

NANO-DISPERSION OF THIN CARBON NANOFIBERS FOR ENHANCING THE PERFORMANCE OF DMFC ANODE CATALYSTS

Mun-Suk Jun, Seong-Hwa Hong, Masaharu Tsuji, Isao Mochida, Seong-Ho Yoon, Institute for Materials and Chemistry and Engineering, Kyushu University, Kasuga, Fukuoka 816-8580, Japan

ABSTRACT

The performance of DMFC anode catalyst supported on very thin carbon nanofiber (CNF) was investigated through the half cell and single cell tests. Enhanced dispersion of thin CNFs using nano-dispersion apparatus (Primix Corporation., Filmix) can afford the increase the effective surface for supporting the catalyst, achieving around 1.5 times increasing of catalytic performance with 40wt% PtRu/CNF catalyst compared to commercial 60% of Johnson Matthey PtRu catalyst. The well dispersion of thin CNF was proved to be a key prerequisite to improve the anodic performance of DMFC catalyst.

INTRODUCTION

DMFC has attracted much attention for its potential application as clean mobile power source in near future. Carbon is the most widely used materials as the support for fuel cell catalyst (1).

Generally, CNFs show an excellent electric conductivity, relatively high surface area, electrochemical stability, and controllable various structures such as diameter, surface, and texture for applications of catalyst supports, catalysts, composites and materials for energy storage.

In the present study, the authors have tried to develop the potential use of very thin carbon nanofibers as an anodic catalyst supporting materials. The five thin-CNFs, which were selectively prepared in our laboratory, were classified with structural features. The performances of 40%Pt-Ru/CNFs catalysts were exactly examined with self-designed single cell tester.

EXPERIMENTAL

Five CNFs in this study were selectively prepared in our laboratory through thermal catalytic pyrolysis of CO, ethylene, or methane on the various metal combinations of Fe, Cu, Ni, Mg at 450 – 550°C under the optimistic conditions. Obtained thin CNFs were dispersed using nano-dispersion apparatus (Primix Corporation., Filmix) for the reducing entangled structures of fibers with impeller agitation of 16500 rpm for 30 minutes. The PtRu catalysts controlled for containing 40wt % of PtRu with an atomic ratio of 1:1 by NaBH₄ reduction. Single cell performance of the resultant catalysts was compared with Johnson Matthey 60wt% (Pt: 2, Ru: 1, and Carbon: 2mg/cm²) catalyst. PtRu/CNF catalyst (Pt:1.33, Ru:0.67, and

CNF:3mg/cm²) and Pt catalyst (7mg/cm², Johnson Matthey, Hispec1000) were applied to the anode and cathode, respectively. All electrodes were prepared by brushing method on carbon paper. The Nafion ionomer content in catalyst layer was controlled in weight compositions of 20wt% for anode and 7wt% for cathode. A pair of electrodes (a cathode and an anode) was hot-pressed on both sides into the polymer electrolyte membrane (MEA) with Nafion 115 at a temperature of 135°C and with a pressure of 100kg/cm² for 10min. Current-Voltage curve was recorded by single cell test at a flow rate of 2ml/min in 2M methanol and at 200ml/min pure oxygen at 30°C, 60°C, and 90°C, respectively.

RESULTS AND DISCUSSION

Figure 1 and Figure 2 show the SEM and TEM images of the thin-CNFs, respectively: (a) FMM (FeMo/MgO catalyst), (b) CM (Co/MgO catalyst), (c) NM (Ni/MgO catalyst), (d) NFM (NiFe/MgO catalyst), (e) NMM (NiMo/MgO catalyst). The average diameters of (a) FMM, (b) CM, (c) NM, (d) NFM, (e) NMM were (a) 5-15nm, (b) 7-20nm, (c) 10-60nm, (d) 20-50nm, (e) 10-50nm, respectively.

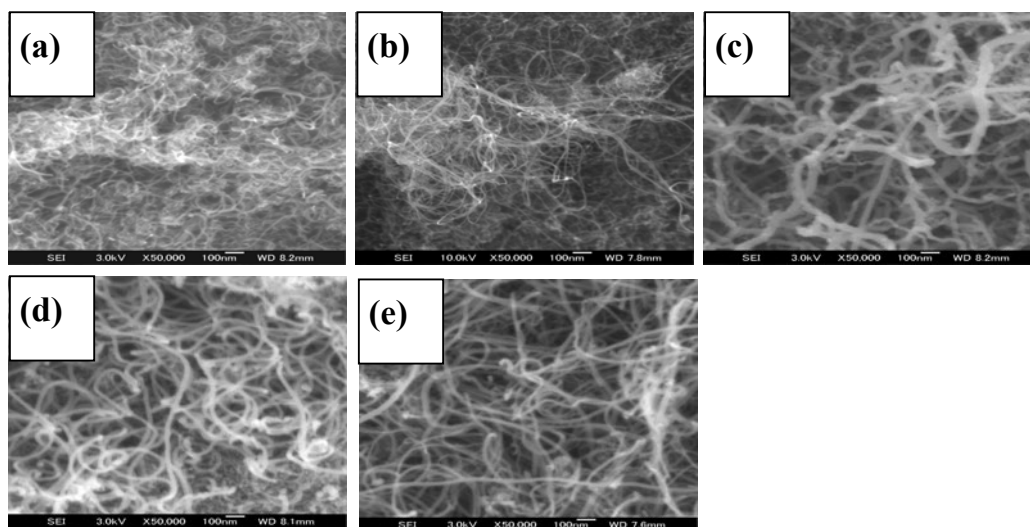


Figure 1. SEM photographs of thin-CNFs: (a) FMM, (b) CM, (c) NM, (d) NFM, (e) NMM.

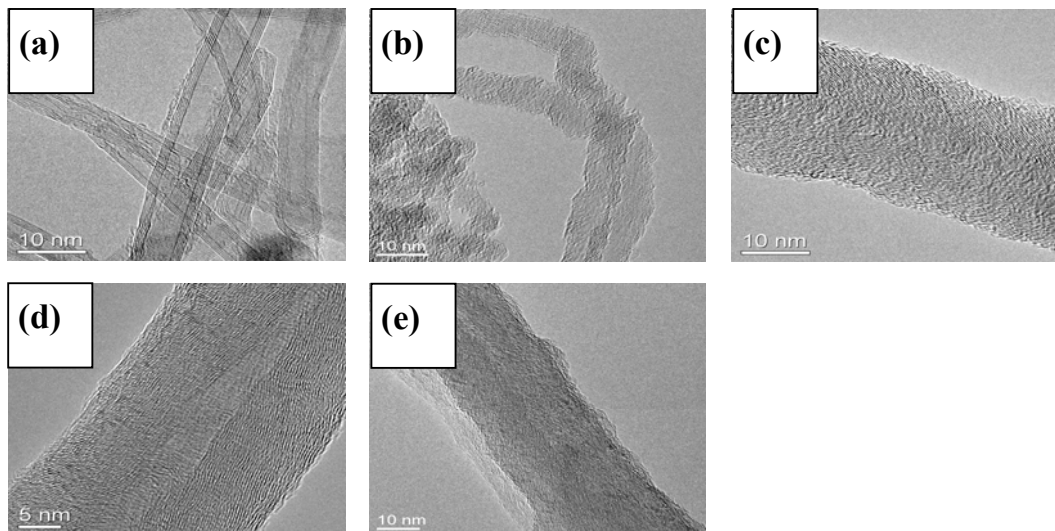
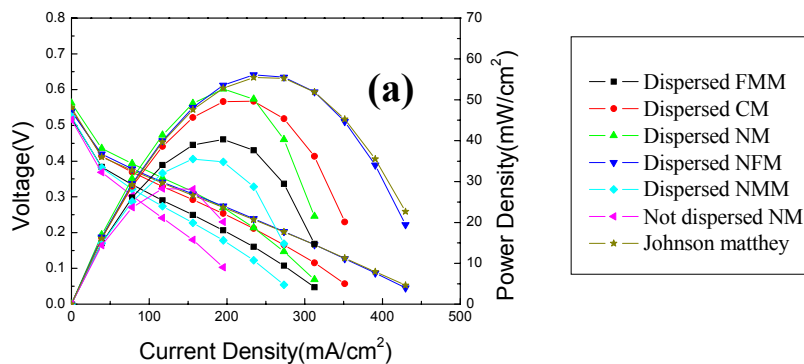


Figure 2. TEM photographs of thin-CNFs: (a) FMM, (b) CM, (c) NM, (d) NFM, (e) NMM.

FMM showed four walled tubular structure (Figure 2-(a)). CM also showed the herringbone-tubular structure (Figure 2-(b)). NM, NFM, and NMM showed the herringbone structures with different average diameters (Figure 2-(c, d, and e)). Surfaces of FMM and CM were covered mainly with basal planes. However, the surfaces of NM, NFM, and NMM showed edge rich states under TEM images.

Figure 3 shows single cell performances of 40wt% PtRu catalysts supported on thin CNFs and 60wt% PtRu of Johnson Matthey catalyst. The NM-based catalyst after dispersion treatment showed superior maximum power density as 52, 108, and 182 mW/cm^2 than that of not-dispersed one as 28, 81, and 97 mW/cm^2 at 30, 60, and 90°C, respectively. NFM-based catalyst showed the highest maximum powder density as 56, 118, 184 mW/cm^2 at 30, 60, and 90°C, respectively. In comparison, 60wt% Pt-Ru of Johnson Matthey catalyst showed almost same maximum powder density as 55, 121, 162 mW/cm^2 at 30, 60, and 90°C, respectively, with NFM-based catalyst.



(b)

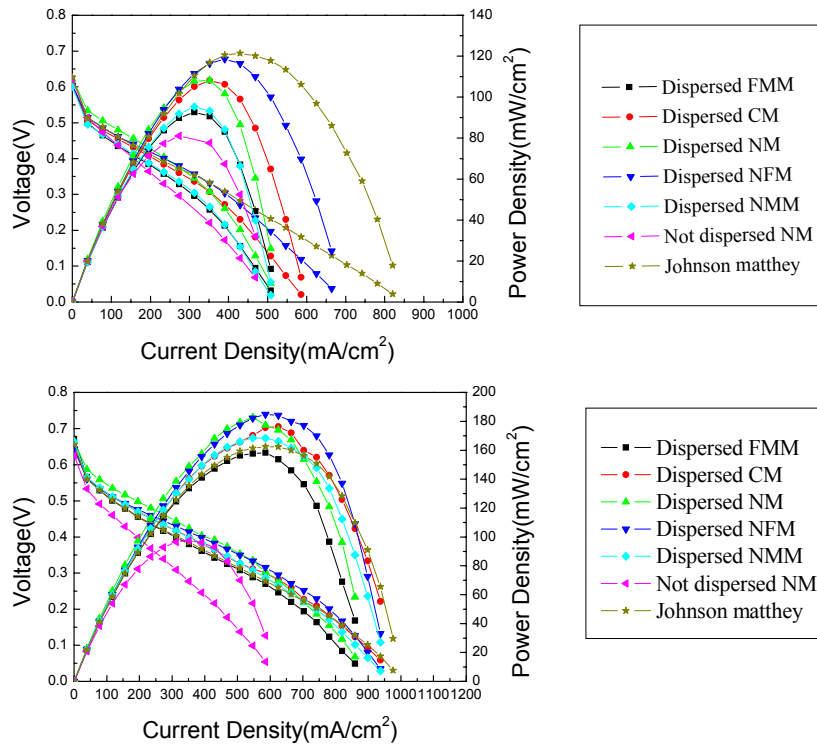
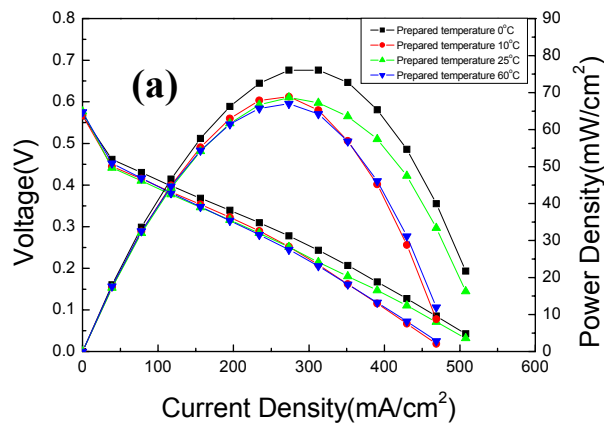


Figure 3. Single cell performance of catalyst supported on various thin CNFs examined at (a) 30°C, (b) 60°C, and (c) 90°C.

Figure 4 showed single cell performances of NFM-based catalyst prepared at different NaBH₄ reduction temperatures. The best performance was obtained at the catalyst prepared at 0°C as the maximum power density of 76, 140, 246 mW/cm² at 30, 60, and 90°C, respectively.



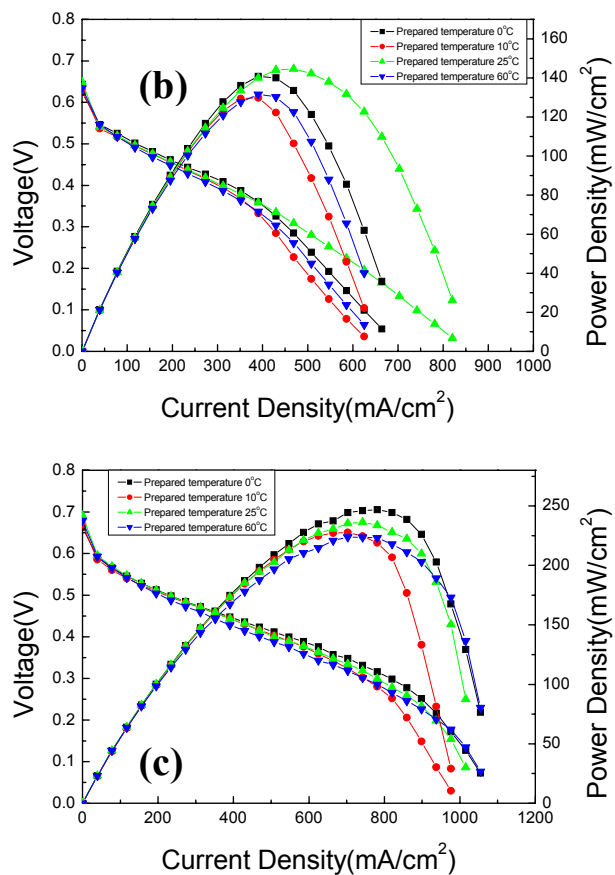


Figure 4. Single cell performance of catalyst supported on NFM examined at (a) 30°C, (b) 60°C, and (c) 90°C.

CONCLUSION

First of all, thin-CNFs were very effective to afford larger active surface for PtRu supporting compared to carbon blacks or other carbons. However, the better dispersion for reducing entangled structures of thin CNF was prerequisite for obtaining high active surface because non-dispersed thin CNF showed very low performance. The performance of resultant catalyst was astonishingly improved after dispersion of thin CNFs.

The supporting temperature of PtRu catalyst was one of the important factors to govern the activity of resultant catalyst. As for the thin CNFs, the lower temperature, the more effective is. The retardation of initiation and growth of PtRu particles might be a proper reason for improving the performance of the catalyst. The 40wt% PtRu (Pt:1.33, Ru:0.67, and CNF:3mg/cm²) of thin CNF-based catalyst showed superior performance than that of the commercial 60wt% (Pt:2, Ru:1, and Carbon:2mg/cm²) catalyst.

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