Non-Precious Metal Catalyst for Microbial Fuel Cells

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Objectives

A catalyst that is comparable to platinum in power output and stability is being researched. The alternative catalyst is significantly cheaper and will replace platinum.

Background

Microbial fuel cells (MFCs) are capable of generating power by oxidizing organic materials and reducing oxygen. MFCs do not yet generate enough power to be useful as large scale energy producers, but they are potentially useful in recovering energy from wastewater and breaking down contaminates to non-toxic forms. Platinum is the best oxidation /reduction catalyst, but is expensive.

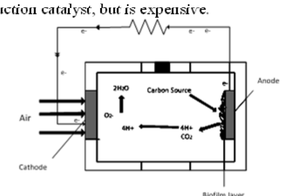
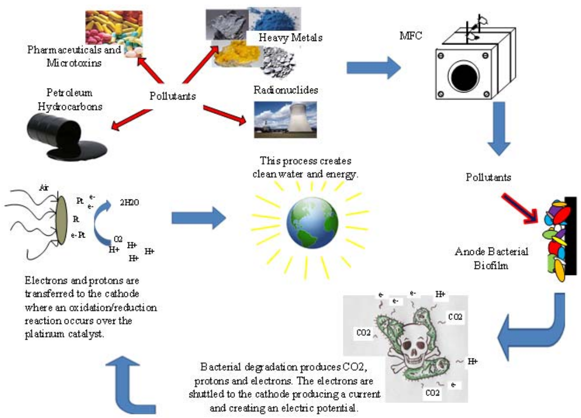


Figure 1. The chemical process of a MFC. The entire reaction occurs spontaneously.



Cost Analysis

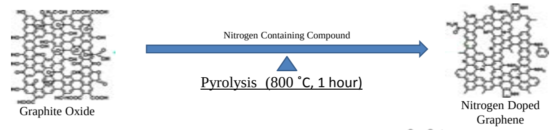
Potential materials being investigated cost significantly less than platinum.

Table 1. A comparison of potential catalyst materials and how much it costs per test cathode .

Metal	Cost ($/gram)	Loading per square meter	Cost per square meter
EDTA	00.36	35.4 g	$12.7
Cobalt ($CoCl_2$)	0.81	16 g	$12.9
Iron ($FeSO_4$)	00.15	16 g	$2.4
Carbon Powder	00.0718	23.4 g	$1.7
Platinum Powder (20% with Carbon)	96.90	50 g	$4800

Catalyst Method

Nitrogen Doped Graphene-



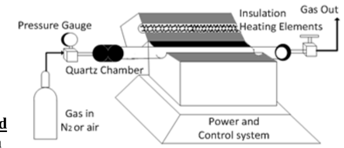
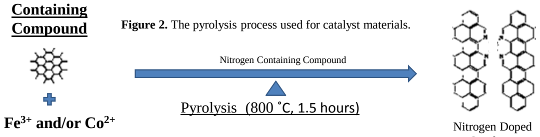


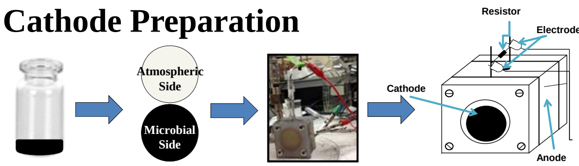
Figure 2. The pyrolysis process used for catalyst materials.

Metal Chelated with Nitrogen Containing Compound



Fe^{3+} and/or Co^{2+}

Cathode Preparation



Material is loaded into a vial with Nafion.

Catalyst is painted onto the microbial side of the cathode. The atmospheric side has a prepainted PTFE layer for gas diffusion.

Chronopoteniometry or linear sweep voltametry is performed to ensure cathode is working.

Cathode performance in MFC is determined.

Nitrogen Doped Graphene Results

Catalysts behave well initially, but degrade over time. Platinum does not exhibit degradation and a viable alternative catalyst should be similar. The platinum controls differ, as the experiments were done on different days.

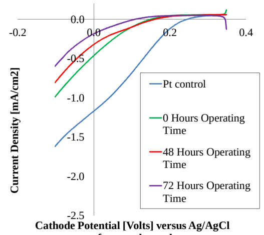


Figure 3. Degradation of nitrogen doped graphene over 3 days. The catalyst degrades quickly in a short time.

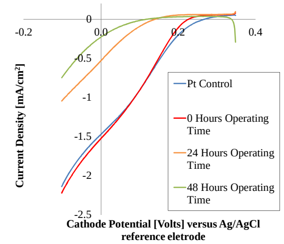


Figure 4. Degradation of Fe/EDTA over a period of time. The first test was comparable to platinum.

Nitrogen Doped Graphene with Cobalt Oxide Nanocrystals

Figure 5 shows that this catalyst is stable over a long period of time. Much of the catalytic activity in the region of positive potential decreases with time, while the catalytic activity in the negative region increases. This is likely due to the fact that nitrogen doped graphene catalyst ceases to be active after several hours of operating time. A second active site of cobalt oxide nanocrystals becomes the dominant active site in that region.

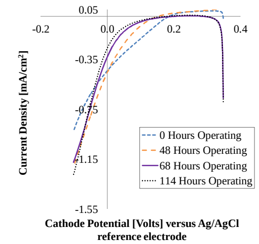


Figure 5. The nitrogen doped graphene with cobalt oxide nanocrystals catalyst did not degrade as quickly as other catalysts

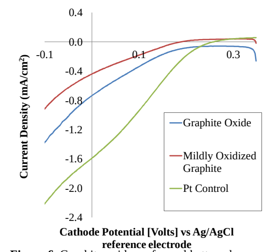


Figure 6. Graphite oxide performed better when used in catalysts than the mildly oxidized graphite.

The more strongly oxidized graphite will yield a more carbon matrix with higher surface area when pyrolyzed. This is reflected in the catalyst performance. Figure 6 shows the two different oxidations of graphite used in catalysts and the graphite oxide performed better than the mildly oxidized graphite.

Analysis and Conclusions

- Significant research is being conducted on non-precious metal catalysts for oxygen/ reduction type fuel cells. One category of materials was examined in this project.
- The materials used thus far are not suitable to replace platinum. The mechanisms which cause deterioration are unknown.
- It is suspected that the Fe/EDTA and nitrogen doped graphene catalysts have the same active site.
- Cobalt oxide is stable over several 100 hours of operating.
- All procedures used to create nitrogen doped graphene have resulted in unstable catalysts.
- Using a more highly oxidized carbon substrate yields better catalysts performance due to more surface area.

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References

Saito et al. Neutral Hydrophilic Cathode Catalyst Binders for Microbial Fuel Cells. 2010, Energy and Environmental Science.