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Silver-Palladium Nanoparticle Electrodeposition on Vulcan for the Oxygen Reduction Reaction.

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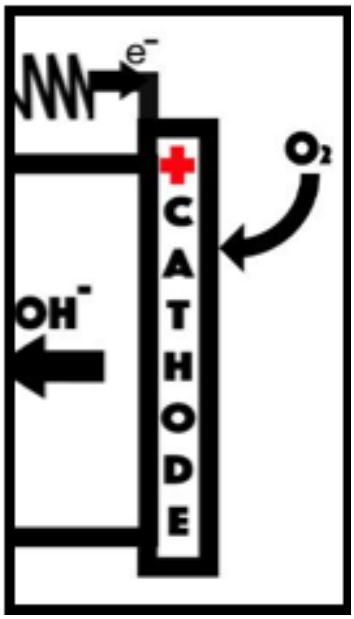
Abstract:
The search for green and clean energy sources has been the topic of great debate in recent years, creating increasing demands for renewable energy sources. As a response Fuel cells have risen as potential sources for clean energy posing viable methods and holding superior energy conservation efficiency. However, due to the slow kinetics of the oxidation-reduction reaction (ORR), this process can become hindered in its overall performance. Thus, necessitating the use of a catalysts having qualities such as low cost and high catalytic stability. Currently platinum has proven to be the optimal catalyst for ORR but, due to its high cost, low abundance and instability for long-term applications, efforts have been made to replace it. As of now, Silver (Ag) has been the focus of research, based on its relatively inexpensive cost and good catalytic activity for ORR in alkaline media. However, the published material has demonstrated that utilizing only Silver deposited on a carbon support is not very efficient when carrying out a direct reduction in the oxidation-reduction reaction by a 4-electron pathway. To enhance the performance and selectivity of Silver, a bimetallic catalyst between silver and palladium in a mass-to-mass ratio of 4:1(Ag: Pd) has been developed by our team, as a mean to improve catalytic activity while minimizing costs. Having developed this thru the use of three different methods of metal salt electrodeposition utilizing the Rotating Disk Slurry Electrodeposition technique (RoDSE). An electrodeposition method consisting of the synthesis of highly dispersed Ag/Pd nanoparticles on Vulcan XC-72R in acidic media. Both decreasing the amount of time spent in preparation of the catalyst and, achieving the desired effect. This tested method consisted of an alternated, sequential and simultaneous formation of addition for electrodeposition.

Introduction:

Each day thousands upon thousands of compounds and pollutants are created by the burning of Non-green and environmentally unfriendly energy sources such as Oil, Coal, etc. These methods not only harm the environment but are incredibly inefficient at converting energy from its source to usable electric or mechanical energy. However, there are many alternatives to those previously mentioned such as Fuel cells. These pose Environmentally friendly alternatives that have the capacity to convert energy at much higher efficiency's while producing Non-harmful by-products like that of water. Most fuel cells consist of the use of an inherent chemical potential that works towards the conversion of an electrochemical gradient into a form of electric current. These fuel cells can vary greatly in membranes and electrolytes used, by which the focus of our attention will be that of an alkaline fuel cell. With specificity towards the Oxygen Reduction Reaction (ORR), occurring in the cathode of this cell.



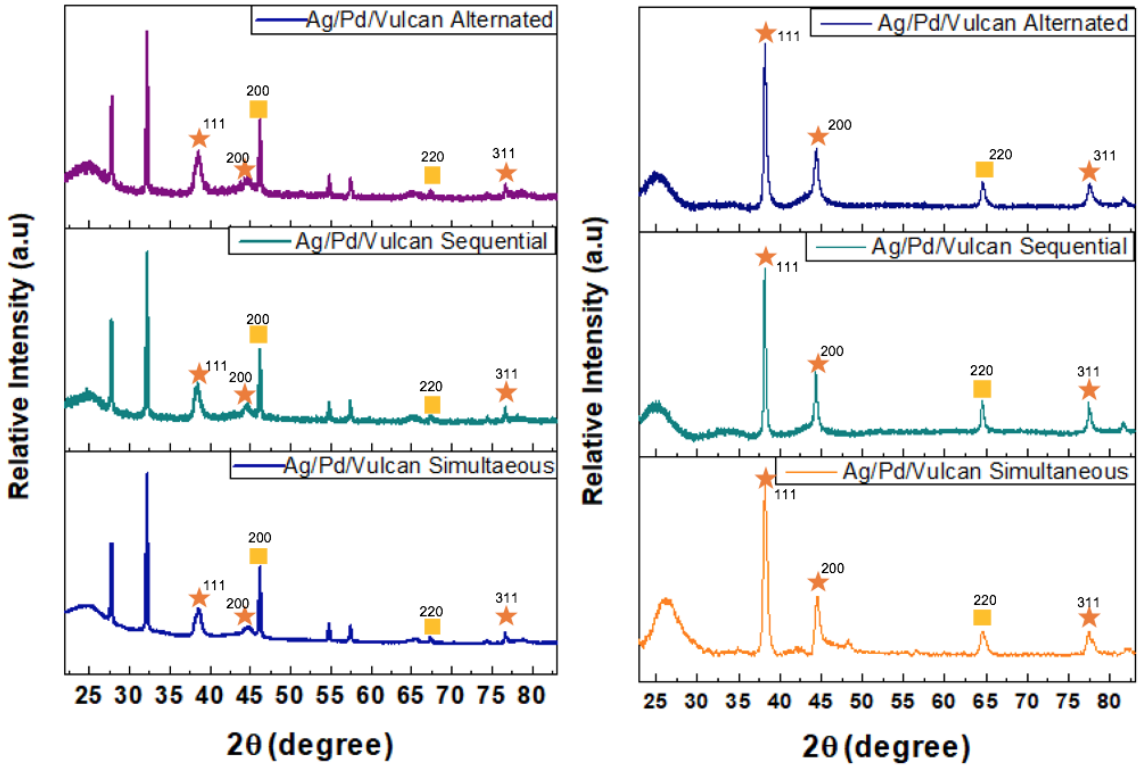
In this, the cathode, bimolecular oxygen is reduced by breaking its double bond and releasing electrons in the process. However, due to the energy required to convey this process, this reaction tends to have slow kinetic speeds. By which it would require the use of a catalyst to properly function at desirable speeds. So far being platinum and platinum-based materials the best catalysts. Posing additional problems such as high cost and low availability of this metal. As a solution to these problems, other catalysts have been employed, yielding varied results and costs.

However special focus has been made towards the use of Bimetallic compounds with specificity towards the use of Silver, palladium and a carbon or base such as that if Vulcan. Due to the desired factors, producing a silver-palladium bimetallic compound may reduce costs while improving activity. This based on silvers high catalytic activity and stability over wide ranges in the pH scale, additionally taking into consideration palladiums High catalytic activity at higher pH scales. Making them suitable candidates for the formation of a catalyst used in alkaline mediums. Finally, electro-depositing these two metals on a Vulcan (carbon) base as to further lower costs, while simultaneously taking advantage of its high electronic conductivity, surface area, and porosity to disperse the metals and lower the amounts needed.

Data:

X-Ray Diffraction

- Established comparison of X-Ray diffraction Data after changing established palladium salts, $AgNO_3$ and $PdCl_2$ Salt (Previous Salt) and Bimetallic using $AgNO_3$ and PdAc Salt (New Salt).



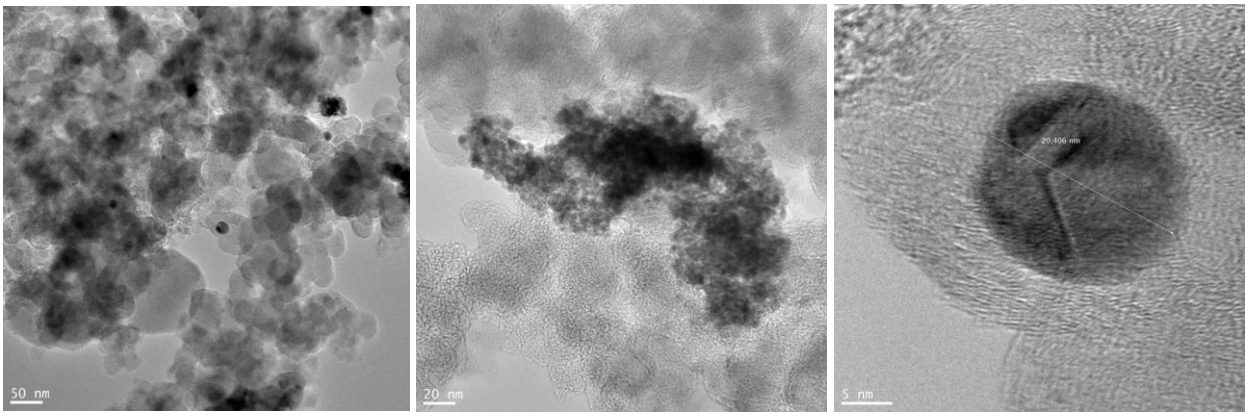
**Stars corresponds to Peaks characteristic of Silver, squares correspond to peaks characteristic to Palladium **

- Average Mean sizes established by Scherrer's equation

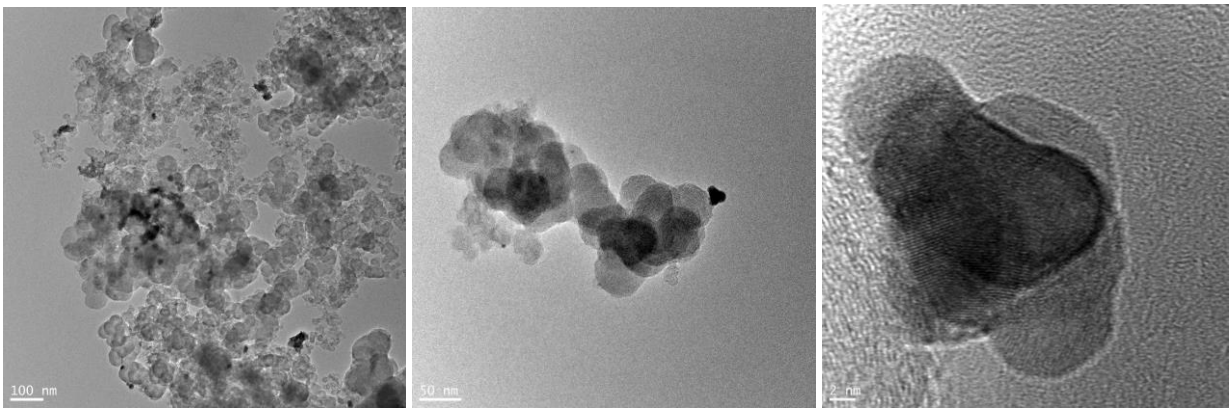
Catalysts	**Mean Average (nm)**
Ag / Vulcan	**28.0**
Pd / Vulcan	**23.1**
Ag / Pd / Vulcan Alternated	**22.0**
Ag / Pd / Vulcan Sequential	**27.2**
Ag / Pd / Vulcan Simultaneous	**20.8**

Transmission Electron Microscopy (TEM):

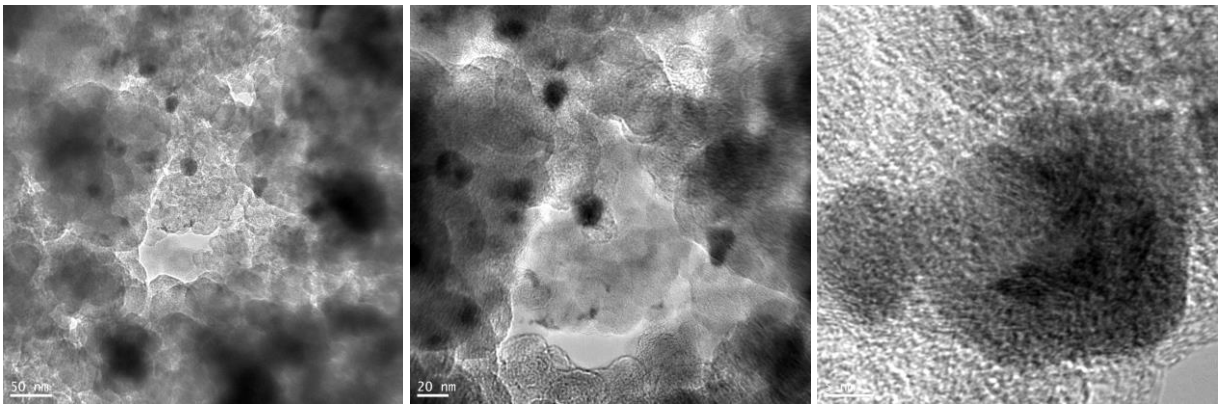
- Images for the Alternated method



- Images for the Sequential method



- Images for the Simultaneous method



Analysis:

To analyze our catalyst and its effectiveness a series of measurements and characterization techniques were required. However, the procedures and data obtained during this research can be established in the presented data. Having X-ray diffraction and Transmission electron microscopy as forms of both visual and characteristic forms of data collection for our results. In the analysis of X-ray diffraction, it can be stated that based on the identified peaks and comparison with previously known X-ray diffraction patterns for both palladium and silver on Vulcan, that the metals desired have been deposited on our carbon support. Additionally, in the analysis of the data provided, it can be stated the use of both a "new" and a "previous" metal precursor salt for palladium, due to the presence of undesired and uncharacteristic peeks corresponding to impurities within the sample. This in part is thought to be caused by the mixing of silver nitrate and palladium chloride, producing

the insoluble salt Silver chloride, whose peeks are characteristic to those seen in the first XRD measurement. This furthermore being confirmed after the substitution of the palladium metal precursor salt, to palladium acetate. Yielding visual confirmation of the elimination of the undesired peeks in the secondary XRD image. Finally with use of the peeks obtained off the XRD Measurements and use of the Scherrer's equation, mean sizes of 22.0nm, 27.2nm and 20.8nm respectively for each of the three methods. These being the Alternated, Sequential and Simultaneous forms of addition. Moreover, these mean sizes being correlated with the obtained by the Transmission Electron Microscopy, having obtained nanoparticles of the expected sizes. With some additional agglomeration characteristic to silver Nanoparticles.

Conclusion:

In finality after Having reviewed the data and know information, it can be concluded that the objectives desired have been achieved as based on the X-ray diffraction data it can be stated that a silver-palladium-Vulcan (Ag/Pd/Vulcan) bimetallic electrocatalyst was synthesized via the RoDSE technique. Additionally confirming the size and appearance of our desired catalyst using Transmission electron microscopy and thru the use of the Scherrer's equation determining mean sizes of 22.0nm, 27.2nm, and 20.8nm respectively for each of the three methods. These being the Alternated, Sequential and Simultaneous forms of addition.

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