Novel Materials for *Energy Storage* and *Conversion*

Professor Meilin Liu's Group

School of Materials Science and Engineering, Georgia Tech

Societal Context

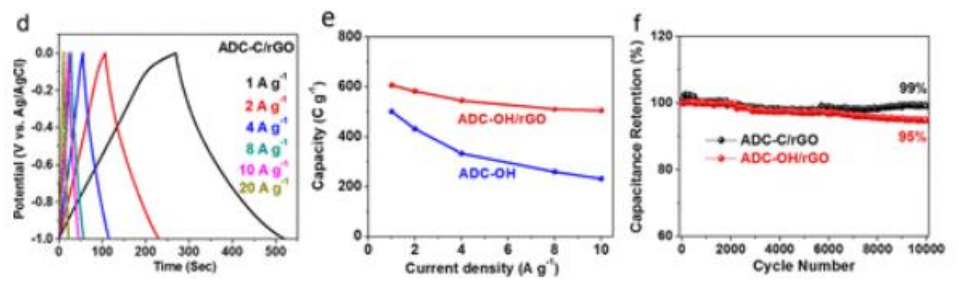
- Electrical Energy Storage & Conversion (EESC) systems are **key** for the development of technologies that are **efficient and sustainable**
- The performance of EESC systems depends on the development of **new materials**/nanostructures with dramatically enhanced ionic/electronic conductivity and catalytic activities
- Advanced EESC systems can enable the deployment of **higher efficiency and greener** methods for chemical conversion and energy storage for applications like **electric vehicles, mobile devices, grid-scale energy storage, and chemical production**

Electrochemical Materials R&D

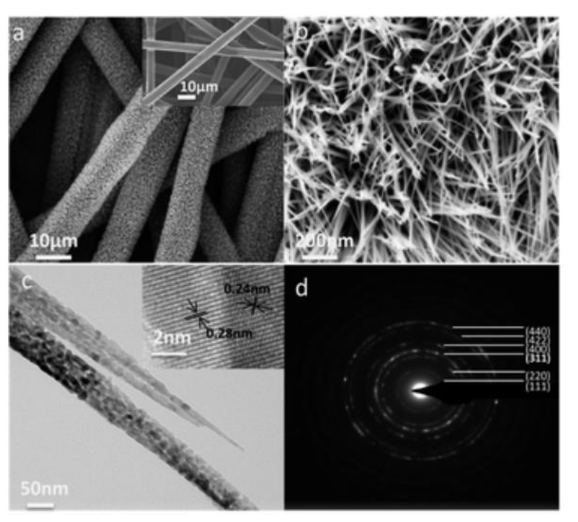
- The discovery of novel materials/nanostructures are at the center of the creation of next-generation energy storage & conversion systems (e.g., **batteries, fuel cells, and supercapacitors**) for renewable energy
- The rates and efficiency of many chemical and energy transformation processes are determined by materials (catalysts, electrodes, etc…)

Batteries and Supercapacitors

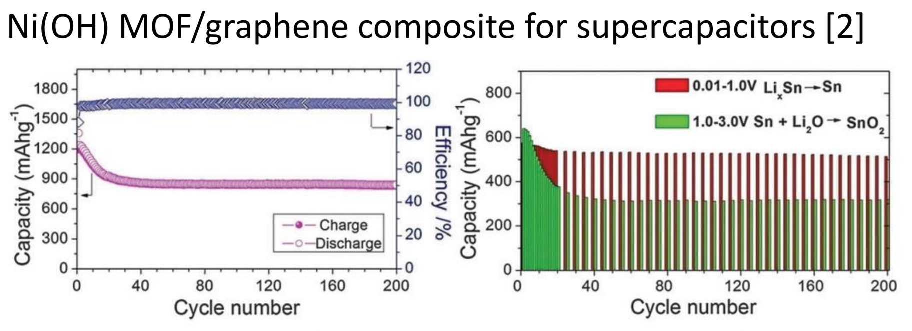
The improvement of battery and supercapacitor technology requires the development of **new materials and electrode architectures**

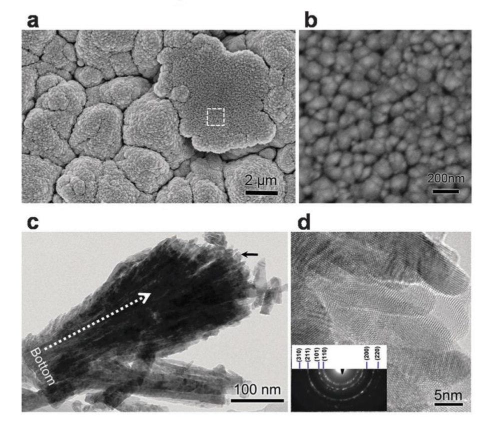


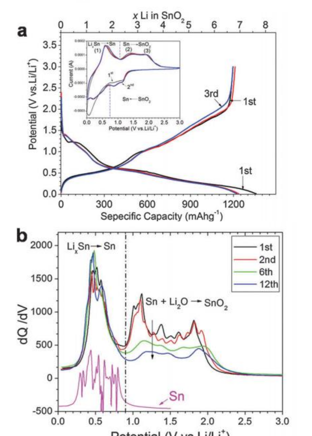
Ni(OH) MOF/graphene composite for supercapacitors [2]



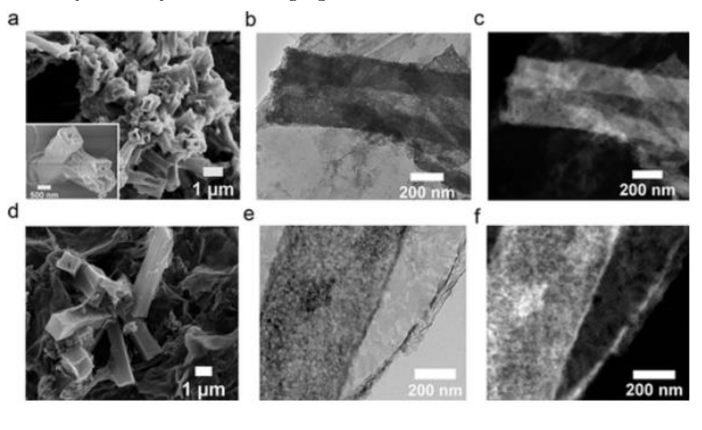
$NiCo_2O_4$ Nanowires on Carbon Paper for supercapacitors [1]







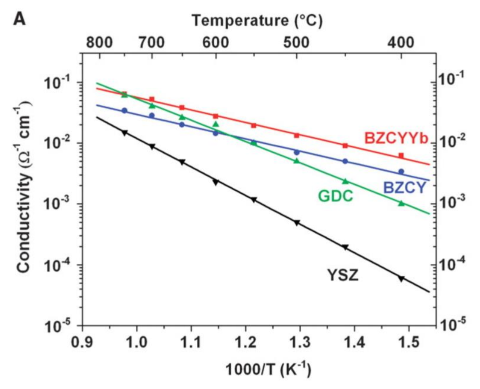
Reversible LiO_2 formation in SnO_2 nanostructures [3]

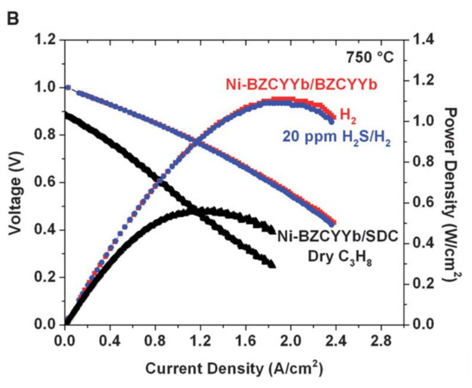


Ni(OH) MOF/graphene composite for supercapacitors [2]

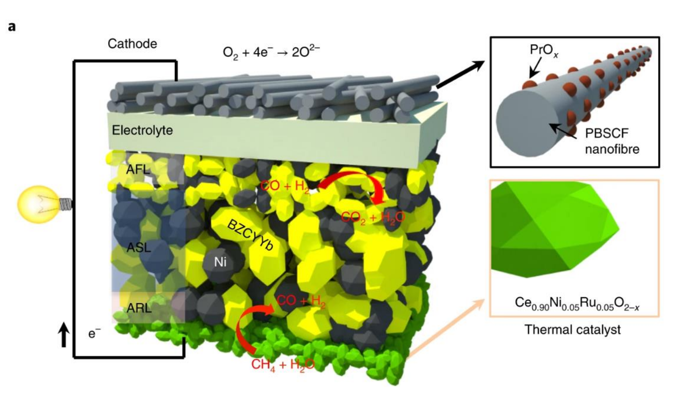
Reversible Solid Oxide Cells

The improvement of fuel cells require **development of catalysts to enable low-temperature operation and protection against contamination**

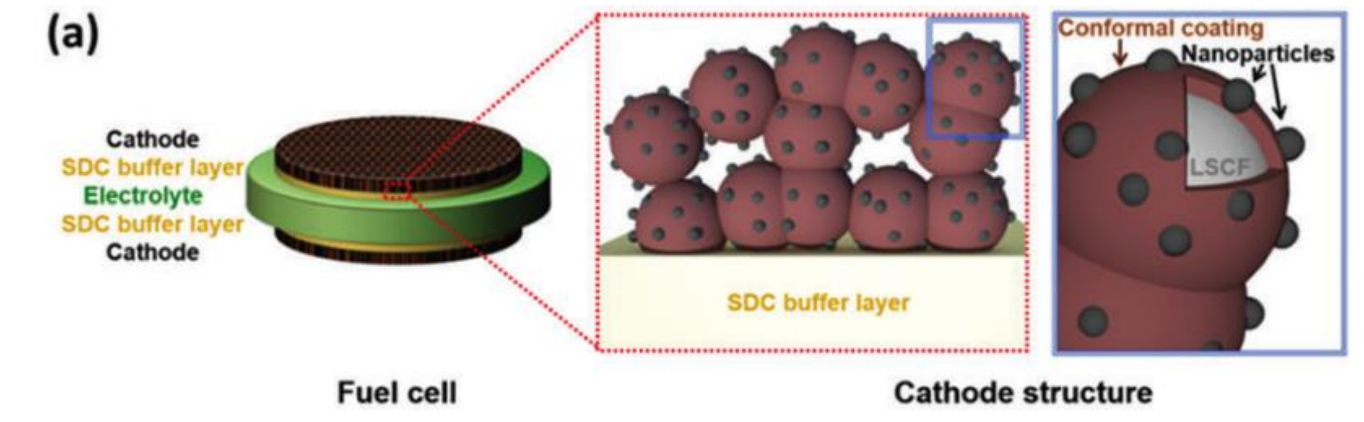


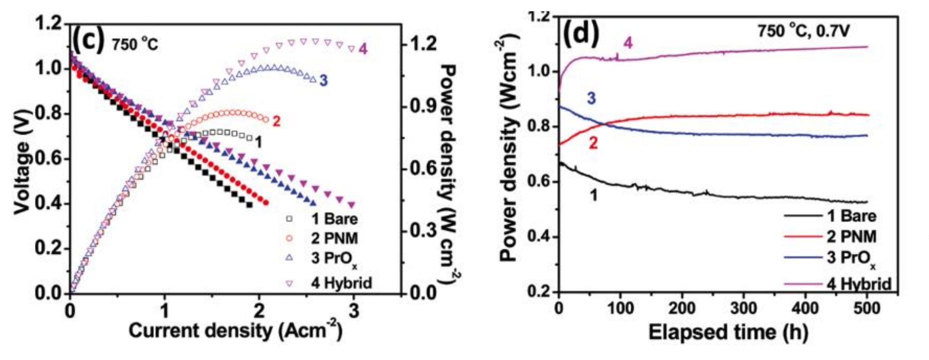


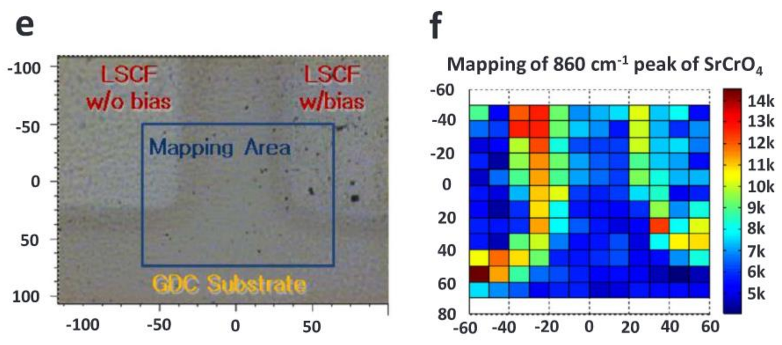
Development of new electrolyte materials (BZCYYb) [4]



Low temperature methane operation [5]



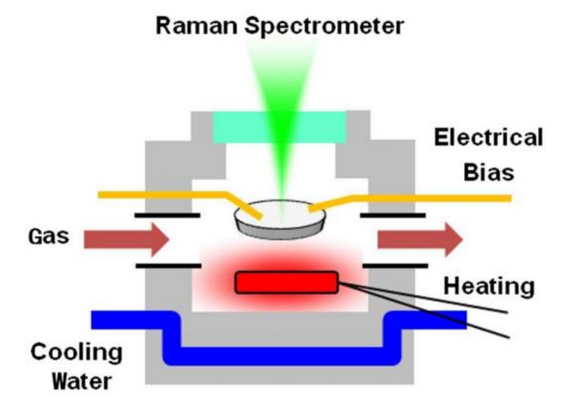


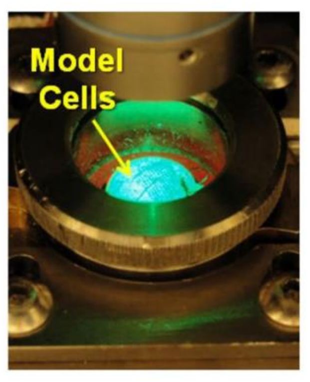


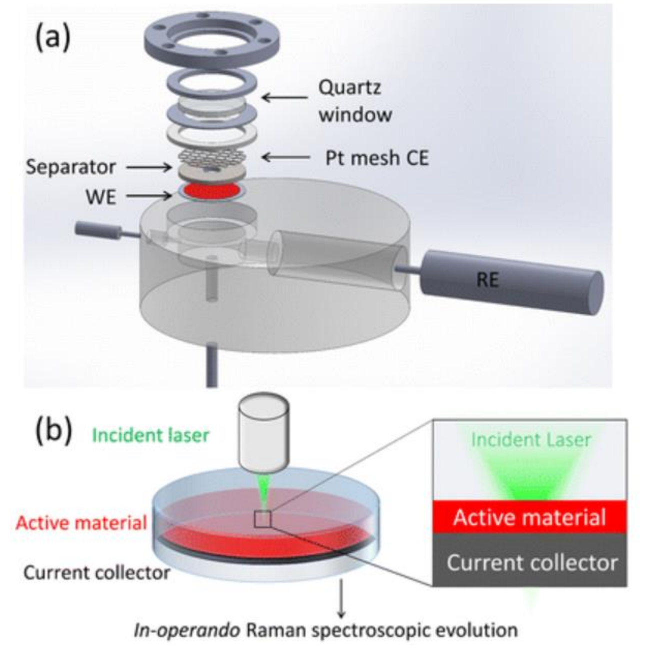
$PrNi_{0.5}Mn_{0.5}O_3$ coated $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$ (LSCF) for enhanced Oxygen Reduction [6] and analysis and mapping of Cr poising using Raman Spectroscopy [7]

Operando and In-Situ Analysis

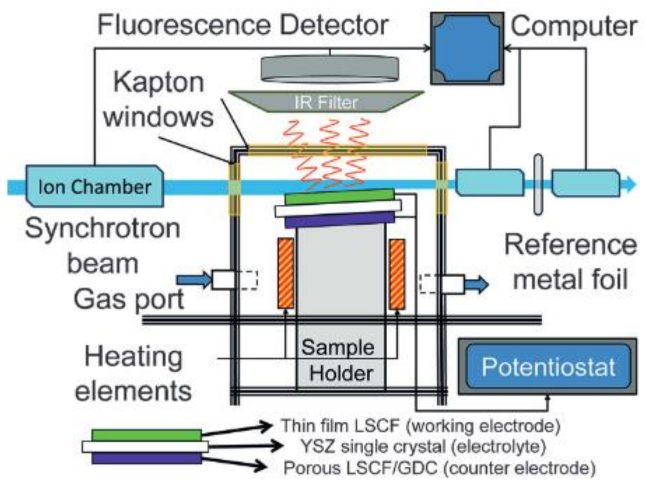
- Use of *Operando* and *in-situ* techniques enables the collection of *more realistic* data and simplifies complex phenomenon using *model systems*

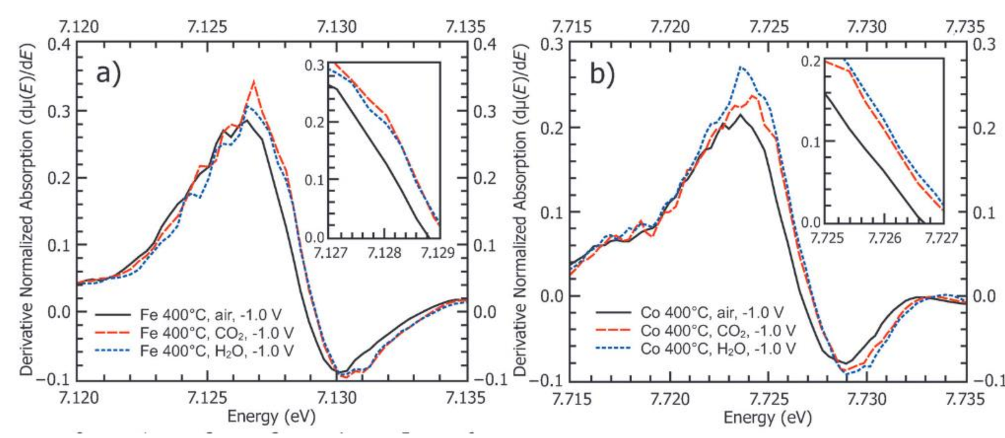




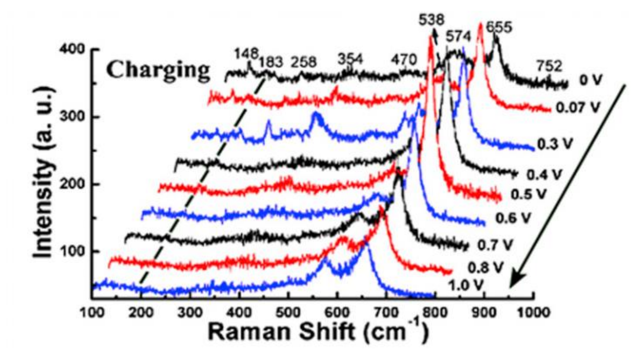


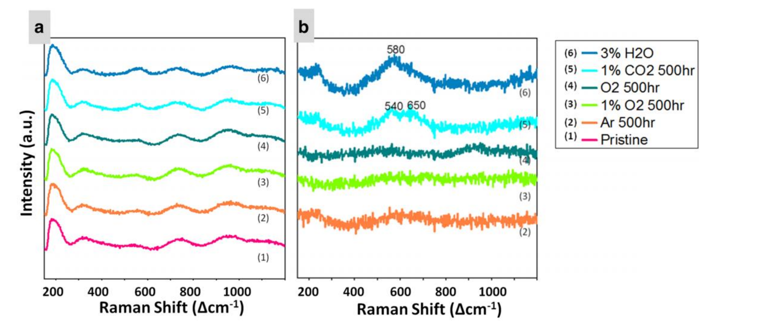
Operando Raman Measurements Cells for high (left) and low temperature electrochemistry (right) [8-9]





Operando XAS set-up (left) and corresponding operando XANES of LSCF (right) [10]

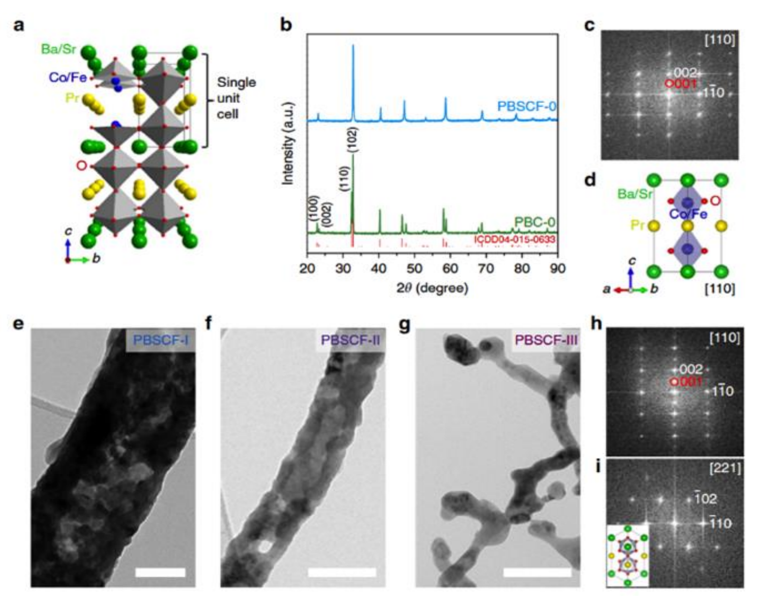


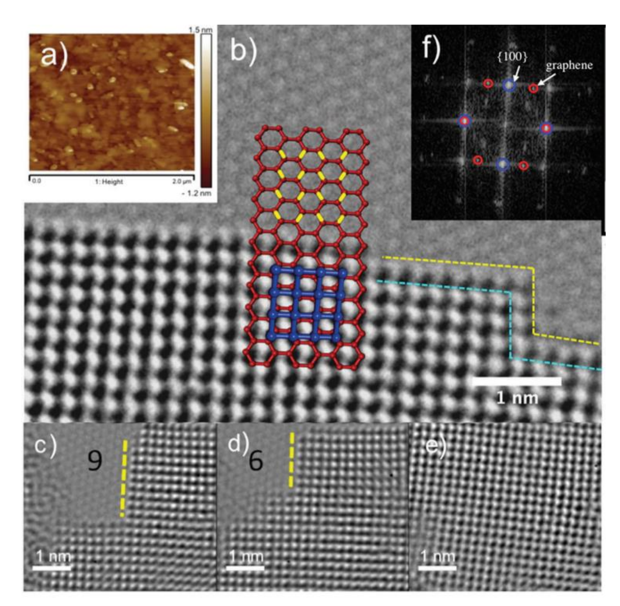


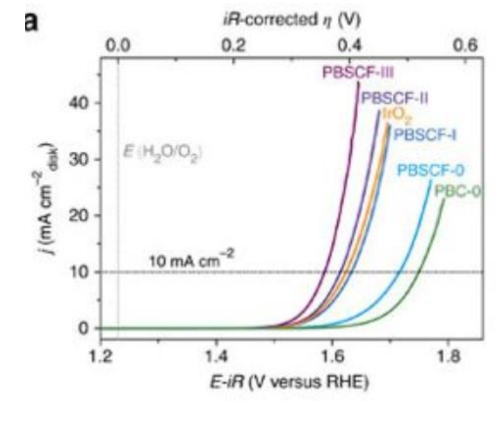
Operando low temperature Raman of $Ni(OH)_2$ band evolution [9] and operando study of coking in SOFCs [8]

- Raman spectroscopy is one of the few techniques that are capable of probing and mapping electrode surfaces under practical operating conditions, allowing direct correlation between the microscopic features and the electrochemical performance of an electrode subject to an applied voltage or current in a wide range of electrochemical environment at temperatures up to 650°C.

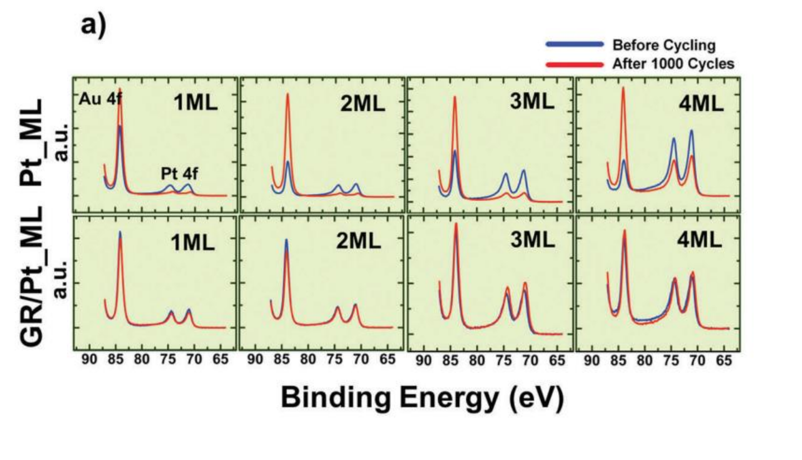
Electrocatalysis and Low Temperature Fuel Cells







$PrBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+\delta}$ nanofibers for OER [11]



Pt/graphene hybrid for ORR [12]

References

1. Huang, L.; Chen, D.; Ding, Y.; Feng, S.; Wang, Z. L.; Liu, M. *Nano Letters* **2013**
2. Jiao, Y.; Zhao, B.; Liu, M.; Walton, K. S., *ACS Applied Energy Materials* **2019**.
3. Hu, R.; Liu, M., *Energy & Environmental Science* **2016**
4. Yang, L.; Wang, S.; Blinn, K.; Liu, M.; Liu, Z.; Cheng, Z.; Liu, M., *Science* **2009**
5. Chen, Y.; deGlee, B.; Liu, M., *Nature Energy* **2018**
6. Chen, Y.; Crumlin, E. J.; Yang, C.; Liu, J.; Yildiz, B.; Liu, M., *Energy & Environmental Science* **2017**
7. Chen, Y.; Zhao, B.; Murphy, R.; deGlee, B.; Liu, J.; Liu, M., *Nano Energy* **2018**
8. Li, X.; Blinn, K.; Chen, D.; Liu, M., *Electrochemical Energy Reviews* **2018**
9. Chen, D.; El-Sayed, M. A.; Liu, M., *Chemistry of Materials* **2015**
10. Lai, S. Y.; Liu, M.; Alamgir, F. M., *ChemSusChem* **2014**
11. Zhao, B.; Xiong, X.; Liu, M., *Nature Communications* **2017**
12. Abdelhafiz, A.; Alamgir, F. M., *Energy & Environmental Science* **2018**