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Supplementary Materials

Nano-Graphene Layer from Facile, Scalable and Eco-Friendly Liquid Phase Exfoliation Strategy as Effective Barrier Layer for High-Performance and Durable Direct Liquid Alcohol Fuel Cells

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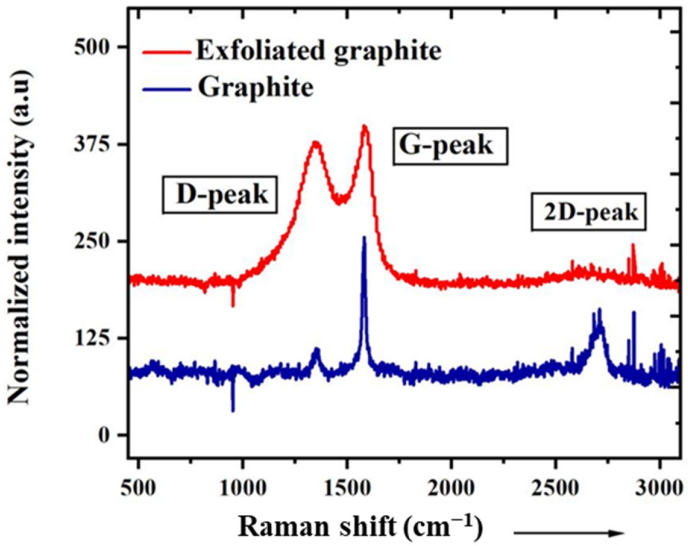

Figure S1. Raman spectrum of graphite and graphene, dropcasted on silicon wafer.

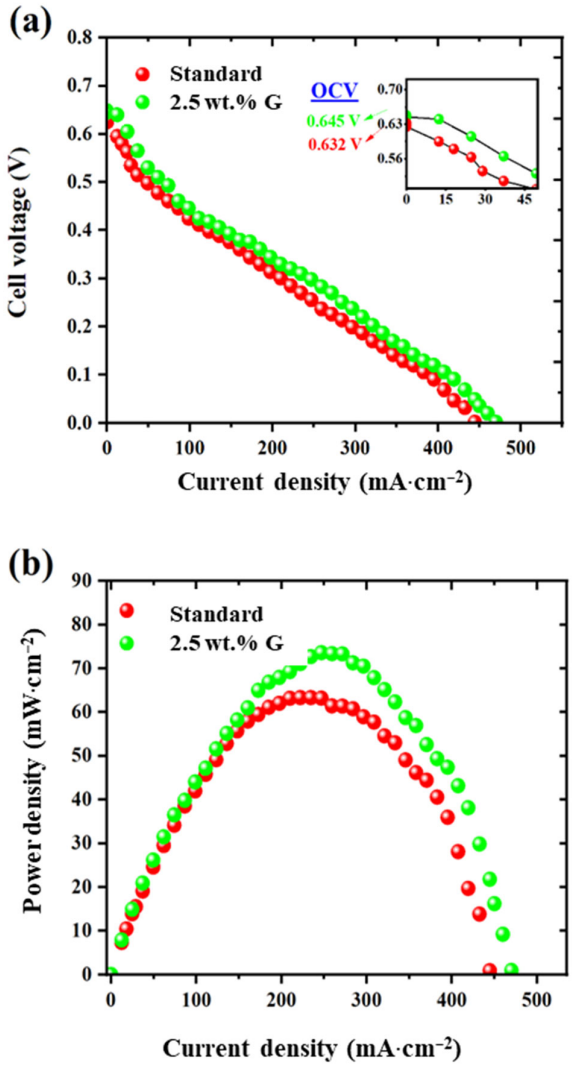

Figure S2. (**a**) Cell voltage; (**b**) Power density profile obtained at 60 °C in 1 M methanol/oxygen conditions for standard and 2.5 wt.% graphene MEAs.

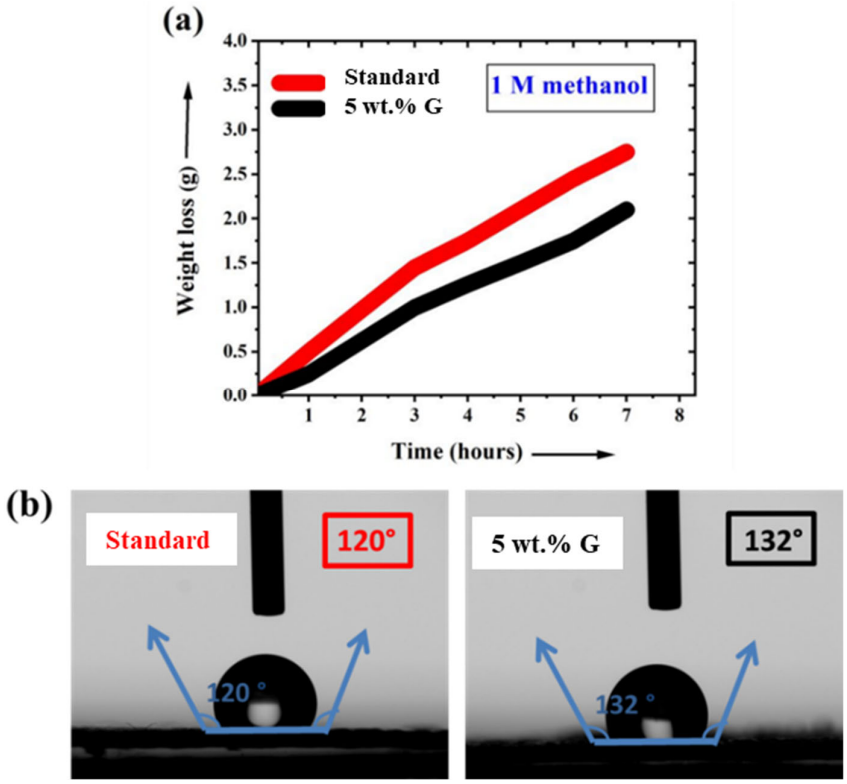

Figure S3. (**a**) Methanol permeability (by gravimetric mode) at 1 M methanol condition and (**b**) Wettability (contact angle) for standard and graphene 5 wt.% electrodes.

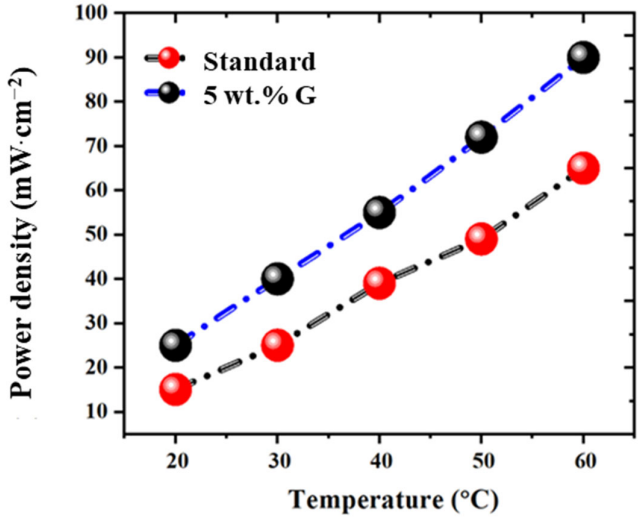

Figure S4. Peak power density values for standard and 5 wt.% graphene MEAs at different temperatures.

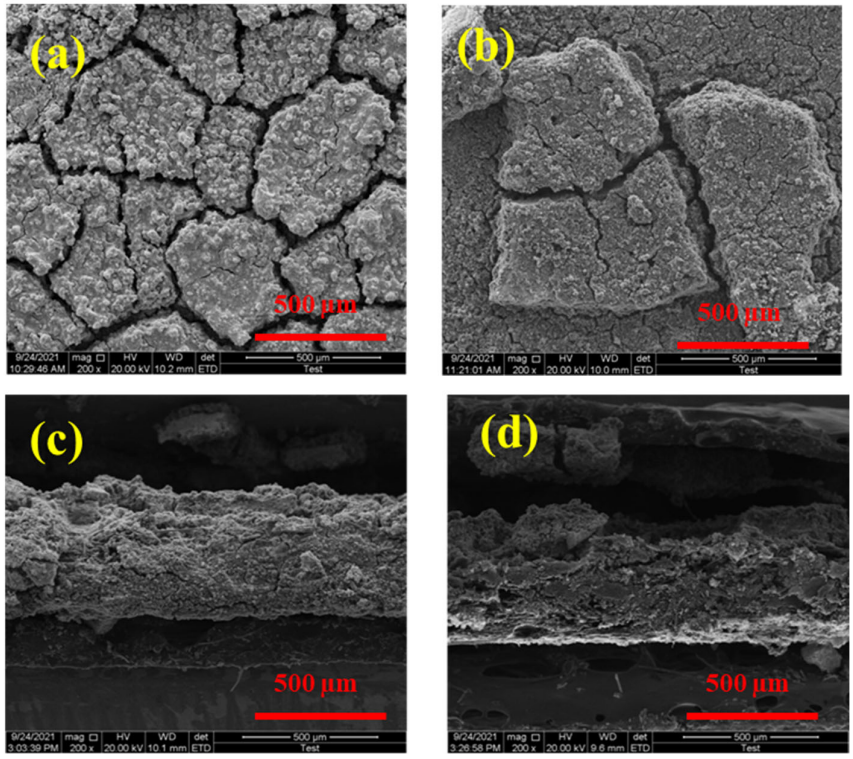

Figure S5. SEM images (**a**, **b** - top-view and **c**, **d** - cross-sectional) of electrodes coated with 5 wt.% graphene before and after durability testing.

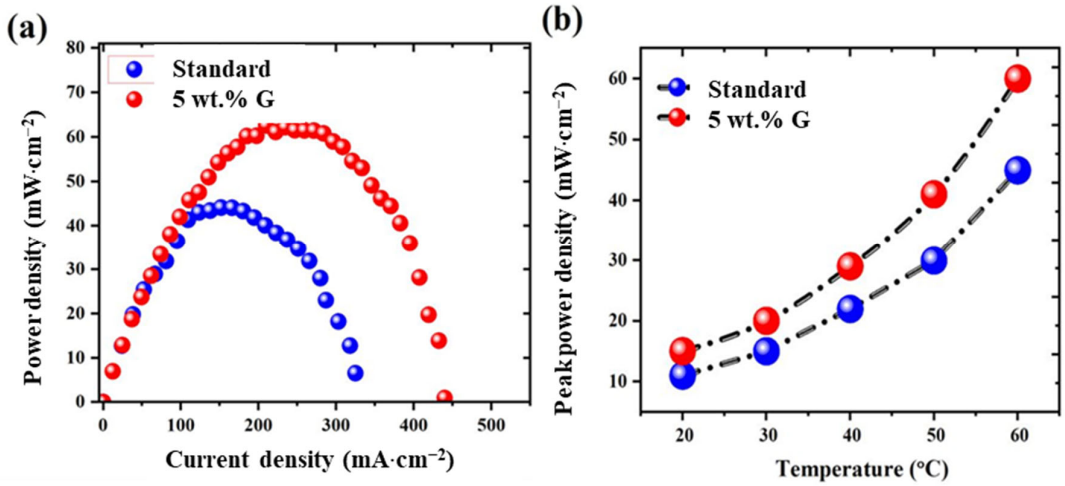

Figure S6. (**a**) Power density curve and (**b**) temperature profile of standard and 5 wt.% graphene MEAs at 1 M ethanol concentration.

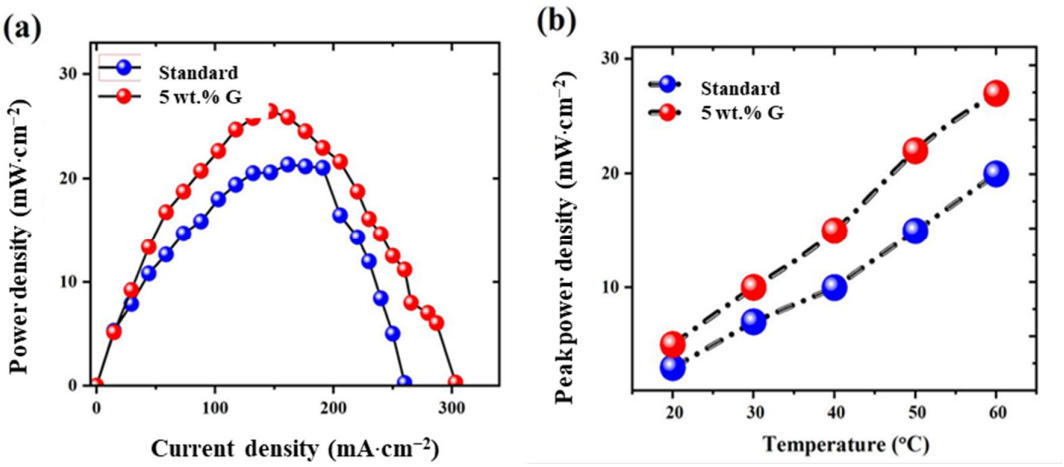

Figure S7. (**a**) Power density curve and (**b**) Temperature profile of standard and 5 wt.% graphene MEAs at 1 M 2-propanol concentration.

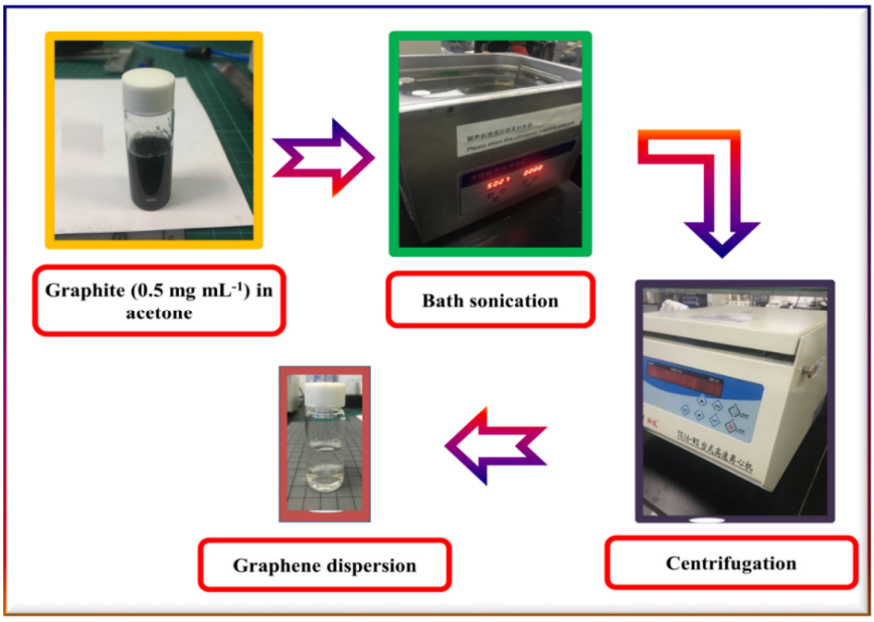

Figure S8. Graphene dispersion preparation procedure.

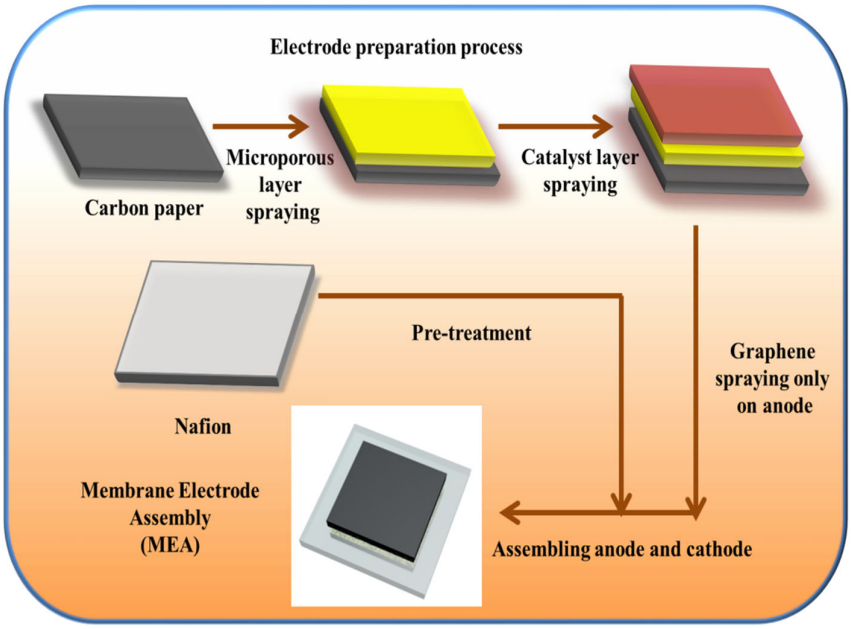

Figure S9. Membrane electrode assembly (MEA) preparation methodology.

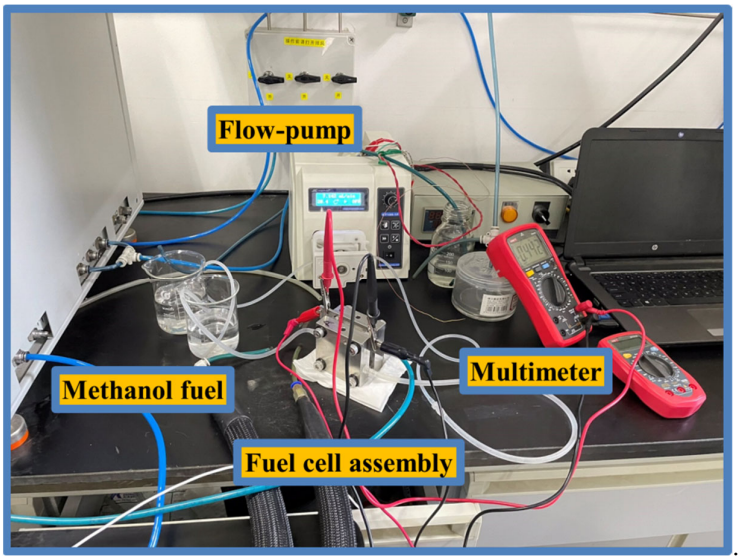

Figure S10. Single fuel cell set up used in the laboratory.

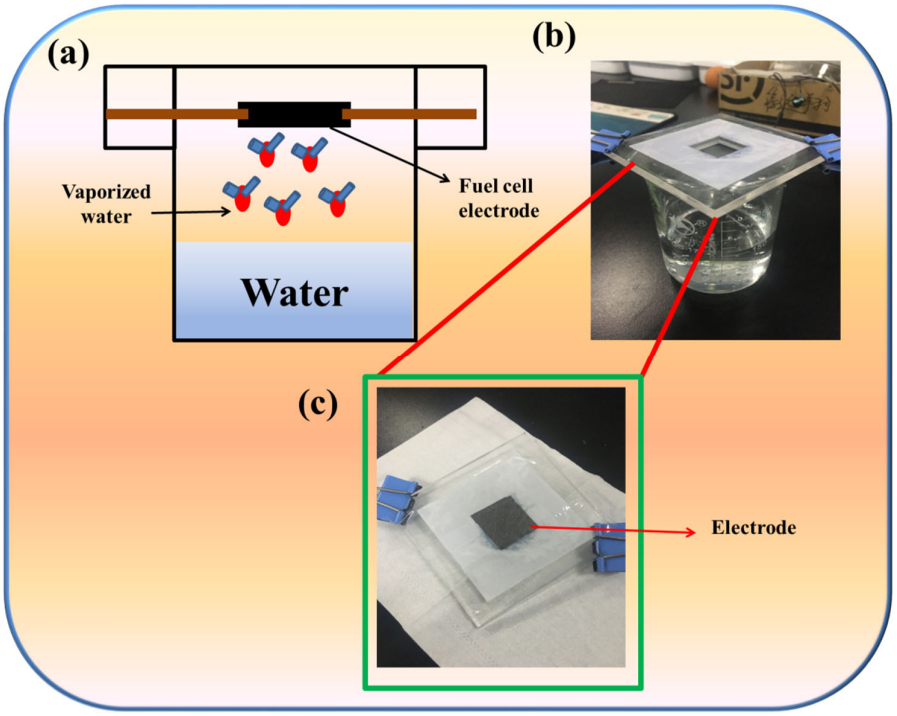

Figure S11. (**a**). Schematic of electrode porosity measurement; (**b**) Lab-made set up; (**c**) Closer view of the electrode arrangement.

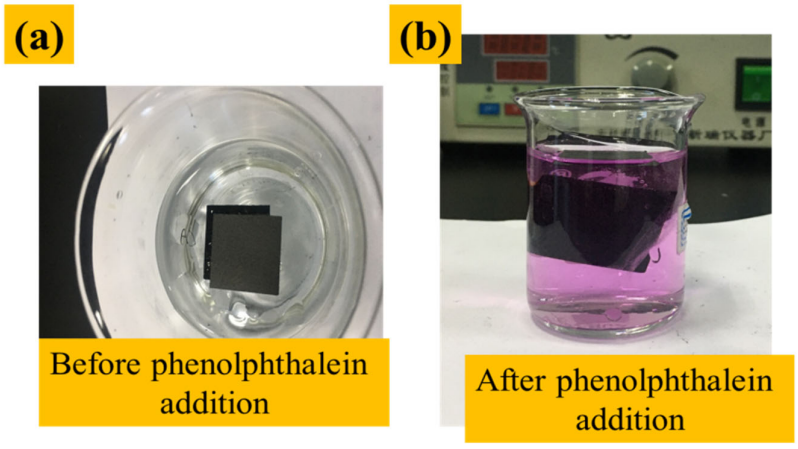

Figure S12. Determination of ion-exchange capacity experiment - (**a**) Before and (**b**) After phenolphthalein addition.

Table S1. Average values of elemental analysis results of graphene flakes by elemental dispersive spectroscopy (EDS).

GRAPHENE FLAKE	WEIGHT PERCENTAGE (wt.%)
Carbon	**82**
Oxygen	**18**

Table S2. Comparison of water-uptake (WU) and ion-exchange capacity values of different electrodes.

ELECTRODE	WATER UPTAKE (WU) (%)	ION-EXCHANGE CAPACITY (%)
Standard	--	--
2.5 wt.%	−6	4
5 wt.%	−7	5
7.5 wt.%	−10	11
10 wt.%	−22	18
20 wt.%	−24	21
25 wt.%	−32	27

Table S3. Open circuit voltage, and peak power density values of standard and different graphene wt.% MEAs.

MEA	OPEN CIRCUIT VOLTAGE (V)	PEAK POWER DENSITY (mW cm^{-2})
Standard	0.632	63
2.5 wt.%	0.645	73
5 wt.%	0.660	91
7.5 wt.%	0.595	61
10 wt.%	0.550	45
20 wt.%	0.500	29

Table S4. Comparison of this work with recent literature.

MATERIAL	PREPARATION METHODOLOGY	PERFORMANCE RESULTS AND CONDITIONS	REFERENCE
Graphene-1,4 phenyl diamine hydrochloride (PDHC)	50 layered arrangement of graphene oxide - PDHC.	Maximum performance of 65 mW cm^{-2} compared to showing 35 mW cm^{-2} reporting by reducing crossover.	Wang et al. 2015 [51]
Ozonated graphene (OG)	Graphene is exposed to ozone gas	Nafion-OG-Nafion membrane shows 180 mW·cm^{-2} compared to Nafion-G-Nafion performance of 120 mW·cm^{-2}	Gao et al. 2014 [52]
Hexagonal nitride (hBN)	hBN by mechanical exfoliation	Spincoated hBN on Nafion showed reduced fuel (hydrogen) permeability reported stable open circuit voltage (OCV)	Lee et al. 2019 [53]
Graphene	Chemical vapour deposited (CVD) graphene is transferred onto fuel cell electrode	45% improvement in performance are reported	Holmes et al. 2016 [20]
Graphene	CVD graphene sandwiched between two Nafion 212	120% performance improvement at high concentration methanol passive fuel cell systems	Yan et al. 2016 [21]
Graphene	Graphene dispersion from XFNano Inc is sprayed onto anode	82% improvement in performance are reported at 8 M methanol fuel cell conditions	Xu et al. 2020 [22]
Graphene	Graphene prepared by liquid phase exfoliation and added as barrier layer	36% improvement in methanol fuel cell performance are reported inaddition to ethanol and propanol systems	This work

References for Supporting Information

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