Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID: 049-B**

Wireless Biosensing for Monitoring of Aquatic Ecosystems

Category: B. Water Resources

Total Project Budget: $ 981,249

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

Specifically we propose to develop a microchip device that produces wireless signal using the nutrient content from the targeted system. The signal is generated with a microbial system whose growth

Name: Ping Wang

Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Self-powered miniaturized biosensor chips with remote wireless communication capability will be developed for real time data acquisition on water quality over large areas. Photo of biofuel cell device. Stand-alone design of a biofuel cell developed from previous work in the PI's lab, such devices will be further optimized and designed for lab-on-a-chip structure for the proposed biosensing application; (b) Proposed field wireless monitoring and data analysis via a biosensor network for real-time monitoring of large areas.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage		_____ TOTAL

PROJECT TITLE: Wireless Biosensing for Monitoring of Aquatic Ecosystems

I. PROJECT STATEMENT

Healthy aquatic ecosystems are vitally important to the sustainability of the natural resources and environment in Minnesota. This project seeks the development of novel self-powered miniaturized biosensor chips with remote wireless communication capability for real time data acquisition and remote collection of health quality of aquatic ecosystems. The biosensor microchip will integrate a radio generation unit powered by an electrical power generation biofuel cell unit following a lab-on-a-chip design concept. Environmentally friendly carbon materials supporting a microbial consortium will be deployed for the biofuel cell, which produces electrical power using nutrition contents from the hosting aquatic systems. Since the strength of the radio signal will vary in accordance to the microbial growth rate that is sensitive to the health quality of the hosting environment, the radio signals generated from such a device should serve the purposes of sensing and evaluation of natural ecosystems. Bio-contamination including high levels of nitrates, phosphates and carbohydrates may generate signals stronger than those from normal referee conditions; while toxic conditions including exposure to chemical pollutants may inhibit the microbial growth, and thus weaker signals are expected. In addition, overwhelmingly strong changes in signals may indicate significant environmental interruptions, such as unexpected large-scale death of animals or plants, destructive human activities, or activities of invasive species.

The overall goal of the project is to develop microchip biosensor technology that can be used for remote monitoring and evaluation of the gross toxicity and contamination of aquatic ecosystems in Minnesota. Such biosensors can be distributed over large areas of either underground or surface waters, providing data for the health quality of natural water resources that are important to wildlife, humans, and aquatic and terrestrial species; it also facilitates implementation of environmental standards for nitrates or other contaminants. The self-powering nature of the biosensors should allow them to work for extended period of time. Our long-term goals are to expand the application of novel biosensor concept as a new platform technology for a broader spectrum of environmental quality controls such as antibiotic and heavy metal contamination, as well as in form of implantable miniaturized devices for health monitoring of moving targets such as fish and animals.

Research activities proposed include both lab-based experiments and field tests. The lab-based experiments will explore the integration of biofuel cell and radio signal generation units, and further establish the baseline correlations between signal strength and environmental quality. Field tests will be conducted in the later stage of the project to evaluate the compatibility and sensitivity of prototype devices with the targeted environment.

II. PROJECT ACTIVITIES AND OUTCOMES

The project will be implemented through three phases. Phase I will focus on the test of quantitative correlation between microbial growth, power generation, signal generation to establish the integration of biofuel cell and radio generation units. Phase II is to evaluate and improving the sensitivity of the devices corresponding to the microbial growth condition in terms of environmental quality by varying the concentrations of nitrates, phosphates, carbohydrates, and toxic chemicals such as chlorinated chemical compounds that found as water contaminants in Minnesota. The third phase is to develop biosensor systems for field tests to evaluate their reliability and sensitivity. Specific activities are provided below.

Activity 1: Development of biofuel cells for radio signal generation **Budget: $328,576**

Microbial species that can form microfilms on surface of environmentally friendly carbon materials will be examined for power generation. The biofuel cell unit will be evaluated for lab-based radio generation. Signal collection and analysis will also be developed to evaluate the performance of the devices with respect to its preferred standard conditions, providing the baseline calibration for health quality of the targeted aquatic ecosystems.

Outcome	Completion Date
1. Biofuel cells with microbial consortium power generation	*Nov. 1, 2015*

2. Realization of radio generation and collection with biofuel cells	*Feb. 1, 2016*
3. Knowledge of system constraints and capability of the biosensor system	*June 30, 2016*

Activity 2: Devices performance evaluation in lab-based tests **Budget: $318,509**

Portable biosensor systems with integrated biofuel cell and signal generation units will be developed for lab-based experiments in aqueous medium mimicking environmental variations. Experiments are to evaluate the performance of the biosensor systems with respect to toxicity and nutrition level of water. Toxicity will be controlled by addition of contaminants such as heavy metals, antibiotics, and organic pollutants; nutrition variation will be realized by controlling the concentrations of nitrates, phosphates and carbohydrates. Data analysis will be conducted to establish correlation between wireless signals and health quality of water.

Outcome	Completion Date
1. Portable biosensor devices for lab-based experiments	*Sept. 30, 2016*
2. Baseline Correlation and data analysis for water quality	*May 1, 2017*
3. Biosensor optimization and miniaturization	*June 30, 2017*

Activity 3: Field tests of prototype self-powered biosensor devices **Budget: $334,164**

Development of miniaturized devices with microchip designs for optimized interfacing with surrounding water environment for field tests. The prototype devices will be developed for tests at the bottom of rivers and lakes, as well as top layer waters with ground attachment. Radio signals will be collected from deployed sites on a weekly basis, along with water samples taken for lab-based gross toxicity analysis and concentrations of nutrition and chemical species, thus establishing quantitative correlation between biosensor signal strength and water quality.

Outcome	Completion Date
1 Miniaturized remote biosensor devices with environmental compatibility design	*March 31, 2018*
2. Data Collection of river and lake ecosystems (both winter and summer seasons)	*May 31, 2018*
3. Performance assessment and plan for future development and implementation	*June 30, 2018*

III. PROJECT STRATEGY

A. Project Team/Partners

The research team has demonstrated ability and expertise that are needed for the proposed research.
Prof. Ping Wang, PI of the project, serves as the leader, supervisor and manager of the research team;
Dr. Xueyan Zhao, Senior Research Associate, is responsible for biofuel cells and microbial growth;
Mr. Benjamin Frigo, Product Engineer and Technician, microbiology research and product development;
Postdoc Researcher (to be recruited), electronic device and circuit design, wireless communication; and
Two doctoral graduate students (to be recruited), one on biotechnology, the other on natural resources.

B. Project Impact and Long-Term Strategy

This project promotes capability of monitoring and evaluation of natural water resources and wildlife, facilitating data collection and sharing in Minnesota. It serves the need for sustainability development of natural water resources, aquatic ecosystems and wildlife.

C. Timeline Requirements

The proposed research activities are divided into three phases with goals and outcomes suited to achieve within three years for the research team. Activity 1 to be conducted during a period of the firs budget year, Activity 2 will be finished within the 2nd year, and Activity 3 will take place in the third year of the project.

2015 Detailed Project Budget

Project Title: Wireless Remote Biosensing for Monitoring and Evaluation of Aquatic Ecosystems

IV. TOTAL ENRTF REQUEST BUDGET *[Insert # of years for project]* **years**

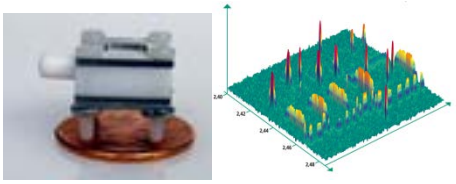
BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel:	$ 849,249
PI (about 1.5 Months) per year (75%salary/25%fringe) - $75,000	
Research associate; 1 FTE (75% salary/25% fringe) - $174,000	
Product development engineer; 1 FTE (79% salary/21% fringe) - $148,500	
Electrical engineering post-doc, 1 FTE; (75% salary/25% fringe - $186,000	
Two PhD graduate students 1 FTE (58% salary/42% fringe) - $265,749	
Contracts: Electronic Circuit Design for prototype devices, radio generation and collection systems with digital strenth reading	$ 25,000
Equipment/Tools/Supplies: Construction of 60 biofuel cell devices for totally about $12,000; Lab-based radio detetion and analysis systems ($30,000); Lab supplies and analysis services ($15,000 per year, $45,000 for 3 years)	$ 87,000
Acquisition (Fee Title or Permanent Easements): *In this column, indicate proposed number of acres and and name of organization or entity who will hold title.*	$ -
Travel: *Field trip to lake superior and river, local field trip and data collection for 4 months ($20,000); conference ($5,000 per year, totaolly $15,00 0 for 3 years)*	$ 20,000
Additional Budget Items:	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 981,249

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *NSF SBIR grant*	$500,000	*pending*
Other State $ To Be Applied To Project During Project Period: *MnDrive*	$500,000	*Pending*
In-kind Services To Be Applied To Project During Project Period: *Unrecovered F&A*	$ 460,000	*Secured*
Funding History:		
Remaining $ From Current ENRTF Appropriation:		

PROJECT TITLE: Wireless Biosensing for Monitoring of Aquatic Ecosystems

Self-powered miniaturized biosensor chips with remote wireless communication capability will be developed for real time data acquisition on water quality over large areas.



(a) (b)

Fig. 1 Biofuel Cell Devices and Proposed Research. (a) Stand-alone design of a biofuel cell developed from a previous work in the PI's lab, such devices will be further optimized and designed for lab-on-a-chip structure for the proposed biosensing application; (b) Proposed field wireless monitoring and data analysis via a biosensor network for real-time monitoring of large areas.

Ping Wang, PhD

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PROFESSIONAL PREPARATION

B.S., Chemical Engineering, East China University of Science and Technology, China, 7/85
M.S., Chemical Engineering, East China University of Science and Technology, China, 7/88
Ph.D., Chemical Engineering, Tufts University, Medford, Massachusetts, 2/95
Postdoc. Research Associate, Bioprocess/Biocatalysis, Oak Ridge National Lab., 5/97 - 8/99
Postdoc. Research Associate, Biocatalysis/Biopolymers, The University of Iowa, 1/95 - 4/97

PROFESSIONAL EXPERIENCE

Professor, Department of Bioproducts and Biosystems Engineering; Biotechnology Institute, University of Minnesota, 8/09- present
Associate Professor, Department of Bioproducts and Biosystems Engineering; Biotechnology Institute, University of Minnesota, 7/06-7/09
Associate Professor, Department of Chemical and Biomolecular Engineering, The University of Akron, 9/05-6/06
Assistant Professor, Department of Chemical Engineering, The University of Akron, 9/99-8/05
Visiting Scientist, Department of Chemical Engineering, Massachusetts Institute of Technology, 5/90~7/91.

SYNERGISTIC ACTIVITIES

1. ***Meeting Session Organization****:* Session Chair for AIChE and ACS annual meetings, as well as other organizations/occasions such as Biochemical Engineering and Enzyme Engineering Conferences
2. ***Outreach Activities***: Poster and Presentation and Exhibition of Biofuel Cells, USDA Open House of Renewable Energies, Waseca, MN. September 11, 2008; 3r Crop Producer Meetings – Biomass Market, Rural Advantage. Fairmont, MN. Feb. 25, 2008; St Paul Campus Power Puzzle Session, Lego League's Alternative Energy Event for talented high school students at UMN. Oct. 18, 2007.

SELECTED RECENT PUBLICATIONS (from over 80)

Five related publications:

Y. Zhou, X. Wang, H. Li, K. Lin, Y. Liu, P. Wang, X. Du. Immobilized Bio-Beads with Anaerobic Active sludge, Zero-Valent Iron and Active Carbon for Removal of Trichloroethane. Environ. Sci. Technol. Submitted.

B. El-Zahab, L. Meza, T. J. Cutright, Ping Wang. Enzymatic Degradation of TCE Using Enzyme Extracts Isolated From a Bacterial Consortium. *Applied Biochemistry and Biotechnology*. 117(3):165-174, 2004.

L. Meza, T. Cutright, B. El-Zahab, P. Wang. Biodegradation of TCE Using a New Aerobic Bacterial Consortium. *Biotechnology Letters*. 25: 1925-1932, 2003.

X. Zhao, X. Lu, W. T. Y. Tze, P. Wang. A Single Carbon Fiber Microelectrode with Branching Carbon Nanotubes for Bioelectrochemical Processes. *Biosensors and Bioelectronics.* 25: 2343-2350, 2010.

Ping Wang, C. A. Woodward, E. N. Kaufman. Poly(ethylene glycol)-modified ligninase enhances pentachlorophenol biodegradation in water-solvent mixtures. Biotechnology and Bioengineering, 64(3): 290-197, 1999.