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.

This quarter we focused on writing and refining the final project report. We have submitted the final report to the sponsor. Overall, we are pleased to have preliminarily proven the novel "concentrate-&-destroy" concept and tested the technology for treating PFAS in water and landfill leachate. Despite the technical challenge due to the highly recalcitrant nature of PFAS and the

strong matrix effect of landfill leachate, we obtained some encouraging data, which warranted further development of this promising technology.

This research project ended July 31, 2023.

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.

In the past quarter, we made significant progress in both our research and collaborative efforts. We finalized and submitted our findings for peer review and are currently preparing another manuscript focusing on optimizing comfort of the textile. During this period, two master's students who contributed to the project successfully graduated, bringing the total number of graduates funded by this program to four, thereby enriching the local educated workforce. We also advanced discussions and finalized essential agreements with major clothing manufacturers, leveraging our preliminary successes to detail potential manufacturing collaborations. Moreover, our research included a specialized computer modelling analysis, demonstrating how our innovative textiles can potentially mitigate disease spread in epidemics, the details of which are included in our under-review research.

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 we continued to focus 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. 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 completed recruitment of participants through partnering employers. The final sets of participant samples are at the laboratory for testing and analysis. We expect to return results from these samples during the upcoming quarter. 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.

This quarter's emphasis has been on progressing companies through the Future Ready engagement process and providing support following the assessment. The team has also continued outreach activities to begin engagement with additional companies. Multiple outreach channels are continuing to be leveraged, including mass and direct email, economic development organizations, and referrals from companies already engaged. A very successful benchmarking workshop was conducted for companies that may struggle to commit to a full engagement. During the workshop, they were guided through a self-assessment and provided with the Future Ready Implementation Guide, accompanying forms, and tools. To date, 24 companies are engaged in the Future Ready program.

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 from July to October 2023, the team performed a comprehensive examination of micromobility trip origins using data from a pilot micromobility deployment in Birmingham, Alabama, from July 2021 to July 2022. The work focused on understanding the spatial distribution of the Birmingham micromobility trips. Data preparation and cleaning were meticulously carried out, incorporating ArcGIS and machine learning techniques. Trips originating or concluding outside the designated operational area were intentionally excluded, and the analysis was narrowed down to 81 Census Block Groups (CBGs) within the operational zone, encompassing a dataset of 130,756 trips. Key findings include identifying areas with the highest trip concentrations, notably Five Points South, UAB Campus/Southside, Fountain Heights, Center City, and Druid Hills. Using the Kernel Density Estimation tool, geographical mapping techniques revealed areas with elevated trip densities near downtown, the university campus, and Five Points South. The temporal analysis highlighted distinct weekday and weekend trip density patterns and highlighted a shift of higher concentration of trip origins from UAB Campus/Southside on weekdays to downtown on weekends.

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 team has been working on the preparation of the final prototype consisting of a multiPAD assembly, which will be utilized for developing the calibration curve and used for the optimal determination of formaldehyde in gas. During this quarter, a significant reduction on the color distribution on the individual PADs was achieved. This improvement is poised to reduce the error rate in the detection method, thus improving the sensitivity of the sensor significantly.

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.

This quarter, a complication arose in the first planned surgery, and it took some time to devise a solution to the problem. We plan on conducting a few more surgeries, if possible, to conclude the study by the end of the year and summarize our results for the project.

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 quarter we identified the adhesives needed for the fabrication of cross-laminated bamboo (CLB) and polyurethane reactive (PUR) based adhesive was procured. We also fabricated CLB panels. We have completed the compression testing of CLB panels and characterized the CLB

panel behavior under compression loading. We completed the moisture ingress testing to understand the moisture transfer across ultra high-performance concrete – cross-laminated timber (UHPC-CLT) interfaces.

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 pyrolysis oil was upgraded using a two-step hydrotreatment procedure that involved mild treatment followed by upgrading under extreme conditions in the presence of an appropriate catalyst at each step at two different heating rates. In the previous quarter, we reported that the final upgraded oil yield was much lower than what we anticipated, and we thought a heating rate might have an impact on the final product yield. In this quarter, we examined the role of heating rates. Previously, the heating rate used for two-step hydrotreatment was varied from 14 to 23 °C/min, compared to the slow heating rate (~5 °C/min) of the current procedure. In this process, the PyroRK pine oils were subjected to a first step: mild hydrotreatment in a 450 mL Parr reactor by adding about 80 g of parent PyroRK oil with a noble metal catalyst (Ru/C) at a ratio of 70:1, followed by adding pure hydrogen (H2) gas at 1000 psi, and finally heating the reactor to 150 °C at 4.5-4.6 °C/min heating rate for 2 hours residence time with a continuous stirrer at 300 rpm. The resulting oil from mild hydrotreatment was termed mild hydrodeoxygenation (HDO) oil. For the second step: severe treatment, approximately 50 g of the mild HDO oil with an alumina-supported cobalt molybdenum (CoMo/Al2O3) catalyst at a feedstock-to-catalyst ratio of 70:1 was placed into the same 450 mL Parr reactor. The initial pressure of hydrogen was maintained at 1000 psi for the severe hydrotreatment, where the reactor was heated to 400 °C at a heating rate of 4.5-4.9 °C/min heating rate for 4 hours residence time with a continuous stirrer at 300 rpm. The products formed were oil, aqueous phase, solid (coke formation and non-reacting catalyst), produced gas, and a balance that resembled the residual product that could not be removed from the reactor. The yields were determined on a weight basis. With the slow heating rate, our upgraded oil yield is about 50 wt.%. The upgraded oils were characterized by ultimate analysis (elemental composition) and gas chromatography-mass spectrometry technique.

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 Q3 2023, we successfully produced biogas from anaerobic digestion (AD) of mixed food and fish waste, with food waste from Auburn University Campus Dining and fish sludge from Auburn University Fisheries Center. The experiments will allow us to optimize the operation conditions to achieve high biogas productivity.

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 validated the quality of harvested barley from our farm partners and Alabama A&M. We moved this barley to our two malting partners, who are in the process of malting and preparing this material for distribution to brewing partners across the state. We have continued the testing of black and pinto beans at Alabama A&M in an over-summer field trial. We have made progress on developing an economic model to support local barley growing and brewing uses and are developing a consumer choice survey to evaluate interest in local products coming out of this project.

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.

This update covers activities of Q2 2023; a new project director has been assigned to complete the project. This quarter we prepared polyvinylidene fluoride (PVDF) thin film using spinning coating. The PVDF thin films in thickness from 2 to 5 um have been successfully prepared. We tried an electrical spinning technique to prepare PVDF thin film. The PVDF thin film was successfully prepared, but the films were porous not solid film. We also built a setup to characterize the piezoelectric behavior of flexible thin film. To achieve a high piezoelectric effect, it is better to use P(VDF-TrFE) copolymer.

We have purchased poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)) from China; however, it has yet to arrive, which is slowing progress. Due to the delay, we used PVDF for the film preparation, which is of low quality. However, due to the similarity between the PVDF and P(VDF-TrFE), the process condition and expertise gained from PVDF preparation can be directly used to prepare the P(VDF-TrFE) thin film.

Since the postdoctoral research assistant on this project was not meeting satisfactory expectations, he was replaced by a graduate research assistant who has 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.

The experimental results of the SPR study based on the proposed concept are promising. The samples used are an air-dried sugar solution with known concentrations. The comparison between the experimental and theoretical numbers for these samples will be done in the next quarter.

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.

We have produced several kilograms of feed binder SBH-1 in a pilot-scale reactor with 50% solid content (Binder B). We are evaluating the binder's binding capacity in comparison with the binder we produced earlier using a lab scale with 10% solid content (Binder A). The project is on track with no issues impacting the project's progress, cost, and/or schedule.

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 this quarter, our efforts have been multifaceted and geared toward advancing our research. We successfully developed a complex rat amputation model; although, refining the technique was time-consuming, particularly regarding anesthesia administration and minimizing post-surgery tissue damage. In addition, we've been actively engaged in designing and 3D printing the titanium fluted 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 Q3 of 2023, we focused on synthesizing the new serotype 3 glycoconjugates. During the synthesis, we noticed that the conjugation reaction conditions affected the reaction outcomes and reproducibility significantly. In order to improve reproducibility, we decided to develop a new synthetic strategy, and we have been making steady progress in this direction.

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.

After coating the stent using our proprietary coating, we studied the blood protein interactions with various coating formulations in in vitro static conditions. The qualitative experiments showed promising results with blood-protein and coated stent surfaces as expected. However, whole blood

interaction meaning blood platelet interaction with coated stent is required before moving on to cell-culture studies or preclinical studies.

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.

During Q3 of 2023, the research team established all necessary training and project preparation. The research team and industry partner held several technical meetings to discuss transporting materials and protocol development. Summer undergraduate students and high school students joined, trained, and assisted with the project. Research instrumentation facilities were arranged for the material characterization and process. Cell study condition was optimized for the planned experiments.

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.

During this quarter, our main emphasis was on conducting an extensive literature review encompassing various synthesis techniques for both MXene and fluorinated MXene. We extensively examined existing research on these materials, analyzing different methodologies and strategies employed in their synthesis. This comprehensive review significantly enriched our comprehension of the latest cutting-edge methods and their prospective applications. Furthermore,

we successfully synthesized MXene and F-MXene nanosheets, subjecting them to thorough characterization. Additionally, we conducted experiments to assess their adsorption capacity for PFOS, demonstrating that F-MXene nanosheets exhibited enhanced adsorption capabilities when compared to regular MXene.

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.

During this quarter, we performed a state-of-art review of current technology related to UHPC material development and completed the construction of test molds. A graduate student started working on the project this quarter and developed a few trial mixes and examined the compressive strength evolution with time.

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.

A major aspect of this project is to validate the safety and performance of an iron-based MRI contrast agent. Demonstrating these aspects of the minimum viable product requires the use of animal studies, but initial preliminary work will be conducted using in vitro models. This will allow for the agent to be well characterized prior to the initiation of animal studies. The focus for the past quarter was on recruiting graduate students to conduct the planned studies.