Metal-organic framework (MOF) as a template for syntheses of nanoporous carbons as catalyst supports for direct borohydride fuel cell

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Introduction

Direct borohydride fuel cell (DBFC) has been considered to be a promising power sources for portable and mobile applications owing to its high theoretical open circuit voltage (OCV) of 1.64 V, high energy density of 9.3 Wh g⁻¹ and fast anode kinetics at many metallic surfaces [1]. Unfortunately, it has not been commercialized so far. The major challenge is the high cost caused by the exclusive use of scarce precious metals as its primary catalysts. As is widely known, making the noble catalysts disperse as nanoparticles on electronic conducting supports is one of the most effective pathways to increase the utilization of catalysts.

Recently, Nanoporous carbons (NPCs) possessing high surface area and well-developed porosity are technologically important for a variety of applications, including adsorbents, catalytic supports, drug delivery carriers and electrode materials for supercapacitors and fuel cells. To the best of our knowledge, the NPCs synthesized by MOFs templates as catalyst supports are rarely reported in the studies of the fuel cells. Herein, we prepare the nanoporous carbons (NPCs) using a metal-organic framework (MOF-5) as a template, and then Pt precursor has been deposited on the as-prepared NPCs via the modified NaBH₄ reduction method at room temperature. The electrochemical performance of borohydride oxidation on the Pt/NPCs (Pt/NPCs) and single DBFC cell tests have been investigated in detail.

Experimental

NPCs were synthesized using MOF-5 ([[Zn(O(bdc))₆]], bdc = 1,4-benzenedicarboxylate) as a template and furfuryl alcohol (FA) as a carbon precursor [2]. The MOF-5 was prepared by solvothermal method with the best synthesis conditions according to the reported strategy [3]. Then the as-prepared MOF-5 was degassed at 200 °C for 24 h to remove the solvent molecules, followed by furfuryl alcohol (FA) introducing into the pores of degassed MOF-5 by the incipient wetness technique. Subsequently, the FA/MOF-5 was heated at 80 °C for 24 h, then 150 °C for 6 h in an Ar flow. Finally, the samples were carbonized at 650°C, 800°C, 900°C for 6 h respectively. The resultant carbon materials were denoted as NPC-650, NPC-800, NPC-900. The Pt/NPCs and Pt/XC-72 catalysts were prepared according to a modified NaBH₄ reduction method reported in our previous work [1].

Results and Discussion

Fig.1 represents the BH₄⁻ cyclic voltammograms on the Pt/NPCs and Pt/XC-72 electrodes. The Peak a, b, c and d at about -0.15 V are given by the direct oxidation of borohydride. The current density of Peak a was the highest on the Pt/NPC-900 electrode, about 36.32 mA cm⁻², followed by Pt/NPC-650 (31.62 mA cm⁻²), Pt/XC-72 (26.58 mA cm⁻²) and Pt/NPC-800 (25.12 mA cm⁻²). Apparently, higher current density suggests much higher catalyst utilization. Thus, it can be concluded that both Pt/NPC-650 and Pt/NPC-800 electrodes have higher electrocatalytic activity than Pt/XC-72 electrode, especially, Pt/NPC-900 catalyst shows the best catalytic performance among all four electrodes.

Fig. 2 shows plots of both cell voltage and power density vs current density for DBFC. It can be found from Fig. 2 (a) that both the Pt/NPC-900 and Pt/NPC-800 anode have smaller polarization for BH₄⁻ oxidation than the one using Pt/XC-72 anode from the beginning. Meanwhile, the maximum power densities for the DBFCs using the Pt/NPC-650, Pt/NPC-800, Pt/NPC-900 and Pt/XC-72 anode at 20 °C are approximately 18.21 mW cm⁻², 40.29 mW cm⁻², 57.38 mW cm⁻², 34.12 mW cm⁻², respectively, as shown in Fig. 2 (b), and it is evident that the DBFC using Pt/NPC-900 anode catalyst has the best performance.

Conclusion

We have successfully prepared NPCs with high surface area and large pore volume through carbonization of MOF-5 with FA as the carbon source, and the resulted NPCs have been employed to support Pt nanoparticles as anode electrocatalysts for DBFC. The Pt/NPC-900 and Pt/NPC-800 electrocatalysts show superior electrocatalytic activity for borohydride oxidation, in comparison to Pt/XC-72 nanoparticles.

Therefore, the NPC-900 is a good alternative catalyst support for electrode catalysts in DBFC.

Reference


Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (Grant No. 51072713), Doctoral Fund of Ministry of Education of China (Grant No. 20094301110085), and Key project of Education Department of Hunan Province (Grant No. 11A118).