Advanced MicroSystems and Circuits Research Group AMSaC Michigan State

Newsletter

Spring 2012

Advanced MicroSystems and Circuits research group. Director: Prof. Andrew J. Mason
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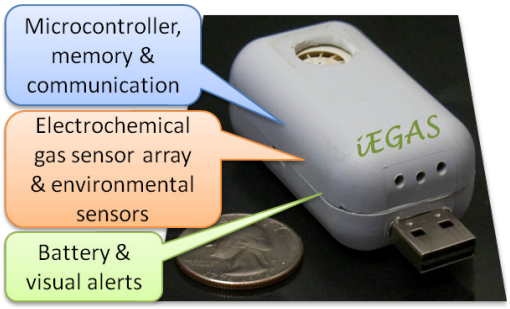
Recent News

Spring 2012	AMSaC lab presents two papers at the ***IEEE ISCAS Conf***, May 2012, in Korea
Fall 2011	Congratulations to ***2011 AMSaC graduates***: Yue Huang, Awais Kamboh (Ph.D.), Haitao Li, Lin Li (MS).
Fall 2011	Dr. Mason serves as a General Chair of ***2011 IEEE BioCAS Conf.***
Fall 2011	AMSaC lab presents four papers at ***IEEE BioCAS Conf.***, Nov 2011, in San Diego
Fall 2011	AMSaC lab presents two papers at ***IEEE Eng. Medicine Biology Conf.***, Aug 2011, in Boston
Summer 2011	Dr. Mason delivers **keynote talk** at *IEEE Inter. Workshop Advances Sensors Interfaces*, June 2011, Italy.
Fall 2010	Congratulations to ***2010 graduates*** from the AMSaC lab: Waqar Qureshi, Xiaoyi Mu, Xiaowen Liu (MS)
Fall 2010	IEEE BioCAS 2010 ***Best Student Paper Award*** goes to Awais Kamboh, Andrew J. Mason, "On-Chip Feature Extraction for Spike Sorting in High Density Implantable Neural Recording Systems"
Fall 2010	AMSaC research recognized in ***IEEE Spectrum*** <here>
Fall 2010	Dr. Mason receives **$1.9M R01 grant** to develop gas sensor arrays for underground mine safety
Spring 2010	Dr. Mason receives the 2010 ***Withrow Award for Teaching Excellence***

Recent Research Highlights

Electrochemical Gas Analysis Microsystem

Xiaoyi Mu (PhD student) and *Haitao Li* (PhD student)



Components of the *iEGAS* wearable gas analysis microsystem in a USB thumb-drive package.

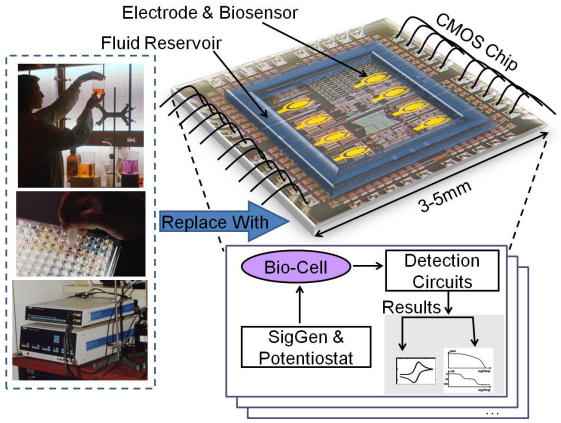
Despite continued safety improvements and increased regulations, underground mines remain a very dangerous work environment. To prevent explosions and exposure to toxic gas concentrations, new gas sensors that are low-cost, low-power, reliable, portable, and capable of real-time monitoring are needed. Although numerous gas sensors have been developed, real-time explosive and toxic gas monitoring devices that can be widely distributed in mines still do not exist.

We are developing several key sensor technologies to form a miniaturized *intelligent electrochemical gas analysis system* (iEGAS) tailored to the needs and challenges of mine safety applications. The electrochemical sensor array under development is capable of measuring concentrations of several gases to predict and prevent fires and explosions (CH_4, O_2, etc.) and to limit worker exposure to hazardous exhaust gases (SO_2, etc.). Customized sensor instrumentation IC chips are being developed to record sensor responses to multiple electrochemical measurement techniques. The integrated *iEGAS* prototype is small enough to carry or wear without encumbering mine personnel, and it is capable of autonomous communication with a PC or wireless device for uploading recorded data. Further research is underway to realize an autonomous system that will integrate electrochemical sensor arrays, electrochemical instrumentation circuits, and low-power sensor array classification algorithms running on an embedded microcontroller to provide maintenance-free operation and intelligent self-management and self-correcting features.

Multi-function Electrochemical Biosensor Microsystem

Xiaowen Liu (PhD student) and *Lin Li* (PhD student)

Advances in microelectronics and lab-on-chip devices have enabled the development of highly integrated biosensor arrays on the surface of CMOS instrumentation chips to provide a low cost, high resolution, and high throughput solution for quantitative measurement of a wide range of biochemical analytes. The resulting miniaturized biosensor microsystem can be applied to point-of-care diagnostics, environmental monitoring, drug screening, and other healthcare applications.



Multi-function electrochemical biosensor microsystem to replace bulky benchtop sample analysis tools with a highly integrated CMOS-based array device.

The goal of this project is to develop an integrated microsystem platform that incorporates an array of biological recognition interfaces, CMOS electrochemical characterization circuits, and microfluidics for continuous-use, cost-effective, biochemical analysis. We have explored several interdisciplinary technical challenges including: 1) the development of novel nanostructured bio-interfaces appropriate for integration with a microelectronics chip, 2) the design of high performance integrated circuits for multiple electrochemical assays, and 3) the development of microfabrication and packaging techniques enabling a miniaturized, lab-on-CMOS platform with microfluidics. Electrode arrays on silicon have been fabricated and functionalized with nanostructured enzyme and membrane protein interfaces. A new bioelectrochemical readout circuit has been developed that realizes both impedance spectroscopy and amperometry techniques while sharing hardware resources to minimize power and area. Several packaging options are now being explored to integrate all of the microsystem elements, enabling rapid characterization of proteins and development of new biosensor platforms.

Recent Publications

Journal Papers

1. Y. Huang and A. J. Mason, "Lab-on-CMOS Integration of Microfluidics and Electrochemical Sensors on a CMOS Potentiostat," *Lab on a Chip*, (in review).
2. Z. Wang, X. Mu, M. Guo, Y. Huang, A. Mason, X. Zeng, "Ionic liquid Double Layer Capacitor: Quantitative Evaluation of Methane Adsorption at The Ionic liquid–Electrified Metal Interface", *J. Am. Chem. Soc.*, (in review).
3. A. Kamboh, A. J. Mason, "VLSI Architecture for a Configurable Neural Data Compression Systems for Wireless Implants," *IEEE Trans. Biomedical Circ. Systems* (in review).
4. A. Kamboh, A. J. Mason, "Computationally Efficient Neural Feature Extraction for Spike Sorting in Implantable High-Density Recording Systems," *IEEE Trans. Neural Sys Rehabilitation Engineering*, (in review).
5. N. Ward, X. Mu, G. Serrano, E. Covington, C. Kurdak, E. T. Zellers, A. J. Mason, W. Li, "Microfluidic-Packaged CMOS Chemiresistor Detector for Micro-Scale Gas Chromatograph," *IEEE Micro and Nano Letters*, (in press).
6. Y. Huang, B. Hassler, S. Jadhav, R. M. Worden, A. J. Mason, "An On-Chip Protein-Based Electrochemical Biosensor Array Platform," *IEEE Trans. Biomedical Circ. Systems,* (in press).
7. X. Mu, E. Covington, D. Rairigh,C. Kurdak, E. Zellers, A. J. Mason, "A CMOS Monolithic Nanoparticle-Coated Chemiresistor Array for Microscale Gas Chromatography," *IEEE Sensors Journal* (in press)
8. L. Li, X. Liu, W. A. Qureshi, A. J. Mason, "CMOS Amperometric Instrumentation and Packaging for Biosensor Array Applications," *IEEE Trans. Biomedical Circ. Systems,* vol. 5 (5), pp. 439-448, Oct. 2011.
9. C. Yang, S. R. Jadhav, R. M. Worden, A. J. Mason, "Compact Low-Power Impedance-to-Digital Converter for Sensor Array Microsystems," *IEEE J. Solid State Circuits*, vol. 44 (10), pp. 2844-2855, Oct. 2009.
10. D. Rairigh, G. Warnell, C. Xu, E. T. Zellers, A. J. Mason, "CMOS Baseline Tracking and Cancellation Instrumentation for Nanopartical-Coated Chemiresistors," *IEEE Trans. Biomedical Circ. Systems,* vol. 3 (5), pp. 267-276, Oct. 2009.
11. C. Yang and A. Mason, "Fully Integrated 7-Order Frequency Range Quadrature Sinusoid Signal Generator," *IEEE Trans. Instrumentation Measurement*, vol. 58 (10), pp. 3481-3489, Oct. 2009.
12. L. Yu, Y. Huang, X. Jin, A. J. Mason, and X. Zeng, "Ionic Liquid Thin Layer EQCM Explosives Sensor," *Sensors and Actuators B: Chemical,* vol. 140, no. 2, pp. 363-370, July 2009.
13. C. Yang, Y. Huang, B. L. Hassler, R. M. Worden, A. J. Mason, "Amperometric Electrochemical Microsystem for a Miniaturized Protein Biosensor Array," *IEEE Trans. Biomedical Circ. Systems*, vol. 3, no. 3, pp. 160-168, June 2009.
14. X. Jin, Y. Huang, A. Mason, and X. Zeng, "Multichannel Monolithic Quartz Crystal Microbalance Gas Sensor Array," *Analytical Chemistry*, vol. 81, no. 2, pp. 595-603, January 2009.

Conference Papers

1. L. Li, X. Liu, A. J. Mason, "Die-level Photolithography and Etchless Parylene Packaging Processes for on-CMOS Electrochemical Biosensors," *IEEE Int. Symp. Circuits and Systems*, May 2012.
2. X. Mu, N. Ward, L. Li, E. Covington, G. Serrano, C. Kurdak, E. Zellers, W. Li, A. J. Mason, "CMOS Monolithic Chemiresistor Array with Microfluidic Channel for Micro Gas Chromatograph." *IEEE Int. Symp. Circuits and Systems*, May 2012.
3. N. Ward, X. Mu, G. Serrano, E. Covington, C. Kurdak, E. Zellers, A. Mason, and W. Li, "Adaptable Chip-level Microfluidic Packaging for a Micro-gas-chromatograph," *IEEE Int. Conf. Nano/Micro Engineered Molecular Systems*, Kyoto Japan, March 2012.
4. Y. Yang, A. J. Mason, "On-Chip Spike Clustering & Classification Using Self Organizing Map for Neural Recording Implants," *IEEE Biomedical Circuits Systems Conf.*, pp. 145-148, Nov. 2011.
5. H. Li, A. J. Mason, "Comprehensive Analysis and Optimization of CMOS Neural Amplifiers for Wireless Recording Implants," *IEEE Biomedical Circuits Systems Conf.*, pp. 73-76, Nov. 2011.
6. X. Liu, L. Li, B. Awate, R. M. Worden, A. J. Mason, "Biosensor Array Microsystem on a CMOS Amperometric Readout Chip," *IEEE Biomedical Circuits Systems Conf.*, pp. 305-308, Nov. 2011.
7. S. Guan, J. Gu, Z. Shen, J. Wang, Y. Huang, A. Mason, "A Wireless Powered Implantable Bio-Sensor Tag System-on-Chip for Continuous Glucose Monitoring," *IEEE Biomedical Circuits Systems Conf.*, pp. 193-196, Nov. 2011.
8. X. Mu, X. Liu, D. Rairigh, A. J. Mason, "Rapid Impedance Measurement of Tethered Bilayer Lipid Membrane Biosensors," *IEEE Eng. Medicine Biology Conf.*, Boston MA USA, pp. 4796 - 4799, August 2011.
9. Y. Yang and A. J. Mason, "Implantable Neural Spike Detection using Lifting-Based Stationary Wavelet Transform," *IEEE Eng. Medicine Biology Conf.*, Boston MA USA, pp. 7294 - 7297, August 2011.
10. X. Mu, D. Rairigh, A. J. Mason, "125ppm Resolution and 120dB Dynamic Range Nanoparticle Chemiresistor Array Readout Circuit," *IEEE Int. Symp. Circuits and Systems*, Rio Brazil, pp. 2213 - 2216, May 2011.
11. A. M. Kamboh and A. J. Mason, "Channel Characterization for Implant to Body Surface Communication," *IEEE Int. Symp. Circuits and Systems*, Rio Brazil, pp. 913 - 916, May 2011.
12. Y. Huang, A. J. Mason, "Lab-on-CMOS: Integrating Microfluidics and Sensor Arrays on CMOS," *IEEE Int. Conf. Nano/Micro Engineered Molecular Systems*, Feb. 2011.
13. A. Kamboh, A. J. Mason, "On-Chip Feature Extraction for Spike Sorting in High Density Implantable Neural Recording Systems," *IEEE Biomedical Circuits Systems Conf.*, Cyprus, pp. 13-16, Nov. 2010 (Best Student Paper).
14. Y. Yang, A. Kamboh, A. J. Mason, "Adaptive Threshold Spike Detection using Stationary Wavelet Transform for Neural Recording Implants," *IEEE Biomedical Circuits Systems Conf.*, Cyprus, pp. 9-12, Nov. 2010.
15. L. Li, W. Qureshi, X. Liu, A. J. Mason, "Amperometric Instrumentation System with On-chip Electrode Array for Biosensor Application," *IEEE Biomedical Circuits Systems Conf.*, Cyprus, pp. 294-297, Nov. 2010.
16. L. Li and A. J. Mason, "Post-CMOS Parylene Packaging for On-chip Biosensor Arrays," *IEEE Int. Conf. on Sensors*, pp. 1613-1616, October 2010.
17. X. Liu, D. Rairigh, A. Mason, "A Fully Integrated Multi-channel Impedance Extraction Circuit for Biosensor Arrays," *IEEE Int. Symp. Circuits and Systems*, Paris France, pp. 3140 – 3143, May 2010.
18. A. Kamboh, Y. Yang, K. Oweiss, A. J. Mason, "Design of a Configurable Neural Data Compression System for Intra-Cortical Implants," *IEEE Int. Symp. Circuits and Systems*, Paris France, pp. 3473-3476, May 2010.