Lecture

1. *Retinal Prosthesis Design Considerations*, Pan American Advanced Study Institute: Science & Technology for Advanced Neural Prostheses,3-10 August, 2009, Pilar, Buenos Aires, Argentina

Weiland Invited Lectures

1. *Intraocular Retinal Prosthesis*, University of Maryland Biotechnology Institute (UMBI) "Towards In Vivo Microsystems" symposium, October 2007
2. *Artificial Vision & Neural Prosthesis*, Texas Instruments Fellow Meeting, Dallas Texas, October 2007
3. *Safe and Effective Electrical Stimulation of the Retina*, USC Vision Science Symposium, April 2008
4. *Retinal Prosthesis for the Blind*, Micro/nanoelectronics: Devices and technologies for medical applications, IMEC, Leuven, Belgium, September 2008
5. *Retinal Prosthesis for the Blind*, Engineering Neuroscience and Health Seminar, University of Southern California, October 2008
6. *Challenges for Retinal Prostheses*, Medical Bionics Conference, Lorne, Australia, November 2008
7. *Retinal Prosthesis*, MTL Workshop on "Next Generation Medical Electronic Systems", Cambridge, MA, December 2008
8. *Retinal Prosthesis for the Blind*, Engineering Council Technical Conference, Los Angeles, CA, October 2009
9. *Retinal Prosthesis*, IEEE Engineering in Medicine and Biology, Local Chapter, Northridge, CA June 2010
10. *High Resolution Retinal Prosthesis*, University of North Texas, Dallas, TX August 2010
11. *Advanced Medical Implants*, Texas Instruments Company Seminar, Dallas, TX August 2010

Humayun Invited Lectures

1. UCLA Lake Arrowhead, *Intraocular Retinal Prosthesis*, Lake Arrowhead, CA Sep 2007
2. Duke Medical Alumni Grand Rounds*, Intraocular Retinal Prosthesis*, Raleigh Durham, NC Oct 2007
3. Schepens International Society*, Intraocular Retinal Prosthesis*, Washington D.C. Oct 2007
4. American Academy of Ophthalmology, *A View to the Future*, New Orleans, LA Nov 2007
5. American Society of Retina Specialist, *Intraocular Retinal Prosthesis*, Palm Springs, CA Dec 2007
6. TATRC Bridging the Gap between Personal and Population Health*: Developing an Interdisciplinary Institute for Emerging Health Technologies*, Honolulu, HI Dec 2007

7. Hawaiian Eye 2008, *Advances in Ophthalmology*, Waikoloa, HI Jan 2008
8. American Institute for Medical and Biological Engineering*, Induction Ceremony 2008*, Washington, DC, Feb 2008
9. 36th Annual Aspen Retinal Detachment Society Meeting*, Oh Vitreous Where Is Thy Humor*, Snowmass (Aspen), CO Mar 2008
10. The 53rd Annual Ophthalmology Conference, Snell Memorial Lecturer, University of Rochester, Rochester, NY Mar 2008
11. Malloy Lecture, Artificial Sight, Georgetown University, Washington D.C Mar 2008
12. Cole Eye Institute, The 2nd International Innovations in Ophthalmology Course, Los Cabos, Mexico Mar 2008
13. Parker H. Petit Institute for Bioengineering & Bioscience (IBB), *Artificial Retina*, Georgia Institute of Technology, Atlanta, GA Apr 2008
14. The Association for Research in Vision and Ophthalmology, *Retinal Prosthesis IV*, Ft. Lauderdale, FL Apr 2008
15. Brown University, Frontiers of Health Care Conference, Providence, RI Jun 2008
16. World Ophthalmology Congress, Artificial Sight, Hong Kong, China Jun 2008
17. The 15th Retina International World Congress, *Research into Practice*, Helsinki, Finland Jul 2008
18. University of Wisconsin – Madison, Extraordinary Ophthalmology Conference Madison, WI Jul 2008
19. 5th Biannual LCA Family Conference, Artificial Sight, Cleveland Clinic, Cleveland, OH Jul 2008
20. Blind Veterans Association 63rd National Convention, Artificial Sight, Phoenix, AZ Aug 2008
21. XVIII Brazilian Meeting of Ophthalmology, Blindness Prevention and Visual Rehabilitation, Florianópolis, Santa Catarina, Brazil Sep 2008
22. University of California, San Francisco, Ophthalmology Grand Rounds, San Francisco, CA Sep 2008
23. 26th Annual ASRS Meeting, Survivor Retina, Maui, Hawaii Oct 2008
24. 68th Annual Convention and Scientific Sessions American College of Osteopathic Internists (ACOI*), A Case Study in Medical Innovation: Bioelectronics in Ophthalmology*, San Marcos Island, FL Oct 2008
25. American Academy of Ophthalmology Annual Meeting, *Artificial Retina*, Atlanta GA Nov 2008
26. Duke Institute for Brain Sciences, *Artificial Retina*, Duke University, Durham, NC Dec 2008
27. Hawaiian Eye 2009, Artificial Retina, Wailea, Maui, HI Jan 2009
28. Institutes of Ophthalmology Retina Meeting, *Advances in Surgical Instrumentation and Diagnostic Instrumentation*, Cairo, Egypt Jan 2009
29. Illuminating the Genetic Architecture of Common Eye Disease, *Bioengineering in Ophthalmology*, Avalon, CA Feb 2009
30. AIMBE's 2009 Annual Event, *Translating Medical and Biological Engineering: Bringing Technologies to Life*, Washington, D.C. Feb 2009
31. 37th Annual Aspen Retinal Detachment Society Meeting, *Artificial Retina*, Snowmass, CO Mar 2009
32. Genetech, EyeQ Lecture Series, San Francisco, CA April 2009
33. The Association for Research in Vision and Ophthalmology, *Preliminary Results from Argus® II Feasibility Study: A 60 Electrode Epiretinal Prosthesis*, Ft. Lauderdale, FL May 2009
34. The American Ophthalmological Society, Advanced Imaging in Ophthalmology, Half Moon Bay, CA May 2009
35. Doheny Days, 40th Annual Doheny Days Conference, Los Angeles, CA June 2009
36. SRC Board of Directors' Retreat, The Science and Engineering of Artificial Sight, Palm Springs, CA July 2009
37. 12th Annual Club Vit Meeting Salt Lake City, Utah July 2009

38. 31st Annual Int'l Conference of IEEE Engineering in Medicine and Biology Society, *Engineering the Future of Biomedicine*, Minneapolis, MN Sep. 2009
39. Retina Congress 2009: A Combined Meeting of the American Society of Retina Specialists- The Macula Society and The Retina Society Sep. 2009 New York, NY
40. Italian Artificial Vision Society, *The Science and Engineering of Artificial Sight*, University for Foreigners of Siena, Aula Magna, Italy Oct. 2009
41. American Academy of Ophthalmology, *Translational Research Can Create New Therapeutic Modalities for Challenging Ocular Diseases*, San Francisco, CA Oct. 2009
42. Lions Eye Institute for Transplant and Research, *The Science and Engineering of Artificial Sight*, Orlando, FL Oct. 2009
43. University of California Davis, *The Science and Engineering of Artificial Sight*, Sacramento, CA Dec. 2009
44. USC Emeriti Center College Speaker, The Distinguished Speakers Series, Irvine, CA Jan. 2010
45. Arnold and Mabel Beckman Initiative on Macular Research, Irvine, CA Jan. 2010
46. The University of Utah, *The Science and Engineering of Artificial Sight*, Salt Lake City, UT Feb. 2010
47. Vail Vitrectomy 2010, *The Science and Engineering of Artificial Sight*, Vail, CO Mar. 2010
48. ASCRS / ASOA Symposium and Congress Boston, MA Apr. 2010
49. Vollum Institute Oregon Health & Science University, *The Science and Engineering of Artificial Sight*, Portland, OR Apr. 2010
50. 2010 ARVO Annual Meeting, *Interim Performance Results from the Second Sight Argus® II Retinal Prosthesis Study*, Fort Lauderdale, Florida May 2010
51. IEEE EMBS Forum, *Grand Challenges in Neuro-engineering*, Bethesda, MD May 2010
52. McGowan Institute Stem Cell meeting, *The Science and Engineering of Artificial Sight*, Pittsburgh, PA, May 2010
53. The World Ophthalmology Congress 2010, *The Science and Engineering of Artificial Sight*, Berlin, Germany Jun. 2010
54. 39th Annual Neural Interfaces Conference, *The Science and Engineering of Artificial Sight*, Long Beach, CA Jun. 2010
55. NEI Symposium - Translational Research and Vision, *Bioelectronic Devices for Ophthalmology; From Benchtop to the Clinic*, Bethesda, MD Jun. 2010
56. The Foundation for Retinal Research, 2010 LCA Family Conference, Philadelphia, PA Jul. 2010
57. ASRS 28th Annual Meeting Vancouver Convention Centre Vancouver, BC, Canada Aug. 2010
58. NAE Grand Challenges Summit*, Advancing the Grand Challenges of the National Academy of Engineers*, USC, Los Angeles, CA Oct 2010
59. IOM Annual Meeting The National Building Museum Washington DC, Oct 2010
60. Case Western Conference, 2010/2011 Neural Prosthesis Seminar Series, Cleveland, OH Oct 2010
61. American Academy Ophthalmology Annual Meeting, *The Science and Engineering of Artificial Sight*, Chicago, IL Oct 2010
62. Club Jules Gonin 2010, *The Science and Engineering of Artificial Sight*, The Westin Miyako, Kyoto, Japan Nov 2010

Awards and Honors

Mark Humayun

1. National Academies of Engineering 2011

2. National Academies of Medicine 2009
3. Alcon Research Institute Award, 2009
4. Retina Research Foundation Award of Merit, 2009
5. Foundation Fighting Blindness Visionary Award Honoree, 2009
6. American Institute for Medical and Biological Engineering Fellow 2008
7. IEEE Sr Member 2010

James Weiland
1. IEEE Sr Member 2008

Lindy Yow
1. IEEE Sr Member 2011

Media
MS Humayun speaks on Capitol Hill.

DOE Supported Graduate Students
1. Aditi Ray Ph.D
2. Leanne Chan Ph.D
3. Brooke Basinger Ph.D
4. Kinon Chen Ph.D
5. John Xie MD, Ph. D
6. Adrian Rowley MD, Ph.D

Doheny Team Members

1.	Mark Humayun	Director, PI
2.	James Weiland	Co-PI
3.	Lindy Yow	Program Manager
4.	Gerald Chader	Faculty
5.	David Hinton	Faculty
6.	Biju Thomas	Assistant Faculty
7.	Rajat Agrawal	Assistant Faculty 2004 - 2010
8.	Lucien Laude	Visiting scholar 2005-2010
9.	Konstantin Kolev	Visiting scholar 2005-2010
10.	Atoosa Lotfi	Staff 2005-2010
11.	Xiaopeng Wang	Histopathology
12.	Rong Juan Wu	Histopathology
13.	Zhen Hai Chen	Tech
14.	Carlos Sanchez	Animal Technician
15.	Hossein Ameri	Post Doc 2007-2008
16.	Anderson Pinto	Post Doc 2008-2009
17.	Luis Arana	Post Doc 2009-2010
18.	Rodrigo Brant	Post Doc 2010-2011
19.	Saloomeh Saati	Post Doc 2006-2010

20. Jeffery Eng — Post Doc 2007-2008
21. Aditi Ray — Post Doc, Graduate student 2005-2010
22. Adrian Rowley — Graduate student 2004-2011
23. Brooke Basinger — Graduate student 2004-2009
24. Kinon Chen — Graduate Student 2007-2009
25. Tim Nayar — Graduate student 2006-2011 expected Fall Graduation
26. Alice Cho — Graduate Student 2006-2012 expected graduation 2012
27. Navya Davuluri — Graduate student 2008-2013
28. Leanne Chan — Graduate student 2004-2009
29. Mike Javaheri — MD/PhD Grad Student 2004-2008
30. John Xie — MD/PhD Grad Student 2004-2010
31. Shauna Higgins — Intern 2010-2011
32. Kelsey Ford — Intern 2010-2011
33. Alejandra Calle — Intern 2010-2011
34. Erick Bonilla — Administrative Support

Lawrence Livermore National Laboratory

Accomplishments & Presidential Milestones
200+

- FY'2007
  - Q1 – Built and evaluated mechanical models of 200+ system in animals
  - Q2 – Characterized thin film electrode array in in-vivo testing
  - Q3 – Developed and evaluated initial process modules for integration of subcomponents
  - Q4 – Tested and characterized an integrated 200+ system
- FY'2008
  - Q1 – Redesigned thin film electrode array and integration process modules based on A-60 clinical trails
  - Q2 – Completed fabrication and assembly of preclinical mechanical model for in-vivo characterization and testing.
  - Q3 – Finalized electronic subsystems and completed characterization and testing
  - Q4 – Began the fabrication and assembly of an active 200+ system
- FY'2009
  - Q1 – Built active electronics package for 200+ system
  - Q2 – Completed the fabrication and assembly of an active 200+ system
  - Q3 – Completed the functional characterization of the active 200+ system
  - Q4 – Fabricated and assembled an 200+ system for implantation and in-vivo characterization
- FY'2010
  - Q1 – Design verification of subsystems for preclinical 200+ system
  - Q2 – Completed the fabrication and assembly of two preclinical 200+ system
  - Q3 – Completed the in-vitro characterization of two preclinical 200+ system

- Q4 –Implantation of two preclinical 200+ systems

- FY'2011
  - Q1 – Redesign of 200+ electronics package based on new integrated electronics, begin technology transfer of 200+ to Second Sight Medical Products
  - Q2 – Fabrication and assembly of mechanical models for integrated electronics

Patents

1. Maghribi MN, Krulevitch PA, Wilson TS, Hamilton JK, Park C. *Serpentine and corduroy circuits to enhance the stretchability of a stretchable electronic device.* United States Patent 7,265,298 (10/826,477). Patent Issued: September 4, 2007
2. Maghribi MN, Krulevitch PA, Davidson JC, Wilson TS, Hamilton J, Benett WJ, Tovar AR. *Stretchable polymer-based electronic device.* United States Patent 7,337,012 (10/825,787). Patent Issued: February 26, 2008.
3. Krulevitch PA, Maghribi MN, Benett W, Hamilton JK, Rose K, Davidson JC, Strauch MS. *Electronic unit integrated into a flexible polymer body.* United States Patent 7,342,311 (11/326,967). Patent Issued: March 11, 2008.
4. Maghribi MN, Krulevitch P, Hamilton J. *Silicone metallization.* United States Patent 7,462,518 (11/586,271). Patent Issued: December 9, 2008.
5. Maghribi MN, Krulevitch PA, Wilson TS, Hamilton JK, Park C. *Serpentine and corduroy circuits to enhance the stretchability of a stretchable electronic device.* United States Patent 7,871,661 (11/827,612). Patent Issued: January 18, 2011.

Pending Patents:

1. Krulevitch, P, Polla DL, Maghribi MN, Hamilton J. *Flexible electrode array for artificial vision.* United States Patent Application 20030097166 (09/992248). Filed: November 16, 2001.
2. Maghribi MN, Krulevitch PA, Davidson JC, Hamilton JK. *Flexible multi-level cable.* United States Patent Application 20060042830 (10/926882). Filed: August 25, 2004
3. Provisional Filed – 04/19/2011 – Method of Fabricating Hermetic High-Density Electrical Feedthroughs
4. Provisional Filed – 05/16/2011 – Method of Fabricating High-Density Hermetic Feedthroughs using insulated wire bundles

Abstracts

See Group abstracts

Presentations

Artificial Retina: Restoring Sight to the Blind, Lawrence Livermore National Security Board of Governor's Meeting, 09/2010

Media

San Francisco Business Times – 04/05/2010

Lawrence Livermore Team Members

1. Satinderpall Pannu — Principal Investigator
2. Phillipe Tabada — Lead Engineer
3. Terri Delima — Lead Technician
4. Kedar Shah — Lead Packaging and Assembly Engineer
5. Angela Tooker — Lead Design and Fabrication Engineer
6. Heeral Sheth — Fabrication and Characterization Engineer
7. Vanessa Tolosa — Post-doctoral Researcher
8. Maxim Shusteff — Electrical Engineer
9. Emil Geiger — Post-doctoral Researcher
10. Courtney Davidson — Biomedical Engineer
11. Julie Hamilton — Fabrication Technician

Oak Ridge National Laboratory

Major Accomplishments:

- Constructed specialized experimental equipment that mimics electrode arrays in the eye
- Measured electric field potentials above a 60 electrode array and model 200+ electrode array
- Demonstrated the importance of opposite sense pulsing ("virtual electrodes") for enhancing information content of the field
- Measured first and second spatial derivatives as guide to effective information transfer and excitation of neural cells
- Contributed to an evaluation of safety and efficacy of Photosystem I proteoliposome subretinal injection in retinal degenerate rats

PENDING PATENTS:

1. Method for Treating Ischemic Diseases," Elias Greenbaum, Mark S. Humayun and Charlene A. Sanders, U. S. Patent draft application, UT-Battelle ID 1658/ QB920976.00041, prepared September 15, 2006, assigned to UT-Battelle, LLC.

BOOK CHAPTERS

1. E. Greenbaum and B. R. Evans, "Synthetic Chromophores and Neural Stimulation of the Visual System," in *Visual Prosthetics: Physiology, Bioengineering, Rehabilitation*, G. Dagnelie (Ed.) Springer (2011), pp. 193 – 206. ISBN 978-1-4419-0753-0.

PUBLISHED JOURNAL ARTICLES

1. C. P. Pennisi, E. Greenbaum and K. Yoshida, "Analysis of Light-Induced Transmembrane Ion Gradients and Membrane Potential in Photosystem I Proteoliposomes," *Biophys. Chem.* 146, 13-24 (2010).
2. M. Rodriguez, Jr. and E. Greenbaum, "Detection Limits for Real-Time Source Water Monitoring Using Indigenous Freshwater Microalgae," *Water Environ. Res.* 81, 2363-2371 (2009).

3. C. P. Pennisi, P. E. Jensen, V. Zachar, E. Greenbaum, and K. Yoshida, "Incorporation of Photosynthetic Reaction Centers in the Membrane of Human Cells: Toward a New Tool for Optical Control of Cell Activity," *Cell. Mol. Bioengin.* **2**(1), 156-165 (2009).
4. E. Greenbaum, M. S. Humayun, C. A. Sanders, D. Close, H. M. O'Neill, and B. R. Evans, "Metabolic Prosthesis for Oxygenation of Ischemic Tissue," *IEEE Trans. Biomed. Engin. 56, 528-531 (2009).*
5. C. P. Pennisi, E. Greenbaum and K. Yoshida, "Spatial Distribution of the Electric Potential from Photosystem I Reaction Centers in Lipid Vesicles," *IEEE Trans. Nanobiosci.* **7**, 164-171 (2008).
6. S. A. Eliza, I. Lee, S. K. Islam and E. Greenbaum, "Cantilever Embedded MOSFET Characteristics for Detection of Photosystem I Reaction Centers," *Sensors and Transducers Journal* 91, 24-30 (2008).

ABSTRACTS

See group abstracts

HONORS AND AWARDS

- E. Greenbaum was named 2010 ORNL/UT-Battelle, LLC Distinguished Inventor

OAK RIDGE NATIONAL LABORATORY TEAM MEMBERS

1. Barbara Evans, ORNL Staff Scientist
2. Charlene Sanders, ORNL Senior Laboratory Technologist
3. Christopher Wright, University of Delaware, SULI undergraduate intern
4. Laura Petrasky, Hope College, SULI undergraduate intern
5. Jeffrey Lowe, Michigan Technological University, SULI undergraduate intern
6. Nathan Poon, Texas A&M University, SULI undergraduate intern

Sandia National Laboratories

Major Accomplishments:

Micro-Machined Designs

- Micro Tools for high-density feed-through connections allow 200+ die pad to flex cable connections with 100 µm diameter at a 150 µm pitch.
- Dual-Sided IC for advanced packaging with active electronics. Potential for hermetic packaging with high density feed-throughs and integral electronics.

Implant Electronics

- Demultiplexer for the 200+ prototype. This custom ASIC extends the A60 electronics capability allowing 200+ electrodes from the 60 electrode basic design.
- Switching Supply for Demultiplexer. This design allows powering an external digital circuit via switching digital waveforms, eliminating corrosive dc voltages on cables.
- High Voltage transistors used with low voltage process, allows large voltage electrode driving circuits on Sandia processed ASICS including dual side IC designs.

High-Density Ceramic Feed-Throughs

- Developed custom plating processes, tanks and fixtures to fabricate high density Pt feed-throughs for ceramic substrates.
- Designed and utilized custom plating fixtures to optimize the chemistry and desired physical properties for high density hermetic feed-throughs using Pt.
- Designed and tested unique He leak detection fixture to measure flat substrates. This fixture eliminated many of the industry known problems related to low level leak detection.

Patents

Issued Patents:

#7,308,317 Micromachined Electrode Array, Wessendorf, Kurt O.; Okandan, Murat; 12/11/2007

Pending Applications:

#12/502,698 Demultiplexer Circuit for Neural Stimulation, Wessendorf, Kurt O.; Okandan, Murat; Pearson, Sean, 7/14/2009

Publications:

None

Sandia National Labs -ABQ Team Members:

1. Kurt Wessendorf (MTS) Principal Investigator
2. Murat Okandan (MTS) MEMS/Electronics Engineer
3. Sean Pearson (MTS) Electronics/ASIC Engineer
4. Dahwey Chu (MTS) Advanced Packaging Engineer
5. Adrian Casias (MTS) Chemical/Ceramics Engineer

Argonne National Laboratory

Major Accomplishments:

- Developed a novel giant-dielectric constant (up to ~ 1000) material for embedded microchip energy storage supercapacitor, based on a TiO_2/Al_2O_3 superlattice layered thin film structure grown on a large area 3-D large ridge array (this supercapacitor can be used for energy storage devices).
- Developed an Al_2O_3 (high electrical insulating layer)/ultranananocrystalline diamond (UNCD) (chemically robust layer resistant to eye saline chemical attach) layered bioinert/biocompatible hermetic coating for encapsulation of the artificial retina microchip to enable implantation inside the eye
- Initiated R&D focused on developmental biology approach to grow embryonic stem cells and induce differentiation into photoreceptors, as a far reaching biological approach for an artificial retina.

Approved Patents:

1. US Patent # 7,714, 405, "Layered Cu-based Electrode for High-Dielectric Constant Oxide Thin Film-Based Devices", O. Auciello, Issued May 11, 2010.
2. US Patent # 7,556,982, "A Method To Grow Pure Nanocrystalline Diamond Films at Low Temperatures and High Deposition Rates", J.A. Carlisle, D.M. Gruen, O. Auciello, and X. Xiao, Issued July 7, 2009.

Publications

Book Chapters

1. "Science and Technology of Bio-Inert Thin Films as Hermetic-Encapsulating Coatings for Implantable Biomedical Devices: Application to Implantable Microchip in the Eye for the Artificial Retina", O. Auciello and B. Shi, Ch 3 in "Implantable Neural Prostheses 2: Techniques and Engineering Approaches, Eds David D. Zhou and Elias Greenbaum. Springer (2010) p. 63.

2. "Microchip Embedded Capacitors for Implantable Neural Stimulators", O. Auciello, in "Implantable Neural Prostheses: Techniques and Engineering Approaches, Eds. David D. Zhou and Elias Greenbaum. Springer (2010) p. 331.

Published Journal Articles

See Group Articles

Invited Review Articles

1. "Status Review of the Science and Technology of Ultrananocrystalline Diamond (UNCD^{TM}) Films and Application to Multifunctional Devices", O. Auciello and A. V. Sumant, Diamond and Related Materials, **19** (2010) 699–718.
2. "Large Area Low Temperature Ultrananocrystalline Diamond (UNCD) Films and Integration with CMOS Devices for Monolithically Integrated Diamond MEMS/NEMS-CMOS Systems", A.V. Sumant, O. Auciello, H.-C. Yuan, Z. Ma, R.W. Carpick, and D.C. Mancini, Proc. SPIE, vol 7318 (2009) 17-1.

CONTRIBUTED ARTICLES

1. "Giant Dialectic Constant Dominated by Maxwell-Wagner Relaxation in Al_2O_3/TiO_2 Nanolaminates Synthesized by Atomic Layer Deposition," W. Li, O. Auciello, R.N. Premnath, and B. Kabius Appl. Phys. Lett. 96 **(**2010) 162907/1-3.
2. "Effect of Pretreatment Bias on the Nucleation and Growth Mechanisms of Ultra-nanocrystalline Diamond Films via Bias-Enhanced Nucleation and Growth: An Approach to Interfacial Chemistry Analysis via Chemical Bonding Mapping," X. Y. Zhong, Y. C. Chen, N. H. Tai, I. N. Lin, J. M. Hiller, O. Auciello, J. Appl. Phys. 105 (2009) 034311.
3. "Large Area Low Temperature Ultrananocrystalline Diamond (UNCD) Films and Integration with CMOS Devices for Monolithically Integrated Diamond MEMS/NEMS-CMOS Systems," A.V. Sumant, O. Auciello, H.-C. Yuan, Z. Ma, R.W. Carpick, and D.C. Mancini, Proc. SPIE, vol 7318 (2009) p. 7318171-7.

4. "Temperature Dependence of Mechanical Stiffness and Dissipation in Ultrananocrystalline Diamond," V.P. Adiga, A.V. Sumant, S. Suresh, C. Gudeman, O. Auciello, J.A. Carlisle, and R.W. Carpick, SPIE, vol 7318 (2009) p. 7318181-9.
5. "Fundamentals of Ultrananocrystalline Diamond (UNCD) Thin Films as Biomaterials for Developmental Biology: Embryonic Fibroblasts Growth on the Surface of (UNCD) Films," B. Shi, Q. Jinb, L. Chen and O. Auciello, Diamond and Related Materials**,** vol. 18 (2-3), (2009) 596-600.
6. "Synthesis and Characterization of Smooth Ultrananocrystalline Diamond Films via Low Pressure Bias-Enhanced Nucleation and Growth," Y. C. Chen, X. Y. Zhong, A. R.Konicek, D. S. Grierson, N. H. Tai, I. N. Lin, B. Kabius, J. M. Hiller, A. V. Sumant, R. W. Carpick, and O. Auciello, Appl. Phys. Lett. 92 (2008) 133113.
7. "Ultrananocrystalline Diamond Film as an Optimal Cell Interface for Biomedical Applications," P. Bajaj, D. Akin, A. Gupta, D. Sherman, B. Shi, O. Auciello, and R. Bashir, Biomedical Microdevices vol. 9 (No6) (2007), 787-794.
8. "Ultrananocrystalline Diamond Film as an Optimal Cell Interface for Biomedical Applications", P. Bajaj, D. Akin, A. Gupta, D. Sherman, B. Shi, O. Auciello, and R. Bashir, Biomedical Microdevices vol. 9 (No6) (2007), 787-794.

ABSTRACTS

See Group Abstracts

TALKS & PRESENTATIONS

1. January 26, 2011, King Abdullah University of Science and Technology (KAUST), Jeddah, Saudi Arabia, *Science and Technology of Multifunctional Ultrananocrystalline Diamond (UNCD) Films for Applications to a New Generation of Implantable Biomedical Devices*, (Keynote Lecture), O. Auciello, Winter Enrichment Program at KAUST,
2. October 2-3, 2010, Denver, CO, *Ultrananocrystalline Diamond (UNCD) Films for Biomedical Applications* (Keynote Talk), O. Auciello, B. Shi, Q. Jin, and L. Chen, MRS Workshop "Functionalized Nanobiomaterials for Medical Applications", Topic A: Functionalized Nanobiomaterials for Medical Applications.
3. September 2-3, 2010, Buenos aires, Argentina, "Science and Technology of Multifunctional Thin Films and Application to Multifunctional Devices from the Macro to the Nanoscale: A View to USA-Argentina Cooperation on Science and Technology," **(Invited talk)**, **O. Auciello**, US-Argentina Meeting for cooperation in Science and Technology, Buenos Aires,
4. August 30, 2010, Buenos Aires, Argentina, "Science and Technology of Multifunctional Thin Films and Application to Multifunctional Devices from the Macro to the Nanoscale," (**Invited Talk)**, **O. Auciello,** Instituto Nacional Tecnología Industrial.
5. May 16-20, 2010, Suzhou, China, "Science and Technology of Ultrananocrystalline Diamond Films for Application to Multifunctional Micro and Nanodevices," **(Keynote Talk), O. Auciello,** A. V. Sumant, S. Balachandran, C. Goldsmith, S. O'Brien, S. Sampath, A. Datta, C. Gudeman, J.A. Carlisle, D. C. Mancini, J. Swonger, D. Czaplewski, S. Balachandran, J.M. Hiller, B. Kabius, W. Li, B. Shi, Q. Jin, and L. Chen, The 4th International Conference on New Diamond and Nano Carbons.

6. August 24, 2010, Colorado Springs, "Science and Technology of Multifunctional Ultrananocrystalline Diamond (UNCD) for Implantable Biomedical Devices and as Platform for Developmental Biology," **(Invited University Talk)**, O. Auciello, University Colloquium, University of Colorado-Colorado Springs.
7. "Status of the Science and Technology of Ultrananocrystalline Diamond (UNCD) Films and Application to Multifunctional Devices from the Macro to the Nanoscale" **(Plenary Talk), O. Auciello,** A. V. Sumant, J.A. Carlisle, Y. C. Chen, X. Y. Zhong, B. Kabius, J. M. Hiller, N. H. Tai, I. N. Lin, A. R. Konicek, A.R. Krauss, D.M. Gruen, J. Libera, C. Goldsmith, D. Forehand, S. Sampath, A. Datta, C. Gudeman, J.A. D. C. Mancini, M. Burgener, J. Swonger, V. P. Adiga, R. W. Carpick, S. Pacheco, B. Shi, X. Xiao, R. Freda, J. Weiland, and M. Humayun, Q. Jin, L. Chen, M. P. Zach, D. B. Seley, D. A. Dissing, R. Divan, C. S. Miller, E. A. Terrell, L.E. Ocola, and D.M. Lopez, Diamond 2009, 20th Anniversary Conference, Athens, Greece, September 6-10, 2009.
8. July 14-17, 2009, La Plata, Buenos Aires, Argentina, "Fundamentals of Ultrananocrystalline Diamond (UNCD) Thin Films as Biomaterials for Developmental Biology: Embryonic Fibroblasts Growth on the Surface of (UNCD) Films" **(Plenary Lecture), O. Auciello**, B. Shi, Q. Jin, and L. Chen, Lecture at the "First Argentine School of Nanotechnology and Regenerative Medicine, Universidad Nacional de la Plata.
9. October 1-3, 2008, Washington DC, "Nanostructured Thin Films and MEMS/NEMS/Electronic Structures for Advanced Biomedical Devices and Biosensors", **O. Auciello**, B. Shi, L. Chen, Q. Jin, A.V. Sumant, D.C. Mancini Military Health Support Systems Conference: Providing Military Health Through Technology and Advancing Protocols.
10. December 1-6, 2008, Boston, MS, "Investigation on Hermetic Oxide Bioinert/Biocompatible Coatings for Implantable Microelectronic Devices", W. Li and **O. Auciello**, MRS Fall Meeting,
11. June 20, 2008, Chicago**,** Science and Technology of Multifunctional Ultrananocrystalline Diamond Thin Films and Applications to Novel Neural Prosthesis", **University Seminar**, **O. Auciello,** University of Chicago Brain Institute,
12. May 30, 2008, Cheng Kung, Taiwan, "Science and Technology of Multifunctional Ultrananocrystalline Diamond Thin Films and Applications to Multifunctional Devices", University Seminar, O. Auciello, Cheng Kung University.
13. May 26 -29, 2008, Taipei, Taiwan, "Fundamentals of Ultrananocrystalline Diamond (UNCD) Thin Films as Biomaterials for Developmental Biology: Embryonic Fibroblasts Growth on the Surface of (UNCD) Films", B. Shi, Q. Jin, and L. Chen, and O. Auciello, New Diamond and Nano Carbon Conference.
14. April 20, 2008, "Science and Technology of Multifunctional Ultrananocrystalline Diamond Thin Films and Applications to Biomedical Devices Devices", University Seminar, O. Auciello, University of Chicago Medical School, Department of Pathology.
15. November 5, 2007, Córdoba, Argentina, "Science and Technology of Multifunctional Ultrananocrystalline Diamond Thin Films and Applications to Multifunctioinal Devices", O. Auciello (Special University Lecture on Receiving 'Doctor Honoris Causa" at Universidad Nacional de Córdoba).
16. July 1-6, 2007, Singapore, "Fundamentals of Ultrananocrystalline Diamond (UNCD) Thin Films as Biomaterials for Implantable Medical Devices and Biosensors " (Plenary Talk), O. Auciello, B. Shi, Q. Jin, L Chen, and A.V. Sumant, ICMAT 2007, Symposium B - Developing Nano-bio Interfaces.

17. June 3-8, 2007, Hong Kong, China, "Study on the Cell Culture Cytotoxicity of Ultrananocrystalline Diamond (UNCD) Thin Films as Biomaterials for Implantable Medical Devices", (Invited Talk), O. Auciello, B. Shi, Q. Jin, L. Chen, and, Conference on Nanoscience and Nanotechnology for Biological/Biomedical/Chemical Sensing.
18. June 3-8, 2007, Hong Kong, China, "Science and Technology of Ultrananocrystalline Diamond Hermetic Bioinert Coating for Encapsulation of Implantable Artificial Retina Microchip and other Biodevices", (Invited Talk), O. Auciello, A.V. Sumant, and Bing Shi, Conference on Nanoscience and Nanotechnology for Biological/Biomedical/Chemical Sensing,

MEDIA

2010 Interviewed by Channel 7 TV and La Nación and Clarín Newspapers in Buenos Aires to discuss our research on nanotechnology at ANL, September 2, 2010.

2009 "Featured in "La Nación" (Largest circulation Newspaper in Argentina) for contribution in large team to research and development of artificial retina to restore sight to people blinded by retina degeneration", September 4, 2009.

2007 "Featured in National and Provincial (Córdoba) TV and Newspapers in Argentina for contribution in large team to research and development of artificial retina to restore sight to people blinded by retina degeneration", November 6, 2007.

Auciello Honors and Awards

1. **Named Argonne Distinguished Fellow of Argonne National Laboratory;** this is the laboratory's highest scientific and engineering rank, equivalent to an endowed chair at a top-ranked university, recognizing sustained outstanding scientific and engineering research and outstanding technical leadership of major, complex, high-priority projects.
2. **Elected Fellow of the Materials Research Society (November 2009),** for outstanding contributions to the science and technology of multifunctional thin films.
3. **Elected Fellow of the AAAS (October 2009),** for scientifically and socially distinguished efforts to advance materials science and its applications for the improvement of life.
4. **University of Chicago Distinguished Performance Award, June 24, 2008**.
5. **R&D 100 Award (R&D Magazine), July 17, 2008**, for development of UNCD film technology (this technology was introduced in the market in 2008 by ADT, the company founded by O. Auciello and J.A. Carlisle).
6. **"Doctor Honoris Causa"** title from the University of Córdoba, Argentina, November 5, 2007, This is a special honor since the University of Córdoba is my "Alma Matter", where I studied Electronic Engineering from 1964 to 1970, before going to study Physics at the "Balseiro Institute" (University of Cuyo-Argentina).

Educational

Presented exhibit on the work on the DOE funded artificial retina program at Argonne National Laboratory Open House on October 2010 (about 5,000 people visited the exhibit)

Argonne National Laboratories Team Members

1. Orlando Auciello Ph.D Argonne Distinguished Fellow Principal Investigator

2. Pablo Gurman MD (Argentina) Ph.D student, 2009-present
3. Wei Li Dr. Postdoc (2007-2010)

Los Alamos National Laboratory

Major Accomplishments

(drawn from quarterly reports, in approximate chronological order)

Develop and apply techniques for optical functional imaging of retinal tissue.

- Implement DSU confocal system on Olympus upright microscope, develop optical and neurophysiology setup based on an inverted microscope
- Optical imaging of electrical stimulation of retinal neurons
- Develop new analysis techniques for functional optical imaging (rolling difference technique)
- Video based stimulation of isolated retina
- New Imaging Capabilities: high performance CMOS imager, Adaptive optics, fundus camera, OCT

Develop and apply technology, analysis techniques for functional imaging, behavioral and psychophysical studies of human visual function.

- Anatomical imaging with 2T MRI system, ULF MRI system
- Preliminary work toward neural current MRI of retina
- Advances in implementation of ULF MRI and understanding of neural current imaging by MRI
- Bayesian method to characterize the neural responses of cortical visual areas in single passes, based on multi-modality integration of human functional neuroimaging data
- New neuroscience Experiments: modeling, imaging and electrophysiology; psychophysics: Rapid Serial Visual Presentation (RSVP) protocol
- Characterization of optimal masking in Speed of Sight Experiment
- Optimal masking in psychophysical experiments, Amoeba task, LED task, masking by local features
- Cognitive studies with 256 channel EEG
- Human Brain Mapping: Combined MEG, fMRI at ULF
- Neuroscience Experiments: two alternative forced choice, ROC analysis, masking model based on psychophysics experiments
- New Eyetracking capabilities
- Advanced magnets, gradient amp, dense sensor array for ULF fMRI
- Neuroscience Experiments: Perceptual consequences of synchronous firing, hyperacuity
- MEG/ULF-MRI strategies for functional imaging: Flow-based imaging, impedance tomography
- Multi-modality neuroimaging: fMRI retinotopic mapping with MEG single-pass dynamics

Undertake coupled experimental studies and computer simulation of the biophysical properties and information processing activities of neurons, networks, and tissue.

- Geometrical modeling of realistic neurons

- Computational Neuroscience: Modeling suggests a perceptual role of microsaccades and fixational eye movements via response synchronization
- Cortical circuit models for object segmentation.
- Lateral interactions in visual cortex: Computational studies of popout phenomena
- Learning of visual features by STDP
- Visual System Models for detection of Co-linearity and Co-circularity
- Perceptual consequences of eye movements, synchronous firing

Advanced concepts for device design, manufacturing, and stimulation protocols for prosthetic systems.

- Described a strategy for fabrication of a curved electrode array by Laser Chemical Vapor Deposition (LCVD)
- Successful deposition of Pt by LCVD
- Fabrication of Boron doped silicon fibers by LCVD.
- Lazzi, an NCSU student, and George have developed novel designs for a miniature/micro magnet stimulation device for neural tissue.
- Exploration of novel LANL technologies for coating, nanofabrication: Energetic Neutral Atom Beam Lithography and Epitaxy (ENABLE),
- Initial development and testing of hydrophobic, self-healing, self assembled perfluorocarbon coatings
- Characterize surface reorganization in perfluorocarbon coatings.
- Describe method to achieve improved stability in perfluorocarbon coatings.
- Proposed scheme for high density feed-thrus in a hermetic ceramic substrate
- New test articles for perfluorocarbon coatings
- Proposed scheme for capacitive sensors and stimulators
- Stimulation paradigms to maximize gradients and allow synchronous firing
- Impedance spectroscopy of hydrophobic coatings
- Strategies for Virtual Stimulating Electrodes

Develop proposals that extend or leverage scientific directions of the Artificial Retina project

- **LDRD-DR** project: Synthetic Cognition through Petascale models of Primary Visual Cortex.
- DARPA whitepaper on VLF MRI invited for full proposal
- Proposals for advanced technology and applications for Ultra-low field MRI.
- Submission of Vision related proposals for LDRD, DARPA, NIH
- High performance neural stimulation: NSF and LDRD projects, micro-magnetic stimulation.
- High performance neural stimulation: NSF and LDRD projects, micro-magnetic stimulation.
- Los Alamos et al response to the DARPA SyNAPSE program.
- *NSF Center for High-Performance Neural Computing* (Garrett Kenyon, PI) for the development of simulation tools, infrastructure and demonstration applications.
- NIH Challenge grant application: ULF-MRI, Neural Current Imaging
- LDRD-DR project: Probing Brain Dynamics by Ultra-Low Field Magnetic Resonance, (Michelle Espy and John George selected for funding, October 2009

PATENT DISCLOSURE

George, JS, Encoding Scheme and Architecture for a Densely Interconnected Array of Neuromorphic Processors.

Publications

BOOK CHAPTERS

1. George, JS. Casting Light on Neural Function: A Subjective History. Imaging the Brain with Optical Methods, Roe, AW, ed. Springer, NY, in press)
2. Rector DM, Yao XC, Harper RM, George, JS. In vivo Observations of Rapid Scattered Light Changes Associated with Neurophysiological Activity. In vivo Optical Imaging of Brain Function, Second Edition. Frostig R. Ed.

PUBLISHED JOURNAL ARTICLES

1. Perry, BH and JS George. *Dopaminergic modulation and rod contribution in the generation of oscillatory potentials in the tiger salamander retina*, Vision Research, 47(3):309-314 (2007)
2. Heller, L., Barrowes, B, George, JS. (2009) *Modeling Direct Effects of Neural Current on MRI*, Human Brain Mapping. 30(1): 1-12
3. Plis, SM; George, JS; Jun, SC; Pare-Blagoev, J.; Ranken, DM; Wood, CC; Schmidt, DM. *Modeling spatiotemporal covariance for MEG or EEG source analysis*. Physical Review E ((75)1):11928-1-1 (2007)
4. Plis S, George, JS, Jun SC, Ranken DM, Volegov PL, Schmidt DM, *Probabilistic Forward Model for EEG Source Analysis* Physics in Medicine and Biology. 52:5309-5327 (2007)
5. Jun, SC; George, JS; Kim,W, Pare-Blagoev, J, Plis, SM; Ranken, DM; Schmidt, DM; (2009) *Bayesian Brain Source imaging based on combined MEG/EEG and fMRI using MCMC*. Neuroimage 40(4): 1581-1594.

ABSTRACTS, TALKS & PRESENTATIONS

1. Yao XC., and J.S. George., Fast Optical Imaging of Neural Activation in Isolated Retina. OSA Biomedical Optics.
2. Xin-Cheng Yao, John S. George, Imaging Fast Intrinsic Optical Signals for Studies of Retinal Function. VSS
3. George JS, Yao XC, Lateral Interactions in Outer Retina Disclosed by High Resolution Dynamic Optical Imaging of Neural Activation (VSS, 2007)
4. George JS, Dynamic Functional Neuroimaging though Probabilistic Integration of Multiple Imaging Modalities, (Soc. Math. Psychology, 2007)
5. George, JS. Mapping Neuronal Current by Magnetic Resonance Imaging. (OHBM, 2008)
6. George, JS, Optical Imaging of Neuronal Dynamics in Retina, Santa Fe Institute, 2008
7. George, JS, Engineering a High Definition Electro-neural Interface, UAB, 2008
8. George, JS, Dynamic Imaging of Visual System Function from Retina to Brain, UAB, 2008
9. George, JS, Multi-modality studies of Dynamic Visual Processing, MIND Institute, 2008
10. Sahin-Owens, T, Yao, XC, George, JS, Dynamic Optical Imaging of Spatiotemporal Neural Activity in Retina. Turkish American Scientists and Scholars Association, Harvard 2008.
11. George, JS. Mapping Neuronal Current by Magnetic Resonance Imaging. HBM Symposium, 2008

12. Jun, SC, George, JS, Pare-Blagoev, J, Plis, S, Ranken, DM, Schmidt, DM. Bayesian Brain Source Imaging based on combined MEG/EEG and fMRI using MCMC. HBM, 2008.
13. George, JS, Engineering a High Definition Electro-neural Interface, Gwangju Institute , South Korea
14. George, JS, Dynamic Imaging of Visual System Function from Retina to Brain, Gwangju Institute , South Korea
15. JS George, GT Kenyon, MI Ham, IM Nemenman, LM Bettencourt, Modeling Consequences of Microscopic Eye Movements on Visual Spatial Perception (OHBM, 06/2009)
16. JS George, GT Kenyon, MI Ham, IM Nemenman, LM Bettencourt, Modeling Consequences of Microscopic Eye Movements on Visual Spatial Perception (Poster presentation, OHBM, 06/2009)
17. J. S. George, S. Barr, M. Ham, C. Renaudo, J. Hammond, V. Gintautas, S. Brumby, K. Sanbonmatsu, I. Nemenman, L. Bettencourt, G. Kenyon. Not so fast: optimized masks increase processing time for object detection on speed-of-sight tasks. Society for Neuroscience, 2009.
18. GT Kenyon, S Barr, M Ham, V Gintautas, C Rinaudo, I Nemenman, M Anghel, S Brumby, J George, L Bettencourt. *Top-down models explain key aspects of a Speed-of-Sight character recognition task.* Visual Sciences Society. 2010.
19. JS George, L Heller, P Volegov, B Travis, K Maskaly, M Flynn, T Owens, A Matlashov, R Kraus, M Espy *Direct measurement of neuronal current by MRI.* Biomag 2010
20. J George, M Ham, S Barr, V Gintautas, C Rinaudo, I Nemenman, M Anghel, S Brumby, G Kenyon, L Bettencourt. *Hiding in Plain Sight: Effective Masking in Speed of Sight Tasks.* Organization for Human Brain Mapping. 2010
21. J George, M Ham, S Barr, V Gintautas, C Rinaudo, A Guthormsen, M Anghel, P Loxley, S Brumby, G Kenyon, L Bettencourt. Visual object recognition and masking in speed-of-sight tasks. Society for Neuroscience. 2010

PROFESSIONAL ACTIVITIES

1. George and Kenyon serve as organizers: Grand Challenges in Neural Computation workshop held Feb 2008 in Santa Fe

2. George organized CNS Theme of Bioscience, Biosecurity, and Cognitive science capability review, Los Alamos, May, 2008. Projects on ULF MRI and Optical Imaging/Artificial Retina project were cited by the review committee as particularly outstanding.

3. A symposium on ***Neural Current Imaging by MRI***, organized by George and colleagues, was presented at the Organization for Human Brain Mapping in Melbourne Australia, 2009.

4. George served on External Advisory Board meeting of NIH NCRR Center for Integrative Biomedical Computing at the University of Utah 2008-2011
5. George served on the Review Panel for the NIH *Human Connectome Project*,

6. Project planning and program development: DOE Extreme Biology, DARPA initiative in novel neural interfaces: George chaired the working group on Tissue, Organ and Physiology modeling and authored the committee report

7. George participated in a DARPA scoping workshops on novel neural interfaces, neural prosthesis control

8. George and Kenyon serve as organizers: Grand Challenges in Neural Computation II: Neuromimetic Processing and Synthetic Cognition. Feb 2011 in Santa Fe

PH.D THESIS

Beth Perry: Electrophysiological characterization of oscillatory potentials in isolated amphibian retina

Los Alamos National Lab Team Members

1. John S. George
2. Tuba Sahin Owens
3. Garrett Kenyon
4. Bryan Travis
5. James Maxwell
6. Karlene Maskaly
7. Bryan Travis
8. Mark Hoffbauer
9. Petr Volegov
10. Jurgen Schmidt
11. Andrew Dattelbaum
12. Michael Ham

University of California, Santa Cruz

MAJOR ACCOMPLISHMENTS

2007-

Design and fabricate the 1Mbps Differential Phase Shift Key (DPSK) data telemetry IC
Develop data telemetry prototype system
Develop the power telemetry prototype system
Setup and test the dual-band power and data telemetry prototypes together

2008-

Design, fabricate, and test the high compliance voltage test chip of stimulator and digital controller with TSMC 0.18um high-voltage CMOS process
Design, fabricate, and test the new 2Mbps DPSK chip (at National Semiconductor 0.35um CMOS process) for data telemetry

Design and layout of the new 2Mbps DPSK chip (at TSMC 0.18um high-voltage CMOS process) for data telemetry

2009-
Design and layout of the integrated 256-channel high compliance voltage stimulator IC (Retina-8.0) using TSMC 0.18um high-voltage CMOS process
Fabricate Retina-8.0 at TSMC
Design the test board for Retina-8.0
Test and characterize Retina-8.0, including DPSK data receiver, digital controller, and stimulator pixel

2010-
Design, analysis, simulation, and layout of the on-chip multiple-voltage Timing-Controlled Rectifier (TCR) and regulator
Characterization and measurement of Argonne National Lab's capacitors
Assemble and demonstrate a system consisting of camera, power and data transmitters, dual-band coils, Retina-8.0, and LED display board
Develop and assemble a hardware-software co-design of 16-channel high-voltage stimulator with versatile waveforms, delivered to Oakridge National Lab (ORNL)

BOOK CHAPTERS:

1. M. Chae, Z. Yang, and W. Liu, "Microelectronics for recording, stimulation and wireless telemetry," Implantable Neural Prostheses: Part II. Techniques and Engineering Approaches, *Springer New York*, ISBN: 978-0-387-98119-2, pages 253-330, 2010.
2. Z. Yang, Y. Han, L. Hoang, Y. Lo, K. Chen, J. Lao, and W. Liu, "Wireless Power and Data Telemetry System for Implantable and Wearable Electronics," Wireless Body Area Networks: Technology, Implementation and Applications, *Pan Stanford Publishing,* 2010.
3. E. Basham, Z. Yang, N. Tchemodanov, and W. Liu, "In vitro systems for magnetic stimulation of neural tissue," book chapter in Implantable Neural Prostheses: Part I. Devices and Applications (Eds: E.Greenbaum and D. Zhou), *Springer New York*, ISSN: 1618-7210, pages 293-351, 2009.

JOURNAL ARTICLES:

1. W. Liu and Z. Yang, "Neural prosthetic devices and nanotechnology," Nanotechnology II: Global Prospects, 2011.
2. Z. Yang, Q. Zhao, and W. Liu, "Neural Signal Classification Using a Simplified Feature Set with Energy Based Non-parametric Clustering," **Neurocomputing**, Elsevier, Volume: 73, pages 412-422, Dec. 2009.
3. Z. Yang, Q. Zhao, and W. Liu, "Improving Spike Separation Using Waveform Derivative,"Journal of Neural Engineering (**JNE**), doi: 10.1088/1741-2560/6/4/046006, Aug. 2009.
4. M. Chae, W. Liu, M. Sivaprakasam "Design Optimization for Integrated Neural Recording Systems," IEEE J. Soild-State Circuits, vol. 43. no. 9, pp. 1931-1939, Sep. 2008.
5. M. Zhou, M. R. Yuce, W. Liu, "A Non-Coherent DPSK Data Receiver with Interference Cancellation for Dual-Band Transcutaneous Telemetries," IEEE Journal of Solid-State Circuits, Volume: 43, No. 9 Sep. 2008.

6. Z. Yang, W. Liu, E. Basham, "Inductor Modeling in Wireless Links for Implantable Electronics", IEEE transactions on Magnetics, Volume: 43, No. 10. Oct. 2007

Post Docs

1. Mohan Sivapraksam

PhD students

1. Eric Basham - 2010
2. Zhi Yang - 2010
3. Moo-Sung Chae
4. Jung Suk Kim
5. Hingcho Kim
6. Linh Hong
7. Kuan Fu Chen
8. Yi Kai Lo
9. Lewis Zheng
10. Jian Lao
11. Robert Kelbley

Undergraduate

1. Chuck Chan
2. Natalia Tchemodanov

Ph.D. Theses:

1. Eric J. Basham, Platform Development for In Vitro Study of Magnetically Induced Excitation of Neural Tissue, 2010.
2. Zhi Yang, Neural spike feature extraction and data classification, 2010.
3. Mingcui Zhou, Data telemetry with interference cancellation for retinal prosthesis, 2007.

MS Theses

1. Zhi Yang, Inductor modeling for biomedical telemetry, 2007.
2. Linh Hoang, Digital architecture for high resolution micro-simulator for retinal prosthesis, 2007.

Invention disclosures:

1. “Active circuits under pad (CUP) structure to reduce the implatable device size which needs the High Density Electrodes”, (with J. Kim, M. S. Chae, W. Liu) UCSC invention disclosure, July 2008
2. “Integrated high voltage stimulus driver with wireless power telemetry for biomedical applications”, (with J. Kim, M. S. Chae, W. Liu, M. Sivaprakasam) UCSC invention disclosure, Apr. 2008

News and Interviews:

1. Santa Cruz ***Good Times*** ran a cover story about innovative research at UCSC featuring electrical engineer Wentai Liu, Jan 5 2010

2. Science Today, “An artificial retina recognized for its innovation,” Oct. 05, 2009. http://www.ucop.edu/sciencetoday/article/22039
3. Science Today, “A microchip that restores eyesight to patients with degenerative diseases,” May 11, 2009. http://www.ucop.edu/sciencetoday/article/21137
4. Science Today, “A microchip developed to help restore vision to the blind,” Apr. 27, 2009. http://www.ucop.edu/sciencetoday/article/21041
5. Science Notes, “Engineering Vision,” Jan. 2009. http://sciencenotes.ucsc.edu/0901/pages/vision/vision.html
6. UC Santa Cruz News, “Microchip developed by UCSC engineer is helping restore vision to the blind,” June 24, 2008. http://news.ucsc.edu/2008/06/2301.html
7. UC Santa Cruz Review, “Engineering Hope: UCSC bioelectronics engineer designs prostheses that promise to change lives,” spring 2008. http://review.ucsc.edu/spring08/text.asp?pid=2069

Conference papers:

1. Z. Yang, Q. Zhao, E. Keefer and W. Liu, "Noise Characterization, Modeling, and Reduction for In Vivo Neural Recording," Advances in Neural Information Processing Systems (*NIPS 22*), pages 2160-2168, 2010.
2. W. Liu and Z. Yang, "Engineering Hope with Biomimetic Microelectronic Systems," invited paper (Plenary Lecture) to European Solid-State Circuit Conferences (ESSCIRC/ESSDERC), Sep., 2010.
3. Z. Yang, Q. Zhao and W. Liu, "Spike Feature Extraction Using Informative Samples," Spotlight presentation, Advances in Neural Information Processing Systems (*NIPS 21*), pages 1865-1872, 2009.
4. K. Chen and W. Liu, "Highly Programmable Digital Controller for High-Density Epi-Retinal Prosthesis,", International Conference of the IEEE Engineering in Medicine and Biology Society (*EMBS*), Sept. 2009.
5. B. Liang, Z. Yang, and W. Liu, "An ASK Demodulator for Data Telemetry in Biomedical Application," International Conference of the IEEE Engineering in Medicine and Biology Society (*EMBS*), pages 1561-1564, Sep. 2009.
6. Z. Yang, Q. Zhao, and W. Liu, "Energy Based Evolving Mean Shift Algorithm for Neural Spike Classification," International Conference of the IEEE Engineering in Medicine and Biology Society (*EMBS*), pages 966-969, Sep. 2009.
7. Q. Zhao, Z. Yang, H. Tao, and W. Liu, "Evolving Mean Shift with Adaptive Bandwidth: A Fast and Noise Robust Approach," Asian Conference on Computer Vision (*ACCV*, Oral Presentation, one of the two "Honorable Mentions"), Sep. 2009.
8. T. Chen, K. Chen, W. Liu, and L. Chen, " On-chip principal component analysis with a mean pre-estimation method for spike sorting," IEEE International Symposium on Circuits and Systems, Pages: 3110 - 3113, May 2009.
9. L. Wu, Z. Yang, E. Basham, and W. Liu, "An Efficient Wireless Power Link for High Voltage Retinal Implant," in Prof. IEEE Biomed. Circuits and Syst. Conf., pp.101-104, Nov. 2008
10. J. Kim, M. Chae, L. Wu, W. Liu, “A fully integrated DPSK demodulator for high density biomedical implants,” in Prof. IEEE Biomed. Circuits and Syst. Conf., pp. 93- 96, Nov. 2008.
11. M. Chae, J. Kim, W. Liu, "Fully-differential self-biased bio-potential amplifier," Electron. Lett., vol. 44, no. 24, pp. 1390-1391, Nov. 2008.

12. E. Basham, W. Liu, and Z. Yang, "Circuit for Generating Asymmetric Current Pulses for in Vitro Neural Magnetic Stimulation, " BMES Annual Fall Meeting, St. Louis, MO. Oct.2-4, 2008.
13. E. Basham, W. Liu, C. Baker, Z. Yang, and D. Parent, "Analyzing the Effect of Stimulus on Rhythmic Pattern Generation," BMES Annual Fall Meeting, St. Louis, MO. Oct.2-4, 2008.
14. J. Kim, M. Chae, M. Sivaprakasam, W. Liu, “An Integrated High Voltage Stimulator for High Density Neural Interfaces”, BMES Annual Fall Meeting, St. Louis, MO. Oct.2-4, 2008
15. Z. Yang, T. Chen, and W. Liu, "Neuron Signature Based Spike Feature Extraction Algorithm for On-Chip Implementation," International Conference of the IEEE Engineering in Medicine and Biology Society (*EMBS*), pages 1716-1719, Aug. 2008.
16. M. Chae, K. Chen, W. Liu, M. Sivaprakasam, J. Kim, "A 4-channel Wearable Wireless Neural Recording System,” Proceedings of the IEEE International Symposium on Circuits and Systems, May 2008, pp. 1760-1763.
17. M. Chae, W. Liu, Z. Yang, T. Chen, J. Kim, M. Sivaprakasam, and M. R. Yuce, "*A 128-channel 6mW Wireless Neural Recording IC with On-the-fly Spike Sorting and UWB Transmitter*," International Solid-State Circuits Conference (*ISSCC*), Pages: 146-147, Feb. 2008.

University of Utah

Major Accomplishments

- Computational and experimental determination of the electromagnetic fields induced in the human body by the wireless telemetry system;
- Computation of the electromagnetic fields induced in the human body by MRI fields;
- Optimization of the design of the external and internal telemetry coils, including proposed size reduction without affecting performance;
- Development of two alternative schemes and coils for back telemetry;
- Development of computational models and methods for the thermal analysis of the latest visual prosthesis by Second Sight;
- Developed computational models and methods to determine the effect of the position of the current return on the current flow in the tissue;
- Developed computational models and methods to determine the impact of electrode parameters on voltages and currents induced in the retina;
- Developed a novel technique to introduce a virtual electrode;
- Developed a novel multicoil system for increased wireless telemetry efficiency

Patents Filed:

1. M. Dickey, G. Lazzi, J. So, J. Thelen, A. Qusba, and G. Hayes, “Reversibly Deformable and Mechanically Tunable Fluidic Antennas,” Approx. filing date: 10/1/2010 (supported by Associated project)

Provisional Patents Filed:

1. C.J. Cela and G. Lazzi, “Virtual Electrodes,” Approx. filing date: 4/5/2011
2. Kumar and G. Lazzi, “Multicoil Telemetry System,” Approx. filing date: 2/1/2011 (supported by Associated Project)

Publications

BOOK CHAPTERS

1. C. J. Cela and G. Lazzi, “Retinal Cell Excitation Modeling,” in Visual Prosthetics, G. Dagnelie (Editor). Springer/AIP Press, New York, 2011
2. C. Furse, O.P. Gandhi, and G. Lazzi, “Linear Antennas,” in Modern Antenna Handbook, C. Balanis Editor, Wiley, 2007
3. M. Ghovanloo and G. Lazzi, “Transcutaneous Magnetic Coupling of Power and Data,” (invited paper) Wiley Encyclopedia of Biomedical Engineering, M. Akay Editor, Wiley (2007)

JOURNAL ARTICLES

1. C.J. Cela, R.C. Lee, and G. Lazzi. "Modeling Cellular Lysis in Skeletal Muscle due to Electric Shock," IEEE Transactions Biomedical Engineering, 2011 (Associated Project)
2. V. Singh, A. Ajeet, J. Ziriax, J. D’Andrea, G. Lazzi, “Computation of Induced Current Densities in the Human Body at Low Frequencies Due to Contact Electrodes using the ADI-FDTD Method,” IEEE Transactions on Electromagnetic Compatibility, Vol. 52, pp. 537-544, 2010 (Associated Project)
3. J. So, J. Thelen, A. Qusba, G.J. Hayes, G. Lazzi, M.D. Dickey, “Reversibly Deformable and Mechanically Tunable Fluidic Antennas,” Advanced Functional Materials, pp. 3632-3637, Nov. 2009 (Associated Project)
4. S. Soora, K.C. Gosalia, and G. Lazzi, “A Comparison of Two and Three Dimensional Dipole Antennas for a Retinal Prosthesis,” IEEE Transactions on Antennas and Propagation, Volume 56, Issue 3, pp: 622 – 629, March 2008

CONFERENCE PAPERS

1. K. Loizos, C. J. Cela, and G. Lazzi. “Activation of Sensory and Motor Peripheral Nerves due to Cutaneous Electrical Stimulation,” URSI National Radio Science Meeting. Boulder, CO, Jan. 2011
2. A.Rajagopalan, A.K.Ramrakhyani and G.Lazzi, “On using Metamaterials to increase power transfer efficiency in Telemetry Systems,” URSI National Radio Science Meeting. Boulder, CO, Jan. 2011
3. K. Ramrakhyani, S. Srinivas and G. Lazzi, “Wireless Power Transfer Efficiency Improvement using Multiple Coils,” URSI National Radio Science Meeting. Boulder, CO, Jan. 2011
4. G. Lazzi, “Advances in Shape-Shifting, Self-Healing, and Small Antennas and Applications,” (invited paper) 6th Annual Military Antennas, Washington, DC, Oct. 2010
5. J. Cela, R. C. Lee, G. Lazzi. “Modeling Electrical Injury In Skeletal Muscle Tissue.” IEEE International Symposium on Antennas and Propagation and URSI National Radio Science Meeting Toronto, Canada. July 2010
6. G. Hayes, M.R. Khan, J.-H. So, A. Qusba, G. Lazzi, M. Dickey. “The Application of Liquid Metal Alloys (EGaIn) To Reconfigurable Antennas,” IEEE International Symposium on Antennas and Propagation and URSI National Radio Science Meeting Toronto, Canada. July 2010

7. J. Cela and G. Lazzi. “On the Numerical Determination of Neural Activation in Retinal Surface due to Stimulation with Corneal Electrodes.” URSI National Radio Science Meeting. Boulder, CO. January 2010
8. G. Hayes, J.-H. So, A. Qusba, G. Lazzi, M. Dickey. “Characterization of a Liquid Metal Alloy (EGaIn) Losses in RF Coil and Microstrip Patch Antenna Configurations.” URSI National Radio Science Meeting. Boulder, CO. January 2010
9. G. Lazzi, “Progress in Computational and Experimental Bioelectromagnetics for a Retinal Prosthesis,” ICEAA 2009 (Invited Session Organizer and Invited Speaker), Sept. 2009
10. G. J. Hayes, A. Qusba, J. L. Thelen, M. D. Dickey, G. Lazzi, “Characterization of a Liquid Metal Alloy (EGaIn) Dipole Antenna,” IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting. Charleston, SC. June 2009
11. Qusba, V. Singh and G. Lazzi, “On the Design and Electromagnetic Safety Assessment of Telemetry Coils for a Retinal Prosthesis”, IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting. Charleston, SC. June 2009
12. J. Cela and G. Lazzi, “Numerical Prediction of Neural Activation In Electrically Stimulated Retina,” (Invited Presentation) 13th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM)/URSI. Banff, AB, Canada. February 2009.
13. Qusba, V. Singh and G. Lazzi, “Design of Telemetry coils for a Retinal Prosthesis”, URSI General Assembly, Chicago, 2008.
14. J. Cela and G. Lazzi. On the Intraocular Impedance of an Epiretinal Electrode Array. URSI General Assembly, Chicago, IL. August 2008.
15. G. Lazzi, A. Qusba, and V. Singh, “On the design of telemetry coils and implantable small antennas for a retinal prosthesis to restore partial vision to the blind,” 2008 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, San Diego, CA, July 2008
16. S. Srinivas, J. George, and G. Lazzi, “Finite Difference formulation to calculate the induced current density profile inside the retina by a microcoil array,” 2008 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, San Diego, CA, July 2008
17. V. Singh, A. Ajeet, and G. Lazzi, “Computation of induced fields in the human torso at low frequencies due to contact electrodes using the ADI-FDTD method,” 2008 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, San Diego, CA, July 2008
18. S. Jasti, V. Singh, and G. Lazzi, “On the modeling of the electromagnetic fields induced by MRI fields in patients with a retinal implant,” 2008 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, San Diego, CA, July 2008
19. Qusba, V. Singh, and G. Lazzi, “On the Design of Inductively Coupled Telemetry Coils for a Retinal Prosthesis,” 2008 URSI National Symposium, Boulder, CO, Jan. 2008
20. S. Srinivas, J.S. George, and G. Lazzi, “Micromagnetic Stimulation of the Retina: Numerical Solution and Preliminary Results,” 2008 URSI National Symposium, Boulder, CO, Jan. 2008
21. V. Singh, A. Roy, R. Castro, K. McClure, R. Greenberg, J. Weiland, M. Humayun, G. Lazzi, “SAR in the Human Body by a Wireless Telemetry System for a Retinal Prosthesis,” 2007 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, Honolulu, Hawaii, June 2007

22. S. Jasti, V. Singh, G. Lazzi, “On the Modeling of the Electromagnetic Fields Induced by MRI Fields in Patients with a Retinal Implant,” 2007 IEEE Antennas and Propagation International Symposium and URSI North American Radio Science Meeting, Honolulu, Hawaii, June 2007
23. V. Singh, A. Qusba, G. Lazzi, “Modeling of Telemetry Systems and Electromagnetic/Thermal Effects of a Retinal Prosthesis to Restore Vision to the Blind,” URSI - CNC/USNC North American Radio Science Meeting, Ottawa, ON, Canada, July 2007
24. V. Singh, A. Ajeet, G. Lazzi, “The Use of the D-H ADI-FDTD Method for Low Frequency Contact Currents and Bioelectromagnetic Interactions,” URSI - CNC/USNC North American Radio Science Meeting, Ottawa, ON, Canada, July 2007
25. Cela, G. Lazzi, “On the modeling of Current Induced in the Retina due to High Density Implantable Electrode Arrays,” URSI - CNC/USNC North American Radio Science Meeting, Ottawa, ON, Canada, July 2007
26. S. Srinivas, G. Lazzi, “Modeling of Micromagnetic Stimulation of Retina: Analytical and Numerical Solutions,” URSI - CNC/USNC North American Radio Science Meeting, Ottawa, ON, Canada, July 2007

Media

1. Interview on Italian National Radio (RAI), program “Hello Italia,” 4/26/2011
2. Featured guest of “Radio in Vivo” radio show, Apr.4, 2007, WCOM-FM 103.5, Carrboro, NC
3. Research on Liquid antennas featured in 2009-2010 in Forbes magazine, Signal magazine, EE Times, and many others

Lazzi Honors and Awards

1. ALCOA Foundation Distinguished Engineering Research Achievement Award, NCSU (2009)
2. IEEE Fellow, for “Contributions to Bioelectromagnetics and Implantable Devices” (2008)
3. IEEE GLOBECOM 2008 Best Paper Award (2008)
4. Editorial Board Member, Proceedings of the IEEE, 2011-2013
5. Member of the Selection Committee, IEEE Sensors Council “Technical Achievement Award,” 2010
6. IEEE Sensors Council, IEEE Fellow Evaluation Committee, 2009 - Present
7. Editor-in-Chief, IEEE Antennas and Wireless Propagation Letters, 2008-Present
8. Technical Program Committee Chair, IEEE Antennas and Propagation Int. Symposium, Charleston, SC, 2009
9. Member-at-Large, US National Committee of the National Academies for the International Union of Radio Science (USNC-URSI), 2009-Present
10. Chair (2006-2008), Commission K, US National Committee of the National Academies for the International Union of Radio Science
11. IEEE H.A. Wheeler Award for the best paper published in IEEE Trans. on Antennas and Prop. in 2005 (2006)

- 7 PhD students
- 4 MS students

that resulted in

- 5 PhD graduates
- 3 MS graduates

PhD Graduates

1. Carlos Cela (2010)
2. Vinit Singh (2008)
3. Ajit Rajagopalan (2008)

University of Utah Team Members

1. Gianlucca Lazzi PhD
2. Sundar Srinivas, PhD (completed)
3. Amit Qusba, Grad student PhD
4. Anil Kumar, Grad student PhD
5. Nitin Kwatra, MS (completed)
6. Saam Yasseri, Grad Student MS
7. Ajeet Ajeet, MS (completed)
8. Gaurav Gupta, PhD (completed)
9. Randall Barlow, MS (completed)
10. Srinivas Jasti, MS (completed)
11. Carlos Cela, PhD (completed)
12. Vinit Singh, PhD (completed)
13. Ajit Rajagopalan, PhD (completed)

Second Sight

Oct – Dec 2007

- SSMP assembled first ceramic stack substrates with discrete components to facilitate a mechanical mock-up of the internal electronics layout by LLNL.
- SSMP procured and provided a thermo-forming jig for LLNL.
- SSMP provided design feedback on the 200+ array design.
- SSMP integrated demux control feature into A60Lp design spec

Jan – Mar 2008

- SSMP continued to test DEI Pt metalized silicone arrays, including new arrays, and more open loops were detected.
- SSMP built 3 mechanical models for pre-clinical evaluation.
- SSMP assisted LLNL in evaluation of hermeticity of their ceramic substrates and means of interconnection to the package.
- SSMP attended the design review of the 256 chip, and offered feedback on the design and further details on the RF coil configuration and performance.

April – June 2008

- SSMP continued to test DEI Pt metalized silicone arrays, including new arrays. Some

failures occurred.
- The electronics stacks of three 200+ implants were assembled by SSMP this quarter according to the design developed by LLNL and Second Sight using the Second Sight A60 chip, associated daughter board and discrete components, and the SNL demux chip.
- SSMP conducted integration testing of the 200+ electronics stacks, with positive results.

July – Sept 2008
- SSMP continued to test DEI Pt metalized silicone arrays, including new arrays. Some failures occurred.
- New shorting issues were discovered in the functional 200+ assemblies.

Oct – Dec 2008:
- SSMP continued to test DEI Pt metalized silicone arrays, and new samples received for testing were fixtured.
- SSMP continued to provide components and assembly resources to LLNL as required.
- SSMP continued to provide components, design inputs of demux chips and engineering support to SNL as required.

Jan – March 2009
- Completed the final assembly of six 200+ electrode arrays. The 200+ polyimide flex circuit, front and back silicone flanges were provided by LLNL. These components were manually assembled using fixtures designed to result in an array radius of curvature of less than 12mm in order to provide suitability for pre-clinical in vivo testing.
- One 200+ implant was completed and electrically tested.

April - June 2009
- SSMP continued to test DEI Pt metalized silicone arrays, and new samples received for testing were fixtured.
- SSMP continued to provide components and assembly resources to LLNL as required, as well as resources for characterization and trouble-shooting of the integrated 200+ device.

July – Sept 2009
- SSMP continued to test DEI Pt metalized silicone arrays, including new samples received for testing during the quarter.
- SSMP continued to provide components and assembly resources to LLNL as required, as well as resources for characterization and trouble-shooting of the integrated 200+ device.

Oct – Dec 2009
- Tested ALD alumina chip coating samples from Argonne.
- Tested Doheny Pt metalized silicone arrays.
- Tested PDMS array samples from LLNL.
- Preliminary evaluation of through-silicon via samples provided by Sandia.
- Provided components and assembly resources to LLNL.
- Provided resources for characterization and trouble-shooting of the integrated 200+ device

Jan – Mar 2010

- Built six A60 modified implants for implantation in dogs.
- SSMP continued testing DEI silicone arrays through March 2, when testing was discontinued.
- SSMP continued to test PDMS array samples from LLNL.
- SSMP continued to work with LLNL to assemble and test 200+ units. One unit was completed, packaged and sterilized.
- SSMP continued passive soak testing of one 200+ implant.

April – June 2010

- Continued to test PDMS array samples from LLNL.
- Continued to work with LLNL to assemble and test 200+ units.
- Continued passive soak testing of one 200+ implant. The device remained viable for 2 years accelerated life (26 weeks at 57°C), but then seemed to have failed. Troubleshooting efforts were initiated.
- SSMP, Sandia, and LLNL tested the new SSMP -006 chip with the new demux chip, and the chips worked correctly together. This resolved the reset problems encountered in earlier version parts.
- SSMP evaluated new LLNL via substrates for hermeticity, both as received and after the heat cycle. Four of five substrates showed no detectable helium leak in all three tests.

July – Sept 2010

- SSMP continued to test PDMS array samples from LLNL.
- Two 200+ devices were built, tested and successfully implanted in animals.
- SSMP continued passive soak testing of one 200+ implant. The device remained viable for 2 years accelerated life (26 weeks at 57° C), and was thought to have failed. Revision to the test system shows the device is still functioning at 4 years accelerated life.

Oct 2010 – May 2011

- SSMP continued to test PDMS array samples from LLNL.
- Test was carried out on the two 200+ devices that were implanted in animals during September 2010. One of the devices was still functional on April 27, 2011, with stable link and 230 working electrodes. The other device was only able to achieve RF link too briefly to get electrode measurements.
- SSMP continued passive soak testing of one 200+ implant. The device remains viable at 6 years accelerated life (555 days at 57° C).
- In collaboration with LLNL, four 200+ mechanical models were built for acute pre-clinical studies.

SECOND SIGHT ARGUS® II CLINICAL STUDY

- The Second Sight Argus ®II trial is the largest trial of a retinal prosthesis to date and the only FDA-approved IDE (Investigational Device Exemption) trial. Registered at http://clinicaltrials.gov/show/NCT00407602
- Cumulatively, Argus® II subjects have been implanted **73.4*** subject-years

- The results demonstrate that Argus® II (like Argus® I) can reliably withstand long-term implant with an acceptable safety profile
- Using the system, blind subjects are able to detect light and improve their performance on some visual tasks
- Subjects report using Argus® II in their daily lives, and efforts to develop a rehabilitation program have begun
- Second Sight received CE Mark approval for Argus® II in March 2011. With this approval the device can be sold within the 31-nation European Economic Area.
- Application for FDA market approval will be submitted in 2011

PATENTS

78 patents awarded

96 pending patents

Caltech

2007-2010 Project Terminated 9/2010
Major Accomplishments

- Conducted tests of the tuning algorithms involving *blind* subjects with retinal implants, using both binary (i.e., black/white) and grayscale stimulation patterns.
- Devised and constructed prototype of a Tactile Feedback Device (TFD) to communicate to (blind) subjects for 4x4 and 6x10 arrays.
- Developed software package that supports tests of the Artificial Retinal Implant Vision Simulator (ARIVS) with actual retinal implant carriers by interfacing with the VPU via its NTSC port
- Matlab/Ethernet interface between ARIVS/STIMÖL and Clinical Fitting System/VPU.
- Successful transmission of electric stimulation patterns from STIMÖL to the SSMP VPU via SSMP PTS and SSMP CFS.
- Apple iPhone Implementation of Portable Real-Time Image Processing System ARIVS: Next Generation VPU for Independent User Mobility.

Patents

See group patent

Caltech Team Members

Wolfgang Fink, Ph.D.	Principal Investigator
Mark Tarbell, M.S.	Software Architect, Millennium

5. Commercialization Possibilities

For the first time ever, a device able to capture some sight for the blind has been authorized for marketing throughout Europe. After three years of tests with thirty patients in several centers in the United States, Mexico and Europe, Second Sight Medical Products' Argus® II has demonstrated its reliability, security and above all its capacity to restore the sight of most forms to the people, who are blind due to retinitis pigmentosa.

Some patients, such as the National Medical Centre of Ophthalmology (CNHO) Hospital des Quinze-vingt, Paris, arriving even read very large print. “It’s something unique in twenty-five year career,” says Professor José-Alain Sahel, Director of the Institute’s vision for the Three Hundred, who participated in the validation of this system very high technology.

The artificial retina can now be implanted University Hospitals of Geneva, Switzerland, the UK Royal Eye Hospital, Manchester, and Moorfields Eye in London and in France, CNHO. “We will begin to equip persons able to receive the Argus® II once it is paid by Social Security, said José-Alain Sahel. In Germany, the repayment of such devices is already authorized up to 85,000 euros. “

6. Detailed Description of Second Sight’s CRADA Assignments and Their Fulfillment

1. Second Sight will cross license, for research purposes, all licensed, issued, and pending patents that are required in order for the DOE consortium to pursue research in this field.

   Second Sight’s obligation to cross-license was met during negotiation of the CRADA. Article 33 of the CRADA permits the use of any party’s Background Intellectual Property by any other party solely in performance of research under the Statement of Work.

2. Second Sight will provide proprietary requirements and specifications for device and component technologies that have been developed according to FDA requirements for Design Control and which will allow incorporation of DOE technology into Second Sight’s retinal prosthesis.

   Second Sight has provided proprietary requirements and specifications that were necessary for ensuring that technologies developed by the partners could be used in Second Sight’s retinal prosthesis. Examples are:

   - *Second Sight provided substrate and chip layout dimensions to Sandia National Lab to allow the development of a 1-4 demultiplexer that would fit within the Second Sight implant package design and connect to the Second Sight ASIC.*
   - *Second Sight provided electrode array dimensions and specifications to allow fabrication of a 200+ electrode array that would integrate with the Second Sight package concept.*
   - *Second Sight provided details of the Argus® II implant packaging design to Lawrence Livermore National Lab, who extended the design to the 200+ electrode version.*

3. Second Sight will assign an engineer or scientist to act as the engineering liaison between each DOE lab and Second Sight. This liaison will be responsible for communicating all relevant information to the lab, formulating a project plan, assisting in each stage of the design control process, and monitoring progress.

   Second Sight assigned Jim Little, VP of Implant R&D, as liason with all the national labs. Specific engineer or scientist assignments have been made as well: Ronqing Dai has worked with Sandia and University of California, Santa Cruz; David Zhou and Brian Mech have worked with Argonne National Lab; Neil Talbot has worked with Lawrence Livermore National Lab, Kelly McClure has worked with Cal Tech, NC State University, and University of Utah. David Zhou has worked with Oak Ridge National Lab.

4. Second Sight will provide materials and technology testing services. These include electrochemical testing of microelectronic packages, electrode materials testing, and electrode array testing. Second Sight will provide mechanical and analytical testing services where

appropriate. Second Sight will also work in collaboration with Oak Ridge National Laboratory to utilize the special electrochemical testing technologies that they have developed for electrode testing.

Second Sight has assigned David Zhou, Chief Scientist, Electrochemistry, to provide materials and technology testing services. His lab has provided test results to Doheny Eye Institute, Argonne National Lab, Lawrence Livermore National Lab, and Oak Ridge National Lab. In addition, Dr. Zhou has been a frequent attendee at PI review meetings and has participated in the formative discussions at those meetings.

5. Second Sight will provide relevant information and results from ongoing internal R&D efforts as they pertain to DOE technology development.

   Second Sight has provided updates on internal R&D progress as well as Argus® II human clinical trial progress, both at periodic PI reviews and on biweekly PI conference calls.

6. Second Sight will provide the future results from ongoing pre-clinical (animal) and clinical (human) trials of its retinal implant.

   Second Sight has provided unlimited, almost continuous access to pre-clinical and clinical trials to Dr. Mark Humayun, the PI at Doheny Eye Institute. Presentations of status of the trials have been made to all the other PIs at PI reviews.

7. Second Sight will provide access to system or platform device architectures for integration of DOE technologies (e.g. Model 1, Model 2 systems).

   Second Sight has provided access to system architectures when required. An example is that Second Sight personnel provided interface documentation and worked with Cal Tech to integrate the Stimoel software with the Argus® II external system.

8. Second Sight will provide regulatory support in order to allow clinical testing of technologies developed by the DOE labs. This will include the preparation of required submissions to the FDA.

   Certain DOE technologies became part of the Argus® II system, and Second Sight regulatory support was provided to gain approval of the design changes. The 200+ channel device developed within the program did not reach the point of initiating a human clinical study.

9. Second Sight will make every commercially reasonable effort to incorporate DOE technology that is fully qualified and demonstrates a clear and economic benefit into a commercial product.

   Second Sight is now evaluating, and will continue to evaluate, DOE technologies for incorporation into a commercial product.

10. Second Sight will participate in review meetings such as the regularly scheduled PI reviews and ad hoc design and planning reviews.

    Second Sight provided at least one, and sometimes as many as eight science and engineering staff to participate in review meetings. Participating staff have included Robert Greenberg, Brian Mech, David Zhou, Jim Little, Neil Talbot, Kelly McClure, Matthew McMahon, and Rongqing Dai.

11. Second Sight will participate in regularly scheduled 'executive' planning conference calls to review project status and update planning.

    Robert Greenberg, President and CEO of Second Sight, has been the senior participant in the 'executive' planning calls, with the assistance of Brian Mech, VP of Business Development, and Jim Little, VP of Implant R&D.

12. Second Sight will, where applicable, assist in producing mechanical model and active implants for further pre-clinical and clinical testing.

    Second Sight has, in cooperation with Lawrence Livermore National Lab and Doheny Eye Institute, fabricated and tested mechanical models and active implants for pre-clinical testing. The 200+ channel device developed within the program did not reach the point of initiating a human clinical study.

Conclusions

The DOE-Second Sight CRADA accomplished the following:

- facilitated the efficient and expeditious development, transfer, and exploitation of Federally owned or originated technology to non-DOE entities for the public benefit and enhanced the accomplishment of DOE missions;
- leveraged DOE resources, through its programs and facilities, through partnering;
- ensured fairness of opportunity, protected the national security, promoted the economic interests of the United States, and provided a variety of means to respond to private sector concerns and interests about facility technology partnering activities.