10-23-2009

RET Site: Sensors!

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Principal Investigator: Vetelino, John F.
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Organization: University of Maine
Submitted By:
Vetelino, John - Principal Investigator
Title:
RET Site: Sensors!

Project Participants

Senior Personnel

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

Name: Holden, Constance
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Millard, Paul
Worked for more than 160 Hours: No
Contribution to Project:
Dr. Paul Millard, assistant professor of biological engineering, supervised 2006 RET Joanne Adair.

Name: Connell, Laurie
Worked for more than 160 Hours: No
Contribution to Project:
Dr. Laurie Connell, assistant research professor, marine sciences, co-supervised 2006 RET David Ploch.

Name: Neivandt, David
Worked for more than 160 Hours: No
Contribution to Project:
Dr. David Neivandt, assistant professor of chemical engineering, co-supervised 2006 RET David Ploch.

Name: Collins, Scott
Worked for more than 160 Hours: No
Contribution to Project:
Dr. Scott Collins, professor of chemistry, supervised 2006 RET Debra Merrill.

Post-doc

Name: Fick, Joerg
Worked for more than 160 Hours: No
Contribution to Project:
Mr. Fick, post-doctoral student in chemical engineering, served as a senior research associate to 2006 RET David Ploch.

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Name: Arsenault, Joe

Worked for more than 160 Hours: No

Contribution to Project:

Mr. Arsenault coordinated all aspects of recruiting, scheduling, and programming for the 2006 RET: Sensors! program.

Name: Doore, Brian

Worked for more than 160 Hours: No

Contribution to Project:

Doore observed the day-one kick-off meeting and final workshop presentations given by 2006 RETs. Doore conducted pre- and post-surveys of all teachers, as well as a focus group of the 2006 RETs. Doore observed several RET-GK-12 workgroup meetings. Doore will present findings for the 2006 program in an evaluation report to be completed by May 2007.

Research Experience for Undergraduates

Name: Ellis, Lucas

Worked for more than 160 Hours: No

Contribution to Project:

2006 REU: Sensors! undergraduate Lucas Ellis performed laboratory research with 2006 RET David Ploch.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: California Polytechnic State University, San Luis Obispo, CA

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2006

REU Funding: No Info

Organizational Partners

Maine Mathematics and Science Alliance

Other Collaborators or Contacts

UM Research Facilities--

Laboratory for Surface Science and Technology (LASST):

RET: Sensors! PI Dr. John Vetelino, Prof. Electrical Engineering
Dr. Mauricio Pereira da Cunha, Prof. Electrical Engineering
Dr. Robert J. Lad, Prof. Physics & Director of LASST
Dr. William J. Desisto, Assist. Prof. Chemical Engineering

Advanced Engineered Wood Composites Center:

Dr. Eric Landis, Assoc. Prof. Civil & Environmental Engineering
Dr. Michael Peterson, Assoc. Prof. Mechanical Engineering

National Center for Geographic Information and Analysis:

RET: Sensors! co-PI Dr. Constance Holden, Instructor, Spatial Information Science and Engineering
Dr. Peggy Agouris, Assist. Prof. Spatial Information and Engineering
Dr. Anthony Stefanidis, Assist. Prof. of Spatial Information and Engineering

Activities and Findings

Research and Education Activities:

2009 RET Program

2009 RET participant Reginald Ruhlin teaches mathematics at Brewer High School, Brewer Maine. He worked with PI John Vetelino, assisted by University of Maine masters' candidate Jason McGann and visiting researcher Christian Peters, from Magdeburg University (Germany), at UM-LASST as part of an international PhD-research exchange. Ruhlin also interacted regularly with NSF-REU minority participant Ernest Jones, a junior CEN major from Benedict College, Columbia, SC, whose research was closely related to Ruhlin's.

Abstract

Industry and research laboratories need the ability to deposit thin films in the 10^(-9) m (nanometer) to 10^(-6) m (micron) range. Currently, the industry standard in thin film monitoring systems is the use of a quartz crystal microbalance (QCM) sensor. Previous work by University of Maine graduate student Kris Sgambato1 examined the feasibility of using Lateral Field Excited (LFE) sensors as a replacement for the QCM technology, hoping to show that the bare sensing surface of a LFE sensor would provide increased sensitivity to mass loading when compared to a QCM sensor, thus providing improved monitoring of thin film deposition systems.

While Sgambato?s previous work showed no significant differences between the LFE and QCM rate monitors, two factors were not considered: 1) the effect of clamping stress caused by contact between the crystal and the electrode that induces the acoustical wave; and 2) the effect of the LFE sensor location relative to the QCM sensor location within the deposition chamber. This work will attempt to eliminate both of these effects and then compare sensitivities of LFE and QCM sensors.

2008 RET Program

1. 2008 RET Laura Matthews teaches 7th grade science at Reeds-Brook Middle School in Hampden, ME. She worked with advisor Dr. John Vetelino, electrical and computer engineering, assisted by graduate researchers Donald McCann and Mitchell Wark.

ABSTRACT

Current methods of testing for the deadly red-tide toxin saxitoxin are time-consuming, expensive, and ethically questionable, leading to a demand for a more appropriate in situ test. In order to create a better sensor, a Lateral Field Excited acoustic wave sensor has been developed using an 18-crown-6-ether film that is sensitive to saxitoxin. After testing in deionized water, salt, and seawater this film was found to detect any cation, rendering it useless. In order to improve the selectivity without damaging sensitivity, an alternate film that would simulate a sodium channel is being researched. Once this sensor is perfected it would allow coastlines everywhere to quickly and definitively determine if their shellfish are suitable for consumption.

2. 2008 RET Terrence Tibbetts teaches 6th grade science at William S. Cohen Middle School in Bangor, ME. Mr. Tibbetts worked with advisor Dr. John Vetelino, electrical and

computer engineering, assisted by graduate researcher Mitchell Wark.

ABSTRACT

Organophosphate pesticides can cause damage to the human nervous system if they are ingested. The organophosphate pesticide, phosmet, is used on wild blueberries in StateplaceMaine. Researchers at the placePlaceTypeUniversity of PlaceNameMaine have recognized the need for an accurate, low cost, portable sensor to detect harmful levels of pesticides. Their work during the summer of 2008 included collaboration with Umaine Food Science experts, Maine blueberry growers, and the use of lateral field excited sensors to detect phosmet.

3. 2008 RET Patrick Tracy teaches 7th grade science at Caravel Middle School. Mr. Tracy worked with advisor Dr. John Vetelino, electrical and computer engineering, assisted by graduate researcher Shane Winters.

ABSTRACT

A rapid detection system is required to recognize biomolecules and other substances that may be harmful. Various methods, such as enzyme-linked immunosorbernt assays have been employed, however, individual samples and excessive time are required to sense harmful substances. During a research experience in 2008, Monolithic Spiral Coil Acoustic Transductor (MSCAT) sensors, which utilize a bare spiral coil antenna and that detection surface that can monitor mechanical and electrical shifts in a specific biochemical film, were used for E.coli detection. Lab procedures evaluated the MSCAT response to our anti-rabbit IgG sensing film and Escherichia coli (E.coli 0157:H7) as a specific analyte.

2007 RET Program

1. 2007 RET Jeff Langevin teaches mathematics at Hermon High School. Mr. Langevin worked with advisor Dr. John Vetelino, electrical and computer engineering, assisted by graduate researcher Joel Ngue Mba.

ABSTRACT

Conductivity Changes in Tungsten Trioxide (WO3) When Exposed to Various Gases and Humidities

The objective of our experiment is to observe and encapsulate the conductivity changes in Tungsten Trioxide (WO3) when it is exposed to various gases and to humidity. WO3 is a semi-conducting metal oxide (SMO), which is used in a number of gas sensors. Based on our experiment, we will identify any cross-sensitivity problems as well as any selectivity problems.
We have two models for our experiment. The first model consists of a thin film of WO3 deposited onto a sapphire substrate, connecting electrodes above or embedded in the substrate, and placing all of this on top of a heating element. By varying the experimental parameters (frequency range, film thickness, temperature, and film structure), we will be able to capture the film?s conductivity response to various gases and to humidity.
The method used to measure the conductivity response of the WO3 is called impedance spectroscopy (IS):

Impedance Spectroscopy measures the impedance by applying a single-frequency voltage or current to the interface and measuring the phase shift and amplitude, or real and imaginary parts, of the resulting current at the frequency using either analog circuit or fast

Fourier transform analysis of response.

From the data provided via impedance spectroscopy, we will fit the experimental response to that of an equivalent circuit.
The second substrate we will be using is quartz, which is a piezoelectric material:

Piezoelectricity is the ability of some materials to generate an electric charge in response to applied mechanical stress. If the materials is not short-circuited, the applied charge induces a voltage across the materials.

A thin film of WO3 will be deposited onto the surface of a quartz substrate and two metal electrical connectors will be attached to the bottom of the quartz, which results in an electric field in the plane of the plate. This type of sensor is known as a lateral field excited acoustic wave sensor (an LFE sensor):

Acoustic wave sensors are described by the mode of wave propagation through the substrate. As the acoustic wave propagates through the surface of the quartz, any changes to the characteristics of the propagation path affect the velocity and/or amplitude of the wave. Changes in velocity can be monitored by measuring the frequency or phase characteristics of the sensor and can then be correlated to the corresponding physical quantity being measured.

Similar to IS, the data will be fitted to that of an equivalent circuit.
In closing, our experiment should capture whatever changes happen to the thin film WO3 while it?s being exposed to various gases and to humidity. Our goal is to gain knowledge of cross-sensitivity and selectivity issues with thin film WO3.

References quoted:

Barsoukov & Macdonald, Impedance Spectroscopy: Theory, Experiment, and Applications, (Wiley-Interscience 2005) 4.

Wikipedia: The Free Encyclopedia, http://en.wikipedia.org/wiki/Piezoelectricity.

Y. Hu, L. French Jr., K. Radecsky, M. Pereira da Cunha, P. Millard, and J. Vetelino, ?A Lateral Field Excited Liquid Acoustic Wave Sensor,? IEEE Transactions on Ultrasonics, Feeoelectrics, and Frequency Control, vol. 51, No. 11, Nov. 2004, pp. 1373-1379.

B. Drafts, ?Sensors,? HYPERLINK 'http://www.sensorsmag.com/sensors/article/articleDetail.jsp?id=327439' http://www.sensorsmag.com/sensors/article/articleDetail.jsp?id=327439, Oct. 2000.

2. 2007 RET Frank Page teaches 7th grade science at Brewer Middle School. Mr. Page worked with advisor Dr. John Vetelino, elecrical and computer engineering, assisted by graduate researcher William 'Kyle' Spratt.

ABSTRACT

Measuring the density of fluids and gases using torsional waves in various waveguides

The first portion of the project involves assisting Kyle Spratt and Radek Glaser in their research on the above task. My role will be to contribute to the design of ideas and assist with the data collection and analysis.

Milestones:

--Construct a waveguide/transducer stand that is adjustable for various waveguide diameters and lengths
--Re-construct experiment performed in Materials Evaluation, June 2004, to verify results and find optimum waveguide dimensions
--Compare sensitivities of four waveguide materials
1. XT Graphite
2. Commercially Pure Titanium
3. 6010 Aluminum
4. 316 Stainless Steel

--Design and construct pressure vessel to test feasibility of sensor measurement in various types of gases:
1. Vacuum
2. Air
3. Helium
4. Argon
5. Steam

--Repeat gas testing but vary temperature to see what effects this has on results
--Calibrate RMG bluff body as a density sensor and record its sensitivity

The second component to the summer program will be the design, development and implementation of the sensor concepts into the seventh grade curriculum at Brewer Middle School; my instructional practice encompasses conceptual physics. I will be applying newly created laboratory experiments utilizing temperature, motion, and friction sensors purchased from the Vernier Corporation. The instruction on sensors will be interfaced with Apple laptops?especially with respect to data collection and analysis. All experiments will be written and aligned with the Maine learning Results. The experiments will be executed throughout the 2007-08 school year with the assistance of GK-12 fellow Kyle Spratt.

Equipment Purchases:
--Temperature Sensor
--Motion Sensor
--Dual Range Force Sensor
--Interface Links

Sample Laboratory Experiments:
--Greenhouse Effects
--Relative Humidity
--Heating of Land & Water
--Effect of salt on boiling and freezing points of water
--Velocity
--Falling objects
--First class levers
--Pulleys
--Buoyancy

2006 RET Program

1. 2006 RET Joanne Adair teaches biology at Brewer High School. Ms. Adair worked with

advisor Dr. Paul Millard, biological engineering, assisted by graduate researcher Erik McCarthy.

ABSTRACT

Detecting ISAV IHNV Using Molecular Padlock Probes

Background:
The purpose of this study is to develop a technique to detect ISAV (Infectious Salmon Anemia Virus) and IHNV (Infectious Hematpoetic Necrosis Virus) that utilizes a reusable sensing device. The sensing technique has been created, but work still needs to be done regarding the optimum parameters of the established protocols.

Prior Research & Experiments:
Originally, biotin was used on the gold substrate, as it has an extremely high affinity for avidin, the protein attached to the probe, and which will attach to the biotin (or DSB ? which has a lower affinity for avidin) to affect a measurable change. The affinity for biotin to avidin is so high, however, that to break the bonds between them denatured everything else, rendering the substances useless. As a result, DSB was used, however, DSB alone on the substrate produced minimal results. The solution was to apply something else between the substrate and the DSB. A protein was used, which gave good results, but worked using polystyrene as a substrate (not good for a sensor), so a dendrimer was laid down, which yielded good results.

Summer Research Steps:
- Test simple hot water stripping of biotin and avidin
- Find optimum D-Biotin competition concentrations and incubation times
- Find optimum probe concentrations for cMPP amplification
- Test cMPP amplification results using hot water pre-rinsing
- Test amplification and regeneration at room temperature using D-biotin and other detergents as stripping agents

2. 2006 RET Marti Dayton teaches mathematics at Ellsworth High School. Ms. Dayton worked with advisor (and RET: Sensors! PI) Dr. John Vetelino, electrical engineering, assisted by John Peckenham, Assistant Director/Senior Research Scientist, Senator George Mitchell Center for Environmental and Watershed Research.

ABSTRACT

In?Situ pH and Conductivity Sensor Development

Although currently there are many commercial sensors readily available for the detection of pH and conductivity, there yet remains to be one that is economically feasible and maintains a wide variety of sensitivity. The goal then, is to design a sensor array to detect changes in pH in addition to determining the levels of conductivity of water within a specific water sample and/or well. The various pH levels will be tested, ranging from a pH of 1 to 14, using DI water as our initial substance. The solution will be brought down to an acid, reneutralized and then brought up to a base. With respect to conductivity, the anions that commonly contribute to conductivity include chloride, nitrate and sulfate, while the cations are sodium, magnesium, calcium, ammonium, iron and aluminum. Although natural salts in water are essential to organisms, in excess, they could cause harm. Conductivity ranges in this area are from 50μS/cm and 2000μS/cm, and therefore the sensor must be sensitive enough to detect conductivity changes within this range. In an attempt to keep cost to a minimum while not compromising sensitivity, the type of sensor that will be used is what is commonly referred to as the Lateral Field Excited (LFE) Device. This is an acoustic wave sensor that offers in-situ monitoring qualities. It is a reliable, fast responding real-time detector that has the sensitivity required to detect even

the minutest changes in pH and conductivity. The long-range goal is to develop a series of sensors that can quickly and accurately detect various components that might indicate well damage or pollution.

3. 2006 RET Debra Merrill teaches chemistry at Hermon High School. Ms. Merrill worked with advisor Dr. Scott Collins, chemistry and researcher at Laboratory for Surface Science and Technology.

ABSTRACT

Watching Paint Dry with NMR

Nuclear Magnetic Resonance Spectroscopy (NMR) is one of the most powerful tools available to the chemist for the determining the structure of solvated species. It is a non-invasive technique that is based upon the absorption of radio waves by the nucleus of certain isotopes. This project proposes to use the NMR to study the structural changes that occur during the drying of a polymer colloid, specifically, latex paint. Previous studies have shown that the drying of paint represents the change from an aqueous dispersion to a hardened film. This change occurs in 4 distinct stages, evaporation, deformation, coalescence and finally cross-linking between the molecular chains to create the solid film. Even though latex paint is well studied, specific molecular interactions during the drying process are not yet fully understood. In addition to analyzing structural changes that occur as the latex beads coalesce, interactions between the latex and the surface to which the paint is applied will also be analyzed. A micro-NMR coil, specifically designed to analyze surface interactions, will be utilized during this study. The use of the micro-coil will simulate possible real-time monitoring that would be required in a production facility.

4. 2006 RET David Ploch teaches biology at Old Town High School. Mr. Ploch worked with advisors Dr. Laurie Connell, marine sciences, and Dr. David Neivandt, chemical engineering, assisted by chemical engineering post-doc Joerg Fick.

ABSTRACT

Saxitoxin - Detection by Capture

Paralytic shellfish poisoning (PSP) is caused by consumption of shellfish that have ingested toxic algae such as Alexandrium ssp. containing saxitoxin. Extensive and expensive monitoring is used by coastal states such as Maine in order to protect populations and to regulate the shellfish industry. The current accepted test is the mouse bioassay. This test requires a lab to inject the sample into three mice and use time to mortality to calculate toxin concentration. The mouse bioassay is limited to 37 micrograms PSP/100 grams of sample. Lethal dose in humans is one to three milligrams. An easy to use rapid response detection device in situ would save valuable time, therefore saving lives. Coordinated test sites would provide multiple data points that would improve management of the shellfish industry by shutting down only the areas at risk and not the current broad geographic areas due to current testing limits. The objective of the project is to create a device that will link electronics, surface technologies and biochemistry in order to directly measure saxitoxin presence. The device could measure in the ocean (buoy mount), or perhaps directly from tissue samples of shell fish. Ongoing work is employing a crown ether to capture the saxitoxin. The crown ether is tethered to the surface of a sensing device. A novel alternative to the crown ether approach is being investigated specifically using a zeolite filtering system. Zeolites can be natural or manmade porous minerals. Zeolites are usually hydrated alumino-silicates that readily accommodate positive ions. The zeolite filtering will become part of a device that will link electronics, surface technologies and biochemistry in order to directly measure saxitoxin presence. The short term outcomes are expected to be determination of affinity for saxitoxin of zeolite materials using

florescence and other lab techniques. The long term goal is a fast functional sensor for saxitoxin and perhaps other toxins in an array system produced by a Maine company.

5. 2006 RET Sue Wentworth teaches middle school science at Indian Island School, Old Town, ME. Ms. Wentworth worked with advisor (and RET: Sensors! co-PI) Dr. Connie Holden, spatial engineering.

ABSTRACT

Virtual Preservation Using ArcGIS

This project involves the virtual preservation of sugar plantation structures and the historical record of the enslavement of thousands of Africans in the West Indies to produce sugar in the seventeenth, eighteenth, and nineteenth centuries on plantations located in the Virgin Islands National Park (VINP), St. John, Virgin Islands. Over 500 structures exist in the VINP, most in ruins or well on their way. It is critical to locate and model the structures accurately on a three-dimensional model of the island. The project focuses in utilizing surveying and geographic information systems, to be able to better locate and map the structures on the ground of the island.

Data to construct a digital model and appropriate features will be used to develop an image of the three-dimensional structure.

Findings:

2009 Findings:

See Appendix 21 in attached file.

2008 Findings:

Laura Matthews:

See Appendix 12 in attached file.

Terrence Tibbetts:

See Appendix 13 in attached file.

Patrick Tracy:

See Appendix 14 in attached file.

2007 Findings:

Jeff Langevin:

The sensor studied involved a thin coat of WO3 deposited on a sapphire substrate. On top

of the substrate are electrodes, and below the substrate is a heating element. Electrical properties were measured by impedance spectroscopy. The resistance of the the sensor decreased from room temperature to approximately 370o C and then increased until 400o C. This may be attributable to a crystal phase change of the Tungsten Trioxide. Heating the sensor to 400C for 16 hours produced a considerable increase in resistance. The change happened at low frequency (below 1000 Hz). This indicates a change in the behavior at the grain boundary.

Frank Page:

The target goal was to successfully reproduce ultrasonic torsional echoes generated by a shear transducer onto a waveguide similar to that in Nguyen's 2004 Materials Evaluation paper. Several steps were involved in achieving the target goal: A device was constructed for mounting electronics and waveguide with a testing apparatus. The first four weeks were devoted to constructing 3D models using SolidWorks software to optimize both design and machining. Two systems were identified: 1.A fully adjustable waveguide/transducer mounting rack that could support all electronics and still be run through tests; 2. A gas chamber rated up to 1,000 psi with a complex adjustable gasket that works with the waveguide system. Thereafter, a study of variations of burst widths, frequencies, waveguide designs and transducer configurations was conducted and results documented. The purpose of the study was to determine methods for generating clean reflections using equipment and working with the equipment designed. As a result of this work, LASST researchers have established a method for generating torsional waves and recovering their reflections.

2006 Findings:

Joanne Adair:

The ability to detect fish pathogens is a great asset to Maine's fishing industry; being able to do so quickly and repeatedly is ideal. Previous biosensor research has culminated in a technique for detecting both IHNV and ISAV in Maine's salmon population. This summer, Joanne worked to optimize the parameters for regeneration of the biofilms, as well as confirm the efficacy of materials being used. Joanne's work suggests that DSB is a viable alternative to Biotin for this regenerative biosensor, however some conditions still need to be optimized.

Marti Dayton:

This summer, I worked on determining the sensitivity of the LFE with respect to the levels of conductivity and pH commonly found in well water. We found the LFE to be extremely reliable and of comparable sensitivity with other sensors commonly being used and marketed for such tests. It provided extremely accurate results within the specified parameters. It is our hope that by doing further tests, that we will be able to develop a multi-parameter sensor using the LFE. The next step would be to design a LFE that can determine the amount of dissolved oxygen in water.

Debra Merrill:

NMR spectroscopy is a powerful tool used to investigate molecular structure. Recent research efforts have been focused on the development of micro radio frequency coils that can be used in the analysis of nanoliter sized samples. Debra assisted in the development and testing of a new micro-coil design that can be utilized to examine surface interaction between cross-linked polymers and various substrates.

Dave Ploch:

Paralytic shellfish poisoning (PSP), commonly associated with 'Red Tide', is a major health threat with serious economic impacts. The current test for the toxins that cause PSP is to inject test material in mice (mouse bioassay) and observe time to death. Development of a fast in situ sensor is the goal of current research. Zeolites (a naturally occurring porous mineral) were tested for their ability to 'capture' saxitoxin, one of the main toxins causing PSP. Continued testing will determine the viability of this strategy.

Sue Wentworth:

Virtually preserving the historical record of the enslavement of thousands of Africans in the West Indies is the goal of University of Maine researchers. Using data collected by a variety of sensors, Sue researched and helped create a geographic information system for one of the structures. It is hoped that in the future the Park service will have the funding to use this information to restore the structure to its present condition.

Training and Development:

2009 Training and Development

* Project Title and Research Supervisor/s:

Refer to Table 6.

*Recruitment and Selection Process:

Project Announcement Distribution

Written announcements (see Appendix 19) were first mailed to principals of middle and high schools in mid-central Maine, with follow-ups to systems already participating in the closely allied NSF GK-12 Sensors! program (John Vetelino, PI). A subsequent, similar mailing was addressed to teachers identified by principals as potential RET candidates. An announcement (see Appendix 20) was also placed on the University of Maine Department of Electrical and Computer Engineering website.

Applications

Two teachers applied to the NSF-RET program (see Table 7). Applications consisted of a letter of intent and a letter of reference from a school administrator.

Method of Participant Selection

Teachers applying for the NSF-RET taught in STEM-related fields in middle or high schools. Consideration was based on the quality of the letter of intent and strength of reference letter, the number of years teacher taught in STEM-related field, number of years teacher taught at current institution, and expressed interest in pursuing sensor-related curricular integration. Special consideration was also given to women, minorities and/or handicapped persons. Final selections for participation in the NSF-RET program were made by the PI and co-PI.

Participating Teachers and Faculty

One teacher and one faculty advisor participated in the NSF-RET program. One man (Reginald Ruhlin) participated in the program. NOTE: A second candidate, Ms. Gott, of Veazie Community School, was also accepted, but declined the offer due to irreconcilable schedule conflicts.

*Adjunct Activities:

The NSF-RET teacher was involved in several activities related to his NSF-RET participation. The teacher was given special instructions relative to research activities such as laboratory safety, research ethics and report writing. Particular emphasis was placed on relating the teacher?s research to problems understood by people not in mainstream science and engineering. The teacher also attended and participated in regular research meetings and collaborated with NSF-GK-12 Sensors! fellows, developing strategies for curricular integration of sensors science and the RET experience. (See appendices 1, 2, 12, 13, 14 for details.)

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Previous Year Reports:

* Project Title and Research Supervisor/s:

2008: Refer to Table 5.
2007: Refer to Table 4.
2006: Refer to Table 1.

*Recruitment and Selection Process:

Project Announcement Distribution

2008: Written announcements (see Appendix 15) were mailed to principals of select middle schools in systems that participate in the closely allied NSF GK-12 Sensors! program (John Vetelino, PI) and to teachers identified by former RET-Sensors! participants (see Appendix 16). A subsequent mailing was addressed to teachers identified by principals as potential RET candidates. An announcement (see Appendix 17) was also placed on the University of Maine Department of Electrical and Computer Engineering website.

2007: Written announcements (see Appendix 7) were mailed first to principals of middle and high schools throughout central Maine (predominantly to rural schools), including schools already participating in the closely allied NSF GK-12 Sensors! program (John Vetelino, PI). A subsequent mailing (see Appendix 8) was addressed to teachers identified by principals as potential RET candidates. An announcement was also circulated online (see Appendix 9; also http://www.eece.maine.edu/research/ret/2007RETFellowships.pdf).

2006: Soon after the official announcement of the RET sites was made by NSF, written announcements were mailed to solicit applicants to the program. The announcements (see Appendix 5) were mailed to STEM teachers in middle and high schools throughout central Maine and Portland, predominantly to rural schools. It was the intent of this wide distribution of the announcement to generate a significant applicant pool of qualified women, minorities and teachers with disabilities for the NSF-RET program.

Applications

2008: Three teachers applied to the NSF-RET program. Applications consisted of a letter of intent and a letter of reference from a school administrator.

2007: Two teachers applied to the NSF-RET program. Applications consisted of a letter of intent and a letter of reference from a school administrator.

2006: A total of 12 teachers applied to the NSF-RET program. Applications consisted of a letter of intent and a letter of reference from a school administrator. A listing of applicants and schools is presented in Table 2.

Method of Participant Selection

2008: Teachers applying for the NSF-RET taught in STEM-related fields in middle schools. Consideration was based on the quality of the letter of intent and strength of reference letter, the number of years teacher taught in STEM-related field, number of years teacher taught at current institution, and expressed interest in pursuing sensor-related curricular integration. Special consideration was also given to women, minorities and handicapped persons. The final selections for participation in the NSF-RET program were made by the PI and co-PI.

2007: The teachers applying for the NSF-RET taught in STEM-related fields in high or middle school. Consideration was based on the quality of the letter of intent and strength of reference letter, the number of years teacher taught in STEM-related field, number of years teacher taught at current institution, and expressed interest in pursuing sensor-related curricular integration. Selections for participation were made by the PI and co-PI.

2006: The teachers applying for the NSF-RET taught in STEM-related fields in high or middle school. Consideration was based on the quality of the letter of intent and strength of reference letter, the number of years teacher taught in STEM-related field, number of years teacher taught at current institution, and expressed interest in pursuing sensor-related curricular integration. Special consideration was also given to women, minorities and handicapped persons. The final selections for participation in the NSF-RET program were made by the PI and co-PI.

Participating Teachers and Faculty

2008: Three teachers and one faculty advisor participated in the NSF-RET program. One woman (Laura Matthews) and two men (Terrence Tibbetts, Patrick Tracy) participated in the program.

2007: Two teachers and one faculty advisor participated in the NSF-RET program. Two men (Jeff Langevin and Frank Page) participated in the program.

2006: A total of five teachers and five faculty members participated in the NSF-RET program. Four women (Joanne Adair, Marti Dayton, Debra Merrill and Sue Wentworth), one man (David Ploch) and one minority teacher (Marti Dayton) participated in the program. A listing of teachers and their research supervisors is presented in Table 3.

*Adjunct Activities:

2006-2008: The NSF-RET teachers were involved in several activities related to their NSF-RET participation. Teachers were given special instructions relative to research activities such as laboratory safety, research ethics and report writing. Particular emphasis was placed on relating the teacher?s research to problems understood by people not in mainstream science and engineering. Teachers were required to attend and participate in seminars presented by faculty and outside speakers. Teachers also participated in workshops with NSF-GK-12 Sensors! fellows, developing strategies for and examples of curricular integration. (See appendices 1, 2, 12, 13, 14 for details.)

Outreach Activities:

Refer to appendices 1, 2, 3, 4, 10 and 18 in attached file.

Journal Publications

Arsenault, Joe, Stephen Godsoe, Constance Holden, John Vetelino, "Integration of Sensors into Secondary School Classrooms", Proceedings of the 35th Annual Frontiers in Education Conference, Indianapolis, Indiana, p. S2F-33, vol. October, (2005). Published,

Arsenault, Joe, Stephen Godsoe, Constance Holden, Brian Doore, John Vetelino, "Work In Progress: Integration of Sensors into Middle School Classrooms", Proceedings of the 36th Annual Frontiers in Education Conference, San Diego, CA
, p. M1C3, vol. October, (2006). Published,

Crowley, Adam, Stephen Godsoe, Constance Holden, John Vetelino, "Work In Progress: Integration of Sensors into High School Classrooms", Proceedings of the 34th Annual Frontiers in Education Conference, Savannah, Georgia, p. F4D-12, vol. October, (2004). Published,

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Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Please refer to Journal Publications, Books and One Time Publications, and Findings in Activities and Findings.

Contributions to Other Disciplines:

Since the NSF-RET Program is focused on the area of sensors which is interdisciplinary, teachers work very closely with faculty and researchers across disciplines.

2009 projects focused on design, fabrication and testing of sensing platforms with applications in thin films manufacturing.

2008 projects focused on design, fabrication and testing of sensing platforms with bio-sensing applications.

Contributions to Human Resource Development:

2009: One teacher participated in the program, working with the PI to develop his research topic. The teacher was given preliminary reading material. The project director held informal discussions with the participant weekly throughout the duration of the program. The participant kept a notebook of his activities which enabled other people in his research area to benefit from the work and presented a final report (see Appendix 21).

The project director and other faculty members participating in the NSF-RET program believe the research and educational experience gained by participating teachers has a noticeable effect on curricula in area middle- and high-schools that participate in GK-12 Sensors!. Please refer to Appendices 1, 2, 3, 4 and 18 for details.

Research projects involved in the NSF-RET program also benefited in terms of the results of participant research.

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2008: The NSF-RET program as outlined in the original proposal proceeded in a very coherent fashion throughout. Three teachers participated in the program. Each participant worked with the PI to develop her/his research topic and supervisor and was given preliminary reading material. The project director held informal discussions with each participant weekly throughout the duration of the program. Each participant kept a notebook of his activities which enabled other people in his research area to benefit from the work. The RET participants 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 presentation session was held at which each RET made a PowerPoint presentation of her/his research findings and proposals for curricular integration of sensor science and engineering. The RET presentations were attended by faculty and graduate advisors.

The project director and other faculty members participating in the NSF-RET program believe the research and educational experience gained by the teachers during the summer has had a noticeable effect on curricula in area middle- and high-schools that participate in GK-12 Sensors!. Please refer to Appendices 1, 2, 3, 4 and 18 for details.

Research projects involved in the NSF-RET program also benefited in terms of the results of participant research.

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2007: The NSF-RET program as outlined in the original proposal proceeded in a very coherent fashion throughout. A total of 2 teachers participated in the program. Each participant chose his research topic and supervisor and was given preliminary reading material. The project director held informal discussions with each participant and his research supervisor periodically throughout the duration of the program. Each participant kept a notebook of activities which enabled other people in his research area to benefit from the work. The RET participants 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 conference was held at which each RET made a PowerPoint presentation of his research findings and proposals for curricular integration of sensor science and engineering. The RET conference was attended not only by faculty and graduate advisors but participating GK-12 teachers, including former RET: Sensors! participants, LASST faculty, and other people both inside and outside the University of Maine.

The project director and other faculty members participating in the NSF-RET program believe the research and educational experience gained by the teachers during the summer has had a noticeable effect on curricula in area middle- and high-schools that participate in GK-12 Sensors!. Please refer to Appendices 1, 2, 3, 4 and 10 for details. An example of direct impact is contained in Appendix 11.

The research projects of faculty members involved in the NSF-RET program also benefited in terms of the results of participant research.

In conclusion, the 2007 NSF-RET program was a success that gave both the teachers and the University an excellent experience in both research and teaching, generating 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-RET program.

2006: The NSF-RET program as outlined in the original proposal proceeded in a very coherent fashion throughout. A total of 5 teachers (four women, one a minority teacher) participated in the program. Each participant chose his/her research topic and supervisor and was given preliminary reading material. 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 RET participants 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 was held in which each RET made PowerPoint presentations of their research findings and proposals for curricular integration of sensor science and engineering. The RET conference was attended not only by faculty and graduate advisors but participating GK-12 teachers, including former RET: Sensors! participants, LASST faculty, and other people both inside and outside the University of Maine. This workshop also served to provide 2006 RETs and all 2006-07 participating GK-12 Sensors! teachers and fellows an opportunity to plan interactions in and out of the classroom during the 2006-07 school year (see Appendix 6).

The project director and other faculty members participating in the NSF-RET program believe the research and educational experience gained by the teachers during the summer has had a noticeable effect on curricula in area middle- and high-schools that

participate in GK-12 Sensors!. Refer to appendices 1, 2, 3 & 4 in attached file for details.

The research projects of faculty members involved in the NSF-RET program also benefited in terms of the results of participant research.

In conclusion, the 2006 NSF-RET program was an outstanding success that gave both the teachers and the University an excellent experience in both research and teaching, generating 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-RET program.

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Refer to appendices 1, 2, 3, 4,10 and 18 in attached file, and to Publications and Products.

Conference Proceedings

Categories for which nothing is reported:

Any Web/Internet Site

Any Product

Contributions: To Any Resources for Research and Education

Any Conference