Supporting Information for *Acta Phys. -Chim. Sin.* doi: 10.3866/PKU.WHXB202009103

具有经济性的碱性膜燃料电池氢气氧化反应催化剂

薛延荣[1]，王兴栋[1]，张向前[1]，方锦杰[1,2]，许志远[1,2]，张宇烽[1]，刘雪瑞[1,2]，刘梦园[1]，朱威[1]，庄仲滨[1,2,3,*]

[1]有机无机复合材料国家重点实验室，北京化工大学，北京 100029

[2]北京软物质科学与工程高精尖创新中心，北京化工大学，北京 100029

[3]能源环境催化北京市重点实验室，北京化工大学，北京 100029

Cost-Effective Hydrogen Oxidation Reaction Catalysts for Hydroxide Exchange Membrane Fuel Cells

Yanrong Xue [1], Xingdong Wang [1], Xiangqian Zhang [1], Jinjie Fang [1,2], Zhiyuan Xu [1,2], Yufeng Zhang [1], Xuerui Liu [1,2], Mengyuan Liu [1], Wei Zhu [1], Zhongbin Zhuang [1,2,3,*]

[1] State Key Lab of Organic-Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China.

[2] Beijing Advanced Innovation Center for Soft Matter Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China.

[3] Beijing Key Laboratory of Energy Environmental Catalysis, Beijing University of Chemical Technology, Beijing 100029, China.

[*]Corresponding author. Email: zhuangzb@mail.buct.edu.cn Tel.: +86-10-6443-4780.

Table S1 Summary of the HEMFC performances.

	Catalyst	Catalyst loading ($mg \cdot cm^{-2}$)	Membrane	T_{Cell} (°C)	Back pressure (kPag)	PPD for H_2/O_2 ($W \cdot cm^{-2}$)	PPD for H_2/Air ($W \cdot cm^{-2}$)	Ref.
anode	PtRu/C	0.7	BCP of PNB	80	Not given	3.37		1
cathode	Pt/C	0.6			Not given			
anode	PtRu/C	0.2	PAP-TP-85	95	250	1.58	1.0	2
cathode	Pt/C	0.4			250			
anode	PtRu/C	0.6	PAP-TP-85	95.5	150	1.89	1.31	3
cathode	Pt/C	0.4			250			
anode	PtRu/C	0.4	QAPPT	80	200	2.08		4
cathode	Pt/C	0.4			200			
anode	Pt/C	1.25	ETFE-g-VBCTMA	60	0	0.67	0.59	5
cathode	Pt/C	1.25			0			
anode	Pt/C	0.4	QAPPT	80	200	1.92		4
cathode	Pt/C	0.4			200			
anode	Pt/C	0.4	PAP-TP-85	95.5	150	1.52		3
cathode	Pt/C	0.4			250			
anode	Pt/C	0.45	Acta S.p.A.'s	50	0		0.4	6
cathode	Pt/C	0.45	membrane		0			
anode	Pd-CeO_2/C	0.25	ETFE-BTMA	80	0	1.4		7
cathode	Pt/C	0.4	membrane		0			
anode	Pd-CeO_2/C	0.42[a]	ETFE-BTMA	70	200	1		8
cathode	PdCu/C	0.58[a]	membrane		100			
anode	Pd/C-CeO_2	0.3	CellEra's membrane	73	300		0.5	9
cathode	Ag/C	3.0			100			
anode	Pd/C	0.3	CellEra's membrane	73	300		0.1	9
cathode	Ag/C	3.0			100			
anode	Pd/Ni	0.3	CellEra's membrane	73	300		0.4	10
cathode	Ag/C	3.0			100			
anode	IrRu NWs	0.1	TMA-SEBS-OH	60	100	0.485		11
cathode	Pt/C	0.3			100			
anode	IrNi@PdIr/C	0.1	A201 Tokuyama	60	0	0.31		12
cathode	Pt/C	0.3			0			
anode	$Pd_{0.33}Ir_{0.67}$/N-C	0.2	QASEBS	79	100	0.514		13
cathode	Pt/C	0.3			100			
anode	Ru/C	0.5	A201 Tokuyama	50	0	0.25		14
cathode	Pt/C	0.5			0			
anode	Ru/C	0.1	QAPPT	80	100	0.76		15
cathode	Pt/C	0.45			100			
anode	Ru/Meso C	0.1	QAPPT	80	100	1.02		15
cathode	Pt/C	0.45			100			
anode	RuPdIr/C	0.2	POCellTech's	80	100	0.95		16
cathode	AgPd	1	membrane		100			
anode	Ru_7Ni_3/C	0.2	PAP-TP-85	95	250	2.03	1.23	2
cathode	Pt/C	0.4			250			
anode	Rh/C	0.5	A201 Tokuyama	50	0	0.05		14
cathode	Pt/C	0.5			0			
anode	Ag/C	0.5	A201 Tokuyama	50	0	0.002		14
cathode	Pt/C	0.5			0			
anode	Ni/C	5.0	TPQPOH152 membrane	70	250	0.076		17
cathode	Ag/C	0.5			250			
anode	NiCr	5.0	QAPS membrane	60	130	0.05		18
cathode	Ag/C	1.0			130			

anode	NiW	17.5	xQAPS	60	0	0.04	0.028	19
cathode	CoPPY/C	2.0			0			
anode	NiMo/KB	4.0	A201 Tokuyama	70	138	0.12		20
cathode	Pd/C	0.2			138			
anode	NiCu/KB	4	Tokuyama's	80	138	0.35		21
cathode	Pd/XC-72R	0.2	membranes		138			

[a]: These are Pd based loadings.

References

(1) Huang G.; Mandal, M.; Peng, X.; Yang-Neyerlin, A, C.; Pivovar, B, S.; Mustain, W, E.; Kohl, P, A. *J. Electrochem. Soc.* **2019,** *166*, F637. doi: 10.1149/2.1301910jes

(2) Xue, Y.; Shi, L.; Liu, X.; Fang, J.; Wang, X.; Setzler, B, P.; Zhu, W.; Yan, Y.; Zhuang Z. *Nat. Commun.* **2020,** *11*, 5651. doi: 10.1038/s41467-020-19413-5

(3) Wang, T.; Shi, L.; Wang, J.; Zhao, Y.; Setzler, B, P.; Rojas-Carbonell, S.; Yan, Y. *J. Electrochem. Soc.* **2019,** *166*, F3305. doi: 10.1149/2.0361907jes

(4) Li, Q.; H. Peng H.; Wang, Y.; Li X.; Lu, J.; Zhuang, L. *Angew. Chem. Int. Ed.* **2018,** *58*, 1442. doi: org/10.1002/anie.201812662

(5) Omasta, T. J.; Wang, L.; Peng, X.; Lewis, C. A.; Varcoe, J. R.; Mustain, W. E. *J. Power Sources* **2018**, *375*, 205. doi: 10.1016/j.jpowsour.2017.05.006

(6) Piana, M.; Boccia, M.; Filpi, A.; Flammia, E.; Miller, H, A.; Orsini, M.; Salusti, F.; Santiccioli, S.; Ciardelli, F.; Pucci, A. *J. Power Sources* **2010,** *195*, 5875. doi: 10.1016/j.jpowsour.2009.12.085

(7) Bellini, M.; Pagliaro, M, V.; Lenarda, A.; Fornasiero, P.; Marelli, M.; Evangelisti, C.; Innocenti, M.; Jia, Q.; Mukerjee, S.; Jankovic, J. *ACS Appl. Energy Mater.* **2019,** *2*, 4999. doi: 10.1021/acsaem.9b00657

(8) Omasta, T. J.; Peng, X.; Miller, H, A.; Vizza, F.; Wang, L.; Varcoe, J, R.; Dekel, D, R.; Mustain, W, E. *J. Electrochem. Soc.* **2018,** *165*, J3039. doi: 10.1149/2.0071815jes

(9) Hamish A.; Miller, A. L. Vizza, F.; Marelli, M.; Di Benedetto, F.; D'Acapito, F.; Paska, Y.; Page, M.; Dekel, D, R. *Angew. Chem. Int. Ed.* **2016,** *55*, 6004. doi: 10.1002/ange.201600647

(10) Alesker, M.; Page, M.; Shviro, M.; Paska, Y.; Gershinsky, G.; Dekel, D, R.; Zitoun, D. *J. Power Sources* **2016,** *304*, 332. doi: 10.1016/j.jpowsour.2015.11.026

(11) Qin, B.; Yu, H.; Gao, X.; Yao, D.; Sun, X.; Song, W.; Yi, B.; Shao, Z. *J. Mater. Chem. A* **2018,** *6*, 20374. doi: 10.1039/c8ta07414c

(12) Qin, B.; Yu, H.; Jia, J.; Jun, C.; Gao, X.; Yao, D.; Sun, X.; Song, W.; Yi, B.; Shao, Z. *Nanoscale* **2018,** *10*, 4872. doi: 10.1039/c7nr09452c

(13) Cong, Y.; McCrum, I, T.; Gao, X.; Lv, Y.; Miao, S.; Shao, Z.; Yi, B.; Yu, H.; Janik, M, J.; Song, Y. *J. Mater. Chem. A* **2019,** *7*, 3161. doi: 10.1039/c8ta11019k

(14) Ohyama, J.; Sato, T.; Satsuma, A.; *J. Power Sources* **2013,** *225*, 311. doi: 10.1016/j.jpowsour.2012.10.051

(15) Zeng, L.; Peng, H.; Liu, W.; Yin, J.; Xiao, L.; Lu, J.; Zhuang, L. *J. Power Sources* **2020,** *461*, 228147. doi: 10.1016/j.jpowsour.2020.228147

(16) Tatus-Portnoy, Z.; Kitayev, A.; Vineesh, T, V.; Tal-Gutelmacherb, E.; Pageb, M.; Zitoun, D. *Chem. Commun.* **2020,** *10*, 36467. doi: 10.1039/D0CC00008F

(17) Gu, S.; Sheng, W.; Cai, R.; Alia, S.; M.; Song, S.; Jensen, K. O.; Yan, Y. *Chem. Commun.* **2013,** *49*, 131. doi: 10.1039/c2cc34862d

(18) Lu, S.; Pan, J.; Huang, A.; Zhuang, L.; Lu, J. *Proc. Natl. Acad. Sci. USA* **2008,** *105*, 20611. doi: 10.1073/pnas.0810041106

(19) Hu, Q.; Li, G.; Pan, J.; Tan, L.; Lu, J.; Zhuang, L. *Int. J. Hydrogen Energy* **2013,** *38*, 16264. doi: 10.1016/j.ijhydene.2013.09.125

(20) Kabir, S.; Lemire, K.; Artyushkova, K.; Roy, A.; Odgaard, M.; Schlueter, D.; Oshchepkov, A.; Bonnefont, A.; Savinova, E.; Sabarirajan, D, C. *et al. J. Mater. Chem. A* **2017,** *5*, 24433. doi: 10.1039/c7ta08718g

(21) Roy, A.; Talarposhti, M, R.; Normile, S, J.; Zenyuk, I, V.; De Andrade, V.; Artyushkova, K.; Serov, A.; Atanassov, P. *Sustain. Energy Fuels.* **2018,** *2*, 2268. doi: 10.1039/c8se00261d