

## Oxidation behavior of ashless coal extracted from a bituminous coal in a coin type direct carbon fuel cell

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An ashless coal, calling HyperCoal, extracted from a bituminous coal was served as fuel in a direct carbon fuel cell and its oxidation behavior was investigated in terms of temperature, coal to carbonate ratio, and gas compositions in the cell. The open circuit voltage and voltage at a polarization state were definitely dependent on the temperature, and high carbon to carbonate ratio showed higher performance. Dominant product gases from the coal were  $H_2$  and CO in the tested range.

Coal is relatively abundant energy source compared with other fossil fuels. Regardless of its abundance and long history of usage, inconvenience of its use reduces coal consumption at present. Coal as a solid fuel has a big problem of remaining ash in its use. Ashless coal has been attempted to overcome the problem. So far, ashless coal can be produced by two ways; one is removing ash compounds with acids and alkalines in the coal, calling UCC(Ultra Clean Coal), and another one is extracting organic compounds from the coal with organic solvents, named by HyperCoal.

In this work, HyperCoal was produced by a micro-wave method with a polar solvent of NMP. The electrochemical oxidation behavior of HyperCoal was investigated with respect to temperature, coal to carbonate ratio, and gas compositions in a coin type direct carbon fuel cell (DCFC).

The raw coal used in this work was Berau bituminous supplied by KEPRI in Korea. A coin type direct carbon fuel cell was fabricated by molten carbonate fuel cell technology. The diameter of electrodes was about 3 cm. The anode was porous Ni-Al alloy, and the cathode was porous Ni. The matrix was made of  $LiAlO_2$ . The long alumina tube at the upside of the cell was installed for the coal supply to the anode. A mixture of 62 mol%  $Li_2CO_3$  and 38 mol%  $K_2CO_3$  was served as electrolyte. The cathode gas was 70 % air and 30 %  $CO_2$ . More details of the DCFC operation was described in a previous work [1]. The normal  $H_2$  fuel for the anode was  $H_2:CO_2 = 0.125 \text{ L/min} : 0.025 \text{ L/min}$  with ca. 5 % of  $H_2O$ . Temperature ranged from 923K to 1123K. Coal to carbonate ratios were 3g to 3g, 3g to 1g, and 1g to 3g. Gas compositions in the cell were analyzed with a gas chromatography (HP 5890II).

Figure 1 shows OCV behaviors of fuel change from the normal  $H_2$  fuel to carbon and HyperCoal fuels, respectively at 1123K. The carbon fuel was a mixture of 3 g of biomass based carbon and 3 g of Li-K carbonates, while the HyperCoal fuel was a mixture of 3 g coal and 3 g of Li-K carbonates. Before 0 s the OCV was determined by the  $H_2$  fuel. After 0 s the carbon fuel shows only one minimum whereas the HyperCoal does two minimums. The first minimums around 150 s at the fuels were due to the change of fuel from hydrogen to solid fuels. Interruption of hydrogen reduces OCV and supplying solid fuels to the anode raise it again. In the carbon fuel, the OCV rise after the solid fuel supplying was found to be CO generation in the anode [2].

Figure 2 shows gas compositions and OCV with respect to the time. As shown in the figure, at the very first stage  $H_2$  was a dominant gas species. However after 20 s CO composition is also a comparable species to the  $H_2$ . Other species of  $CO_2$ ,  $CH_4$ , and  $N_2$  were very small amounts and their effect would be insignificant. From the gas behavior, the two minimums at the HyperCoal were attributed to the composition change from  $H_2$  to CO. Thus the first OCV rising would be due to  $H_2$  generation while the second rising did to the CO generation.

Higher performance of HyperCoal was obtained at a higher temperature. One point should be noted is the HyperCoal showed relatively high performance even at 923K. Indeed, the carbon fuel from biomass showed very low performance at the temperature.

Higher carbon to carbonate ratio also gave higher performance probably due to the larger  $H_2$  and CO generation at the ratio.

### ACKNOWLEDGEMENT

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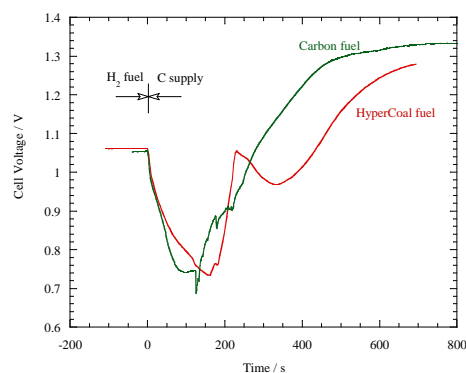


Fig. 1 Behaviors of open circuit voltage by the fuel change from  $H_2$  fuel ( $H_2:CO_2=0.150 \text{ L/min} : 0.025 \text{ L/min}$ ) to carbon fuel (3 g Carbon from a biomass and 3 g of Li-K carbonate) and ashless coal (3 g HyperCoal: 3g Li-K carbonates) at 1123K.

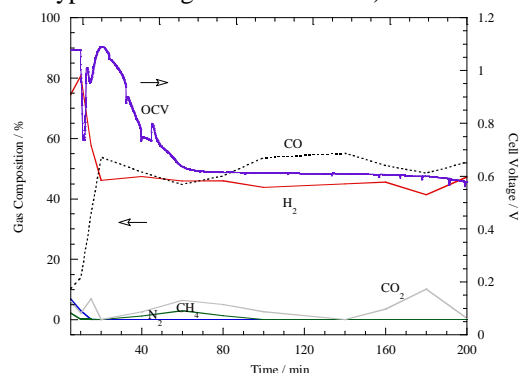


Fig. 2 Gas composition change at the anode with respect to time with HyperCoal fuel at 1123K.

### References

- [1] C.-G. Lee, H. Hur, M.-B. Song, J. Electrochem. Soc., 158(4), B410-B415 (2011).
- [2] C.-G. Lee, M.-B. Song, Fuel Cells, 12(6), 1042-1047 (2012).