Alabama Research and Development Enhancement Fund
Quarterly Report
December 2022

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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 further investigated various ways to enhance the effectiveness of Bi/TNTs@AC for photocatalytic destruction of PFOA spiked in an Alabama landfill leachate. The major activities and key findings are summarized as follows:

1. Tested the temperature effect on the photocatalytic defluorination of PFOA. The results showed that the defluorination rate was significantly increased by moderately elevating the reaction temperature.
2. Determined the optimal pH value in the photodegradation process. Our preliminary data indicated that alkaline solution pH (>9) favors the degradation of PFOA.
3. Explored the combined effect of Fe3+, S2O82-, and temperature on the photocatalytic defluorination of PFOA. The combination of Fe3+, S2O82-, moderately elevated resulted in much enhanced destruction of PFOA in the leachate. Tested the photocatalytic defluorination of PFOA pre-sorbed on 3%Bi/TNTs@AC in the presence of various radical scavengers (IPA, AgNO3 and BQ). The results revealed roles of various reactive species in the degradation of PFOA.

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 fused our knitting laboratory with Auburn knitting partner Straehle and Hess. We electrically disconnected our three main knitting machines and coordinated freight movers to transfer the machines and re-install them within Straehle and Hess. One of our recent graduates, Bryan Holt, was hired at our industry partner Straehle and Hess. We are now upscaling manufacturing of our textile product in rolls. We evaluated a clothing sewing/assembly company, Beverly Knits, for their ability to take our textiles and assemble male long-sleeve shirts and we evaluated and settled on a final design for a male t-shirt, which will be our first product line.

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 our work on modifying CNCs extracted from wood to enable them to be used to detect pesticide residues in water and presented results at conferences. We are also exploring other sources of CNC and the detection of food allergens such as milk allergen (β-lactoglobulin). 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. Our current focus is on increasing the selectivity of the detection and understanding the differences between agriculturally- and forestry-derived CNC's. 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's 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 also began collecting survey 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.

Outreach efforts are ongoing. An outreach strategy has been revised for connecting with over 300 newly identified companies through local chambers across the state.

Five companies have completed their assessments and results review sessions. Customers have expressed their satisfaction with the level of detail and insights gained into their overall resiliency. A plan has been developed for completing all proposed implementation support actions.

Upon the completion of these sessions, our team identified seven common trends where 89% of customers need to increase their sustainability and resiliency capabilities. Our team is developing templates of capabilities to be used across these common trends to better assist current and future customers.

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, 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 October to December 2022, the team obtained and analyzed field data from the 2021 micromobility pilot deployment in Birmingham, AL. The objective was to determine micromobility usage patterns in the Birmingham region and use such information to enhance our MATSim simulation model. Data were obtained from Veo shared mobility service. They provided detailed information on trip origin/destination (lat/long), ride date, ride start time, ride duration, and ride distance. The shared e-scooter data were collected from 7/1/2021 to 7/1/2022, and the shared e-bike data were gathered from 12/2/2021 to 7/1/2022. The team preprocessed the data to remove anomaly trip records such as those with distances less than 0.01 miles or average speed over 15 mph. A total of 95,146 trips remained after the cleanup, 81,144 of which were e-scooter trips, and the remaining 14,002 were e-bike trips. The team derived a few interesting observations, such as (1) the micromobility use reaches peak in September and valley in January; (2) the micromobility use is the highest in Fall, and Spring is the next highest, likely because most users are students; (3) the micromobility use keeps increasing from 8 am to 10 pm, which is surprising and the reason will be explored in the coming quarter; and (4) over 80% of the e-scooter trips are within 3 miles. In the coming quarter, we will perform additional analysis of the micromobility dataset to determine origin-destination patterns and develop and test new simulation scenarios that incorporate realistic micromobilty mode use and update the Birmingham MATSim model accordingly.

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.

The project entitled "Formaldehyde paper-based device (PAD) for a cost-efficient detection of formaldehyde emissions from wood panels" focuses on the development of a prototype of a paper-based device (PAD) for measuring formaldehyde concentration in air. The ultimate goal of the project is to develop an accessible, rapid, accurate analytical tool for the determination of formaldehyde in the air at concentration levels below 1 ppm.

During the fourth quarter of 2022, our team focused on testing the performance of the paper-based formaldehyde sensor prototype at high levels of formaldehyde emissions. For that purpose, an electronic sensor and the paper-based formaldehyde sensors (at least ten replicates) were placed next to the hot press during the fabrication of a laminated veneer lumber process.

Figure 1. An electronic formaldehyde sensor and paper-based formaldehyde sensors (10 replicates) were placed in the hot press next to the fabrication point of a wood composite.

Figure 2. Paper-based formaldehyde sensor consisted of five discs capable of changing the color in the presence of formaldehyde in the air.

For the validation of the prototype, we compared the results obtained by the image analysis of the scanned sensors with the results obtained in the electronic formaldehyde sensor. The preliminary results will help tune the performance of the formaldehyde sensor at high-level formaldehyde emissions to cover a wide range of formaldehyde emissions levels.

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.

We have completed a successful survival study of the artificial graft and are now analyzing the results while we prepare for a longer (21-day) survival study. The longer study will help us observe longer-term effects on the implant such as signs of thrombosis or leakage. We also hope to find further integration of the graft with the body such as cell growth on the interior of the graft.

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.

This research project focuses on the development of innovative materials and construction processes that can aid in enhancing the resilience and sustainability of Alabama's building and transportation infrastructure. As part of this research to build hybrid panels, the mechanical behavior of UHPC material has been studied and two UHPC panel prototypes have been created for impact testing. In addition, we conducted a literature assessment of composite cross-laminated timber (CLT)-concrete construction to identify potential gaps and define testing standards. Regarding interface preparation and the moisture transfer capability of UHPC-to-CLT interfaces, we found few literature gaps and we are working toward experimental tests to address these gaps. In order to predict the structural capacity of UHPC-CLT composite specimens, we performed additional analysis of experimental data from UHPC-CLT panel testing and produced a spreadsheet tool. To present the outcomes of this analysis at a U.S.-based international conference, we have submitted an abstract. We identified measurement tools that may be utilized to measure the thermal and noise properties of these composites, thereby advancing the state-of-the-art in hybrid wood-concrete panel performance. Currently, we are identifying suppliers of bamboo-derived components and CLT. We are currently working diligently to order the required materials for the delayed large-scale studies, which have been prompted by supply chain issues.

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 completed two-stage hydrotreatment of pyrolysis oil with carinata and poultry fat for the production of transportation fuels. Additionally, the Recipient characterized commonly used household plastics and liquefied them for the production of liquid fuels using the hydrothermal liquefaction (HTL) process. A mixture of five prominent plastic polymers, as simulated household waste, was depolymerized using the HTL process with and without the use of "red mud" as a catalyst for liquid oil production. The selected plastics were polyethylene terephthalate (PET, #1), high-density polyethylene (HDPE, #2), low-density polyethylene (LDPE, #4), polypropylene (PP, #5), and polystyrene (PS, #6). The plastic crude oil possessed 36-92 wt.% gasoline-range compounds, while the chemical composition varied with the feedstock. Without a catalyst, HDPE decomposed into straight-chain alkanes, whereas PP and PS-derived products consisted of aromatic and cyclic compounds. In the next quarter, the Recipient will (i) finalize waste plastic liquefaction paper for publication, and (iii) continue collecting necessary pyrolysis data using biomass and plastic as input materials.

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 Q4 2022, we improved the design of CCBP and manufactured a prototype based on the new design. We also performed screening of microalgae and methanotroph strains using the screening station that we developed in Q2 2022 and identified two pairs as the most promising candidates for further verification.

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 (October-December 2022) we completed a field season for black and pinto beans and harvested them at Winfred Thomas Ag Station (AAMU). Based on this year's data, we have selected 20 genotypes to scale up production within the summer of 2023. We planted high-performance barley varieties at two field stations, AAMU and Auburn Tennessee Valley (TVREC), and selected 4 farmer partners to increase production of barley for brewing test in 2023. We planted additional varieties at AAMU and TVREC in a research design to collect data on additional cultivars. With our malt house partner, we performed test malting and with a local brewery brewed a test batch of Alabama barley-based beer. With Auburn, we have begun planning an economic framework for barley to evaluate profitability of barley production for Alabama. For outreach, we attended the National FFA (Future Farmers of America) Convention and Expo in Indianapolis to connect to students, educators, and agricultural companies and raise awareness of this effort of growing new crops in Alabama. In addition, we have been attending Alabama Young Farmers Meetings and local high schools to talk to agriscience students about these efforts and potential future careers in this field.

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.

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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.

We have four achievements to report. The principal investigator (Dr. Jason Clark) has been awarded a United States utility patent for the invention on which this project is based. International patents are presently being applied for. Recipes of piezopolymers (without conductors) have been successfully 3D printed using the Nanoscribe. Two new processes for making s-drives are being explored: Sol-gel and prefabricated piezosheets. We have started fabricating s-drive arrays using the sol-gel process due to needed repairs of the Nanoscribe. The two issues that we ran into are as follows: (1) A method for bonding of piezosheets to wafers for subsequent micromachining is unknown to manufacturers and laboratory staff. This is an issue that we will explore at a later date; and (2) The nanoscribe's coarse positioning stage needs servicing. Although the fine positioning stage (which can be used for very small structures) is working, coarse positioning is required for large arrays of s-drives.

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 graphene layers (6-8 layers) on top of the gold film with air as the sample medium, were obtained. Currently work is underway to build a chamber to facilitate flow of sample to obtain the SPR curve with the sample. Numerical calculations were done to study the optimal parameters for a novel structure (Au-MoS2-Gr) of the sensor surface to detect urea samples. These results were published as a chapter in the book titled, 'Graphene-Recent Advances, Future Perspective and Applied Applications', published by InTechOpen (URL to the book chapter: https://www.intechopen.com/online-first/83631; DOI: 10.5772/intechopen.106556).

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.

As we reported in the last quarterly report, safety inspection of the new equipment identified a concern of potential exhaust gas accumulation and recommended extending a snorkel to the reactor. We are working on getting an extension so that we can start the scale-up production, characterization, and optimization of the feed binder using the modified equipment.

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 the last quarter, this project made good progress including antibacterial efficacy studies, evaluation of cell viability and proliferation, set up of reaction process for scale up, and submission of a provisional patent.

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 Q4 2022, we focused on optimizing VSA formulation as described in the proposal. In the recently finished formulation studies with BALB/c mice, we identified several promising formulations. We will conduct more immunological evaluations of the mouse serum samples to confirm the optimal formulation and then apply the optimal formulation in new in vivo evaluations with PCV antigen.

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.

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 presented as recurrent infections, which lead 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 a 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. Therefore, 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 current treatment regimen and to prevent sequential oral disease and infection. Successful outcomes from this project will lead to developing strategic partnerships with biotech companies for commercialization, which will lead to increased employment, product development, and to building and supporting the biotech workforce in Alabama.

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.