Alabama Research and Development Enhancement Fund
Quarterly Report
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Background

The Alabama Innovation Act (AIA) was established by Legislative Act #2019-404 and became effective June 6, 2019. The Act designated the Alabama Department of Economic and Community Affairs (ADECA) as the state agency to establish and administer the Alabama Research and Development Enhancement Fund (ARDEF) Program.

The purpose of the ARDEF Program is to encourage new and continuing efforts to conduct research and development activities within the state. The Fund is designated to receive appropriations from the legislature, or from the receipt of gifts, grants, or federal funds to be expended for the purpose of increasing employment opportunities, products and services available to the citizens of Alabama.

Overview of 2020 Program Year

Projects Funded Under 2020 Round One Grant Period

Applicant	Amount
Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama	$193,960.00
Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles	$868,145.00
Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources	$245,864.77
HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings	$969,409.00

Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama

This project aimed to remove and destroy the so-called forever chemicals, per- and polyfluoroalkyl substances (PFAS), from Alabama water and landfill leachate. PFAS have been detected in chemical manufacturing wastes and landfill leachate in Alabama and have caused some serious cases of drinking water contamination in the state. Ongoing health concerns and regulatory development associated with PFAS are threatening the sustainable development of the Alabama economy and business. The goal of this research was to develop an innovative "Concentrate-&-Destroy" technology to cost-effectively remove and degrade PFAS in water and landfill leachate. The new remediation technology will provide the affected industries and water utilities with a powerful remediation means to mitigate the PFAS-related issues, thereby assuring sustainable development of the economy and the wellbeing of Alabama citizens.

Within this quarter, we carried out some preliminary experiments to treat PFAS in an Alabama landfill leachate under field leachate conditions. The preliminary results revealed the great potential of Bi/TNTs@AC for selective adsorption of perfluorooctanoic acid (PFOA) in the leachate and subsequent photocatalytic destruction of pre-adsorbed PFOA on the solid particles.

Addition research is warranted to further enhance the photocatalytic degradation through additional engineered means, such as the addition of persulfate or ferric iron during the photodegradation stage.

In this quarter, we also started preparing the final project report. We are planning to complete this project in the upcoming quarter.

Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles

Insects transmit crippling diseases to humans. Nearly a half-million people die of malaria each year. In Alabama, citizens encounter Dengue and Zika virus invasions as well as a multitude of encephalitis variants. The worse vector-borne diseases are transmitted in the hottest climates like Alabama, and it is uncomfortable to wear the thickest clothing. This project will research different textile and weave patterns to create clothing that is cool in heat and capable of blocking mosquito bites and develop prototypes based on this research. Beyond the prototype phase, research will be done to measure the effectiveness this product will have on the Alabama economy.

During this quarter we worked on writing up our results to date for publication. One student, Alexa England, is preparing to graduate with her master's degree in biosystems engineering. During this quarter Alexa wrote and revised her master's thesis which includes data collected to be published from this research. Her thesis was submitted to the committee, and her defense was held on Friday, April 14, 2023. We also finalized a final draft of our large manuscript which reports all discoveries made to date. This manuscript was submitted for publication and is currently under review. We are also working on a second manuscript that focuses on comfort of the mosquito bite blocking textiles. We also worked with accountants to revise the final budget for the remaining time on this project.

Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources

The main goal of this project is to utilize Alabama's forestry products and agricultural resources for extracting cellulosic nanomaterials (CNM) by using these nanomaterials in advanced biosensing. As timber production and other agricultural products are essential for the economy in Alabama, these materials are a great resource for obtaining cellulosic nanomaterials.

Outstanding laboratory facilities along with the support from ADECA are enabling scientific knowledge contributions and revalorization of agricultural and forestry waste products as biosensors. Trees and crops contain tiny materials known as cellulose nanomaterials (CNMs). Developing new applications for CNMs could enable forestry and crop waste to provide additional economic benefits for Alabama citizens. An Auburn University research team is exploring using CNMs from cotton, soybean hulls, and wood to produce sensors for the detection of allergens and water contaminants. Thus far, the team has shown that CNMs can be used to absorb carbofuran which is a common pesticide. They have also shown that CNMs can be used to absorb beta-lactoglobulin, a milk allergen. In ongoing work, they are improving the chemistry to make sensors that cannot only absorb multiple species but also selectively detect the materials of interest (analytes). The long-term goal of this work is to have a family of portable CNM sensors that can be used by citizens to test for water contaminants and food allergens.

This project is focused on using Alabama's forestry and agricultural products such as wood, cotton, and soybean hulls as sources of an exciting nanomaterial called cellulose nanocrystals (CNC). Cellulose nanocrystals are found in all biomass. Their high strength, large specific surface area, and natural organic chemistry make them exciting for a range of applications. We are focused on developing sensors to improve water safety and the health of Alabama citizens. This quarter we continued working toward using CNCs as sensors. We are using laboratory tools such as Quartz Crystal Microbalance with Dissipation (QCMD) and Surface Plasmon Resonance (SPR) to validate our approach. So far, we have increased the stability of the CNC when exposed to water and demonstrated analyte absorption.

This quarter the work focused on refining our production of CNCs from soy and cotton, exploring the processing window for making shear cast films from these materials, and evaluating film optical and mechanical properties. Additional efforts focused on optimizing CNC device fabrication conditions after a change in fabrication materials and equipment repair. In addition, the investigators discussed the potential use of CNCs as sensors at the American Chemical Society meeting and during other professional interactions.

Auburn University's outstanding laboratory facilities and the support from ADECA are helping the research team continue to gain insights on how an exciting material hiding in our abundant forestry and agricultural resources can be transformed to enable Alabama citizens to detect contaminants and allergens in their water and food.

HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings

Genomic medicine is a form of precision medicine that uses approaches customized to each patient to treat disease and optimize prescription medicine based on a genetic profile. This project will test and develop a genomic health complete delivery system for Alabama patients and physicians at healthcare systems and community hospitals with limited expertise in genomics. This system includes: 1) Partnering with Auburn University to develop community-based models for health programs; 2) Refining and optimizing the process including insuring access by rural and underserved areas, and 3) Developing the health IT infrastructure needed to fully integrate genetic test reporting and education into an electronic health records system. The proposed development of new products and services will result in improved health outcomes for Alabamians, opportunities for employers to increase competitiveness and reduce costs, and modernization of health care in an equitable way for Alabama communities, large and small, regardless of socioeconomic status.

The HudsonAlpha project continues to work with partners across the state of Alabama to provide genetic testing as an employee wellness benefit. Genetic results provided as part of this project include pharmacogenetics, to inform the selection and dosing of medications, as well as risk for certain diseases such as cancer and cardiac conditions. Program impact is assessed through the analysis of de-identified participant test results as well as follow-up surveys. This past quarter we continued recruitment of participants through partnering employers. We held a series of successful recruitment events with our newest partner, Alabama A&M University. We continue to collect data from staff at partner sites describing how they have implemented the workplace genetic testing program, challenges that have arisen, and factors that have contributed to project success. Data

disseminated through the HudsonAlpha project will provide valuable insight into the clinical and personal utility of genetic testing in the context of employee wellness.

Projects Funded Under 2020 Round Two Grant Period

Applicant	Amount
University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap	$746,104.00
University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast	$172,073.00
University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations	$394,926.00
Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19	$75,374.00
Auburn University – Formaldehyde Paper-based Device (PAD) for a Cost-efficient Detection of Formaldehyde Emissions from Wood Panels	$247,142.00
University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial	$906,458.00
Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-promoting Bacteria (PGPB) Inoculants	$7,500.00

University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap

Recent events, such as the global COVID-19 pandemic, are having detrimental impacts on companies throughout Alabama, including the products and services they provide and the citizens they employ. Other impactful events that can occur may include the sudden loss of a major customer or supplier, a natural disaster, or even a diminishing source of skilled labor. The objective of this project is to research potential impacts on businesses and organizations across several business sectors to develop and deploy a comprehensive Resiliency and Sustainability Index and Roadmap (RSIR) model. The RSIR can be further tailored to fit each business sector and individual organization. Additionally, the UAH team will directly support businesses in the customization and implementation of their RSIR along with assistance in developing the ability to execute the roadmap and plan should the need arise.

As of Q1 2023, outreach efforts are ongoing. Extensive research was conducted to strategically identify over 1,300 additional qualified companies. Forty-nine chambers of commerce were identified and contacted. Virtual meetings were held with twelve (12) of those Chambers and they agreed to share the program details with their eligible members.

Four additional companies have started the Future Ready program, one of which has completed their assessment. Implementation support actions are ongoing as templates/resources are developed and research is conducted on behalf of the customers' support actions.

University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast

As irrigated agriculture develops in our rural communities, it is imperative Alabama has the tools and data needed to ensure water resources are available for sustainable economic development. The goals of this project are to update the existing manual center pivot irrigation survey completed by UAH for the years to include 2017 and 2019 and develop a state-specific machine-learning framework from multiple sources of remote sensing products to efficiently and semi-autonomously identify the irrigated areas in Alabama to include all irrigated land such as golf courses and other irrigation system types beyond just center pivots. This information will be used to update the report "Estimates of Future Agricultural Water Withdrawal in Alabama," produced by the Water Resources Center, Auburn University for OWR in 2017. The result will include updated estimates as well as methodologies utilizing more recent urban growth and land use change data. The results and outcomes of this project will support the Alabama Department of Economic and Community Affairs (ADECA) Office of Water Resources (OWR) to accurately analyze and forecast water use across the State.

During Q4 2022, this project's final quarter, the team finalized the results and concluded the project. The results and outcomes of this project will support the Alabama Department of Economic and Community Affairs (ADECA) Office of Water Resources (OWR) to accurately analyze and forecast water use across the State. In 2015, a total of 121,394 acres of center pivot irrigation was identified. This was about a 37,000-acre increase from 2013. The current study mapped center pivot irrigation for the years 2017, 2019 and 2021. We show that irrigation has continued to increase, though the rate of increase has decreased. Overall, center pivot irrigation grew 24,594 acres from 2015 to 2021 at an average annual rate of approximately 4,000 acres per year. This varied by region with the Wiregrass region increasing the most over the same period (5,600 acres total). A pilot project was developed to assess the potential of automating the center pivot survey. Though the Alabama specific methodology performs as well as or better than many national products, there are still improvements that are needed to meet the accuracy needed for water use surveys. Lastly, a land use change model was employed to estimate the future growth in irrigation to inform future water use estimates. Overall, our results show a greater than 50% increase in irrigation by 2040.

This research project ended October 15, 2022.

University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations

This project focuses on the development of a comprehensive data science software toolkit to support transportation planning for Alabama's businesses and vulnerable populations. Research activities include: (i) use of transportation user surveys and open data source collection to build a web-based data portal for mobility analysis in Alabama; (ii) development of agent-based urban transportation simulation models, and employment of machine learning techniques for transportation forecasts; and (iii) use of the developed tools to study scenarios that address pressing mobility needs in Alabama. Examples include (1) building a COVID-19 simulator to explore how various business reopening strategies affect the population's mobility and hence the virus spread; and (2) studying the impact of shared mobility services such as Uber/Lyft/Via, Zyp BikeShare

stations and dockless electric scooters on local traffic congestion, transit use; and accessibility and mobility of vulnerable populations. The project will provide helpful recommendations to transportation policymakers about transportation initiatives that can help Alabamians, including economically and physically disadvantaged ones, to gain access to jobs and critical amenities in an equitable and efficient manner.

During the reporting period of January to March 2023, the team finalized a technical paper and submitted the paper to Future Transportation Journal. The paper is titled "Operational Impacts of On-Demand Ride-Pooling Service Options in Birmingham, AL" and summarizes our recently completed analysis of on-demand transportation options, such as Uber and Lyft, and their impact on traffic operations. The results indicate that when Transportation Network Company (TNC) vehicles are added to the network, the Vehicle Kilometers Traveled (VKT) decrease by up to 5.78% for the door-to-door (d2d) service and up to 2.71% for stop-based (sB) services, as compared to the baseline scenario (no TNC service). The findings also suggest that an increase in the size of the ride-pooling fleet results in a rise in total ride-pooling service VKT, network-wide total VKT, and detour distance; a fleet of 200 ride-pooling vehicles can meet the current demand for service in the Birmingham region at all times, thus it is the optimal ride-pooling TNC fleet size for a medium-sized city such as Birmingham.

The team also expanded the analysis of the micromobility Veo dataset from Birmingham. These efforts aimed at providing insights into micromobility usage patterns of e-scooter and e-bike use in the Birmingham region, across different periods and locations. Our analysis showed that the majority of trips were short in distance and duration with mean values of 2.3 mi and 15.9 min, respectively, and the average speed was around 9 mph. Moreover, we observed that the distribution of trips varied by day of the week, with weekends having higher trip volumes than weekdays. We also found that there were distinct patterns in trip volumes by hour on weekends, with the highest volumes occurring from 6 PM to 10 PM. With respect to monthly variations of usage of micromobility options, we observed that trip volumes occurring during the colder months (from November 2021 to February 2022) were lower than those observed in spring, summer, and fall. Finally, our analysis revealed that there were no geographic differences in trip volumes in 2021 and 2022, with downtown and university campuses having higher micromobility trip volumes than others. These insights can be helpful for stakeholders involved in the micromobility industry, such as city planners and micromobility services operators, to make informed decisions about infrastructure development and service offerings.

Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19

One of the most effective ways to prevent viral spread of the Coronavirus is to use face masks and respirators. Available reusable face masks are often not as effective as single-use coverings, which are costly and environmentally irresponsible. Currently, there is limited knowledge available on the performance of fabrics used in masks. Filtration efficiencies as a function of aerosol particulate sizes in 10 nm to 10 μm range are relevant for respiratory virus transmission but lack evaluation. The purpose of this research was to develop novel face masks to fight the pandemic based on scientific and engineering principles. In this research, novel medical face masks were designed, produced, and tested to reduce the spread of COVID-19 while improving on deficiencies present in currently used textile reusable face coverings. The project incorporates additive manufacturing,

computer aided design (CAD), third party testing of both Bacterial Filtration Efficiency (BFE) and differential pressure measurements, and laser-visualization tools for illuminating leakage.

This project resulted in a textile face mask design with enhanced capabilities as compared to other textile masks currently available on the market. Through the employment of various testing methods, including bacterial filtration efficiency, breathability, initial filtration efficiency, laser leakage illumination, and performance testing, various mask iterations were evaluated and improved to perform better. Different engineering methods were utilized, including textile engineering, additive manufacturing, and laser imaging, all to construct a device with the capability of reducing the spread of COVID-19 or another disease, if a pandemic such as COVID-19 were to occur again.

This research project ended May 15, 2022.

Auburn University – Formaldehyde Paper-Based Device (PAD) for a Cost-Efficient Detection of Formaldehyde Emissions from Wood Panels

Formaldehyde emission can be toxic to people depending on the time of exposure coupled with formaldehyde concentration. This level of exposure is generally not high in forest products because companies that make indoor products currently measure formaldehyde through quality control techniques. Companies also use safe adhesives ("glues") by partnering with their suppliers. Nevertheless, these companies are regulated to federal standards such as the California Air Resources Board (CARB) to ensure this safety. To assist with the more expensive and laborious methods in CARB, this project endeavors to create a relatively cheap paper-based sensor that changes color based on formaldehyde exposure. Such a product can help to reinforce the safety of our forest products while maintaining the jobs of our many Alabamians.

During Q1 2023, our team primarily worked on testing the sensor's performance. The selected condition for testing the sensor's performance was the point next to the hot press where a wood composite was prepared.

Because the laminated veneer lumber (LVL), presented in the previous quarterly report, was damaged, it was not possible to continue monitoring the formaldehyde emissions. So, we requested a new batch of Resol Phenol/Formaldehyde resin, and it has arrived at our facilities. Our team is currently working on conditioning the wood strands for the fabrication of new oriented strand board (OSB) panels, in which formaldehyde emissions will be monitored every two weeks until the emission level complies with the 0.09 ppm threshold value set for OSB panels by the California Air Resources Board.

In the meantime, the student assistant has been focusing on the preparation of the sensors for the experiments and evaluating new formulations for improving the current prototype.

University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial

The goal of the project is to finalize the development of an artificial vascular graft for surgical implantation. The graft has relevance to the current COVID-19 pandemic in that numerous patients are reporting kidney infections and blood clots. UAB has been working on this project since 2007

and has reached a point where funds are needed for an animal trial. Once this graft has been validated through this process, we plan to market it to a biomedical implant company to set up a division in Alabama or to establish a spin off company for the production and distribution. This graft has the potential for an estimated $50 million in annual sales based on conservative estimates of the number of surgical interventions that could use the implant in an unmet market and lead to a number of jobs for highly skilled workers in the State of Alabama.

Our project has been paused for the last few months for our student researcher to finish the requirements for his graduate studies. He is now resuming work and will be providing the surgical team with more grafts so that we can resume the animal trials. We anticipate that we will be able to conduct several trials in succession to study the longer-term performance of the grafts.

Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-Promoting Bacteria (PGPB) Inoculants

Inoculation of plants with plant growth-promoting bacteria (PGPB) that enhance the yield of crops and growth performance of environmental plants is an old practice. Two main factors control the success of inoculation—effectiveness of the bacteria and application technology. If the suspensions of bacteria are inoculated into the soil without a proper carrier, the bacteria population declines rapidly. These unprotected inoculated bacteria must compete with the often better-adapted native microflora and withstand predation by soil microfauna. Consequently, a major role of formulation of bioinoculants is to provide a more suitable microenvironment, combined with physical protection for a prolonged period to prevent a rapid decline of introduced bacteria. This project explored the feasibility of using cellulose fibers as carriers, to improve survival and enhance the PGPB viability.

This research project ended March 15, 2022.

Overview of 2022 Program Year

Projects Funded Under 2022 Grant Period

Applicant	Amount
The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures	$341,679.00
Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics	$727,677.00
Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics	$294,008.00
HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy	$968,365.00
University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama	$603,206.00
Auburn University – Polymer Smart Machines	$268,353.00
University of North Alabama – Surface Plasmon Resonance-based Biosensors	$10,353.33

Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls	$300,432.00
University of Alabama at Birmingham – Amputation	$700,000.00
University of Alabama at Birmingham – Pneumococcal Vaccine	$635,926.67

The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures

This research project focuses on the development of innovative materials and construction techniques that can help improve the sustainability and resilience of Alabama building and transportation infrastructure. The overall research goal of this project is to develop innovative hybrid structural building elements using fiber reinforced concrete and laminated wood materials (traditional lumber and/or bamboo); and characterize their performance under several loading conditions. As part of this research, we will develop two types of hybrid elements and perform large-scale testing of these elements whereby they will be subjected to mechanical and impact loading (representing expected debris impact during a tornado event). We will also investigate the acoustic and thermal performance of these elements to understand their energy efficiency for building applications. The novel and validated structural elements can provide opportunities to attract new industries and supply chains related to prefabricated building systems.

During Q1 2023, we have completed a detailed literature review on the bamboo composites and types of glues used in fabrication. We have identified two glue types (PUR and PRF) for the fabrication of cross-laminated bamboo specimens. Currently, we are in the process of ordering the glues from the companies. We have completed a draft of a journal article on the state of the review of bamboo panel manufacturing and material properties. It is currently undergoing internal review, and we plan to submit the article to a journal next quarter. During this quarter, we sourced and placed an order for bamboo materials needed for the fabrication of the cross-laminated bamboo specimens. These materials are scheduled to be delivered in mid-April. There were a few delays in shipping due to supply-chain logistic issues. We have also submitted an extended abstract to an international conference (scheduled in June 2023) on the work done so far on combining mass-timber with ultra-high-performance concrete (CLT-UHPC) panel behavior. The extended abstract has been accepted for presentation. The formworks to pour UHPC-CLT interface specimens have been fabricated. We are currently preparing to pour the interface specimens to characterize the CLT-UHPC interface behavior with different interface characteristics.

Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics

The main goal of this project is to advance economic development in Alabama (and the nation) through reinvigoration of our natural resource-based industries and to establish new industries based on advanced liquid fuels from woody biomass grown in the state and the waste plastics collected from our local cities. Woody biomass prevalent in Alabama will be co-liquefied with waste plastics using a pyrolysis technology, which will then be subjected to hydrogen treatment to produce jet- and diesel- fuels. The funding from the Alabama Innovation Fund will be used to overcome technical barriers faced in converting woody biomass to biofuels and waste plastics recycling. The research will be focused on developing: (i) a process that would require lower capital and operating cost for biomass liquefaction; (ii) catalysts for the production of jet- and

diesel-fuels; and (iii) a pathway for recycling waste plastics for the production of liquid fuels along with woody biomass. The team will leverage existing infrastructure and expertise at the Center for Bioenergy and Bioproducts at Auburn University.

The project aims to produce transportation fuels using biomass and non-recyclable waste plastics. During this quarter, the recipient performed biomass (pine) pyrolysis under three conditions. The pyrolysis experiments were performed without any catalyst and two sacrificial catalysts (red mud and gypsum). The hypothesis is that the iron-enriched red mud and sulfate mineral gypsum can reduce the acidity of pine-derived oil which will influence the downstream upgrading (hydrotreatment) of the same oil. While it was not expected, the total acid numbers of all three oils were very similar. However, there was a slight increase in bio-oil yield. In the next quarter, the recipient will conduct hydrogen treatment experiments using pyrolysis oils produced from three conditions.

Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics

Alabama is one of the top agricultural producing states in the U.S., with annual agricultural exports exceeding $1 billion. As a result, there is a significant amount of organic wastes produced in the state, and Alabama ranks 14th among all states in terms of biogas generation potential from organic waste through anaerobic digestion (AD). These organic wastes represent an underutilized renewable feedstock for biofuel and biochemical production. This project aims at researching and assessing the economic feasibility of converting organic wastes into bioplastics. Specifically, the project will develop and optimize a prototype of a patent-pending biotechnology that enables the conversion of organic wastes into bioplastics, and to assess its technical and economic feasibility at scale through techno-economic analysis (TEA). In the proposed technology, a microalgae-methanotroph coculture will be cultivated in a novel patent-pending circulation coculture biofilm photobioreactor (CCBP) to convert biogas (both methane and carbon dioxide) derived from organic wastes into microbial biomass while simultaneously recovering chemicals from AD effluent to produce treated clean water. The produced mixed microbial biomass can be economically processed to produce high-value bioplastics that are in rising demand. The project will advance the progress of the patent-pending biotechnology towards commercialization, which has potential to create many new jobs in the State of Alabama.

During Q1 2023, we improved the CCBP system's chain-membrane system and added a temperature control system. We further improved the species screening system, which can now regulate six abiotic factors for screening and exploratory applications which includes temperature, agitation rate, pH, light intensity, gas composition, and gas flow rate.

HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy

The HudsonAlpha ADECA/ARDEF project, in collaboration with Auburn University Crop, Soil and Environmental Science and Pathology Departments, and Alabama A&M University (AAMU) Winfred Thomas Agricultural Research Station will develop a pilot pipeline to import and test new crop varieties that could be deployed by Alabama farmers. We will connect the advanced agronomy crop research at Alabama Land Grant Institutions to the advanced plant genetic and genomic science expertise at HudsonAlpha. For two crops, barley and beans, the team will bring

in diverse germplasm, plant and evaluate cultivars to advance in additional trials. Barley will be tested as an overwinter crop for a spring harvest in Northern and Southern Alabama and dry beans will be tested as a summer crop in North Alabama. The team will evaluate disease, environmental, and weed pressure and other important agronomic traits for a crop to be successful in our challenging farming climate. As part of the goals, the partners will focus on increasing economic awareness of local barley and beans, connecting into existing educational and career development frameworks, and partnering with end users for brewing and food applications to increase the value of these Alabama crops. As this project develops, the teams will work with local farmers who are interested in planting alternative crops and engage stakeholders in workshops to discuss the science of next generation crop development to expand partnerships and apply this strategy to more crops useful for Alabama. With this newly developed research and collaborative infrastructure to bring in additional crop options, we can take control of the future of Alabama farming by optimizing the genetics and germplasm for Alabama, train new scientists in advanced plant science, open up new economic development in agriscience, and expand the current impact of local food and beverage industries.

In this quarter, we have monitored the overwinter barley plantings at our research station partners and farmer partners for winter damage and spring fungal infections. We have begun to prepare for our first large-scale harvest of Alabama-grown barleys and have extended our collaborations for malting and brewing. At AAMU, our graduate student has been collecting field data on the summer/fall 2022 bean harvest and preparing for this summer's grow out of black and pinto beans. We have engaged a group at Auburn to develop an economic model for barley for Alabama and a consumer survey.

Finally, we had several outreach events including the Alabama Farmers Cooperative Membership Meeting in Montgomery and the annual Alabama Young Farmers Conference in Birmingham. We also hosted a visit from Snead State Horticulture, an Alabama community college to highlight career opportunities in crop improvement and genetics for Alabama students.

University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama

The overall goal of the proposed institutional collaboration is to assist in the transition of Alabama from a low-labor-cost manufacturing state to a leader in the research and development of next generation manufacturing sciences. To meet this goal, our primary objective is to *expedite trans-disciplinarily, inter-disciplinarily, and multi-disciplinarily* training of Alabama for entering the industrial and government workforces and contributing to the implementation and advancement of the emerging manufacturing technology through Additive Manufacturing. Student teams from University of Alabama in Huntsville (UAH) and Calhoun Community College (CCC) have developed a documentation system to track vital information on builds with complete specimen builds in 316L under both Nitrogen and Argon atmospheres. Student understanding of the documentation requirements is critical to their future employers' efforts to qualify and certify additive manufactured components.

All activities are intended to mirror industrial expectations for workers at different educational levels (technician vs. engineer). This teaming builds an appreciation for different skills required in industry. Additional equipment is being added to CCC to expose students to industry standards. In

addition to the collaborative efforts by the team of CCC Students with UAH students, UAH graduate students also serve as instructors for an introductory course on Materials Science.

Auburn University – Polymer Smart Machines

This project aims to research and develop the foundational building blocks of polymechatronics, which will enable the realization of 3D printable polymer smart machines. The research and development includes designing, fabricating, modeling, and characterizing piezopolymer versions of traditional mechanical and electrical building blocks such as actuators, sensors, energy harvesters, energy storers, and analog & digital circuit elements. Conventional 3D printed structures do not actuate or compute. However, if successful, the proposed project will lead to the first 3D printable smart machines that can actuate and compute without the need of externally-manufactured actuators and circuits. Compared to traditional devices, polymer smart machines are expected to be less expensive, easier to manufacture, biocompatible, recyclable, use less energy, operate over a larger range of temperatures, offer new functionalities, and be more environmentally friendly. Such attributes are expected to enable a wide spectrum of novel mechatronic components and products for consumers.

- **Geometric Optimization.** It was discovered that there is an optimal geometry for the s-drives that allows it to achieve the largest deflection per applied voltage when used as an actuator, or conversely, allows it to generate the largest voltage per unit length when used as an energy harvester. Since the results are nonintuitive to an expert in the area and could have a societal benefit, we will inquire about patenting the discovery prior to publishing the results in a technical journal.
- **Personnel Change**. Since the postdoctoral research assistant on this project has not been meeting satisfactory expectations, he is being replaced by two graduate research assistants that have expertise in the materials science of piezopolymers.

University of North Alabama – Surface Plasmon Resonance-based Biosensors

Biosensors are devices that convert a biological response into an electrical signal; and, they are increasingly prevalent across multiple industries including (i) food industry to check and verify the quality of the vegetables, fruits and meat, (ii) medicine and health industry to diagnose biological samples for diseases, ailments etc., and (iii) monitor safety industry to identify harmful chemicals. The current state of biosensors' sensitivity is often limited to minute concentrations of the molecules/agents under testing, usually in the range of 5 ng/mL. Due to this limitation, the biosensor output may lead to a failed detection and/or recognition that might cause harm to life.

A novel technique will be used to enhance the sensitivity of the biosensors based on the principle of surface plasmon resonance (SPR). Numerical investigations have suggested that this novel technique can improve the sensitivity by at least 5-fold, which facilitates easier detection of biomolecules in concentrations not possible using other biosensors. Upon building and successful testing of the SPR sensor system with regular glucose samples, the plan is to detect cow milk allergy agent and Staphylococcal enterotoxin B (SEB), which are important biomolecule agents in the food industry. The proposed biosensor setup can also be used for medical diagnostics.

SPR Curves with electrical biased graphene layers (6-8 layers) on top of the gold film with air as the sample medium were obtained. The work on building a fluid-cell is ongoing. We designed and 3D printed a model for the fluid-cell. It is being used to test the SPR configuration. The 3D printed model will be replaced with a custom-built glass blown model from a commercial vendor to help us design the final fluid-cell that will be used in the system. Numerical calculations were done to study the optimal parameters for a novel structure (Gold-Graphene-Silver-Black Phosphorus) of the sensor surface to detect cancerous cells. These results were submitted as a journal article to be published in the special issue of the Open-Access journal SENSORS (MDPI, Postfach, CH-4020 Basel, Switzerland; www.mdpi.com). The manuscript went through the first review, and we submitted our response to the first round of reviewers' comments. We are waiting for the final word on the publication status.

Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls

The goal of this project is to establish a low cost, high value, and novel compound feed binder from soybean hulls (SBH), a co-product of soybean processing for oil and meal production. The specific objectives of this project are twofold: 1) to scale-up feed binder production to around 1.5 kg/hour and optimize process conditions for production; and 2) to scale-up shrimp feeding trials simulating shrimp farming operations at a commercial shrimp operation in West Alabama. Successful completion of this project will establish a high value and novel compound feed binder platform using 100% soy hulls that is ready for commercial scale productions and applications with significant economic and environmental benefits. It will significantly enhance competitive advantage of shrimp farmers in Alabama by reducing their feed costs. This will in turn improve employment opportunities in seafood farming and processing sectors, making more local seafood and services available to the citizens of Alabama. In addition, it will also significantly improve water quality by reducing leached nutrients.

Our new equipment for the scale-up production of our soybean hulls-based binders with 50% solid content is now fully functional. We have produced several kilograms of binders using the new equipment and are evaluating the binder's binding capacity in comparison with the binders we produced earlier using a lab scale with 10% solid content.

University of Alabama at Birmingham – Amputation

Approximately 1.6 million people live with an amputation within the U.S., and amputation cases are expected to rise to approximately 3.6 million by 2050. 185,000 people have an amputation each year in the U.S., with a significant increase noted associated with COVID-19 infection. The conventional technology is unable to adapt to the dynamic residual limb as it atrophies over time and swells with heat or weight gain. Percutaneous osseointegrated prostheses (POP) are a promising development for the limb-prosthesis interface involving the direct skeletal attachment of the prosthetic device. Alongside the promising benefits of POP, significant risks are present at the bone-implant interface including superficial and deep infection, inflammation, insufficient osseointegration, lack of vascularization, and implant loosening. The main goal of this project is to develop the multifunctional nanomatrix coating on POP that can be clinically translated for improved osseointegration of prosthetics, and other types of orthopedic and dental implants in order to help promote healing and prevent infection.

During last period, this project made good progress including the studies of the effect of the multifunctional nanomatrix on angiogenesis, osteogenesis, and anti-inflammatory responses. We have made progress on fabrication and coating optimization of titanium fixture and abutment of POP.

University of Alabama at Birmingham – Pneumococcal Vaccine

Streptococcus pneumoniae is a leading cause of bacterial pneumonia and meningitis, resulting in more than 2 million pneumococcal infections and more than 6,000 deaths each year in the United States. Mortality rates are high especially in very young, elderly, and immunocompromised individuals. In Alabama, invasive *Streptococcus pneumoniae* represents a special concern to the State's aging population, as well as in the rural and economically deprived communities with limited access to routine health care. The currently available pneumococcal vaccines in clinic, *e.g.*, PPV23 and PCV13, have limitations. For example, PPV23 is not effective in children younger than two years old, the elderly, and immunocompromised individuals; and while PCV13 is effective for children, it has limited serotype coverage (fewer than PPV23) and requires an inconvenient four-dose immunization schedule for infants and young children. Moreover, none of these clinical vaccines provide effective protection against *S. pneumoniae* serotype 3 (ST3), a significant cause of morbidity and mortality worldwide. In this project, we will develop enhanced PPV23 and PCV13 vaccines which can provide increased protection with reduced number of immunizations. The enhancement will be achieved by employing the potent new vaccine adjuvants recently discovered in the Principal Investigator's laboratory at UAB. Success of this project will benefit the citizens of Alabama and have broader positive impacts on global health as well.

In Q1 of 2023, we confirmed and optimized the new formulations of VSA-1 in mice. We also re-analyzed the serum samples of the previous immunization studies with PCV13/VSA-1 and PCV13/VSA-2. We obtained IgG subclass compositions (i.e., IgG1 and IgG2a titers) with enzyme-linked immunosorbent assay (ELISA), and these new results confirmed that VSA-1 is a suitable new adjuvant for glycoconjugate pneumococcal vaccines.

Overview of 2023 Program Year

Projects Funded Under 2023 Grant Period

Applicant	Amount
University of Alabama at Birmingham – Plasma Technology for New Neurovascular Stent	$316,910.00
University of Alabama at Birmingham – Development of a Novel Bioactive Material for Dental Pulp Treatment	$350,000.00
The University of Alabama – Advanced Membrane Technology for Removal and Degradation of Short- and Long-Chain PFAS from Water	$399,831.00
The University of Alabama – Ultra-High Performance Concrete (UHPC) with Local Materials	$86,195.00
Auburn University – Iron-Based Contrast Agent for Magnetic Resonance Angiography (MRA)	$184,773.00

University of Alabama at Birmingham – Plasma Technology for New Neurovascular Stent

Stroke is a common disease affecting over 90,000 people annually in the U.S and costs the healthcare system over $33 billion. It represents the leading cause of serious long-term disability and third leading cause of death. While recent advances in stroke intervention have radically improved upon the natural history of the disease, minorities have benefitted less than the general population, in part due to the higher prevalence of carotid occlusion into the acute stroke setting (COASS). Carotid stenosis is implicated in 20-30% of strokes and poses unique therapeutic challenges. In contrast to cardio-embolic stroke, which responds well to intravenous tissue plasminogen activator (tPA) and mechanical thrombectomy, ruptured atherosclerotic plaque requires stent implantation to achieve effective reperfusion. However, a major obstacle in the field is that stent placement requires dual antiplatelet therapy (DAPT) that predisposes to hemorrhagic conversion of ischemic brain tissue. The translational relevance of the proposed project lies in resolving this clinical dilemma by developing a blood-compatible surface modification, potentially enabling carotid stent placement without DAPT. The overall goal of this project is to complete a preclinical study of UAB surface-engineered stents in animal model to demonstrate feasibility.

The overall aim is to coat new stent using adaptable plasma processing technology that we have developed by low temperature organic plasma processing to have better biocompatibility through animal studies. Initial coating experiments show OPS coating onto metal, but further optimization of parameters and coating evaluation for wettability, uniformity, and surface properties are underway.

University of Alabama at Birmingham – Development of a Novel Bioactive Material for Dental Pulp Treatment

According to the American Association of Endodontists, 22 million endodontic root canal treatment (RCT) procedures are performed annually in the United States. When a tooth is severely infected or decayed, RCT is recommended to preserve the tooth structure and avoid extractions and artificial replacement (i.e., implants, dentures, etc.). In many cases, RCT is not an available treatment option to some populations due to accessibility and financial burden. In addition, 10-15% of RCTs do not demonstrate long-term success and present as recurrent infections, which leads to permanent tooth loss. However, the need for RCT could be prevented by early detection of the initial stage of dental caries and treatment with the proper application of biomaterials. Therefore, early diagnosis of dental caries and appropriate treatment using biomaterials are critical for the maintenance of pulp vitality with long-term success and for the prevention of RCT and tooth loss. Thus, direct pulp capping (DPC) is a preferred treatment option which is less invasive, reduces patient discomfort and clinic time, and is less expensive. Although numerous DPC materials have been used to improve clinical outcomes with moderate clinical success, many characteristics of these DPC materials still need to be improved, such as pulp cellular compatibility, regenerative potential, physical/mechanical properties (i.e., pH control and setting time), and cost-effectiveness. The main goal of this project is to develop a novel bioactive DPC material that improves the current treatment regimen and to prevent sequential oral disease and infection.

The project has successfully started with setting up grant accounts, recruiting, hiring, and training of research staff, and making progress in preparation of the proposed research project.

The University of Alabama – Advanced Membrane Technology for Removal and Degradation of Short- and Long-Chain PFAS from Water

Per- and poly-fluoroalkyl substances (PFAS) are a group of persistent organic compounds of industrial origin that are now ubiquitous in the environment, including drinking water sources. PFAS are a source of great concern due to their harmful impact on ecosystems and human health. Therefore, the development of efficient technologies for their removal from water/wastewater is a worldwide need. To achieve this goal, the research plan of this proposal is focused on a complete understanding of the PFAS adsorption properties of MXenes, followed by rigorous design and fabrication of highly efficient MXene-adsorptive NF membranes.

The University of Alabama – Ultra-High-Performance Concrete (UHPC) with Local Materials

The proposed research aims to create an ultra-high-performance concrete (UHPC) mix using local ingredients (obtained from Alabama and nearby states) for use in precast manufacturing settings, with the ultimate goal of lowering the cost of UHPC to between $650 and $1,000 per cubic yard. This will be completed in collaboration with Contech Engineering Solutions LLC, a Birmingham-based precast producer (an industry partner). The mechanical and structural performance of the generated UHPC mixture will be experimentally evaluated as part of the planned research. Through laboratory testing, the study team will also assess the structural performance of beam and pipe constructions made from this material. We intend to disseminate the accumulated knowledge to local manufacturers and government organizations through personal meetings and webinars, brief online videos, and invitations to observe laboratory experiments.

Auburn University – Iron-Based Contrast Agent for Magnetic Resonance Angiography (MRA)

Contrast-enhanced magnetic resonance imaging is a staple diagnostic procedure for imaging blood vessels. Over 450 million gadolinium-based contrast agent (GBCA) doses have been administered, since regulatory approval 30 years ago, to improve image quality. While GBCAs offer excellent MRI properties, they have been associated with numerous side effects. Therefore, there is a strong need for new contrast agents able to provide enhanced imaging capabilities without resulting in long-term accumulation and dangerous side effects. In addition, because GBCAs are toxic and designed to be rapidly cleared through kidney filtration, the imaging window is short and provides sub-optimal imaging of the vascular system. Compared to currently utilized contrast agents, our envisioned product has the potential to disrupt the MRA contrast agent markets because of its improved safety profile and enhanced imaging of the vascular system. The product will initially be marketed to radiologists and medical institutions that perform MRA, for application in diagnosing deep venous thrombosis, which affects up to 900,000 people each year in the U.S., vascular malformations, and pediatric imaging. The envisioned contrast agent can also be used in other applications, such as peripheral arterial disease (PAD) and renal imaging, allowing improved imaging of vascular structures while reducing the risk of long-term side effects.

Activities during the past quarter were focused on validating the pharmacokinetics, MRA imaging, and safety of a candidate contrast agent. Our formulation showed a relatively constant concentration in blood for 15 minutes post-injection, followed by a sharp decrease – indicating a delayed clearance from blood. This 15-minute window provided ample time for high-resolution

MRA imaging of vascular structures. It was also observed that the agent was primarily cleared by renal filtration. Compared to Feraheme®, our agent showed less than one-third accumulation in the liver and less than one-sixth accumulation in the spleen. Histopathology showed that our agent had negligible effects on tissue morphology.