Supporting Information

Core-shell-structured CNT@hydrous RuO_2 as a H_2/CO_2 fuel cell cathode catalyst to promote CO_2 methanation and generate electricity

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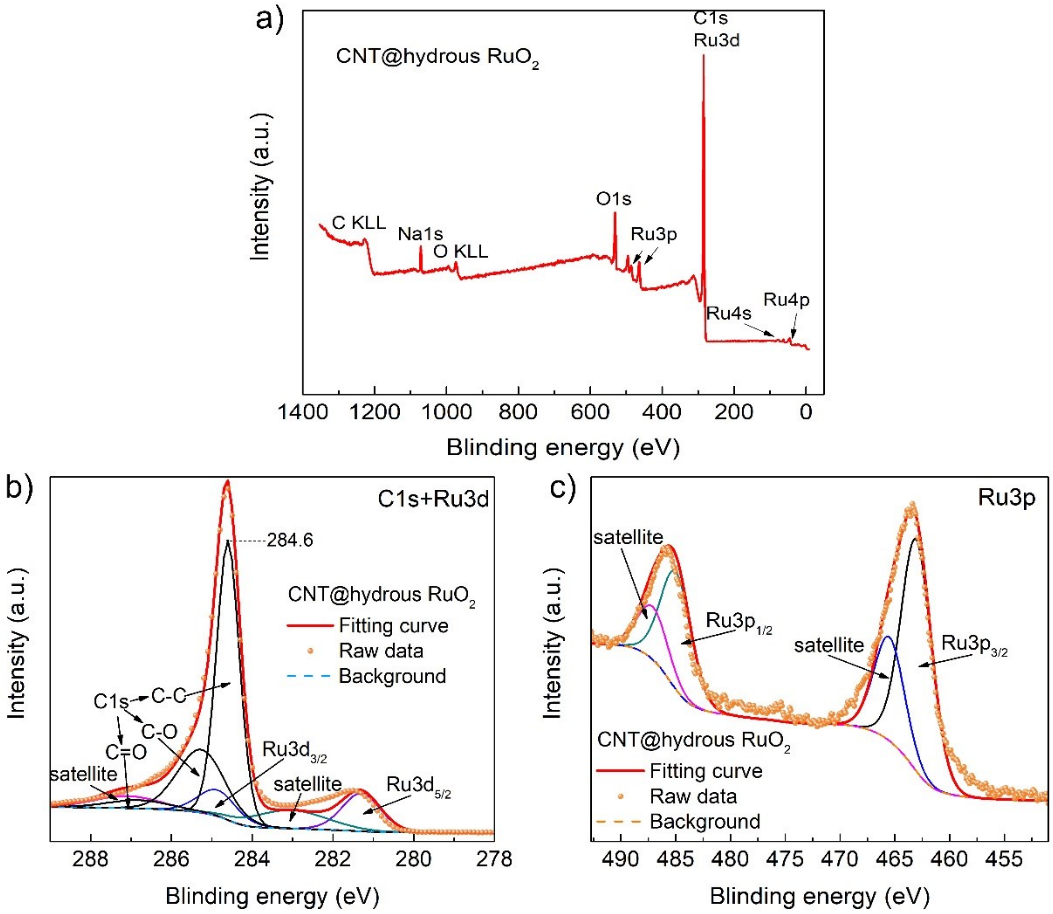

Fig. S1. (a) Survey XPS spectra of CNT@hydrous RuO_2. (b) high-resolution spectra of XPS of CNT@hydrous RuO_2 for C 1s and Ru 3d. (c) high-resolution spectra of XPS of CNT@hydrous RuO_2 for Ru 3p.

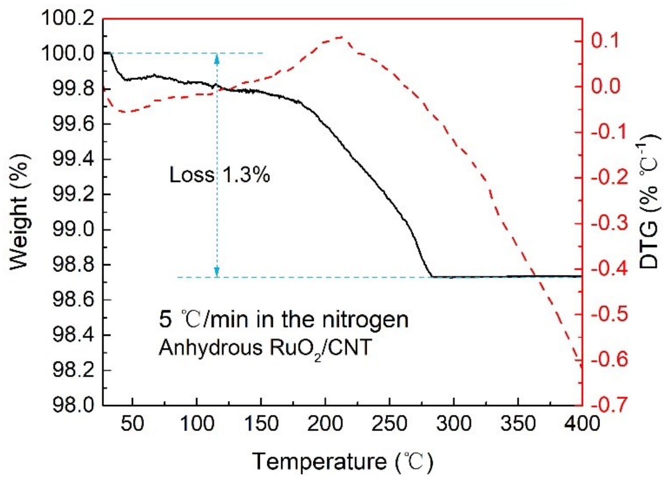

Fig. S2.TGA/DTG curves of anhydrous RuO_2/CNT in the flowing nitrogen.

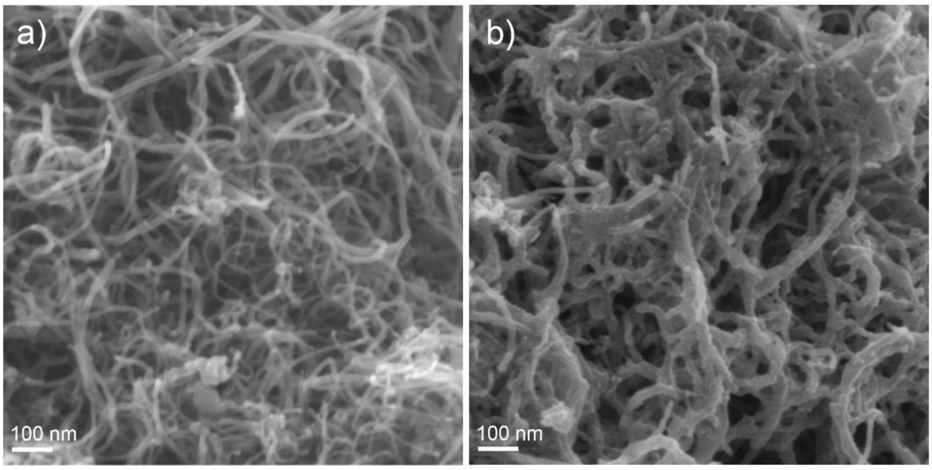

Fig. S3. (a) SEM images of acid-treated CNT. (b) SEM images of CNT@hydrous RuO_2

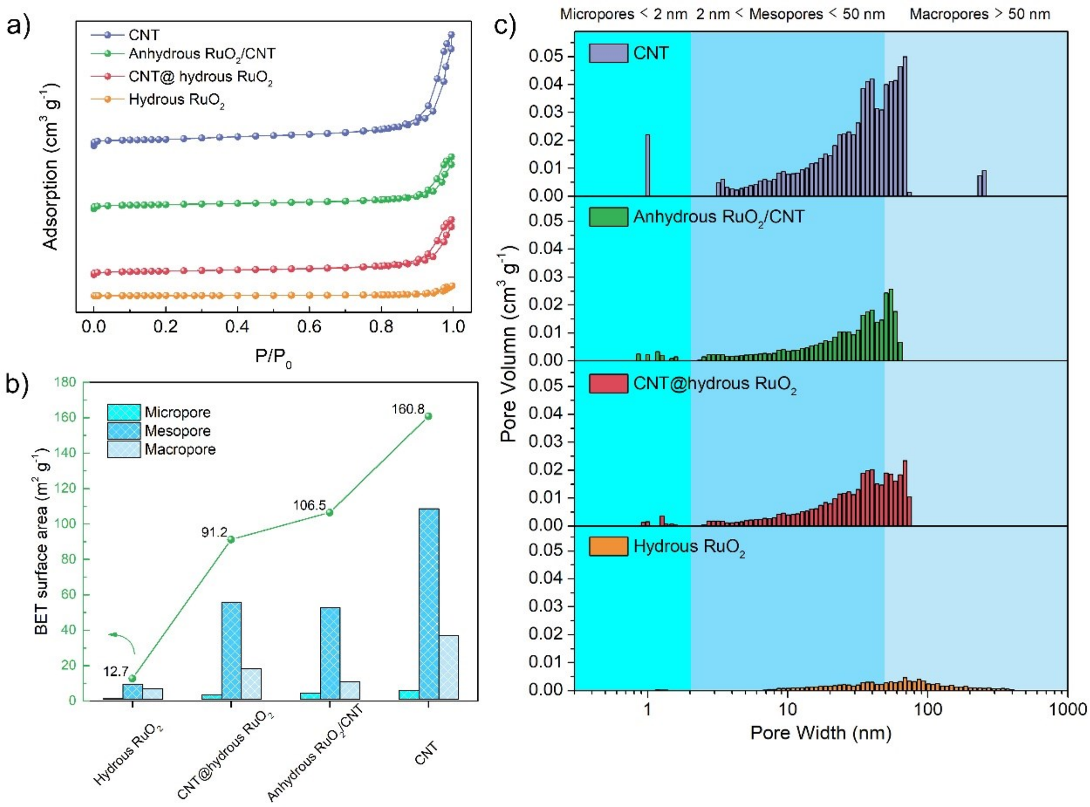

Fig. S4. (a) N_2 adsorption and desorption curves, (b) surface area and pore distribution plots, and (c) pore volume distribution graphs for hydrous RuO2, CNT@hydrous RuO_2, anhydrous RuO_2/CNT and CNT.

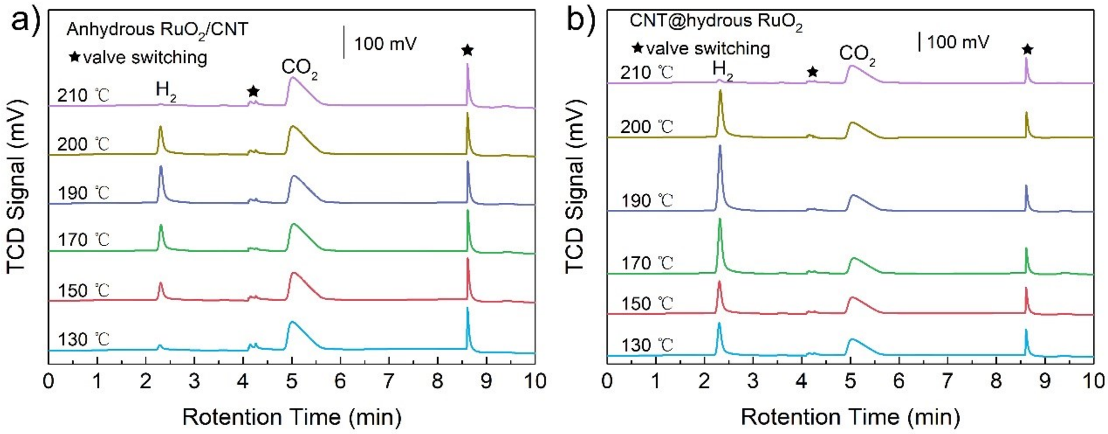

Fig. S5. TCD Spectra of Gas Chromatography at Different Temperatures. (a) Anhydrous RuO_2/CNT as CO_2RR catalyst. (b) CNT@hydrous RuO_2 as CO_2RR catalyst.

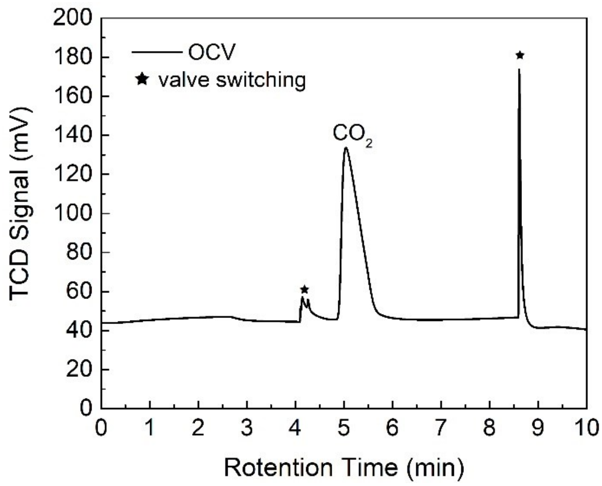

Fig. S6. The gas chromatography thermal conductivity detection (TCD) spectrum is obtained under open-circuit voltage (OCV).

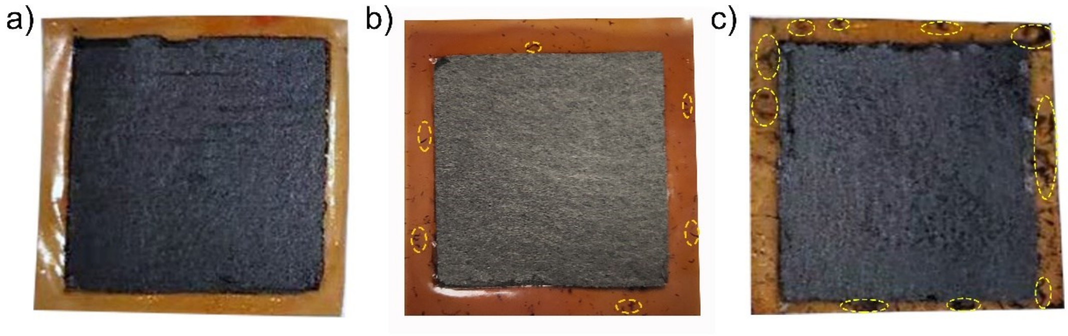

Fig. S7. Photo of MEA after testing battery in the different temperature range. (a) 130-190℃: MEA has no abnormalities. (b) 200℃: A few black spots on the membrane. (c) 210℃： A lot of dark spots on the membrane. the appearance of abnormal dark spots in the yellow dashed ellipse represents PBI membrane damage.

The generation rate of CH_4 (γ) was calculated by the equation:

$$\gamma = \frac{u(ml/\min)\times 60(\min/h)\times c(vol\%)\times \rho(mg/ml)\times 1000}{M(g/mol)\times L(g)}$$

γ: methane generation rate, umol·g_{cat}^{-1}·h^{-1}

u: mass flow meter detects gas flow rate, ml/min

c: Gas volume concentration detected by hydrogen flame ionization detector in gas chromatography, vol%.

ρ: density of product CH_4, 0.717 mg/ml.

M: molar mass of CH_4, 16 g/mol.

L: cathode catalyst mass loading, g.

The transfer efficiency (TE) of gas products was calculated by the equation:

$$\left.\begin{array}{l} pV = nRT \\ TE = \dfrac{Q_{CO_2RR}}{Q_{total}} = \dfrac{nzF}{It} \\ V = utc \end{array}\right\} \Rightarrow TE = \frac{puzFc}{RIT}$$

$$TE = \frac{p(N/m^2)\times u(ml/\min)\times 10^{-6}\times z\times F(C/mol)\times c(vol\%)}{R[N\cdot m/(mol\cdot K)]\times I(C/s)\times 60(s/\min)\times T(K)}$$

p: atmospheric pressure, 1.013×10^5 N/m^2.

u: mass flow meter detects gas flow rate, ml/min

z: number of electrons transferred by electrode reaction.

F: faradaic constant, 96485 C/ mol.

c: Gas volume concentration detected by hydrogen flame ionization detector in gas chromatography, vol%.

R: gas constant, 8.314 N·m/(mol·K)

T: temperature, K.

I: Discharge current of external circuit detected by battery test system. C/s.

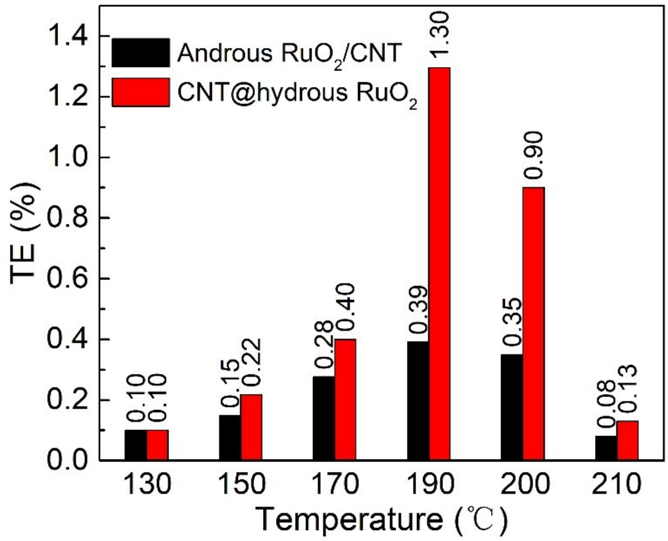

Fig. S8. TE at different temperatures is obtained under limit current discharge.