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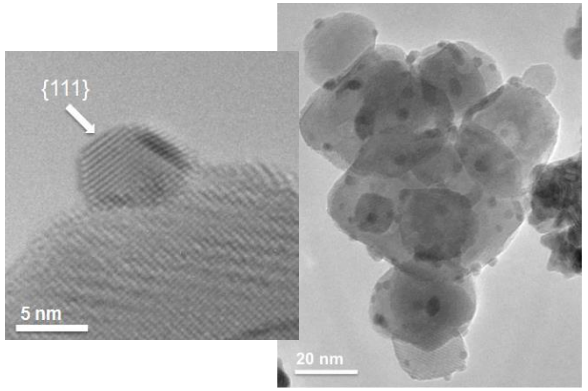
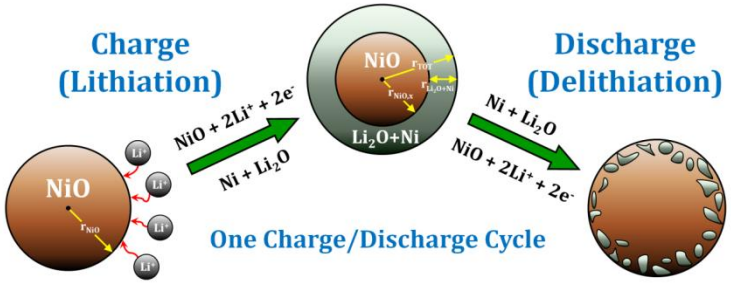
Research interests:

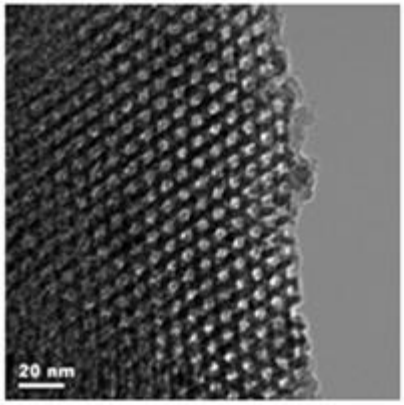
- Utilization of CO_2 for electrochemical synthesis of fuels at room temperature
- Alternative electrocatalysts supports (i.e. ceramics, functionalized carbon)
- High energy density electrodes for Li-ion batteries and supercapacitors

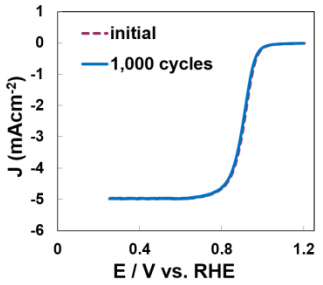
Techniques:

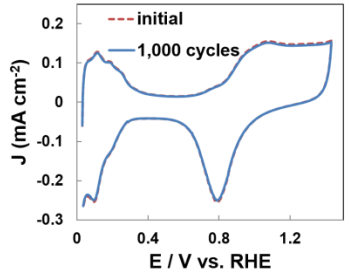
- Synthesis of high surface area materials
- Voltammetry, Electrochemical Impedance, CPR, chrono-methods
- XPS, XRD, RAMAN, FT-IR, TEM, SEM, TGA, MS, TPD





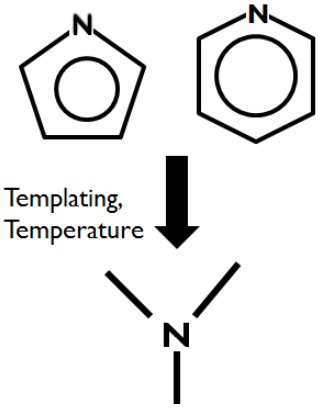


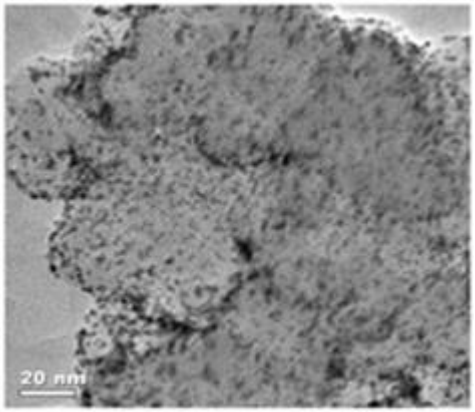




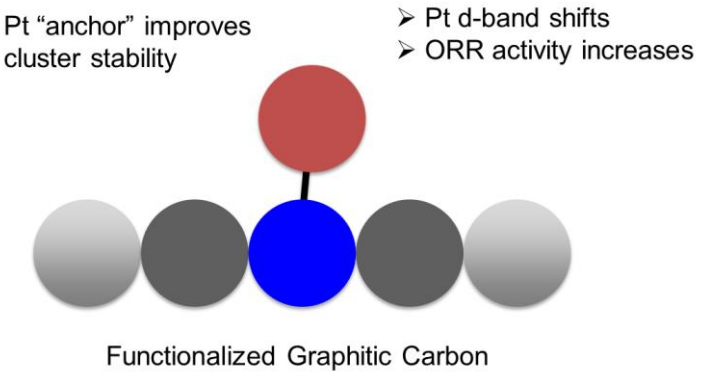
Controlling Microstructure and Surface Chemistry of Ordered Carbons for Fuel Cells and Supercapacitors

- Traditional carbon supports offer several near-ideal properties.
- Graphitized carbon blacks (CBs) have limited interaction with supported Pt – leading to large Pt particles and poor Pt stability.
- To yield high dispersion of Pt, CBs are oxidized in caustic environments – this gives very poor control over the types of functional groups and provides corrosion centers that limit long-term stability.





Good Pt dispersion, ORR Activity and Stability



- Purposeful incorporation of adatoms into the carbon structure (i.e. N, S, P, B) has the potential to provide charge centers for strong-Pt bonding while not building in intrinsic instability.
- Recent work has shown that Pt catalysts with excellent dispersion (Pt < 2nm - left) even at high loading (50wt% Pt) with 10% surface N.
- Mass activities for <u>un-optimized</u> 50 wt% Pt/N-doped carbon > 120 mA/μg_{Pt}
- Can leverage the same techniques to increase the areal capacitance from ~ 10$\mu F/cm^2$ to > 25$\mu F/cm^2$

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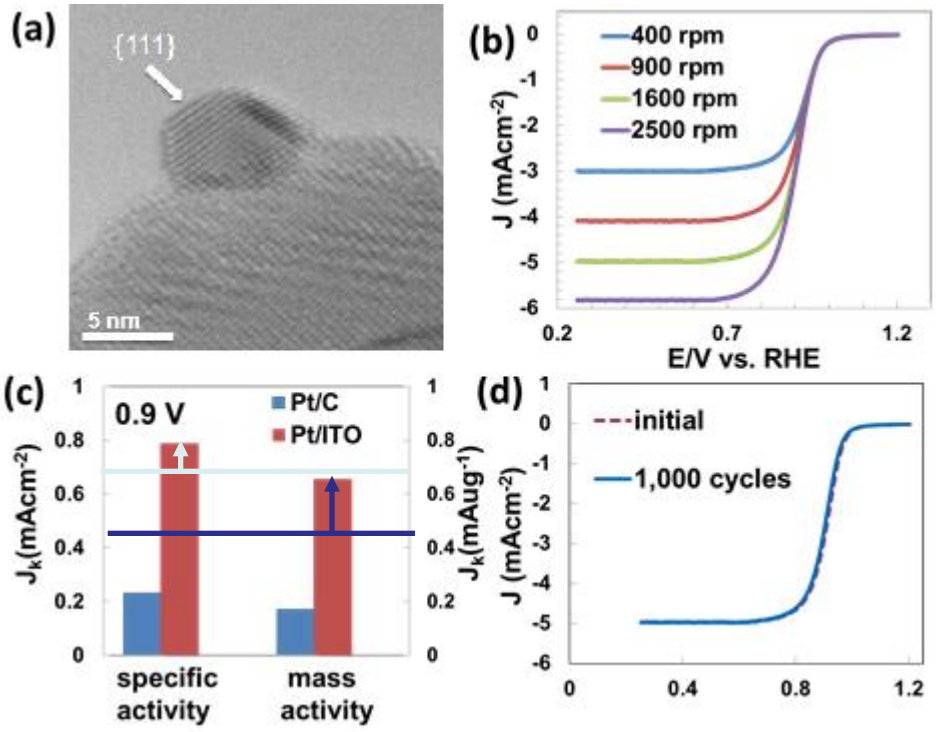
Non-Carbon Supports for Enhanced ORR Activity and Stability of Pt

- Carbon-based supports offer several near-ideal properties
- Carbon has limited interaction with supported Pt – leading to large Pt particles and poor Pt stability; also difficult to enhance the intrinsic activity of Pt to avoid alloying
- Carbon corrosion is thermodynamically favored at ORR relevant potentials and kinetically facile during startup/shutdown
- Non-carbon supports have been shown to enhance the activity of Pt by electron transfer – allowing the Pt oxidation potential to be raised (i.e. Pt/WC)
- Non-carbon supports can also ; 2) impose Pt geometry & preferential faceting (i.e. Pt/ITO – right) for significantly higher activity than Pt/C.
- There is still a need to enhance the stability of ceramic supports to avoid oxidation cycles and structural deformation.
- MEA testing is also needed



Pt/ITO has Excellent ORR Pt activity and <u>NO</u> measurable performance loss over 1000 cycles

	DOE 2015 Targets	Pt/ITO
Specific Activity (mA/cm^2)	0.72	0.750
Mass Activity ($mA/\mu g_{Pt}$)	0.44	0.621

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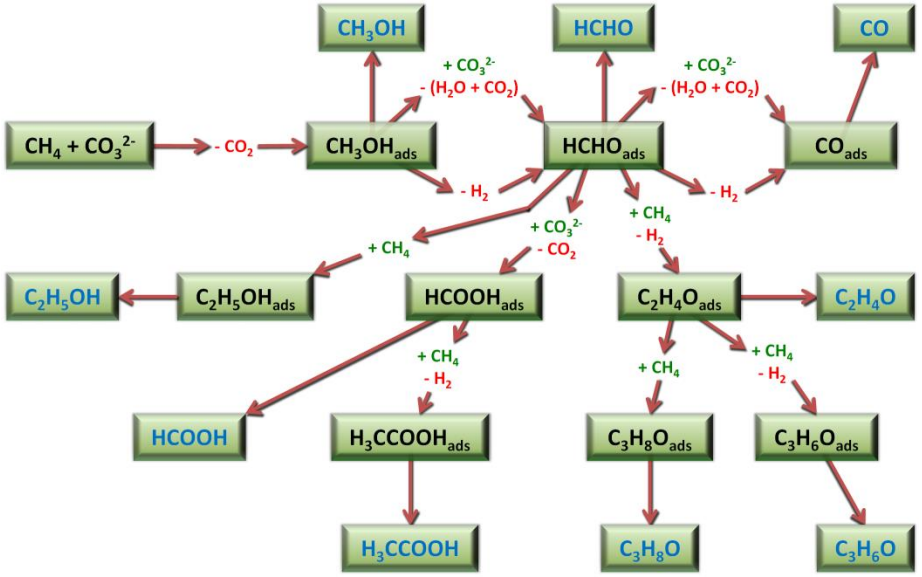
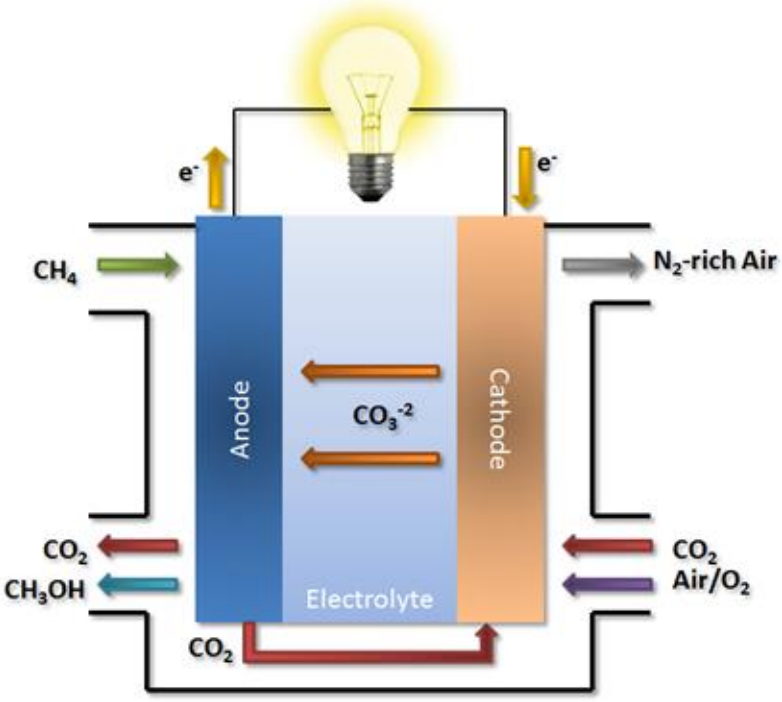
Electrochemical Recovery and Utilization of CO_2 for the Room Temperature Synthesis of Fuels

- Methane steam reforming (MSR) to syngas is one of the most important chemical processes – leading precursor for methanol, formaldehyde and H_2.
- MSR is energy intense & large CO_2 producer
- Oxidation of CH_4 ($8e^-$) to CO ($2e^-$), then reduction to desired product (i.e. CH_3OH, $6e^-$) wastes energy and adds system complexity.





- Room T carbonate electrochemical devices (left) offer a new pathway to oxidize methane to oxygenates and fuels. To date, mostly small oygenates have been synthesized (shown above).
- Novel metal-metal oxide bifunctional are being devised to destabilize the C-H bond with much lower energy at room T and atmospheric pressure.
- Work to understand the atomic-level mechanism, controlling product selectivity and scale-up remains.

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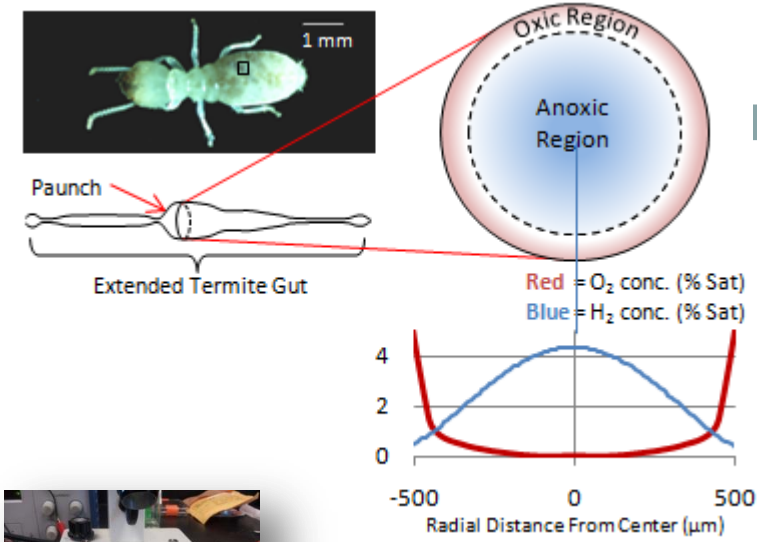
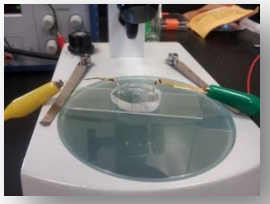
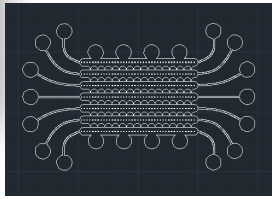
Creation & Manipulation Of An Artificial Termite Gut Through Control Of The Microenvironment

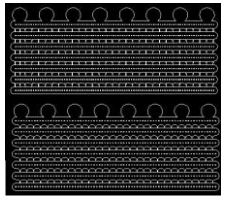
- Currently, efforts to convert wooden materials limited by the inability of synthetic (human) systems to design reactors to process lignocellulosic material

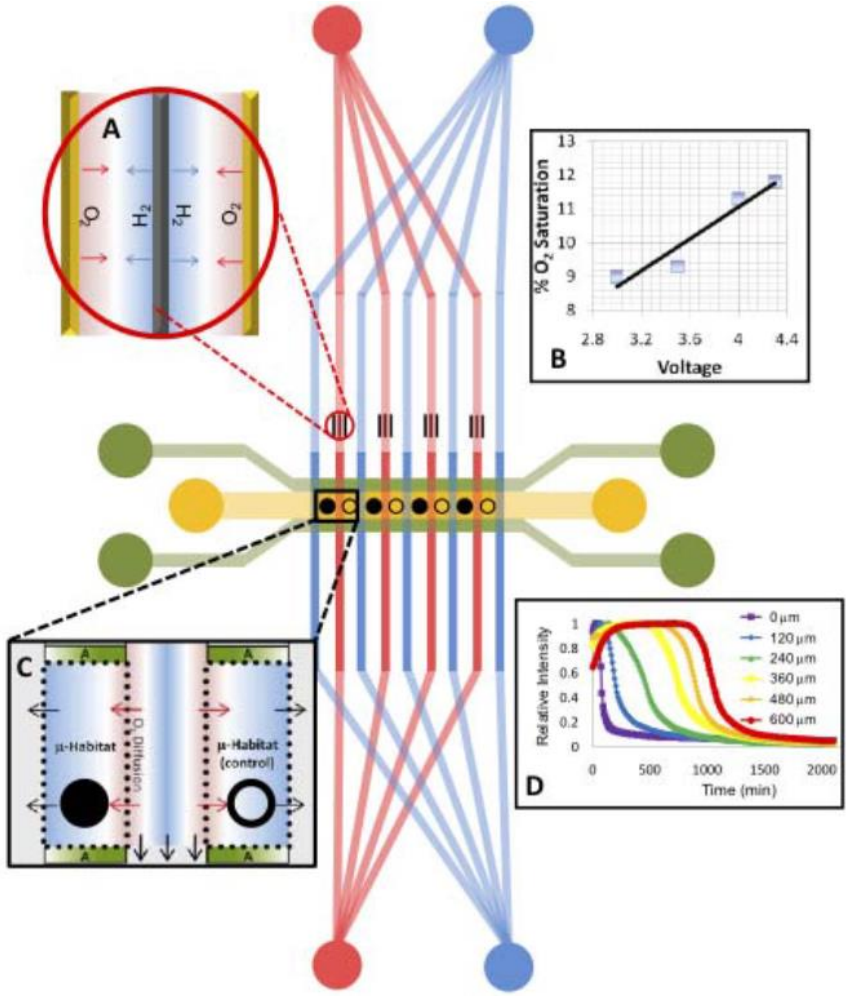
- What is the most efficient known system?
    - Termite hindgut











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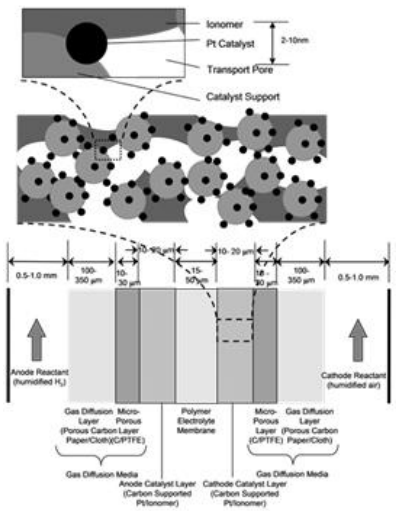
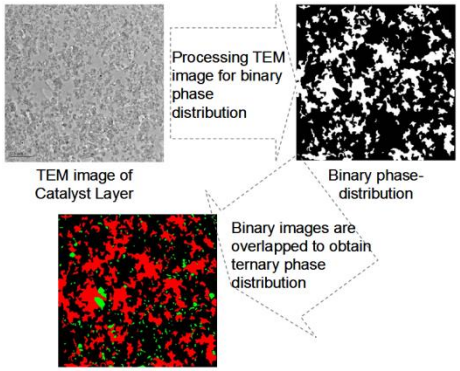
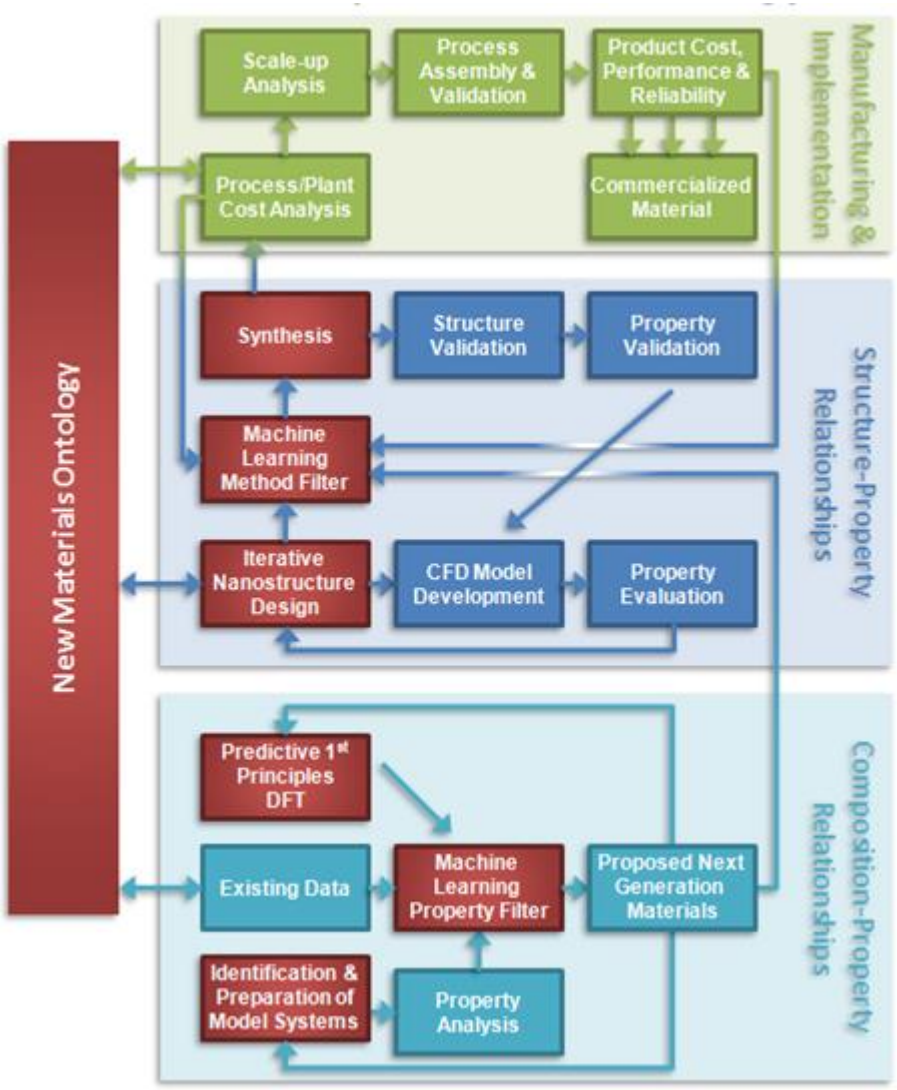
Materials Genomics

- Materials development and implementation are currently very linear processes, which makes the process very time intensive
- There does not exist a sufficient understanding of the structure-property and materials-property relationships to make a truly predictive materials design approach
- As a result, scientists and engineers rely on trial-and-error approaches for materials development.
- Our goal is to a-priori predict what to make, what structure it should have and what the best approach is to achieve the desired chemistry-structure relationship







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