Center of Excellence in Nanobiomaterials Derived from Biorenewable and Waste Resources
was established at Tuskegee University (TU) with the funding from NSF for a period of five years starting October 2011. Collaborators from within the USA include Auburn University (AU), Cornell University (CU), the University of Alabama at Birmingham (UAB), and several industry and national laboratories. Currently, only AU and CU are involved as prime collaborators during the no-cost extension (reporting) period. International collaboration is built upon the existing relationships with researchers from Brazil and India. In addition, during this reporting period, there were two CREST supplemental awards for collaborative research work with University of Wisconsin and Iowa State University.

The research focus areas of the center include: (a) synthesis of plant based nanofibers through electrospinning and forcespinning™ methods; (b) production of bacterial cellulose fibers from soy waste products; (c) synthesis of nanoparticles from biodegradable sources such as egg shells and their use as nano-fillers in advanced composites; (d) synthesis of biopolymers; (e) development and characterization of advanced green nanocomposites using these materials with natural fibers; and (f) product design, prototyping and commercial feasibility studies. These efforts are carried out through three subprojects; 1) Synthesis and characterization of nanobiomaterials, 2) Synthesis and characterization of biopolymers and nanobiocomposites, and 3) Processing, performance evaluation and technology transition of green nanobiocomposites to products. The materials developed provide an alternative to the current generation of high performance ‘advanced’ composites materials which use thermoset polymers and man-made fibers like glass, carbon and Kevlar®. Further, these polymers are derived from petroleum, an expensive and scarce commodity, and composites are not biodegradable.

The intellectual merits of this grant lie in the fact that the development of biodegradable nanofibers, nanoparticles, nanobiopolymers and their characterization, processing and characterization of advanced green composites will provide significant knowledge that can be used to develop new applications in automotive and building industries. Work is being carried out on the four campuses in close collaborations. At Tuskegee University, efforts are focused studies on PVS bionanocomposites reinforced with cellulose nanofibers, synthesis and characterization of epoxide soybean oil, jute bio-nanocomposites reinforced with grafted halloysite nanotubes added PHBV polymer, thermal, durability and biodegradation properties of halloysite nanotube reinforced poly (3-hydroxybutyrate-co-3-hydroxyvalerate) Films, eggshell-silver nanoparticles tailored co-polyester polymer blend film with antimicrobial properties, coconut shell sourced carbon Tailored biofilm from PLA and PBAT blend, influence of cellulose on the mechanical and thermal stability of ABS plastic composites, a facile benchtop reactor design using dendrimer-templating technology for the fabrication of PEI-coated Cu nanoparticles on the gram-scale, Forcespun PLA fibers enhanced using graphene nanoplatelets, montmorillonite nanoclay and lignin. In these efforts funding was leveraged from other NSF funded grants.

At Auburn University (AU), research is focused on synthesis and characterization of biopolymers and nanobiocomposites. Specifically, work was focused on Triglycerides and Phenolic
Compounds as Precursors of Bio-based Thermosetting Epoxy Resins. Cornell University (CU) work is focused on development of high performance green nanocomposites using aligned bacterial cellulose and soy protein.

**Broader impacts**
There has been significant research achievement, which has been disseminated to larger technical community through publications in journals and presentations at conferences. Science and technology open-house activities are held annually by Tuskegee University on bringing middle and high school students together to interact with their peers from colleges across the state of Alabama. All the students were provided opportunities to present their work in international conferences and/or student paper competitions (both oral and poster). Several students obtained MS and PhD degrees. Many of the students completing MS degrees are joining PhD programs elsewhere. Students who obtained PhD degrees have got jobs either in industry or in academia. High school students participated in a program called SciTrek where they spend a week and got trained by graduate students. This is an ongoing activity, details of which will be reported next year. TU faculty and students were involved with NSF funded REU program in mentoring undergraduate students. Dr. Curry, other faculty members and graduate students at Tuskegee were involved in RET program. Results of research findings have been communicated to broader research community through publications in book chapters, journal articles, articles in conference proceedings as well as oral and poster presentations by the students.

**Participants**
- Dr. Mahesh Hosur, PI, Professor, Materials Science and Engineering, Tuskegee University (TU), PI: NSF-EPSCoR-Alabama Center for Nanostructured Materials, ONR, ERDC-CERL, Co-PI: NSF-PREM, HBCU-RISE.
- Dr. Maria L. Auad, Professor, Polymer and Fiber Engineering, Auburn University (AU).
- Dr. Maria Charlton, Associate Professor, Mechanical Engineering, TU.
- Dr. Michael Curry, Associate Professor, Chemistry, TU.
- Dr. Mohammad K. Hossain, Associate Professor, Mechanical Engineering, TU.
- Dr. Esperidiana Moura, Instituto de Pesquisas Energéticas e Nucleares - IPEN-CNEN/SP, Sao Paulo, Brazil.
- Dr. Anil Netravali, Professor, Fiber Science and Apparel Design, Cornell University (CU).
- Dr. Haibin Ning, Assistant Professor, Materials Science and Engineering, University of Alabama at Birmingham (UAB).
- Rohit Kumar Rana, Scientist, Indian Institute of Chemical Technology (IICT), Hyderabad, India.
- Dr. Vijaya Rangari, Co-PI, Professor, Materials Science and Engineering, TU, Co-PI: NSF-HBCU-RISE, PREM, EPSCoR.
- Dr. Pradosh Ray, Professor and Head, Mechanical Engineering, TU.
- Dr. Melissa Reeves, Associate Professor, Chemistry, TU.
- Dr. Uday Vaidya, UT/ORNL Governor’s Chair in Advanced Composites Manufacturing Professor, Mechanical, Aerospace and Biomedical Engineering (MABE) Chief Technology Officer, Institute for Advanced Composites and Manufacturing Innovation (IACMI)
- Dr. Selvum (Brian) Pillay, Professor, Materials Science and Engineering, UAB.
- Dr. Alfred Tcherbi-Narteh, Assistant Professor, Materials Science and Engineering, TU.
• Dr. Sabu Thomas, Professor, School of Chemical Sciences, Mahatma Gandhi University (MGU), Kerala, India.
• Dr. Shaik Zainuddin, Associate Professor, Materials Science and Engineering, TU.
• Ms. Felecia Grant, Associate Director, Grantsmanship and Compliance, TU.
• Ms. Danette Hall, Director, Sponsored Programs, TU

Key Personnel

Collaboration with National Labs and University Centers

Tuskegee University and its partners have developed collaborative arrangements with various academic intuitions, national labs and industry for support of research and educational programs of the proposed Center.

Partner institutions
• Auburn University (PI: Dr. Maria Aaud)
• Cornell University (PI: Dr. Anil Netravali)
• The University of Alabama at Birmingham (PI: Dr. Uday Vaidya, Dr. Haibin Ning)

Industry
Lockheed Martin Space Systems Company (Contact Person: Dr. Suraj Rawal)
Metters Inc. (Contact Person: Dr. Greg Gaddy)
Raytheon Missile Systems (Contact Person: Dr. Renee’ Rogers)
Composites Innovation Centre, Manitoba, Canada (Contact Person: Dr. Sean McKay)

National laboratories
United States Department of Agriculture, Agricultural Research Service, South Atlantic Area, Clemson, SC. (Contact Person: Dr. John Foulk)
Oak Ridge National Laboratory (contact persons: Drs. John Nemeth and Jim Roberto) Naval Research Laboratory (Contact Person: Dr. Duane Simonson)

International Exposure
We have developed a collaborative relationship with several international universities and research labs. We have selected the following institutions where our students will conduct research and sample culture in those countries.
Indian Institute of Chemical Technology, Hyderabad, India (Dr. Rohit Kumar Rana) Mahatma Gandhi University, Kerala, India (Dr. Sabu Thomas)
Instituto de Pesquisas Energéticas Nucleares - IPEN-CNEN/SP, Sao Paulo, Brazil (Dra. Esperidina Moura)

Outputs of CREST participants (2016-2017)

Book Chapters

Publications

Journal Publications


Conference publications


Bio-composites”, The Composite and Advanced Materials Expo, TP17-0239, Orlando, FL (Submitted).


**Patent Applications**


19. Filtration system and methods of using such system for improved water filtration, Vijaya Rangari, Vitus Apalangya, Bonifce Tiimob, Temesgen Samuel: Submittee, pending, USPA#15-492-878,

**Presentations**


10. Manal Alwohaibi, Chemar Huntley, and Michael L. Curry 253rd ACS National Meeting “Extraction and characterization of nanocellulose from different biomass sources” San Francisco, California, April 2-6, 2017. PAPER ID: 2658868

11. Donald H. White, Chemar Huntley, and Michael L. Curry 253rd ACS National Meeting “Synthesis and fabrication of CNF-based plastic nanocomposites” San Francisco, California, April 2-6, 2017. PAPER ID: 2659069


34. Jasmine Tanthongsack, S. M. Kamrul Hasan, Dr. Mohammed K. Hossain, "Processing of Jute Fiber reinforced Nanophased PLA-PHBV Blend Based Plant Composite", Nanobio


47. S. Gaillard, S. Ahmed, L. Jiang, M. Biswas, V. Rangari, N.S. Korivi, Biomimetic micromolding: Micro- and Nano-structuring of Polydimethylsiloxane (PDMS) using Bio-
and Nature Inspired Templates”. In EIPBN, Walt Disney World Disney’s Coronado Springs Resort Lake Buena Vista, Florida May 30 – June 2, 2017 (Abstract).

**Honors/Awards**

1. **Best Poster in Polymer and Fiber Engineering, Development of Bio-Based Novolac-Epoxy Interpenetrating Polymer Networks, Mehul Barde, Maria L. Auad, Graduate Engineering Research Showcase 2016, Auburn University, AL, October 2016.**
2. **Best Poster in Materials Engineering and Sciences, AIChE, Drug Delivery Mechanism of Sulfathiazole from Polyurethane Films, Montoia Davis, Mehul Barde, Shivani Rangari, Maria L. Auad, 2016 Annual Student Conference, AIChE, San Francisco, CA, November 2016.**
3. **Jasmine Thanthongsack, S. M. Kamrul Hasan, Dr. Mohammed K. Hossain, " Processing of Jute Fiber Reinforced Nanophased PLA-PHBV Blend Based Plant Composite”. Professional Agricultural Workers Conference, Dec. 3-5, 2016, Kellogg Center, Tuskegee University, Tuskegee, AL., USA. (First Place Winner), 2017.**
4. **Farooq Syed- Graduate Research Scholar Program Award- National Science Foundation-EPSCoR. (2016-2017)**
5. **Farooq Syed-Poster Presentation Award (JARS Symposium 2016) (Second Prize)**
6. **Farooq Syed-Poster Presentation Award (SAMPE Conference, Long Beach CA 2016 (Third Prize)**
7. **Farooq Syed-University Research Symposium, CAMX 2017 (Semifinalist)**

**Student Graduations**

**Ph.D**

1. **Muhammad Rahman, Protein Based Green Resins and Nanocomposites from Waste Residues, PhD, August, 2017, Cornell University.**
2. **Bernal Sibaja Hernandez, Thermosetting Polymers from Renewable Resources, PhD, August 2016. Auburn University.**
3. **Boniface Jabik Tiimob, Development of antimicrobial flexible biodegradable polymer blend alternative packaging material, Ph. D, July 2016. Tuskegee University.**
4. **Hannah Harding, Synthesis of carbon from e-waste and its comparison with high grade commercial carbon for electronic and polymer reinforcement applications, Ph. D, July 2016.**
5. **Vertonica Powell-Rose, Fabrication, Characterization and Biodegradability Studies of Flax Fiber Reinforced Biopolymer/Nanoparticle Composites, Ph. D., July 2017, Tuskegee University.**
6. **Chemar Jordae Huntley, The Influence of Functionalization on the Biodegradability and Recyclability of Cellulose-Reinforced ABS and HIPS Plastics, Ph. D., July 2017.**

**M.S. (all from Tuskegee University)**


**Sustainability Efforts (2016-2017)**

1. Collaborative Research: Making to Advance Knowledge, Excellence, and Recognition in STEM (MAKERS), PI: Mohammed Qazi and CoPI: Michael Curry, and Shaik Zainuddin, NSF DUE, $1,873,571.00, 10/2016-08/2021

2. Collaborative Research: Building Unique Inventions to Launch Discoveries, Engagement and Reasoning in STEM (BUILDERS), PI: Mohammed Qazi and CoPI: Michael Curry, Alicia Curry, Mohamed Abdalla, and Shaik Zainuddin, NSF DRL, $704,535.00, 03/2017-08/2020

3. Implementation Project: Preparing Interdisciplinary Minority Material Scientists and Engineers of the Future PI: Shaik Jeelani and CoPI: Michael Curry, Mohammed Qazi, Vijay Rangari, and Mahesh Hosur, NSF HRD, $1,799,388.00, 07/2017-08/2022

