Underwater Energy Systems

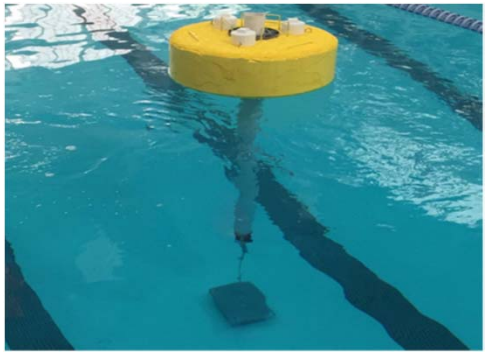
Overview of Underwater Energy Systems

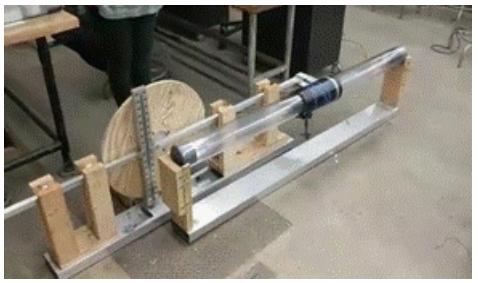
People:

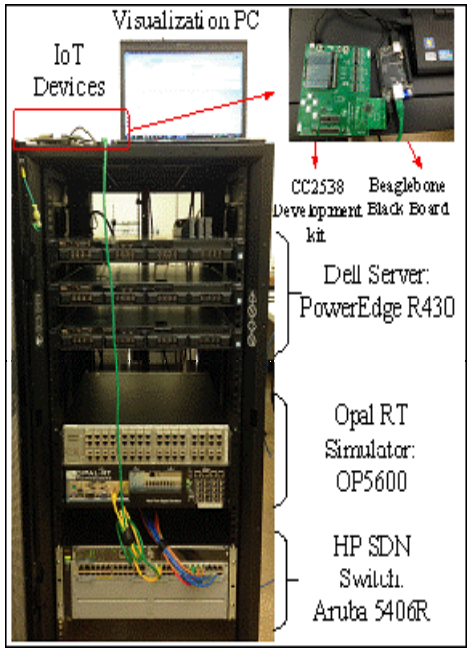
- **Arijit Bose**, *Distinguished Engineering Professor of Chemical Engineering*, URI (Lead)
- **Wilson K. S. Chiu**, *Professor*, Mechanical Engineering, UConn
- **M. Reza Hashemi**, *Assistant Professor*, Ocean Engineering, URI
- **Radenka Maric**, *Professor*, Materials Science and Engineering, and Vice President for Research, UConn
- **Ugur Pasaogullari**, *Professor*, Mechanical Engineering, Director, Center for Clean Energy Eng. UConn
- **Peng Zhang**, *F. L. Castleman Associate Professor*, Electrical & Computer Engineering, UConn
- **Yi Zheng**, *Assistant Professor*, Mechanical, Industrial, and Systems Engineering, URI

Capabilities

- Wireless underwater charging
- High performance lithium ion batteries
- Tidal power generation
- Wave energy conversion
- Air independent power sources
- High energy density fuel cells
- Fuel cells with logistical fuel potential
- Oxygen generating electrolyzers
- Shipboard power systems
- Microgrids, networked microgrids
- Stability and cyber-physical security
- Formal analysis and verification







- URI has unique facilities for testing and calibration of batteries.
- UCONN has wave energy converter prototypes, underwater wireless charging testbed, real-time hardware-in-the loop testbed for power & energy systems, etc.

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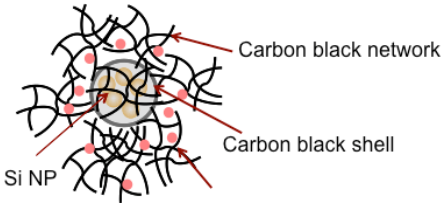
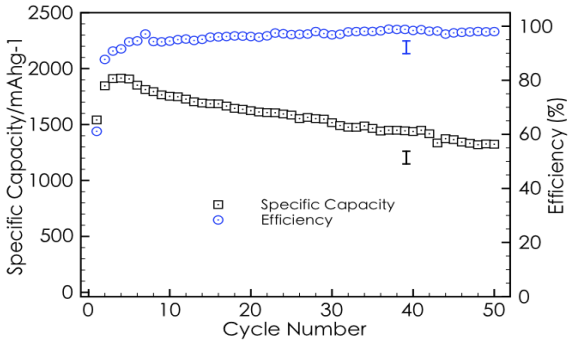
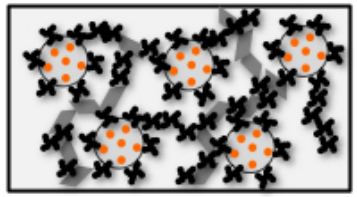
High specific energy and cycle stability in lithium ion batteries is critical for underwater vehicles

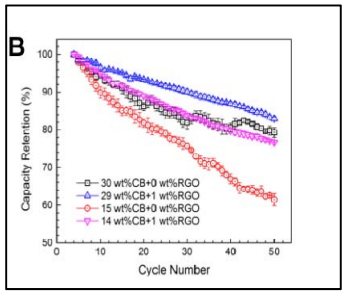


Spatially organize SiNP, CB and binder to maximize specific energy and cycle stability

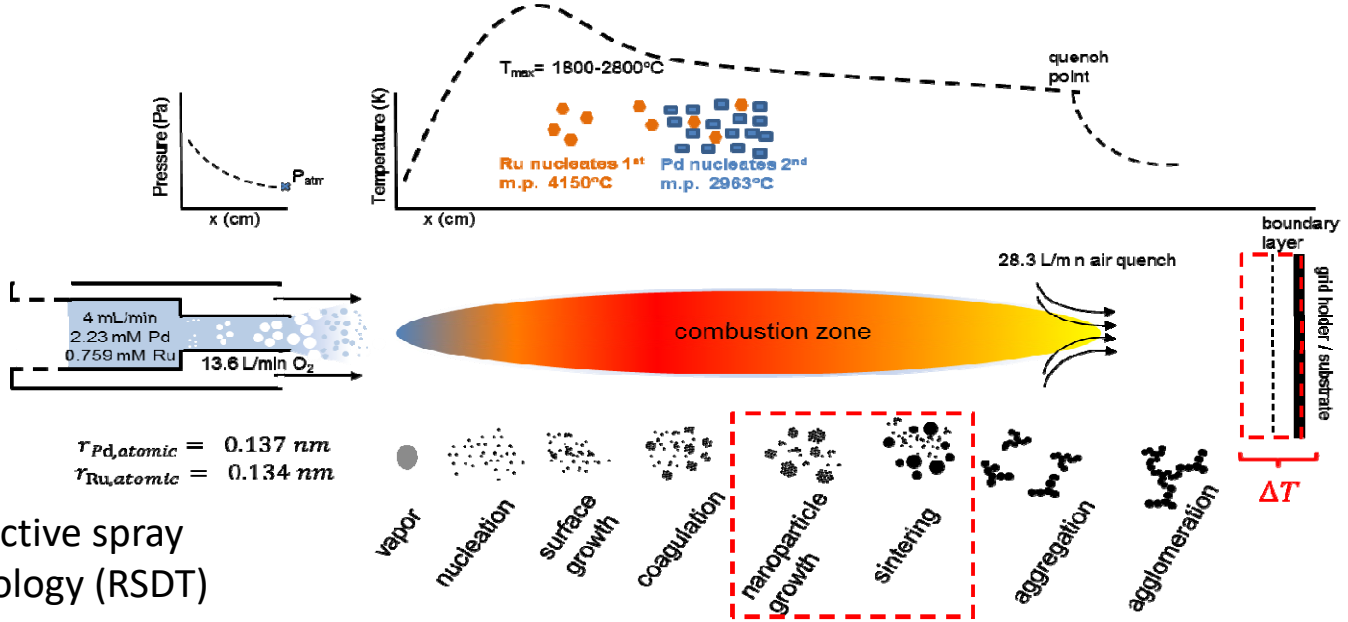




Replace CB with RGO to reduce total carbon



Bose group



Maric group: Reactive spray deposition technology (RSDT)

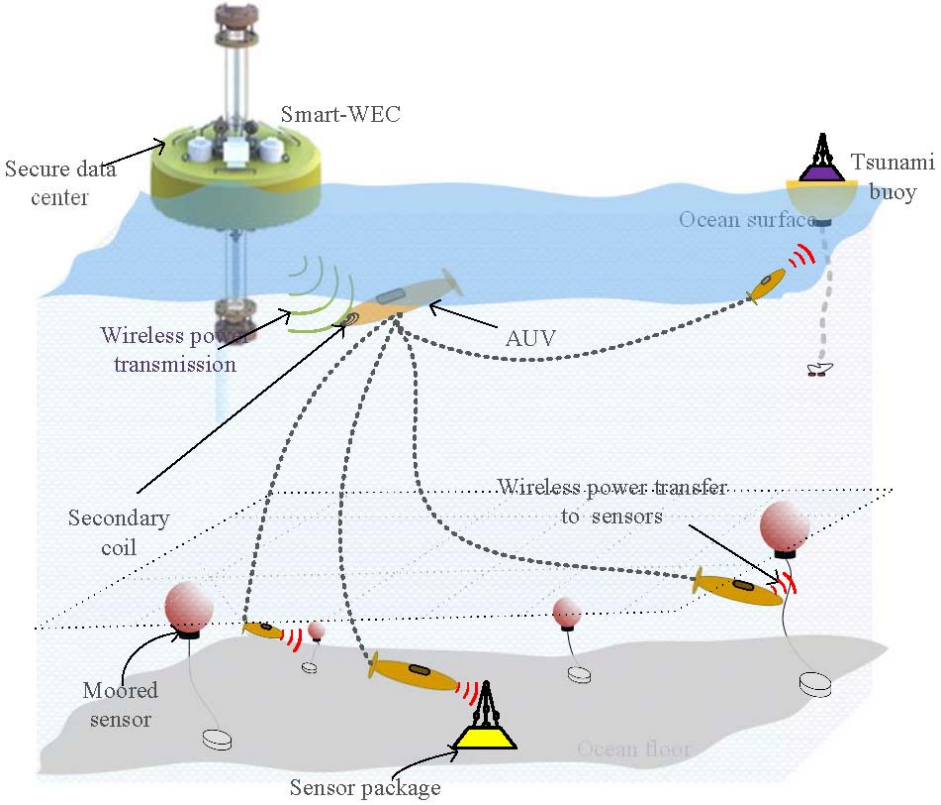
Improve the performance to cost ratio of fuel cell materials and components; develop low temperature Solid Oxide Fuel Cell (SOFC)

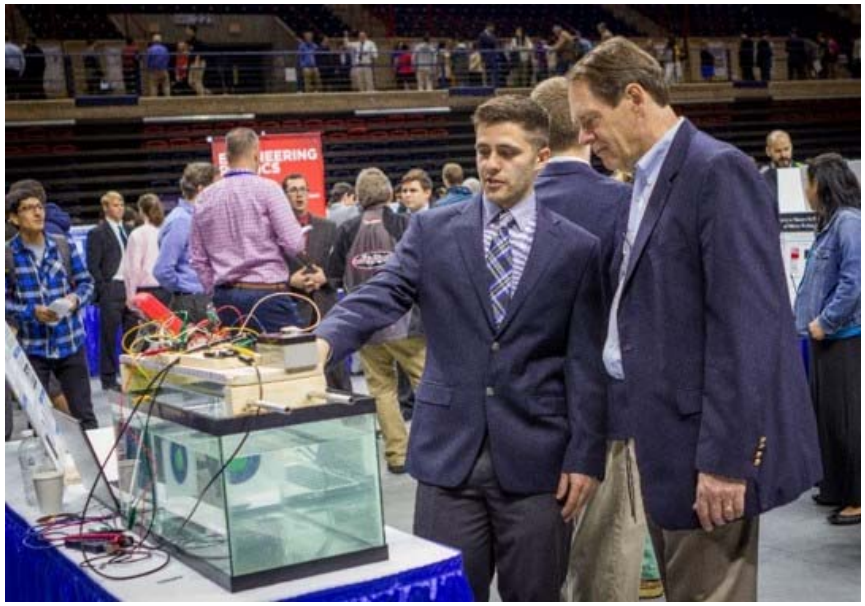
Underwater Energy Systems

Smart Ocean Energy Systems Research at UConn Power Lab

- **Underwater Wireless Power Transfer**
- **Smart-Wave Energy Conversion**
- **Power Electronics**
- **Tidal Energy Generation**
- **Cyber Security in Smart Ocean Systems**
- **Microgrids and Networked Microgrids**

http://power.engr.uconn.edu

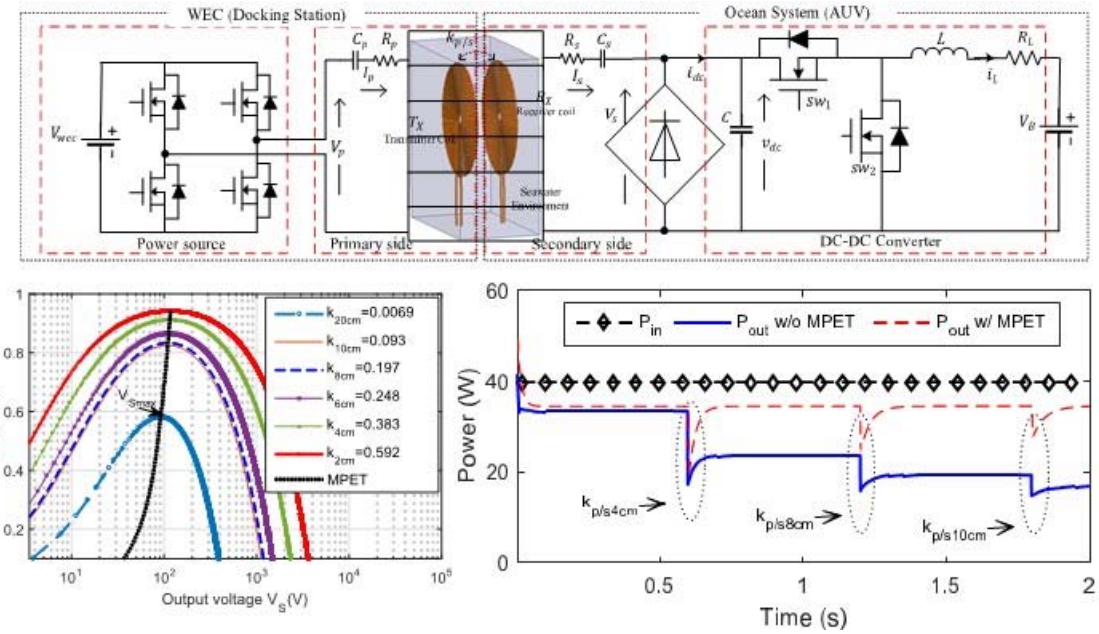


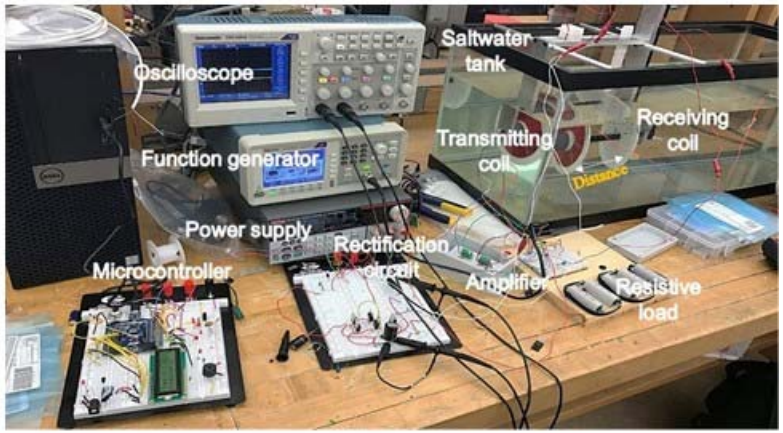


UConn's underwater wireless charging system (Senior design advisor: P. Zhang)

T. Orekan, P. Zhang, ***Smart Ocean Energy Systems***, Springer, to be published in 2018
P. Zhang, Y. Li, and L. Ren, ***Networked Microgrids***, Cambridge University Press, to be published in 2018

Underwater Energy Systems

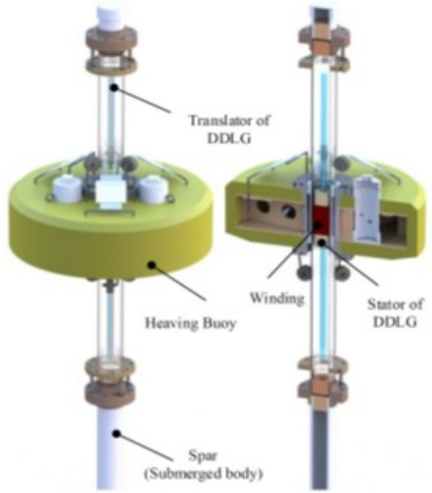


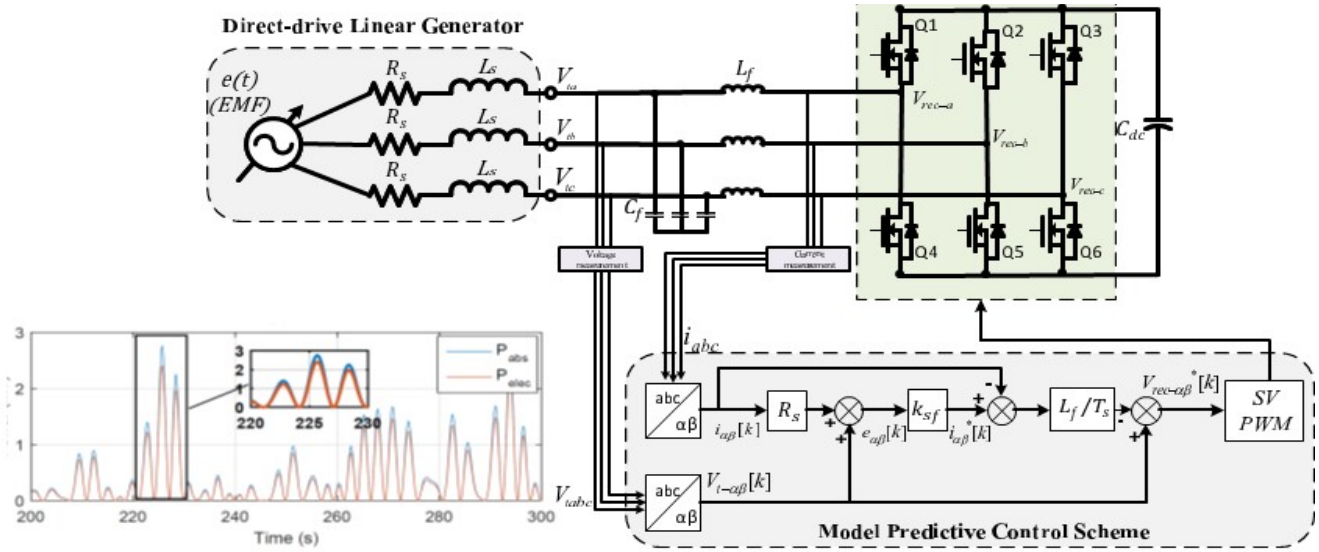


- **Underwater wireless power transfer**
  - Resilient to highly uncertain marine environment
  - Maintain high power efficiency under dynamically changing loads/coupling coefficients
  - Critically important to reduce power losses and preserve energy for undersea applications
- **MPET**:
  - A novel **Maximum Power Efficiency Tracking** (MPET) method for achieving maximum power efficiency **without communication or feedback** from the transmitting side of the UWPT system

T. Orekan, P. Zhang, and C. Shih, "Analysis, design and maximum power efficiency tracking for undersea wireless power transfer," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, published on Aug. 4th, 2017, DOI: 10.1109/JESTPE.2017.2735964.

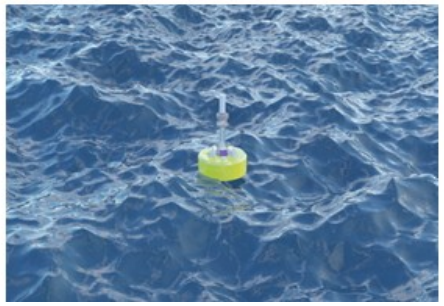
Underwater Energy Systems





Smart-WEC

- Single body point absorber type wave energy converter oscillating in heave motion
- Air-cored direct-drive linear generator (DDLG)
- Unique features:
  - ❑ Underwater WPT
  - ❑ Intelligent controls (MPET, MPC, MLCT)
  - ❑ Cyber security



– In the foreseeable future, Smart-WEC can offer power solutions in the ocean space, which could help accelerate sustainable development and deployment of distributed ocean systems that requires electrical power.

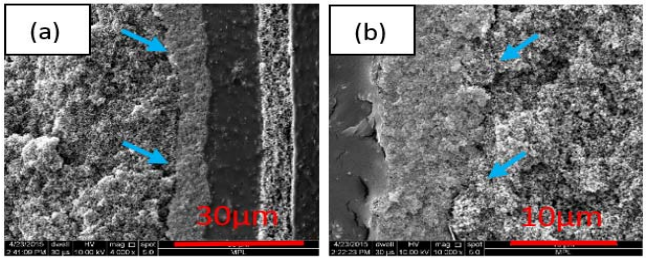
T. Orekan and P. Zhang, "Modelling and maximum power extraction of a novel smart wave energy converter," *IEEE Transactions on Sustainable Energy*, under review, 2018.

Underwater Energy Systems

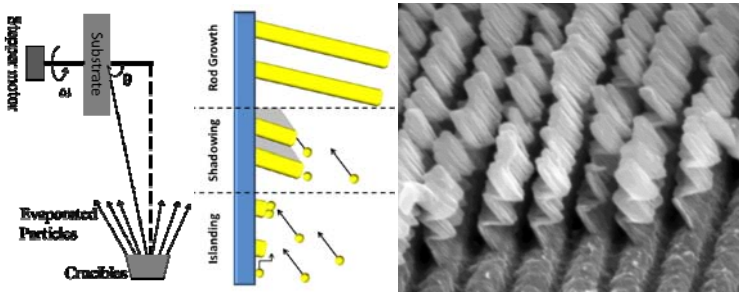
Low Temperature Electrochemical Systems: Pasaogullari group

- Focus:
  - Low temperature electrochemical systems
    System/component evaluation, fabrication
  - Hydrogen refueling system components
- Key capabilities:
  - Electrode, MEA fabrication
  - Nanofabrication (e-beam PVD)
  - Electrochemical characterization
  - Material characterization
  - Modeling

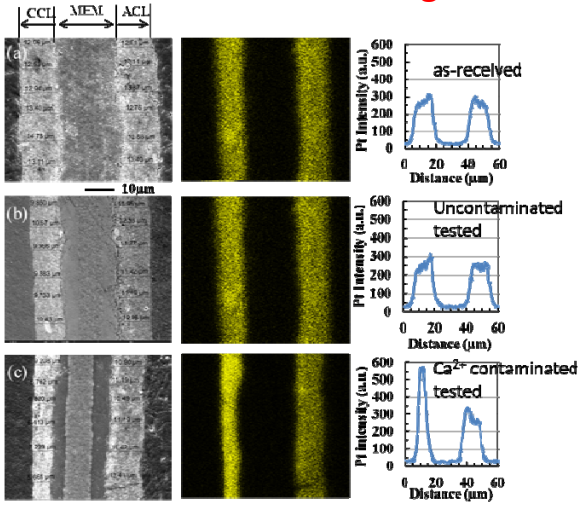
Novel gas diffusion media



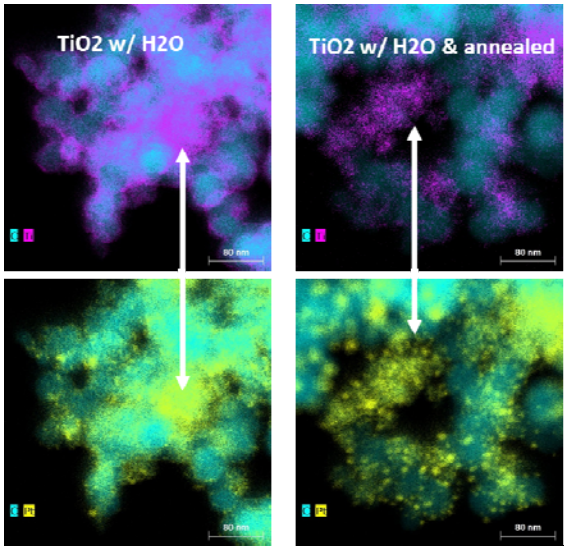
Engineered Nanostructures with GLAD



Role of environment on degradation



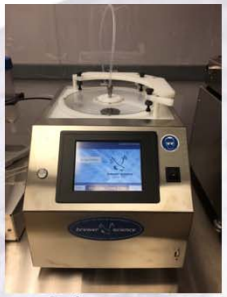
Stabilized carbon support



Underwater Energy Systems

- ✓ **URI Zheng**: Professional in design, theoretical calculation, micro/nano fabrication, and experimental measurement of photonic nanoscale (meta-)materials.
- ✓ **Undersea Energy Applications**:
  - ➢ Fine control of visible, near-/mid-infrared optical/radiative properties of nanomaterials for stealth technology (infrared suppression) of naval vessels, such as submarines and warships.
  - ➢ Undersea thermo-photovoltaic energy conversion and undersea vehicles waste heat recovery
  - ➢ Novel Energy Management and Saving Technique: Radiative (photon-based) cooling photonics for naval unmanned vehicles
  - ➢ Microfluidic devices for undersea bio-sensing, ocean monitoring, and anti-biofouling
- ✓ **URI Zheng's available facilities, highlighting unique capabilities** (Link: http://egr.uri.edu/energylab/facilities/)

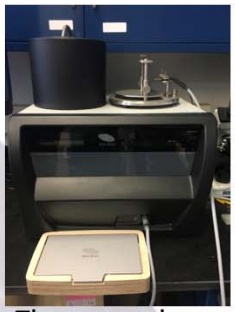
Mask aligner



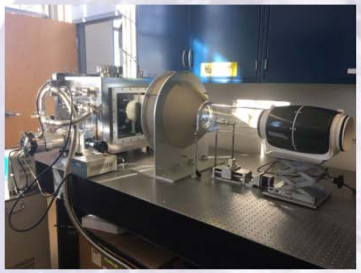
Spin coater

Plasma esher

FT/IR Spectrometer



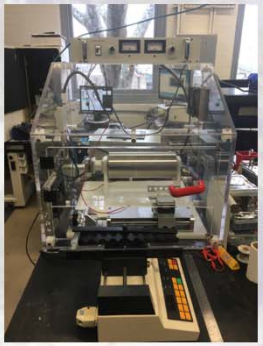
Thermo analyzer



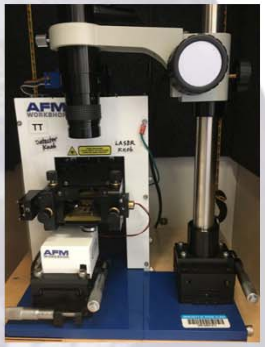
Radiative cooling and Thermo-photovoltaic measurement apparatus (High vacuum chamber with a high vacuum of 10^{-4}Pa and leak rate of $1x10^{-12}Pa.m^3/s$

Oxygen-Free-Copper (OFC) based precise temperature control system (Inside vacuum chamber)

Low temp thermostat (range: -40C ~ 100C, resolution: 0.1C)



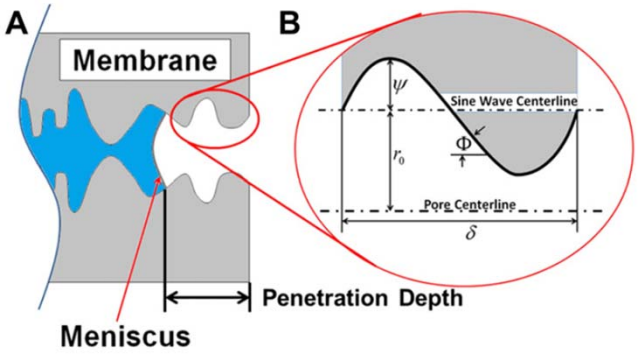
Nanofiber fabrication



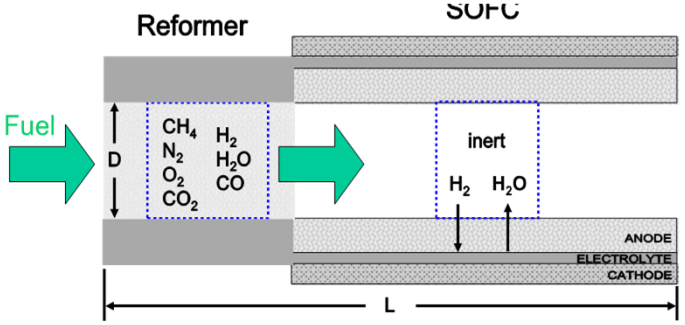
AFM

Research Capabilities – Wilson K. S. Chiu (UConn)

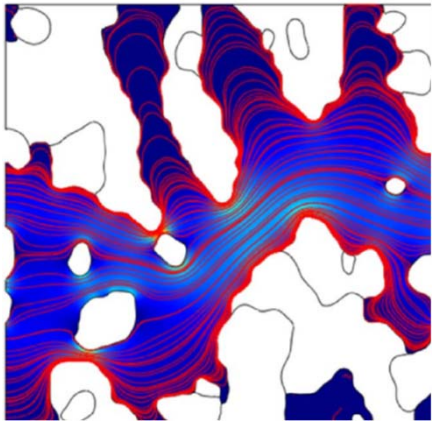
- High energy density fuel cells
- Air independent power sources
- Fuel cells with logistical fuel potential
- Oxygen generating PEM electrolyzers



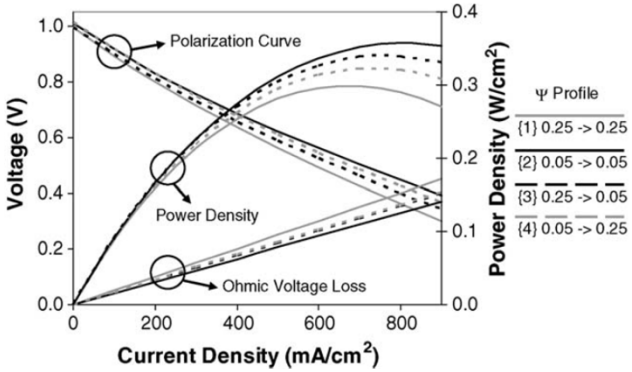
Int. J. Hydrogen Energy 37, 12451, 2012.



J. Fuel Cell Sci. Tech. 7, 031017, 2010.



J. Fuel Cell Sci. Tech. 8, 031001, 2011.



J. Power Sources 161, 225, 2006.

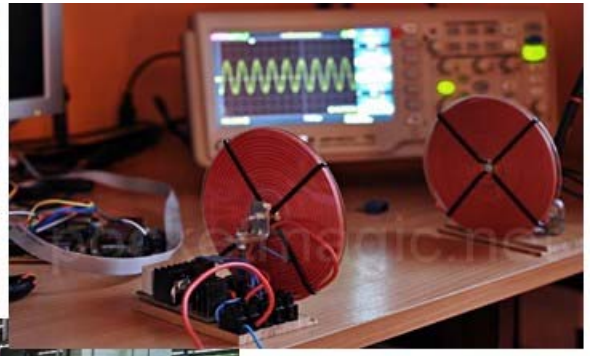
Underwater Energy Systems

Relevant Research Projects – Wilson K. S. Chiu (UConn)

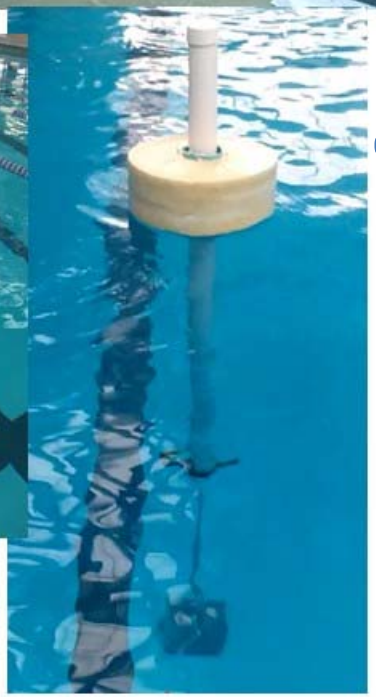
1. Investigated fuel cells as underwater power sources**. Electrochemical Modeling of Advanced Naval Fuel Cell Systems,** Office of Naval Research, 6/02-5/05.
2. Hydrocarbon-based and logistic fuels for use in fuel cells**. *Advanced Fuel Cell Research for Weapon Applications*,** Office of Naval Research, 10/04-9/07.
3. The use of hydrogen peroxide in air-independent fuel cells for UUV applications. ***Fuel Cell Performance Using Hydrogen Peroxide Reformate as the Oxidant*,** Office of Naval Research, 12/06-3/11.
4. Hydrocarbon-fuel solid oxide fuel cells. ***Structural Imaging and Optimization of Microtubular Solid Oxide Fuel Cell Electrodes*.** Army Research Office, 4/05-3/09.
5. Investigating the limiting current condition in submarine electrolyzers. ***High Pressure Electrolyzer Membrane Mass Transport*,** Hamilton Sundstrand, 1/10-12/11.

The Navy's undersea vehicles.
NUWC Newport Graphics







Thank you!