UNIVERSITY OF PITTSBURGH
Mascaro Center for Sustainable Innovation

2020 Undergraduate Summer Research Projects & Advisors
***** updated January 28, 2020***

"ChemCyling": Towards a Circular Economy for Plastics
Advisors: Eric Beckman, chemical & petroleum engineering
Götz Veser, chemical & petroleum engineering
Plastics are miracle materials with vast benefits for quality of life, but at the same time are creating increasingly unsustainable environmental problems at both ends of their usable life: when sourced from fossil fuels, and when discarded into the environment. In principle, one could close the anthropogenic cycle for plastics production and use by depolymerizing plastics back into their constituent chemicals at the end of their lifetime and (re-)use those chemicals as feedstock for production of pristine new plastics. Such a "circular" approach would directly address both the sourcing and the environmental problems. However, in practice, efficient pathways to depolymerize most common plastics are lacking. In this project, we are pursuing an ambitious goal of utilizing an entirely novel process scheme to achieve depolymerization of polyolefins, one of the most difficult but most abundant classes of plastics, through a combination of reaction engineering and materials science discoveries.

Silk-based lithography: a sustainable alternative towards green micro-/nano-manufacturing?
Advisors: Mostafa Bedewy, industrial engineering
Leanne Gilbertson, civil & environmental engineering
Photolithography and electron-beam lithography are staple processes for micro- and nano-fabrication in the semiconductor industry. In such processes, a polymeric material referred to as "resist" is patterned by the controlled exposure to photons or electrons. Conventional approaches require strong acids/bases, and hazardous solvents, in addition to energy-intensive processing. In this project, a silk-derived material will be developed and its performance tested for potential use as a direct patterning resist. A life-cycle assessment will be pursued simultaneously to reveal the environmental benefits of replacing commercial polymers with the water-soluble silk alternative.

Building as Material Banks: Towards a Circular Economy for the Built Environment
Advisor: Melissa Bilec, civil & environmental engineering
The current consumption model is linear: (1) acquire raw materials, (2) produce and use goods, and then (3) dispose of them. This 'take, make, waste' model has dominated the global economy for hundreds of years. A circular economy (CE) aims to decouple economic growth from resource consumption by cycling products and materials back into production, either by returning materials to generate new products, or by releasing benign substances to the environment through degradation. Housing a growing population has led to a search for new materials, like manufactured composite wood products, that do not degrade and cannot currently be recycled, and hence over 38 million tons migrate to landfills each year in the US. Cumulatively, global extraction of construction minerals exceeds 10 billion metric tons each year, representing the fastest growth rate in any sector over the past century. In this project, we are exploring how the built environment can act as a key sector to foster the CE through material flow and life cycle analyses.

Biodiversity collapse at the urban-rural interface: Consequences for the sustainability and economic viability of small, privately-owned forests in Pennsylvania.
Advisor: Walter Carson, biological sciences
Privately owned forests at the urban-rural interface are under siege by a combination of dozens of non-native, invasive plant species and over-abundant deer. This research is using adaptive management strategies to identify ways to restore a 600-acre degraded forest at Chatham University's Eden Hall Campus of Sustainability.

Energy-efficient processors, sensors, and systems for space-based sensing and computing
Advisor: Alan George, electrical & computer engineering
The focus of this research opportunity is to study and contribute to a topic in advanced computer architectures, apps, sensors, networks, systems, and/or services, often in the context of resource constraints and environmental hazards, with the goal of maximizing performance, energy-efficiency, and resilience. Students will learn and employ selected concepts, methods, and technologies in parallel, reconfigurable, dependable, and/or distributed computing, by working on a research task for next-generation spacecraft, autonomous systems, or supercomputers, in the NSF Center for Space, High-performance, and Resilient Computing (SHREC) headquartered in the ECE Department at Pitt.

Bugs Against Drugs: Taking the Headache out of Ibuprofen and Naproxen Pollution by Harnessing the Degradation Power of Microorganisms

Advisor: Sarah Haig, civil & environmental engineering

Domestic wastewater effluent is one of the main contributors of pain relief medications such as ibuprofen and naproxen into the environment, due to incomplete removal at the treatment plant. The presence of these drugs in aquatic environments has been linked to adverse health outcomes in various organisms; hence, there is an immediate need to find a way to reduce the concentration of these drugs leaving the treatment plant. This project will involve identifying and isolating ibuprofen and naproxen degrading bacteria from the environment, which could be used in a batch reactor to reduce the concentration of these drugs.

Structural Design with Bamboo

Advisors: Kent Harries, civil & environmental engineering
Ian Nettleship, mechanical engineering & materials science

Dr. Harries is presently leading the effort to develop an international standard for design with bamboo (ISO 22156). As a result, there are multiple opportunities for self-contained research studies which will have a direct and immediate benefit on this standard! Projects include study of test methods for shear, bamboo connection methods, creep, and durability. Architecture students or those taking the Architecture Minor would have the opportunity to design bamboo structures.

Bond Behaviour of GFRP Reinforcing Bars

Advisors: Kent Harries, civil & environmental engineering
Peter Ludvig, Centro Federal de Educação Tecnológica de Minas Gerais, Brazil
Elayne Marques Silva, Centro Federal de Educação Tecnológica de Minas Gerais, Brazil

Glass fibre reinforced polymer (GFRP) bars for reinforcing concrete provide a promising means of mitigating deterioration and thereby providing a resilient and more sustainable civil infrastructure. Behaviour of reinforcing bars in concrete is dominated by bond. This project is a collaboration with CEFET-MG in Brazil and provide opportunities for students to engage in large-scale experimental-based research with a visiting PhD candidate from Brazil. Civil Engineering students with interest in Structural Engineering are preferred.

Designing a composite piezoelectric wave energy generator

Advisor: Katherine Hornbostel, mechanical engineering & materials science

This project will involve designing and testing a composite prototype with both ceramic and flexible piezoelectric components that can produce power from waves. The student will be responsible for ordering parts, fabricating a prototype, testing it in a wave tank, and analyzing experimental data.

Membrane testing for ocean carbon capture

Advisor: Katherine Hornbostel, mechanical engineering & materials science

This project will involve ordering and testing hollow fiber membrane devices for CO2 removal from synthetic seawater. The student will be responsible for ordering parts, modifying an existing experimental apparatus, and collecting/analyzing experimental data.

Improving the performance of nanoparticles in clean-energy applications: Investigating how metal nanoparticles stick to surfaces.

Advisors: Tevis Jacobs, mechanical engineering and materials science
Götz Veser, chemical & petroleum engineering

While nanoparticles are widely used in sustainability--from removing the most harmful gases in car exhaust to more efficiently harvesting energy from the sun--they are inherently unstable and degrade over time. This project aims to use experimental adhesion tests on nanoparticles to develop a fundamental understanding of how they stick and how to make them last longer.

Electromagnetic Modeling of Power Systems Elements using COMSOL Multiphysics

Advisor: Bob Kerestes, electrical & computer engineering

In this summer research project, the student will become familiar with the finite element analysis software COMSOL Multiphysics, and use this software to create models of common electric power distribution devices.

Plastic Trade and Implications for Sustainability

Advisor: Vikas Khanna, civil & environmental engineering

This project will utilize network theory and industrial ecology techniques to model the global plastic trade. This will allow us to evaluate the implications of plastic trade for environmental sustainability and managing end-of-life.

Towards a Consumption Based Modeling of Food-Energy-Water Nexus
Advisor: Vikas Khanna, civil & environmental engineering
This project will focus on building a consumption-based framework for modeling the food trade network.

Using machine-learning models to identify wildlife species in field recordings
Advisor: Justin Kitzes, biological sciences
Our lab uses small, inexpensive acoustic recorders to record soundscapes at field sites across the United States. We are interested in hosting a summer fellow who will work with us on this research. The main tasks will be developing and testing machine learning models to identify species of birds, bats, frogs, and/or insects within long field recordings, but tasks may also include deploying recorders in the field, managing incoming data, and testing new hardware designs.

Controlling Hole Transport in Oxide Photoanodes for Sustainable Water-fuel Conversion
Advisor: Jung-Kun Lee, mechanical engineering & materials science
A photoanode is an essential component of photoelectrochemical (PEC) cells which converts water to fuel using sun light. While semiconductor oxides meet most requirements of photoanode materials, slow hole transport of oxides still needs to be addressed. Due to small diffusion length and slow oxidation kinetics, hole transport is slow in oxide photoanodes. This often limits the performance of PEC cells. The objective of this summer project is to engineer the microstructure of oxide films at micro/nanoscale and improve the hole transport in oxide photoanodes for sustainable conversion of water to fuel.

Reducing Temperature Dependence of Ceramics Capacitors for Electric Vehicles
Advisor: Jung-Kun Lee, mechanical engineering & materials science
The rapid development of electric vehicles has brought a challenge to a capacitor that is a common passive electric component. In automobile industry, ceramic capacitors are required to operate between -30ºC and 125°C without a significant temperature dependence. However, this is not easily observed in common high dielectric materials. The objective of this summer project is to explore the temperature dependence of dielectric constant in ceramics capacitors and modify it for the electric vehicle application. In addition to materials engineering, a more precise characterization technique will be studied during the project period.

Simulations of First Solar Solar Cells
Advisor: Paul Leu, industrial engineering
First Solar is the largest manufacturer of solar modules in the US. They make cadmium telluride (CdTe) thin film solar panels as opposed to the conventional crystalline silicon panels. This project seeks to simulate CdTe solar modules and understand the effects of material properties, device layer thickness, and other factors on power conversion efficiency.

Durable, anti-soiling, self-cleaning, antireflective solar glass
Advisor: Paul Leu, industrial engineering
Solar cells are installed in urban or dessert environments where they may be soiled with particulates that reduce their power conversion efficiency. Solar panels also consist of glass that reflects light that lead to less power conversion. This proposal seeks to create new durable glass surfaces that are anti-soiling, self-cleaning, and antireflective across a wide variety of wavelengths and incidence angles.

Electrochemistry for Sustainable Chemical Production
Advisor: James R. McKone, chemical & petroleum engineering
This experimental research project involves learning how to manipulate chemical reactions with electricity in order to create completely new technologies for generating chemicals using renewable energy. No prior experience necessary, but students with an interest in chemistry and electronics are especially encouraged to apply.

Intelligent Management for Energy Efficiency in Computer Systems
Advisors: Daniel Mosse, computer science
Vinicius Petrucci, computer science
Heterogeneous processors and hybrid memories/storage have been adopted by hardware engineers to balance performance and power efficiency on emerging computer devices. Still, the main research challenge for runtime systems software is to cleverly allocate execution processes to the heterogeneous resources, while meeting strict user-facing performance targets with minimal resource consumption. This research project will enhance resource management decisions by automatically learning an optimal scheduling policy that can determine energy-efficient resource allocations for applications running on heterogeneous computing platforms.

Project: Microcapsule-mediated bioremediation of crude oil

Advisor: Tagbo H. R. Niepa, chemical & petroleum engineering

Each year massive amounts of oil are accidentally or deliberately spilled into seawaters, which pollute the ecosystem. Quick remediation responses, including *in-situ* burning or dispersant spraying, have been insufficient to mitigate the long-lasting harm caused by the spills. Moreover, these remediation techniques are turning out to be toxic and damaging to the ecosystem in which they are practiced. Therefore, sustainable strategies are required to eradicate the persistent ecological impacts of hydrocarbon pollution. Here we propose to investigate the ability of synthetic organic sorbents in facilitating crude oil bioremediation. *We hypothesize that the microcapsules can promote crude oil bioremediation by acting as a substrate lowering the interfacial energy between oil and water that oil-eating bacteria have to overcome to metabolize the oil*. Thus, the goal of this research thrust is to elucidate the effects of the microcapsule on the metabolic performance of bacteria.

Solving the PFAS Problem with Microbial Power

Advisors: Carla Ng, civil & environmental engineering
Sarah Haig, civil & environmental engineering

Per and polyfluorinated alkyl substances (PFAS) are widespread drinking water and environmental contaminants that are difficult to treat and extremely persistent. Recent publications suggest specific microbes may have the ability to break down PFAS. This project will use cutting edge molecular techniques and analytical chemistry to identify "superbugs" that can help solve the PFAS problem.

Smarter Riversheds – real-time sensor networks

Advisor: David Sanchez, civil & environmental engineering

Combined sewer overflows result in over 9 billion gallons of sewer/storm water flowing into Pittsburgh's rivers each year. Identifying water-quality trends in real-time is essential to solving this problem projected to cost over $3billion for Pittsburgh. With many cities across the US facing this challenge, this project focuses on triangulating historical, historical, and grab sample water quality data to understand water quality dynamics in real-time and to evaluate Green infrastructure. Student will gain experience in environmental sampling, analytical chemistry techniques and data science.

Using Microbial Fuel Cells to degrade emerging contaminants of concern

Advisor: David Sanchez, civil & environmental engineering

There is a growing portfolio of emerging contaminants in the environment that are unregulated but pose risks to human and environmental health. The goal of this project is to evaluate the potential for biofilms and micro-electrodes to degrade these contaminants. The project will focus on designing micro-electrodes for biofilms, and selectively adapting electrodes to degrade these contaminants. Additional aims will focus on identifying governing parameters (material morphology, electrochemical activation) to optimize degradation kinetics. All disciplines are welcomed to apply.

Harnessing ambient energy for manipulation using additively manufactured structures

Advisor: Ravi Shankar, industrial engineering

Shankar's group invites participants to study additive manufacturing of molecularly-patterned solids to directly utilize ambient energy sources such as light, heat and humidity to power mechanical manipulation. The research effort will focus on understanding the structure-property relationships in magnetically-assisted additive manufacturing to enable sun-tracking photovoltaics, harvesters of low-grade heat and biomedical implants that can harness biobenign stimuli.

A novel process for purely thermal desalination

Advisor: Sachin Velankar, chemical and petroleum engineering

This project will implement a bench-top continuous desalination process in which a polymer selectively binds water from a salt+water mixture, and then releases it upon gentle heating. The project is mostly experimental, but may involve some process modeling using the Aspen software.

Designing nanocatalysts for responsible use of natural gas

Advisor: Götz Veser, chemical & petroleum engineering

Shale gas is both an economic opportunity and an environmental threat. In order to assure a resurgence of a cleaner, more efficient and environmentally responsible domestic chemical industry, novel concepts for natural gas utilization (beyond combustion and the use of "crackers") are needed. We are exploring the use of microwave-based processes to upgrade methane to aromatics in a drastically more efficient way. Towards this goal, we are exploring the design of nanostructured catalysts to for microwave-based processes, i.e. how careful design from the nanoscale up can make a material a good candidate for microwave catalysis.

Going with a Bang: Cavitation reactors for chemicals production

Advisor: Götz Veser, chemical & petroleum engineering

Cavitation reactors (CR) constitute an efficient, but to-date poorly understood and hence rarely utilized reactor concept. In a CR, a localized pressure gradient is created (typically through hydrodynamics, i.e. fluid flow) which results in localized boiling, i.e. in the formation of small, short-lived bubbles throughout the liquid. The spontaneous implosion of these bubbles then results in simultaneous localized heating and mixing in an unconventional, yet highly efficient way. In close collaboration with an industrial partner, we are exploring CR for reactive processing of specialty chemicals with the aim of reducing energy intensity and reducing waste in comparison to a conventional industrial process.

Hardware acceleration of artificial neural network for neuromorphic computing

Advisor: Feng Xiong, electrical & computer engineering

Neuromorphic computing has recently attracted immense research interest for its potential in artificial intelligence and next-generation computing. We will develop an artificial synapse to achieve the hardware acceleration of deep neural network. Student with a basic background in semiconductor device is preferred, prior experience with LabVIEW is a plus.

Efficient and scalable two-dimensional thermoelectric devices

Advisor: Feng Xiong, electrical & computer engineering

Thermoelectric (TE) technology allows us to harvest and convert waste heat into electricity. We will develop a high-efficiency, flexible TE device with two-dimensional materials. Students with a basic background in semiconductor device is preferred.

3D printing of graded alloys for power plant with enhanced energy efficiency

Advisor: Wei Xiong, mechanical engineering & materials science

The development of 3D printing methods has changed the landscape of materials research over the past decade. Researchers are just beginning to realize the full potential of benefits AM possesses over standard subtractive methods. One of these benefits is the ability to fabricate parts that utilize material composition gradients to yield optimized local material properties. The ability to use AM to produce parts with gradient compositions will enable an engineer to design components that utilize multiple exotic materials, thus improving overall performance. The students working in this project will learn the techniques regarding graded alloy build and study process-structure-property relationships for the graded alloy manufacturing, including post-heat treatment. The materials will be used in repairing the power plants, and some critical materials design models will be developed through this mini-project.

Design of high strength alloys for energy efficiency

Advisor: Wei Xiong, mechanical engineering & materials science

This project directly performs the new alloy design, which is critical to improve the service life of the naval craft and thus increase the energy efficiency of alloy production. The corrosion test and post-heat treatment will be applied to the new alloys that we designed in order to optimize the manufacturing of the advanced alloys. In addition, further improvement of steel composition will be applied using the ICME (Integrated Computational Materials Engineering) models will be applied to further modify the processing of these new alloys for naval craft manufacturing.

Multi-scale defects characterization for 3D printed metallic parts

Advisor: Xiayun (Sharon) Zhao, mechanical engineering & materials science

Laser Powder Bed Fusion based Additive manufacturing (AM) is a widely-used metal 3D printing method to fabricate complex-shaped metal components for various applications. However, due to the possible porous defect formation during the AM process and its detrimental effect on mechanical strength, it is critical to inspect the resulted components for defects at different scales. This project aims to establish metrics for porous defects and quantify them via experimental characterization such as X-ray computed tomography (micro-CT). The outcome will be correlated to an overall AM qualification framework via data mining to establish an in-depth understanding of "Process-Structure-Properties" in metal 3D Printing.

Develop a novel high-throughput multi-resolution additive manufacturing (3D Printing) process

Advisor: Xiayun (Sharon) Zhao, mechanical engineering & materials science

Despite the fame or hype, additive manufacturing (AM, known as 3D Printing), is still facing critical challenges such as slow build rate and poor accuracy, which limit its wide adoptions by industry. The goal of this project is to develop a novel AM process for non-metal materials which can print multi-resolution structures faster than existing commercial counterpart AM machines.