Nanotechnology Center for Biomedical, Environmental, and Sustainability Applications – Phase II
NSF Grants NºHRD 0833112 & 1345156 (CREST program).

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Founded in 1911, the University of Puerto Rico at Mayaguez (UPRM) is among the three largest Hispanic Serving Institution in the nation. As such, UPRM has held a prominent place in its contributions to the national STEM workforce. Most times disregarded by the mainland's statistics for being in a US Commonwealth island, this university (a land grant and sea grant institution) is considered the largest provider of Hispanic engineers in the nation according to the American Society for Engineering Education. Being the only unit among the eleven-campus UPR system offering BS degrees in engineering, by the end of the 2017-2018 academic year, the UPRM College of Engineering (CoE) served 4,312 undergraduate students (out of a total enrollment of 11,560), making it the largest engineering school in the island and one of the largest in the US. Further, Engineering PhD degrees conferred by UPRM include: Civil, Chemical, Electrical, and Mechanical Engineering as well as Bioengineering. Additionally, the institution offers doctoral degrees in Applied Chemistry, Marine Science, and Computer Science & Engineering. Some of those degrees along with the MS in Materials Science and Engineering (MSE) are unique in Puerto Rico.

This much enriching environment has been hosting the very first Nanotechnology Center in Puerto Rico that started through a large NSF award, i.e. $4,200,000 from Sept. 1, 2008 through August 31, 2014. The breakthroughs and extensive impact of the initiative created the necessary momentum for the Phase II of the Center as part of its Centers for Research Excellence in Science and Technology (CREST) program, i.e. $5,000,000 from April 1, 2014 through March 31, 2020. Currently, 18 professors and 3 staff members (administration) constitute are part of the Nanotechnology Center. NSF funds help support 20 graduate students and 8 undergraduates, although the Center is impacting near 70 more students through collaborations. Fifteen public school teachers are members of the Center, as mentors of the MSE clubs sponsored by the Center and their 550 members.

The Center is organized in three interdisciplinary research groups (IRGs) and an interdisciplinary education group (IEG). The IRGs focus on the following areas:

i. Underpinned by strong ongoing research, IRG1 is working on the development of new nanoscaled materials for cancer therapy assisted by the application of magnetic fields and specialized light sources. Their toxicity and transport are assessed using model human cancer cell lines and other appropriate models. The final goal of this team is to create non-invasive therapeutics for treatment of patients suffering from diverse forms of cancer. In particular, this endeavor demonstrated the possibility of externally actuated heat and drug delivery using magnetic composite nanocarriers. Multicompartment microwell devices with 3 cells types were tested under hyperthermia conditions and compared between fabrication materials PS and PDMS. Influence of tumor-adjacent cancer and normal cell niches composed by fibroblasts and macrophages was established post-heat damage. These researchers constructed, characterized, and preliminary tested a prototype for laparoscopic application of MFH.

ii. In IRG2, the study of nanoporous structures is oriented to the fabrication of a novel series of composites for the removal of emerging contaminants from water sources, including pharmaceuticals and personal care products, and selected pathogens. The group revealed that it is possible to impart hydrophobic characteristics to water treatment adsorbents with minimal impact on selectivity via seeded nano-crystal zeolitic growth onto mesoporous carbon monoliths or the use of transition metal amine grafted mesoporous silica. When decorated with Cu^{2+} centers, the composites display impressive selectivity and capacity toward neutral CECs, like carbamazepine, which is a pharmaceutical compound prescribed for treating epilepsy and known to have considerable concurrency in water sources and wastewater. These researchers also unraveled the interactions between LiCl and Zn(bdc) (ted)0.5 and how this functionalized metal-organic framework interacts with CO_2. DFT calculations demonstrate that the formation of a LiCl-DMF complex within the pores of Zn(bdc)(ted)0.5 is energetically favorable.

iii. IRG3 has a multifold approach to the development of new nanomaterials for sustainable systems and applications. For instance, expansive research on nanoconcrete has led to the formulation of high performance and sustainable (low-energy consuming upon fabrication) concrete mixes. Through a partnership with a recycling company, this team was able to design a new type of structural concrete using repurposed plastics disposed by biomedical companies. Upon the study of catalytic conversion of cellulose to levoglucosenone (LGO) using propylsulfonic acid functionalized SBA-15 (PS-SBA-15) in tetrahydrofuran (THF), the team discovere that the use of a solid acid catalyst for the conversion of cellulose should be assisted by a homogeneous acid catalyst such as sulfuric acid (H2SO4) to promote the depolymerization of cellulose into levoglucosan (LGA). Moreover, in the synthesis and characterization of novel ionic polymer nanocomposite membranes (PNMs), sulfonated and sulfonated/phosphonated block copolymer membranes have been synthesized and a comprehensive materials characterization study has allowed the understanding of their nanostructure. The ionic polymer membranes have been further improved with organic and inorganic additives creating PNMs with: TiO_2 nanoparticles, Graphene Oxide (GO) films, Single-Walled Carbon Nanotubes (SWCNT), and Ionic Liquids (ILs). In addition to the materials characterization study to understand their nanostructure, transport properties for direct methanol fuel cell (DMFC) applications were measured. The study of the functionalized PNM's has revealed significant differences in the transport properties of protons and methanol. Furthermore, a better understanding of the transport mechanisms of protons and methanol has been obtained, including the role of water and the new ionic interconnections in the transport properties throughout the PNMs.

Through a multilevel strategy, the Interdisciplinary Education Group is forming a competitive cadre of Hispanic professionals by expanding their education and training required for a competitive Nanotechnology workforce, beyond traditional Science and Engineering concepts. Hence, Center participants are to become well-rounded scientists and engineers equipped with innovation and entrepreneurship skills, able to foster transformational advances in society. In particular, this IEG has focused on in-depth training of students from public schools and undergraduate and graduate students (UGS). Originally engaging two high schools, after 10 years, the Center Phase II's Interdisciplinary Education Group (IEG) maintains 15 Materials Science and Engineering clubs in middle and high schools in Western Puerto Rico. This strategy is at the core of the Center's social impact, as many of their members represent economically-disadvantaged households. Mentored by a teacher affiliated to and trained by the Center, each club provides an enriching venue through planned hands-on interventions by the IEG and carried out by the Center's UGS. The clubs' Annual Meeting held at UPRM's Coliseum serves as an entertaining activity, where the participants learn by building large-scale balloon models that demonstrate complex functionalities of nanostructured materials studied in the Center's four research groups. Meanwhile, these groups have been solidly productive and trained more than a hundred UGS, including former MSE club members, who nowadays pertain to the STEM and Nanotechnology workforce.