Investigation of Effect of Ammonia Treatment on Surface Morphology of Platinum Catalysts for Use in “Swiss Roll” Reactors.

Patrick J. Hyland and Dr. J. Ahn
School of Mechanical and Materials Engineering at Washington State University, Pullman, WA

Introduction

Swiss Roll Reactors are thermally insulating, have no moving parts and can use solid oxide fuel cells to generate electrical energy.

- Hydrocarbon fuels have a much higher energy storage density than batteries. (e.g. propane, 46.4 MJ/kg) > > batteries (= 0.5 MJ/kg for Li-ion)
- Nanoscale or microscale fuel → electrical power conversion device would provide much higher energy/weight than batteries for low power applications, even at very low efficiencies
- Problems working at micro-scale that Swiss rolls reduce / eliminate
  - Heat losses to walls - flame quenching, efficiency loss
  - Friction losses in devices with moving parts
  - Precision manufacturing and assembly difficult

Applications

Swiss roll could be used as a power source for:
- MEMS
- Micro scale devices
- Mobile devices (cell phones, laptops, handheld GPS)

Flow Control System

- PC control and data acquisition using LabView / NI data modules
- Mass flow controllers for fuel, ammonia & air
- Thermocouples to measure reactor temperature

Previous Work

Prior tests noted changes in the surface morphology possibly due to NH3 treatments. I observed similar structures in more recent work.

Research Question

How is ammonia modifying the Pt catalyst surface and how does the modified surface morphology affect the catalyst’s affect on the ignition temperature, extinction limits vs Reynolds number, and thermal behavior?

Method

Sample treatment - Pt samples were placed in combustion chamber of 1d Titanium reactor. Treatments involved combusting gaseous fuels (air, propane, ammonia) which were pumped into the Swiss roll reactor and ignited using an induction heating device.

Different factors were varied to affect the surface modification
- Air/Fuel/Ammonia Mixtures
- Combustion Durations
- Combustion Temperatures (between ~300 C and ~1200 C based on varying fuel velocity and mixtures)

SEM Imaging

Secondary Electron images from a Scanning Electron Microscope (SEM) were used to examine the morphological surface features of Pt relevant to this project.

Observations

Untreated Pt - microstructure based on rolling used to form foil
Ammonia treatment etches surface of grains and grain boundaries under certain conditions.

Some surface structures formed from:
- Plastic deformation
- Deposits (from combustion products or chamber materials contribute to Pt etching)
- Etching of grains
- Etching of grain boundaries
- Surface deposits affect etching
- Grain surface morphologies based on grain orientation and crystallography
- Some grains reminiscent of twinned microstructures
- Surface changes may not always be affected by treatment history

Future Work

- Analyze how NH3 concentration and Pt surface pretreatment affect surface etching.
- Analyze effect of new surface morphology on combustion behavior
- Examine Post treatment combustion natures

3d Swiss Roll

1d and 2d designs had been developed for Swiss Roll reactors. It had not been discovered how to design one in 3d.

Theoretically, a spherical design would have the most efficient heat loss reduction. It would insulate the combustion chamber in every direction. A tetrahedral design was worked on because it was easier to design and manufacture.

Using Solidworks, a 3d tetrahedral model was developed. Using Blender and Pepakura Designer paper models were created. The next step will be to create a testable reactor out of Kapton film.

Acknowledgements:

The REU work was supported through the National Science Foundation: Division of Materials Research REU site program under grant number 0463554.

Relevant Literature