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Preparation and Characterization of Ruthenium-Gold Raman-Active Catalytic Surfaces

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Introduction

In order for a reaction to occur, it has to overcome activation energy barrier. For some reactions, the energetic barrier is so large, that such reaction would take a tremendous amount of time to proceed. Catalysts are substances that can interact with the reactants and lower the activation energy barrier, providing a more efficient pathway for the reaction.

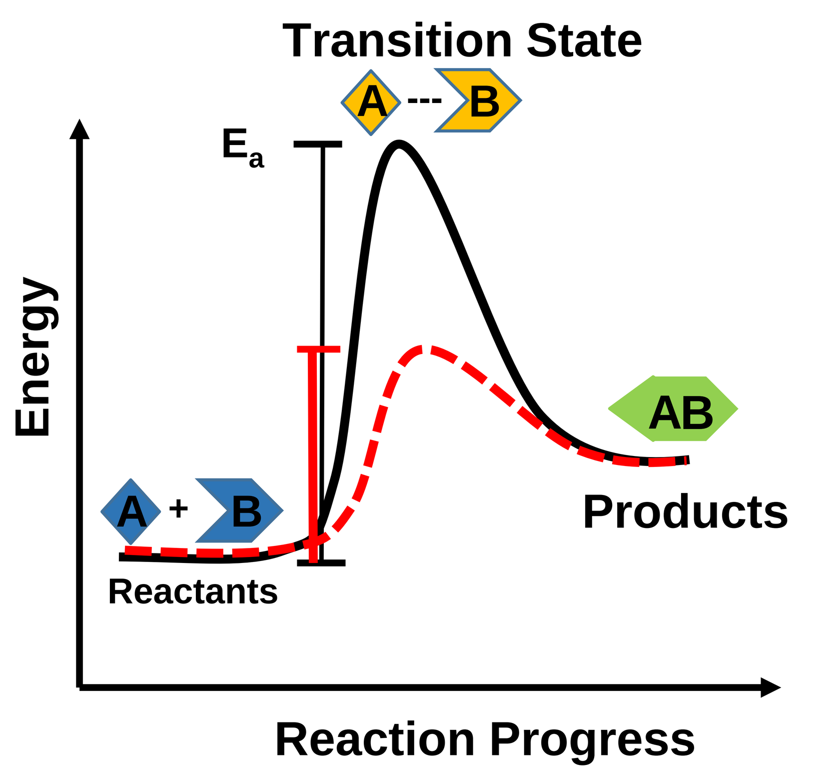

Figure 1. Comparison between uncatalyzed and catalyzed reaction pathway

Metallic catalysts are especially important in reactions involving gaseous molecules. Due to their rapid movement and overall low density, it is difficult for gaseous molecules to effectively collide and react. Metallic catalysts provide a surface interface where molecules can arrange and form bonds more efficiently.

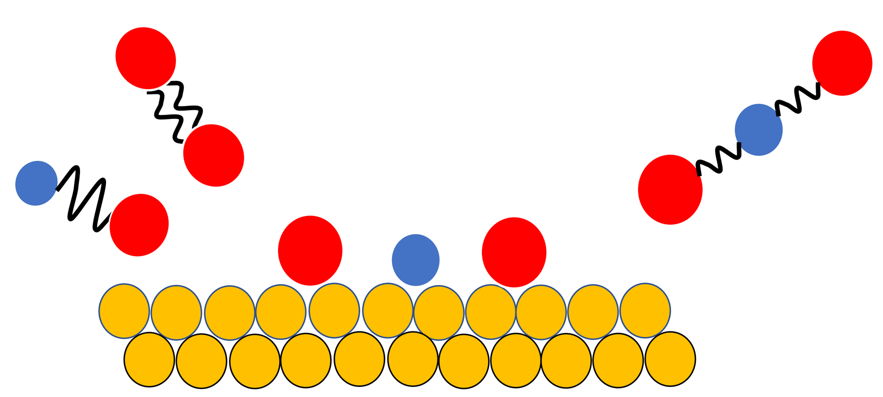

Figure 2. Example of metallic catalyst

Reactions involving gaseous molecules also impose another problem. They are difficult to observe and study. One powerful analytical tool that can help chemists resolve this is Raman Spectroscopy. The technique relies on a phenomenon called Raman scattering, which is the inelastic scattering of an excitation light source, typically laser, off a surface where analytes reside. This weak scattering effect , however, needs to be enhanced by a special Raman-active surface in order produce reliable signals. Such surface can be combined with another metallic catalyst to generate a catalytic system.

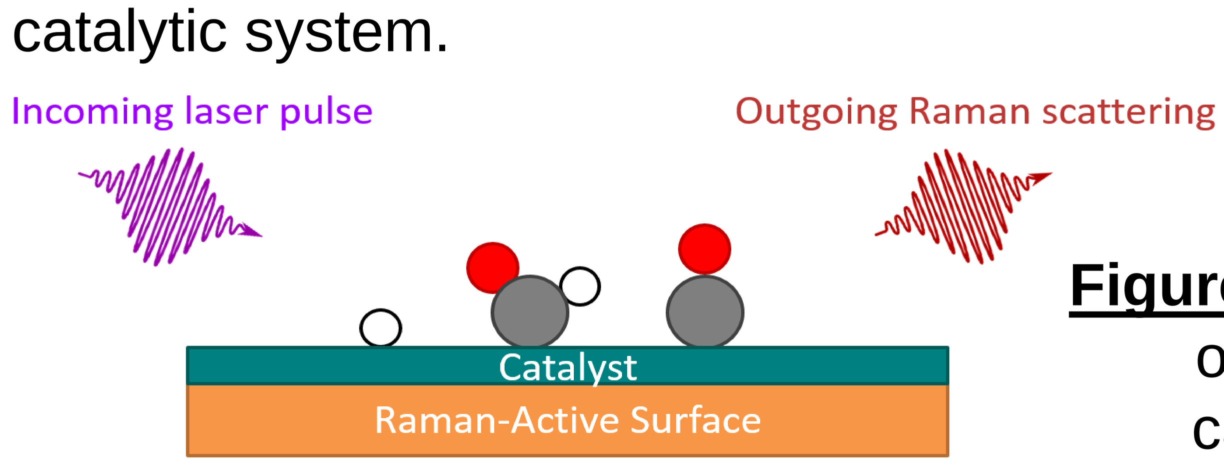

Figure 3. Schematic of Raman-active catalytic system

Methods

This study focuses on the process of creating a Raman-active catalytic surface from gold and ruthenium. The mechanism of Raman enhancement involves a special metallic surface structure called plasmonic structure. Plasmonic structure allows the electromagnetic field of the laser to be amplified, thus increasing the signal of Raman. Gold is known as one of the most prominent plasmonic metal

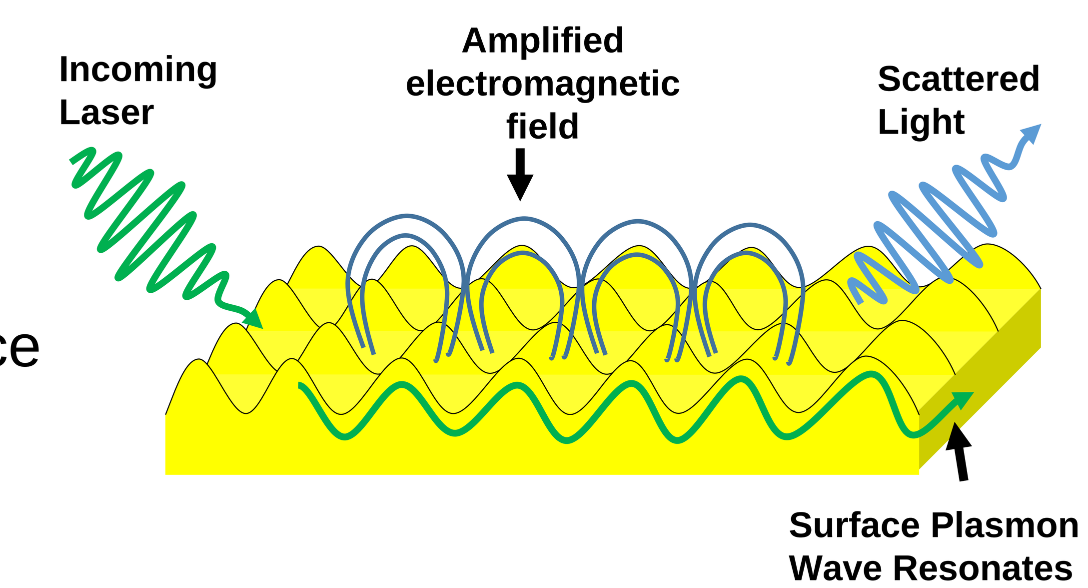

Figure 4. How plasmonic structure enhance Raman signal

In order to incorporate Raman-enhancing features to raw gold samples and develop a catalytic system with Ruthenium, the samples have to go through the following preparation process:

1) Mechanical, chemical, electrochemical smoothening to bring homogeneity to the surface.
2) Electrochemical roughening to generate microscopic plasmonic features.
3) Electrochemical deposition of Ruthenium to create catalytic surface.

Changes of the surface structure are visualized using Atomic Force Microscope (AFM) and Scanning Electron Microscope (SEM). Ultimately, the samples will be used as a catalyst to studied oxidation of carbon monoxide using Raman Spectroscopy.

Results & Discussion

Figure 5.a) shows the surface of a raw gold sample, with very large, inconsistent peaks. Figure 5.b) shows the surface of the sample after the mechanical smoothening step, which significant improves. The majority of the surface are homogeneous, with some rough peaks. Figure 5. c) shows the surface after the chemical and electrochemical smoothening step, with the surface now being fully homogeneous.

The plasmonic structures generated from electrochemical roughening step are displayed in Figure 5.d). The average roughness of the surface increases, but the consistency and homogeneity are maintained. This result fits with our initial hypothesis of plasmonic structure. The feature is maintained before and after Ruthenium deposition, shown from Figure 5.e), which further support that the achieved structure can be plasmonic and is not affected by the catalytic Ruthenium layer.

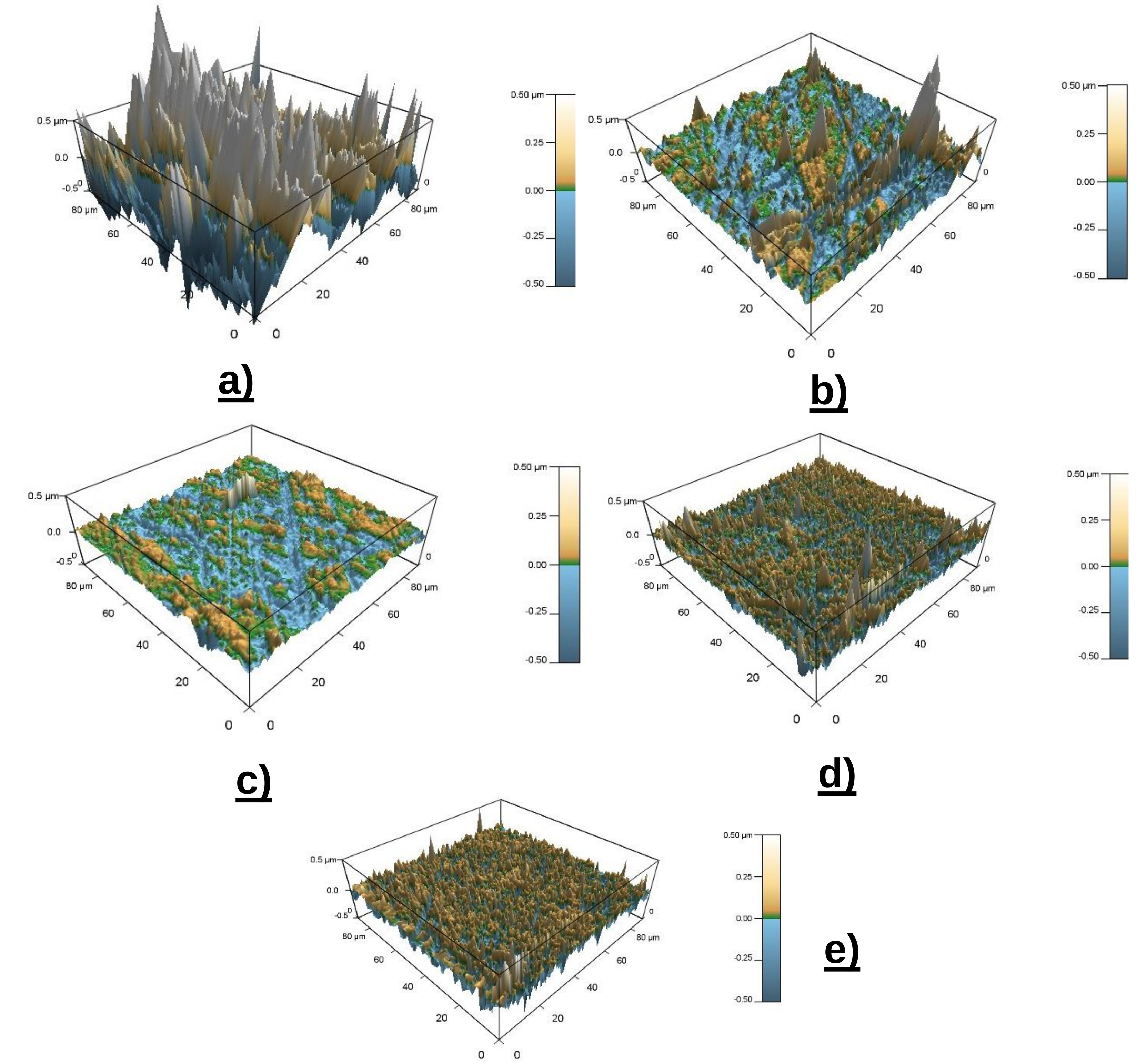

Figure 5. AFM images of the gold sample after each step of preparation

Conclusion & Future Work

As a preliminary result of the current project, much more consistently roughened features, which are promising to be plasmonic, is observed on a electrochemically roughened gold samples. Future work will be to test the samples under Raman Spectroscopy

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