PEM Fuel Cell Reactor for Chemicals-energy Cogeneration

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Fuel cell type reactor for chemicals-energy cogeneration has become one of new application for fuel cell system [1-2]. According to electrochemical reaction, PEM fuel cell can be used as a reactor for selective hydrogenation of unsaturated organic compound. A few reports have been done to demonstrate hydrogenation, especially for cogeneration of chemicals-energy in PEM fuel cell reactor. Here, we reported the selective hydrogenation of nitrobenzene (NB) to cyclohexylamine (CHA), and allyl alcohol (AA) to propanol in a PEM fuel cell reactor. Effects of operating conditions on reactivity and cell performance were also discussed.

Experimental

Fig.1 shows a schematic view of PEM fuel cell reaction system. The trial PEM fuel cell reactor consisted of a membrane electrode assembly (MEA) which fabricated in house. Anode and cathode were prepared using 20% Pt/C catalyst purchased from Johnson Matthey Ltd (Shanghai). The electrodes were made by a brushing/rolling technique with a Pt catalyst loading of approximately 0.5mg cm^{-2} unless otherwise stated. The effective area of the electrode (anode and cathode) was 6.25cm^2. Nafion 117 membranes were used after cleaning in boiling 3% H_2O_2, 1M H_2SO_4 and deionized water to remove organic and metallic impurities. The electrodes were incorporated into MEAs with Nafion 117 membrane by hot press technique at 150 ^oC, 1000 kgf cm^{-2} for 3 min. Carbon plates, with flow channels, were used for distribution of the reactants. Twin copper plate was used as both bus plate and end plate. The experimental procedure was described in detail elsewhere [3]. Selective hydrogenation of NB, and the hydrogenation of AA using this PEM fuel cell reactor was performed, respectively.

Results and discussion

These results demonstrate that cogeneration of CHA and aniline (AN) with electrical power may be possible in a PEM fuel cell reactor. According to the reaction observed, the reactions within the PEM fuel cell reactor undergo electro-oxidation by hydrogen dissociation and electro-reduction by the hydrogenation of NB. A selectivity of 57.3% to CHA, and a selectivity of 28.2% to AN, with 8.2% conversion of NB were obtained when the hydrogen flow rate was 20 ml min^{-1} at 70 ^oC for 2 hours.

The hydrogenation of AA to 1-propanol in PEM fuel cell reactor was also studied. It shows that there is no external electricity applied when hydrogenation of AA occurred, but generates electricity. Open circuit cell potentials were about 0.3-0.4 V and current density varied from 4 to 40 mA/cm^2. The maximum power density was 2.0mW/cm^2. The optimum reaction condition is: 50°C, 2M AA with 3ml^{-1} min flow rate of the reactant.

It can be seen from the above results that hydrogenation of AA to 1-propanol was easily than those hydrogenation of NB when applying a PEM fuel cell reactor. As for the hydrogenation of NB to CHA and AN, it just can operation well in the first run, the performance decayed obviously in the subsequent runs. But when the hydrogenation of AA to 1-propanol was carried out in the PEM fuel cell reactor, the reactor can still operate well after 10 runs. Nevertheless, the conversion of NB and AA, and cell performance was lower than the need of application. It is probably due to the limitation of the proton transportation and low catalytic activity of the catalyst for hydrogenation on cathode. It is needed to develop new catalyst with high activity for the target hydrogenation reaction reactor. It shows that PEM fuel cell is a potential reactor for hydrogenation in the future.

Acknowledgements

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References

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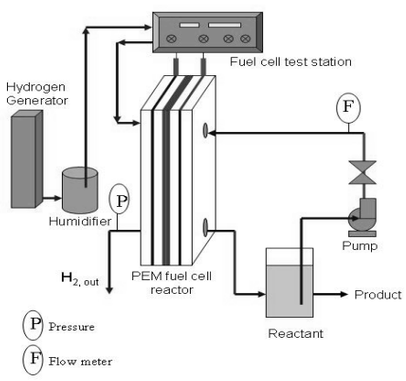

Fig.1 A schematic of PEM fuel cell reaction system