Summer Undergraduate Research Experience (S.U.R.E.)

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LEWIS UNIVERSITY
A Catholic and Lasallian University

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<u>Role of Surfactant on Ag/TiO_2 Nanoparticle Properties and Antimicrobial Effectiveness</u>

James P. Fitman, Dr. James V. Rago, and Dr. Jason J. Keleher

Photochemical synthesis of Ag-coated/TiO_2 nanoparticles with controlled particle size distribution and surface charge (zeta potential) has been identified as a pathway for the development of "self-cleaning" surfaces. The potential uses of such nanoparticles are quite extensive with applications ranging from antimicrobial paints to surface coatings for advanced medical devices and equipment. In order to harness the full potential of these nanocomposite materials, it is necessary to develop an efficient and robust synthetic process to control the desired particle properties. Furthermore, a correlation between the particle properties and the antimicrobial effectives is necessary. One major obstacle in the development of such nanomaterials is the ability to reduce particle aggregation, both during the reaction and post-reaction treatment steps. Commonly practiced synthetic processes result in severe particle aggregation during the photochemical reaction, producing particles well above 2000nm. Although these large particles do exhibit some antimicrobial properties, smaller particles are of significant importance because they can more readily diffuse through bacterial cell walls, resulting in greater antimicrobial efficiency. This research will focus on the effect of two surface modifying agents (surfactants), sodium dodecyl sulfate and PE1198, during the post-reaction treatment steps of Ag/TiO_2 nanoparticle synthesis to minimize aggregation. The introduction of these anionic surfactants will create a desired surface charge of approximately -30mV on the particles, which in previous studies has been shown to inhibit bacterial growth. Initial results reveal that the structure of the surfactant and the subsequent intermolecular forces present play a key role in both the reduction of the overall particle size and the modulation of the particles' zeta potential. SDS showed limited effect on the aggregation process while the addition of the alkyaryl phosphonic acid (PE1198) surfactant has allowed for the production of particles around 400nm in size. This presentation will address the modifications to the photochemical preparation of the nanoparticles to reduce aggregation as well as discuss the relationship between particle properties and antimicrobial effectiveness.

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Automating Market Analysis To Maximize Profits and Minimize Risk

Brian Wilhelm and Dr. Ray Klump

Investing has always been plagued by risk. As time has gone on, various strategies have been created to help brokerage firms and traders reduce their exposure while helping maximize profit. Actuaries are used in conjunction with seasoned traders in the financial sectors to help develop balanced investment approaches for the gain of large firms and banks. There has never been a strategy that is perfect at this as is evident by prior financial collapses such as the one in 2008. For this project, we investigated and combined numerous metrics to identify current and emerging trends of individual stocks to create anticipatory buy and sell signals. If a system such as this were developed and offered to the mass markets, perhaps the automated signals with the supporting information could be of benefit to the end user to avoid manic sell-offs. By using our algorithms, we have seen potential gains using a diversified strategy, which would far exceed the traditional buy and hold approach of past investors. Future work will seek to refine the logic, which generates "Buy" and "Sell" signals to the end user so that they may realize higher profits through all market conditions.

Examining Particle Interactions for Detector Shielding Using G4Beamline

Elizabeth DeWaard and Dr. Joseph Kozminski

Particle colliders are an important tool for physicists to understand the subatomic particles that constitute our universe. However, for these collider experiments to be a success, the backgrounds produced from particle decay processes and other phenomena must be adequately reduced. Computer simulations can be utilized to research, develop, and optimize detector shielding for particle physics experiments such as a Muon Collider or the more imminent Mu2e Experiment at Fermilab. Such shielding studies also have applications in the fields of nuclear and medical physics. This project involved running Monte Carlo simulations of neutron beam interactions with various materials using G4beamline, a user-friendly front-end to Geant4. G4Beamline validation studies were done by comparing neutron absorption cross sections calculated from simulation results to known cross sections obtained from the National Nuclear Data Center. These studies specifically examined thin targets of Lithium, Boron, Cadmium, and Gadolinium. Since these elements absorb low energy neutrons best, polyethylene is used in detector shielding to slow the neutrons. Therefore, a series of studies examining neutron absorption by polyethylene doped with Lithium and Boron was also performed. Target performance was studied for incident neutron energies ranging from 1 eV to 100 MeV. Various target thicknesses were also considered. This work is being conducted in collaboration with members of the Northern Illinois Center for Accelerator and Detector Development (NICADD) group at Northern Illinois University and Muons, Inc.

<u>Biofilm Development: Many characters, different plots</u>

Aleksander Pecherek and Dr. Jerry Kavouras

Biofilms are ubiquitous. They can be found on your driveway and in your mouth. Biofilms composed of *Escherichia coli* and *Staphylococcus aureus* are leading causes for nosocomial infections. Biofilms provide protection to bacteria from harsh environments and antibiotics. Understanding environmental factors that influence the development of biofilms may lead to better control methods. The purpose of this work is to study biofilm development under varying environmental conditions. The hypothesis is that surface chemistry, temperature, nutrients, and time influence the arrangement of cells within a biofilm, cell densities, and biofilm matrix production. Single-species biofilms of *E. coli* and *S. aureus* were developed on glass and polystyrene surfaces at 28°C and 37°C from log phase batch cultures. Cell arrangements and densities within the films were examined for early phase (1hr) and older (24hr) biofilms. The cells within the biofilms were fixed, stained with crystal violet, and then visualized by light microscopy. The films were examined at 30 random locations on each surface. Cell arrangement for each cluster of cells was categorized as individual, 2, 3, 4, or 5+ cells, and direct counts were performed. All experiments were performed in triplicate. Previous research by this group demonstrated that temperature plays a significant role in the arrangement of cells within the biofilm. Cells within biofilms developed at 28°C were predominantly clustered, whereas bacteria were mostly individual at 37°C. Work performed this summer indicated *S. aureus* biofilms had greater cell densities in general than their *E. coli* counterparts, polystyrene biofilms typically had more attached cells than glass biofilms, and biofilms developed at 28°C have greater cell densities then those developed at 37°C. The cell densities of early phase *E. coli* biofilms had lower cell densities than their older film counterparts (ANOVA $p<0.05$), but the opposite trend was observed for *S. aureus* biofilms, early phase had greater densities than older films (ANOVA $p<0.05$). Based on the data, it appears that *S. aureus* biofilms develop over time using different mechanisms than *E. coli*. Further research will examine the role of nutrients in these complex microbial-surface interactions and the role environmental factors play in the production of biofilm matrix polymers.

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<u>Sensing and Measurement of Frustration on Mobile Devices</u>

Michael Korby and Dr. Cindy Kersey

With the mounting number of individuals using smartphones, the devices have become not only more widely recognized but are in common use. The purpose of this project was to utilize this familiarity in affective research. Current methods for researching and modeling affect require peripheral devices, many of which are uncomfortable for or disconcerting to the user. To more realistically identify indicators of certain affective states, we have developed an application, **frustDroid.** The application uses a basic matching game that is designed to frustrate the user after several rounds of game play. The intent of this application is not only to minimally frustrate the user, but to also measure how the user responds at varying levels of stress. The application utilizes a number of sensors located in a standard device running the Android operating system, including the accelerometer and pressure monitor. At time of release, we have not begun user studies, however we intend to begin them soon. Further development plans include incorporating additional sensors, including front and rear facing cameras. Long-term research plans include the development of a sensor-based model to identify and potentially manage user frustration. Such a mechanism could be deployed in applications such as games and intelligent tutoring systems to enhance the user experience.

Synthesis of Flexible Anodic Nanomaterials for Bio-inspired Solar Energy Production

Olivia M. Chesniak and Dr. Jason J. Keleher

Economic distress resulting from dependence on diminishing fossil fuels has emphasized the urgent need for new, clean, and efficient fuel sources. Developments in understanding solar energy, a versatile, renewable resource, have resulted in the production of bio-inspired materials, including solar cells, which harness the power of light to produce energy. Commercially available solar cells face severe cost, efficiency, and structural limitations, which must be overcome as the energy crisis progresses. Building on a molecular understanding of photosynthesis and the established electron-transfer principles of dye-sensitized solar cells (DSSC), this work has begun to develop flexible anodic nanomaterials for use in solar energy production. The highly conductive polyaniline emeraldine base (EB) was synthesized and dispersed in thin, flexible polyvinyl alcohol (PVA) films using a novel microwave method. The resulting films were coupled (surface or embedded) with a dye-modified titanium dioxide (TiO_2) nanoparticle dispersion which serve as the antenna for photon capture. Initial results indicate that the voltage produced by a DSSC with a polymeric anode is dependent on the concentration and homogeneity of EB present in the nanocomposite film. Furthermore we have demonstrated the addition of the dye-nanoparticle dispersion directly into the anode polymeric matrix results in greater stability of the electron transfer process. Much development is necessary before the long-term goal of producing a flexible, complete DSSC is accomplished; anodic optimization and cathode development are in progress. The flexibility, low cost and ease of preparation of the EB-PVA polymer film creates great possibilities for widespread application and maximized efficiency of DSSCs.