

The Electrochemical Oxidation of Various Carbonaceous Fuels in a Direct Carbon Fuel Cell

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The DCFC (Direct Carbon Fuel Cell) that uses solid carbon directly has been investigated by many research groups because of dramatically high efficiency. The performances of this fuel cell depend on the characteristics of electrochemical oxidation reaction of carbonaceous fuel as anode. The DCFC has a definite advantage of fuel flexibility such as coal, biomass, wastes, etc. To investigate the characteristics of electrochemical reactions of various fuels in DCFC, three different rank coals (Shenhua coal, Adaro coal, and Openblue coal), a bio-coal, and a RDF (Refuse Derived Fuel) were selected in this research because coals are traditional power sources and the bio-coal and the RDF are eco-friendly material which can replace the existing fuels.

The characteristics of electrochemical reactions of fuels were investigated under various temperature and stirring conditions and the correlation with fuels properties are also discussed. Significant fuel properties, such as the thermal reaction, the crystallinity, the specific surface area and the surface functional groups, were analyzed by various methods of Thermo-gravimetric Analysis (TGA), X-ray diffraction (XRD), Gas adsorption (BET), X-ray Photoelectron Spectroscopy (XPS).

The potential of fuels (via current density) in molten electrolyte was measured in potentiostatic method. Three different electrodes (Working electrode, Counter electrode, Reference electrode) made from silver were used for electrochemical measurement with a KST-P1 (Physio Lab., Korea). The effective area of working electrode was 1.34 cm² in the standard cell. A mixture of 62:38 mol% Li₂CO₃ and K₂CO₃ was used as an electrolyte. The working electrode was purged by He (150ml/min) during experiments. The counter electrode and reference electrode were filled with CO₂ (50ml/min) during heat-up. After that, a mixture of O₂ (25ml/min) and CO₂ (50ml/min) was supplied to the counter and the reference electrode at the operating temperature. The counter and the reference electrode were separated from carbonaceous fuels by the alumina tube.

The electrochemical reaction in the DCFC was divided by three polarizations (Activation polarization, Ohmic polarization, Concentration polarization). In the activation polarization region (from OCV to -0.6 V), the activation energy of the bio-coal and the RDF was lower than other coals because surface carbon content and non-crystalline structure. In the ohmic polarization region, Shenhua coal maintained potential until high current density because of much fixed carbon of fuels relatively. In the cases of the bio-coal and the RDF, they show similar performance to coal fuels due to surface properties and weak structure in the low current density. However, the potential of the bio-coal and the RDF decreased rapidly because of low amount of total carbon in the ohmic polarization region.

In previous works, the enhancement in performance was observed by temperature increase. [1] This result was caused by decreased resistance based on lowered activation energy and improved ion transport rate in the molten electrolyte. On the contrary to this result, the performance of the bio-coal and the RDF was decreased above 700 °C because of lack of fixed carbons due to the characteristics of gasification. The performance of the bio-coal and the RDF reached 60 ~ 70 % and 40 ~ 50 % level comparing to coal fuels, respectively.

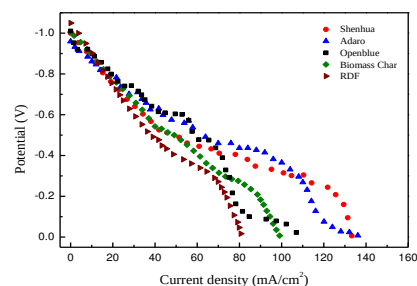


Figure 1 I-V Curves various fuels at 700 °C

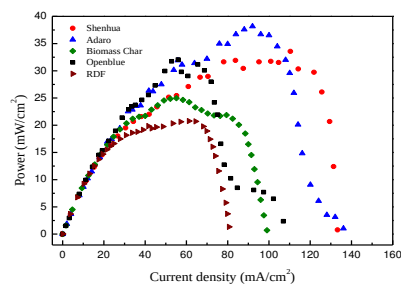


Figure 2 I-P Curves various fuels at 700 °C

Reference

- [1] Xiang Li, Zhonghua Zhu, Roland De Marco, Andrew Dicks, John Bradley, Shaomin Liu, Gao Qing Lu. Factors that determine the performance of carbon fuels in the direct carbon fuel cell, Industrial & engineering chemistry research (2008) 47