NC-1194 Report

University of Arizona, Jeong-Yeol Yoon (jyyoon@email.arizona.edu)

Project/Activity Number: NC-1194
Project/Activity Title: Nanotechnology and Biosensors
Period Covered: October 1, 2013 – September 30, 2014
Date of This Report: November 17, 2014

Outputs

1. Yoon has actively participated AZ Furnace program from Arizona Commerce Authority and Proof of concept program from Tech Launch Arizona, to develop an extremely rapid and reprogrammable PCR machine that is based on wire-guided droplet PCR technology. The device is aimed to be used as point-of-care medical diagnostics specifically for bloodstream infection and heart valve endocarditis.
2. Yoon has recently started collaborative research with Terrence J. Monks (University of Arizona, College of Pharmacy), to study the behavior of human liver and kidney upon exposure to environmental toxins, using the miniaturized mock-up system called organ-on-a-chip (OOC).
3. Yoon has recently received two contracts from Seoul VioSys, one for developing a paper microfluidic device with smartphone identification for urinalysis (focused on diagnosing urinary tract infections, UTI, and sexually transmitted diseases – STDs, specifically gonorrhea, and the other for direct detection of particulate matter from HEPA filters (used in an air purifier).
4. Yoon has also started collaborative research with Kelly A. Reynolds (University of Arizona, College of Public Health), to develop a smartphone-based immunosensor strip towards multiplexed detection of water quality parameters, including E. coli, Cr(VI), Cl, caffeine, hardness, and pH.

Impacts

1. Wire-guided droplet PCR technology have been applied for veterinary diagnostics (influenza A), blood infection, and endocarditis, which is very fast and works with blood and tissue samples. A handheld prototype has recently been developed. Two patent applications have been filed.
2. Current efforts in OOC have been focused on stem cell differentiation and cancer study, while our effort is the first of its kind towards environmental toxicology. Specifically, 1) the use of our novel nanoensemble surface towards OOC, and 2) connecting two OOCs (liver and kidney) in series will make our work to be the first-ever demonstration.
3. Our paper microfluidics and smartphone-based optical detection can be used by general public, not just the healthcare or environmental professionals, due to its small size, ease-of-use, and rapid assay time.

Publications (October 1, 2013 – September 30, 2014)

<u>Journal Papers (Peer-Reviewed)</u>

Ariana M. Nicolini, Christopher F. Fronczek and Jeong-Yeol Yoon, "Droplet-Based Immunoassay on a 'Sticky' Nanofibrous Surface for Multiplexed and Double Detection of Bacteria Using Smartphones," *Biosensors and Bioelectronics*, **2014**, doi:10.1016/j.bios.2014.09.040.

Pei-Shih Liang, Tu San Park and Jeong-Yeol Yoon, "Rapid and Reagentless Detection of Microbial Contamination within Meat Utilizing a Smartphone-Based Biosensor," *Scientific Reports*, **2014**, 4: 5953.

Tu San Park, Cayla Baynes, Seong-In Cho and Jeong-Yeol Yoon, "Paper Microfluidics for Red Wine Tasting," *RSC Advances*, **2014**, 4(46): 24356-24362. *Highlighted in RSC Advances Blog.*

Hyuck-Jin Kwon+, Christopher F. Fronczek+, Scott V. Angus, Ariana M. Nicolini and Jeong-Yeol Yoon, "Rapid and Sensitive Detection of H1N1/2009 Virus from the Aerosol Samples with a Microfluidic Immunosensor," *Journal of Laboratory Automation*, **2014**, 19(3): 322-331. (+ these authors contributed equally.)

Christopher F. Fronczek, Tu San Park, Dustin K. Harshman, Ariana M. Nicolini and Jeong-Yeol Yoon, "Paper Microfluidic Extraction and Direct Smartphone-Based Identification of Pathogenic Nucleic Acid from Field and Clinical Samples," *RSC Advances*, **2014**, 4(22): 11103-11110.

C. Christopher Stemple+, Scott V. Angus+, Tu San Park and Jeong-Yeol Yoon, "Smartphone-Based Optofluidic Lab-on-a-Chip for Detecting Pathogens from Blood," *Journal of Laboratory Automation*, **2014**, 19(1): 35-41. (+ these authors contributed equally.)

Dustin K. Harshman, Roberto Reyes, Tu San Park, David J. You, Jae-Young Song and Jeong-Yeol Yoon, “Enhanced Nucleic Acid Amplification with Blood in Situ by Wire-Guided Droplet Manipulation (WDM),” *Biosensors and Bioelectronics*, **2014**, 53: 167-17.

Tu San Park, Wenyue Li, Katherine E. McCracken and Jeong-Yeol Yoon, "Smartphone Quantifies Salmonella from Paper Microfluidics," *Lab on a Chip*, **2013**, 13(24): 4832-4840.

Conference Proceedings (Peer-Reviewed)

Tu San Park, Dustin K. Harshman, Christopher F. Fronczek and Jeong-Yeol Yoon, “ Smartphone Detection of *Escherichia coli* from Wastewater Utilizing Paper Microfluidics,” *The 17th International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2013)*, Freiburg, Germany, 27-31 October 2013, pp. 1347-1349.

Christopher F. Fronczek, Tu San Park and Jeong-Yeol Yoon, “Paper Microfluidic Extraction of Bacterial and Viral Nucleic Acid from Field and Clinical Samples towards a Direct MicroTAS Apparatus,” *The 17th International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2013)*, Freiburg, Germany, 27-31 October 2013, pp. 1114-1116.

Dustin K. Harshman, Roberto Reyes, Jeong-Yeol Yoon, “Direct Detection of Plasmid-Mediated Antibiotic Resistance in Bloodstream Infection by PCR Using Wire-Guided Droplet Manipulation (WDM),” *The 17th International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2013)*, Freiburg, Germany, 27-31 October 2013, pp. 470-472.

Conference Abstracts

Cayla Baynes, Tu San Park, Jeong-Yeol Yoon, “Enhanced fluorescent light scatter detection of cancer biomarkers using paper microfluidics,” *Biosensors 2014: World Congress on Biosensors*, Melbourne, Australia, 27-30 May 2014. Paper number O76.

Ariana M. Nicolini, Christopher F. Fronczek, Jeong-Yeol Yoon, “Rapid, single-step, droplet-based bacterial assay playform on a nanofibrous substrate,” *Biosensors 2014: World Congress on Biosensors*, Melbourne, Australia, 27-30 May 2014. Paper number O112.

Tu San Park, Cayla Baynes, Jeong-Yeol Yoon, “Paper microfluidics for red wine tasting,” Biosensors 2014: *World Congress on Biosensors*, Melbourne, Australia, 27-30 May 2014. Paper number P3.198.

Phat L. Tran, Daniel A. Martin, Jessica R. Gamboa, Jeong-Yeol Yoon, Marvin J. Slepian, “Nanopost fence: a novel strategy of preventing smooth muscle cells topographic migration,” *Society For Biomaterials (SFB) 2014 Annual Meeting and Exposition*, Denver, CO, 16-19 April 2014.

Tu San Park, Cayla Baynes, Seong-In Cho, Jeong-Yeol Yoon, “Paper microfluidics for red wine tasting,” *The 9th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (IEEE-NEMS 2014)*, Waikiki Beach, HI, 13-16 April 2014.

Ariana M. Nicolini, Celine M. Cohn, Jessica R. Gamboa, Marvin J. Slepian, Xiaoyi Wu, Jeong-Yeol Yoon, “Fabrication of a pro-adhesive surface using electrospun PCL nanofibers interspersed with peptide conjugated polystyrene particles," *The 9th IEEE International Conference on Nano/Micro Engineered and Molecular Systems (IEEE-NEMS 2014)*, Waikiki Beach, HI, 13-16 April 2014.

Ariana M. Nicolini, Celine M. Cohn, Marvin J. Slepian, Xiaoyi Wu, Jeong-Yeol Yoon, "Fabrication of a pro-adhesive surface using electrospun PCL nanofibers interspersed with peptide conjugated polystyrene particles," *Annual Meeting of IBE*, Lexington, KY, 6-8 March 2014.

Tu San Park, Jeong-Yeol Yoon, "Smartphone-based paper microfluidic detection of E. coli from field or waste water," *Annual Meeting of IBE*, Lexington, KY, 6-8 March 2014.

Scott V. Angus, Soohee Cho, Dustin K. Harshman, Jeong-Yeol Yoon, "Wire-guided droplet manipulation based quantitative PCR device towards food and veterinary diagnostics," *Annual Meeting of IBE*, Lexington, KY, 6-8 March 2014.

Tu San Park, Cayla Baynes, Jeong-Yeol Yoon, "Paper microfluidics for red wine tasting," *Annual Meeting of IBE*, Lexington, KY, 6-8 March 2014.

Participants

1. Individuals: Jeong-Yeol Yoon (PI); Tu San Park, Christopher F. Fronczek (post-docs); Pei-Shih Liang, Christopher F. Fronczek, Dustin K. Harshman, Scott V. Angus, Cayla Baynes, Ariana M. Nicolini, Soohee Cho, Tigran Nahapetian, Katherine E. McCracken (graduate students); Roberto Reyes, Sarah Rogan, Tyler Connel, Kirstie Birmingham, Serge Dogbevi, Brianna Rao, Victoria Raught, Jessica Mergener, Tyler Toth (undergraduate students).
2. Partner organization: Seoul VioSys.
3. Collaborators: Terrence J. Monks (University of Arizona College of Pharmacy), Kelly A. Reynolds (University of Arizona College of Public Health).

Development of nanosensors for food pathogen detection, Cornell University, A.J. Baeumner: Report November 2014

1. Impact Nugget: Miniaturized biosensors for pathogen detection are being developed. Main focus was on the bioanalytical ability for multi-analyte detection and sample preparation aspects.

2. Unique Project Related Findings. We were able to demonstrate that dual detection using two commercially available electrochemiluminescence markers is feasible. A unique dual-detection system was established.

4. Accomplishment Summaries.
Investigations were carried out toward the development of a miniaturized dual detection system for the simultaneous detection of at least two food-borne pathogens. Various reports exist that use chemically modified electrochemiluminescence (ECL) markers to accomplish dual or multi-analyte detection. However, the molecules are not commercially available and require complex syntheses. Here, we therefore investigated the use of two commercially available luminescence molecules (a ruthenium complex and luminol). Specific standard curves for each analyte were prepared reaching limits of detection at 35 and 26 nM, respectively.

In a dual detection approach, the simultaneous detection of the ECL components within a miniaturized measurement cell, an optical fiber and PIN detection system, limits of detection were reached that were at 0.7 and 1.7 microM. While higher than those obtained for the separate optimized standard curves, these values are excellent in comparison to other multi-analyte ECL approaches and will therefore be continued in further investigations.

We also study the use of nanofibers for sample preparation purposes. Here, we investigate the isolation of E. coli cells from samples for concentration and subsequent detection. Preliminary data show a high isolation capability through electrostatic interactions resulting in concentration factors of > 10.000.

4. Impact Statements.
The development of highly sensitive biosensors for food pathogen detection is very important so that contamination can be measured. Here, the signal generation technology and sample preparation technology are two main factors of an analytical device that influence the achievable limit of detection. Both areas of study will enable the development of diagnostic systems that can detect foodborne pathogens at levels important to determine the safety of food products.

5. Published Written Works.

Reinholt, S., Baeumner, A.J. "Microfluidic Nucleid Acid Purification" Angewandte Chemie, International Edition (available online, DOI: 10.1002/anie.201309580) 2014
.
Matlock-Colangelo, L., Baeumner, A.J. "Biologically Inspired Nanofibers for Use in Translational Bioanalytical Systems" Annu. Rev. Anal. Chem. 2014. 7:23–42 (2014)

Title:	Nanotechnology and Biosensors		
Sponsoring Agency	NIFA	**Project Status**	ACTIVE
Funding Source	Hatch/Multi State	**Reporting Frequency**	Annual
Accession No.	1002960	**Project No.**	FLA-ABE-005316
		Multistate No.	NC1194
Project Start Date	05/09/2014	**Project End Date**	09/30/2016
Reporting Period Start Date	05/09/2014	**Reporting Period End Date**	09/30/2014
Submitted By		**Date Submitted to NIFA**	

Project Director

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Agricultural and Biological Engineering

Non-Technical Summary

Development of sensing and processing technologies based on nanoscale phenomena becomes increasingly relevant for our society as we continue to advance our knowledge of biological phenomena related to food, agriculture, environment and energy. As we understand the molecular mechanisms that underlie the emergence and spread of pathogens and their consequent impact on our agricultural and food systems, it becomes evident that the technology to intervene and mitigate their effects on public health need to be correspondingly small, i.e. within the realm of nanotechnology.

Accomplishments

Major goals of the project

(1)
Develop new technologies for characterizing fundamental nanoscale processes

(2)
Construct and characterize self-assembled nanostructures

(3)
Develop devices and systems incorporating microfabrication and nanotechnology

What was accomplished under these goals?

In addition to develop new technologies to characterize and understand fundamental nanoscale processes, we also explore the envornmental appliations and implications of nanotechnology.

What opportunities for training and professional development has the project provided?

The project provide training and professional development opportunities to several graduate and undergraduate students.

How have the results been disseminated to communities of interest?

In addition to journal publications and conference presentations, the findings from the research project was also integrated with education by training graduate and undergraduate students with a diverse array of backgrounds.

What do you plan to do during the next reporting period to accomplish the goals?

Will continute the research and education activities to accomplish the objectives.

Participants

{Nothing to report}

Target Audience

{Nothing to report}

Products

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

A. Dathe, Y. Zevi, B.K. Richards, B. Gao, J.Y. Parlange, T.S. Steenhuis. 2014. Functional models for colloid retention in porous media at the triple line. Environmental Science and Pollution Research, 21 (15), 9067-9080

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

H. Chen, B. Gao, H. Li. 2014. Functionalization, pH, and ionic strength influenced sorption of sulfamethoxazole on graphene. Journal of Environmental Chemical Engineering, 2 (1), 310-315

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

M. Zhang, B. Gao, J.J. Chen, Y.C. Li, A.E. Creamer, H. Chen. 2014. Slow-release fertilizer encapsulated by graphene oxide films. Chemical Engineering Journal, 255, 107-113

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

W.J. Sang, C.R. Stoof, W. Zhang, V.L. Morales, B. Gao, R.W. Kay, L. Liu, Y.L. Zhang, T.S. Steenhuis. 2014. Effect of Hydrofracking Fluid on Colloid Transport in the Unsaturated Zone. Environmental Science & Technology, 48 (14), 8266-8274

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Awaiting Publication	2014	NO

Citation

H. Chen, B. Gao, H. Li. 2014. Removal of sulfamethoxazole and ciprofloxacin from aqueous solutions by graphene oxide. Journal of Hazardous Materials, doi: 10.1016/j.jhazmat.2014.03.063

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

L. Wu, R. Munoz-Carpena, B. Gao, W. Yang, Y.A. Pachepsky. 2014. Colloid Filtration in Surface Dense Vegetation: Experimental Results and Theoretical Predictions. Environmental Science & Technology, 48 (7), 3883-3890

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

M. Zhang, B. Gao, D.C. Vanegas, E.S. McLamore, J. Fang, L. Liu, L. Wu, H. Chen. 2014. Simple approach for large-scale production of reduced graphene oxide films. Chemical Engineering Journal, 243, 340-346

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2014	NO

Citation

Z.H. Ding, X. Hu, V.L. Morales, B. Gao. 2014. Filtration and transport of heavy metals in graphene oxide enabled sand columns. Chemical Engineering Journal, 257, 248-252

Other Products

{Nothing to report}

Changes/Problems

{Nothing to report}

Hawaii (University Hawaii)

Some accomplishments from the University Hawaii were presented at the IEEE-NEMS meeting by Dr. Daniel M. Jenkins (Table 1; Title of Presentation: "Nanoparticle Assisted Biofilm Disruption for Rapid Recovery and Detection of Bacterial Pathogens"). A summary of these accomplishments is provided below.

Output. Most of the progress has been a continuation of outputs reported in the previous calendar year, most significantly extending the availability of technologies already developed for rapid field based diagnostics. In addition, we have started evaluating novel approaches for concentrating highly dispersed pathogenic organisms from food and agricultural samples through nanoparticle assisted biofilm disruption and electroflotation. Specific outputs include:

1) We conducted a workshop with USDA-ARS for citrus growers interested in using our technology, and initiated field trials of our handheld diagnostic platform with citrus producers for detection Candidatus Liberibacter *asiaticus* (citrus greening organism) in the field.
2) In the project year we put together two separate builds of moderate volumes (25 each) of beta versions of our handheld diagnostic platform. We also designed a newer version with additional hardware features to facilitate field use (i.e., internal battery and indicator lights to show charge and connection status), significantly improved signal to noise ratio, reduced signal drift, more robust data classification algorithms, and additional software functionality to facilitate record keeping and recording including map based activities to record sample origin and description, and display color coded test results on a map. We are currently building this design at a more commercial scale (100 devices to start).
3) We have continued collaborations to conduct field evaluation of our technology with potential stakeholders, notably with the US Navy during "Balikatan 14" joint exercise in the Phillipines in April 2014.
4) In the project year we initiated the investigation into different functionalized nanoparticles to determine their efficacy at disrupting biofilms of Salmonella and E.coli, and developed preliminary designs for a handheld electroflotation unit to concentrate out trace contaminations of pathogenic bacteria.

Impact. The technologies developed in this research are intended to allow rapid detection of agricultural and food-borne pathogens to improve food security and safety. Handheld rapid detection has been identified as a critical need by the USDA for enhancing food safety and implementing effective surveillance programs to exclude harmful pathogens from agricultural settings.

In the 2011 annual project meeting for NC-1194 (then NC-1031), commercialization of sensor technologies was identified as being a critical activity as the technologies themselves are rapidly reaching maturity. Most of the focus has been on accelerating the technology transfer to put these new emerging technologies in stakeholders hands as a routine tool for agricultural diagnostics.

Publications.

Two publications related to this project, which had previously been reported as being accepted, were officially published during the project year.

Yasuhara-Bell, J. H., R. Kubota, D. M. Jenkins, and A. M. Alvarez. 2013. Loop-mediated amplification of the *Clavibacter michiganensis* subsp. *michiganensis* micA gene is highly specific. *Phytopathology*. 103(12):1220-1226.

Marrero, G., K. L. Schneider, D. M. Jenkins, and A. M. Alvarez. 2013. Phylogeny and classification of *Dickeya* based on multilocus sequence analysis. *International Journal of Systematic and Evolutionary Microbiology*. 63(9):3524-3539.

Additionally, three additional publications related to this project were submitted immediately following the project year, and have been accepted (they will be reported in next year's report).

NC-1194

report period: 10/01/2013-09/30/2014

Su lab University of Hawaii

11/2014

Output

Nanobiotechnology research in the laboratory of Winston Su at the University of Hawaii addresses NC-1194 project objective two - construct and characterize self-assembled nanostructures. During this reporting period, research has focused on development and investigation of a novel method for facile biosynthesis of complex protein nano-scaffolds for assembling multifunctional nanofactories. Specifically, recombinant engineered scaffold proteins called scaffoldins possessing up to eight *Clostridia* cohesin modules were successfully assembled in *E. coli* by employing split-intein mediated protein ligation. The cohesin octamer is the longest artificial scaffoldin known in the literature. Using this panel of oligomeric cohesin scaffoldins, cellulosomal enzyme complexes were assembled containing endoglucanase, exoglucanase, and scaffoldin-borne carbohydrate binding module. Under a fixed total cellulase concentration, improved hydrolysis of a model microcrystalline cellulose substrate, Avicel, is noted by recruiting both endoglucanase and exoglucanase on the same scaffoldin, for all scaffoldins tested, despite with different extents, compared with free cellulases. The improvement is more profound with scaffoldins having a higher Exo- to Endo-glucanase ratio. These results point to the importance of using scaffoldins with sufficiently high numbers of cohesin units to achieve an optimal exo-/endo-glucanase ratio to create efficient designer cellulosomes. Furthermore, the cohesin scaffoldins can be of use to assemble additional multi-functional enzyme complexes and enzyme/nanoparticle hybrid nanomaterials. Investigation of these novel nanomaterials for biosensing and other biotechnology applications is currently underway.

Impact

Findings from this study lead to facile synthesis of novel nano-scaffolds with tunable functionality. These materials offer new possibilities in biocatalysis, biosensing, and tissue engineering applications, and should help advancing food safety, agriculture biosecurity, and biomedical sciences.

Publications

Presentation:
Su, W. W. Protein engineering to aid biochip and biosensor development. Invited seminar at the Sogang University, Korea, 9/29/2014.

Participants

Su, Wei Wen (PI)

Han, Zhenlin (Postdoc)

Title:	Nanotechnology and Biosensors		
Sponsoring Agency	NIFA	**Project Status**	ACTIVE
Funding Source	Non Formula	**Reporting Frequency**	Annual
Accession No.	0227391	**Project No.**	IOW0
		Multistate No.	NC-1194
Project Start Date	10/1/11	**Project End Date**	9/30/16
Reporting Period Start Date	10/1/13	**Reporting Period End Date**	9/30/14

Project Director
Yu, Chenxu

Non-Technical Summary

Food and biosafety is one of the key national interests. Rapid threat response relies on on-site analysis that recognizes potential hazards at the earliest possible time with high fidelity. Nanotechnology plays a key role in the development of modern sensing methodologies that support rapid response yet miniaturized sensors for quick deployment. The focus of this multistate project is to incorporate nanotechnology research and biosensor development to yield novel technological breakthroughs that will facilitate the advance of technology for in-field foodborne pathogen detection.

Accomplishments

Major goals of the project

Develop new technologies for characterizing fundamental nanoscale processes. Construct and characterize self-assembled nanostructures. Develop devices and systems incorporating microfabrication and nanotechnology. Produce education and outreach materials on nanofabrication, sensing, systems integration and application risk assessment.

What was accomplished under these goals?
The activities during this period included: 1. further development of multiplexing dual-recognition SERS-microfluidic biosensor, three-epitopes target detection is achieved at single cell level; 2. The development of nanophotocatalyst-embedded biodegradable film for food safety control. 3. Further development of Raman spectroscopic imaging system for characterization of glaucoma and parkinson's disease at an early stage. 4. Further development of a THz spectroscopic detector and an ultrasonic imager for bacterial contamination inside eggs. 5. Development of nano-vaccine delivery systems for more effective vaccines.
What opportunities for training and professional development has the project provided? (if appropriate, Nothing to report)
Attending the IEEE-NEMS meeting
How have the results been disseminated to communities of interest?
These findings were presented in several peer reviewed conferences and journal articles.
What do you plan to do during the next reporting period to accomplish the goals? (if final, Nothing to report)
Continue ongoing research on nano-enabled biosensor development

Actual FTEs for this Reporting Period

Role	Faculty and Non-Students	Students within Staffing Roles			Computed Total By Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	5	3.0	2.0	2.0	12.0
Professional	0.0	0.0	0.0	0.0	0.0
Technical	0.0	0.0	0.0	0.0	0.0
Administrative	0.0	0.0	0.0	0.0	0.0
Other	1.0	0.0	0.0	0.0	1.0
Computed Total	0.0	0.0	0.0	0.0	0.0

Target Audience

These works were presented in five peer reviewed conferences. The audience included engineers and scientists developing novel nanomaterials and sensing platform/technologies for various applications in agriculture, biological and biomedical engineering, chemistry, environmental engineering. The five conferences are also open to industrial personnel as well as general public. Our target audience also includes people who are interested in identifying novel technologies to address their needs for disease diagnosis, monitoring chemical contaminations and biological hazards in water, food and environments, as well as people who are interested in identifying novel ways to evaluate food quality nondestructively.

Products

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	published	2014	Y

Citation

Wang, C., C. G. Yoo, Chenxu Yu, T. Kim, Raman Spectroscopic characterization of Photonanocatalyst Aided Alkaline Pretreated Corn Stover biomass, Advanced Materials Research, 877, 1576-1580

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	published	2014	Y

Citation

Yao, L., W. Zhou, M. Liu, C. Yu and T. Wang, Quantification of egg yolk contamination in egg white using UV/Vis spectroscopy: prediction model development and analysis, Food Control, 43, 88-97, 2014.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	published	2014	N

Citation			
Liu, M., L. Yao, T. Wang, J. Li and C. Yu, Rapid determination of egg yolk contamination in egg white by VIS spectroscopy, Journal of Food Engineering, 124C, 117-121, 2014.			
Type	**Status**	**Year Published**	**NIFA Support Acknowledged**
Journal Articles	accepted		Y
Citation			
Kadam, D. M., C. Wang, S. Wang, D. Grewell, B. Lamsal, C. Yu, Microstructure and antimicrobial functionality of nano-enhanced protein-based biopolymers, Transactions of the ASABE, in press			
Type	**Status**	**Year Published**	**NIFA Support Acknowledged**
Journal Articles	accepted		N
Citation			
Wang, C.* and C. Yu, Analytical characterization using surface-enhanced Raman scattering (SERS) and microfluidic sampling. Nanotechnology			
Type	**Status**	**Year Published**	**NIFA Support Acknowledged**
Conferences and presentations	published	2014	Y
Citation			
Suleiman, R. A., C. Yu, K. Rosentrater. Techno-economic analysis (TEA) of Extruded aquafeeds. ASABE Annual International Meeting, Montreal, Canada, (July 13-16, 2014)			
Type	**Status**	**Year Published**	**NIFA Support Acknowledged**
Conferences and presentations	published	2014	Y
Citation			
Yu, C., Q. Wang*, R. Campos*, K. Hamouche*. Raman spectroscopic evaluation of Meat quality. AgEng 14, Zurich, Switzerland, (July 6-10, 2014)			
Type	**Status**	**Year Published**	**NIFA Support Acknowledged**
Conferences and presentations	published	2014	Y
Citation			
Wang, C.*, F. Madiyar, J. Li and C. Yu. A Multiplex Self-Referencing Detection of Pathogens Using Surface Enhanced Raman Scattering Nanoprobes with a nano-DEP Microfluidic concentrator. Biosensors World Congress, Melbourne, Australia, (May 25-28, 2014)			

Type	Status	Year Published	NIFA Support Acknowledged
Conferences and presentations	published	2014	Y

Citation

Yu, C. Exploring Raman Spectroscopy for the evaluation of glaucomatous retinal changes, The 3rd annual conference and EXPO of AnalytiX, Dalian, China, (April 24-27, 2014)

Type	Status	Year Published	NIFA Support Acknowledged
Conferences and presentations	published	2014	Y

Citation

Wang, C.*, F. Madiyar, J. Li and C. Yu. A self-referencing detection of pathogens using SERS nanoprobes in a nano-DEP microfluidic biosensor, IEEE-NEMS, Honolulu, Hawaii, (April 14-16, 2014)

Other Products

Nothing to report

Changes/Problems (if appropriate, Nothing to Report)

Nothing to report

Participants

Chenxu Yu, Associate Professor, Iowa State University, Department of Agricultural and Biosystems Engineering

Tong Wang, Professor, Iowa State University, Department of Food Science and Human Nutrition

David Grewell, Professor, Iowa State University, Department of Agricultural and Biosystems Engineering

Buddhi Lamsal, Associate Professor, Iowa State University, Department of Food Science and Human Nutrition

Chien-Ping Chiou, Associate Scientist, Center for non-destructive evaluation

Chao Wang, Graduate student, Iowa State University, Department of Agricultural and Biosystems Engineering

Shaowei Ding, undergraduate student, Iowa State University, Department of Agricultural and Biosystems Engineering

Muhua Liu, visiting scholar, Iowa State University, Department of Agricultural and Biosystems Engineering

Dattatreya Kadam, postdoc, Iowa State University, Department of Agricultural and Biosystems Engineering

Linxing Yao, postdoc, Iowa State University, Department of Food Science and Human Nutrition

NC-1194 Report from University of Maryland

Objective 2. Construct and characterize self-assembled nanostructures

Output: Research accomplishments at University of Maryland include: 1) Development and characterization of cationic beta lactoglobulin (CBLG) via a simple peptide coupling reaction; 2) Preparation of beta lactoglobulin (BLG) and CBLG nanoparticles loaded with a model drug (curcumin), using an organic solvent desolvation process; (3) Investigation of curcumin-loaded BLG and CBLG nanoparticles in a series of biological processes that are relevant to oral administration. Using BLG which is a major component of whey protein, we synthesized a broad spectrum of cationic polymers that inherited the advantages of both native BLG (e.g., resistance against peptic digestion, good solubility, and satisfactory encapsulation efficiency) and cationic polymers (e.g., high mucoadhesion capacity and cellular uptake). In addition, we used the variety of synthesized protein derivatives as a model system to assess the impact of surface properties (such as surface charge, hydrophobicity and steric hindrance) on the transport and delivery of drug-loaded nanoparticles.

We have disseminated the results to the academic journals including Biomacromolecules and Journal of Agricultural and Food Chemistry, as well as at professional conferences such as IFT and ACS.

Impact: This study will provide a novel drug delivery system consisting of food derived, minimally modified proteins. The superior properties of the system, including stability in the GI tract, strong mucoadhesion, satisfactory transport across the small intestine, low cytotoxicity, and elevated cellular uptake, made it an attractive candidate as a bioavailability enhancer for poorly absorbed nutrients and drugs. Moreover, the results from the study revealed the significant influence of biological environment on the stability and behavior of biopolymer-based nanoparticles, which may shed some light on the development of drug carriers with precisely controlled transport and delivery properties.

Future work: Future research will focus on the screening of proper cationizers and other surface decorators that confer polymeric nanoparticles with controllable surface properties, followed by the application of the resulting products in various fields in the food and pharmaceutical industry.

Objective 3. Develop biological interfaces and sensing systems incorporating microfabrication and nanotechnology

Output:

Research accomplishments at University of Maryland include: 1) Development of biosensor based on bio-polymeric magnetic soft matters and control of the magnetic properties using electric and magnetic field; 2) Synthesis of amine- and carboxyl-functionalized magnetic nanoparticles/microparticles for fabrication of bio-magnetic soft film and antibody conjugation; 3) Fast detection of *E.coli* in drinking water by fluorescence microscopy coupled with magnetically activated cell sorting techniques. We have developed a variety of magnetic nano-/micro-materials and studied the potential applications in food safety area, specifically for the development of biosensors and rapid detection of food borne pathogens in food and food contacting surfaces.

The results of these studies will be disseminated to the industry and scientific communities in academic journals and professional conferences such as IFT, ACS.

Future work:

Future research will focus on the innovative investigation into the applications polymeric magnetic biosensors in biological microelectromechanical systems (BioMEMS) platforms. Special emphasis will be put on the fast detection techniques of viable microbes, such as electrodetection and quorum sensing detection.

Publications:

Journal papers

1. Z. Teng*, Y. Li*, Y. Niu, Y. Xu, L. Yu, Q. Wang. “Cationic β-lactoglobulin Nanoparticles as a Bioavailability Enhancer: Comparison between Ethylenediamine and Polyethyleneimine as Cationizers” *Food Chemistry*, 2014, 159, 333-342.
2. Z. Teng*, Y. Li*, Y. Luo*, B. Zhang*, Q. Wang. “Cationic β-lactoglobulin Nanoparticles as a Bioavailability Enhancer: Protein Characterization and Particle Formation”. Biomacromolecules, 2013, 14, 2848-2856.

Conference Abstracts:

1. Y. Li*, Z Teng*, **Q. Wang**. “Self-assemble nanoemulsions and zein-nanoparticles for the stabilization of allyl isothiocyanate in aqueous dispersion”. *IFT annual meeting*, New Orleans, LA, June 2014.
2. Z. Teng*, B. Zhang*, Y. Li*, **Q. Wang**. “Cationic β-lactoglobulin Nanoparticles as a Bioavailability Enhancer: Protein Characterization and Particle Formation” *IFT annual meeting*, New Orleans, LA, June 2014.
3. Z. Teng*, Y. Li*, **Q. Wang**. Cationic β-lactoglobulin nanoparticles as a bioavailability enhancer: application of polyethyleneimine as a cationizer”. *IFT annual meeting*, New Orleans, LA, June 2014.

Participants:

Qin Wang, Associate Professor, University of Maryland, Department of Nutrition and Food Science.

Ying Li, Post-doc, University of Maryland, Department of Nutrition and Food Science.

Zi Teng, Ph.D student, University of Maryland, Department of Nutrition and Food Science.

University of Missouri

Accomplishments Report

Project/Activity Number: NC−1194

Project/Activity Title: Nanotechnology and Biosensors

Period Covered: October 1, 2013 to September 30, 2014

1) Outcomes

Outcomes of this project include:

(1) A simple two-step method was developed to create standing gold nanorod arrays using gold nanorods with aspect ratio of 2.0 as building blocks. Results show that nearly all the nanorods (~95%) were vertically aligned on the silicon surface except a very small amount of nanorods near the pinned edge. Standing gold nanorod arrays were also created by the two-step method using gold nanorods with a higher aspect ratio (~3.4). These standing gold nanorod arrays were used in rapid detection of chemical food contaminants such as pesticides.

(2) We developed a rapid and simple method to functionalize gold nanorods by polyethylene glycol (PEG). PEG was successfully loaded on the CTAB-protected gold nanorods in 30 min using Tris buffer with pH of 3.0. The concentration of mPEG-SH has no significant influence on the optical property of gold nanorods modified by the proposed method. The result shows that the PEG-modified gold nanorods could sustain the 1.0 M of NaCl while CTAB-protected gold nanorods aggregated immediately after the addition of NaCl. Compared to a traditional 24-h method in CTAB/carbonate solution, the proposed method has a higher loading speed and a higher coverage density of PEG on gold nanorods.

(3) A combination of analytical techniques was used to detect, characterize, and quantify engineered NPs (cerium (IV) oxide (CeO_2), silica (SiO_2) NPs, and their mixture) in food matrices. A series of concentrations of CeO_2, SiO_2, and their mixtures were mixed in soybean powders and the presence of engineered NPs was investigated using transmission electron microscopy and scanning electron microscopy coupled with energy dispersive spectroscopy. The concentration of nanoparticles in soybean powders was analyzed by epithermal instrumental neutron activation analysis (EINAA). Satisfactory recoveries and detection results were obtained for food samples.

(4) Results have been disseminated to scientific communities and to the public via peer-reviewed publications, oral presentations, and collaboration with a local startup company Nanova Inc.

2) Impacts:

(1) The results of these study will help improve public health by quickly detecting chemical and biological contaminants in foods and consumers will benefit from improved food safety; Having sensitive and rapid analytical methods would assist regulatory agencies and the food industry to better assess product safety early on and increase public confidence in our food supply.

(2) The new approach could be used as a reproducible, high-yield, and simple route to fabricate vertically aligned gold nanorod arrays. This novel method does not need to modify gold nanorods by thiolated ligands, synthesize strictly monodispersed gold nanorods, or use highly concentrated gold nanorod solution for the assembling. The new nanosensors can be used to improve food safety by rapid detection of chemical food contaminants such as pesticides and foodborne pathogens.

(3) A rapid and simple method was successfully established to functionalize gold nanorods by polyethylene glycol (PEG) that can be used for plasmonic sensing and other applications. This method might open a new route to fabricate substrates for bio-medication, detection of food contaminants, and environmental monitoring.

3) Publications:

Lin, M. 2014. Nanotechnology and its applications to improve detection of chemical hazards in foods. In: *Food Chemical Hazard Detection: Development and Application of New Technologies* (Editor: Shuo Wang). Wiley-Blackwell Publishing.

Zhang, Z.; Lin, M. 2014. High-yield preparation of vertically aligned gold nanorod arrays via controlled evaporation-induced self-assembly method. *J. Mater. Chem. C.* 2, 4545-4551.

Zhang, Z.; Lin, M. 2014. Fast loading of PEG-SH on CTAB-protected gold nanorod. *RSC Adv.* 4(34), 17760-17767.

Zhang, Z.; Zhang, S.; Lin, M. 2014. DNA-embedded Au-Ag core-shell nanoparticles assembled on silicon slides as a reliable SERS substrate. *Analyst* 139(9), 2207-2213.

Song, X., Li, H., Hu, Z.Q., Mustapha, A., Lin, M. 2014. Characterization and quantification of engineered nanoparticles in food by epithermal instrumental neutron activation analysis and electron microscopy. *J. Food Measurement & Characterization.* 8(3), 207-212.

Yoo, A., Zhang, Z., Lin, M., Mustapha, A. 2014. The effects of zinc oxide and silver nanoparticles on intestinal bacteria. 2014 International Association for Food Protection (IAFP) annual meeting. Indianapolis, Aug 3-6, 2014.

Nguyen, T. H.D.; Mao, X.; Mustapha, A.; Lin, M. Toxicity of graphene oxide on intestinal bacteria and Caco-2 cells. 2014 IFT Annual Meeting. New Orleans, LA. June 21-24, 2014.

Zhong, Z.; Wang, P.; Lin, M. 2014. Competitive effect in surface enhanced Raman spectroscopy (SERS) detection of food contaminants. 2014 IFT Annual Meeting. New Orleans, LA. June 21-24, 2014.

4) Participants

This project has provided training for three doctoral students and three Master's students.

Purdue Station Report

Outcomes and Impacts

In the reporting year, principle investigators at Purdue University in the State of Indiana made significant advances in the area of nanotechnology and biosensors. In the area of environmental effects of nanotechnolgy, our custom biosensor technology was used to examine the toxicity and mechanism of toxicity of siliver nanoparticles compares to ionic silver in an environmentally important model system. We also made significant progress in the application of the technology to the study of the physiology of living systems. An autonomous biosensor system containing single fern spores was launched on a nanosatelitte into microgravity. The complete device system, known as SporeSat, reported to earth measured spores as they germinated in microgravity environments, thus providing fundamental information about how plants sense gravity as well as microgravity thresholds for calcium currents and plant germination in space. Advances in the biocompatibility of biosensors residing in vivo were made advanced sensor coatings and by methods to insert increasingly smaller electrodes into living tissues. Several new intracellular sensor technologies were developed to measure the real time kinetics of cellular events such as gene expression and epigenetic modifications were developed. Finally existing nanosensor technologies were applied to the quantification of food quality and safety.

Publications

Stensberg MC, Madangopal R, Yale G, Wei Q, Ochoa-Acuna H, Wei A, McLamore ES, Rickus JL, Porterfield DM, Sepulveda M. 2013. "*Silver nanoparticle-specific mitotoxicity in Daphnia magna*." Nanotoxicology. Vol. 8, No. 8 , Pages 833-842. PMID: 23927462. 2012 Impact Factor 7.844.

Amani Salim, Joon Park, Jenna Rickus, Josh Benton, Lee Brownston, Miles Cote, Greg Defouw, Michael Henschke, Chris Kitts, Ed Luzzi, Nghia Mai, Andres Martinez, Mario Perez, Marshall Porterfield, Abraham Rademacher, Mike Rasay, Antonio Ricco, Stan Roux, Mari Salmi, Aaron Schooley, Adam Sweet, and Brittany Wickizer "*SporeSat: A nanosatelilite platform Lab-on-a-Chip System for Investigating Gravity Threshold of Fern Spore Single-Cell Calcium Currents"* Proceedings of the Hilton Head Solid-State Sensors, Actuators, and MicroSystems Workshop. June 8-12, 2014. Hilton Head Island, SC.

*Sommakia, S., J. Gaire, J.L. *Rickus, and K.J. *#Otto. 2014. "*Resistive and reactive changes to the impedance of intracortical microelectrodes can be mitigated with polyethylene glycol under acute in vitro and in vivo settings*" Frontiers in Neuroengineering. Vol. 7, article 33, pp 1-8.

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Participants

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