CAREER: Development of Bio-MEMS for determining cell structure using microfluidics and bio impedance

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ABSTRACT: *The objective of this research project is to develop an E. coli counter that will quantify the presence of bacteria. The approach seeks to leverage expertise of the host laboratory in nanoparticle synthesis and biology with USF's expertise in Sensors and MEMS to integrate existing state of the art in photcatalysis and sensors to develop a new class of multi-use, affordable sensors that have applications from healthcare to food safety.*

INTRODUCTION (LIMIT: 1 PAGE)

The awardee institution for the NSF award is the University of South Florida in Tampa. Under the current NSF award, bio-impedance measurements and analyses have been performed to characterize cells and skin using planar microelectrodes. The effect of microelectrode size on bio-impedance measurments has been studied, along with the study of cell growth and death to ultimately characterize and optimize the use of microelectrodes.

The objective of this IREE research project is to develop an E. coli counter that will quantify the presence of bacteria. The approach seeks to leverage expertise of the host laboratory in nanoparticle synthesis and biology with USF's expertise in Sensors and MEMS to integrate existing state of the art in photcatalysis and sensors to develop a new class of multi-use, affordable sensors that have applications from healthcare to food safety.

The propsed E. coli counter could be constructed using cantilever arrays coated with nanoparticles, such as titanium dioxide (Ti_2O), integrated with a UV light source. The nanoparticles will serve as a catalyst for oxidization of E. coli in UV. This technique is commonly known as photocatalysis, which can be used for inactivating pathogenic bacteria since it produces highly oxidizing radicals that can kill or severely damage bacteria. When the cell is oxidized, cell damage is observed in terms of an increase in lipid peroxidation (production of malondialdehyde, MDA), cellular respiration (reduction of 2,3,5-triphenyltetrazolium chloride, TTC), and antioxidant enzyme (glutathione-S-transferase). Capturing and measuring the release of these byproducts on the cantilever may cause it to bend. The bending/change in loading of the cantilevers can be measured using numerous techniques including resonant frequency change, piezoelectric change, pyroelectric change, electrons produced, or restorative force needed to bring the cantilever back to normal. The degree of bending could be related to the quantity of cells present. By measuring the bending of different length cantilever arrays versus a constant concentration of bacteria, a relationship can be determined that will allow quantification of the bacteria. Both cantilever based sensing and photocatalysis are standard techniques. However they have never been integrated to derive advantages of both technologies in a single system.

The goals for the summer include: (1) understanding photocatalysis and get basic experimental results; (2) exploring how the nanoparticles can be applied on MEMS structures; and (3) studying the level of stress changes induced due to (a) nanoparticles, (b) e-coli and (c) reversibility through photocatalysis.

The host laboratory, National Chamical Laboratory (NCL), is and research and development institution located in Pune, India. Its research focus is mainly chemistry and chemical engineering. According to www.ncl-india.org, there are approximately 200 scientific staff with PhDs, and approximately 400 students pursuing doctoral degrees.

The name of the traveler is Dorielle Price and dates of travel were June 18, 2007 through August 27, 2007; however, due to an inability to adjust to the food and environment, the researcher had to return early because of sickness.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION (LIMIT: 1-1/2 PAGES)

The first research goal was to apply a monlayer of titanium dioxide (TiO_2) nanoparticles to the cantilever surface. A non-uniform layer could be applied; however, measurements would not be reproducible. The Langmuir Blodgett (LB) technique was implemented to coat the substrate with a monolayer. In this technique, amphiphilic molecules are condensed on the water surface by a physical barrier and the substrate (cantilever) is submersed within the condensed monolayer of molecules. The molecules then attach to the surface of the substrate. In order to use this technique, the TiO_2 nanoparticles must be made hydrophobic so that they float on the water surface.

The researcher shadowed a student of the host laboratory, NCL, as he tested different methods of chemically altering the nanoparticles to make them hydrophobic. Some methods included: (1) mixing NH_4OH solution (5%), oleic acid (3mL), and hydrochloric acid (1M) and (2) phase transfer of the nanoparticles. These methods were unsuccessful, so the chemists began searching for more promising methods.

Additionally, the researcher was trained on the Langmuir Blodgett system using a standard solution (steric acid and chloroform). Figure 1 shows a schematic of the LB system. As the barrier compresses the surface molecules, the sensor detects the change in surface pressure.

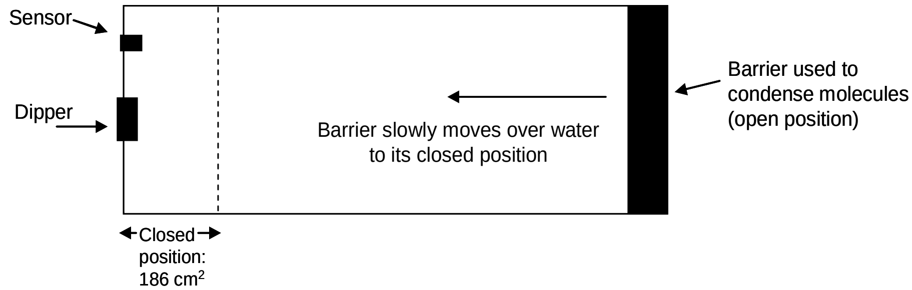

Figure 1: Schematic of LB system

The sensor is connected to a computer and a computer program called NIMA outputs a real-time pressure-area isotherm plot, as seen in figure 2. As the molecular area decreases, the surface pressure increases, causing the molecules to behave more like a solid. At a critical point, the surface pressure begins to decrease. This point is called the collapse pressure (π_c) and it is the maximum pressure in which the monlayer can be compressed before the molecules begin to overlap. The zero-pressure molecular area (A_o) can be found by extrapolating the slope of the solid phase to zero pressure.

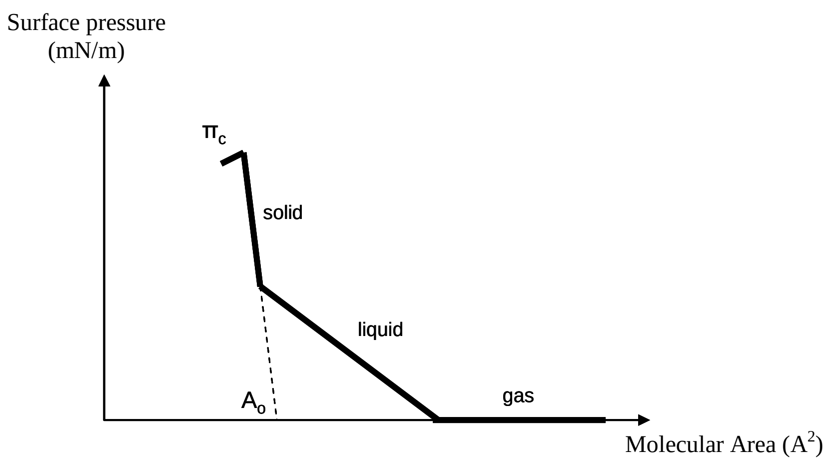

Figure 2: Pressure-Area isotherm; output from LB

BROADER IMPACTS OF THE INTERNATIONAL TRAVEL (LIMIT: 1-1/2 PAGES)

This international travel experience proposed to expand the original scope of the current award by integrating chemistry with MEMS and sensor technology to detect and quantify bacteria.

When interacting with the students at the host institution, the researcher answered questions they had about the University of South Florida (and the U.S. in general) and also showed them the websites of USF and the MEMS research group as a reference for additional information. The researcher was exposed to the native language, as many students communicated with each other, as well as restaurant and store employees. It was noticed that the students worked very closely with each other and their advisor in all (daily) aspects of their research. Everyone worked together to solve problems and propose solutions; and the working atmosphere was very friendly.

DISCUSSION AND SUMMARY (LIMIT: 1 PAGE)

Within the limited amount of time spent at the host laboratory, the most significant accomplishment of the international research experience was learning how to use the Langmuir Blodgett system to apply a monolayer of nanoparticles to a substrate. Before this trip, the researcher had not worked with nanoparticles; therefore, it was a great learning experience.

ACKNOWLEDGEMENTS

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REFERENCES (INCLUDE IF RELEVANT; SAMPLES BELOW)

1. P. Martin and M. Szablewski. NIMA Technology. Langmuir Blodgett Systems. Operating Manual 3rd Edition. Nima Technology, Ltd. 1992.

BRIEF BIOGRAPHIES OF RESEARCHERS (SAMPLES BELOW)

Dorielle Price received the B.S. degree in electrical engineering from Clark Atlanta University (Atlanta, Georgia) in 2004. She is currently pursuing a doctoral degree in electrical engineering with a concentration in Bio-MEMS at the University of South Florida. Her interests include bio-impedance measurements and microneedles.