INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: SUPPORTED TRANSITION METAL-BASED ELECTROCATALYSTS FOR ETHYLENE GLYCOL FUEL CELL

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SHORT ABSTRACT

Fuel cells convert chemical energy to electrical energy. The direct alcohol fuel cells (DAFC) used an alcohol as fuel and an oxygen as the oxidant. The monohydric alcohols like ethanol and methanol were commonly used whereas polyhydric alcohols such as ethylene glycol (EG) offer advantages. This study analyzed the electro-oxidation of polyhydric alcohols using cost-effective transition metal catalysts. This study aimed to conduct a comprehensive analysis of the electro-oxidation of polyhydric alcohols with several cost-effective transition metal-based electrocatalysts and various supports.

Firstly, effect of various supports on the electro-oxidation of EG was first investigated with Cu as the active metal. In an acidic medium, the highest current density of 5.61 mA/cm^2 was generated by 20Cu-RGO, followed by 20Cu-VC (2.59 mA/cm^2). The current density in the basic medium was as follows: 20Cu-ALS-TC (0.73 mA/cm^2) < 20Cu-AC (1.23 mA/cm^2) < 20Cu-VC (1.61 mA/cm^2) < 20Cu-RGO (2.78 mA/cm^2). The mass activity of 20Cu-RGO was 47.8 mA/mg_{Cu} and 23.7 mA/mg_{Cu} in acidic and basic media, respectively. The superior performance of 20Cu-RGO over other catalysts was attributed to its higher electrochemical surface area (ECSA), larger pore size, and improved metal dispersion. The various transition metal (Cu, Ni, Co, or Fe)-based catalysts were then evaluated with low-cost commercial activated carbon (AC) support. The electrochemical activity was assessed in both acidic and basic environments, with and without EG. In the presence of EG, 20Ni-AC generated the maximum current density of 7.62 mA/cm^2 at 0.49 V and 11 mA/cm^2 at 1 V in acidic and basic media, respectively. Thus, in the presence of EG, Ni-AC with the highest specific ECSA (44.3 m^2/g) produced the maximum current density in all media.

The most active support RGO with various transition metals (Cu, Ni, Fe, and Co) for EG electro-oxidation was studied. The 20Ni-RGO exhibited the highest current density of 86 mA/mg_m, followed by 20Cu-RGO (61 mA/mg_m), 20Co-RGO (54 mA/mg_m) and 20Fe-RGO (39 mA/mg_m). The trend of the obtained current density was consistent with the increasing electrochemical surface area and decreasing Tafel slope. In addition, the effect of metal loading in the range of 20 to 40 wt.% was examined in order to determine the best-performing monometallic catalyst. Ni loadings of 30 wt.% was able to provide a high current density of 102 mA/mg_m.

Furthermore, Ni-based bimetallic catalysts were developed with Co, Cu and Fe as co-metals. The overall metal loading was maintained at 30 wt. %, with a Ni to co-metal ratio of 3:1. CV studies showed that NiCo-RGO had the maximum current density, followed by NiCu-RGO and NiFe-RGO. The ECSA of bimetallic catalyst increased in the order of NiFe-RGO < NiCu-RGO < NiCo-RGO. Based on the performance of NiCo-RGO, the optimal electro-oxidation conditions were determined to be 1 M KOH with 0.75 M EG at 75 °C. Furthermore, NiCo-RGO also showed significant activity for electro-oxidation of glycerol as well as propane-1,2-diol. The single cell fuel cell study of NiCo-RGO provided insight into the power generation of the best bimetallic catalyst. The study showed that ethylene glycol generated the highest power density (7.07 mW/cm^2), followed by glycerol (6.11 mW/cm^2) and propane-1,2-diol (3.71 mW/cm^2). Hence, the suggested electrocatalyst could be employed for commercial fuel cell applications with polyhydric alcohol as fuel.