CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

Aditya Menon

Project Number

S0622

Project Title

Engineering Biologically Inspired Enzymatic Analogs: A New Class of Hybrid Organic/Inorganic Nanocatalysts

Abstract

Objectives/Goals

The objective of this project is to develop more active and selective catalysts by integrating the inherent strengths of biological and synthetic catalyst characteristics while reducing their weaknesses.

Methods/Materials

To accomplish this, we developed methods to (1) synthesize and improve an organic support, (2) impregnate metal nanoparticles onto a microporous polymer organic framework support, (3) utilize spectroscopic methods to probe ligand removal and catalytic activity, and (4) overcoat the metal with an additional layer of the same organic framework to better replicate enzymatic machinery.

Results

The results show that a viable polymer organic framework with the critical features of thermal stability (up to 400 °C), high surface area (754 m^2/g), and microporosity (6 Å) was synthesized. Transmission electron microscopy was used to demonstrate that nanoparticles were evenly distributed onto the surface of the polymer with size 7.3 ± 1 nanometers. The optimal thermal pretreatment (300 °C for 20 minutes) was found to remove ligands, which block catalytic activity, from the surface of nanoparticles. Catalytic activity was measured using infrared spectroscopy, which revealed approximately 100% conversion of CO to CO(2) by 250 °C. This reveals that a fully functional hybrid organic/inorganic catalyst has been successfully developed. Finally, the catalyst was encapsulated by another layer of polymer. The encapsulated catalyst was able to maintain its structure, increase surface area (913 m^2/g), and regrow 6 Å micropores which were destroyed from the thermal pretreatment. The encapsulated catalyst showed increased efficiency in catalytic testing, reaching 100% conversion by 220 °C.

Conclusions/Discussion

Therefore, this project reveals the development of a functional, selective, and active hybrid organic/inorganic nanocatalyst which takes advantage of the inherent strengths of both biological and synthetic catalysts while reducing their weaknesses. It also presents a method to develop more active and selective materials by following the inspiration of enzymatic machineries with the potential to increase efficiency in important chemical reactions such as methane partial oxidation and carbon dioxide hydrogenation.

Summary Statement

I developed novel hybrid organic/inorganic catalysts by integrating the inherent strengths of both biological and synthetic catalysts while reducing their weaknesses.

Help Received

Andrew Riscoe, a PhD student, was my mentor for this project. He guided me through the initial methodology of this project. Dr. Matteo Cargnello provided overall guidance for the project. The facilities and instruments in the Department of Chemical Engineering at Stanford were used.