**Project Abstract:**

The purpose of this research is to directly synthesize ethanol from carbon monoxide (CO) and hydrogen (H2)—also known as “syngas”. To achieve this goal, the research will focus on developing and testing a rhodium based heterogeneous catalyst that will give high conversion and selectivity of ethanol as well as maximum activity and stability. To increase catalytic activity, the catalyst should be synthesized with ultra-high surface area and complete, uniform dispersion of promoters on a support. An ideal catalyst resists inactivation and poisoning by impurities; this is a secondary objective. The characterization of each tested catalyst by BET, TPR, and XRD along with the product analysis by GC is fundamental in understanding the catalytic behavior and mechanisms in order to efficiently facilitate improvements that achieve the primary and secondary goals.

The setup works by merging two different gas lines into one at high pressure and different flow rates through a “reactor” that houses that catalyst and analyzing the products as shown below.
Industrialization and a rapidly increasing world population require energy and food in increasing amounts. This demand has led to dependence on non-renewable fuels sources that pollute the environment. Modern legislation and research continues to push and fund the development of smarter technology and alternate fuels, which have increased efficiency and reduced pollution in the atmosphere, but the dependence on fossil fuels remains, and the demand increases with population. Therefore, the search for viable carbon-neutral alternatives to fossil fuels intensifies. As wind and solar energy supplement electricity demands, ethanol and biodiesel supplement liquid fuel demands. Corn in America is one of the biggest sources of food, food additives, and ethanol; it follows that using more corn (or other food sources) to produce ethanol will decrease the amount used for food, effectively limiting supply resulting in higher prices. Most gasoline filling stations blend ethanol at 10% by volume as a fuel additive in standard gasoline, and recently the US EPA announced it will permit an increase to 15% by volume. E-85, termed “flex fuel,” is another blend of 85% ethanol by volume that is available at more filling stations. The trend in the increase of ethanol consumption explains the need of an ethanol source independent from food sources.

Ethanol is safe, non-toxic, and can be “carbon-neutral” when its combustion yields the same amount of CO₂ that the plant removed from the atmosphere. It can also be used to store hydrogen for fuel cell. As a fuel additive, ethanol burns more cleanly, increases the octane rating in gasoline—which is a measure of the tendency to burn in a controlled manner, and has high oxygen to carbon atom ratio. Despite these benefits, ethanol as a fuel in an internal combustion engine produces more acetaldehyde (which produces ozone through photo catalytic reactions) than gasoline, has less energy density by both volume and weight, and may damage older engines in small blend amounts. The affinity for water can potentially cause problems such as the inability to be transported through some modern pipes. Energy from fossil fuels used to produce ethanol nearly equals the amount released through combustion, which does not significantly relieve the overall environmental impact or the potential for anthropogenic climate change. Producing ethanol from renewable sources could, however, eliminate these disadvantages.

Despite the clear benefits and current insufficiencies of ethanol fuel use, the research for its production is vital to the renewable energy solution. If ethanol production could be powered by wind or solar energy and the CO and H₂ derived from biomass and water, then this resource could essentially be renewable. Adding to the body of knowledge always has unforeseeable benefits. The Water Gas Shift (WGS) reaction produces CO₂ and H₂ from water and CO; perhaps the success of the WGS could influence the ethanol production research and result in a way to use CO₂ as a reactant for fuel production which could be captured and transformed again. The production of ethanol is the main focus for now, but in the future perhaps it would be easier and more realistic to produce other higher carbon/environmentally-neutral alcohols and hydrocarbons.
A literature review shows two broad categories of catalysts, those with noble metal and those without noble metals. Rhodium (Rh) supported catalysts have been shown to have consistently high success in ethanol selectivity via a direct mechanism route. Other noble metals such as Iridium (Ir) have been used as promoters for both conversion and selectivity along with other lanthanide and alkali metals. Sulfur based catalysts have been shown to be resistant to sulfur poisoning, which is important for syngas conversion from coal. The catalysts are supported on oxide supports, usually Titania (TiO2), Silica (SiO2), and Alumina (Al2O3). The reactor temperature ranges from 200-400 centigrade, and the pressures range from 20-60 bars. Despite the various approaches, the best CO conversion is around 60% and the best ethanol selectivity is about 50%, which leaves much room for improvement. Also, previous research lacks stable catalysts that do not incorporate expensive noble metals of limited availability with both high selectivity and conversion.

This project is unique because it focuses on non-fermentation means to produce ethanol, which is potentially orders of magnitude faster and more efficient. Traditionally, ethanol is produced from corn or other plants, but recently there has been a lot of research on forming ethanol as a byproduct of bacterial consumption. Relying on these “bugs” can be problematic because of a high sensitivity to pH levels, genetic engineering needs, and sensitivity to heat and impurities.

References: