The electrochemical conversion of carbon dioxide ($\text{CO}_2$) into liquid fuels is a technology to recycle carbon while also storing intermittent renewable energy (e.g. wind and solar) into chemical energy (Figure 1). The advancement of this technology is currently limited by the lack of 1) efficient and stable catalysts, and 2) operative electrode architecture for solid-state electrochemical cell employment. The traditional metal catalysts require high overpotential (low energy efficiency) for the electrocatalytic CO$_2$ reduction reaction (eCO$_2$RR) due to the “linear scaling relationship” between reaction intermediates adsorption energy. More importantly they are deficient in C-C coupling to produce ethanol ($\text{C}_2\text{H}_5\text{OH}$). Additionally, they face a serious durability issue. The current electrochemical cell for eCO$_2$RR includes a buffer layer through which liquid neutral or alkaline electrolyte flows.$^1$ The involvement of liquid electrolyte not only results in large Ohmic loss but also causes extra cost in modular assembly.

**Scope of Research**

**Fuels from CO$_2$ and H$_2$O**

![Diagram showing the conversion of CO$_2$ and H$_2$O into fuels](image)

**Figure 1.** The catalytic approach for conversion of CO$_2$ into fuels and chemicals.

This project dedicates to achieve direct eCO$_2$RR to produce C$_2$H$_5$OH in a solid-state electrolyzer by realizing the following objectives: 1) develop carbon materials based catalysts through nanoscale design of topological structure; 2) maximize the triple-phase interface boundary in the catalyst layer by percolating theory; 3) design and manufacture a continuous flow solid-state electrolyze prototype by 3D printing. The refined electrochemical system targets eCO$_2$RR into C$_2$H$_5$OH with a Faradaic efficiency (FE) of 90%, energy efficiency of 50%, current density 600 mA/cm$^2$, and 1000 h stability. The students will be involved in a multidisciplinary team to learn: catalysis, nanomaterials, 3D printing, and mass transport simulation by COMSOL.