Electronic Supplementary Information

Polymer fiber membrane-based direct ethanol fuel cell with Ni-doped SnO$_2$ promoted Pd/C catalyst

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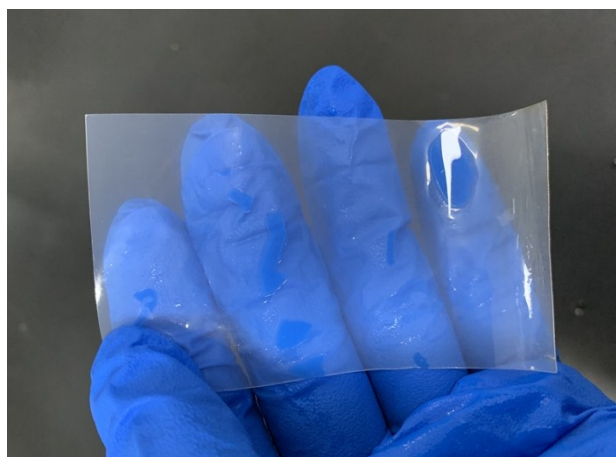
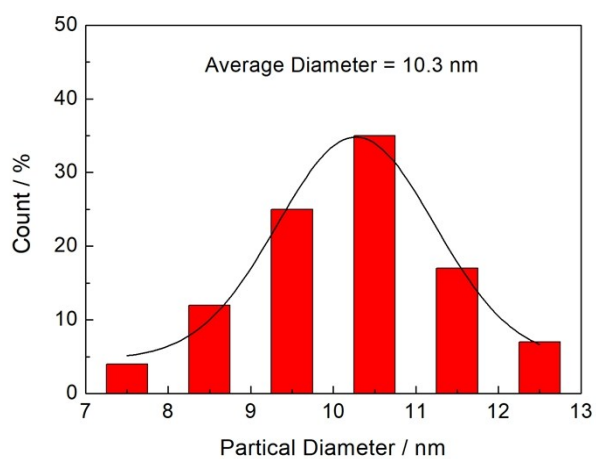**Fig. S1.** The image of the 'hm-e17270' anion-exchange membrane.

Fig. S2. Size histogram of SnO_2 nanoparticles (average diameter: 10.3 nm).
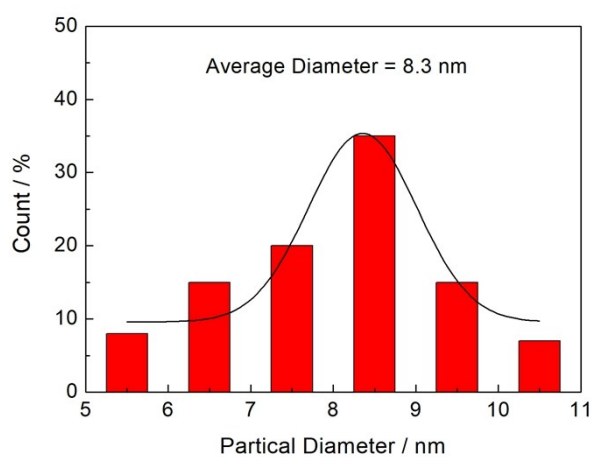

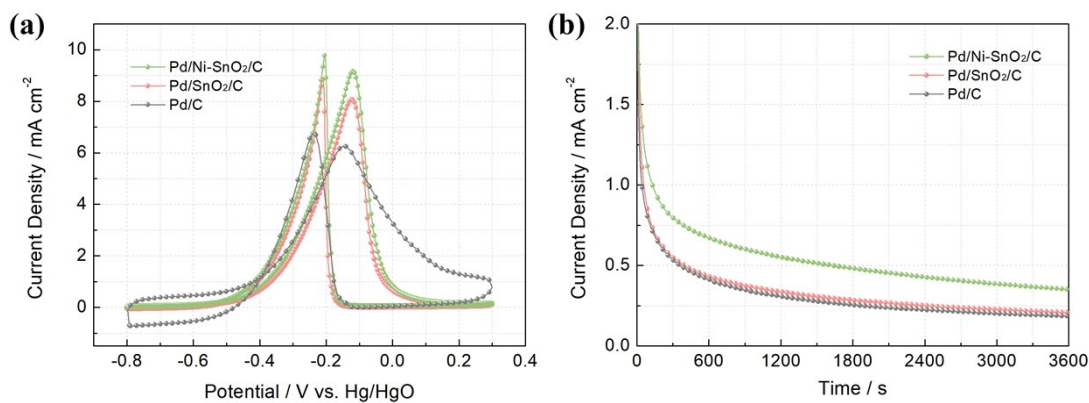**Fig. S3.** Size histogram of Ni-doped SnO_2 nanoparticles (average diameter: 8.3 nm).

Fig. S4. (a) CV and (b) CA curves of Pd/C, Pd/SnO$_2$/C and Pd/Ni-SnO$_2$/C catalysts in 1.0 M KOH and 1.0 M EtOH mixed solution (-0.8 to 0.3 V vs Hg/HgO, sweep rate 50 mV s^{-1}).
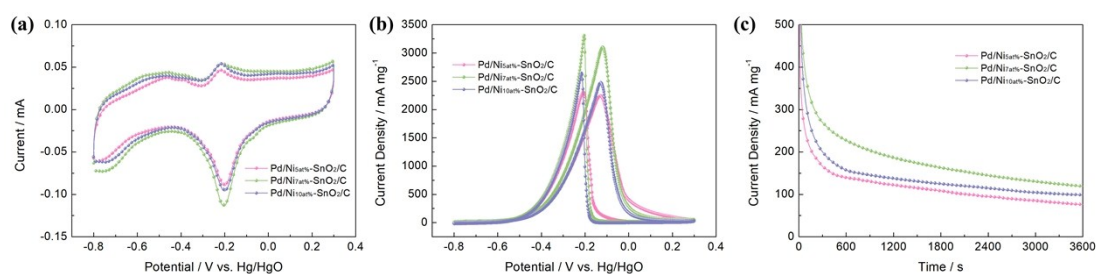

Fig. S5. (a) CV curves of Pd/Ni$_{5at\%}$-SnO$_2$/C, Pd/Ni$_{7at\%}$-SnO$_2$/C and Pd/Ni$_{10at\%}$-SnO$_2$/C catalysts in 1.0 M KOH solution. (b) CV and (c) CA curves of Pd/Ni$_{5at\%}$-SnO$_2$/C, Pd/Ni$_{7at\%}$-SnO$_2$/C and Pd/Ni$_{10at\%}$-SnO$_2$/C catalysts in 1.0 M KOH and 1.0 M EtOH mixed solution (-0.8 to 0.3 V vs Hg/HgO, sweep rate 50 mV s^{-1}).
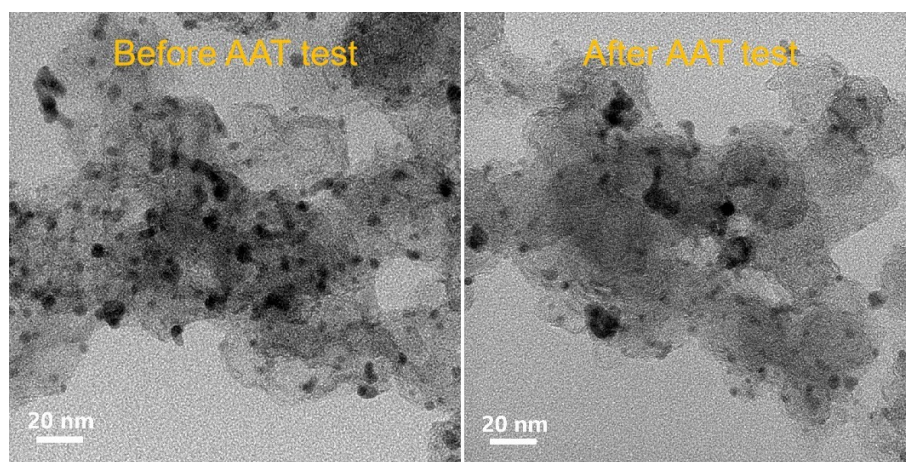

Fig. S6. A TEM image of Pd/Ni-SnO$_2$/C catalyst before and after the AAT test.
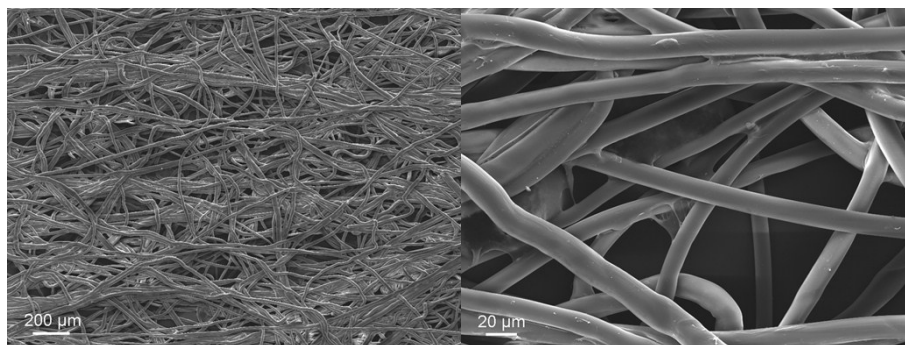
Fig. S7. SEM images of polymer fiber membrane.
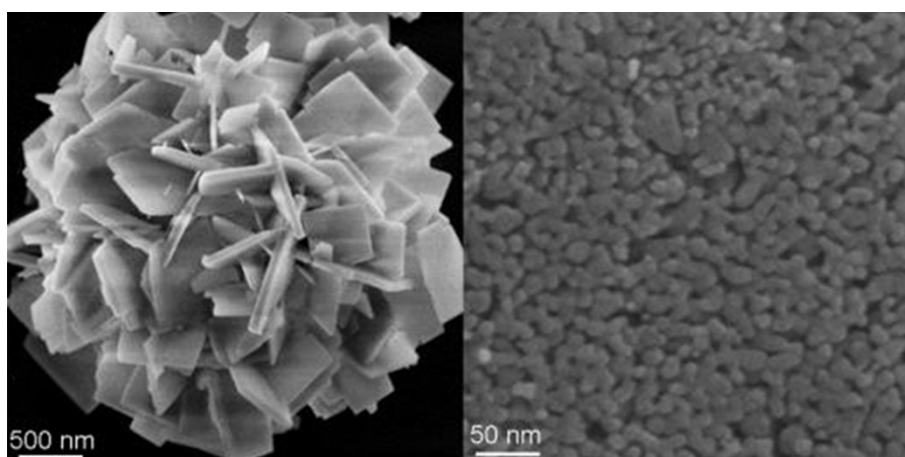

Fig. S8. SEM images of porous $NiCo_2O_4$ catalyst.
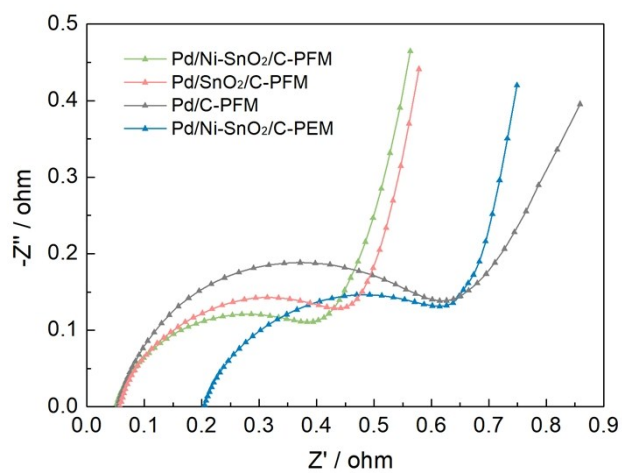

Fig. S9. Nyquist plots of the DEFCs with the Pd/C, $Pd/SnO_2/C$ and $Pd/Ni-SnO_2/C$ anode catalysts at 30 °C.
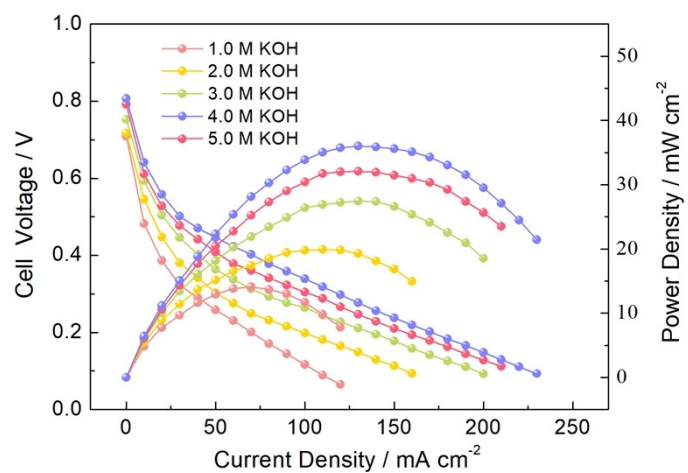
Fig. S10. Polarization and power density curves of PFM-based DEFC with Pd/Ni-SnO$_2$/C (anode) and NiCo$_2$O$_4$ (cathode) catalysts in a 1.0 M EtOH solution containing different KOH concentrations.

Table S1. Physical properties of PFM

Physical property	Value
Thickness (μm)	159.3
Basis Weight (g m^{-2})	61.5
Air Resistance (sec 100 ml)	4.51
Electrolyte Holding Ratio (%)	195
S Content (%)	0.70

The information is provided by Nippon Kodoshi Corporation.

Table S2. Physical properties of PEM

Physical property	Value
Thickness (μm)	200
Membrane area resistance (Ω cm^{-2})	≤ 2.2
Water transmissivity (mL h^{-1} cm^{-2} MPa^{-1})	≤ 0.1

The information is provided by Huamotech Corporation.

Table S3. The summary of the particle size characterization (XRD, TEM)

	β (101)	θ (101)	Crystallite size (nm) from XRD	Particle size (nm) from TEM
SnO$_2$	0.716	33.856	11.6	10.3
Ni-SnO$_2$	0.912	34.086	9.0	8.3

Table S4. Comparison of DEFCs performance in alkaline media

Anode (catalyst loading / mg cm^{-2})	Cathode (catalyst loading / mg cm^{-2})	Solution	Electrolyte	Temperature (°C)	Power density (mW cm^{-2})	Refs.
Pd/C (1$_{Pd}$)	NiCo$_2$O$_4$ (20)	KOH	PFM	30	10.5	This work
Pd/SnO$_2$/C (1$_{Pd}$)					17.9	
Pd/Ni-SnO$_2$/C (1$_{Pd}$)					47.4	
Ni$_{29}$Pd$_{34}$Pt$_{37}$/C (1)	Pt/C (1$_{Pt}$)	NaOH	Tokuyama A006	40	41	1
Pd$_1$Nb$_1$/C (1$_{Pd}$)	Pt/C (1$_{Pt}$)	KOH	Nafion 117	70	18.11	2
PdNi/EGO (1$_{Pd}$)	Pt/C (1)	NaOH	Tokuyama AS4	50	16.6	3
Pd/C (2.56)	(Bg-CA-M)-Fe/N/C (2.56)	KOH	Tokuyama A201	90	64	4
PdNiSn/C$_F$ (1)	Pt/C (1)	NaOH	Nafion 117	100	38.8	5
Pd/C (6$_{Pd}$)	FeCo (2)	KOH	Tokuyama A201	room temperature	32	6

Supplementary References

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