Pt-Re-Sn as Metal Anode Catalysts for Electro-oxidation of Ethylene Glycol in Direct Ethylene Glycol PEM Fuel Cell

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Abstract—*Different compositions of Pt-Re-Sn catalysts were prepared using impregnation method and tested for current and power density using direct ethylene glycol fuel cell (DEGFC). The prepared catalysts were physically characterized using transmission electron microscopy (TEM), X-ray diffraction (XRD) techniques, and electrochemically characterized using cyclic voltammetry (CV), linear sweep voltammetry (LSV), and Chrono-amperommetry techniques (CA). In direct ethylene glycol fuel cell. Pt-Re-Sn/C (20:5:15) shows a peak power density of 31.2 mW/cm^2 at 100 ^{o}C. The effect of operating parameters such as fuel concentration, oxygen flow rate, operating temperature were studied using Pt-Re-Sn (20:5:15) as metal catalyst.*

1. INTRODUCTION

Direct ethylene glycol fuel cells (DEGFCs) are arising interest as an alternative power source. Recent studies have shown that the use of a second or third metal element may alter the electro-catalytic properties of Platinum (Pt) metal catalyst. To promote the electro catalytic activity of Platinum for DEGFCs applications, elements like Rhenium (Re) and Tin (Sn) has been added [1-4].The catalytic activity of Pt based catalysts is dependent on the size of catalyst particles, dispersion of catalyst and also depend on the characteristics of support material used. Rhenium has been found to be effective in breaking the C-C bond in the reforming and cracking processes of petroleum fractions [4].

In the present paper, Pt-Sn/C (20:20), Pt-Re/C (20:20), Pt-Re-Sn/C (20:10:10) and Pt-Re-Sn/C (20:5:15) catalysts were prepared using impregnation reduction method to study the electro-oxidation of ethylene glycol for direct ethylene glycol PEM fuel cell. The prepared electro-catalysts were physically characterized using transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD) analysis. And the catalysts were electrochemically characterized using cyclic voltammetry (CV), chrono-amperommetry (CA), linear sweep voltammetry (LSV). Finally the prepared anode catalysts were tested for their performance in direct ethylene glycol PEM fuel cell. The

effect of various operating parameters such as fuel flow rate, fuel concentration, operating temperature and oxygen flow rate were studied using Pt-Re-Sn (20:5:15) as anode catalyst. Also the effect of different support materials using mesoporous carbon nitride (MCN) as support material was studied.

2. EXPERIMENT

For the preparation of metal anode catalysts $H_2PtCl_6.6H_2O$ (Alfa Aesar, USA), $SnCl_2.2H_2O$ (Merck, Germany) and $ReCl_3$ (Alfa Aesar, USA) precursors were used. Pt-Re-Sn (20:5:15) metal as anode catalysts were prepared on different supports, e.g., MCN, multiwall carbon nanotubes (MWCNTs) and Vulcan-XC were prepared with the final metal loading 40 wt% on 60 wt% support. Calcined mesoporous silica, SBA-15 (ACS material) was used as template for the preparation of MCN support [4].

3. CATALYST PREPARATION

The Pt-Re-Sn (20:5:15) were supported on MCN, MWCNTs, and Vulcan-XC using co-impregnation reduction method. Requisite amount of metal precursors were first engrossed in iso-propanol by ultrasonicating for 3 hour. Different supports were preheated to 70 ^{o}C for 2 h and suspended in iso-propanol separately by ultrasonicating for 3 h.

4. RESULTS AND DISCUSSION

Direct ethylene glycol fuel cells (DEGFCs) are hopeful candidate as a future power source for portable electronic devices such as laptops, mobile phones, etc. [1-3]. The aids of using ethylene glycol as a fuel in DEGFCs are high energy density, low volatility, high activity and high boiling point compared to other commonly used alcohols and other fuels [1]. Different compositions of Pt-Re-Sn catalysts as Pt-Re-Sn/C (20:5:15) and Pt-Re-Sn/C (20:10:10) were prepared and tested for their performance in DEGFCs. The prepared

catalysts were physically characterized using transmission electron microscopy (TEM) and X- ray diffraction (XRD) techniques, and electrochemically characterized using linear sweep voltammetry (LSV) and cyclic voltammetry (CV) techniques. In CV tests the peak current density of 0.07 mA/cm^2 was observed using Pt-Re-Sn/C (20:5:15) as anode electro-catalyst (fig. 1).
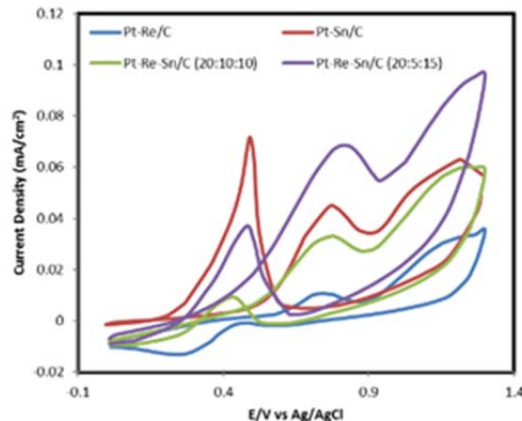
Fig. 1: Cyclic voltammetry curves of Pt-Sn/C (20: 20), Pt-Re/C (20: 20), Pt-Re-Sn/C (20:10:10) and Pt-Re-Sn/C (20:5:15) electro-catalysts.

The performance of prepared electro-catalysts were tested using direct ethylene glycol fuel cell [4]. Pt-Re-Sn/C (20:5:15) shows peak power density of 31.2 mW/cm^2 at 100 $^{\circ}$C (fig. 2). The effect of various operating parameters such as fuel flow rate, anode diffusion layer, fuel concentration, operating temperature and oxidant flow rate were studied using Pt-Re-Sn (20:5:15) as anode metal catalyst. At 0.5 M concentration of ethylene glycol mass transport losses were observed. At high concentration kinetic losses were observed due to fuel crossover. The effect of support materials such as mesoporous carbon nitride (MCN) and multiwall carbon nanotube (MWCNT) were studied. The DEGFCs complete cell test at 90 $^{\circ}$C, 1 bar with a catalyst loading of 1.5 mg/cm^2 and 2 M ethylene glycol as anode fuel the catalytic activity observed as Pt-Re-Sn/MCN>Pt-Re-Sn/MWCNT>Pt-Re-Sn/C.   Pt-Re-Sn/MCN (20:5:15) exhibited highest performance among all the catalysts prepared with a power density of 49.2 mW/cm^2 in DEGFC operating at 90 $^{\circ}$C.
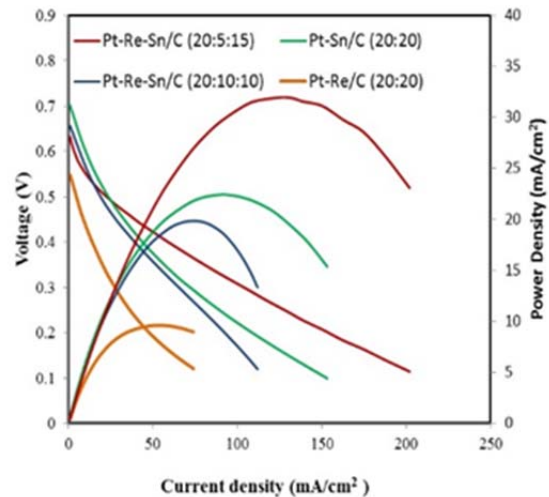
Fig. 2: Performance curves for different catalysts at 100 $^{\circ}$C for DEGFCs.

5.   CONCLUSION

Ethylene glycol was tested as anode fuel for its performance in fuel cell using Pt-Re-Sn (20:5:15) as anode metal catalyst. An enhancement in performance was observed using MCN supported Pt-Re-Sn (20:5:15) anode metal catalysts.

6.   ACKNOWLEDGEMENTS

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