REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	10/29/2004	Final Progress Report 8/1/01 - 7/31/04

4. TITLE AND SUBTITLE

Pulsed Power and Transient Plasmas: Basic Research With Application to Ignition, Emissions, and New Pulsed Power

5. FUNDING NUMBERS

DAAD19-01-1-0698

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

42713.1-PH

11. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12 a. DISTRIBUTION / AVAILABILITY STATEMENT	12 b. DISTRIBUTION CODE
Approved for public release; distribution unlimited.	

13. ABSTRACT (Maximum 200 words)

Scientific progress lies in three areas: Pulsed power, transient plasma ignition, and applications of pulsed power to biology. We report here 1) Progress in studies of SiC pulsed power JFET devices for applications to pulsed power, 2) Significant progress in the application of transient plasma to ignition, with results during the previous year in the ignition of pulse detonation engines, and 3) Significant progress in the study of the effects of nanosecond pulsed electric fields on biological cells, including visualization of intracellular calcium bursts and certain additional processes in Jurkat-T lymphocytes. During the next year we plan to develop advanced pulse generation devices for both biological applications and transient plasma ignition, and conduct further experiments in collaborations with several institutions.

14. SUBJECT TERMS	15. NUMBER OF PAGES
pulsed power, pulsed power applications, SiC JFET, plasma ignition, pulse detonation engine, bioelectrics	10
	16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION ON THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	**UNCLASSIFIED**	**UNCLASSIFIED**	**UL**

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. 239-18
298-102

Enclosure 1

Statement of the Problem Studied

Summary of proposed work, from original proposal: It is proposed to research topics with an optimal composition of technology, physics, and applications overlapping these areas to the extent possible. Pulsed Power is essentially a unifying enabling technology. Basic plasma research is necessary in not only pulsed power, but also in the pollution remediation and combustion-ignition areas. The application of fields to cells (and tumors) is enabled by new pulsed power technology, and is interdisciplinary with researchers in the life sciences, biology, medicine and biomedical engineering.

Summary of the Most Important Results

Scientific progress lies in three areas: Pulsed power, transient plasma ignition, and applications of pulsed power to biology. We report here 1) Significant progress in the application of transient plasma to ignition, and 2) Significant progress in the study of the effects of nanosecond pulsed electric fields on biological cells. The work in transient plasma ignition and bioelectrics is summarized each on a separate page.

These diverse areas lie within the study of pulsed power and its applications, and although very diverse, do fall within the scope of the original proposed work (summary reprinted below). The projects described have also received significant support from the AFOSR and the ONR.

Progress in SiC Pulsed Power Switch Research

Because of its larger bandgap energy and higher electron mobility in comparison with 6H-SiC, the SiC polytype 4H-SiC is a promising semiconductor material for applications to pulsed power technology. Pulsed power applications simultaneously require high blocking voltage, high peak current, fast turn-on, and low forward drop. However, poor oxide quality and oxide breakdown have thus far limited the performance of 4H-SiC MOSFETs, and the high breakdown field strength of SiC as high as ~3MV/cm has not been fully exploited. To address these issues, we have during the previous year initiated studies of the high dielectric materials TiO_2 and Al_2O_3 of Metal-Insulator-SiC (MIS) structures as possible gate dielectrics for SiC devices. TiO_2 and Al_2O_3 were chosen because of their high dielectric constants and bandgap energies as well as because of the acceptance of Ti and Al in most modern CMOS fabrication facilities. Nitridation technology has been widely used in Si device fabrication to improve the interface quality and prevent the formation of an interfacial layer of SiO_2 by annealing Si in a NO ambient. For comparison, we have applied this technology to the interface between the insulator and the SiC MIS structure. MIS capacitors (Fig.1) have been fabricated to evaluate whether TiO_2 and Al_2O_3 deposited by E-beam evaporation truly have potential as gate dielectrics in pulsed power SiC devices [1].

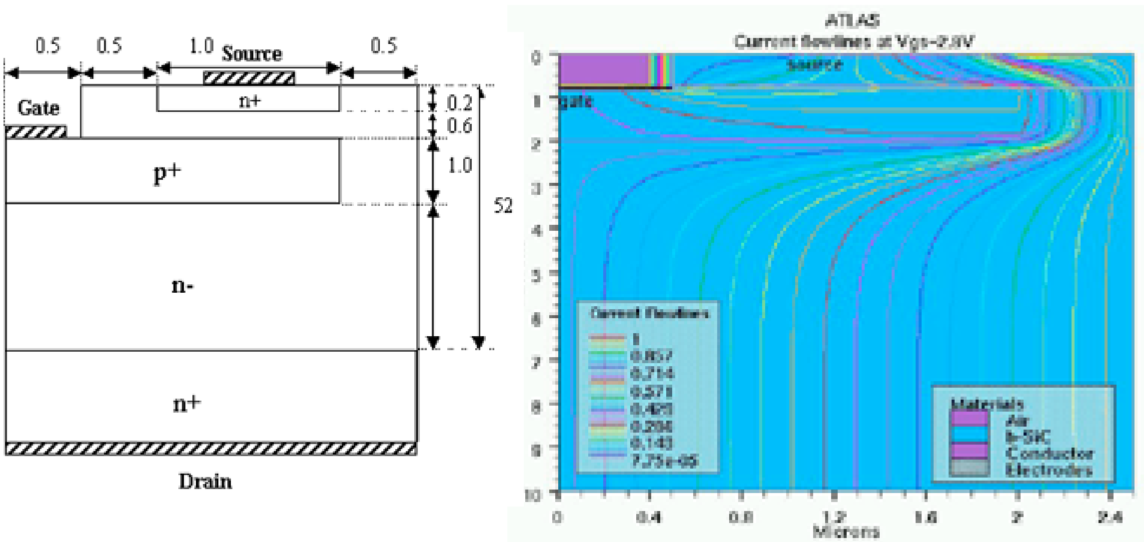


Fig. 1. Schematic of a half-cell of the 4H-SiC VJFET (Distances are in micrometers). Right: ATLAS simulation of current flow in gate region.

1) This work was reported at the IEEE 2004 Power Modulator Conference, San Francisco CA, May 23-26 2004. "Investigation of 4H-SiC MIS Capacitors with TiO_2 and Al_2O_3 as Gate Insulators," Qiong Shui, Michael S. Mazzola, Xianyue Gu, M.A. Gundersen, and Charles W. Myles.

Transient plasma ignition

Transient (true non-thermal, 30 to 100 nsec) plasma discharges have been investigated as a potential new method for flame and pulse detonation engine (PDE) ignition. Experimental results show that transient plasma discharge results in shorter ignition delay and pressure rise time (typically by a factor of 3 for CH_4/Air quiescent mixture, and even more for flowing pulse detonation engine ethane-air mixtures). Further benefits include higher maximum pressure indicative of improved efficiency. Pulse energies were typically 50 mJ to 1 J, demonstrating low energy required, comparable to traditional spark ignition. We conducted experiments in quiescent fuel air mixtures including methane, ethane, propane, butane and octane for various equivalence ratios.

We observed

- improved ignition with reduced delays and improved combustion efficiencies in various fuel-air mixtures,
- improved PDE ignition (through ONR support in studies at the NPS, with partial AFOSR support).

A diagram of experimental apparatus for quiescent studies is shown in Figure 2. Additional figures are included as an attachment (Appendix I). Reports have been presented at several technical meetings, and published in AIAA Proc. [2] (see also attached list of presentations and publications).

In all cases significant modification of initial combustion chemistry appears to be occurring, leading to more effective combustion over a wider range of parameters, such as pressure and fuel composition.

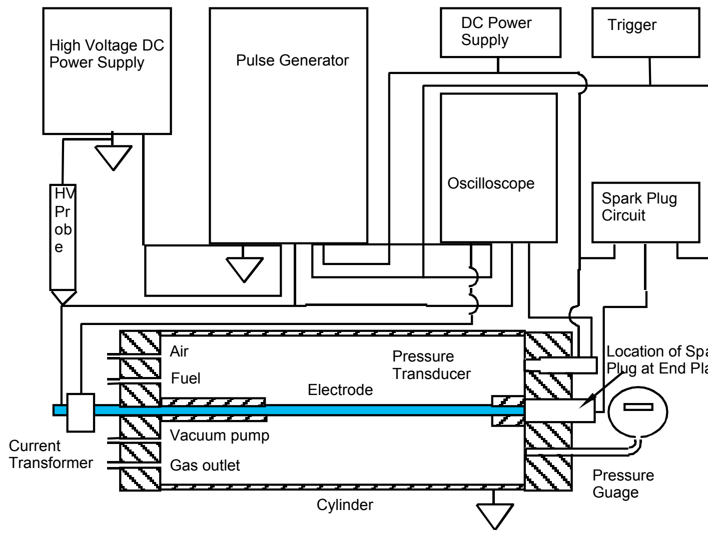
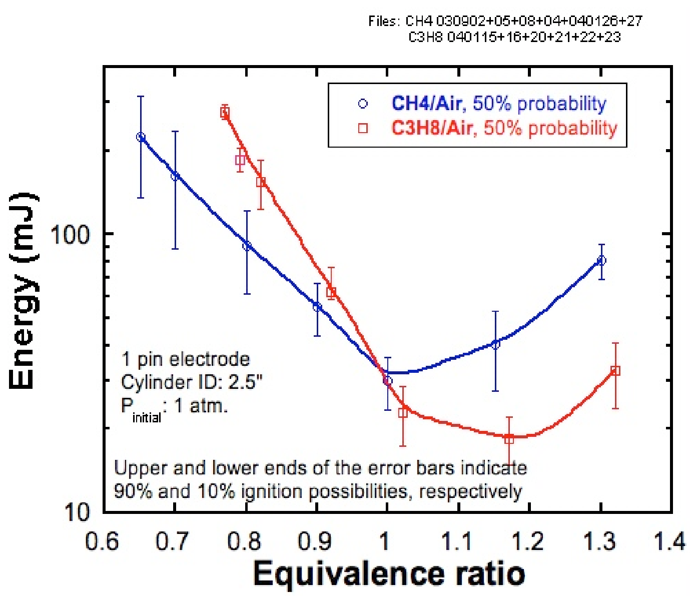


Figure 2. Apparatus for quiescent fuel mixture studies. Pulse generator employs either thyratron (100 nsec or longer pulses) or pseudospark (50 nsec pulses).

Based on studies of quiescent fuel mixtures at USC, off campus studies of pulse detonation engine (PDE) ignition at the Naval Postgraduate School (NPS), and initial studies of transient plasma enhanced radical production in collaboration with the U. Cincinnati, (UC) we conclude that transient plasma has strong potential for improved ignition, flameholding, and combustion enhancement.

Future work is planned to specifically delineate the production and effect of key species. Collaborations are planned that, if support is available, will address diagnosis, fuel mixing strategies, and theoretical support necessary to develop fundamental understanding and provide a pathway to implementation. This work also received support from the AFOSR (Dr. Julian Tishkoff) and the ONR (Dr. Gabriel D. Roy).



In Appendix I several slides which illustrate some of the experimental situations are presented. These include further detail of the quiescent and the PDE experimental arrangements, an example of typical data from quiescent studies. The difference between a transient plasma streamer array, and an arc, is shown graphically.

Figure 3. Plot showing minimum ignition energy for methane-air and propane-air mixtures, well under 100 mJ. This is indicative of the energy efficiency, and the low energy cost, implicit in this approach.

The transient plasma results suggest several future directions. This appears to be promising for a variety of ignition situations, and it would be valuable to explore further new applications. This is because data collected in quiescent and flowing mixtures shows substantial improvement in conditions for ignition (such as not requiring additional oxygen for a PDE, and reducing ignition delays in PDE to the point that substantially higher repetition rates may be envisaged). An improved understanding of the transient plasma physics, including contributions from theory, would be valuable in providing a basis for understanding.

2) J.B. Liu, P.D. Ronney, F. Wang, L.C. Lee, and M.A. Gundersen, "Transient Plasma Ignition For Lean Burn Applications," Proceedings of 2003 American Institute of Aeronautics and Astronautics, 41st Aerospace Sciences Meeting, Reno, Nevada, January 6-9, 2003, No. 2003-6208; See also J.B. Liu, P.D. Ronney, and M. Gundersen, "Premixed Flame Ignition by Transient Plasma Discharges," Proceedings of the Third Joint Meeting of the U.S. Sections of the Combustion Institute, Chicago, Illinois, March 16-19, 2003, Paper B-25 Several papers related to this work were presented at the 2004 AIAA Reno meeting, and are listed as an attachment.

Observation of Field Dependent Electroperturbation of Jurkat-T Lymphoblasts

The most important results during the past year which have been published or accepted for publication in refereed journals are in the area of "bio-nano-electrics", that is, in the study of the effects of intense electric fields applied for very short times to biological cells (typically Jurkat-T lymphoblasts, a human cancer cell). These results were primarily supported by funding from the AFOSR, and were supplemented with ARO support, partly because of the importance that we attach to this new research direction and the data that is emerging.

In Figure 4 is shown the effect of a 30 nsec, 2.5 MV/m (averaged over cuvette electrode separation) on a Jurkat cell (approx. 10 micron size). Evident in the upper right cell, after applying the nano-pulsed field, are intracellular elements, which are fluorescing due to Calcium release (probably from the endoplasmic reticulum). This demonstrates the penetration of the electric field into the interior of the cell, and that the field affects internal cell organelles.

We were able to observe real-time imaging of calcium bursts in human lymphocytes exposed to nanosecond, megavolt-per-meter pulsed electric fields. Ultra-short (less than 30 ns), high-field (greater than 1 MV/m), electric pulses induce increases in cytosolic calcium concentration and translocation of phosphatidylserine (PS) to the outer layer of the plasma membrane in Jurkat T lymphoblasts. Pulse-induced calcium bursts occur within milliseconds and PS externalization within minutes. Caspase activation and other indicators of apoptosis follow these initial symptoms of nanosecond pulse exposure. Pulse-induced PS translocation is observed even in the presence of caspase inhibitors. Ultra-short, high-field, electroperturbative pulse effects differ substantially from those associated with electroporation, where pulses of a few tens of kilovolts-per-meter lasting a few tens of microseconds open pores in the cytoplasmic membrane. Nanosecond pulsed electric fields, because their duration is less than the plasma membrane charging time, develop voltages across intracellular structures without porating the cell [3].

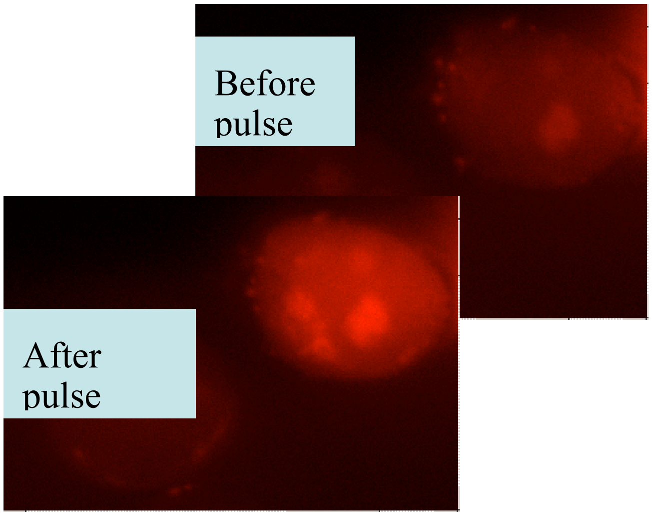


Figure 4. Observation of Ca^{2+} fluorescence with Rhod-2 dye following application of 2.5 MV/m electric field. 1 pulse at 0 seconds, then 4 pulses at 7 seconds.

3). P. T. Vernier, Y. Sun, L. Marcu, S. Salemi, C. M. Craft, and M. A. Gundersen, "Calcium bursts induced by nanosecond electric pulses", *Biochem. Biophys. Res. Commun.* 310:286–295, 2003.

Papers published in peer-reviewed journals:

M. Behrend, A. Kuthi, X. Gu, P.T. Vernier, L. Marcu, C.M. Craft and M. A. Gundersen, "Pulse Generators for Pulsed Electric Field Exposure of Biological Cells and Tissues," *IEEE Trans. Dielect. Ins.* 10:820-825, 2003.

P.T. Vernier, Y. Sun, L. Marcu, S. Salemi, C.M. Craft and M.A. Gundersen, "Calcium Bursts Induced by Nanosecond Electric Pulses," *Biochem. Biophys. Res. Commun.* 310:286-295, 2003.

Vernier, P. T., A. Li, L. Marcu, C. M. Craft, and M. A, Gundersen, "Ultrashort pulsed electric fields induce membrane phospholipid translocation and caspase activation: differential sensitivities of Jurkat T lymphoblasts and rat glioma C6 cells, IEEE Trans. Dielect. Elect. Ins. 10:795—809, 2003.

Vernier, P. T., M. Thu, L. Marcu, C. M. Craft, and M. A. Gundersen, Nanosecond electroperturbation -mammalian cell sensitivity and bacterial spore resistance, in press, *IEEE Trans. Plasma Sci.*, August 2004.

Vernier, P. T., Y. Sun, L. Marcu, C. M. Craft, and M. A. Gundersen, Nanoelectropulse-induced phosphatidylserine translocation, in press, *Biophys. J.* 86, 2004.

Gaudet, J. A., Barker, R.J., Buchenauer, C.J., Christodoulou, C., Dickens, J., Gundersen, M.A., Joshi, R.P., Krompholz, H.G., Kolb, J.F., Kuthi, A., Laroussi, M., Neuber, A., Nunnally, W., Schamiloglu, E., Schoenbach, K.H., Tyo, J.S., Vidmar, R.J., "Research issues in developing compact pulsed power for high peak power applications on mobile platforms," Proceedings of the IEEE, Vol. 92, Issue 7, July 2004, pp. 1144-1165.

Shamiloglu, E., Barker, R.J., Gundersen, M., and Neuber, A.A., "Modern Pulsed Power: Charlie Martin and Beyond," IEEE Proceedings, Volume 92, Issue 7, July 2004, pp. 1014-1020.

Vernier, P. T., Y. Sun, L. Marcu, C. M. Craft, and M.A. Gundersen, "Nanosecond Pulsed Electric Fields Perturb membrane Phospholipids in T Lymphoblasts," FEBS Letters, 572:103-108, 2004.

C. Jiang, A. Kuthi and M. A. Gundersen, "Small Pseudospark Switches," invited paper for inclusion in a special issue of IEEE Trans. Plasma Science.

F. Wang, J.B. Liu, J. Sinibaldi, C. Brophy, A. Kuthi, C. Jiang, P. Ronney and M. A. Gundersen, "Transient Plasma Ignition of Quiescent and Flowing Fuel Mixtures," invited paper for inclusion in a special issue of IEEE Trans. Plasma Science.

Papers published in non-peer-reviewed journals or in conference proceedings:

Kuthi, A., Liu, J., Ronney, P. D., and Gundersen, M. A., "Premixed Flame Ignition By Pulsed Corona Discharges," Western States Section, The Combustion Institute, 2002 Spring Meeting, March 25-26, 2002.

Gu, X., Myles, C. W., Kuthi, A., Shui, Q., and Gundersen, M. A., "Gallium Arsenide and Silicon FET-Type Switches for Repetitive Pulsed Power Applications," Conference Record of the Twenty-Fifth International Power Modulator Symposium and 2002 High Voltage Workshop, pp. 437-440.

Behrend, M., Kuthi, A., Vernier, P. T., Marcu, L., Craft, C., and Gundersen, M., "Micropulser for Real-Time Microscopy of Cell Electroperturbation," Conference Record of the Twenty-Fifth International Power Modulator Symposium and 2002 High Voltage Workshop, pp. 358-361.

Kuthi, A., Vernier, T., Gu, X., and Gundersen, M., :Compact Nanosecond Pulse Generator for Cell Electroperturbation Experiments," Conference Record of the Twenty-Fifth International Power Modulator Symposium and 2002 High Voltage Workshop, pp. 354-357.

M. Gundersen, P. T. Vernier, L. Marcu, A. Li, X. Zhu, A.Z. Ghalam, T. Katsouleas, C. Young, M. Behrend, and C. Craft, "Ultrashort Pulse Electroporation: Applications of High Pulsed Electric Fields to Induced Caspase Activation of Human Lymphocytes," Conference Record of the Twenty-Fifth International Power Modulator Symposium and 2002 High Voltage Workshop, pp. 667-670.

J.B. Liu, P.D. Ronney, F. Wang, L.C. Lee, and M.A. Gundersen, "Transient Plasma Ignition For Lean Burn Applications," Proceedings of 2003 American Institute of Aeronautics and Astronautics, 41st Aerospace Sciences Meeting, Reno, Nevada, January 6-9, 2003, No. 2003-6208.

J. B. Liu, N. Theiss, P. D. Ronney, and M. A. Gundersen, "Minimum ignition energies and burning rates of flames ignited by transient plasma discharges", 2003 meeting of Western States Section/Combustion Institute, UCLA, Oct 10-11, 2003, Paper 03F-88.

A. Kuthi, C. Young, F. Wang, P. Wijetunga and M. Gundersen, "Rapid Charger For High Repetition Rate Pulse Generator", 14th International Pulsed Power Conference, Dallas, TX, June 15-18, 2003, pp. 950-952.

A. Kuthi, B. Eccles, Q. Yao, C. Jiang, M. Gundersen and K. Frank, "Advanced Multi-Gap Pseudospark Switch," 14th International Pulsed Power Conference, Dallas, TX, June 15-18, 2003, pp. 946-949.

A. Kuthi, R. Alde and M. Gundersen, "Marx Generator Using Pseudospark Switches," 14th International Pulsed Power Conference, Dallas, TX, June 15-18, 2003, pp. 241-244.

X. Gu, Q. Shui, C. W. Myles and M. A. Gundersen, "Comparison of Silicon, Gallium Arsenide, Silicon Carbide and Gallium Nitride FET-type Switches for Pulsed Power Applications," 14th International Pulsed Power Conference, June 15-18, 2003, Dallas TX, pp. 362-365.

X. Gu, P. Wijetunga, A. Kuthi, M. Behrend, P.T. Vernier and M. Gundersen, "Nanosecond Rise Time Minipulser for Cell Electroperturbation," 14th International Pulsed Power Conference, June 15-18, 2003, Dallas TX, pp. 943-945.

Q. Shui, X. Gu, C.W. Myles, M. Mazzola, and M.A. Gundersen, "Simulations of a High Power 4H-SiC VJFET," 14th IEEE International Pulsed Power Conference, June 15-18, 2003, Dallas TX, pp. 123-126.

M. Gundersen, J. Dickens and W. Nunnally, "Compact, Portable Pulsed Power, Physics and Applications" 14th IEEE International Pulsed Power Conference, June 15-18, 2003, Dallas TX, pp.9-12.

J.B. Liu, F. Wang, L.C. Lee, P.D. Ronney, and M.A. Gundersen, "Effect of Fuel Type on Flame Ignition by Transient Plasma Discharges," Proceedings of 2004 American Institute of Aeronautics and Astronautics, 42nd Aerospace Sciences Meeting, Reno, NV, January 5-8, 2004, No. 2004-837.

J.B. Liu, F. Wang, L.C. Lee, N. Theiss, P.D. Ronney, and M.A. Gundersen, "Effect of Discharge Energy and Cavity Geometry on Flame Ignition by Transient Plasma," Proceedings of 2004 American Institute of Aeronautics and Astronautics, 42nd Aerospace Sciences Meeting, Reno, NV, January 5-8, 2004, No. 2004-1011.

F. Wang, C. Jiang, A. Kuthi and M. A. Gundersen C. Brophy and J. O. Sinibaldi, L. C. Lee, "Transient Plasma Ignition of Hydrocarbon-Air Mixtures in Pulse Detonation Engines", 42nd Aerospace Sciences Meeting, 6th Weakly Ionized Gases Workshop, Reno, Nevada 5 - 8 Jan 2004, No. 2004-834.

C. Jiang, A. Kuthi, B. Eccles, and M.A. Gundersen, "Small BLT Switches for Compact Pulsed Power Applications," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

C. Jiang, Q. Yao, B. Eccles, A. Kuthi, and M.A. Gundersen, "Pseudospark Discharge-Based Extreme-Ultraviolet Radiation Source," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

F. Wang, A. Kuthi, C. Jiang, Q. Zhou, and M.A. Gundersen, 'Flyback Resonant Charger for High Repetition Rate Pseudospark Pulse Generator," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

F. Wang, A. Kuthi, X. Wang, and M.A. Gundersen, "Compact High Repetition Rate Pseudospark Pulse Generator," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

Q. Shui, M.S. Mazzola, X. Gu, C.W. Myles, and M.A. Gundersen, "Investigation of Al_2O_3 and TiO_2 as Gate Insulators for 4H-SiC Pulsed Power Devices," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

X. Gu, Q. Shui, C. Jiang, Y. Sun, and M.A. Gundersen, "High Energy Density Ceramic Film Capacitors for Compact Pulsed Power," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

X. Gu, A. Kuthi, M. Behrend, P.T. Vernier, and M.A. Gundersen, "Compact Pulse Generator for Nanosecond Electroperturbation of Biological Cells," 26th IEEE International Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

A. Kuthi, P. Gabrielson, M. Behrend and M. Gundersen, "Nanosecond Pulse Generator Using a Fast Recovery Diode," 26th IEEE Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

A. Kuthi, M. Behrend, T. Vernier and M. Gundersen, "Bipolar Nanosecond Pulse Generation Using Transmission Lines for Cell Electromanipulation," 26th IEEE Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

A. Kuthi, P. Gabrielsson and M. Gundersen, "Feedback Stabilized Pseudospark Switch for Fast Rise Marx Generator Application," 26th IEEE Power Modulator Conference, San Francisco, CA, May 23-26, 2004.

P.T. Vernier, Y. Sun, L. Marcu, C.M. Craft, and M.A. Gundersen, "Nanosecond Pulsed Electric Fields Trigger Intracellular Signals in Human Lymphocytes," Nanotech 2004, Boston, MA, March 7-11, 2004, Technical Proceedings of the 2004 NSTI Nanotechnology Conference and Trade Show, Vol. 1, Ch. 1, pp. 7-10, 2004.

Y. Sun, P.T. Vernier, M. Behrend, L. Marcu, and M.A. Gundersen, "Microscope Slide Electrode Chamber for Nanosecond, Megavolt-Per-Meter Biological Investigations", Nanotech 2004, Boston, MA, March 7-11, 2004, Technical Proceedings of the 2004 NSTI Nanotechnology Conference and Trade Show, Vol. 1, Ch. 11, pp. 485-488.

P. T. Vernier, L. Marcu, Y. Sun, S. Salemi, C. M. Craft, and M. A. Gundersen, "Real-time imaging of mammalian cells in nanosecond, megawatt, millijoule pulsed electric fields", BiOS 2004 (SPIE), San Jose, Jan. 2004.

F. Wang, A. Kuthi, and M.A. Gundersen, "Technology for Transient Plasma Ignition," 17th ONR Propulsion Meeting, Cambridge, MA, June 16-18, 2004.

Papers presented at meetings, but not published in conference proceedings:

A. Kuthi, P. Gabrielson and M. Gundersen, "Marx Generator Using Dense Plasma Switches," 31st IEEE International Conference on Plasma Science, June 28-July 1, 2004, Baltimore, MD.

A. Kuthi and M. Gundersen, "Simple Model of Pseudospark discharge Initiation," 31st IEEE International Conference on Plasma Science, June 28-July 1, 2004, Baltimore, MD.

A. Kuthi, C. Jiang and M. Gundersen, "Plasma Generation with a Thin-wire Discharge for Use as Pseudospark Discharge Initiation," 31st IEEE International Conference on Plasma Science, June 28-July 1, 2004, Baltimore, MD.

F. Wang, J.B. Liu, J. Sinibaldi, C. Brophy, A. Kuthi, C. Jiang, P. Ronney and M. A. Gundersen, "Transient Plasma Ignition of Quiescent and Flowing Fuel Mixtures," 31st IEEE International Conference on Plasma Science, June 28-July 1, 2004, Baltimore, MD.

C. Jiang, L.C. Lee, F. Wang, and M. A. Gundersen, "Radical Kinetics Simulation for Transient Plasma Ignition for Fuel – Air Mixtures," 31st IEEE International Conference on Plasma Science, June 28 – July 1, 2004, Baltimore, MD.

C. Jiang, A. Kuthi and M. A. Gundersen, "Small Pseudospark Switches," 31st IEEE International Conference on Plasma Science, June 28 – July 1, 2004, Baltimore, MD.

Non-invasive intracellular electroperturbation of human lymphocytes," Vernier, P.T., Y. Sun, L. Marcu, S. Salemi, C. M. Craft, and M. A. Gundersen, "Workshop on High-Field Effects and Fast Pulse Responses in Bio-Systems, IEEE Conference on Electrical Insulation and Dielectric Phenomena, Albuquerque, 2003.

"Field-dependent nanosecond electroperturbation of Jurkat T lymphoblasts," Vernier, P. T., Y. Sun, L. Marcu, C. M. Craft, and M. A. Gundersen, Scientific Conference, Society for Physical Regulation in Biology and Medicine, San Antonio, 2004.

"Nanosecond, megawatt, millijoule pulses selectively perturb but do not porate mammalian cells," Vernier, P. T. and M. A. Gundersen, Air Force Office of Scientific Research, Chemistry and Life Sciences Directorate, Bio-Inspired Concepts Review, Annapolis, MD, 2003.

"Fluorescence microscopy studies of a peripheral benzodiazepine receptor-targeted molecular probe for brain tumor imaging," Marcu, L., P. T. Vernier, C. H. Manning, S. Salemi, A. Li, C. M. Craft, M. A. Gundersen, and D. J. Bornhop, Diagnostic Optical Spectroscopy, European Conference on Biomedical Optics, Munich, Germany, 2003.

"Germination of *Bacillus atrophaeus* spores after exposure to ultra-short, high-field electric pulses," Thu, M., P. T. Vernier, M. Behrend, S. Salemi, C. M. Craft, and M. A. Gundersen, ElectroMed 2003, San Antonio, 2003.

"Compact pulse generator for nanosecond electroperturbation of biological cells," Gu, X., A. Kuthi, M. Behrend, P. T. Vernier, Q. Zhou, and M. A. Gundersen, IEEE 26th International Power Modulator Conference, San Francisco, 2004.

"A catheter electrode for ultra-short, high-field pulses," Thu, M., M. R. Behrend, P. T. Vernier, Y. Sun, A. Kuthi, L. Marcu, C. M. Craft, and M. A. Gundersen, IEEE 26th International Power Modulator Conference, San Francisco, 2004.

"Real-time imaging of mammalian cells in nanosecond, megawatt, millijoule pulsed electric fields," Vernier, P. T., L. Marcu, Y. Sun, S. Salemi, C. M. Craft, and M. A. Gundersen, BiOS 2004 (SPIE), San Jose, 2004.

"Nanosecond pulsed electric fields trigger intracellular signals in human lymphocytes," Vernier, P. T., Y. Sun, L. Marcu, C. M. Craft, and M. A. Gundersen, Nanotech 2004, Boston, 2004.

"Nanoelectropulse perturbations of calcium and phospholipid distribution in human lymphocytes," Vernier, P. T., Y. Sun, L. Marcu, C. M. Craft, and M. A. Gundersen, Bioelectromagnetics Society 26th Annual Meeting, Washington, 2004.

"Optical imaging of electroperturbative effects in Jurkat T lymphoblasts induced by ultrashort pulsed electric fields," Marcu, L., P. T. Vernier, S. Salemi, M. Behrend, C. M. Craft, and M. A. Gundersen, World Congress on Medical Physics and Biomedical Engineering, Sydney, Australia, 2003.

"CMOS-compatible MEMS on multi-project wafers: fabrication and characterization, National Institute of Standards and Technology," Vernier, P. T., Semiconductor Electronics Division, Electronics and Electrical Engineering Laboratory, Gaithersburg, MD, 2003.

"Nanosecond electroperturbation of malignant cells," Vernier, P. T., A. Li, L. Marcu, X. Zhu, C. M. Craft, and M. A. Gundersen, World Congress on Medical Physics and Biomedical Engineering, Sydney, Australia, 2003.

"Nanosecond, megawatt, millijoule pulses selectively perturb but do not porate mammalian cells," Vernier, P. T. and M. A. Gundersen, Air Force Office of Scientific Research, Chemistry and Life Sciences Directorate, Bio-Inspired Concepts Review, Annapolis, MD, 2003.

"Non-invasive approaches to nano-biology through advanced pulsed power," Y. Sun, P. T. Vernier, M. Behrend, L. Marcu, and M. A. Gundersen, Workshop on High-Field Effects and Fast Pulse Responses in Bio-Systems, IEEE Conference on Electrical Insulation and Dielectric Phenomena, October 19-22, Albuquerque, 2003.

Manuscripts submitted, but not published:

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Mr. Matthew Behrend	Undergraduate Research Assistant
Ms. Qiong Shui	Graduate Research Assistant
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Dr. Chunqi Jiang	Postdoctoral Research Associate
Dr. P. Thomas Vernier	Ph.D. – June 2004
Mr. Clayton Young	Graduate Research Assistant
Mr. Ali F.Z. Ghalam	Graduate Research Assistant

Report of Inventions (by title only):

Method for Intracellular Modifications within Living Cells using Pulsed Electric Fields, (USC017.003A), filed pursuant to U.S. Provisional No. 60/336,587