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# SENSORS: A Novel Lateral Field Excited Acoustic Wave Sensor for Chemical and Biological Agents

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**Final Report for Period:** 09/2008 - 06/2009

**Submitted on:** 11/20/2009

**Principal Investigator:** Vetelino, John F.

**Award ID:** 0330100

**Organization:** University of Maine

**Submitted By:**

Vetelino, John - Principal Investigator

**Title:**

SENSORS: A Novel Lateral Field Excited Acoustic Wave Sensor for Chemical and Biological Agents

### Project Participants

#### Senior Personnel

**Name:** Vetelino, John

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Frankel, David

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Tripp, Carl

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Millard, Paul

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

#### Post-doc

#### Graduate Student

**Name:** French, Lester

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Hu, Yihe

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** McCarthy, Erik

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Meissner, Mike

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Pinkham, Wade

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** York, Chris

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Parks, Jesse

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Jesse Parks involvement in this project is being supported by a business incubated out of this grant, Mainely Sensors, LLC.

**Name:** Dhake, Parag

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Meulendyk, Bennett

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** McGann, Jason

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Winters, Shane

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** McCann, Donald

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Sgmabato, Christopher

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Duy, Walter

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Peters, Christian

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

#### **Undergraduate Student**

**Name:** Redecsky, Kristen

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Sells, Jeremy

**Worked for more than 160 Hours:** Yes

**Contribution to Project:****Name:** Rioux, Benjamin**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Conroy, Melinda**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Evans, Jonathan**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Hillegass, James**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Jones, Matthew**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Kalanyan, Berc**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Fecteau, Michael**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Hunter, David**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Harrison, Craig**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Patterson, Eulan**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Davis, Trevor**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Collier, Gabriel**Worked for more than 160 Hours:** Yes**Contribution to Project:**

**Name:** Jones, Ernest

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Technician, Programmer**

**Other Participant**

**Research Experience for Undergraduates**

### Organizational Partners

Mainly Sensors, LLC

### Other Collaborators or Contacts

Other contacts include Ralf Lucklum, Ulrike Hempel and Thomas Schneider, University of Magdeburg; Peter Hauptmann, University of Magdeburg. The University of Magdeburg is located in Magdeburg, Germany.

### Activities and Findings

#### **Research and Education Activities:**

Major research and educational activities have been reported in recent papers presented at conferences and submitted to journals for publication. These reports include the following:

Note: Complete report citations are included in the Journal Publication and Other Specific Products sections of this report.

Journal Publications:

'A Lateral Field Excited Acoustic Wave Biosensor,' Chemical Sensors Vol. 20, SupB, pp. 212-213, 2004. C. York, L. French, Y. Hu, P. Millard and J. F. Vetelino.

'Pesticide Detection Using A Lateral Bulk Excited Acoustic Wave Sensor,' Chemical Sensors Vol. 20, SupB, pp. 262-263, 2004 W. Pinkham, L. French, Y. Hu, D. Frankel and J. F. Vetelino.

'A Lateral Field Excited Liquid Acoustic Wave Sensor,' IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Vol. 51, No. 11, pp. 1373-1380, 2004. (Y. Hu, L.A. French, K. Radecsky, M.P. daCunha, P. Millard and J. F. Vetelino.

'Pesticide Detection Using Lateral Field Excited Acoustic Wave Sensor,' Sensors and Actuators B Chemical 108, pp. 910-916, 2005. W. Pinkham, D. Frankel, L. French, Y. Hu and J. F. Vetelino.

'Pure SH-SAW Propagation, Transduction and Measurements on KNbO<sub>3</sub>,' IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 53, No. 1, pp. 199-208, 2006 T.B. Pollard, T.D. Kenny, M.P. daCunha and J. F. Vetelino.

'Advanced Application of the Impedance Spectrum of a Lateral Field Excited Sensor,' Sensors & Actuators: A. 142, pp. 97-103, 2008. U. Hempel, R. Lucklum, P. Hauptmann and J. F. Vetelino.

'Lateral Field Excited LiTaO<sub>3</sub> High Frequency Bulk Acoustic Wave Sensor,' IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 56, No. 4, pp. 779-787, 2009. D. F. McCann, J.M. McGann, J.M. Parks, D.J. Frankel, M.P. daCunha and J. F. Vetelino.

'Recent Advances in Lateral Field Excited and Monolithic Spiral Coil Acoustic Transduction Bulk Acoustic Wave Sensor Platforms,' J. of

Measurement Science and Technology, 2009 (in press). D. McCann, L. French, M. Wark and J. F. Vetelino.

Conference Proceedings:

'A Lateral Field Excited Liquid Acoustic Wave Sensor,' 2003 International Ultrasonics Symposium Proceedings, Honolulu, Hawaii, pp 46-51, Oct. 2003. Y. Hu, K. Radecky, L. French, P. Millard, M. DaCunha and J. F. Vetelino.

'Lateral Field Excited Bulk Wave Biosensor,' 10th Int. Meeting Chem. Sensors Tech. Digest, Tsukuba, Japan, July 11-14, 2004. Y. Hu, P. Millard, and J. F. Vetelino.

'Pesticide Detection Using a Lateral Field Excited Acoustic Wave Sensor,' 10th Int. Meeting Chem. Sensors Tech. Digest, Tsukuba, Japan, July 11-14, 2004. Y. Hu, H. Li, D. Frankel and J. F. Vetelino.

'Electrode Optimization from Lateral Field Excited Acoustic Wave Sensors,' 2004 IEEE Ultrasonics, Ferroelectrics and Frequency Control Symposium, Montreal, Canada, pp. 314-318, Aug. 23-27, 2004. L. French, C. York, M. Meissner, G. Bernhardt, M. DaCunha and J. F. Vetelino.

'A Lateral Field Excited Acoustic Wave Biosensor,' 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, pp. 44-49, Sept. 19-21, 2005 C. York, P. Millard, L. French and J. F. Vetelino.

'A Lateral Field Excited Acoustic Wave Pesticide Sensor,' 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, pp. 2279-2283, Sept. 19-21, 2005 W. Pinkham, L. French, M. Wark, S. Winters, D. Frankel and J. F. Vetelino. \*\*Chosen as the best student paper at the conference.\*\*

'Crystal Orientation for Lateral Field Excited Sensor Applications,' 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006. Jesse Parks, Don McCann and J. F. Vetelino.

'A Novel Monolithic Spiral Coil Acoustic Transduction Sensor,' 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006. D. McCann, G. Flewelling, G. Bernhardt and J. F. Vetelino.

'Detection of Phosmet in Apples Using a Lateral Field Excited Acoustic Wave Sensor,' 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006. W. Pinkham, M. Wark, D. Frankel and J. F. Vetelino.

'Lateral Field Excited Acoustic Wave E. Coli Sensor,' 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006. Submitted to Sensors and Actuators. C. York, L. French, P. Millard and J. F. Vetelino.

'A Lateral Field Excited Sensor Array on a Single Piezoelectric Substrate,' 2006 IEEE Ultrasonics Symposium, Vancouver, B.C., pp. 876-879, Oct. 3-6, 2006. C. York, W. Pinkham, M. Wark, S. Winters, G. Bernhardt and J. F. Vetelino.

'A Monolithic Spiral Coil Acoustic Transduction Sensor,' 2006 IEEE Ultrasonics Symposium, Vancouver, B.C., pp. 890-893, Oct. 3-6, 2006. D. McCann, G. Flewelling, G. Bernhardt and J. F. Vetelino.

'A Lateral Field Excited Acoustic Wave Sensor,' Transducers and Eurosensors XXI 2007, Lyon, France, June 10-14, 2007, pp. 1287-1290. L. French, D. McCann, M. Wark, S. Winters and J. F. Vetelino.

'Compact RF Impedance-Spectrum-Analyzer for Lateral Field Excited Liquid Acoustic Wave Sensor,' Proc. of IEEE Sensors 2007 Conference, pp. 280-283. T. Schneider, U. Hempel, S. Doerner, D. McCann, P. Hauptmann and J. F. Vetelino.

'Lateral Field Excited High Frequency Bulk Acoustic Wave Sensor,' Proc. of 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007, pp. 264-267. D. McCann, J. Parks, J. McGann, M. daCunha and J. F. Vetelino.

'A Lateral Field Excited Acoustic Wave Sensor for the Detection of Saxitoxin in Water,' 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007, pp. 1217-1220. M. Wark, B. Kalanyan, L. Ellis, J. Fick, D. Neivandt, L. Connell and J. F. Vetelino. \*\*Chosen as best student paper at the conference.\*\*

'Application of a Portable RF Impedance Spectrum Analyzer for the Investigation of Lateral Field Excited Acoustic Wave Sensors in a Liquid Environment,' 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007, pp. 373-376. U. Hempel, T. Schneider, S. Doener, R.

Lucklum, P. Hauptmann and J. F. Vetelino.

'Novel Transducer Configurations for Bulk Acoustic Wave Sensors,' 2008 IEEE Conference, Lecce, Italy, Oct. 26-29, 2008, pp 1448-1451. D.F. McCann, M.S. Wark, L.A. French and J. F. Vetelino.

'The Detection of Chemical and Biological Analytes Using a Monolithic Spiral Coil Acoustic Transduction Sensor,' 2008 IEEE Ultrasonics Symposium, Beijing, China, Nov. 2-5, 2008, pp. 1187-1190. D. McCann, M. Wark, P. Millard, D. Neivandt and J. F. Vetelino. **\*\*Finalist for the best student paper at the conference.\*\***

'Monolithic Lateral Field Excited Well Structures in Quartz,' 2008 IEEE Ultrasonics Symposium, Beijing, China, Nov. 2-5, 2008, pp. 272-275. S. Winters, G. Bernhardt, D. Frankel and J. F. Vetelino.

'A Monolithic Spiral Coil Acoustic Transduction E. coli Sensor,' The 12th International Meeting on Chemical Sensors, Columbus, Ohio, July 13-16, 2008, p. 21. D.F. McCann, M. Wark, J. Evans, P. Millard and J. F. Vetelino.

'Acoustic Mode Behavior in Lateral Field Excited Sensors,' 2009 IEEE Ultrasonics Symposium, Rome, Italy, Sept. 20-23, 2009 (in press). J. McGann, K. Sgambato, D. McCann and J. F. Vetelino.

'The Electromagnetic Fields Radiated From a Monolithic Spiral Coil Acoustic Transduction Sensors,' 2009 IEEE Ultrasonics Symposium, Rome, Italy, Sept. 20-23, 2009 (in press). D. McCann and J. F. Vetelino.

#### Patents:

1. 'Lateral Field Excited Acoustic Wave Sensors,' US Patent #7,075,216, July 11, 2006. J. F. Vetelino.
2. 'Monolithic Antenna Excited Acoustic Transduction Device,' US Provisional Patent Application #28146, June 20, 2006. D. McCann and J. F. Vetelino.

#### **Findings: (See PDF version submitted by PI at the end of the report)**

Major findings have been described in earlier and details may be found in papers cited.

#### **Training and Development:**

The research involved in this project has educated participants in the field of microwave acoustics and sensors. Many participants are involved in our NSF funded GK-12 Sensor! program and/or our NSF funded Research Experience for Teachers (RET) program. They have utilized the information they have gathered from this project and are conveying it to both high school and middle school classrooms.

#### **Outreach Activities:**

Outreach activities include ongoing research projects that have resulted in the creation of modules designed for presentation in more than a dozen Maine high schools.

#### **Journal Publications**

Pollard, TB; Kenny, TD; Vetelino, JF; da Cunha, MP, "Pure SH-SAW propagation, transduction and measurements on KNbO<sub>3</sub>", IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL, p. 199, vol. 53, (2006). Published,

Hu, YH; Pinkham, W; French, LA; Frankel, D; Vetelino, JF, "Pesticide detection using a lateral field excited acoustic wave sensor", SENSORS AND ACTUATORS B-CHEMICAL, p. 910, vol. 108, (2005). Published, 10.1016/j.snb.2004.11.04

Hu, YH; French, LA; Radecsky, K; da Cunha, MP; Millard, P; Vetelino, JF, "A lateral field excited liquid acoustic wave sensor", IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL, p. 1373, vol. 51, (2004). Published,

Hempel, U; Lucklum, R; Vetelino, JF; Hauptmann, P, "Advanced application of the impedance spectrum of a lateral field excited sensor", SENSORS AND ACTUATORS A-PHYSICAL, p. 97, vol. 142, (2008). Published, 10.1016/j.sna.2007.04.01

D. McCann, J. McGann, J. Parks, D. Frankel, M. Pereira da Cunha and J. Vetelino, "Lateral Field Excited LiTaO<sub>3</sub> High Frequency Bulk Acoustic Wave Sensors", IEEE Transactions in Ultrasonics, Ferroelectrics and Frequency Control, p. 779, vol. 56, (2008). Published,

C. York, L. French, Y. Hu, P. Millard, J. Vetelino, "A Lateral Field Excited Acoustic Wave Biosensor", Chemical Sensors, p. 212, vol. 20, Sup, (2004). Published,

W. Pinkham, L. French, Y. Hu, D. Frankel, and J. Vetelino, "Pesticide Detection Using A Lateral Bulk Excited Acoustic Wave Sensor", Chemical Sensors, p. 262, vol. 20, Sup, (2004). Published,

D. McCann, L. French, M. Wark and J. Vetelino, "Recent Advances in Lateral Field Excited and Monolithic Spiral Coil Acoustic Transduction Bulk Acoustic Wave Sensor Platforms", J. of Measurement Science and Technology, p. 124001, vol. 20, (2009). Published,

### **Books or Other One-time Publications**

J. F. Vetelino and A. Reghu, "Introduction to Sensors", (2010). Book, Accepted  
Bibliography: Taylor and Francis

### **Web/Internet Site**

### **Other Specific Products**

#### **Product Type:**

#### **Presentation**

#### **Product Description:**

"A Lateral Field Excited Liquid Acoustic Wave Sensor," Y. Hu, L.A. French, K. Radecsky, M. Pereira da Cunha, P. Millard, J.F. Vetelino.

#### **Sharing Information:**

This paper was presented at the IEEE Ultrasonics Symp., Honolulu, HI, USA, October 5-8, 2003.

#### **Product Type:**

#### **Presentation**

#### **Product Description:**

"Lateral Field Excited Bulk Wave Biosensor," Y. Hu, P. Millard, J.F. Vetelino.

#### **Sharing Information:**

This paper was presented at the 10th Int. Meeting Chem. Sensors Tech. Digest, Tsukuba, Japan, July 11-14, 2004.

#### **Product Type:**

#### **Presentation**

#### **Product Description:**

"Pesticide Detection Using a Lateral Field Excited Acoustic Wave Sensor," Y. Hu, H. Li, D. Frankel, J.F. Vetelino.

#### **Sharing Information:**

This paper was presented at the 10th Int. Meeting Chem. Sensors Tech. Digest, Tsukuba, Japan, July 11-14, 2004.

#### **Product Type:**

#### **Presentation**

#### **Product Description:**

"Electrode Optimization for a Lateral Field Excited Acoustic Wave Sensor," M. Meissner, L.A. French, C. York, M. Pereira da Cunha, G. Bernhardt, J.F. Vetelino.



**Sharing Information:**

This paper was presented at the 2004 IEEE Int. Ultrasonics, Ferroelectrics, and Frequency Control 50th Anniversary Joint Conference, Montreal, Que, Canada, August 24-27, 2004

**Product Type:**

**Patent**

**Product Description:**

U.S. Patent, 1-24954. Lateral Field Excited Acoustic Wave Sensor. Filed 31 March 2004. J. F. Vetelino

**Sharing Information:**

This product has been registered with the U.S. Patent Office.

**Product Type:**

**Presentation**

**Product Description:**

"Crystal Orientation for Lateral Field Excited Sensor Applications," Jesse Parks, Don McCann and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006.

**Product Type:**

**Presentation**

**Product Description:**

"A Novel Monolithic Spiral Coil Acoustic Transduction Sensor," D. McCann, G. Flewelling, G. Bernhardt and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006.

**Product Type:**

**Presentation**

**Product Description:**

"Detection of Phosmet in Apples Using a Lateral Field Excited Acoustic Wave Sensor," W. Pinkham, M. Wark, D. Frankel and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006.

**Product Type:**

**Presentation**

**Product Description:**

"Lateral Field Excited Acoustic Wave E. Coli Sensor," C. York, L. French, P. Millard and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 11th International Meeting on Chemical Sensors (IMCS), Brescia, Italy, July 16-19, 2006.

**Product Type:**

**Presentation**

**Product Description:**

"A Lateral Field Excited Sensor Array on a Single Piezoelectric Substrate," C. York, W. Pinkham, M. Wark, S. Winters, G. Bernhardt and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 2006 IEEE Ultrasonics Symposium, Vancouver, B.C., Oct. 3-6, 2006.

**Product Type:**

**Presentation**

**Product Description:**

"A Monolithic Spiral Coil Acoustic Transduction Sensor," D. McCann, G. Flewelling, G. Bernhardt and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 2006 IEEE Ultrasonics Symposium, Vancouver, B.C., Oct. 3-6, 2006.

**Product Type:**

**Patent**

**Product Description:**

US Patent #7,075,216, July 11, 2006. "Lateral Field Excited Acoustic Wave Sensors". J. F. Vetelino.

**Sharing Information:**

This product has been registered with the U.S. Patent Office.

**Product Type:**

**Patent**

**Product Description:**

US Provisional Patent Application #28146, June 20, 2006. "Monolithic Antenna Excited Acoustic Transduction Device". D. McCann and J. F. Vetelino.

**Sharing Information:**

This product has been registered with the U.S. Patent Office.

**Product Type:**

**Publication**

**Product Description:**

"A lateral field excited acoustic wave sensor for the detection of saxitoxin in water," M. Wark, L. Ellis, B. Kalanyan, D. Nievandt, L. Connell and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007. \*\*It received the best student paper award.\*\*

**Product Type:**

**Presentation**

**Product Description:**

"Lateral Field Excited High Frequency Bulk Acoustic Wave Sensors," J. Parks, D. McCann, M. Pereira Da Cunha and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007.

**Product Type:**

**Presentation**

**Product Description:**

"Application of a portable RF Impedance Spectrum Analyzer for the Investigation of Lateral Field Excited Acoustic Wave sensors in a Liquid Environment," U. Hempel, R. Lucklulm, P. Hauptmann and J. F. Vetelino.

**Sharing Information:**

This paper was presented at the 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007.

**Product Type:**

**Publication**

**Product Description:**

"A Lateral Field Excited Acoustic Wave Sensor," L.A. French Jr., D.F. McCann, M. Wark, S. Winters and J. F. Vetelino.

**Sharing Information:**

This paper was presented at Transducers '07 & Eurosensors XXI meeting, Lyon, France, 10-14 June 2007.

**Product Type:**

**Presentation****Product Description:**

"A Lateral Field Excited Acoustic Wave Sensor for the Detection of Saxitoxin in Water," M. Wark, B. Kalanyan, L. Ellis, J. Fick, D. Neivandt, L. Connell and J.F. Vetelino.

**Sharing Information:**

This paper was presented at the 12th International Meeting on Chemical Sensors, Columbus, OH, July 13-16, 2008.

**Product Type:****Presentation****Product Description:**

"A Monolithic Spiral Coil Acoustic Transduction E. coli Sensor," D. McCann, M. Wark, J. Evans, P. Millard and J.F. Vetelino.

**Sharing Information:**

This paper was presented at the 12th International Meeting on Chemical Sensors, Columbus, OH, July 13-16, 2008.

**Product Type:****Presentation****Product Description:**

"Monolithic Lateral Field Excited Well Structures in Quartz," D. McCann, W. Wark, D. Neivandt and J.F. Vetelino.

**Sharing Information:**

This paper was presented at the 2008 IEEE International Ultrasonics Symposium, Beijing China, November 2-5, 2008.

**Product Type:****Presentation****Product Description:**

"The Detection of Chemical and Biological Analytes Using a Monolithic Spiral Coil Acoustic Transduction Sensor," D. McCann, W. Wark, D. Neivandt and J.F. Vetelino.

**Sharing Information:**

This paper was presented at the 2008 IEEE International Ultrasonics Symposium, Beijing China, November 2-5, 2008.

\*\*This paper was a finalist for the "Best Student Paper" award at the conference.\*\*

**Product Type:****Presentation****Product Description:**

"Novel Transducer Configuration for Bulk Acoustic Wave Sensors," D. McCann, M. Wark, L. French and J.F. Vetelino.

**Sharing Information:**

This paper will be presented at the 2008 IEEE Sensors Conference, Lecce Italy October 26-29, 2008.

**Product Type:****Presentation****Product Description:**

"A Lateral Field Excited Acoustic Wave Biosensor," C. York, P. Millard, L. French and J. Vetelino

**Sharing Information:**

This paper was presented at the 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, Sept. 19-21, 2005.

**Product Type:****Presentation****Product Description:**

"A Lateral Field Excited Acoustic Wave Pesticide Sensor". W. Pinkham, L. French, M. Wark, S. Winters, D. Frankel and J. Vetelino.

**Sharing Information:**

This paper was presented at the 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, Sept. 19-21, 2005. \*\*Received the best student paper award.\*\*

**Product Type:****Presentation****Product Description:**

"Compact RF Impedance-Spectrum-Analyzer for Lateral Field Excited Liquid Acoustic Wave Sensor," T. Schneider, U. Hempel, S. Doerner, D. McCann, P. Hauptmann and J. Vetelino.

**Sharing Information:**

This paper was presented at the Proc. of IEEE Sensors 2007 Conference.

**Product Type:****Presentation****Product Description:**

"Acoustic Mode Behavior in Lateral Field Excited Sensors" J. McGann, K. Sgambato, D. McCann and J. Vetelino

**Sharing Information:**

This paper was presented at the 2009 IEEE Ultrasonics Symposium, Rome, Italy, Sept. 20-23, 2009.

**Product Type:****Presentation****Product Description:**

"The Electromagnetic Fields Radiated From a Monolithic Spiral Coil Acoustic Transduction Sensors" D. McCann and J. Vetelino.

**Sharing Information:**

This paper was presented at the 2009 IEEE Ultrasonics Symposium, Rome, Italy, Sept. 20-23, 2009.

**Contributions****Contributions within Discipline:**

Our findings have advanced the state of the art as evidenced by our publications and presentations. In particular, we have made significant state of the art contributions in the area of sensing with acoustic wave devices.

**Contributions to Other Disciplines:**

Our findings and techniques have resulted in the development of novel sensors applicable to the areas of food science, microbiology, automotive engineering as described in our published papers and presentations.

**Contributions to Human Resource Development:**

We have educated students to the M.S. and Ph.D levels and encouraged high school students to pursue careers in science and engineering. Furthermore, we have made a significant pool of high school teachers aware of our research programs.

**Contributions to Resources for Research and Education:**

Our activities have provided research topics for M.S. and Ph.D theses and created modules for high school and middle school students. Current research is being conducted in a new, state of the art facility at the University of Maine.

**Contributions Beyond Science and Engineering:**

The incubation of a Mainely Sensors, LLC has had a clear impact on the public welfare beyond science and engineering. Mainely Sensors, LLC has created jobs for Maine residents and is developing the potential to keep talented University of Maine graduate students in-state post-graduation.

**Conference Proceedings****Categories for which nothing is reported:**

Any Web/Internet Site

Any Conference

## Activities and Findings:

The major focus of this project related to the development of a lateral field excited (LFE) microbalance for the sensitive and selective detection of chemical, biological and physical targets. The project involved faculty, graduate students and undergraduate students from the University of Maine and the University of Magdeburg in Magdeburg, Germany. The research work was performed at the University of Maine and researchers from the University of Magdeburg spent anywhere from a few weeks to a year at the University of Maine. Although contributing to the success of the project, the participants from the University of Magdeburg were not supported by the grant.

A significant amount of work was done on developing an operational LFE sensor element. In particular a variety of electrode geometries were tested in both gaseous and liquid environments. The electrode tested included novel half moon, bite wing and spiral coil geometries. It was found that all the geometries tested were capable of exciting both the fundamental and higher order harmonics associated with the pure transverse shear mode (TSM) in AT-cut quartz in liquid environments. Depending upon the target analyte of interest certain geometries had stronger responses than other geometries. Relative to a gaseous environment, the bite wing and half moon geometries were the most appropriate. It was necessary however to contour the sensing surface in order to get an optimal response. In particular when the sensing surface was contoured to be convex the spurious modes which interfere with the pure TSM were eliminated.

Although the primary material used for the LFE sensor was AT-cut quartz, other materials were also examined. In particular the materials included potassium niobate ( $\text{KNbO}_3$ ), lithium tantalate ( $\text{LiTaO}_3$ ), lithium niobate ( $\text{LiNbO}_3$ ) and langatate ( $\text{La}_3\text{Ga}_{5.5}\text{Ta}_{0.5}\text{O}_{14}$  or LGT).  $\text{KNbO}_3$  was found to be highly piezoelectric but difficult to grow due to multiple ferroelectric phase transitions in this material.  $\text{LiTaO}_3$  was examined theoretically and found to have several orientations for which pure TSMs could be excited. Subsequent experimental measurements confirmed the existence of these orientations, but significant spurious modes existed. The existence of the spurious modes and the fact that  $\text{LiTaO}_3$  is pyroelectric made it very difficult to use at temperatures other than room temperature.  $\text{LiNbO}_3$  was found to also have pure TSMs and high piezoelectric coupling. Since this material is not temperature compensated, it must be operated at a constant temperature which is a potential drawback. Finally, LGT was found to have pure TSMs which were temperature compensated at room temperature. This material is currently being examined experimentally for sensor applications.

The LFE sensing platform has been tested for several chemical, biological and physical sensing applications. The chemical applications for which the LFE sensor has been tested include a sensor for phosmet, an organophosphonate commonly used as a pesticide for vegetables and fruits, and a sensor for saxitoxin (STX), a dangerous neurotoxin associated with paralytic shellfish poisoning. The biological applications include a sensor for E. coli O157:H7, a

life threatening bacteria which can appear in liquids (e.g. water), raw fruits, raw vegetables and undercooked meats. The physical application includes the development of an LFE rate monitor which can potential replace the common quartz crystal monitor (QCM) in thin film deposition systems and the development of an LFE array sensing platform.

Phosmet, a pesticide commonly used on fruits and vegetables can cause serious health problems when ingested by humans. The LFE platform was coated with polyepichlorohydrin (PECH) which is a poly ether class polymer that naturally sorbs phosmet in solution and releases it when flushed with water. The PECH coated LFE sensor platform had a sensitivity of 16 Hz per ppm of phosmet in solution, well below the US EPA tolerance level of 10ppm for apples and blueberries.

Saxitoxin, one of the most dangerous naturally occurring neurotoxins, is produced by red tide algae blooms. Shell fish consume and bioaccumulate saxitoxin at levels which can be fatal to humans consuming the shellfish. The LFE sensing element basically consists of an LFE sensing platform coated with a sensing film which can sensitively and selectively sorb STX. The sensing film is based on an 18-crown-6 ether molecule which is covalently bonded to the LFE sensing platform surface. Tests have shown that a differential LFE sensing element is capable of detecting STX concentrations of about 1 $\mu$ M of STX in dionized water.

*E. coli* O157:H7 is the most dangerous of the pathogenic *E. coli* which have been implicated in food or water borne illnesses. An antibody based sensing film was developed and attached to the bare sensing surface of an LFE platform. The resulting LFE sensing platform was shown to be about 5 times more sensitive than the QCM with about one half the detection time. Experiments were performed for *E. coli* O157:H7 in drinking water and apple juice.

The LFE sensing platform is being examined as a sensor to determine the mass and thickness of films deposited in high vacuum deposition systems. In a wide range of microelectronic devices, it is necessary to monitor *in situ* film thickness with resolution to the nanometer range. Currently QCMs with electrodes on both crystal surfaces are being used. The LFE sensing platform with a bare convex contoured sensing surface potentially offers advantages such as high sensitivity, wider dynamic range and lower cost than the conventional QCM.

One other interesting research topic which has also evolved from the LFE grant is work leading to an array of LFE sensor platforms on a single substrate. Tests have been performed which show that 2 different target analytes can be simultaneously detected in a two element LFE sensor array on a single substrate. Currently this work is being extended to an array with many sensing elements on one substrate. The realization of this type of array would allow *in situ* simultaneous detection of a variety of chemical and biological analytes in real time. This LFE sensor array would have immediate medical applications.

Details relating to the research findings can be found in the refereed journal articles and conference publications cited in this report. The conference publications

- (i) 'A Lateral Field Excited Acoustic Wave Pesticide Sensor,' 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, pp. 2279-2283, Sept. 19-21, 2005. W. Pinkham, L. French, M. Wark, S. Winters, D. Frankel and J. F. Vetelino.
- (ii) 'A Lateral Field Excited Acoustic Wave Sensor for the Detection of Saxitoxin in Water,' 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007, pp. 1217-1220. M. Wark, B. Kalanyan, L. Ellis, J. Fick, D. Neivandt, L. Connell and J. F. Vetelino.

were chosen as the best student papers at the 2005 IEEE International Ultrasonics Symposium in Rotterdam, The Netherlands and the 2007 IEEE International Ultrasonics Symposium in New York, New York. The conference publication

- (iii) 'The Detection of Chemical and Biological Analytes Using a Monolithic Spiral Coil Acoustic Transduction Sensor,' 2008 IEEE Ultrasonics Symposium, Beijing, China, Nov. 2-5, 2008, pp. 1187-1190. D. McCann, M. Wark, P. Millard, D. Neivandt and J. F. Vetelino.

was chosen as the finalist for the best student paper at the 2008 IEEE International Ultrasonics Symposium in Beijing, China.

Another exciting spinoff of this grant was the incubation of a small company called Mainly Sensors. This company has received two NSF SBIR, one NSF STTR and two USDA SBJR grants which are a direct result of the LFE research grant.