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# REU Site: Sensor Science and Engineering

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**Final Report for Period:** 03/2008 - 02/2009
**Principal Investigator:** Vetelino, John F.
**Organization:** University of Maine
**Submitted By:**

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**Title:**
REU Site: Sensor Science and Engineering

## Project Participants

**Senior Personnel**

**Name:** Vetelino, John
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Bernhardt, George
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** da Cunha, Mauricio
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Millard, Paul
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Wheeler, Clayton
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Smith, Rosemary
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Tripp, Carl
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Collins, Scott
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Abedi, Ali
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Lad, Robert
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Connell, Laurie
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Neivandt, David
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Lynnworth, Larry
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Emanetoglu, Nuri
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Name:** Hummels, Donald
**Worked for more than 160 Hours:** No
**Contribution to Project:**

**Post-doc**

**Graduate Student**

**Undergraduate Student**

**Technician, Programmer**

**Other Participant**

**Research Experience for Undergraduates**

**Name:** Bellinger, Eric
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Other than Research Site
**Home Institution if Other:** Benedict College
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Breau, Frank
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site

**Home Institution if Other:** University of Rhode Island
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Brown, Antwon
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Benedict College
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Davulis, Peter
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Deane, Jennifer
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:**
**REU Funding:** REU site award
**Name:** Flewelling, Gregory
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Haluska, David
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Hermansen, Kiva
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Kemp, Diletha
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Southern University and A & M College
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Langley, Sarah
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Other than Research Site
**Home Institution if Other:** Colby College
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Montgomery, Dylan
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award
**Name:** Morton, Seth
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Myers, Hampton
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Tulane University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Naranjo, Alejandro
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Other than Research Site
**Home Institution if Other:** Rensselaer
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Tribbet, Justin
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Wark, Mitchell
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2005
**REU Funding:** REU site award

**Name:** Winters, Shane
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:**
**REU Funding:** REU site award

**Name:** Anfang, Michael
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Cedarville University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award

**Name:** Conroy, Melinda
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Ellis, Lucas
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** California Polytechnic State University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award

**Name:** Evans, Jonathan
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Cedarville University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree

**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Goodspeed, Kevin
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award
**Name:** Horton, Brendan
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Freshman
**Home Institution:** Other than Research Site
**Home Institution if Other:** Boston University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award
**Name:** Morgan, William
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Rhode Island College
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award
**Name:** Ngollo, Regine
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award
**Name:** Noonan, Patrick
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site

**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award

**Name:** White, John
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Other than Research Site
**Home Institution if Other:** McGill University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award

**Name:** Wright, Matthew
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2006
**REU Funding:** REU site award

**Name:** Cota, Ryan
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Gao, Qian
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Glaser, Radek
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Hansen, Carl
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Hillegass, James
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** University of Scranton
**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Jones, Matthew
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Kalanyan, Berc
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Lehigh University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement
**Name:** Schrader, Kale
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Other than Research Site
**Home Institution if Other:** Fort Hays State University
**Home Institution Highest Degree Granted(in fields supported by NSF):** Master's Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Withee, Jason
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Wright, Joshua
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

## Organizational Partners

**Mainely Sensors, LLC**

Mainely Sensors is a small business which incubated from the University of Maine. The chief engineer at Mainely Sensors is Lester French, a GK-12 fellow at the University of Maine. The President of Mainely Sensors is John F. Vetelino, the current Principal Investigator on the NSF-REU sensors grant. Several students received guidance from engineers at Mainely Sensors and utilized their facilities.

**Orono Spectral Solutions**

Orono Spectral Solutions is a small business which incubated from the University of Maine. The chief engineer at Orono Spectral Solutions is Luke Doucette, a former NSF-REU student at the University of Maine. The President of Orono Spectral Solutions is Carl Tripp, the advisor for two NSF-REU students during the 2005 summer. Several students received guidance from engineers at Orono Spectral Solutions and utilized their facilities.

**Lynnworth Associates**

Lynnworth Associates is a small business located in Waltham, Massachusetts specializing in physical and thermal sensors based on acoustic wave technology.

## Other Collaborators or Contacts

Sandia National Laboratories, Albuquerque, NM
SAWTEK Inc., Orlando, FL

Marquette University, Milwaukee, WI
South Dakota State University, Brookings, SD
National Semiconductor, South Portland, ME
Los Alamos National Laboratory, Los Alamos, NM
Fairchild Semiconductor, South Portland, ME
Sanders Associates, Nashua, NH
BAE Systems, Nashua, NH
RITEC Corporation, Warwick, RI
Milbank, Tweed, Hadley & McCloy Law Firm, New York, NY
University of Central Florida, Orlando, FL
IDEXX Corporation, Westbrook, ME

Faculty in the Departments of Chemistry, Physics, Chemical Engineering, Food Sciences and Microbiology

## Activities and Findings

**Research and Education Activities:**

**Findings: (See PDF version submitted by PI at the end of the report)**
See attached Table 1 - Major Research Findings by 2007 NSF-REU Students

**Training and Development:**
Training and Development - 2007

À Project Title and Research Supervisor/s:

Refer to Table 2

À Recruitment and Selection Process:

Project Announcement Distribution

Soon after the official announcement of the REU sites was made by NSF, written announcements were mailed to solicit applicants to the program. The announcements (see Appendix A and B) were mailed to department chairpersons, honors program directors and minority affairs officers at the University of Maine, neighboring schools, predominantly minority schools and other selected schools, to be distributed to qualified sophomores and juniors enrolled in Electrical and Computer Engineering, Engineering Physics, Physics and Computer Science. A listing of the schools is presented in Table 3. It was the intent of this wide distribution of the announcement to generate a significant applicant pool of qualified women, minorities and students with disabilities for the NSF-REU program.

Inquiries and Applications

Many students expressed interest in the NSF-REU program. A total of 35 students inquired about the program. Applications, which consisted of a letter of intent and a listing of courses and grades up to and including the 2006 fall semester, were received from 29 students. It was encouraged in the announcement form that the applicants were expected to have a high degree of initiative and independence in thought, not only in laboratories but also in course work. This is reflected in the difference in the number of inquiries and applications. The widespread distribution of the announcement generated over 11 applications from qualified women, minorities and students with disabilities. A listing of the applicants, along with their university or college, their major and their class, is presented in Table 4.

Method of Participant Selection

The students applying for the NSF-REU positions had achieved at least a B average in Physics, Mathematics and Engineering courses. Primary consideration was given to the grades obtained by the students in these courses. Consideration was also given to the backgrounds of the students selected so as to give special consideration to women, minorities and handicapped students. The final selection for undergraduate

participation in the NSF-REU program was made by the faculty involved in the program and the sophomore and junior academic advisors. In the case of students with about equal academic performance in courses, recommendations were sought from faculty who were acquainted with the student.

Participating Students and Faculty

A total of 12 undergraduate students and 11 faculty members participated in the NSF-REU program. In Table 5 general information relating to the student participants and faculty is summarized. Two women (Melinda Conroy and Qian Gao), and one minority student (Qian Gao) participated in the program. The total number of NSF-REU participants was increased to 12 by utilizing a combination of funding from workstudy, research grants and NSF.

À Number of Applicants From Host Institution and From Outside:

Twelve applications were received from the host institution and 17 applications were received from other institutions.

À Adjunct Activities:

The NSF-REU students were involved in several activities related to their NSF-REU participation. Students were given special instructions relative to research activities such as library searching, laboratory safety, research ethics and report writing. Research supervisors were instructed to carefully point the relevance of the research being performed to the NSF-REU student. Particular emphasis was placed on relating the student's research to problems understood by people not in mainstream science and engineering. Students were required to attend and participate in seminars presented by faculty and outside speakers. Students were also given special instructions relative to oral presentations of their research results. In some cases students prepared abstracts for scientific meetings and some of the students will make research presentations at international scientific meetings.

À Level of Stipend Paid and other Expenses Compensated:

Several students received partial or total compensation from sources other than NSF. The stipend paid to each NSF-REU student during the 2007 summer was $5,500. Some of the students, who were from institutions geographically removed from the University of Maine, received travel and lodging compensation. Table 6 summarizes the stipends and expenses associated with each NSF-REU student.

**Outreach Activities:**

In addition to making a formal presentation at the REU conference which was open to the public on their projects, several Summer 2007 NSF-REU students gave presentations at local high schools. In these presentations students described the positive effect of the program on their educational development. After the presentation they met with students in an informal basis and answered questions. These high school presentations have helped the University to recruit more students into engineering. Finally, it has also helped to increase the number of females enrolling in engineering programs.

## Journal Publications

## Books or Other One-time Publications

Wark*, M., Winters*, S., Pinkham, W., French, L., Frankel, D. and Vetelino, J.F., ""A Lateral Field Excited Acoustic Wave Pesticide Sensor"", (2005). Proceedings, Published
Bibliography: 2005 IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, pp. 2279-2283, Sept. 19-21 2005 (Chosen as Best Paper Award)

Davulis*, P., Kosinski, J. and da Cunha, M., ""GaPO4 Stiffness and Piezoelectric Constants Measurements using the Combined Thickness Excitation and Lateral Field Technique"", (2006). Proceedings, Published
Bibliography: 2006 IEEE International Frequency Control Symposium, Miami, Florida, pp. 664-669, June 4-7, 2006

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

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

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

Flewelling,* G., McCann, D., Bernhardt, G. and Vetelino, J.F., ""A Monolithic Spiral Coil Acoustic Transduction Sensor"", (2006). Proceedings, Published
Bibliography: 2006 IEEE Ultrasonics Symposium, Vancouver, B.C., pp. 890-893, Oct. 3-6, 2006

Rivers, S.B., Bernhardt, G., Wright,* M., Frankel, D.J., Steeves, M.M. and Lad, R.J., ""Structure, Conductivity, and Optical Absorption of Ag2-xO Films"", (2007). Proceedings, Accepted
Bibliography: Thin Solid Films

Wright,* M. and Lad, R.J., ""Charge Transport and Optical Transparency of Ag2-xO Thin Films"", (2006). Proceedings, Invited Talk
Bibliography: First International Conference On Transparent Conducting Oxides, Hersonosis, Crete, Oct. 16, 2006

Wright,* M. and Lad, R.J., ""Structure and Charge Transport of Thin Epitaxial Ag2-xO Films Grown on Sapphire"", (2007). Book, Invited Talk
Bibliography: International Workshop on Oxide Surface IWOX-V, Lake Tahoe, CA., Jan. 11, 2007

Hansen*, C, Farah, C., Bassir, M. and Abedi, A., ""Cluster Head Assignment in Wireless Sensor Networks"", (2007). Proceedings, Published
Bibliography: OPNETWORK 2007, Washington, D.C., August 2007

Hansen*, C., Farah, C. and Abedi, A., ""Enhancing Error Correction Code in Transceiver Pipeline"", (2007). Proceedings, Published
Bibliography: OPNETWORK 2007, Washington, D.C., August 2007

Wark*, M., Winters*, S., French, L., McCann, D. and Vetelino, J.F., ""A Lateral Field Excited Acoustic Wave Sensor"", (2007). Proceedings, Published
Bibliography: Transducers and Eurosensors XXI 2007, Lyon France, June 10-14, 2007, pp. 1287-1290

Wark*, M., Kalanyan*, B., Ellis*, L., Fick, J., Neivandt, D., Connell, L. and Vetelino, J.F., ""A Lateral Field Excited Acoustic Wave Sensor for the Detection of Saxitoxin in Water"", (2007). Book, Published
Bibliography: 2007 IEEE Ultrasonics Symposium, New York, NY, Oct. 28-31, 2007 pp. 1217-1220 (Chosen as Best Paper Award)

## Web/Internet Site

**URL(s):**
http://www.eece.maine.edu/research/URP/index.htm
**Description:**

## Other Specific Products

## Contributions

**Contributions within Discipline:**

Please refer to the REU abstracts.

**Contributions to Other Disciplines:**

Since the NSF-REU Program is focused on the area of sensors which is interdisciplinary, many students worked very closely with faculty and researchers in many disciplines. Projects such as the design, fabrication and testing of sensor platforms involved physics, chemistry, bioengineering and electrical engineering while the applications covered areas such as agriculture, medicine, marine science and food sciences.

**Contributions to Human Resource Development:**

Contributions to Human Resource Development:

The NSF-REU program as outlined in the original proposal proceeded in a very coherent fashion throughout. A total of 12 students which included two women and one minority student participated in the program. Each participant chose his/her research topic and supervisor and was given preliminary reading material prior to the onset of the program. The project director held informal discussions with each participant and his/her research supervisor periodically throughout the duration of the program. Each participant kept a notebook of his/her activities which enabled other people in his/her research area to benefit from the work. The REU students were also required to take a course entitled, 'Introduction to Sensors,' for which they received three academic credits. At the end of the summer program a formal two-day conference (see Appendix C) was held in which each REU student made powerpoint presentations of their research findings and submitted a final report to the project director. This conference followed the format of a national or international conference with different sessions, chairpersons (REU advisors) for each session and awards for the best presentation and two runner-up awards. The REU conference was well attended by not only students and REU advisors but many other people both inside and outside the University of Maine. The students were graded on the basis of their day to day performance and development during the summer, their presentation at the conference and their final report. The grade was determined by the project director and the student's research supervisor. The students benefited not only from the research experience but also from the technical writing and speaking required in the program.

The research atmosphere to which the NSF-REU students were exposed in the summer was not truncated at the end of the summer. All of the on-campus participants are continuing their work into the academic year. Some of the students are receiving compensation from either departmental funds or research contracts to continue their research on a part-time basis, while other students are continuing their work in the framework of the University Honors Program. The project director has contacted the advisors of the off-campus students resulting in several off-campus students continuing their work in an appropriate research group.

The project director and other faculty members participating in the NSF-REU program believe the research and educational experience gained by the students during the summer and further experience to be gained during the academic year to be an integral part of the students' education. In this light, the project director is continuing to monitor the progress of the participants throughout the academic year.

The NSF-REU program has had a noticeable effect on the undergraduate curriculum. The NSF-REU participants were awarded six academic credits, three academic credits for taking the course, 'Introduction to Sensors' and three credits for their participation in the program. They will be able to use these credits toward their B.S. degree. Students who continue their research project in the framework of the University Honors Program will receive additional academic credit. This program along with previous NSF-URP and NSF-REU programs have also had an indirect effect on the Electrical and Computer Engineering Department's acquisition of useful excess equipment. National Semiconductor Corporation, Fairchild Semiconductor, Quadic Systems, and Digital Equipment Corporation have viewed with enthusiasm the expanding graduate program along with the research atmosphere being instituted on the undergraduate level in the Electrical and Computer Engineering Department. Owing in part to these factors, they have donated a large amount of equipment and scholarships to the Department. In terms of the undergraduate curriculum, it will no doubt have a significant effect on the present sequence of courses in the area of solid state, electronics and computer engineering.

The research projects of faculty members involved in the NSF-REU program benefited in terms of the results of the research of the participants during the summer. Some of the projects will continue to benefit during the academic year since many of the students are continuing their research. Each of the involved faculty members expressed to the project director their personal enjoyment for the opportunity to work with highly qualified undergraduate students. The work of previous NSF-URP students has been extremely valuable to research at the University of Maine. Several of the NSF-REU students interacted very closely with small businesses such as Mainely Sensors and Orono Spectral Solutions which benefited from their interactions. The value of the contributions of these students is indicated by the numerous publications in which NSF-REU students were co-authors.

The NSF-REU program has provided a valuable boost to the student's motivation toward both present and future graduate study. It has given them the opportunity to apply advanced techniques in mathematics, physics and engineering as well as demonstrating the need for further course work to provide the necessary tools for more advanced research. The program has also caused some of the students to modify their

ultimate educational goals. It has further demonstrated that highly qualified undergraduate students are capable of doing high-quality advanced work. The project director also believes that the program has had a very positive effect on the student body in general. Most of the student applicants who were not chosen voiced the opinion that the program offered an excellent opportunity for advanced study. Several others stated a genuine desire to plan for the opportunity next year. This means a deliberate attempt to improve grades (to qualify) and therefore should have a healthy effect upon the student body in general.

The NSF-REU program has made many faculty realize that undergraduates can indeed make very positive contributions in research. The project director has received many e-mails, telephone calls and letters requesting further information concerning the NSF-REU program at Maine.

In conclusion, I would rate the recent NSF-REU program as being an outstanding success which has given both the student and University an excellent experience in both research and teaching. The project itself and the ensuing seminars caused many fruitful discussions and suggestions with regard to the various research projects. The opportunities for these discussions and suggestions would have perhaps not been possible if not for the unifying nature of the NSF-REU program. The publications and conference presentations and student reports attest to the high level of performance achieved in the program.

This program and previous NSF-URP and NSF-REU programs conducted at the University of Maine have been extremely vital to the education of bright undergraduate students and has guided many to advanced degrees. It has also provided an opportunity for women, minorities and handicapped students to experience research. This has motivated several students in these under represented groups to pursue advanced degrees.

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

**Contributions Beyond Science and Engineering:**

Contributions Beyond Science and Engineering:

Several of the NSF-REU students have interacted with middle and high school teachers and GK-12 fellows during the summer. The middle and high school teachers were supported by an NSF-RET grant and the GK-12 fellows were supported by an NSF GK-12 grant all in the area of sensors. These interactions involved the development of curriculum modules which are being integrated into several middle and high schools in the state of Maine. REU students who graduated from schools involved in the RET and GK-12 programs also made presentations at their former schools. REU students acted as role models to high school and middle school students and helped to convince many of the secondary school students to follow careers in science and engineering.

## Conference Proceedings

## Categories for which nothing is reported:

Activities and Findings: Any Research and Education Activities

Any Journal

Any Product

Contributions: To Any Resources for Research and Education

Any Conference

TABLE 2. NSF-REU PROJECT TITLE AND RESEARCH SUPERVISOR- SUMMER 2007

| NSF-REU Project Title | NSF-REU Participant | Supervisor/s | Year |
|---|---|---|---|
| The Design, Fabrication and Testing of Novel Lateral Field Excited Bulk Acoustic Wave Sensors | Melinda Conroy | George Bernhardt<br>Donald McCann | 2007 |
| Design, Fabrication, and Testing of an Electrochemical Sensor with Thin-Film Carbon and Platinum Electrodes | Ryan Cota | Rosemary Smith | 2007 |
| An Ultra-Sensitive BAW *E. Coli* Sensor | Jonathan Evans | John Vetelino<br>Donald McCann<br>Mitchell Wark<br>Paul Millard | 2007 |
| Computer Interfaced Microfluidic Delivery System and Test Setup for Regenerable DNA Liquid-Phase SAW Biosensor | Qian Gao | Mauricio da Cunha<br>Thomas Pollard | 2007 |
| Torsional Waveguide Density Sensor | Radek Glaser | John Vetelino<br>Larry Lynnworth<br>William Spratt | 2007 |
| Developing a Wireless Sensor Network Simulation Model | Carl Hansen | Ali Abedi | 2007 |
| Optimization of a Monolithic Spiral Coil Acoustic Transduction Sensor | James Hillegass | John Vetelino<br>Donald McCann | 2007 |
| Impedance Spectra and Equivalent Circuit of the LFE Sensor | Matthew Jones | John Vetelino<br>Lester French | 2007 |
| Development and Testing of a Saxitoxin Selective Film for Use in Lateral Field Excited Acoustic Wave Sensors | Berc Kalanyan | David Neivandt<br>Mitchell Wark<br>John Vetelino | 2007 |
| InGaAs Near Infrared Sensors | Kale Schrader | Nuri Emanetoglu<br>Robert Lad | 2007 |
| Passive Wireless Surface Acoustic Wave Sensors | Jason Withee | Donald Hummels<br>Mauricio da Cunha | 2007 |
| AlN/InN Quantum Well Structures | Joshua Wright | Nuri Emanetoglu<br>Robert Lad | 2007 |

Table 3. A Listing of Schools Which Received Announcements
for the 2007 NSF-REU Program

| College/Univ. | City | State | Zip Code |
|---|---|---|---|
| University of Alabama, Huntsville | Huntsville | AL | 35899 |
| University of Alabama | Tuscaloosa | AL | 35487-0286 |
| University of Alabama, Birmingham | Birmingham | AL | 35294-4461 |
| Auburn University | Auburn | AL | 36849-5201 |
| Tuskegee University | Tuskegee | AL | 36088 |
| Embry-Riddle Aeronautical University | Prescott | AZ | 86301 |
| Univ. of California-Riverside | Riverside | CA | 92521 |
| University of Hartford | West Hartford | CT | 06117-1599 |
| Trinity College | Hartford | CT | 06106 |
| Univ. of Connecticut U-157 | Storrs | CT | 06268 |
| Univ. of New Haven | West Haven | CT | 06516 |
| Yale University | New Haven | CT | 06520 |
| Univ. of Bridgeport | Bridgeport | CT | 06602 |
| Wesleyan University | Middletown | CT | 06459-6016 |
| Yale University | New Haven | CT | 06520-8303 |
| The Catholic University of America | Washington | DC | 20064 |
| University of the District of Columbia | Washington | DC | 20008 |
| The George Washington University | Washington | DC | 20052 |
| Southeastern University | Washington | DC | 20024 |
| Howard University | Washington | DC | 20059 |
| University of Delaware | Newark | DE | 19716 |
| University of Central Florida | Orlando | FL | 32816-2450 |
| Florida Atlantic University | Boca Raton | FL | 33431 |
| Florida Institute of Technology | Melbourne | FL | 32901 |
| Florida State University | Tallahassee | FL | 32310 |
| University of Florida | Gainesville | FL | 32611-6200 |
| University of Miami | Miami | FL | 33124 |
| University of South Florida | Tampa | FL | 33620 |
| Georgia Institute of Technology | Atlanta | GA | 30332-0250 |
| Mercer University | Macon | GA | 31207 |
| Illinois Institute of Technology | Chicago | IL | 60616 |
| University of Evansville | Evansville | IN | 47722 |
| Indiana Institute of Technology | Fort Wayne | IN | 46803 |
| Indiana Univ. - Purdue Univ. at Ft. Wayne | Fort Wayne | IN | 46805-1499 |
| Indiana Univ. - Purdue Univ. Indianapolis | Indianapolis | IN | 46202 |
| University of Notre Dame | Notre Dame | IN | 46556 |
| Purdue University | West Lafayette | IN | 47907-1285 |
| Purdue University, Calumet | Hammond | IN | 46323 |
| Rose-Hulman Institute of Technology | Terre haute | IN | 47803-3999 |
| Tri-State University | Angola | IN | 46703 |
| Valparaiso University | Valparaiso | IN | 46383 |
| University of Kentucky | Lexington | KY | 40506-0046 |
| University of Louisville | Louisville | KY | 40292 |
| Grambling | Grambling | LA | 71245 |
| Louisiana Tech University | Ruston | LA | 71272 |
| Southern Univ. and A&M College | Baton Rouge | LA | 70813-0126 |
| Xavier University of Louisiana | New Orleans | LA | 70125 |
| Harvard University | Cambridge | MA | 02138 |
| University of Massachusetts | Amherst | MA | 01003 |

Table 3. A Listing of Schools Which Received Announcements
for the 2007 NSF-REU Program

| College/Univ. | City | State | Zip Code |
|---|---|---|---|
| MIT | Cambridge | MA | 02139 |
| Merrimack College | N. Andover | MA | 01845 |
| Southeastern Mass. Univ. | N. Dartmouth | MA | 02747 |
| University of Lowell | Lowell | MA | 01854 |
| Boston University | Boston | MA | 02215 |
| Northeastern University | Boston | MA | 02115 |
| Tufts University | Medford | MA | 02155-5555 |
| Worcester Polytechnic Institute | Worcester | MA | 01609 |
| Western New England College | Springfield | MA | 01119 |
| Western New England College | Worcester | MA | 01609 |
| Rome Laboratory | Hanscom AFB | MA | 01731-3010 |
| Williams College | Williamstown | MA | 01267 |
| Johns Hopkins University | Baltimore | MD | 21218 |
| University of Maryland at College Park | College Park | MD | 20742 |
| Morgan State University | Baltimore | MD | 21239 |
| Bates College | Lewiston | ME | 04240 |
| Bowdoin College | Brunswick | ME | 04011 |
| Colby College | Waterville | ME | 04901 |
| Univ. of Southern Maine | Portland | ME | 04103 |
| Career Planning Center | Brunswick | ME | 04011 |
| University of Detroit Mercy | Detroit | MI | 48219 |
| GMI Engineering and Management Inst. | Flint | MI | 48504 |
| Lawrence Technological University | Southfield | MI | 48075 |
| Michigan State University | East Lansing | MI | 48824-1226 |
| University of Michigan | Ann Arbor | MI | 48109-2122 |
| Oakland University | Rochester | MI | 48309 |
| Saginaw Valley State University | University Center | MI | 48710 |
| Wayne State University | Detroit | MI | 48202 |
| Western Michigan University | Kalamazoo | MI | 49008 |
| Lamar University | Southfield | MI | 48075 |
| Moorehouse State | Moorehead | MN | 56560 |
| Duke University | Durham | NC | 27708 |
| North Carolina State University | Raleigh | NC | 27695-7911 |
| University of North Carolina at Charlotte | Charlotte | NC | 28223 |
| N.Carolina A&T State University | Greensboro | NC | 27411 |
| Univ. of New Hampshire | Durham | NH | 03824 |
| Thayer School of Engineering | Hanover | NH | 03755 |
| Fairleigh Dickinson University | Teaneck | NJ | 07666 |
| Monmouth University | West Long Beach | NJ | 07764-1898 |
| New Jersey Institute of Technology | Newark | NJ | 07102 |
| Princeton University | Princeton | NJ | 08540 |
| Rutgers, The State Univ. of New Jersey | Piscataway | NJ | 08855-0909 |
| Stevens Institute of Technology | Hoboken | NJ | 07030 |
| Clarkson University | Potsdam | NY | 13699-5720 |
| Columbia Univ. in the City of New York | New York | NY | 10027 |
| The Cooper Union | New York | NY | 10003 |
| Cornell University | Ithaca | NY | 14853-5401 |
| Hofstra University | Hempstead | NY | 11550-1090 |
| Manhattan College | Riverdale | NY | 10471 |

Table 3. A Listing of Schools Which Received Announcements
for the 2007 NSF-REU Program

| College/Univ. | City | State | Zip Code |
|---|---|---|---|
| New York Inst. of Tech.-Metro Campus | New York | NY | 10023 |
| State University of New York at Buffalo | Buffalo | NY | 14260 |
| Polytechnic University | Brooklyn | NY | 11201 |
| Rochester Institute of Technology | Rochester | NY | 14623 |
| University of Rochester | Rochester | NY | 14627 |
| Syracuse University | Syracuse | NY | 13244-1240 |
| Union College | Schenectady | NY | 12308 |
| Houghton College | Houghton | NY | 14744-0128 |
| Rensselaer Polytechnic Institute | Troy | NY | 12180-3590 |
| University of Akron | Akron | OH | 44325-3904 |
| Case Western Reserve University | Cleveland | OH | 44106-7221 |
| Cedarville College | Cedarville | OH | 45314 |
| Universitiy of Cincinnati | Cincinnati | OH | 45221-0030 |
| Cleveland State University | Cleveland | OH | 44115-2403 |
| University of Dayton | Dayton | OH | 45469-0226 |
| Ohio University | Athens | OH | 45701 |
| Ohio Northern University | Ada | OH | 45810 |
| The Ohio State University | Columbus | OH | 43210-1272 |
| The University of Toledo | Toledo | OH | 43606 |
| Wright State University | Dayton | OH | 45435 |
| Youngstown State University | Youngstown | OH | 44555-3012 |
| Bucknell University | Lewisburg | PA | 17837 |
| Carnegie Mellon University | Pittsburgh | PA | 15213-3890 |
| Drexel University | Philadelphia | PA | 19104 |
| Gannon University | Erie | PA | 16541-0001 |
| Grove City College | Grove City | PA | 16127 |
| Lafayette College | Easton | PA | 18042-1775 |
| Lehigh University | Bethlehem | PA | 18015 |
| University of Pennsylvania | Philadelphia | PA | 19104-6390 |
| University of Pittsburgh | Pittsburgh | PA | 15261 |
| Pennsylvania State University | University Park | PA | 16802 |
| University of Scranton | Scranton | PA | 18510-4642 |
| Temple University | Philadelphia | PA | 19122-6077 |
| Villanova University | Villanova | PA | 19085 |
| Widener University | Chester | PA | 19013 |
| Swarthmore College | Swarthmore | PA | 19081 |
| University of Puerto Rico-Arecibo | Arecibo | PR | 00613-4010 |
| University of Puerto Rico-Mayaguez | Mayaguez | PR | 00681-5000 |
| Brown University | Providence | RI | 02912 |
| The Univ. of Rhode Island | Kingston | RI | 02881-0805 |
| Brown University | Providence | RI | 02912 |
| The Citadel Military College | Charleston | SC | 29409 |
| Clemson University | Clemson | SC | 29634-0915 |
| University of South Carolina | Columbia | SC | 29208 |
| Benedict College | Columbia | SC | 29204 |
| South Carolina State Univ. SCAMP | | SC | |
| Christian Brothers University | Memphis | TN | 38104 |
| University of Memphis | Memphis | TN | 38152 |
| University of Tennessee, Knoxville | Knoxville | TN | 37996-2100 |

Table 3. A Listing of Schools Which Received Announcements
for the 2007 NSF-REU Program

| College/Univ. | City | State | Zip Code |
|---|---|---|---|
| Vanderbilt University | Nashville | TN | 37212 |
| George Mason University | Fairfax | VA | 22030 |
| Old Dominion University | Norfolk | VA | 23529-0246 |
| Virginia Commonwealth University | Richmond | VA | 23284-3072 |
| Virginia Military Institute | Lexington | VA | 24450 |
| Virginia Polytechnic Inst. and State Univ. | Blacksburg | VA | 24601-0111 |
| University of Virginia | Charlottesville | VA | 22903-2442 |
| Norwich University | Northfield | VT | 05663 |
| University of Vermont | Burlington | VT | 05401 |
| West Virginia University | Morgantown | WV | 26506-6104 |
| West Virginia Univ. Inst. of Technology | Montgomery | WV | 25136 |

Table 4. List of 2007 NSF-REU Applicants

| LAST NAME | FIRST NAME | SCHOOL | MAJOR | CLASS |
|---|---|---|---|---|
| Albers | Craig | Citadel, SC | EE | SO |
| Albert | Marion | Rensselaer Polytech, NY | EE | JR |
| Al-Mamun | Syed | Columbia University, NY | EE | JR |
| Bole | Brian | FAME-FSU, Florida | Math/EE/CEN | JR |
| Bourgoin | Nathan | U Maine | EE/CEN | SR |
| Chase | Brandon | U Maine | CEN | SO |
| Conroy | Melinda | U Maine | EE | JR |
| Cota | Ryan | U Maine | EE | SO |
| Evans | Jonathan | Cedarville Univ., OH | EE | JR |
| Gao | Qian | U Maine | EE | SO |
| Glaser | Radek | U Maine | ME | JR |
| Hansen | Carl | U Maine | EE | JR |
| Hillegass | James | Univ. of Scranton, PA | EE | JR |
| Horton | Brendan | Boston University, MA | Biochemistry | SO |
| Johnston | Caroline | Univ. of Notre Dame. IN | EE | SO |
| Jones | Matthew | U Maine | ECE | SO |
| Kalanyan | Berc | Lehigh University, PA | Chem. Eng. | JR |
| Kellerman | Jonathan | Rose-Hulman Inst. of Tech.,IN | EE | SO |
| Krueger | Benjamin | Washington Univ. in St. Louis, MO | EE | SO |
| Lampkin | Christopher | Benedict College, SC | CEN | JR |
| Martin | Amad | Xavier Univ. of LA | Eng. | SR |
| Purrington | Heidi | U Maine | EE | SR |
| Schrader | Kale | Fort Hays State Univ, KS | Physics | SR |
| Schwartz | Daniel | Yale, CT | Physics | SO |
| Teshale | Essayas | Univ. of Tennessee | EE | JR |
| Withee | Jason | U Maine | ECE | JR |
| Wotawa-Bergen | Adriane | Univ. of Buffalo, NY | EE | SO |
| Wright | Joshua | U Maine | Physics | JR |
| Zhang | Zhen | Orono, ME HS Senior | no major | no class |

Table 5. General Information on 2007 NSF-REU Students

| Participant | Academic Class, Department and University | Home Address | Research Topic | Research Supervisor/s |
|---|---|---|---|---|
| Melinda Conroy | Sophomore<br>Electrical Engineering<br>University of Maine | 87 Winding Way<br>South Portland, ME 04106 | The Design, Fabrication and Testing of Novel Lateral Field Excited Bulk Acoustic Wave Sensors | George Bernhardt<br>Donald McCann |
| Ryan Cota | Sophomore<br>Electrical Engineering<br>University of Maine | 11 Mayo Street<br>Orono, ME 04473 | Design, Fabrication, and Testing of an Electrochemical Sensor with Thin-Film Carbon and Platinum Electrodes | Rosemary Smith |
| Jonathan Evans | Junior<br>Electrical Engineering<br>Cedarville University, OH | 143 Valley Road<br>Saint Marys, PA 15857 | An Ultra-Sensitive BAW *E. Coli* Sensor | John Vetelino<br>Donald McCann<br>Mitchell Wark<br>Paul Millard |
| Qian Gao | Sophomore<br>Electrical Engineering<br>University of Maine | 133 Elm Street<br>Camden, ME 04843 | Computer Interfaced Microfluidic Delivery System and Test Setup for Regenerable DNA Liquid Phase SAW Biosensor | Mauricio da Cunha<br>Thomas Pollard |
| Radek Glaser | Junior<br>Mechanical Engineering<br>University of Maine | C2 Meadow Lane<br>Old Town, ME 04468 | Torsional Waveguide Density Sensor | John Vetelino<br>Larry Lynnworth<br>William Spratt |
| Carl Hansen | Junior<br>Electrical Engineering<br>University of Maine | 21 Centre Drive, Apt. 6H<br>Orono, ME 04473 | Developing a Wireless Sensor Network Simulation Model | Ali Abedi |
| James Hillegass | Junior<br>Electrical Engineering<br>University of Scranton, PA | 456 Pennsylvania Avenue<br>Cumberland, MD 21502 | Optimization of a Monolithic Spiral Coil Acoustic Transduction Sensor | John Vetelino<br>Donald McCann |
| Matthew Jones | Sophomore<br>Electrical Engineering<br>University of Maine | 20 Roslin Avenue<br>Lewiston, ME 04240 | Impedance Spectra and Equipment Circuit of the LFE Sensor | John Vetelino<br>Lester French |
| Berc Kalanyan | Junior<br>Chemical Engineering<br>Lehigh University, PA | 11 Shady Brook Ln.<br>Malvern, PA 19355 | Development and Testing of a Saxitoxin Selective Film for Use in Lateral Field Excited Acoustic Wave Sensors | David Neivandt<br>Mitchell Wark<br>John Vetelino |
| Kale Schrader | Senior<br>Physics<br>Fort Hays State Univ., KS | 2304 Timber Drive<br>Hays, KS 67601 | InGaAs Near Infrared Sensors | Nuri Emanetoglu<br>Robert Lad |
| Jason Withee | Junior<br>Electrical Engineering<br>University of Maine | 9 Walker Avenue<br>Lewiston, ME 04240 | Passive Wireless Surface Acoustic Wave Sensors | Donald Hummels<br>Mauricio da Cunha |
| Joshua Wright | Junior<br>Physics<br>University of Maine | PO Box 5332<br>Ellsworth, ME 04605 | AlN/InN Quantum Well Structures | Nuri Emanetoglu<br>Robert Lad |

**Table 6. 2007 NSF-REU Awards and Distribution**

| NAME | TRAVEL/LODGE | NSF | OTHER DIST. | DISTRIBUTION |
|---|---|---|---|---|
| Conroy, Melinda | | 5,500 | | 100% NSF |
| Cota, Ryan | | | 5,500 | 100% Other |
| Evans, Jonathan | 400 | 5,500 | | 100% NSF |
| Gao, Qian | | | 5,500 | 100% Other |
| Glaser, Radek | | 5,500 | | 100% NSF |
| Hansen, Carl | | | 5,500 | 100% Other |
| Hillegass, James | 400 | 5,500 | | 100% NSF |
| Jones, Matthew | | 5,500 | | 100% NSF |
| Kalanyan, Berc | 300 | 5,500 | | 100% NSF |
| Schrader, Kale | 400 | 5,500 | | 100% NSF |
| Withee, Jason | | | 5,500 | 100% Other |
| Wright, Joshua | | 5,500 | | 100% NSF |

Appendix A

January 5, 2007

Dear Fellow Educator:

The Electrical and Computer Engineering (ECE) Department and the Laboratory for Surface Science and Technology (LASST) at the University of Maine have offered research experiences for undergraduates (REU) programs for several years. During the 2007 summer the University of Maine with support from the National Science Foundation (NSF) and the US Department of Defense ASSURE (Awards to Stimulate and Support Undergraduate Research Experiences) will offer highly qualified undergraduates REU fellowships in the area of sensor science and engineering. This program encourages highly qualified college sophomores and juniors majoring in electrical, computer, chemical, mechanical and biological engineering, biology, physics and chemistry to participate actively in state-of-the-art research in the summer. The ECE Department and LASST are particularly interested in recruiting women, minorities and persons with disabilities into the program. It anticipated that if members of these groups are involved in meaningful research they may be motivated to enter graduate school and actively pursue an MS and Ph.D. degree. It is well known that these undergraduates, many of whom come from economically and culturally disadvantaged backgrounds, are severely under represented at the MS and PhD level. In order to promote equal educational opportunity, the REU program will provide the opportunity for students to work under the close guidance of faculty members in one of the following areas: metal oxide thin film sensor materials; piezoelectric sensors; microelectromechanical systems (MEMS) and nano sensors; selective detection in sensors using chemical and biological films; biosensors; liquid phase sensors and sensor arrays.

The REU Program awards the participating student a $5,500 stipend for a period of ten weeks during the 2007 summer. Students will be eligible for travel support to the research site and a subsistence award. It is expected that the students applying for the available REU positions will have achieved at least a “B” average in engineering, physics, biology, chemistry and mathematics subjects. Further it is expected that the student display a high degree of initiative and independence in thought, not only in laboratories, but also in course work. It should be clearly understood by the student that this position is not merely a "summer job" but rather an educational experience where the students are treated as junior colleagues. Six undergraduate credits will be awarded to the student for their undergraduate research participation.

Applicants must submit an application form, two letters of recommendation and a listing of courses and grades, up to and including the 2006 fall semester as soon as possible and no later than March 16, 2007.

If you need additional information please do not hesitate to contact me via mail, e-mail, FAX or telephone. Thank you for your prompt cooperation and assistance in encouraging women, minorities and persons with disabilities to apply for the REU Program at the University of Maine.

Sincerely yours,

John F. Vetelino, Professor of Electrical Engineering
Project Director
Telephone: (207) 581-2224; Fax: (207) 581-4531
E-mail: vet@eece.maine.edu

**Appendix B**

**National Science Foundation & US Department of Defense ASSURE**

# 2007 Summer Undergraduate Research Fellowships in Sensor Science and Engineering

Electrical and Computer Engineering Department
and the Laboratory for Surface Science and Technology
University of Maine

**June 4 – August 10, 2007**

During the Summer of 2007 the Electrical and Computer Engineering Department and the Laboratory for Surface Science and Technology (LASST) at the University of Maine will offer the opportunity for a limited number of highly qualified undergraduate students to participate in research under the guidance of various faculty in the area of sensor science and engineering. This program is sponsored by the National Science Foundation in partnership with the US Department of Defense ASSURE (Awards to Stimulate and Support Undergraduate Research Experiences) program, and awards the participating student a stipend of $550/week for a period of ten weeks. Students who live on campus will also be eligible for a subsistence award which will help defray expenses for lodging, meals and travel from the student's home to the University of Maine. Six undergraduate credits will be awarded to the student for his/her undergraduate research participation**. Women, minorities and/or handicapped are strongly urged to apply to the program.**

## Activities:

Students will be involved in fundamental and applied sensor research in a new engineering science research building where they will work with state-of-the-art research equipment and facilities. They will interact with faculty members, research scientists, and graduate students for guidance and consultation throughout the 10-week period. At the completion of the program, students will write a final report and give an oral seminar.

## Possible Research Areas Include:

- Metal Oxide Thin Film Sensor Materials
- Piezoelectric Sensors
- Microelectromechanical Systems (MEMS) and Nano Sensors
- Selective Detection in Sensors using Chemical and Biological Films
- Biosensors
- Liquid Phase Sensors
- Sensor Arrays

## Eligibility:

- U.S. citizen or permanent resident
- Current undergraduate in their sophomore or junior year.

## Award Includes:

- $5,500 stipend
- 6 academic credits

## Application Deadline: March 16, 2007

**Contact Information**:

Susan Niles
The University of Maine, 5708 Barrows Hall
Orono, ME 04469-5708
Phone: 207-581-2224, Fax 207-581-4531
Email: susan@eece.maine.edu
http://www.eece.maine.edu/research/URP/index.htm

Appendix C

**DEPARTMENT OF DEFENSE *ASSURE*-NATIONAL SCIENCE FOUNDATION**

# Research Experience for Undergraduates

# REU: *Sensors!* 2007 Conference

**Arthur St. John Hill Auditorium**

**165 ESRB-Barrows Hall, University of Maine**

**Friday 10 August 2007**

8:45-9 AM **Welcome and Overview** (John Vetelino, PI, REU-Sensors!)

9-10:20 AM **Session 1** *Sensor Design, Fabrication, Testing, Analysis* (Nuri Emanetoglu, Moderator)

1. "Design, fabrication, and testing of an Electrochemical Sensor with Thin-film Carbon and Platinum Electrodes." Ryan Cota, University of Maine (Rosemary Smith, advisor).
2. "The Design, Fabrication and Testing of Novel Lateral Field Excited Bulk Acoustic Wave Sensors." Melinda Conroy, University of Maine (George Bernhardt, Donald McCann (PhD), advisors).
3. "AlN/InN Quantum Well Structures." Joshua Wright, University of Maine (Robert Lad, Nuri Emanetoglu, Thomas Stone (PhD), advisors).
4. "InGaAs Near Infrared Sensors." Kale Schrader, Fort Hays State University, Hayes, Kansas (Nuri Emanetoglu, advisor).

10:20-10:35 AM **Break**

10:35-11:35 AM **Session 2** *Biosensors* (David Neivandt, Moderator)

1. "Computer interfaced microfluid delivery system and Test Setup for Regenerable DNA liquid-phase SAW biosensor." Qian Gao, University of Maine (Thomas Pollard (PhD), Mauricio Pereira da Cunha, advisors).
2. "Development of a Saxitoxin Selective Film for Use in Lateral Field Excited Acoustic Wave Sensors." Berc Kalanyan, Lehigh University, Bethlehem, Pennsylvania (Mitchell Wark (MS), David Neivandt, John Vetelino, advisors).
3. "Ultra Sensitive *E. coli* Sensor." Jonathan Evans, Cedarville University, Cedarville, Ohio (Mitchell Wark (MS), Donald McCann (PhD), John Vetelino, advisors).

11:35-1:30 **Lunch**

1:30-2:10 PM **Session 3** *Wireless Sensors* (Donald Hummels, Moderator)

1. "Developing a Wireless Sensor Network Simulation Model." Carl Hansen, University of Maine (Ali Abedi, advisor).
2. "Passive Wireless Surface Acoustic Wave Sensors." Jason Withee, University of Maine (Donald Hummels, Mauricio Pereira DaCunha, advisors).

2:20-3:20 PM **Session 4** *Novel Solid-State Sensing Platforms* (John Vetelino, Moderator)

1. "Density Sensor Using A Torsional Waveguide." Radek Glaser, University of Maine (John Vetelino, Lawrence Lynnworth, William "Kyle" Spratt (MS), advisors).
2. "Optimization of a Monolithic Spiral Coil Acoustic Transduction Sensor." James Hillegass, University of Scranton, Scranton, Pennsylvania (Don McCann (PhD), John Vetelino, advisors).
3. "Impedance Spectra and Equivalent Circuit of the LFE Sensor." Matthew Jones, University of Maine (Lester French (PhD), John Vetelino, advisors).

3:40 PM **Awards & Concluding Remarks** (John Vetelino, PI REU-Sensors!)

Table 1. Major Research Findings by 2007 NSF-REU Students

| Student | Supervisor | Research Findings |
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| Conroy, Melinda | George Bernhardt<br>Donald McCann | The Design and Fabrication of Lateral Field Excited and Spiral Coil Devices and Sensors project was conducted in the summer of 2007 at the University of Maine in Orono. The purpose of the project was to fabricate electrode patterns on different forms of $SiO_2$ crystals. The crystals were then tested to determine what differences in the crystals affected the operation and sensitivity of the device. At the present time, none of the quartz crystals will work in air with the new electrode designs. Additionally, the electromagnetic fields within the device will be modeled using Ansoft's Maxwell SV software to compare with experimental results. |
| Cota, Ryan | Rosemary Smith | Over the summer I worked on fabricating an electrochemical sensor. It could be used to detect ions or dissolved gases in water, for example heavy metal contamination and dissolved oxygen. Yet this sensor is unique in that its goal is to generate electrochemiluminescence of Ru (bpy) in water without a reducing agent. This work is an extension of the work done by R.L. Smith, et al. on "A Micro-fabricated, electrochemiluminescence cell for the detection of amplified DNA." That titled paper was published in Sensors and Actuators B (chemical) in 1996. That paper really points out the reasoning for this device. Its technical nature in the field of molecular biology is however out of my grasp yet I will try to outline the most important reasons in this paper. In 2002 out at the University of California (UC) Davis, Professor Smith had hired a student to work on developing a process for the electrodes. In working on this project I used an internal document written by the student at UC Davis that outlines his process development for the fabrication of the device. I also ended up using the same photo mask as the student at UC Davis. |
| Evans, Jonathan | John Vetelino<br>Donald McCann<br>Mitchell Wark<br>Paul Millard | The current work specifically concerns methods by which anti-E. coli antibodies can be attached to the sensing surface of Bulk Acoustic Wave devices. A chemical solution was developed that can be used to immobilize anti-E. coli antibodies on $SiO_2$ and $LiTaO_3$ substrates. The immobilizations were performed on an Monolithic Spiral Coil Acoustic Transducer (MSCAT), and the sensitivity of the device to low concentrations of E. Coli was evaluated. |
| Gai, Qian | Mauricio da Cunha<br>Thomas Pollard | Recently a need has emerged for biological assaying platforms suitable for remote- and field-based detection of waterborne pathogens. Requirements for such devices include: (i) high selectivity with low occurrence of false-positives; (ii) sensitivity comparable to traditional fluorometric techniques; (iii) low-power operation; (iv) portability; and (v) low-cost. Of late, the use of surface acoustic wave (SAW) devices has been considered as a candidate platform due to exhibiting may of the aforementioned required characteristics. The goal for this work involves investigating the use of SAW devices, combined with microfluidic packing and biological recognition techniques, as biosensor platforms for the detection of nucleic acids. The SAW device considered consists of two interdigitated transducers (IDTs) surrounding a thin film gold delay region all fabricated on piezoelectric single-crystal quartz substrate. Ideally, highly efficient IDTs constructed from particular materials and appropriate thickness will transfer the majority of input power to the SAW and eliminate excitation and detection of spurious bulk acoustic wave. The use of gold proves to be more efficient than other metals, such as aluminum, in achieving this goal. The biological recognition layer is constructed on the delay region surface. |
| Glaser, Radek | John Vetelino<br>Larry Lynnworth<br>William Spratt | As a part of National Science Foundation-Research for Undergraduates program a torsional waveguide density sensor has been investigated in the Laboratory for Surface Science and Technology at the University of Maine. This simple design uses torsional piezoelectric transducers to generate torsional mode |

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| | | in a long circular rod. The non-circular portion of the waveguide allows for the measurement of different properties of fluids. Theory is presented from energy balance perspective and from the acoustic wave propagation approach. A series of experiments have been conducted with a variety of liquids and gases. Several relationships have been verified and also new have been developed. |
| Hansen, Carl | Ali Abedi | In order to simulate the wireless sensor networks studied at the University of Maine, an accurate computer model must be developed. OPNET's Modeler software is the basis for this platform as it provides a large set of tools for modeling networks and is fully customizable. A wireless sensor scenario will be designed that accurately simulates the Zigbee and IEEE 802.15.4 standard protocols to allow for general testing and research. Error correction codes will be implemented within the physical layer of the IEEE 802.15.4 standard to research performance improvements over the current IEEE standard. |
| Hillegass, James | John Vetelino<br>Donald McCann | A novel monolithic spiral coil acoustic transduction (MSCAT) sensor is currently being developed by University of Maine researchers. The MSCAT will operate as an immunosensor for the detection of the pathogenic bacteria known as E. coli. It is believed that the MSCAT will be able to detect even one bacterium in a sample due to its high sensitivity from being able to detect both mechanical and electrical property changes and being able to operate at frequencies on the order of 1 GHz. The spiral coil acts as an antenna that can efficiently radiate high frequency electric fields. The final realization of a sensor of this nature would enable on site and real time water testing for water born pathogens. Current methods of testing for water born pathogens can take up to 24 hours or more for results to be produced. During this lag time, further infection could occur. This is why a sensor of this nature would be of great interest to municipal water districts and environmental agencies.<br>In order to provide optimum sensor sensitivity, the antenna coil's geometry and operating frequency must be optimized. The coil's geometry is dependent on three variables: the number of coil turns, line width, and space between coil lines. The coil geometry will be optimized to provide the highest acceptable operating frequency. Each of the three variables will be changed while holding the other two variables constant. Each variable will be set to five different values for testing. This will produce a total of fifteen sensors that will be tested with deionized water at varying frequencies. The quality factor (Q) and signal-to-noise ratio (SNR), will be set to a minimum specified value and the highest operating frequency that can produce that Q/SNR will be found. The 15 sets of operating frequencies and their corresponding Q's/SNR's, number of turns, and line and spacing widths will be inputted into a statistical software package called SYSTAT for a linear multiple regression calculation. If the frequency response is roughly linear in response to the three independent variables, an equation will be produced that can estimate the highest operating frequency for a given set of parameters. Likewise a second and third equation will be generated to estimate the Q value and SNR for a set of geometric parameters. A high frequency design will then be chosen with an acceptable Q/SNR value with these equations and implemented. The experimental frequency and Q/SNR will be measured and three percent error calculations will be made with the theoretical values to determine the accuracy of the models. If the linear regression method fails to produce accurate models, nonlinear methods will be explored. This procedure should produce a highly sensitive sensor device using systematic means.<br>In addition to optimizing the sensor's design, it will be tested whether the addition of an amorphous $SIO_2$ layer on the AT-quartz substrate will have a positive or negative affect sensor performance. A test sample of three sensors with geometry and operating frequency held constant will be fabricated: two with varying thickness of $SIO_2$ and one with no $SIO_2$ layer as the control. |

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| Jones, Matthew | John Vetelino<br>Lester French | Sensors abound in the world. They are used to sense things from mechanical acceleration to electric permittivity. In this project I will investigate the lateral field excited (LFE) sensor. I plan to measure its response to changes in liquid conductivity, permittivity and viscosity. In order to accomplish this I will replicate the experiments performed by Hu et al, but instead of looking at the frequency changes of the LFE sensor, I will look at the admittance changes. Using this data I will develop characteristic curves for the measured admittances as the liquid properties change. Using an equivalent circuit model of the LFE, I will fit the admittance curve of the equivalent circuit to the actual sensor response by modifying the values of the circuit.<br>A quartz crystal microbalance (QCM) is a piezoelectric sensor that can be used to detect various mechanical properties such as mass accumulation at the surface or liquid density and viscosity changes by monitoring the frequency changes of the thickness shear mode (TSM). The QCM operates based on the piezoelectric effect which states that an electric field is generated when stress is applied to the crystal. The QCM is often composed of a quartz substrate with an electrode on each side of the quartz. When a voltage is applied to the electrodes the converse piezoelectric effect occurs. An acoustic wave is propagated through the crystal, which causes the crystal to become sensitive to its measurands. The LFE device uses the same principles as the QCM, except the LFE has both of its electrodes on one side of the quartz only, leaving the sensing side bare. This allows the TSM to probe both liquid electrical and mechanical property changes, such as conductivity and permittivity. Prior work by Ballato et al has shown the LFE to be more stable, more sensitive, and easier to fabricate than the QCM. Applications for the LFE sensor include the detection of bacteria, pesticides, or toxins in water. |
| Kalanyan, Berc | David Neivandt<br>Mitchell Wark<br>John Vetelino | Harmful algal blooms are frequent events in northeastern states bordering the Atlantic coast. Harmful algal blooms (HAB), also called red tide, often produce toxins that are detrimental to many species. Following HAB events, a family of neurotoxins called saxitoxins (STXs) is known to accumulate in filter-feeding bivalve mollusks, commonly referred to as shellfish. Although many aquatic species have evolved immunities to STX, human ingestion of the neurotoxin proves fatal in many instances. Saxitoxin is a powerful sodium ion-channel blocker and ingestion of amounts as small as 50 micrograms can result in a condition called Paralytic Shellfish Poisoning (PSP) which poses a serious hazard to human health. In order to ensure public safety, local and state governments require continual monitoring of STX concentrations in fisheries and coastal areas. The benchmark test currently used for STX monitoring is the mouse bioassay. Along with its ethical problems, the mouse bioassay which has an STX detection limit of approximately 40 μg/100 g shellfish tissue, must be performed in a regulatory laboratory, and can take up to a day to conclude. In Maine alone, 4000 to 5000 bioassays costing approximately $250 each are performed annually. Current alternatives to the mouse bioassay include optical fiber based fluorescence tests which have limited sensitivity and immunochromatography tests which are capable of giving only presence/absence results with no information on the actual STX concentration. Consequently, the proposed *in situ* sensor would be deployable in the field, or in the laboratory, and provide accurate, rapid, and responsive measurement. The sensor system would be made with a Lateral Field Excited acoustic wave sensor element that will be functionalized to be sensitive to STX using a selective film containing crown ether molecules, 18-Crown-6-2,3,11,12-tetracarboxylic acid in particular. The crown ethers are known to ensnare the protonated amines of STX. The film will be evaluated based on its sensitivity, selectivity, and reusability. The LFE sensor element which is easily deployable and sensitive to very small concentrations of STX can overcome the cost and time limitations of the mouse bioassay, as well as the sensitivity limitations of optical devices. Such a device can greatly reduce the high costs of |

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| | | current STX monitoring programs, and can provide a fast and accurate method of pinpointing harvest contamination. |
| Schrader, Kale | Nuri Emanetoglu<br>Robert Lad | During my NSF REU at the University of Maine I did research on sensor devices for LADAR (laser detection and ranging) systems. LADAR has many civilian and military applications, including range finding and velocity measurement, 3D imaging, missile guidance, aircraft navigation, remote chemical analysis and remote atmospheric sensing. LADAR is similar to microwave radar, but instead of electromagnetic waves, it uses reflected laser beams bounced off distant objects then detected by a photosensor. It is through this sensor that we are able to accurately interpret the beam, and make precise conclusions about the target object.<br>My research was on the design and analysis of Indium Gallium Arsenide (InGaAs) near infrared sensors used in LADAR systems. These sensors are vital to such technology, however, given the nature of many applications, this specific device has a variety of unique needs such as symmetric current/voltage characteristics, sensitivity to a specific range of optical wavelengths, and if possible, gain. Only with proper research can such a specialized sensor be engineered and produced.<br>I began by simulating such devices in order to design the semiconductor for optimum performance. After sufficient simulation, I began testing prototypes in the lab. In doing so, I devised experimental setups and techniques to allow me to gather the necessary data to insure our final device meets the needs for this application. These tests included dark current, DC responsivity, and AC responsivity. Responsivity is a descriptive characteristic that defines how and to what degree this device reacts to a DC or AC optical signal. |
| Withee, Jason | Don Hummels<br>Mauricio da Cunha | Surface acoustic wave (SAW) sensors are useful in many modern sensor applications where the use of conventional sensors is limited. These sensors are constructed with metal electrodes deposited onto a piezoelectric crystalline substrate. By adding an antenna to this device the sensor may be accessed wirelessly, without the use of batteries or other circuitry attached to the sensor. This enables the use of SAW sensors in environments that are harsh or not easily accessible. Possible applications include sensors on moving parts, at high temperatures or pressures, or in the presence of hazardous chemicals. Certain applications also demand sensing at multiple points in close proximity. Traditional passive wireless SAW sensors cannot be used in these applications because of interference in their responses with other sensors in the same vicinity.<br>A sensor system incorporating coding techniques to achieve multiple access is under development at the University of Maine. This coding technique allows sensors to be individually addressed so that multiple sensors may operate in close proximity. A flexible design wireless interrogation unit is required which: (i) generates digitally the required codes to address any of the sensors; and (ii) reads the sensor data.<br>The scope of this work is the development of a portion of the system that sends a request ping to a sensor and processes the received sensor response. This is accomplished by conditioning and digitizing the received sensor response, and utilizing digital signal processing techniques to isolate the response for each specific sensor. In addition the system should extract the sensor information from the measured data, which consists of changes in the time delay between two similar pulse responses. The use of digital signal processing offers flexibility and minimizes the amount of hardware required to arbitrarily address different sensors. |
| Wright, Joshua | Nuri Emanetoglu<br>Robert Lad | Our project involves the growth and characterization of quantum well structures using AlN and InN. The variations in the bandgap energy levels of these two materials allow for a crystalline growth process that layers the two materials upon one another to create a physical quantum well. The two energy levels act as different potentials with the InN having an energy of ~.7 eV while the AlN |

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| | | exhibits a value closer to 6.4 eV. By adjusting the well width we hope to create uses in the fields of detectors, where the quantum well interacts with the visible light spectra. Alternatively, the quantum wells can be used as a modulation device in optoelectronics. We use reflective high energy electron diffraction (RHEED), x-ray diffraction (XRD), and x-ray photoelectron spectroscopy (XPS) to characterize the structure once grown. These methods allow us to analyze the shapes and composition of the wells and how they interact with one another if at all. |