

UH Materials Science Consortium for Research and Education (UH Materials Science CoRE)

Final report

Nicolas Gaillard (*Lead*, T.T., SOEST-HNEI), Hope Ishii (*Deputy Lead*, T.T., SOEST-HIGP), Matthieu Dubarry (T.T., SOEST-HNEI), Joseph Brown (T.T., COE-ME), Sangwoo Shin (T.T., COE-ME), Przemyslaw Dera (T., SOEST-HIGP), Klaus Sattler (T., CNS-Physics), Craig Jensen (T., CNS-Chemistry), Mehrdad Ghasemi-Nejhad (T., COE-ME), Murli Manghnani (T., SOEST-HIGP), Albert Kim (T., COE-CEE), Woochul Lee (T.T., COE-ME), Godwin Severa (SOEST-HNEI), Yi Zuo (T., COE-ME) and John Bradley (SOEST-HIGP).

Introduction and Background Information

In the United States, Materials Science is one of the strongest areas of federal investment in academic research with many high-level funding opportunities. Most US R1 universities have well-developed and integrated Materials Science programs; however, UH is notably lacking in this critical area, creating tremendous growth opportunities in research and education. A broad spectrum of advanced, often unique, instrumentation for research in Materials Science is available in UH faculty members' individual laboratories. These faculty members have been highly successful in their individual research efforts with outstanding track records of attracting single-PI federal funding. However, their efforts have been isolated by the absence of infrastructure access created by the "stovepipe" character of organization and funding structure and the lack of a network to promote cross-campus collaboration. UH has recently made several new strategic hires with Materials Science expertise, research focus, and teaching capabilities across different Colleges, but without a focused effort to connect the scattered individuals into a well-coordinated research and education network, these new hires will continue to face major hindrances when competing for high-level funding. Materials scientists at UH are also eager to create innovative courses with hands-on experience to engage students in exciting Materials Science projects. Lack of a coordinated on-campus training and research framework in Materials Science severely constrains the educational opportunities and minimizes the impact of existing expertise and instrumentation on student training. The number of courses currently offered in Materials Science is limited, there are no existing graduate programs and students have no ready means to learn about research opportunities.

To address the challenges, we created in 2017 the UH Materials Science Consortium for Research and Education (MS-CoRE) with support from the VCR's Strategic Investment Program (budget \$350,000). This project associates UH's materials experts under one core group and combines Materials Science competence and infrastructure to support education, innovation and the foundations for a future Center for Materials Science at UH. The funds received from the VCR's Strategic Investment Program supports 6 fundamental activities of MS-CoRE:

- 1) Establish the Consortium and create of a web portal to act as an online nexus to all things materials-related happening at UH.
- 2) Subsidized access to state-of-the-art instrumentation to jumpstart innovative, unfunded projects, especially across College and School boundaries,
- 3) Provide funds for augmentation or repairs of existing instrumentation for education,
- 4) Develop a cross-listed, team-taught, undergraduate course on materials synthesis and characterization with a strong undergraduate research experience component,
- 5) Create and manage an Undergraduate Materials Research Program, with student fellowships, to fully engage students in the Consortium research community.
- 6) Involve UH materials experts in the development of collaborative research projects and major proposals for the creation of a Center for Materials Science at UH.

We provide below detailed updates on the progress made by MS-CoRE in each of the six fundamental activities.

1. MS-CoRE launch and development

The original MS-CoRE team consists of 10 faculty based in SOEST (HNEI, HIGP), COE (ME) and CNS (Physics and Chemistry). Together, we bring expertise in synthesis of advanced materials and state-of-the-art analytical capabilities down to atomic resolution, including aberration-corrected transmission electron microscopy, scanning tunneling microscopy, focused ion beam microscopy, time-of-flight mass spectrometry, nuclear magnetic resonance spectroscopy, optical spectroscopies (Raman and Brillouin scattering) and advanced X-ray diffraction, among many others. As of December 2018, 5 new faculty members have officially joined MS-CoRE, providing additional expertise in theoretical modeling and simulation (Prof. Albert Kim, CEE), heat transfer processes down to the nanometer-scale (Prof. Woonchul Lee, ME), physics and chemistry of gas absorption (Dr. Godwin Severa, HNEI), surface engineering for biomedical applications (Prof. Yi Zuo, ME), and high resolution materials characterization (Dr. John Bradley, HIGP). These faculty members bring participation by postdocs and graduate students too numerous to list.

Collecting and disseminating information about Materials Science expertise and instrumentation available at UH is critical to support and build the Consortium. As such, a website (<https://uhmscore.github.io/index.html>) was created to increase awareness of Materials Science presence at UH and act as an online nexus to all things materials-related. This portal provides a comprehensive inventory of instrumentation available at UH for materials research and detailed descriptions of MS-CoRE members research and capabilities. It will also provide networking opportunities and list open internship/research/job offers for undergraduate students.

2. Scientific research enabled by MS-CoRE support

An important mission of MS-CoRE is to leverage UH's existing state-of-the-art instrumentation and ensure they are used. To accomplish this task, we have allocated funding for instrument use specifically to UH faculty members and students with innovative, unfunded ideas to help them demonstrate their proof-of-concept for future proposal submissions.

A call for [short proposal](#) submission was announced early 2018. Faculty members were asked to provide detailed information about their project, the reason for selecting the specific analytical technique(s) and the expected output (report, scientific paper or proposal). All requests were reviewed by independent MS-CoRE members (usually the MS-CoRE lead). To date, a total of 8 requests were granted access to state-of-the-art instrumentation (see Table I for complete list), cumulating in over 117 hours of instrument use (XRD: 62 hrs, FIB+TEM: 55 hours). We highlight below two specific projects led by Profs. Brown (ME) and Sattler (PHYS) and supported by MS-CoRE.

Table I. Subsidized access to state-of-the-art instrumentation

Department	Requester	Characterization technique	Project
HIGP	Patricia Fryer	X-ray diffraction	Serpentinite samples from Mariana Trench
PHYS.	Klaus Sattler	FIB + TEM	Carbon nano-foam
GG	Julia Hammer	FIB + TEM	Volcanic materials
GG	Thomas Shea	FIB + TEM	Diffusion at melts-solid interfaces
HNEI	Matthieu Dubarry	FIB + TEM	Battery materials
HNEI	Matthieu Dubarry	X-ray diffraction	Battery materials
ME	Joseph Brown	FIB + TEM	Tungsten nanolayers for MEMS devices
ME	Mehrdad Nejhad	FIB + TEM	Carbon fiber composites

a. XRD/TEM characterization of alumina-tungsten ALD nanoscale films for MEMS/NEMS engineering

Motivations: Ultrathin films obtained with atomic layer deposition (ALD) are an appealing structural material for MEMS/NEMS engineering because they form conformal, defect-free layers with atomic-scale thickness control and a wide range of available materials. ALD thin films of W have been demonstrated for applications such as interconnected structures, diffusion barriers, and sensors, but the intrinsic stress is largely unknown. The stress may cause several undesired problems, such as cracking, curls or peeling of the film. High yield, reliable fabrication therefore follows from engineering, based on fundamental understanding of the residual stress. Nearly all thin films develop large intrinsic stresses during preparation due to lattice mismatch and coefficient of thermal expansion (CTE) mismatch. Furthermore, nanocrystalline materials have been shown experimentally to experience grain-size effects, and their thermal properties remain poorly understood.

Research: With support from MS-CoRE, Prof. Brown and his team have characterized nanostructures in alumina and tungsten (W) ultra-thin layers fabricated by ALD at 130°C on Si and polyimide (Figure 1). Curvature analysis using a modified Stoney equation indicated the presence of a stress gradient in the tungsten layer. Glancing incidence X-ray diffraction (GI-XRD) performed in Dr. Dera's laboratory (HIGP) demonstrated the presence of primarily the base-centered cubic (bcc) α -W phase, apparent as a broad peak from the (110) plane in vicinity of $2\theta = 40^\circ$. High-resolution transmission electron microscopy (HR-TEM) of the cross-section of the ALD layers performed in Dr. Ishii's laboratory (HIGP) showed the

presence of nanocrystalline tungsten grains of approximately 1-2 nm in size, and this size distribution is confirmed by a curve fit to the (110) W peak. The data obtained in this study represents a step towards a comprehensive understanding of grain size effects on the physical properties of ultra-thin tungsten and other films produced using atomic layer deposition. This study is essential for mechanical engineering and repeatable design and fabrication of devices using ALD materials.

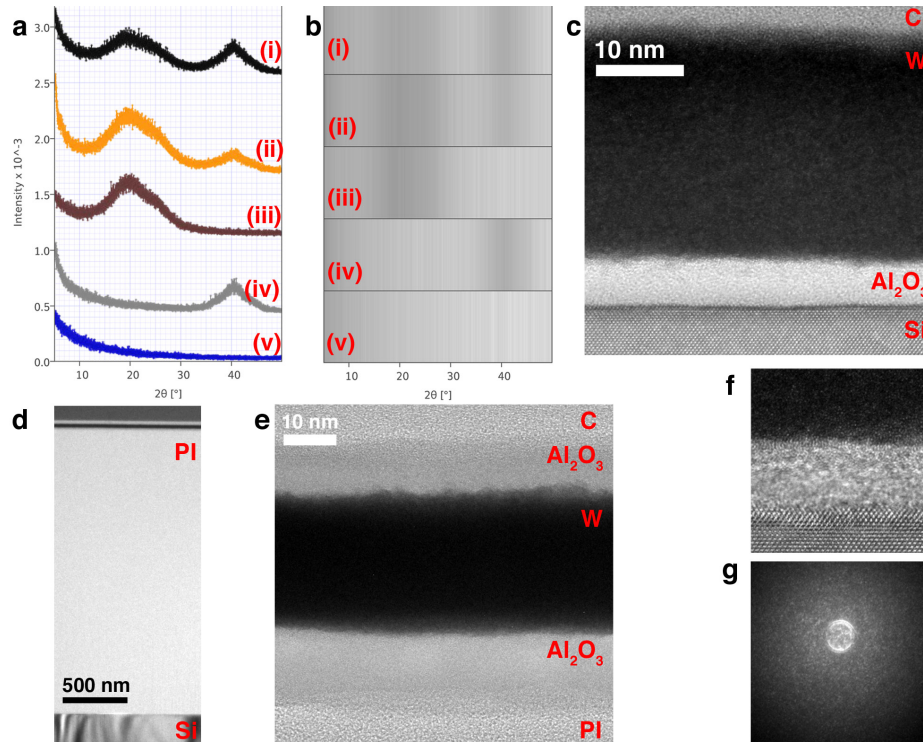


Figure 1: Material characterization data. (a) Grazing incidence x-ray diffraction data acquired from 5 samples using a Bruker powder diffractometer and Cu K α x-rays. (i) Si/polyimide(PI)/Al₂O₃/W/Al₂O₃ (ii) Si/PI/Al₂O₃/W/Al₂O₃, (iii) Si/PI, (iv) Si/Al₂O₃/W, (v) Si/Al₂O₃. (b) The same x-ray diffraction data as (a), visualized using darker color to indicate peak intensity. (c) HR-TEM image of Sample (iv). (d) HR-TEM image of Sample (ii). (e) Magnified TEM image of the ALD layers at the top of the PI in (d). (f) Si/Al₂O₃/W transition from (c). (g) Electron diffraction from the W layer in (e) shows a halo indicating a range of nanocrystal size.

b. Development of carbon nanofoams (PI: Klaus Sattler, Physics)

Motivations: The research of Prof. Sattler focuses on the production and analysis of carbon nanofoam. The foam is synthesized by hydrothermal carbonization where a sucrose solution with the addition of naphthalene is kept at high temperature and high pressure for up to about 100 hours. This is a green production method, and it leads to high-quality ultralight carbon nanofoam. Variation of the process parameters results in a variety of different types of foams. Microscopy studies show that the foam consists of an assembly of carbon micropearls. Our recent molecular storage studies show that the foam has a very high storage capacity which is due to the porous structure of the foam and the microparticles.

Research: High-resolution electron microscopy is essential to study the morphology of the foams and the internal structure of the micropearls. In addition, microtoming can be important to get detailed information about the interior carbon network. Such studies help understanding the complex synthetic procedures, and also explain and complement previous Raman and XPS results. Optical and FIB-SEM imaging performed in Dr. Ishii's laboratory (HIGP) have revealed atomic structural information. This data can be used for designing applications for the carbon nanofoam materials. Four undergraduate students are involved in this research: Joycelyn Ng (supported by the UH Materials Science Consortium, in picture with Prof. Sattler), Asayena Viengmany (supported by the UH Materials Science Consortium), Julia Lee and Jennifer Kim.

3. Upgrade and repair of research and teaching instrumentation

MS-CoRE also provided funding to rehabilitate aging analytical instruments required in educational programs and to purchase modest (yet fundamental) components needed for specific research programs. UH faculty members were invited to submit a short proposal with budget to MS-CoRE for review. A total of \$26K was spent in repair and acquisition (see Table II for more details). We highlight below two specific instrument augmentations made by MS-CoRE for materials research (laser heater, HIGP) and education (X-ray diffractometer, CHEM).

Table II. Acquisition/repairs of instrumentation for Materials Science education

Department	Requester	Instrument	Type	Cost
HIGP	Bin Chen	Muffle furnace	Acquisition	\$2,162
HIGP	Gary Huss	Raman stepper motor	Repair	\$1,697
HIGP	Gary Huss	Digital cameras for microscopes	Acquisition	\$3,800
HIGP	Murli Manghnani	Laser heater	Repair	\$7,000
Chemistry	Craig Jensen	X-ray diffractometer	Repair	\$12,000

a. Laser heater for high-temperature behavior analysis of materials

With the financial support from MS-CoRE, researchers at HIGP conducted repair/completion of the laser heating system with multispectral 4-color temperature detection (LHS-4C) in Mineral Physics Lab, room HIG 117. This instrument, has now become a valuable research and educational resource for materials science on the University of Hawaii at Manoa (UHM) campus. Laser heating is an experimental technique, which allows heating of a small sample (few tens of micrometers) to temperatures as high as 3000-5000K, to study high-temperature behavior of materials; induce chemical reactions, sintering and melting; or promote phase transitions. The technique can also be used for micromachining of metal or ceramic parts through laser ablation. Combined with the diamond anvil cell techniques, laser heating opens doors to experimental exploration of extreme pressure-temperature realms of materials science. The diamond anvil cell provides a very convenient reaction chamber in which a sample can be thermally insulated from the environment and surrounded by controllable atmosphere (typically noble gas or inert, optically transparent solid medium), to

prevent unwanted chemical reactions. The total cost of the project was \$7,000. The project was completed in Spring 2018, and the laser heating system is available for collaborative use.

b. XRD instrument for solid-state chemistry education

MS-CoRE provided financial support (\$12,000) to the Department of Chemistry for repair of an X-ray diffraction instrument. This fundamental analytical method was used in CHEM 425L “Prep. and Analysis of Inorganic Compounds Laboratory”, a laboratory class focused on synthesis and characterization of inorganic materials, until 2012 when it broke down. With support from MS-CoRE, vital components of the XRD instrument were procured and have arrived at UH, including a new controller and X-ray tubes. A service representative is scheduled to come to UH in January 2019 to install these items and get the instrument running. He will also provide training to the core users. We expect this analytical method to be reintroduced in CHEM 425L in a near future.

4. Team-taught undergraduate Materials Science course

Our first team-taught class, entitled “ME435: Experimental Methods in Materials Research”, was offered in Fall19 to 8 ME students. In this MSCoRE-supported hands-on course, students create a sample and characterize it during class time, working on state-of-the-art instruments in the Consortium members’ labs. The course is sub-divided into four 4-week long modules (Table III), each module covering a specific technology: *Photovoltaics* (Dr. Gaillard/HNEI), *Batteries* (Dr. Dubarry/HNEI), *Superconductivity* (Prof. Brown/ME) and *H₂ storage* (Prof. Jensen/CHEM). Additionally, students spend the last week of each module in a user facility where they use X-ray diffraction (Dr. Dera, HIGP) and electron microscopy (Dr. Ishii, HIGP) to gather microstructural and chemical information about their samples.

Students are divided into two groups of 4 individuals. Each module is organized in such a way that the two groups never operate the same instrument at the same time, providing more hands-on experience for each student. At the end of each module, both groups write a report formatted as a research paper, including a clear formulation of their hypotheses, a detailed experimental section, a thorough analysis of their experimental results, and discuss whether or not their hypotheses are valid. Reports are evaluated by each module instructor using a grading scale shared in advance with the students. For the last module, students give an oral presentation in front of their peers and all 6 instructors.

This inaugural class was particularly well received and students graded the course 4.57/5 ([link to course evaluation](#)). All students reported that the course challenged them intellectually (5/5). One student wrote “*this class was, hands down, my favorite course I have taken so far. I did not think that we would be able to be so hands on in this course, and it truly was such a great experience*”, another one noted “*being able to step away from that conventional learning style and being able to apply what we learn on the spot was really eye opening*”. Another student wrote “*the class as a whole was a lot of fun! It was very different from other typical courses offered in the engineering curriculum, and is a welcome change*”, and another added “*I’ve been constantly telling my peers about this course and what we’ve been doing for each module. They expressed that they would love to take the course if given the opportunity again!*”. We hope to resume it in Fall21 and plan to expand it to PHYS and EE in subsequent years.

5. Undergraduate materials research program

The Consortium is committed to including undergraduates as an integral part of the research community from the start. As such, we have allocated specific funds to support 11 undergraduate students to engage them in genuine research in members' labs (see Table IV for details). Each student has received a one-year research fellowship (\$3,000) as well as a budget (\$1,500) to cover the consumables required for their projects. In Spring 2019, undergraduate research students will present their research to their peers and advisors at the Consortium's one-day workshops and (tentatively) the UH Undergrad Research Symposium. We present below 4 projects led by undergraduate students and supervised by ME Profs. Brown, Shin and Nejhad as well as Drs. Dubarry and Severa from HNEI.

Table III. Tentative schedule for the undergraduate "hands-on" class (FALL19).

Block #1-PI: Gaillard / Photovoltaics		Block #2-PI: Dubarry / Batteries	
Week #1	Class intro and safety	Week #5	Synthesis
Week #2	Synthesis	Week #6	Synthesis
Week #3	Testing	Week #7	Testing
Week #4	Microscopy (Ishii)	Week #8	Diffraction (Dera)

Block #3-PI: Brown / Advanced ceramics		Block #4-PI: Jensen / Solid state chemistry	
Week #9	Synthesis	Week #13	Synthesis
Week #10	Synthesis	Week #14	Synthesis
Week #11	Testing	Week #15	Testing
Week #12	Microscopy (Ishii)	Week #16	Diffraction (Dera)

Table IV. List of undergraduate fellowships funded by MS-CoRE

Department	Supervisor	Student name	Research topic
PHYS.	Klaus Sattler	Asayena Viengmany	Carbon-based nano-foam
PHYS.	Klaus Sattler	Joycelyn Ng	Carbon-based nano-foam
ME	Joseph Brown	Geoffrey Garcia	Surface effects on gas absorption
ME	Sangwoo Shin	Jeffrey Zheng	Water filtration
ME	Sangwoo Shin	Trevor Shimokusu	Water filtration
ME	Sangwoo Shin	Katylynn Chun Fat-Ardren	Water filtration
ME	Mehrdad Nejhad	Reginald Tolentino	Nano-composites
HNEI	Matthieu Dubarry	Eric Takahash	Metall-ionic liquids electrolytes
HIGP	Przemek Dera	Rachel Bellah	Advanced characterization
GG	Hope Ishii	Lean Teodoro	Advanced characterization
CHEM.	Craig Jensen	Tamara Allen	Solid-state synthesis of materials

a. Effect of background chemicals on the performance of CO₂-driven water filtration (PI: Sangwoo Shin, Mechanical Engineering)

Motivations: Water purification technologies such as micro-/ultra-filtration and reverse osmosis utilize porous membranes to remove suspended particles and solutes. These membranes, however, cause many drawbacks such as high pumping costs and a need for periodic replacement due to fouling. Preliminary experiments demonstrate that micron-size particles can be separated in gas-permeable channels by exposing a suspension to permeating CO₂ without the use of porous membrane filters (Shin et al. *Nature Comm.* (2017) **8**, 15181). The method is scalable, energy-efficient, and essentially free from fouling. CO₂ is also easy to remove and biologically benign, making it an ideal water filtration agent. With this approach, we propose to study complex aqueous streams with multiple background solutes since wastewater heavily contains dissolved chemicals that can alter the solute gradient established by the dissolution of CO₂. To understand the performance for a wide range of input streams, we studied experimentally more complex aqueous streams containing multiple background solutes and will develop a mathematical model accounting for the background chemicals.

Research: Over the past 12 months, three undergraduate students have participated in the proposed research with the support from the MS-CoRE program. The students have learned how to make polymer-based (polydimethylsiloxane, PDMS) microfluidic devices using standard soft lithography process. By feeding the flow channels with fluorescent nanoparticle suspensions and exposing CO₂ only on one side of the flow channel, the students performed fluorescence microscopy to evaluate the motion of particles induced by CO₂ (Fig. 2). The students have also learned advanced image processing software such as ImageJ and Matlab for post-processing of the experimental data. The suspensions contain a variety of solutes to model actual wastewater such as salts, minerals, contaminants, etc. Throughout the experiments, we have confirmed that the CO₂-driven water filtration technique can withstand ionic strength up to about 5 mM, which is a typical concentration for a regular tap water. This implies that the CO₂-driven water filtration can be used for filtering of a pretreated tap water such as microparticulates and bacteria. For example, Fig. 3 shows the removal of *E. coli* from water using the CO₂-driven water filtration technique, indicating that the proposed technique can be a chemical-free method for removing waterborne pathogens.



Students from Prof. Shin's group supported by MS-CoRE: from left to right, , Mechanical Engineering (2018.1-2018.6 (graduated)), Trevor Shimokusu, Mechanical Engineering (2018.8–current, senior) and Katylynn Chun Fat-Ardren, Mechanical Engineering (2018.10–current, senior)

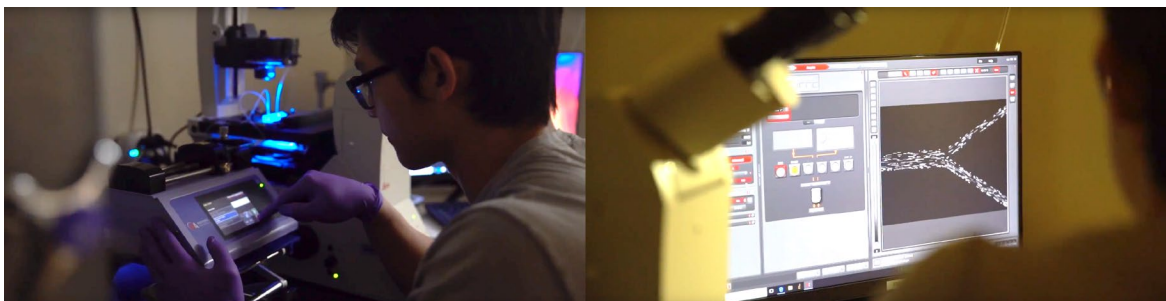


Figure 2. Undergraduate researcher (Jeffrey Zheng, Mechanical Engineering '18) performing microfluidics experiments with fluorescence microscopy to study particle separation using CO₂.

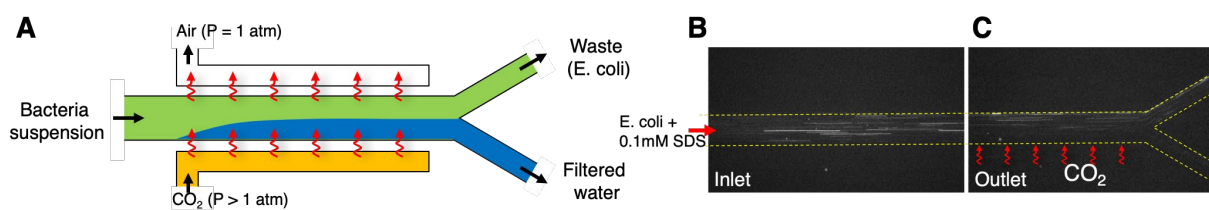


Figure 3. Continuous flow, membraneless bacteria (*E. coli*) separation using dissolution of CO₂. (A) Schematic of the separation process. A porous channel material (PDMS) allows permeation of CO₂ gas into a suspension, inducing directed bacteria motion normal to the flow direction. (B,C) Fluorescence microscopy images of *E. coli* migrating transverse to the flow direction. Images are taken near the (b) entrance and (c) end of the flow channel, where the channel length is 3 cm and the width is 100 μm.

b. Metallo-Ionic Liquids Electrolytes for Batteries (PIs: Matthieu Dubarry and Godwin Severa, Hawaii Natural Energy Institute)

Motivations: The Hawaii Natural Energy Institute battery testing team is a worldwide leader of *in operando* Li-ion diagnosis and prognosis. Current safety limitations for commercial batteries lies in the carbonate-based liquid electrolytes. This project proposes to develop new metallo-ionic liquid electrolytes based on Li, Na, K, Ca or Mg ions as a replacement for batteries conventional electrolytes. The use of ionic liquid as electrolytes in batteries can eliminate the safety concerns whilst still maintaining high battery performance. Ionic liquids have high ionic conductivity, negligible vapor pressures, low flammability, and most have the wide electrochemical window necessary for battery applications.

Research: Eric Takahashi (ME undergraduate) is currently supported by MS-CoRE to work with Drs. Godwin Severa and Matthieu Dubarry on a project aiming at developing new ionic-liquid based electrolytes for batteries. During the first semester, Eric received training about procedures and processes for safely performing materials research on ionic liquids as battery electrolytes. Since this was Eric's first wet materials chemistry laboratory experience, the major emphases were on lab safety protocols, including hazards analyses and mitigation, before the work could begin. Following the in-house safety training, Eric learned about chemical inventory management, general lab instrumentation, and handling of glassware in the lab. During the same time, Eric read literature on ionic liquid applications to broaden his knowledge whilst simultaneously emphasizing literature on their application as electrolytes for battery. Eric will test the performance of ionic liquids as battery electrolytes at the beginning of Spring 2019.

c. Development of High-Performance Ceramic Nanocomposites for Space Applications (co-funded by MS-CoRE and NASA) (PI: Mehrdad Ghasemi Nejhad, Mechanical Engineering)

Motivations: The demand for tough, strong, and light-weight materials in the space/aerospace industry calls for the development and inclusion of nanomaterials to achieve such needs. With the addition of nanoparticles and carbon nanotubes (CNTs) in Ceramic Matrix Composites (CMCs) and Continuous Fiber Ceramic Composites (CFCCs), the mechanical, physical, and optical properties can further enhance the performance of these materials. CMCs and CFCCs have also high-temperature properties which make them highly desirable as structural materials in various engineering applications including gas turbines, space vehicles, aerospace vehicles, and automobiles to name a few. The main objective of this research is to process, characterize, and evaluate the mechanical performance of ceramic nanocomposites from preceramic polymers with and without nanoparticles and CNT-based Nanoforest for use in conditions and environments in high temperature. This report covers the activities during Summer and Fall 2018, results from testing, data reduction, and characterizations of the fractured samples using the Optical Microscopy and SEM facilities of the MS-CoRE at the UH Manoa SOEST, as well as the plans for Spring 2019.

Research: Initially, Reginald Tolentino (undergraduate student supported by MS-CoRE) spent some time on background reading and experimental familiarization on manufacturing of CFCCs material and the fundamentals of nanotechnology to gain a better understanding of the scope of the research. During Summer and Fall 2018, the baseline CFCC samples without nanoparticles and without CNT-based Nanoforest were completed. The fiber system used here was a Nicalon™ fiber (which is a Silicon Carbide based fiber). The Preceramic Polymer resin used here was a SMP-10 material. A wet lay-up technique was used to impregnate the fibers by the resin system to manufacture ASTM C-1341 coupons for 4-point bending test, revealing to the following mechanical properties: Flexural Strength: 40 MPa, Flexural Strain-to-failure: 0.065% (mm/mm), Toughness: 14.56 MJ/m³, and Modulus: 62 GPa.

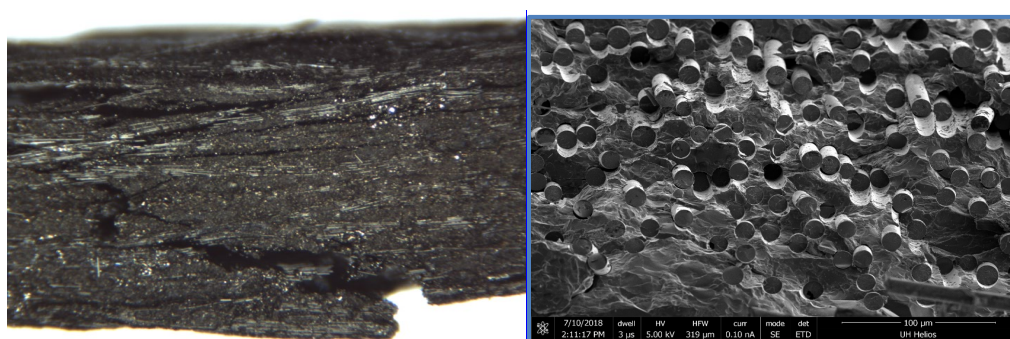


Figure 4. (Left) Optical Microscopy micrograph of Nicalon/SMP-10 CFCC sample fracture after ASTM C-1341 4-point bending test. (Right) Focused Ion Beam - Scanning Electron Microscopy (FIB-SEM) micrograph of Nicalon/SMP-10 CFCC sample fracture surface after ASTM C-1341 4-point bending test showing some fiber pull-outs for these samples pyrolyzed at 1,000°C.

Figure 4 shows the Optical Microscopy photograph of Nicalon/SMP-10 baseline CFCC sample fractured after the ASTM C-1341 4-point bending test. Figure 2 shows the Focused Ion Beam - Scanning Electron Microscopy (FIB-SEM) image of the fracture surface showing

some fiber pull-outs for these samples pyrolyzed at 1,000°C. The manufacture of CFCCs with Nanoparticles in the matrix (Gudapati et al. Journal of Thermoplastic Composite Materials 22, No. 4, (2009), 421) and Nanoforest on the fibers (Veedu et al., Nature Materials 5, (2006) 457) will be completed in Spring 2019. Our research will focus on improving the mechanical properties of ceramic nanocomposites, and hence the data and testing obtained during Summer and Fall 2018 will serve as a baseline for comparison against the hierarchical multifunctional ceramic nanocomposites with nanoparticles inclusions in the SMP-10 matrix and CNT growth on Silicon Carbide fibers.

d. Electric field and electric charge effects on gas adsorption (PI: Joseph Brown, Mechanical Engineering)

Motivations: MS-CoRE funding has had a strong impact on J. Brown's research planning in the last year. Through connections made with this proposal, he was brought into two large proposals in the winter of 2018 (NSF NRT senior personnel, DOE EFRC Co-PI). Although these proposals were not funded, participation in the DOE proposal specifically led to development of an idea for an experiment in fundamental research of chemical bonding. The essential concept is that the population of mobile charge carriers within a material can influence the strength of adsorption reactions at the material surface. In systems that can be tuned by charge and by more complicated electric-field-driven effects, the reactivity of the material can be tuned. On the other hand, adsorption is the basis for molecular doping to change the electrical conductivity of organic conductors and gas sensors, suggesting the potential for a deeper energy and thermodynamics based description of charge transfer, adsorption, and reactivity. This behavior was originally observed to a limited extent for semiconductors in the 1980s, but new availability of 2D nanomaterials such as graphene or molybdenum disulfide presents the opportunity for more profound physical studies. Brown and his students are building apparatus to measure the electrically tunable gas adsorption on 2D materials. This will be performed using a quartz crystal microbalance in an environmental chamber, Figure 5. This fundamental research will be the basis of Brown's intended NSF CAREER proposal in summer 2019.

Research: MS-CoRE funding was used to support an undergraduate Mechanical Engineering student, Geoffrey Garcia, during summer 2018. Geoffrey was a transfer student from Leeward Community College who started at UH Manoa in Fall 2017 and is expected to graduate in Spring 2019. During summer 2018, he worked full time to develop a detailed design for the experimental system described above, and since then he has ordered and assembled the parts he designed, Figure 5. As a result of some of this experience, Geoffrey is now planning to pursue graduate study. This fundamental work towards interfacial physics has also contributed to submission of a DOD equipment proposal with Brown as PI, and submission of a DOE preproposal and a NASA proposal with Brown as Co-PI. Furthermore, a second undergraduate, Branden Lucas, was hired in August 2018 under the same job description as Geoffrey (Materials Fellowship) but under different funding, to pursue system development for energy harvesting devices based on surface physics.

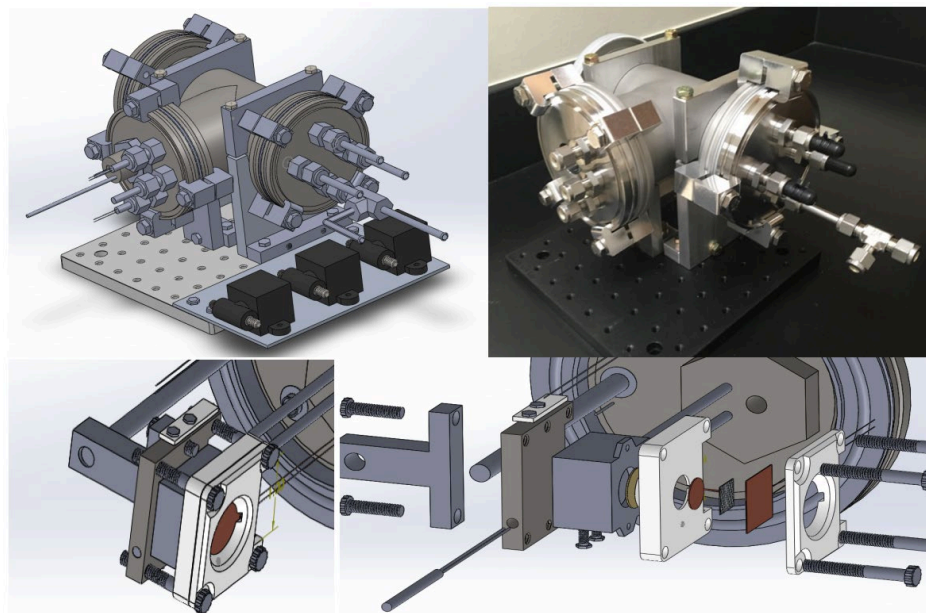


Figure 5. Environmental chamber for measurement of electric field and electric charge effects on gas adsorption. Designed and constructed by Mechanical Engineering undergraduate student Geoffrey Garcia in summer and fall 2018 under the supervision of Prof. Joseph Brown and funding from MS-CORE. (top left) Environmental chamber design. (top right) Fabricated environmental chamber. (bottom left) Quartz crystal microbalance (QCM) assembly for gas adsorption detection. (bottom right) Exploded view of electric field control mechanism designed as an add-on to the QCM assembly.

6. MS-CoRE outreach and future expansion

Several MS-CoRE members have engaged in outreach activities over the past year. Drs. Hope Ishii and Nicolas Gaillard interacted with the Materials Research Society (MRS) and the Hawaii Tourism Authority to help secure the MRS Spring Meeting venue in Honolulu for 2022. This international meeting will bring over 5,000 materials scientists from more than 55 countries, providing unique networking opportunities for UH faculty members and students. A campus visit is scheduled with MRS' Executive Director Todd Osman in February 2019. In addition, Nicolas Gaillard will meet with MRS 2020 organizing committee during the 2019 Spring MRS conference in Phoenix, AZ.

A major goal of MS-CoRE was also to help UH faculty members connect across Colleges and School boundaries and support them in securing large grants to grow Materials Science at UH. Two major proposals were submitted to NSF and DOE in 2018, and two new ones are scheduled to be submitted to the same funding agencies later in 2019.

NSF/NRT (February 2018): a group of MSCoRE collaborators lead by Przemyslaw Dera submitted a \$3M proposal to the NSF Research Traineeship program (NRT). The proposal title was “NRT: Innovative Materials and Technologies for an Adaptable Future (IMTAF)”, and its main goal was establishment of new graduate program in Materials Science on UHM campus. The co-PIs included Hope Ishii (HIGP), Matthieu Dubarry (HNEI), Jason Leigh (ICS), Debora Halbert (AVCAA), Gwen Jacobs (ICS), Nicolas Gaillard (HNEI), Craig Jensen (CHEM), Yi Zuo (ME), and Helen Turner (Chaminade University). The proposal received very positive reviews (1 good, 2 very good, 1 excellent), but was not selected for funding.

DOE/ERFC (April 2018): a group of MScORE collaborators lead by Craig Jensen (CHEM) submitted a DOE proposal to establish a new Energy Frontier Research Center. The proposal title was “The Center for Mesosorptive Gas Storage and Separation”. In addition to the PI, the UHM proposal participants also included Godwin Severa (HNEI), John Head (CHE), Przemyslaw Dera (HIGP), Joseph Brown (ME), as well as a number of external collaborators from Lawrence Livermore National Laboratory, Caltech, Oak Ridge National Laboratory and PNNL. The proposal received very positive reviews, but was not selected for funding.

DOE/EPSCOR (pre-proposal submitted in December 2018): a group of MScORE collaborators lead by Craig Jensen (CHEM) submitted a preproposal entitled “Fostering a Guiding Multiscale Model for the Development of Advanced MgB_2 Hydrogen Storage Materials” to the DOE EPSCOR program. Co-PIs of the proposal included Godwin Severa (HNEI), Przemyslaw Dera (HIGP), Hope Ishii (HIGP), John Head (CHEM) and Joseph Brown (ME).

NSF/MRSEC (preliminary proposal due June 2019): a call was made by NSF late 2018 for the creation of new Materials Research Science and Engineering Centers (MRSEC). This program is designed to provide sustained support for up to 6 years to interdisciplinary groups with focus on materials research and education. MS-CoRE members have already met and discuss about this funding opportunity and will work closely with the VCR office on this proposal in the next few months.