

Improvement of Direct Methanol Fuel Cell Performance Using Novel PtRu Nanowire Network as an Anode Material

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Introduction

Replication has been the mainstay for molding a novel material which is synthesized on various length and shape using a removable template. Especially, considering that the various ordered molecular sieves have been emerged and are expected to come out, it is possible to synthesize new types of nanostructured metals which are potentially useful in future catalysis, quantum-electronic devices and electrochemical sensing. Recently, metal replica prepared using highly ordered silica have been reported. However, these were single metal structures synthesized from single precursor of Pt, Au or Ag and the detailed application has not been reported yet, except for imaging the channels in mesoporous molecular sieves. We here report the synthesis of PtRu nanowire network made from SBA-15 template and show that this novel material can be used as a good electrocatalyst for enhancing the performance of direct-methanol fuel cell (DMFC).

Results and Discussion

As shown in Fig. 1(a), the prepared silica template gives an XRD pattern of highly ordered SBA-15 sample having a hexagonal structure. And XRD pattern shown in Fig. 1(b) indicates that the mesoscopic ordering of SBA-15 was maintained after H₂ reduction of (NH₃)₄Pt(NO₃)₂ and (NH₃)₆RuCl₃ inside SBA-15 structure with the observation of low angle peaks of (100), (110) and (200) reflections. There are no significant structure changes in the silica templates after metal loading, except for the decrease in peak intensity. However, XRD pattern of template-free PtRu nanowire network in Fig. 1(c) only shows the (100) reflection, because Pt/Ru did not fill the entire pore volume of SBA-15 and the synthesized PtRu nanowire is not long enough to show the whole negatives of the template.

Pt nanowire network was also synthesized in the same manner. The lattice parameters for the Pt and PtRu nanowire networks are 3.9204 Å and 3.9166 Å, respectively. These are nearly in good agreement with the available literature which reported the values on composition in atomic % and lattice parameters for PtRu alloy specimens [1]. However, considering that PtRu nanowire network has an atomic ratio (Pt/Ru) of 4.3 which was confirmed by ICP result, the atomic fraction of Ru alloyed with Pt is 46 % and the remaining Ru atoms are present as hcp phase.

Transmission electron microscopy (TEM) was used to image the nanowire network. The length of nanowires varies from 50 to 150 nm and are not scattered. Considering the samples for TEM images were prepared after sonicating a small amount of the

material in ethanol and there were no residual silica template, which were confirmed by EDX and XPS data, it can be known that three-dimensional PtRu nanowires with uniform diameter were prepared using SBA-15 template. The length of nanowires which are interconnected each other can be controlled with the amount of metal-loading and the temperature-increasing rate during the thermal reduction procedure.

We here report an enhanced performance of the PtRu nanowire network as an anode material in DMFC. As shown in Fig. 2, current-voltage curve of DMFC using PtRu nanowire network as an anode catalyst is compared with that of DMFC using unsupported PtRu black (J.M., Hispec 6000). PtRu nanowire network gives a DMFC performance higher than commercial PtRu black catalyst. Considering the BET surface areas of PtRu nanowire network and commercial PtRu black are 31 and 78 m^2/g , respectively, it can be concluded that PtRu nanowire network shows the much higher performance even though the intrinsic surface area of the electrocatalyst does not seem to be a dominant factor in determining relative DMFC performance. The relative anode performance depends strongly on the generation, surface diffusion, and the spillover of proton. And the electrical conductivity of the catalyst layer and mass transport of methanol/water and CO_2 through anode layer also influence the anode performance. The anode performance of DMFC should be highly dependent on the grain size, texture, and morphology of the electrode materials.

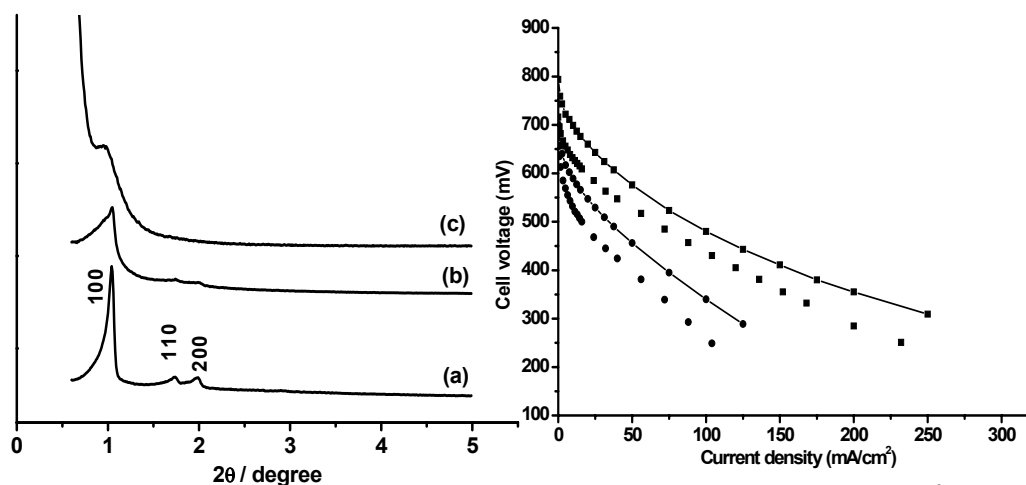


Fig. 1. XRD patterns of (a) SBA-15 silica, (b) PtRu/SBA-15 composite and (c) template-free PtRu nanowire network.

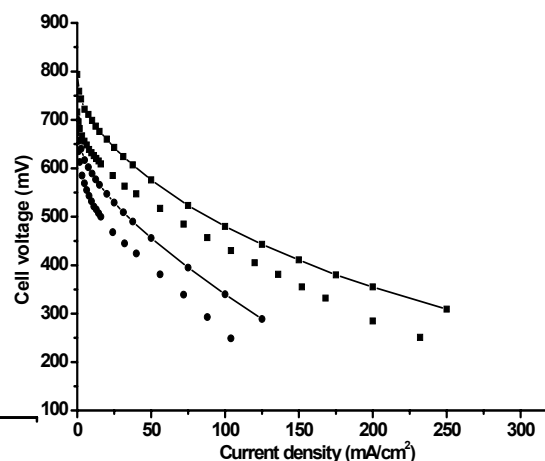


Fig. 2. DMFC I-V curves at 40°C (circles) and 80°C (squares) comparing the performance of PtRu nanowire network (connected data point) with that of J.M. PtRu (unconnected data point) catalyst.

References

- [1] H. A. Gasteiger, P. N. Ross, Jr. and E. J. Cairns, *Surf. Sci.*, 293 (1993) 67.