NDnano
Center for Nano Science and Technology

NDnano Summer Undergraduate Research
2017 Project Summary

1. Student name & university:
Kyle Kotesky – Purdue University

2. ND faculty name & department:
Svetlana Neretina - Aerospace and Mechanical Engineering

3. Project title:
- Catalyst Leaching Project
- Sample Holder Design Project
- Nano Imprint Lithography Stamping Removal Design Project

4. Briefly describe new skills you acquired during your summer research:
I learned that catalyst behave differently with each metal used. Sparging effects the reaction time. When designing an object, there will be multiple revisions before the finished product. Some features might interfere with others and will lead to a revised design. Some calculations might be needed to fit a feature in a tight spot. The type and strength of material should be considered for the type of environment it will be exposed to. Reducing the cost to build an object should always be a priority.

5. Briefly share a practical application/end use of your research:
My research will show a different method of providing evidence of leaching from a catalyst. This experiment will show which types of catalysts leach and what type of coating is needed to prevent leaching from happening.
The sample holder that is used in the spectrometer will have voltage applied to the sample. The spectrometer will analyze the optical spectrum of the sample. The sample holder will allow graduate students to conduct many different experiments.
The stamping removal design will be used frequently with samples. The stamps are used to make imprints in a polymer in a process referred to as nanoimprint lithography. Removing the stamp can be difficult and, as a result, a device was specifically designed for this process.

6. 50- to 75-word abstract of your project:
Catalyst Leach Project
This project consisted of experimenting on different metal catalysts to see if they leach. Thin metal films were used. The atoms of the metal detach from catalyst causing the atoms to form nanoparticles that become catalytic. This causes the reaction to continue even when the initial catalysts is removed. A 3-D drawing was needed to demonstrate how the samples were put in and taken out of cuvette. A spectrometer is used to monitor the solutions reacting time.
Sample Holder Design Project
A design to hold a sample in a spectrometer was needed to apply voltage to the sample. This would allow the spectrometer to monitor the sample that has current travelling through it. This had to be small enough to fit into the spectrometer and hold a 7 cm x 7 cm x 0.07 cm sample.
Stamping Removal Design Project
A new stamping design for nanoimprint lithography was needed to have a better way to remove the sample from the stamp. Once the sample is heated up and stamped, the removal process took too much

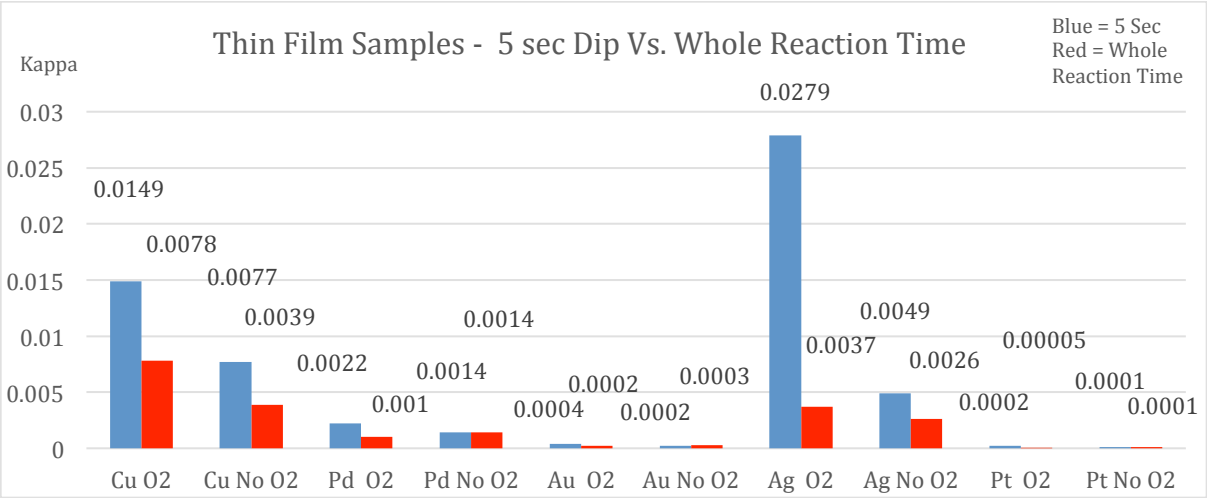
time and did not consistently work. The new design must hold the sample and adjust to the sample size. The holder should remove the sample from the stamp when the holder moves up away from stamp.

One-page project summary that describes problem, project goal and your activities / results:

During my internship at University of Notre Dame in the NDnano Undergraduate Research Fellowship program I worked on multiple projects. The first project had some chemistry involved. The purpose of the project was to figure out if catalysts synthesized in the lab leach. Normally when starting a reaction with two different substances, a catalyst made of metal nanoparticles are put into the reactants. The reaction does not take long before it is finished. The atoms of the metal detach from catalyst causing the atoms to form nanoparticles that become catalytic. Five different metals were tested and each behaved differently. Some of them leached faster than others. In the end, this will inform chemists that they might consider how their catalyst is made and what their catalyst is made from. If their catalyst leaches, inaccurate results on the data would be present. There were 5 metals tested: Ag, Au, Cu, Pd, and Pt. Thin films of the metals were dipped in aqueous solution of 4-nitrophenol and sodium borohydride for 5 seconds where some solutions contained dissolved oxygen and others did not. Before the solution reacts, the solution's color is yellow. After the reaction is complete, the solution's color should be clear. While the solution is reacting, the spectrometer is monitoring the absorbance and graphing the results. This is raw data from the spectrometer is then put into a logarithmic form to find the slope. The equation is shown below that is used to calculate K-apparent.

$$\frac{dc_t}{d_t} = \mathrm{K}_{app}\mathrm{c}_t \;=\; \mathrm{k}_1\mathrm{Sc}_t$$

This makes it easier to take the slope. The slope is the K-apparent. K-apparent is the rate of the reaction which is a measure of the catalytic activity of the leached material. The figure below shows K-apparent for the different metals after being allowed to leach 5 seconds. Ag, Cu, and Pd in this graph have the fastest reaction time, indicating that they are more prone to leaching.



A second project I worked on was designing a sample holder for the spectrometer. This holder would be designed to have voltage applied to the sample while in the spectrometer. The sample size is 7 cm x 7 cm x 0.07 cm. Some problems were encountered with the contacts in that they needed to be bolted to the holder and small enough to fit on sample. Many of the contacts were made to be soldered onto surfaces. Since the holder is made from plastic, soldering was not an option. A contact was found that had a hole on the mounting surface. The next problem was to find a small enough bolt to fit through the hole. The contact needed enough clearance to flex when in contact with the sample. There was not too much room to deal with, but an appropriate bolt was found. Another problem with the first design was that a small threaded hole in using a 3D-printer is not possible to thread something due to inaccuracy. When 3-D printing items, too many supports can negatively impact the end result. In order to 3-D print this part, support material would have been needed to produce threads. When the holder is finished printing, the support material needs to be taken out of threads which would cause damaged threads. This problem was resolved by threading the hole into the aluminum piece that was behind the holder. Figure 1 shows a schematic of the final sample holder design. This design has a hinge that would open and close when inserting or removing the sample. The bolts would lock the hinge from opening and keep the contacts pressed up against the sample. Another sample holder was designed to hold an even smaller sample (5 mm x 5 mm x 0.7 mm).

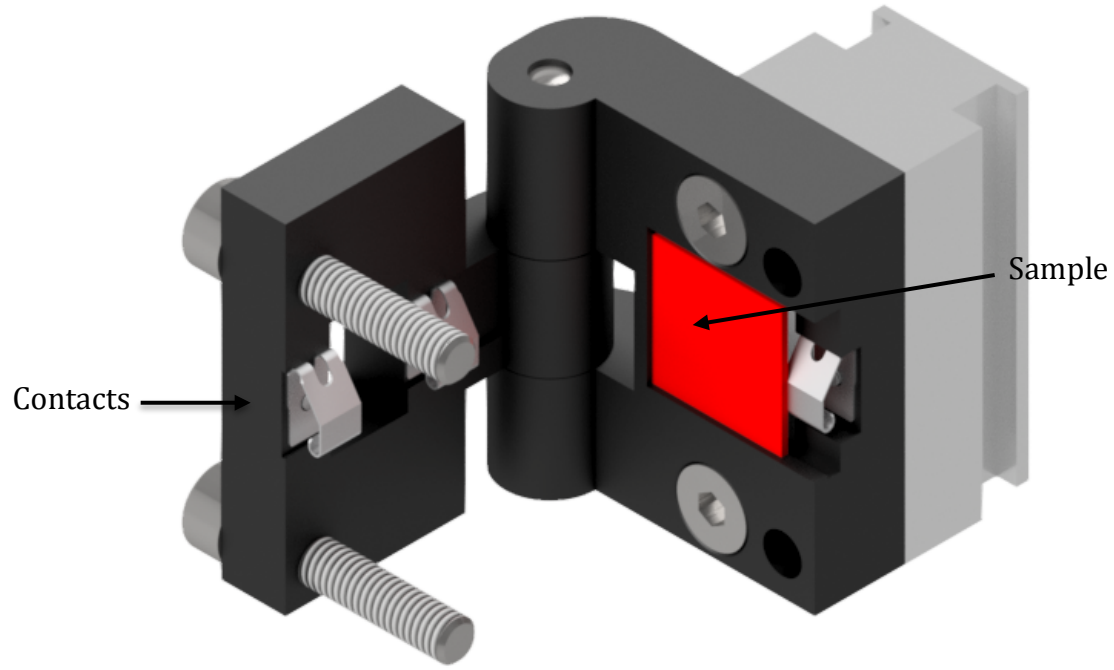
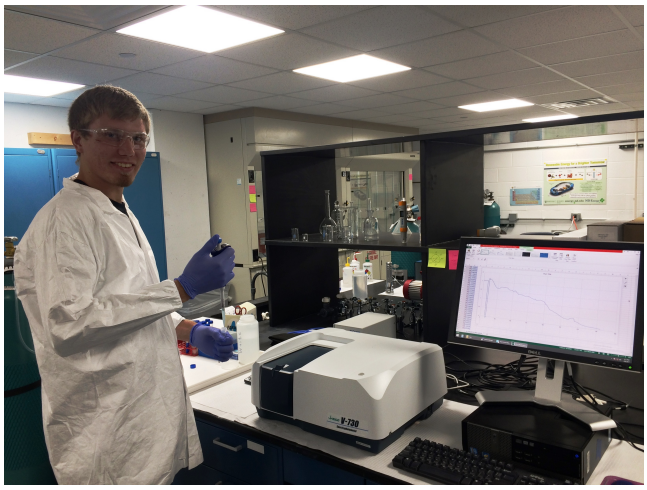


Figure 1



Kyle Kotesky conducting leaching experiments using UV-vis spectrometer.

The last project to design was a stamping device. This device needs to be able to remove the sample from the stamping device. The process to remove the sample takes a while and was not always successful. The sample holder would be designed so that it removes the sample from the stamp. This stamp design must be adjustable for samples that range in size from 5 to 25 mm. A small lip will hold the sample into the holder. The stresses were analyzed on this lip to make sure it can withstand the load from bending and sheering. Thermal conductivity needed also to be analyzed to see what the best way to transfer heat for the crystal bond. The crystal bond will be in between the stamp and the sample for the process of stamping. The figure below shows the initial design but some small revisions may still be necessary before it is manufactured.

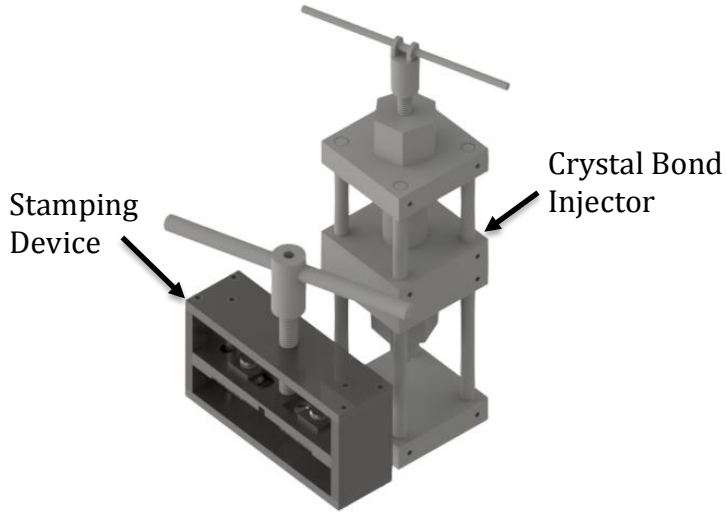


Figure 2