EMPLOYMENT OF FLOURINE DOPED GALLIUM TIN OXIDE COATED STAINLESS STEEL BIPOLAR PLATE FOR PROTON EXCHANGE MEMBRANE FUEL CELL

Joong Kee Lee[1] , JiHun Park[1,2], Dongjin Byun[2]

[1]Battery center, KIST, P.O. Box 131, cheongryang Seoul 130-650, Korea, Dept. of Advanced Materials Engineering, Korea University, Seoul 136-713, Korea

[2]Dept. of Advanced Materials Engineering, Korea University, Seoul 136-713, Korea

Corresponding author: leejk@kist.re.kr

Introduction

Stainless steel can be considered as one of the most promising materials for the bipolar plates of PEMFCs (proton exchange membrane fuel cells), due to its higher mechanical strength, durability to shocks and vibration, impermeability and much superior manufacturability and cost effectiveness when compared to carbon based materials. However, the main handicap of metals is their lack of corrosion resistance in the harsh acidic and humid environment inside PEM fuel cells, which leads to considerable power degradation [1]. The purpose of this study is to evaluate the corrosion resistance, as well as the electrical resistance, of stainless steels with metal oxide coatings. Through this work, the effects of fluorine doped gallium tin oxide (FGTO) composite film on the interfacial contact resistance and corrosion resistance of the bipolar plates in the strong hydro-acid environment of PEMFCs are investigated.

Experimental

An ECR-MOCVD (Electron Cyclotron Resonance-Metallic Organic Chemical Vapor Deposition) system was used for the deposition of the fluorine doped tin oxide (FTO) and fluorine doped gallium tin–oxide (FGTO) composite films. The samples were prepared under the following conditions : a working pressure of 5 mTorr, flow rates of TMT (tetramethyl-tin), TMG (tetramethyl-gallium), SF_6, H_2 and O_2 of 3.6, 1.0, 1.3, 3.2 and 29.23 sccm, respectively, a deposition time of 30 min and a microwave power of 1000 W. A detailed description of the ECR-MOCVD system is given in our previous report [2].

The interfacial contact resistance (ICR) is obtained by calculating the resistance based on Ohm's law [3].

The corrosion characteristics of the coated stainless steel can be represented by the corrosion current which is determined by the Tafel-extrapolation method from the polarization curves in the solution environment of the PEMFC. The composition of the electrolyte mixture is one (molar?) sulfuric acid and 2 ppm of HF and the temperature was maintained at 70^{o}C during the corrosion test.

The single cell is assembled with the catalyst loaded membrane, carbon papers, gasket and prepared bipolar plates. For the preparation of the MEA, a Nafion 212 membrane with platinum loading of 0.2mg/cm^2 (Johnson Matthey) and the CCMs (Corrosion Resistant Construction Materials) method was employed. The area of the active electrode was 5cm^2. In order to operate the single cells, fully humidified hydrogen and oxygen gases were fed to the anode and cathode, respectively.

Results and Discussion

Fig. 1 shows the potentiodynamic polarization curves for the bare stainless steel 316 and FTO and FGTO coated films in $1MH_2SO_4$ + 2ppm HF solution at 70^{o}C. The potential was varied from -250 to 250mV at a scan rate of 1mv/sec. The current densities of the FTO and FGTO coated stainless steels and stainless steel 316, which were determined by the Tafel-extrapolation method, are 0.13, 6.64 and 50.15 μA/cm^2, respectively. As shown in the figure, the FGTO coated stainless steel exhibited the lowest corrosion resistance in the simulated PEMFC environment.

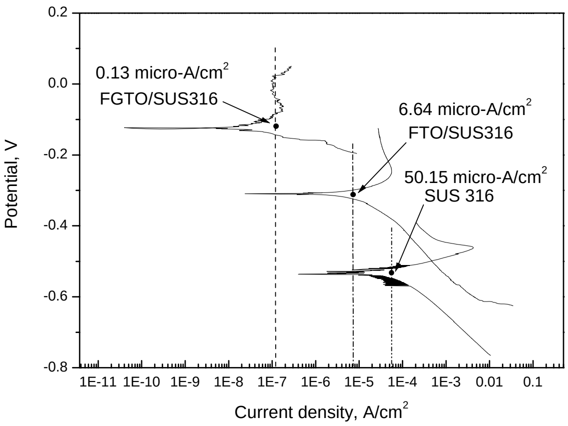

Fig. 1. Corrosion current [A/cm^2] in 1M H_2SO_4 with 2 ppm HF solution for bare stainless steel, and FTO and FGTO films coated on stainless steel.

In order to simulate fuel cell stack conditions, the values of the interfacial contact resistance were evaluated when applying various compaction pressures. As shown in Fig. 4, the interfacial contact resistance of all of the specimens decreased rapidly at a low compaction pressure and then decreased gradually, probably due to the decrease in the interfacial resistance. Obviously, the interfacial conductivities of the FTO and FGTO coated stainless steels were higher than that of the bare stainless steel at all compaction forces. At a compaction pressure of 150N/cm^2, the contact resistances of the bare stainless steel and fluorine doped tin oxide and fluorine doped zinc tin oxide coated stainless steels were measured to be 279, 76 and 17mΩ·cm^2, respectively. The interfacial resistance of the FGTO coated stainless steel is almost the same as that of graphite, viz. 20mΩ·cm^2.

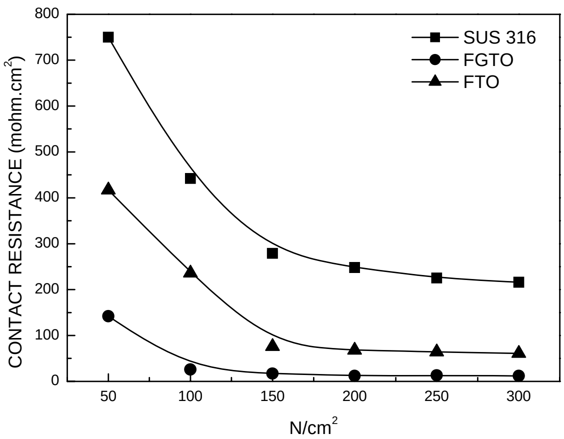

Fig. 2. Comparison of ICR with compaction force for bare stainless steel and FTO and FGTO films coated on stainless steel.

Conclusion

The deposition of the FGTO layers on SUS 316 bipolar plates was carried out by ECR-MOCVD and the properties of the resulting plates were compared with those of the FTO coated and the bare stainless steel 316 for the purpose of evaluating the applicability of bipolar plates in PEMFCs. The FGTO films showed the highest corrosion resistance and lowest contact resistance, which may allow single cells with a high power density to be obtained.

References

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