Supporting Information for

Hydroxyl Group on the Activity and Durability of Supported Carbon-TiO_2 for the Proton Exchange Membrane Fuel Cells

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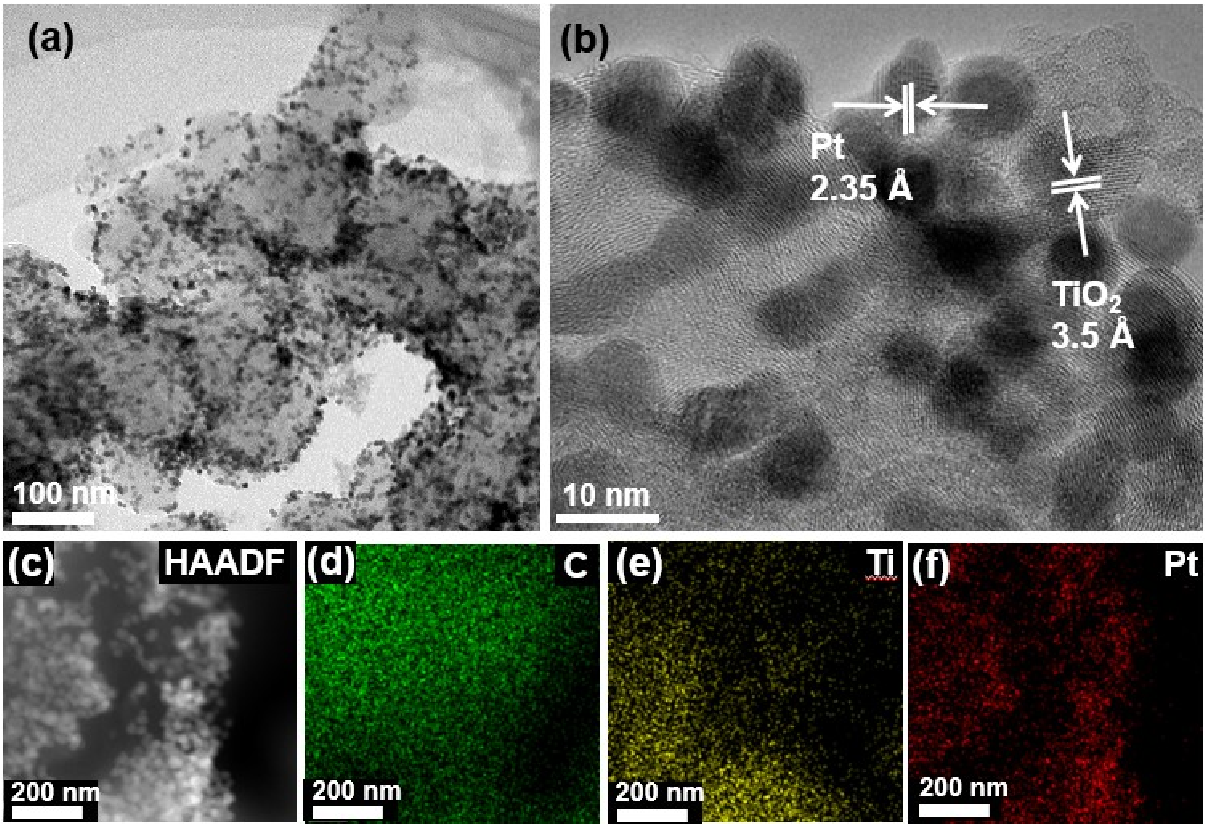

Figure S1. (a) TEM image of TiO_2-Pt/SC-H. (b) HRTEM image of a Pt particle on TiO_2-carbon. (c) HADDF-STEM image and (d-f) corresponding EDS elemental mapping images of TiO_2-Pt/SC-H.

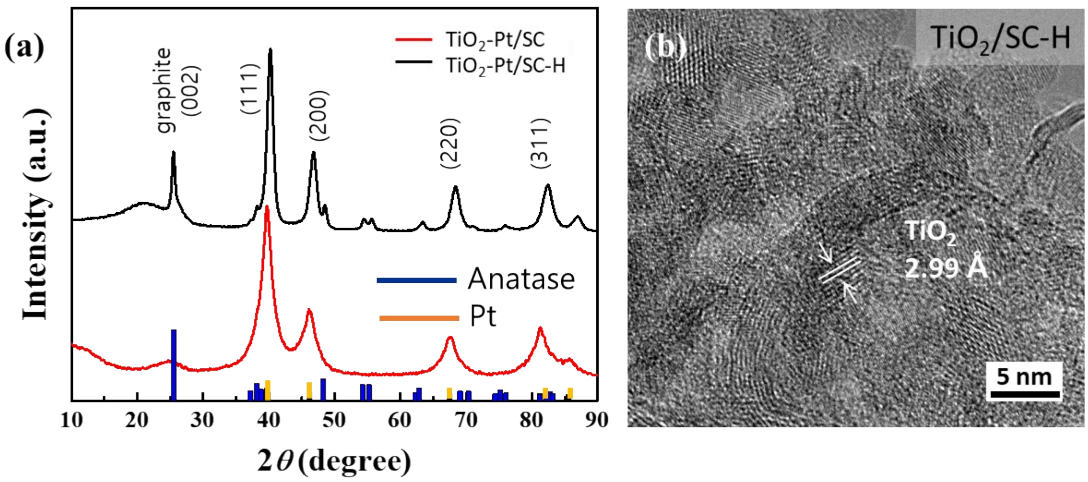

Figure S2. (a) XRD patterns and (b) TEM of TiO_2-Pt/SC-H TEM images.

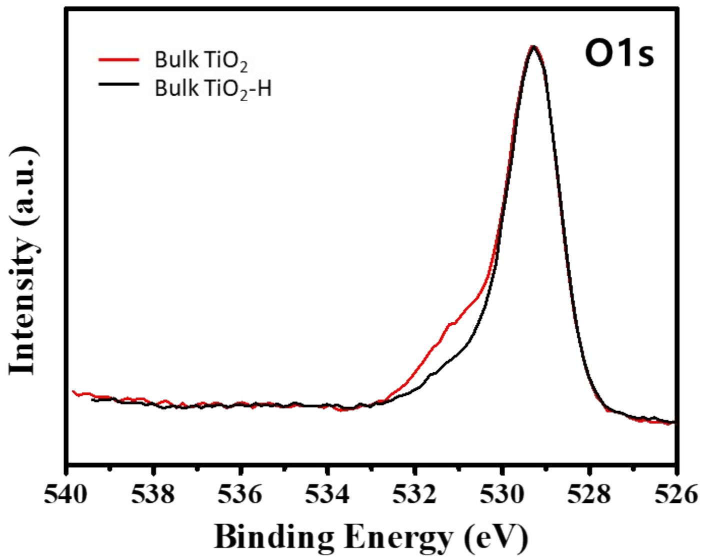

Figure S3. XPS profiles in O1s region for bulk TiO_2 and anatase TiO_2-H.

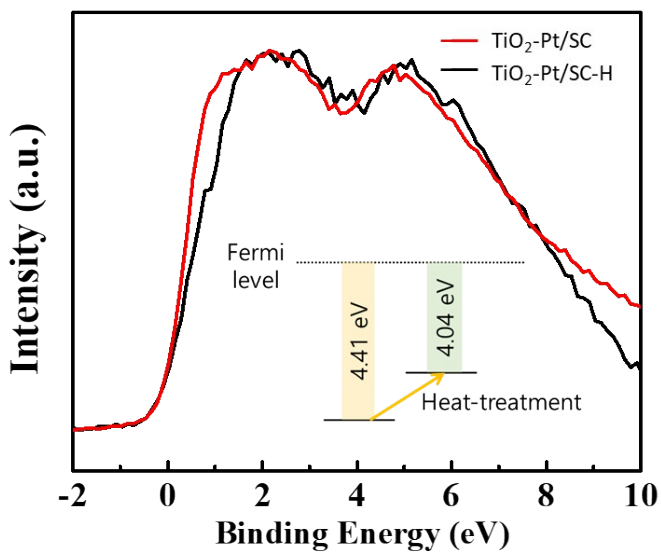

Figure S4. XPS profiles in the valence band region for TiO_2-Pt/SC and TiO_2-Pt/SC-H. The d-band center is calculated by below equation:[1]

$$d - bnad\ center\ =\ -\int_{0eV}^{10eV}[Binding\ energy\ (E) \times Intensity\ (E)]dE / \int_{0eV}^{10eV} Intensity\ (E)dE$$

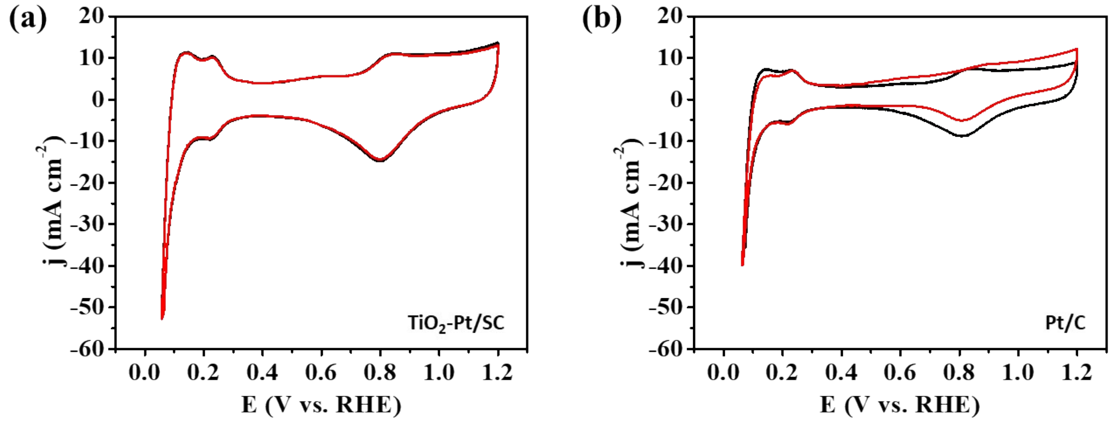

Figure S5. CV curves of MEAs before and after ADT at 70 °C of TiO_2-Pt/SC(a) and commercial Pt/C(b).

Table S1. Comparison of electrocatalytic activities of various catalysts for ORR in acid media

Catalysts	Electrolyte condition	Activity (mA cm^{-2}) 0.9 V	Scan rate	Ref.
TiO_2–Pt/SC	0.1 M $HClO_4$	**1.64**	10 mV s^{-1}	**This work**
Pt SACs	0.1 M $HClO_4$	0.51	10 mV s^{-1}	[1]
Pt/MU-MWCNT	0.1 M $HClO_4$	0.168	10 mV s^{-1}	[2]
Pt/SnO_2/C	0.1 M $HClO_4$	1.12	10 mV s^{-1}	[3]
Pt/$Ti_{0.9}Ni_{0.1}N$ NTs	0.1 M $HClO_4$	1.3	10 mV s^{-1}	[4]
CrePtFe/C	0.1 M $HClO_4$	0.55	10 mV s^{-1}	[5]
CuePtTe NTs	0.1 M $HClO_4$	0.658	10 mV s^{-1}	[6]
Pd@Pt/NPs	0.1 M $HClO_4$	0.297	10 mV s^{-1}	[7]
Pt/C@NGC	0.1 M $HClO_4$	0.308	10 mV s^{-1}	[8]
PtNi-OLEA-Aged/C	0.1 M $HClO_4$	1.39	10 mV s^{-1}	[9]
Pt-Ni@PtD/G	0.1 M $HClO_4$	0.098	10 mV s^{-1}	[10]

1. Z.Song, Y. N. Zhu, H. Liu, M. N. Banis, L. Zhang, J. Li, X. Sun, Engineering the low coordinated Pt single atom to achieve the superior electrocatalytic performance toward oxygen reduction, *Small,* 2020, **16**, 2003096.

2. Q. Shu, Z. Xia, W. Wei, X. Xu, R. Sun, R. Deng, G. Sun, Controllable unzipping of carbon nanotubes as advanced Pt catalyst supports for oxygen reduction, *ACS Appl Energy Mate.,* 2019, **2**, 5446-5455.

3. K. Zhang, C. Feng, B. He, H. Dong, W. Dai, H. Lu, X. Zhang, An advanced electrocatalyst of Pt decorated SnO_2/C nanofibers for oxygen reduction reaction, *J. Electroanal. Chem.,* 2016, **781**, 198.

4. H. Nan, D. Dang, X. L. Tian, Structural engineering of robust titanium nitride as effective platinum support for the oxygen reduction reaction. *J. Mater. Chem. A,* 2018**, 6**, 6065.

5. Y. Cai, P. Gao, F. Wang, H. Zhu, Surface tuning of carbon supported chemically ordered nanoparticles for promoting their catalysis toward the oxygen reduction reaction. *Electrochi. Acta,* 2017, **246**, 671.

6. M. Dong, H. Chen, J. Xu, Z. Chen, J. Cao, Synthesis of Cu-decorated PtTe nanotubes with high electrocatalytic activity for oxygen reduction. *J. Alloys. Compd.,* 2019, **770**, 76.

7. Y. Hashiguchi, F. Watanabe, T. Honma, I. Nakamura, S. S. Poly, T. Kawaguchi, T. Fujitani, Continuous-flow synthesis of Pd@ Pt core-shell nanoparticles. *Colloids. Surf. A Physicochem. Eng. Asp.,* 2021, **620**, 126607.

8. Y. Nie, J. Deng, S. Chen, Z. Wei, Promoting stability and activity of PtNi/C for oxygen reduction reaction via polyaniline-confined space annealing strategy. *International Journal of Hydrogen Energy* 2019, **44**, 5921.

9. G. M. Leteba, Y. C. Wang, T. J. Slater, R. Cai, C. Byrne, C. P. Race, C. I. Lang, Oleylamine aging of PtNi nanoparticles giving enhanced functionality for the oxygen reduction reaction. *Nano Lett.,* 2021, **21**, 3989.

10. X. Lyu, Y. Jia, X. Mao, D. Li, G. Li, L. Zhuang, X. Yao, Gradient-concentration design of stable core–shell nanostructure for acidic oxygen reduction electrocatalysis. *Adv. Mater.*, 2020, **32**, 2003493.

Table 2.

Sample	OCV (V)	MPD (W/cm^2)	Current density (A/cm^2) at 0.8 V	Power density (W/cm^2) at 0.8 V	Current density (A/cm^2) at 0.6 V	Power density (W/cm^2) at 0.6 V	ECSA Loss (1.23 V, 1 h)	MPD Loss (1.23 V,1 h)
initial	1.0	1.076	0.279	0.222	1.519	0.913	6.41 %	2.42 %
After	0.978	1.05	0.199	0.159	1.359	0.818		
initial	0.95	1.009	0.282	0.227	1.522	0.931	29.86 %	10.31 %
After	0.926	0.905	0.242	0.193	1.362	0.817		

Reference

[1] G.V. Ramesh, R. Kodiyath, T. Tanabe, M. Manikandan, T. Fujita, F. Matsumoto, S. Ishihara, S. Ueda, Y. Yamashita, K. Ariga, $NbPt_3$ intermetallic nanoparticles: highly stable and CO-tolerant electrocatalyst for fuel oxidation, *ChemElectroChem* **2014**, 1, 728-732.