

Electronic Supplementary Information for

A high-performance direct methanol fuel cell with a polymer fiber

membrane and RuO₂/CNTs as cathode catalyst

Li Wang, Yongning Liu,* Xiaodong Yang, Yuan Fang, Yuanzhen Chen and Beiping Wang

State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and
Engineering, Xi'an Jiaotong University, Xi'an 710049, PR China

* E-mail: ynliu@mail.xjtu.edu.cn;

Tel: +86-29-8266-4602 ; fax: +86-29-8266-3453

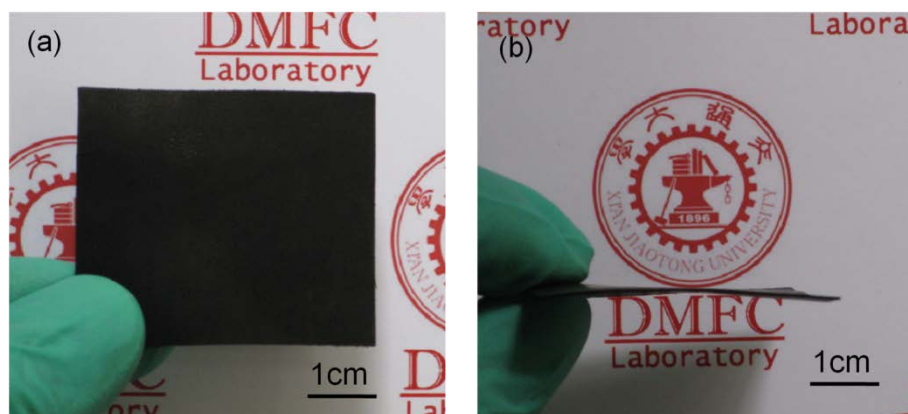


Fig. S1 Photographs of the gas diffusion layer.

PFM details:

The PFM is a wettable, resilient non-woven fabric with sufficient mechanical properties and sufficiently small pores. The fibers in the membrane are neutral and there are no polarity groups grafted on the main chains in fiber.^{S1} Its photographs are showed in Fig. S2 and the corresponding physical parameters are listed in Table S1.

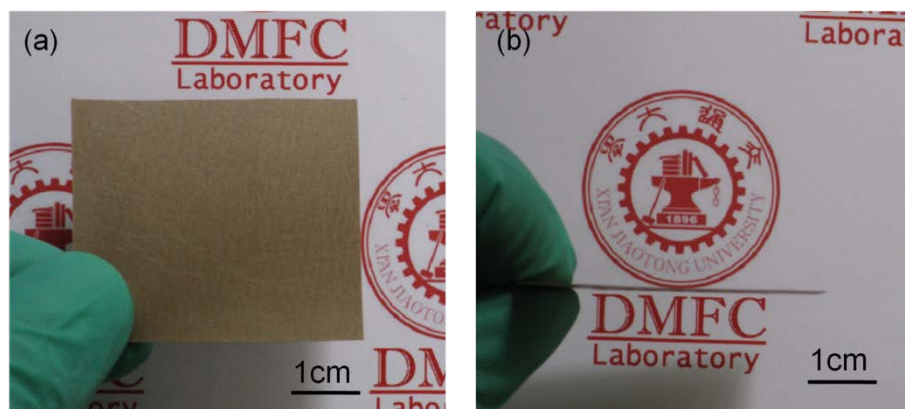


Fig. S2 Photographs of the PFM.

Table S1 The specification of PFM

Specification *	Units	Value
Basis weight	g/m ²	51.4
Thickness ¹	Microns	115.8
MD ² Tensile Strength	N/15mm	49.8
MD Elongation	%	12.4
Average pore size	Microns	9
Electrolyte holding ratio	%	144 (30% KOH)
Electrolyte wicking rate	mm/10min	72(30% KOH)
Air resistance	sec/100mL	5.0
S Content	%	0.88
Cost	US\$/m ²	3-4

** The information is provided by Nippon Kodoshi Corporation.*

¹/Thickness is measured with “Dead Weight Micrometer (ISO534)”.

²/MD = machine direction

Nafion-117 membrane details:

Table S2 The specification of Nafion-117

Specification [*]	Units	Value
Basis weight	g/m ²	360
Typical Thickness	Microns	183
MD ¹ Tensile Strength, maximum	MPa	43 (50% RH, 23°C)
MD Elongation at break	%	225 (50% RH, 23°C)
Water content ²	%	5
Water uptake ³	%	38
Conductivity	S/cm	0.083
Cost	US\$/m ²	790 ^{S2}

^{}The information is provided by DuPont Company.*

¹/MD = machine direction

²/Water content of membrane conditioned to 23°C, 50% relative humidity (RH), compared to dry weight basis.

³/Water uptake from dry membrane to water soaked at 100°C for 1 hour (dry weight basis).

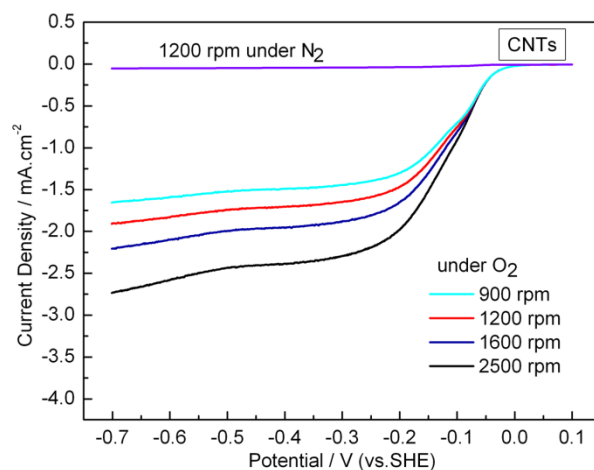


Fig. S3 Linear scan voltammograms for ORR on CNTs in N_2 - and O_2 -saturated 1M KOH solutions at different rotation rates, respectively. Scan rate: 5mV.s^{-1} .

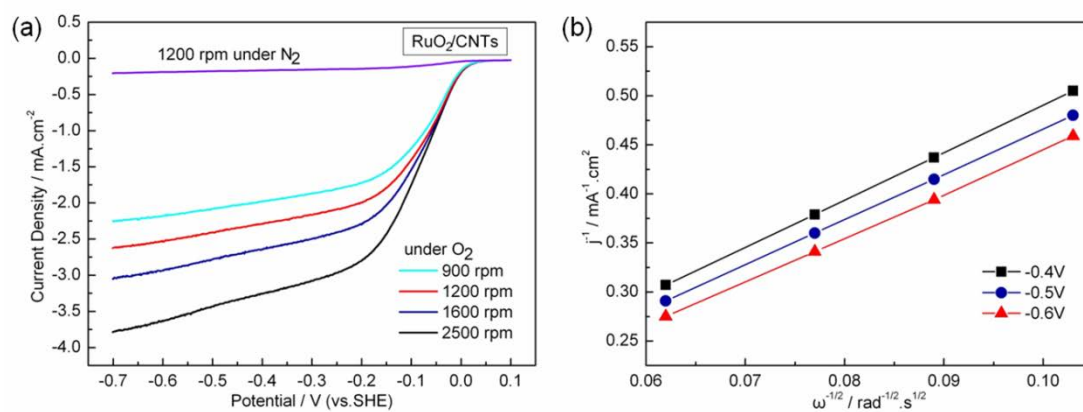


Fig. S4 (a) Linear scan voltammograms for ORR on RuO_2/CNTs catalyst in N_2 - and O_2 -saturated 1M KOH solutions at different rotation rates, respectively; (b) the corresponding Koutecky-Levich plots at different electrode potentials. Scan rate: 5mV.s^{-1} .

The O₂ reduction kinetics of RuO₂/CNTs:

Koutecky-Levich equation was used to analyze the kinetic parameters:^{S3}

$$\frac{1}{j} = \frac{1}{j_k} + \frac{1}{j_{diff}} = \frac{1}{j_k} + \frac{1}{B\omega^{1/2}}$$

Where

$$B = 0.62nFC_oD_o^{2/3}\nu^{-1/6}$$

here, j is the measured current density, j_k is the kinetic current density, j_{diff} is the diffusion limited current density, ω is the electrode rotation rate (rad.s⁻¹), n is the overall number of electrons transferred in O₂ reduction, F is Faraday constant (96500 C.mol⁻¹), C_o is the saturated concentration of O₂ in the electrolyte (0.843×10⁻⁶ mol.cm⁻³), D_o is the diffusion coefficient of O₂ in the solution (1.43×10⁻⁵ cm².s⁻¹), and ν is the kinematic viscosity of the electrolyte (0.01128 cm².s⁻¹).^{S4} In the j^{-1} versus $\omega^{-1/2}$ plot, the slope is $1/B$. Using the so-called B factor, the number of electrons transferred (n) can be obtained. By this method, we get the transferred electron number per O₂ on RuO₂/CNTs, $n=3.6$, which nearly approached the complete reduction of O₂ to OH⁻, a four-electron process.

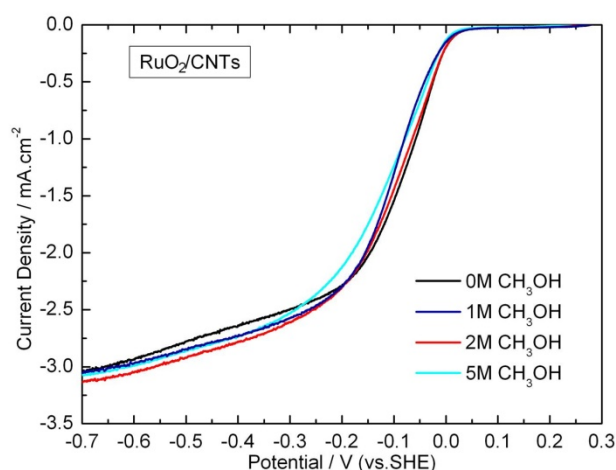


Fig. S5 Linear scan voltammograms for ORR on RuO₂/CNTs catalyst in O₂-saturated 1M

KOH electrolyte containing 0, 1, 2, and 5M methanol at a rotation rate of 1600 rpm. Scan rate:

$$5\text{mV.s}^{-1}.$$

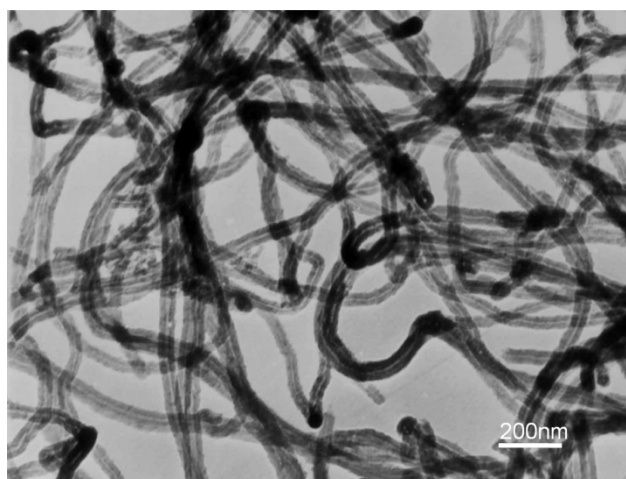


Fig. S6 TEM image of the CNTs.

References:

- S1 X. Yang, Y. Liu, S. Li, X. Wei, L. Wang and Y. Chen, *Sci. Rep.*, 2012, **2**,567; DOI: 10.1038/srep00567.
- S2 V. Neburchilov, J. Martin, H. Wang and J. Zhang, *J. Power Sources*, 2007, **169**, 221-238.
- S3 M.-R. Gao, Q. Gao, J. Jiang, C.-H. Cui, W.-T. Yao and S.-H. Yu, *Angew. Chem., Int. Edit.*, 2011, **123**, 5007-5010.
- S4 I. Roche, E. Chaînet, M. Chatenet and J. Vondrák, *J. Phys. Chem. C*, 2006, **111**, 1434-1443.