2016 Research Award Abstracts

STMD
KSC

AK - 16-EPSCoR2016-0001

Development and Characterization of a New Hybrid Polymer-Nanoparticle Composite Coating for Corrosion Protection in Aerospace Applications

TA: Land transport, shipping, aviation, aerospace, and telecommunications technology, nanocomposites, Corrosion Prevention, Detection, and Mitigation

PI: Thorsen, Denise
ScI: Zhang, Lei

Much effort has been expended to develop coatings to replace toxic chromates used as pretreatments or pigments in aircraft coatings. There have been many claims for chromate replacement in primer or pretreatment for aircraft, although few functioning systems meeting specifications are presently in use. Polymer nanocomposite coatings (PNCCs), which use nanoparticles as fillers in polymers, possess synergistic properties of nanoparticles and polymers. Because of this unique feature, PNCCs have potential to meet the demand in replacing chromate coatings. Properties of PNCCs are greatly determined by the degree of nanoparticle dispersion within the polymer, which is a key to improving mechanical and barrier properties in nanocomposite coatings over pure polymer coatings. In particular, PNCCs with extremely high concentrations of nanoparticle fillers are promising for corrosion protection in various applications. However, it is still challenging to prepare uniform PNCCs with high loadings of nanoparticles because a high loading of nanoparticles tends to aggregate in an uncured and viscous polymer matrix. This problem is especially exacerbated when mixing with non-spherical nanoparticle fillers, even after reducing the viscosity of polymer at an elevated temperature.

This project will develop a new process for producing PNCCs with uniform distribution of nanoparticles at extremely high filler concentrations via polymer capillary infiltration into a dense packing of nanoparticles without any mechanical mixing. New coating techniques derived from PNCCs would be used to protect ground/launch systems and spacecraft from degradation in high saline environments. This project will address NASA's Space Technology Mission Directorate mission roadmap technical area 13.2.1 "Corrosion Prevention, Detection, and Mitigation to develop new corrosion prevention technologies that provide environmentally friendly corrosion resistant/protective materials, coatings, and systems that last longer, require lower maintenance costs, and create less environmental contamination. This research strongly aligns with Alaska's S&T Research Priority 7 "Land transport, shipping, aviation, aerospace, and telecommunications technology". NASA personnel in the Kennedy Space Center Corrosion Technology Laboratory agreed to collaborate with us on this project.

In this project, we have four objectives: (1) In Yr 1, develop a tested procedure to generate PNCCs with a polymer matrix filled with high loadings of TiO2 nanoellipsoids (>40 vol%) on an AA2024-T3 Al alloy with homogenous TiO2 nanoellipsoids dispersity; (2) In Yr 2, measure the corrosion properties (corrosion rate, voltage, and current) of PNCC-coated AA2024-T3 in a 3.5 to 7 wt% NaCl solution against two influencing factors: the degree of salinity and anisotropy of the TiO2 nanoellipsoids with various aspect ratios (1 to 4); (3) In Yrs 2 and 3, measure the susceptibility indices and model the failure mechanisms of stress corrosion cracking of PNCC-coated and uncoated AA2024-T3 under constant strains (up to 0.2% plastic strain) and slow strain rates (10-8 to 10-7 s-1) in a 3.5 to 7 wt% NaCl solution and in an inert environment against two influencing factors: the degree of salinity and anisotropy of TiO_2 nanoellipsoids with various aspect ratios (1 to 4); and (4) Demonstrate research sustainability, collaboration with NASA personnel, and new corrosion protection coating technology development tailored to NASA's missions. Successful outcomes of this project: (a) develop a benchmarked coating procedure for PNCCs with extremely high concentrations of nanoparticles, resulting in improved anti-corrosion performance suited for NASA's applications, (b) reduce the cost of maintenance, inspection, and corrosion damage, (c) establish and strengthen collaborative partnerships with NASA researchers, and (d) prepare and submit proposals for research sustainability beyond this project, based on the project outcomes.

HEOMD/ISS
JSC/LaRC

KS - 16-EPSCoR2016-0003

Novel Smart Skin Biomedical Sensor for Monitoring Crew Health Parameters in a Wireless, Passive, Lightweight, Robust, and Non-invasive Fashion

TA: NASA Sensors, Human factors, wearable health monitoring systems, Cardiovascular and physiological parameters

PI: Miller, Leonard Scott
ScI: Cluff, Kim

A. Central Objectives: This proposal is focused on an innovative bio-monitoring sensor that may serve as a simple yet sophisticated method for monitoring multiple mission critical physiological parameters such as blood-flow, intracranial pressure, body temperature, blood gas concentration, and fitness of the EVA suit in a novel fashion. The objective of this proposal is to develop a bio-monitoring sensor which is passive (does not require batteries), robust and lightweight (does not have electrical components), and able to wirelessly monitor multiple physiological parameters related to astronaut health and performance. We will evaluate our central hypothesis that biological electrical and magnetic properties can be leveraged to detect physiological parameters using a novel micro-coil sensor - applied like a small adhesive bandage or woven into garments. Guided by promising preliminary data, we will attain the objective of this application by pursuing the following specific aims: Aim #1: Develop and achieve the necessary sensor impedance, capacitance, inductance, and sampling rate to measure physiological parameters on human tissue. Aim #2: Investigate the sensor capability to measure multiple physiological parameters such as intracranial pressure, blood flow, temperature, and blood gas CO2. Aim #3: Determine if physiological parameters can be identified when subjects are wearing a Liquid Cooling Ventilation Garment (LCVG) and if the sensor can be used to measure how well the EMU suit fits to gauge performance. Broader Impacts of this proposal include: 1) dissemination of this work by offering an exhibit and educational sessions at the Kansas Cosmosphere and Space Museum, 2) a partnership with Project Lead The Way to provide a research experience for underrepresented high school students, 3) new partnerships with industry and NASA personnel.

B. Methods: A novel bio-monitoring sensor will be designed that leverages the architecture of a paper thin planar spiral micro-coil. The sensor will be comprised of a single baseline component which is a thin conductive trace of copper shaped as a planar spiral, which does not have any electrical components/batteries. When impinged upon by an incident RF wave, the micro-coil develops electrical current flows in the trace and magnetic field-lines formulated around the sensor. Fluctuations in the magnetic field lines will be correlated with changes to physiological parameters. The sensor design factors will be optimized following a process known as impedance matching to achieve the optimal resonant frequency response on human tissue. The capability of the sensor to detect multiple physiological parameters and intracranial pressure will be investigated by configuring an array of micro-coils each tuned to detect a specific physiological parameter. Subsequently, we will evaluate the sensor signal to detect physiological parameters while in the presence of water flowing through an LCVG, and determine the resonant frequency, frequency bandwidth, amplitude, and phase of the sensor. Finally, we will evaluate the sensor's ability to measure proximity to human tissue with the purpose of measuring how well the EMU suit fits on a subject to evaluate performance.

C. Significance/NASA Interests: This proposal addresses NASA research interests in wearable health monitoring systems to address the gaps and risks that are critical to crew health and performance during long duration space missions. Specifically, our research fits well with the directives of the National Space Biomedical Research Institute to develop Smart Medical Systems and Technology. The capability to measure multiple physiological parameters in a single sensor is highly appealing because auxiliary resources are at a premium in a space station or in an EMU suit. This research may provide a foundation for a novel strategy for monitoring mission critical crew health parameters in point-of-care fashion

SMD
GSFC

ME - 16-EPSCoR2016-0005

Multi- and hyperspectral bio-optical identification and tracking of Gulf of Maine water masses and harmful algal bloom habitat

TA: Remote sensing, Oceanography, Climate change, Ocean biology

PI: Shehata, Terry
SciI: Thomas, Andrew C.

Each summer, extensive areas of Maine coastline are closed to shellfish harvesting due to Alexandrium, a toxic dinoflagellate, costing millions of dollars in lost commercial revenue and monitoring efforts. Unlike the harmful algal blooms of other coastal waters, Alexandrium is dangerous even as just a minor part of the phytoplankton community, at concentrations too low to be detectable with current remote sensing technology. However, extensive previous research has shown that these organisms are widespread, have strong spatial and temporal patchiness, are associated with specific temperature and nutrient regimes, and are transported by local physical processes. The waters of the Gulf of Maine, especially those close to shore, are optically complex due to varying amounts, sources and characteristics of colored dissolved matter, suspended sediment, and varying concentrations and diversity of phytoplankton. A systematic investigation of the capability of multispectral satellite data to isolate and monitor the oceanic habitat of Alexandrium has not been carried out. In this proposal, we use NASA multispectral and SST data and new hyperspectral field data to bio-optically classify different Gulf of Maine surface water masses, identify those water masses that are preferred Alexandrium habitat, track these water masses and map their interaction with, and impact on, coastal shellfish harvesting sites. We bring a multi-institution and multi-disciplinary team to address this problem.

The global ocean color community is poised to transition to the next generation of space-borne ocean color data from hyperspectral optical sensors. NASA's focus in this effort is the PACE mission, expected to launch in the next 5-6 years. Maine's ocean scientists and environmental resource managers need to transition to this level of data complexity to remain competitive and fully reap the benefits of these data for Maine applications and priorities. This proposal builds both instrument and intellectual infrastructure with hyperspectral data, while addressing a Maine technology priority and interfacing with a critical marine resource sector.

Our overarching goal is to use NASA's satellite-based measurements of coastal ocean bio-optical and hydrographic characteristics to define, isolate and track those water masses most closely associated with Alexandrium and coastal shellfish toxicity. The research involves a combined retrospective and real-time analysis of existing field observations and multispectral satellite data and 3 years of new fieldwork that leverages an existing, separately funded project, and introduces a project-purchased hyperspectral instrument. This instrument will be deployed on a ship and will emulate PACE, allowing unprecedented spectral resolution of Gulf of Maine surface waters to better discriminate optical water types. Both efforts are supported by numerical modeling of circulation to view interannual and spatial variability in flow trajectories and the forcing that drives these, and GIS modeling to map and model the interaction between these parcels and DMR sampling sites, coastal shellfish beds and both state and municipal stakeholders.

The project leverages existing infrastructure, data sets and research projects in Maine and Canada, and builds upon an existing strong partnership with the ocean biogeochemistry program at NASA Goddard Space Flight Center. The proposal transitions a group of established ocean scientists to a new technology necessary for future NASA ocean color research. The proposal includes a young scientist who has not had prior NASA funding, a Post Doc and two graduate students whose research will straddle satellite data analysis directly applicable to NASA and coastal applications directly applicable to Maine resource management. Lastly, we build in undergraduate research opportunities for 12 students at two Maine campuses using satellite data and GIS as STEM teaching tools.

LA - 16-EPSCoR2016-0006

Damage Healing of Polymer Composite Structures under Service Conditions

TA: Composite Materials, Aviation Safety, Composite Cryotank Technology, in-service self-healing materials

PI: Guzik, T. Gregory
ScI: Warner, Isiah M

The primary research objective of this project is to develop new polymer composite panels for in-service damage self-healing through (1) design, synthesis, characterization, and manufacturing of two-way shape memory polymers (2W-SMPs), which expand when temperature drops, even under compression; (2) multiscale modeling of the smart composite structures; and (3) additive manufacturing using 3D printing and experimental evaluation of the smart composite panels for impact mitigation and in-service crack healing. The material to be investigated will be a smart self-healing composite with 2W-SMP particles dispersed in an ionomer matrix. The basic idea is that we will use the low temperature expansion of the embedded 2W-SMP particles to close the impact-induced crack and the ionomer itself to heal the closed crack. This project targets several programs in the NASA Aeronautics Research Mission Directorate (ARMD) and Human Exploration & Operations Mission Directorate (HEOMD), and responds to State and Institution research priorities. In aerospace and deep-space explorations, lightweight polymer composite structures are a critical component, and yet debilitating incidents from foreign object impact are not uncommon. For these in-service structures, post-impact repair by humans is either inaccessible or impossible, leading to disastrous structure collapse and mission failure, hence the need to develop in-service self-healing materials.

The project educational objective involves developing a "research-oriented approach" designed to attract and retain a greater number of high caliber students, including underrepresented minority students, in STEM disciplines, and train a larger number of high caliber STEM students for NASA related industry. This project brings together researchers and students from Louisiana State University (LSU) â€“ the Louisiana flagship institution, and Southern University (SU) in Baton Rouge-the main campus of the largest HBCU system in the nation, supported by NASA researchers at a variety of centers and industries, for a collaborative project that will provide exciting new results for NASA along with developing an important new capability in Louisiana.

STMD
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OK - 16-EPSCoR2016-0008

High Efficiency Dilute Nitrides Solar Cells for Space Applications

TA: CubeSat applications in which high power, light, low payload systems are desirable, high-energy irradiation, thermal cycling, CubeSats, hydrogenated GaInNAs cells for flexible MJSCs, UV-activated hydrogenation process

PI: Snowden, Victoria Duca
Sci: Sellers, Ian R

Dilute nitride semiconductors have promise for next generation multi-junction solar cells (MJSC). This potential lays in the fact that this alloy can be lattice matched to GaAs and tuned to the important 1 eV absorption window. Despite this potential, several serious materials issues remain unresolved. These issues center on the low solubility of nitrogen in the system, and the formation of larger nitrogen related defect centers. Recently we have shown that deleterious nitrogen-nitrogen clusters and donor impurities localized to isoelectronic centers can be selectively passivated using a UV-activated hydrogenation process, significantly improving the solar cell performance. Here it is proposed to investigate the potential of leveraging these important results to develop next generation MJSCs incorporating these materials.

High performance solar cells are attractive for space applications since they offer the potential for high power generation at lower payloads. These PV systems are also excellent candidates for CubeSat applications in which high power, light, low payload systems are desirable. It is proposed to investigate the potential and suitability of hydrogenated GaInNAs cells for flexible MJSCs via a rigorous investigation of the nature and stability of the H-N bond when subjected to thermal cycling and accelerated lifetime measurements, and under high-energy irradiation.

RI - 16-EPSCoR2016-0010

Testing New Methods to Assess the Environmental and Floral/Faunal responses to Impacts on Earth

TA: Univ of Liverpool, UK Climate Variability and Change, southern hemisphere terrestrial record in the context of moisture and temperature, atmospheric circulation and moisture transport in the southern hemisphere, biogeochemical analyses, carbon and water sequestration, Carbon Cycle and Ecosystems, Water and Energy Cycle, Exobiology

PI: Schultz, Peter H.
SciI: Heil, Clifford William

The loess/loessoid sequences of Buenos Aires province of Argentina span the last 10-12 Myrs. The sequences contain an unprecedented meteorite impact record as well as abundant fossil assemblages. The potential for these sequences to archive geologic, biologic and climatologic changes in a terrestrial environment is immense. In addition, understanding these changes in the context of meteorite impact events and their local and/or regional environmental effects can significantly improve our understanding of impact processes and their effect on our surroundings. Prior and on going work (funded through an NASA EPSCoR-RID award) has helped to develop environmental magnetic and organic geochemical proxies that can be used to characterize these loess sequences. The study proposed here, however, will use these new environmental proxies to test their use to characterize the environmental conditions before, during, and after one specific impact during the mid-Pliocene in Argentina (3.3Ma) near Mar del Plata. This event occurred nearly coincident with a major faunal turnover when 37% of all genera and 53% of all endemic species became extinct. This period of time is of great interest because it was during the mid-Pliocene Warm Period Optimum (period of global warmth ~2.9-3.3 Ma often used as an analog for future climate change. Hence this proposed effort will address the following questions: (a) Can the multi-proxy (organic geochemical and environmental magnetic) methods developed and used successfully in more recent sediments provide equivalent results from older loess/loessoid sediments in Argentina? (b) What are the paleoenvironmental and biological consequences for the Mar del Plata meteorite impact recorded in the loess/loessoid sequence at Chapadmalal? (c) And was the mid-Pliocene faunal turnover impact-related or climate-related? Specifically, we propose to acquire two shallow drill/cores (40m) across this period in a know section of Argentina near Mar del Plata as well as recover more limited sampling across the impact horizon in selected outcrops. This period of time is also of great interest because it was during the mid-Pliocene Warm Period Optimum (period of global warmth ~2.9-3.3 Ma often used as an analog for future climate change. Our study will provide a case study of how one impact event can affect the local and/or regional environments and the aspects of life and ecology in those environments. If successful, then these results can be applied to other important transitions in environmental conditions. This effort directly addresses EPSCoR objectives by continuing and strengthening the collaborative research between jurisdiction universities (University of Rhode Island and Brown University), demonstrating the use of a new tracer of the biologic response to an impact, providing the opportunity to involve graduate and undergraduate students in an international, multidisciplinary research program, and creating and enhancing other funding opportunities (e.g., National Science Foundation, NASA Exobiology).

HEOMD
JSC/MSFC

AL - 16-EPSCoR2016-0013

Development of Dust Free Binders for Spacecraft Air Revitalization Systems

TA: Porous polymers, pellet encapsulation, CO2 removal using adsorbent beds

PI: Gregory, John C.
SciI: Glover, T Grant

The International Space Station's air revitalization system currently removes CO2 from the station using adsorbent beds. Unfortunately, during operation the adsorbent pellets contained in the system breakdown and produce a fine dust that is carried downstream of the adsorbent bed and causes mechanical failures in the air revitalization system. Therefore, the work proposed will develop binders for traditional zeolites and MOF adsorbent powders that will provide effectively zero dusting when regenerated numerous times under vacuum and heat. The work is collaborative with the Marshall Space Flight Center, the Johnson Space Center, the Ames Research Center, the University of Alabama, and the University of South Alabama. To eliminate dusting, adsorbent pellets will be encapsulated with either polyvinylidene fluoride (PVDF) or Matrimid, both of which are commercially available polymers that are typically used in gas membrane systems. The effectiveness of pellet encapsulation at eliminating adsorbent dust will be quantified by measuring the pressure drop across an adsorbent bed containing the encapsulated pellets during numerous adsorption and regeneration cycles. Pellets will be formed from adsorbent powders by pressing the powders with polyvinyl alcohol or clay binders. Encapsulated pellets will be provided to NASA for evaluation and it is anticipated that NASA scientists and the Glover Research Group will work collaboratively to produce academic publications detailing the results of this program. With the program creating a novel way to maintain mechanical integrity of adsorbents and catalysts, it is likely that it will generate intellectual property. Additionally, the project will partner with existing University of South Alabama outreach programs to identify two students from underrepresented groups and provide these students paid internships in the Glover Research Group

VT - 16-EPSCoR2016-0019

Characterization and modeling of biofilm development by a model multi-species ISS bacterial community

TA: biofilm formation, bacterial species derived from the International Space Station (ISS) potable water reclamation system community, microbial processes, fluid physics and complex fluids, viscoelastic biofilm

PI: Hitt, Darren L.
SciI: Wargo, Matthew J

All human habitation in space will take place in a non-sterile environment for two reasons: humans are colonized on every surface and mucosal membrane with upwards of 10,000 different bacterial inhabitants, and there are few surfaces and components that can withstand complete sterilization. In additional to being potential pathogens, bacteria provide important ecosystem functions in air, water, and soil that would be beneficial to exploit during long-term space travel and eventual off-world colonization. Therefore, it is imperative that we improve our understanding of these co-habitants on our space-going vessels. Colonization of spacecraft by bacteria is of particular interest for the systems involved in the water cycle including condensers, potable water dispensers, and storage containers. In these systems, the bacterial communities can form biofilms that persist and replicate despite substantial effort and cost involved in removal and monitoring. These water system biofilms are important for two different reasons: crew health and system engineering. From the standpoint of crew health, many bacteria that are common members of potable water communities are also opportunistic pathogens â€“ capable of causing infection if the immune system is compromised. From an engineering standpoint, growing biofilms can change water flow, surface roughness, and surface tension, interfering with proper operation of valves and regulators. These two aspects of the potable water biofilms will be magnified during long-duration space travel, where equipment must function properly for long durations and where the immune system of the crew will not be fully functional.

Prior work by a subset of our team focused on a low-mass bacterial biofilm eradication strategy using targeted ultrasound-assisted delivery of liposomes loaded with antibiotics to the biofilm. We have demonstrated killing of the majority of bacteria (>80%) on the surface and shown the primary mechanism is ultrasound-driven acoustic streaming and enhanced liposome penetration into the biofilm. During these investigations we made three key observations that lead to this proposed study: (i) the International Space Station (ISS) bacterial isolates can interact to form a reproducible community in vitro, (ii) the bacteria interact with each other to drive community biofilm formation, and (iii) the interactions between these bacteria and the complex and viscous biofilm matrix are amenable to examination using mathematical models.

Given the issues related to bacterial biofilms during space flight, we must understand how complex microbial communities will develop and impact systems and astronauts. The mixed species community isolated from the ISS water reclamation system, including members of the Sphingomonas, Burkholderia, Methylobacterium, and Ralstonia genera provides our model of a bacterial community proven to survive and thrive during space flight. The specific project goals are to:

(1) Characterize bacterial interactions between species in this community including community development in the absence of specific members.

(2) Quantify bacterial species interactions using single-cell analyses to inform the computational models.

(3) Develop three agent-based computational models that simulate (i) initial interaction and surface attachment, (ii) biofilm growth after initial attachment, and (iii) particle and diffusive movement through the biofilm.

(4) Test aspects of the numerical models, including particle movement through the matrix and in situ removal of bacteria, using ultrasound-mediated particle delivery.

These studies will allow us to gain insights into both fundamental questions regarding bacterial biofilm communities and practical questions regarding the stability and resilience of biofilms, aiding in the development of improved mediation strategies for long-duration space travel.

SMD
GSFC

SC - 16-EPSCoR2016-0022

Temporal and Spatial Variability of Floodplain Currents by In-Situ Observations, Radar Interferometry and Numerical Simulations

TA: Surface Hydrology, Floodplain Hydrology and Geomorphology

PI: Runyon, Cassandra Jane
ScI: Sullivan, Jessica Chassereau & Torres, Raymond

The multidisciplinary research described here is in accordance with NASA SMD priorities because the planned activities will improve our understanding of the consequences of climate change and sea level rise on a critical Earth system, floodplains. Floodplains are important because they perform many functions that benefit humans while supporting high biodiversity, and they are important components of the terrestrial carbon cycle. Floodplain services are accomplished by water overflowing the channel banks to help maintain extant wetlands, to create temporary aquatic habitat, and the transport of particulate and dissolved carbon and other nutrients. This research will help advance our scientific understanding of how floodplains function, and how they are likely to respond to natural and human-induced perturbations. We propose to use airborne radar, numerical simulations and in situ observations to quantitatively assess the temporal and spatial dynamics of flow paths and water fluxes over the inundated floodplain of the Congaree National Park, South Carolina. Remote sensing studies have shown that floodplain circulation is highly complex and in this study we endeavor to quantify controls on flow complexity by answering the question: How do inundation flow paths and flow path connectivity, and water residence times vary with flood stage? The Unmanned Airborne Vehicle Synthetic Aperture Radar (UAVSAR) will provide data for interferometry analyses to observe water level at a one to two day cycle during annual flood conditions. The numerical model DELFT3D will be used to simulate water depths, flow directions and fluxes, and conservative tracer dynamics. Initial simulations will guide velocity profiler and stage meter placement, and they will help constrain topographic and vegetation roughness estimates. Later, more refined simulation results will be compared with airborne radar interferometry and in situ observations of velocity and stage. This project represents a major step toward establishing a Coastal Plain Observatory at U.S.C. that is dedicated to understanding large coastal plain systems of which the floodplain is the principle component. Moreover, the methods, findings and inferences resulting from this work will have important implications for all river systems that traverse the U.S. coastal plain, the low gradient landscape that extends from New Jersey to Texas, and to the 5.7x106 km2 of coastal plain worldwide. In addition to the scientific benefits to society we propose to mentor a new female assistant professor at a predominantly undergraduate institution, as well as graduate and undergraduate students. Moreover, this work advances a broader initiative of creating the first U.S. Coastal Plain Observatory and finally, this proposal is timely because South Carolina and the Congaree National Park recently experienced a "1000 year flood" (October, 2015) and results from this project will improve flood response planning and land management practices, and the development of best management practices for floodplain systems world-wide.

SD - 16-EPSCoR2016-0023

Advanced Bioelectrochemical Module (BEM) for Waste-to-Electricity Generation during Long-term Space Exploration

TA: extremophile biology, solid waste treatment, microbial-electrochemistry, and nanotechnology.

PI: Duke, Edward F.
ScI: Gadhamshetty, Venkata R

Long-term, manned space missions are challenged by waste-treatment and power requirements. The proposed project addresses these challenges through development of a bioelectrochemical module (BEM) that generates electricity as a product of treatment of complex solid wastes (SOWs) including synthetic polymers from space missions. The BEM is based on well-studied principles of microbial fuel cells but uses extreme temperatures (>65 deg. C) and photodegradative processes to breakdown recalcitrant wastes to more "palatable" compounds for microbial metabolism. The BEM project aligns with NASA's Space Technology Roadmaps and Priorities related to Space Power and Energy Storage; In-Situ Resource Utilization and Human Exploration Destination Systems; and Human Health, Life Support, and Habitation Systems. The project addresses three prime focal areas identified for research and economic development in South Dakota (SD) jurisdiction (Energy and Environment, Value-Added Agriculture and Agribusiness, and Materials and Advanced Manufacturing).

The BEM will use extremophiles isolated from the deep levels of the Sanford Underground Research Facility (SURF) in SD. The SURF is considered to be similar to extraterrestrial space in that it is seemingly uninhabitable, yet its biosphere harbors an enormous range of extremophiles that thrive in the challenging subsurface environments. Our team has isolated Geobacillus sp. strain DUSELR7 from the SURF biosphere that synthesizes hydrolytic enzymes with remarkable properties; it shows optimum activity at >65 deg. C, thermal stability (e.g., >50% of cellulase and xylanase activity was retained after 35 and 23 days of incubation at 60 deg. C, respectively), and can function in a broad pH range (pH 4-8). Compared to previous reports, the DUSELR7 cellulases and xylanases are among the most thermostable enzymes produced by Geobacillus spp. and other thermophilic microbes. Another SURF isolate, Enterobacter RC202, is a hydrocarbon degrading bacteria capable of utilizing a broad substrate repertoire including plastic degradation products. Preliminary results confirmed the electricity-producing (exoelectrogenic) capabilities of DUSELR7 and Enterobacter RC202. The RC202 was found to degrade lignocellulosic polymers and generate electricity. The BEM project is a unique scientific study that uses the monocultures of SURF extremophiles for treating unprocessed solid organic and polymer wastes in space missions, inhibiting pathogens in human waste, and generating remote power. We will take advantage of nanotechnology (e.g., graphene electrodes), thermophilic fermentation, and design concepts to minimize BEM footprint in space, and use extraterrestrial UVB and UVC radiation for treating synthetic polymers. We will also use TiO_2/MnO_2-graphene composites to develop a graphene supercapacitor for storing the charges from BEM, using a modified maximum power point circuit that integrates digitally controlled potentiometer with hysteresis-based energy converter and metal oxide semiconductor field effect transistor. The project will collaborate with experts at National Laboratories and industry to develop a stacked BEM that supports low-powered electronics including a Mars microrover.

The program provides support for seven PhD students and five university laboratories from South Dakota School of Mines and Technology, University of South Dakota, and South Dakota State University. This project presents a well-defined plan to use NASA assets (JPL, ARC, and KSC), collaborations with regional and extramural experts from research universities, six industrial partners, National Laboratories (Argonne National Laboratory and Navy Research Laboratory), and two tribal colleges. This project also demonstrates a potential to develop infrastructure for research and education, improve competitiveness of faculty researchers, and develop commercial products for SD jurisdiction.

WY - 16-EPSCoR2016-0026

Experimental and numerical investigation of terrestrial stable cool flames for improved understanding of International Space Station droplet combustion experiments

TA: Mechanical and Aerospace Engineering, numerical modeling, microgravity combustion, flame characterization over long burning times, cool flame behavior

PI: Johnson, Paul E.
SciI: Belmont, Erica

The proposed research will utilize a flat flame burner facility constructed by the Science PI at the University of Wyoming (UW) and numerical modeling for the study of low temperature flames, called cool flames. This research will complement and provide terrestrial insights into ongoing research being conducted by the Combustion Branch at the NASA Glenn Research Center (GRC) on cool flame droplet experiments in microgravity aboard the International Space Station (ISS). The fuels that will be investigated include liquid alkane fuels, heptane and decane, which are important components and surrogates of logistical fuels. Furthermore, heptane and decane have been studied by GRC combustion researchers in ISS experiments because of their logistical importance. The proposed research will provide insights into the chemistry and stability of cool flames, including those aboard the ISS, using an experimental platform at UW that permits stable cool flame characterization over long burning times and a range of conditions, including lean to rich equivalence ratios and sub- to above-atmospheric pressures. The Science PI and co-PI will utilize existing experimental tools and develop laser diagnostic techniques for the quantification and visualization of cool heptane and decane flame structures, and will compare experimental results to numerical flame simulations to evaluate the accuracy of existing and derived full and reduced chemical kinetics models. Kinetics models will then be applied to ISS cool burning droplet data to evaluate their ability to predict temporal droplet diameter changes.