The Effect of Various Supports Over Ru Catalysts for the CO_2 Hydrogenation Mechanism

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Introduction

- The combustion of fossil fuels has caused an increase in carbon dioxide emissions over recent years. The spike in CO_2 emissions is becoming a global issue affecting the environment and human health.

$$CO_2 + 4H_2 \rightarrow CH_4 + H_2O$$

- The Sebatier reaction as shown above, also known as CO_2 hydrogenation, hydrogenates CO_2 to create CH_4 gas. This reaction can be carried out either by Fischer-Tropsch synthesis (FTS) or methanol synthesis. CO_2 hydrogenation is essentially a method used to recycle CO_2 gas to synthetic gas or transportation fuels.

- The reverse water gas-shift (RWGS) reaction uses CO_2 to produce adsorbed CO; the formate involved mechanism follows hydrogenation. A catalyst can be used to help enhance this reaction, but some catalytic surfaces have defect sites which enable OH groups to form and affect the reaction mechanism's activity.

- Ruthenium will be used as this project's catalyst because it is commonly used for CO_2 hydrogenation and highly active for methanation.

Objective

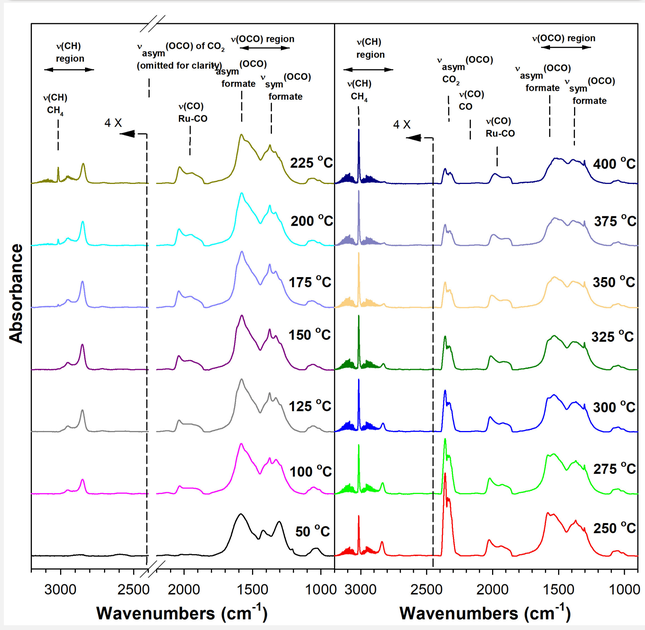
This project investigates the effect of various supports on a ruthenium catalyst regarding the relationship of formate production and the formation of methane gas. During the reaction mechanism, formate plays a role as it is followed by hydrogenation to form CH_4. The five catalysts used were Ru/ZrO_2, Ru/TiO_2 , $Ru/CeZrO_2$, Ru/CeO_2 , and Ru/Al_2O_3.

Method

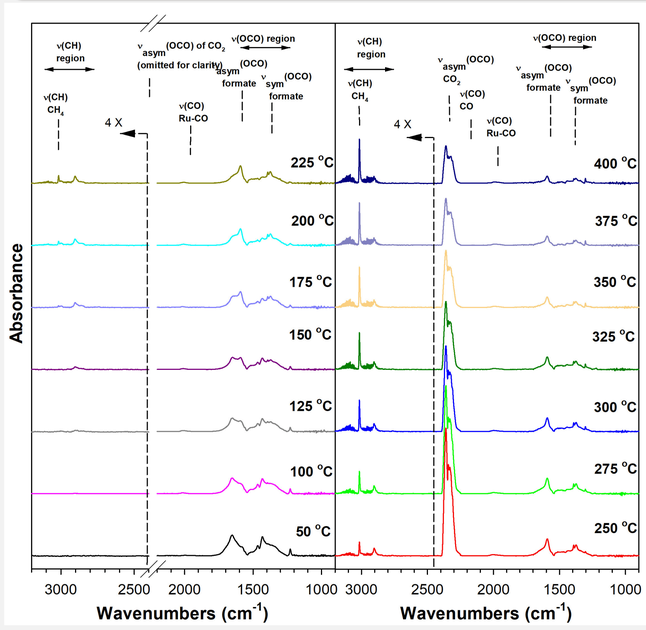
To characterize and analyze the effect of the supports during the reaction mechanism, Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) spectrums were taken at various temperatures throughout the experiment to measure the reaction's activity. After, the data for each catalyst was processed in Excel and placed on the same graph.

Results

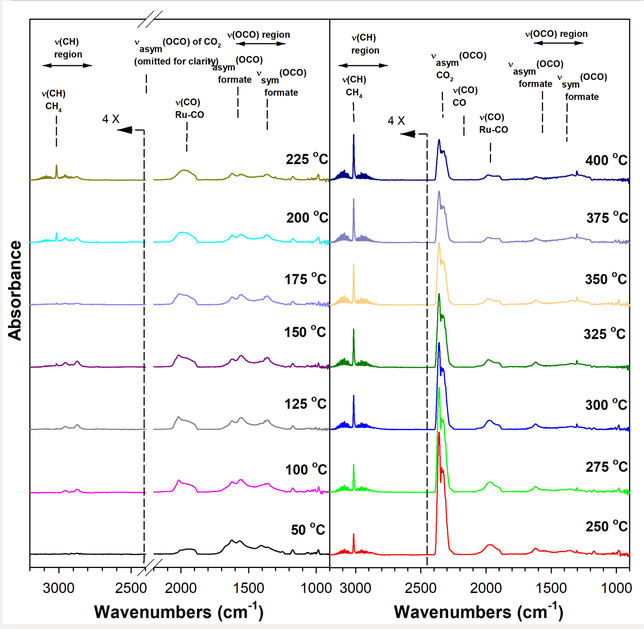
Ru/CeO_2



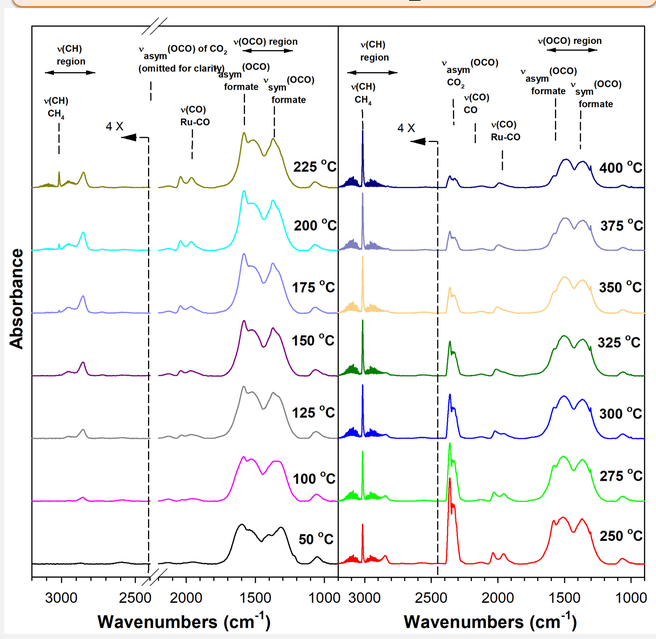
Ru/Al_2O_3



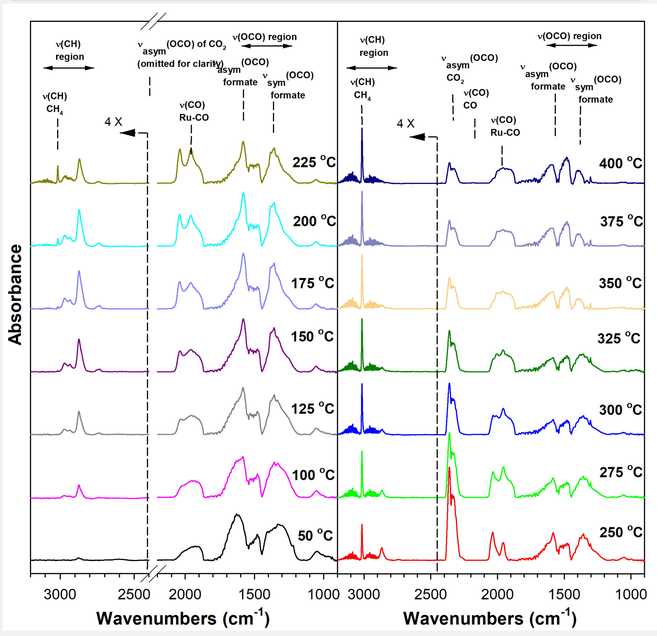
Ru/TiO_2



$Ru/CeZrO_2$



Ru/ZrO_2



For all catalysts, the presence of formate increases and causes carbonate and bicarbonate species to decrease; once hydrogenation has happened, the formate peaks will decrease, and the gas phase methane peak will increase and sharpen by 400°C while the other bands' intensities are reduced. The catalysts Ru/CeO_2, $Ru/CeZrO_2$, and Ru/ZrO_2 must have had more defects on the catalytic surface compared to Ru/Al_2O_3 and Ru/TiO_2 because of the high production of formate and high formation of methane gas. Both Ru/TiO_2 and Ru/Al_2O_3 have very little formate production.

What I learned

During this project, I gained skills including analyzing Fourier-transform infrared spectroscopy (FTIR) and DRIFTS spectrums using Omnic software and combined the spectrums at various temperatures onto a single graph in Excel. The data demonstrates the catalysts with more defects at the catalytic surface formed formate at earlier temperatures and had stronger formate signals compared to the catalysts with less surface defects. However, all samples did produce methane gas.

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