Electrogenerated Chemiluminescent Detection for Microchip Capillary Electrophoresis

Erin M. Gross
Department of Chemistry

In the areas of food, environmental, and biomedical analysis, there is a need for fast detection methods that are sensitive and accurate with little reagent consumption. The proposed research will develop an electrogenerated chemiluminescence (ECL) detection method for analytes separated by microchip capillary electrophoresis (CE). ECL involves the electrochemical generation of reagents that react to produce light. The electrochemical nature of ECL makes it a technique that is amenable to miniaturization, while its luminescent signal makes it a highly sensitive technique with low detection limits. The biggest challenge in developing a microchip CE-ECL detection method is to fabricate a working electrode that is transparent but can be miniaturized and integrated onto a microchip. In our laboratory, we have been evaluating micromolded carbon ink electrodes for the generation of ECL. These electrodes are simple and inexpensive to fabricate and have the transparency required for light collection. We propose to integrate these electrodes with microchip CE and develop a CE-ECL detection method. In order to fabricate the microfluidic CE channel we will use a rapid prototyping method. This method involves using microfabrication facilities at the University of Kansas to fabricate silicon “masters”. At Creighton, poly(dimethylsiloxane) (PDMS) chips can be inexpensively produced from these master chips, which are reusable. The PDMS chips can be reversibly sealed to a microscope slide containing the carbon ink electrode. This assembly is transparent and amenable to photon detection. In addition to device fabrication this research will develop an efficient method for the detection of fluoroquinolone antibiotics, an important class of antibiotics used to treat infections in both humans and animals. Ultimately, the combination of these techniques will provide an analytical method that possesses the advantages of capillary electrophoresis separation (high resolution, fast analysis times, and low solvent and reagent cost) with the sensitivity, selectivity, and cost-effectiveness of chemiluminescence.

I. Problem

Microfluidic devices allow for the manipulation of fluids in micrometer-scale channels and wells. They have been used as an alternative to the Petri dish to mimic and study biological systems and activities such as the propagation of blood clots.[1] Microfluidic devices also offer the possibility of fast, portable, and automated analytical tests with small amounts of sample and reagent consumption. For example, it can be difficult for analytical laboratories to keep up with the large amount of testing required to assess food safety.[2] As food analysis becomes an increasingly larger concern, it will be important to have extremely fast yet accurate detection methodologies. Microfluidic analytical devices allow for the possibility of high-throughput analytical testing. In a micro total analysis system (μTAS) the ultimate goal is to perform all laboratory functions, including sample preparation, injection, fluid handling, reaction, and mixing, along with separation and detection, on a single chip. Currently most microfluidic systems are a hybrid of the micrometer scale chip components and bulky equipment used in conjunction with the chip. As microfluidic devices are used more often by scientists, new instrumentation and detection methodologies must be developed. These detection methodologies must be sufficiently sensitive for the small volumes and amounts of analytes present, but also be easily miniaturized to integrate onto a microchip device.

The primary goal of this research is to develop a separation and detection method on a microchip. The microchip will contain a channel in which samples will be separated by capillary electrophoresis (CE). As an analyte exits the channel, it will be detected by the chemiluminescent signal produced upon oxidation at an electrode and subsequent reaction with a luminescent reagent. This technique is called electrogenerated chemiluminescence (ECL).[3]

II. Significance

CE has been a prominent method for the separation and detection of complex mixtures of analytes. In fact, it had a large impact on the completion of the Human Genome Project.[4] In a microchip format, CE possesses the same advantages as conventional CE, such as high throughput, high resolution and minimal consumption of reagents, plus the promise of portability and the integration with biological systems. The most common detection methods for microchip CE are those commonly used for conventional CE. These include laser induced fluorescence (LIF), mass spectrometry (MS), and amperometry.[5-6] ECL has been a less-studied detection technique for CE. However, it has been coupled to conventional CE methods[7] and more recently with microchip CE methods.[8]

Electrochemical detection methods, such as amperometry and ECL, possess many advantages over LIF and MS. Electrochemical methods have high sensitivities and are easy to miniaturize. Although LIF has some of the lowest detection limits, it is expensive and the equipment is not easily miniaturized. Additionally, analytes must be inherently fluorescent or derivatized with a fluorescent agent. MS is also an expensive technique that is difficult to miniaturize. ECL is already routinely used for DNA analysis and immunoassays[9] and this research will demonstrate that ECL is an advantageous option for microchip CE detection because of its cost-effectiveness, ease of miniaturization, lack of bulky components, and high sensitivity.

The first analytes for which we intend to develop a detection method are fluoroquinolone (FQ) antibiotics. As antibiotic resistance is on the rise and has caught widespread attention,[10] it is important to detect these species in food, environmental and biological samples. Currently FQ's are separated and quantified by high-performance liquid chromatography (HPLC) with UV absorbance or fluorescence detection.[11] CE has been used for a few quinolone analyses,[12] but methods are not yet routine. To date, FQ's have not been detected using a microchip format. CE methods, especially in a microchip design, will be faster and consume fewer reagents than their HPLC counterparts.

Background

Most current research integrating microfluidics and ECL has focused on flow-injection analysis methods in which a single substance is analyzed.[13] The addition of a separation step, such as CE, gives the method greater specificity and the ability to analyze more complex samples. A few cases in the literature have reported combining CE and ECL.[14] In one method devices were produced from microfabricated glass slides.[15] Other studies utilizing the microchip format have focused on depositing an indium tin oxide (ITO) electrode for ECL generation.[16] To fabricate these electrodes, a thin film of ITO is patterned onto a glass substrate. Because of its transparency, ITO has been an excellent electrode for generating ECL and collecting the light. However, patterning a thin film of this material onto a microfluidic device adds an extra step and expense to the microfabrication procedure. ITO also is not robust at some of the applied voltages, so these expensive electrodes are not necessarily reusable. This proposal will outline a simpler, more cost-effective approach that does not require this additional ITO deposition step and does not require the hard photolithographic procedures described above for glass plates.

A convenient method for fabricating microfluidic devices is the rapid prototyping method.[17] First, the desired pattern for the microfluidic device is printed onto a transparency. A typical pattern is the t-design shown in Figure 1. The transparency serves as a photomask when placed over a silicon wafer containing a thin film of negative photoresist. When the wafer is exposed and developed, it is left with the pattern of photoresist protruding from it (similar to an ink stamp). This silicon wafer is the "master". The steps to produce it require microfabrication facilities and a clean-room environment. The following steps can be performed in any laboratory environment. A poly(dimethylsiloxane) (PDMS) pre-polymer is cast and cured over the master. The pattern from the master is imprinted into the PDMS, which after curing has a rubber-like consistency. The PDMS can be coupled with a substrate, such as a glass slide or another piece of PDMS, to complete the device fabrication. The reservoirs can be produced via drilling or with a hole punch. A key advantage of this rapid prototyping method is that once the silicon master has been fabricated, it can be used repeatedly to inexpensively produce PDMS-based microfluidic devices.

A general diagram of a microchip used for CE is shown in Figure 1. Typically, there are 3 reservoirs (A, B, and C), which allow for sample introduction. The lines between the reservoirs represent the microfabricated channels through which fluid flows. Generally, a chip will have channels of ~50 μm in width and 7 mm in length. A detection reservoir (D) contains buffer and allows for application of a voltage to drive the separation. For example a sample plug may be injected electrokinetically by application of a voltage between reservoirs A and D, then the voltage is applied between reservoirs B and D during the separation. A detector placed near the end of the channel responds to the presence of analyte.

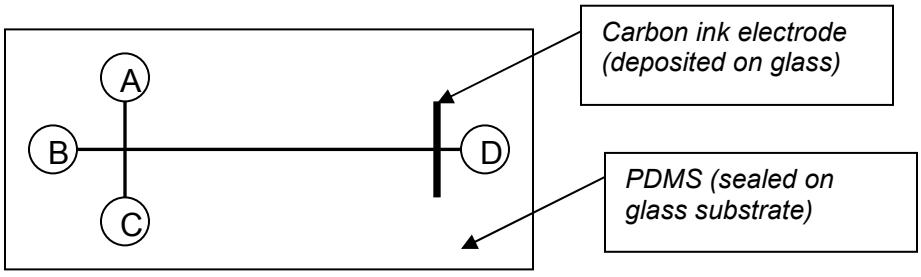

Figure 1. General pattern for microchip CE system. The sample reservoir (A) is across from the sample waste reservoir (C) via the sample injection channel. (B) buffer reservoir. (D) detection reservoir.

Research in our laboratory has been in three areas. The first has been to study novel ECL reactions. We have constructed a flow injection analysis system capable of both ECL and

electrochemical detection. We have studied the ECL reactions of five different FQ antibiotics with the chemiluminescent reagent tris(2,2'-bipyridyl)ruthenium (II) ($Ru(bpy)_3^{2+}$). These reactions were found to produce more intense light than the $Ru(bpy)_3^{2+}$/ tripropylamine system, typically a model system in this area of research. These studies have provided insight into the chemical mechanism of ECL, allowing optimization of the reaction to produce the most intense signal.

The second area of research has involved developing practical electrodes for use with CE-ECL detection and the integration of these electrodes with both a CE system and the optical components for light detection. In CE research, much attention has been given to detector design. The detector must be easily miniaturized and unaffected by the high electric fields (40 - 400 V/cm) applied across the channel or capillary. For ECL detection, the working electrode must be positioned so that it efficiently oxidizes the reagents, but also so that the photons generated at its surface can be efficiently collected. The set up must be robust and convenient to use, so time is not wasted trying to align the electrode and optical components properly. Optically transparent electrodes, such as ITO, are the best for configuring the electrode, capillary and light-collection device. Typically, the light is collected by direct placement in front of a photon detector or an optical fiber. Imagine trying to align two garden hoses and a flashlight so that one hose sprays onto the flashlight, and the other hose must "catch" the light. This is the situation when trying to align a working electrode which generates the ECL with a capillary during conventional CE. When ECL is coupled with a microchip CE format, the working electrode (along with other electrodes) can be patterned onto a glass slide. This glass slide can be "sealed" to the microchip channel. This device then eliminates the problem of trying to align the electrode and capillary. However, when ITO has been used as an electrode, the ITO must be patterned onto the device using high vacuum microfabrication techniques. A more economical and simpler method to fabricate transparent electrodes for use with microchip CE-ECL is to produce micromolded carbon ink electrodes.[18] In a collaboration with Prof. Scott Martin's group at St. Louis University (see attached letter), we have learned how to fabricate these electrodes and have successfully used them to generate ECL from a reaction between $Ru(bpy)_3^{2+}$ and enrofloxacin, a FQ antibiotic. To construct these electrodes, only one silicon master must be fabricated. From this "master", PDMS molds can be constructed by the rapid prototyping method. The molds contain a channel to define the electrode dimensions and are sealed to a microscope slide. The carbon ink mixture is pulled through the channel on a piece of glass and the ink is allowed to cure in an oven. The PDMS mold is removed and the cured ink is left on the glass slide. These electrodes can simply be placed adjacent to a phomultiplier tube (PMT) for light detection. We have found that the ink layer is sufficiently thin that light can be collected through it. This is the first demonstration of using carbon ink micromolded electrodes for ECL generation. Once a PDMS mold is constructed, is can be used to make multiple electrodes.

The third area of research involves the fabrication of microfluidic CE chips that can be coupled with both an electrode and optical components for ECL detection. Because of the alignment complications described above, the best format for conducting a CE-ECL separation and detection method will be on the microchip format, where analytes run through the separation channel and are detected at an electrode that is part of the microchip. The plastic PDMS into which the channel is formed is optically transparent, while the carbon ink electrode (which is formed on a glass slide) is also sufficiently thin as to be transparent. A "sandwich" can be made between the PDMS channel and the glass slide containing the electrode, as shown in Figure 1. The two materials can be reversibly sealed to one another. This device can be placed over the window of a PMT for light collection. Once the masters have been fabricated, these PDMS-electrode assemblies can be quickly and inexpensively produced. No expensive equipment (such as micromanipulators and microscopes) is needed for aligning the small components.

III. Research questions/hypotheses

The research in this proposal will determine if we can couple PDMS-based microchip CE with micromolded carbon ink electrodes for ECL detection. During a microchip CE separation, a potential of ~5000 V is typically applied to drive the separation. We will determine if this electric field applied to the channel affects the ECL signal. Concurrently, we will determine the optimal separation and detection conditions for ECL between $Ru(bpy)_3^{2+}$ and the analyte, fluoroquinolone antibiotics. We will determine the analytical figures of merit for the method to assess whether the detection limits are sufficient for food, environmental, or biological samples.

IV. Design and methods

A. Design of study

In our laboratory, we have developed procedures to fabricate micromolded carbon ink electrodes. We have used these electrodes to generate ECL and are in the process of optimizing the light produced. Currently we use these electrodes to characterize a single analyte in a relatively simple matrix; next we will to use them to detect multiple analytes and samples in more complex matrices. Therefore, the next step is to construct the capillary electrophoresis microchips. At Creighton, we possess the instrumentation necessary to run a CE experiment, but do not have microfabrication facilities. We will use the facilities at the University of Kansas (see attached letter from Prof. Susan Lunte). We will use the previously described rapid prototyping method.[16] First, we will travel to KU to construct silicon masters. These masters will contain the dimensions for the CE separation and injection channels. We will evaluate a few different channel dimensions to optimize the process. The masters will be taken back to Creighton and used to mold and fabricate the PDMS separation channels. The complete microchip system is formed when the PDMS layer is reversibly sealed to a glass plate containing the electrode. We will use the carbon ink electrodes, which we can construct at Creighton as previously described. At the KU facilities, we can also fabricate metal contacts for the carbon ink electrodes, which aids in making efficient electrical contact, along with reference electrodes and separation voltage electrodes. The glass plates containing the metal electrodes can be used multiple times, as a carbon electrode can be scraped off and another one produced in the same spot.

B. Procedures and Data Analysis

When the microchip devices have been constructed, different parameters can be evaluated to optimize the separation and detection method. Capillary electrophoresis separations are based on analyte charge so the magnitude of the separation voltage will be varied. Additionally the buffer type, ionic strength and pH will be evaluated. These parameters can affect the charge state of the analyte and its mobility. These will be important in developing an efficient separation.

We have used the carbon ink electrodes to generate an ECL signal from a chemiluminescent reaction involving enrofloxacin. Using these electrodes for microchip CE demands a small-sized electrode. Although the small size does not adversely affect amperometric measurements, the small size will reduce the ECL signal, as the light intensity is proportional to electrode area. First, we will evaluate the ECL intensity of the reaction as a function of $Ru(bpy)_3^{2+}$ concentration. For the reaction, the luminescent reagent ($Ru(bpy)_3^{2+}$) concentration will be in excess of the analyte concentration. We will find the optimal concentration of $Ru(bpy)_3^{2+}$ for the reaction.

If we find that these electrodes still do not give sufficiently low detection limits when used with CE, we will take additional steps to improve the ECL efficiency. These electrodes are more resistive than other carbon electrodes, such as glassy carbon. However, they possess

the advantageous properties of carbon, such as a wide potential window and stable background. One method to reduce the resistance is to deposit a metal, such as gold or platinum, onto the surface. Using the method of Wang, et. al.[19], we can electroplate a sufficient amount of gold onto the surface to increase the conductivity and the light emission, without compromising carbon's advantageous surface properties. This process can be done in a few minutes and has been found to dramatically increase the electrochemical response of a carbon ink electrode to a test solution in our laboratory.

Electrochemical detection has been the most convenient method to miniaturize for microchip CE experiments.[4-5] One drawback is that the separation voltage can interfere with the analytical signal during an amperometric detection method. There is also the possibility that electronic equipment can be damaged. An advantage of ECL detection is that the signal is light, rather than current. For this reason, it is expected that the separation voltage may not adversely affect the analytical signal in ECL. However, no conclusive evidence exists in the literature. We expect that, because a potential is applied to generate the ECL, the high voltages used in CE may affect the magnitude of the voltage required to generate ECL. In amperometric detection, a decoupler can be employed to isolate the detection cell from the CE electric field.[20] We will investigate whether a decoupler is necessary for ECL detection. We will compare different microchip detection formats such as on-chip end channel detection, in channel detection, and off channel detection with a decoupler.[5] We will be able to fabricate palladium decouplers using the KU facilities. It may only be necessary to apply an overvoltage to generate ECL in the presence of the high electric field.[21] In order to protect our potentiostat and miniaturize the system, we evaluated alternate power sources. We can use a combination of two 1.5 V batteries and a voltage divider to apply the required potential for light generation. We will integrate this approach with a CE-ECL system. This method is significantly less costly than using a potentiostat and is more amenable to miniaturization and portability.

C. Schedule for completing the project

Currently two undergraduate students are working on the micromolded carbon ink electrode project. I expect to have one or two students working on the project during the summer. At the beginning of the summer, we will travel to KU to fabricate silicon masters and also perform any necessary metal deposition. We will spend the rest of the summer at Creighton developing the separation method on the PDMS microchips and evaluating the carbon ink electrodes. By the end of the summer, I would expect to have sufficient data to report the development of this method in the literature. At this time a manuscript could be written and could be submitted by the end of October. The success of this project depends on the use of microfabrication facilities. With this grant, we would be able to develop a method for microchip CE-ECL detection using carbon ink electrodes. Once this method is developed and we have fabricated the silicon masters, we will be able to develop additional methods for other analytes or find more in depth applications for the method. For example, we could develop the method to detect fluoroquinolone antibiotics in food. These applications would be of interest to funding agencies, such as the National Science foundation or NIH. The preliminary data and demonstrated expertise with microfabrication acquired with this grant would make this a more competitive proposal for these funding agencies. This project is also an excellent experience for an undergraduate research student. The student will have the benefit of closely working with a faculty mentor, as is the model at Creighton, while having access to brand new state of the art microfabrication research facilities available at a large research university.

V. References

1. Runyon, M. K.; Johnson-Kerner, B. L.; Kastrup, C. J.; Van Ha, T. G.; Ismagilov, R. F. Propagation of Blood Clotting in the Complex Biochemical Network of Hemostasis Is Described by a Simple Mechanism. *J. Am. Chem. Soc.* **129**, 7014-7015 (2007).
2. Arnaud, C.H. Testing Our Food. *C & E News* **85**, 92-94 (2007).
3. Richter, M. M. Electrochemiluminescence (ECL). *Chem. Rev*. **104**, 3003-3036 (2004).
4. Zubritsky, E. How Analytical Chemists Saved the Human Genome Project . . . or at least gave it a helping hand. *Anal. Chem.* **74**, 22A-26A (2002)
5. Dolnik, V., Liu, Shaorong, Liu, & Jovanovich, S. Capillary electrophoresis on microchip. *Electrophoresis* **21**, 41-54 (2000).
6. Vandaveer, W.R. IV, Pasas-Farmer, S., Fischer, D.J., Frankenfeld, C.N., & Lunte, S.M. Recent developments in electrochemical detection for microchip capillary electrophoresis. *Electrophoresis* **25**, 3528-3549 (2004).
7. Wang, E. and Yin, X.-B. Capillary electrophoresis coupling with electrochemiluminescence detection: a review. *Anal. Chim. Acta*. **533**, 113-120 (2005).
8. Qiu, H., Yan, J., Sun, X., Liu, J., Cao, W., Yang, S. & Wang, E. Microchip capillary electrophoresis with an integrated indium tin oxide electrode-based electrochemiluminescence detector. *Anal. Chem*. **75**, 5435-5440 (2003)
9. Blackburn, G.F., Shah, H.P., Kenten, J.H., Leland, J., Kamin, R.A., Link, J., Peterman, J., Powell, M.J., Shah, A., Talley, D.B., Surendera, K.T., Wilkins, E., Wu, T. & Massey, R.J. Electrochemiluminescence detectioin for development of immunoassays and DNA probe assays for clinical diagnostics. *Clin. Chem*. **37**, 1534-1539 (1991).
10. Hileman, B. Poultry Antibiotics Pose Human Threat. *C & E News* **78**, 11 (2000).
11. Samanidou, V.F., Christodoulou, E.A. & Papadoyannis, I.N. *Current Pharmaceutical Analysis* **1**, 155-193 (2005).
12. Flurer, C. L. Analysis of antibiotics by capillary electrophoresis. *Electrophoresis* **22**, 4249-4261 (2001).
13. Yan, J.; Yang, X. & Wang, E. Electrogenerated Chemiluminescence on Microfluidic Chips. *Anal. Bioanal. Chem.* **381**, 48-50 (2005).
14. Yan, D. & Wang, E. Capillary Electrophoresis and Microchip Capillary Electrophoresis with Electrochemical and Electrochemiluminescence Detection. *J. Sep. Sci.* **30**, 875-890 (2007).
15. Aurora, A.; Eijkel, J.C.T.; Morf, W.E. & Manz, A. A Wireless Electrochemiluminescence Detector Applied to Direct and Indirect Detection for Electrophoresis on a Microfabricated Glass Device. *Anal. Chem.* **75**, 5435-5430 (2001).
16. Yan Du, H.Y., Kang, J., Yan, J., Yin, X., Yang, X. & Wang, E. Microchip capillary electrophoresis with solid-state electrochemiluminescence detector. *Anal. Chem*. **77**, 7993-7997 (2005).
17. Duffy, D. C., McDonald, J. C., Schueller, O. J. A., & Whitesides, G. M. Rapid prototyping of microfluidic systems in poly(dimethylsiloxane). *Anal. Chem*. **70**, 4974-4984 (1998).
18. Kovarik, M.L., Torrence, N.J., Spence, D.M. & Martin, R.S. Fabrication of carbon microelectrodes with a micromolding technique and their use in microchip-based flow analyses. *Analyst*, **129**, 400-405 (2004).
19. Wang, J., Chatrathi, M.P. & Tian, B. Micromachined separation chips with a precolumn reactor and end-column electrochemical detector. *Anal. Chem*. **72**, 5774-5778 (2000).
20. Park, S., Lunte, S. M. & Lunte, C. E. A perfluorosulfonated ionomer joint for capillary electrophoresis with on-column electrochemical detection. *Anal. Chem*. **67**, 911-918 (1995).
21. Forry, S. P., Murray, J. R., Heien, M. L. A. V., Locascio, L. E. & Wightman, R. M. Probing electric fields inside microfluidic channels during electroosmotic flow with fast-scan cyclic voltammetry. *Anal. Chem*. **76**, 4945-4950 (2004).

ERIN M. GROSS
Department of Chemistry
Creighton University
2500 California Plaza
Omaha, Nebraska 68178
(402) 280-1425
eringross@creighton.edu

Education:

Ph.D. in Chemistry, Department of Chemistry, University of North Carolina, Chapel Hill, May 2001

B.S. in Chemistry, *summa cum laude*, Creighton University, Omaha, NE, May 1996

Appointments:

Assistant Professor of Chemistry, Creighton University, Aug. 2004 – present

Research Scientist, Cardinal Health (formerly Magellan Pharmaceutical Development) Research Triangle Park, North Carolina, June 2001 – April 2004

Research Assistant, University of North Carolina at Chapel Hill, May 1997 – May 2001

Teaching Assistant, University of North Carolina at Chapel Hill, Aug. 1996 – May 1997

Teaching Assistant, Creighton University, Aug. 1994 – May 1996

Academic Honors:

Freshman Advising Award (2007)
Charles N. Reilley Memorial Fellowship (1996-1997)
Department of Chemistry Academic Achievement Award (1996)
Clare Booth Luce Women in Science Scholarship (1995-1996)
Carl M. Reinert Academic Scholarship (1992-1996)

Grants received:

Nebraska EPSCoR Small Grant for Underrepresented Groups in Science and Math (2005)
Creighton University Summer Faculty Research Fellowship (2006)
Nebraska EPSCoR Small Grant for Underrepresented Groups in Science and Math (2006)
Jacobson Chair Software Grant (2007)

Professional Memberships and Service:

Nebraska Academy of Sciences
American Chemical Society
Society for Electroanalytical Chemistry
Manuscript reviews for the journal *Electrophoresis*
Proposal reviews for the National Science Foundation
Participation in Creighton University Ferlic Summer Research Program

Publications:

Note: Erin McDonald and Erin Gross are the same person

Matthew S. Burkhead, Heeyoung Wang, Marcel Fallet, and Erin M. Gross "Electrogenerated Chemiluminescence: An Oxidative-Reductive Mechanism between Quinolone Antibiotics and Tris(2,2'-bipyridyl)ruthenium(II)", submitted to *Analytical Chemistry*, September 2007.

Andrew F. Slaterbeck, Timothy D. Meehan, Erin M. Gross, and R. Mark Wightman "Selective Population of Excited States during Electrogenerated Chemiluminescence with 10-Methylphenothiazine." *J. Phys. Chem. B* **2002**, *106,* 6088 – 6095.

Erin M. Gross, Neal R. Armstrong, and R. Mark Wightman, "Electrogenerated Chemiluminescence from Phosphorescent Molecules Used in Organic Light-Emitting Diodes." *J. Electrochem. Soc.*, **2002** *149*, E137-E142.

Erin M. Gross, Paolo Pastore, and R. Mark Wightman, "High-Frequency Electrochemiluminescent Investigation of the Reaction Pathway between Tris(2,2'-bipyridyl)ruthenium (II) and Tripropylamine Using Carbon Fiber Microelectrodes", *J. Phys. Chem. B* **2001**, *105*, 8732-8738.

Neal R. Armstrong, R. Mark Wightman, and Erin M. Gross, "Light Emitting Electrochemical Processes." *Ann. Rev. Phys. Chem.* **2001**, *52*, 391-422.

E.M. Gross, J.D. Anderson, A.F. Slaterbeck, S. Thayumanavan, S. Barlow, Y. Zhang, S.R. Marder, H.K. Hall, M. Flore Nabor, J.-F. Wang, E.A. Mash, N.R. Armstrong, and R.M. Wightman, "Electrogenerated Chemiluminescence from Derivatives of Aluminum Quinolate and Quinacridones: Cross Reactions with Triarylamines Lead to Singlet Emission through Triplet-Triplet Annihilation." *J. Am. Chem. Soc.* **2000**, *122*, 4972-4979.

Russel G. Maus, Erin M. McDonald, and R. Mark Wightman, "Imaging of Nonuniform Current Density at Microelectrodes by Electrogenerated Chemiluminescence." *Anal. Chem.* **1999**, *71*, 4944-4950.

R. Mark Wightman, Corrine L. Curtis, Paul A. Flowers, Russel G. Maus, and Erin M. McDonald, "Imaging Microelectrodes with High-Frequency Electrogenerated Chemiluminescence." *J. Phys. Chem. B* **1998**, *102*, 9991-9996.

J.D. Anderson, E.M. McDonald, P.A. Lee, M.L. Anderson, E.L. Ritchie, H.K. Hall, T. Hopkins, E.A. Mash, J. Wang, A. Padias, S. Thayumanavan, S. Barlow, S. R. Marder, G.E. Jabbour, S. Shaheen, B. Kippelen, N. Peyghambarian, R.M. Wightman, and N.R. Armstrong, "Electrochemistry and Electrogenerated Chemiluminescence Processes of the Components of Aluminum Quinolate/Triarylamine, and Related Organic Light-Emitting Diodes." *J.Am. Chem. Soc.* **1998**, *120*, 9646-9655.

Neal R. Armstrong, Jeff Anderson, Paul Lee, Erin McDonald, R. Mark Wightman, Hank K. Hall, Tracy Hopkins, Anne Padias, S. Thayumanavan, Steve Barlow, and Seth Marder, "Electrochemcial models for the radical annihilation reactions in organic light-emitting diodes." *Proceedings of SPIE, Organic Light-Emitting Materials and Devices II.* July **1998**, *3476*, 178.

Oral Presentations:

"Investigation of the electrochemiluminescent reaction of fluoroquinolone antibiotics with tris(2,2'-bipyridyl)ruthenium(II)" Matthew Burkhead*, Heeyoung Wang and Erin Gross, Department of Chemistry, Creighton University, presented at the Nebraska Academy of Sciences Meeting April 20, 2007.

“Development of a detection method for fluoroquinolone antibiotics using flow injection analysis with electrochemiluminescent detection.” Heeyoung Wang*, Matthew Burkhead, and Erin Gross, Department of Chemistry, Creighton University, presented at the Nebraska Academy of Sciences Meeting April 20, 2007.

“Development of an Electrogenerated Chemiluminescent Detection Method for Fluoroquinolone Antibiotics” Erin M. Gross*, Marcel Fallet, Rohesh Fernando, Kylie Steuben, and Evan Kimura, Nebraska Academy of Sciences, April 21, 2006.

“Incorporation of Nafion® into Capillary Electrophoresis with Detection by Electrogenerated Chemiluminescence”. Rohesh Fernando* and Erin M. Gross, presented at the Nebraska Academy of Sciences, April 21, 2006.

“Development of an Electrogenerated Chemiluminescent Detection Method for Fluoroquinolone Antibiotics” Erin M. Gross* and Marcel Fallet, presented at the Pittsburgh Conference for Analytical Chemistry and Applied Spectroscopy, Orlando, Florida, March 14, 2006.

“Development of an Electrogenerated Chemiluminescent Detection Method for Fluoroquinolone Antibiotics”; Erin M. Gross, invited seminar, University of Nebraska Lincoln, Dec. 7, 2005.

"Electrochemistry and Electrogenerated Chemiluminescence of Compounds Used in Organic Light-Emitting Diodes." Erin M. McDonald*, Jeffrey D. Anderson, Neal R. Armstrong and R. Mark Wightman, presented at the Pittsburgh Conference, New Orleans, LA, March 14, 2000.

"High Efficiency Electrogenerated Chemiluminescence at Microelectrodes." Erin M. McDonald* and R. Mark Wightman, Department of Chemistry, University of North Carolina at Chapel Hill, presented at the Pittsburgh Conference, Orlando, FL, March 10, 1999.

Poster Presentations:

“Investigation of the electrochemiluminescent reaction of fluoroquinolone antibiotics with tris(2,2'-bipyridyl)ruthenium(II)” Matthew Burkhead, Heeyoung Wang and Erin Gross*, Department of Chemistry, Creighton University, presented at the Joint Academic Forum University-Wide Celebration of Scholarship, April 24, 2007.

“Investigation of the electrochemiluminescent reaction of fluoroquinolone antibiotics with tris(2,2'-bipyridyl)ruthenium(II)” Matthew Burkhead*, Heeyoung Wang and Erin Gross, Department of Chemistry, Creighton University, presented at the American Chemical Society Meeting in Chicago, IL on March 26, 2007.

“Development of a detection method for fluoroquinolone antibiotics using flow injection analysis with electrochemiluminescent detection.” Heeyoung Wang*, Matthew Burkhead, and Erin Gross, Department of Chemistry, Creighton University, presented at the American Chemical Society Meeting in Chicago, IL on March 26, 2007.

“Development of a detection method for fluoroquinolone antibiotics using flow injection analysis with electrochemiluminescent detection.” Heeyoung Wang*, Matthew Burkhead, and Erin Gross, Department of Chemistry, Creighton University, presented at the Undergraduate Science Research Poster Presentation at Creighton University, November 20, 2006.

"Establishing a Reaction Pathway Between Tris(2,2'-bipyridyl) ruthenium (II) and Tripropylamine." E. McDonald* and R.M. Wightman, Department of Chemistry, University of North Carolina at Chapel Hill, presented at Electrochemical Society meeting, Boston, MA, Nov. 2, 1998.

Research Associates

Undergraduate Students

Evan Kimura (B.S.Chm. 2005)
Kylie Steuben (B.S.Chm. 2005)
Marcel Fallet (B.S.Chm. 2006)
Rohesh Fernando (B.S.Chm. 2006)
Adam Ritton (B.S.Chm. 2007)
Heeyoung Wang (B.S.Chm. 2007)
Holli Blum (B.S.Chm. 2007)
Matthew Burkhead (B.S.Chm. expected 2008)
David Skoglund (B.S.Chm. expected 2008)
Sarah Frederick (B.S.Chm. expected 2009)
Sarah Roszhart (B.S. Chm. expected 2010)

Collaborators

Prof. Scott Martin, St. Louis University
Prof. James Fletcher, Creighton University

Courses taught:

CHM 105	Introductory Chemistry
CHM 203	General Chemistry I
CHM 205	General Chemistry II
CHM 286	Chemical Analysis laboratory and laboratory lecture
CHM 297	Directed Research
CHM 456	Instrumental Analysis
CHM 466	Instrumental Analysis laboratory and laboratory lecture
CHM 496/7	Directed Independent Research I/II
RSP 101	Introduction to the Culture of Collegiate Life

Committee Work and Service

Chemistry Department Assessment Committee, chair
College of Arts and Sciences Assessment Committee
University Committee on Lectures, Films and Concerts
Women in Medicine and Science (WIMS, Creighton University)
College of Arts and Science Faculty Senate

Budget and Budget Justification

Travel to University of Kansas	$3000
Materials and supplies	$800
Summer Stipend	$1000
TOTAL	$4800

Monies are requested in the amount of $3000 for travel to the University of Kansas and for the fees associated with use of the facilities. An amount of $800 is requested for materials to be purchased for the research at Creighton (i.e. electrode fabrication materials, PDMS, and chemicals). A summer stipend of $1000 is requested for Dr. Gross.