

Supporting Information

Electrochemical Reduction of Gaseous CO₂ at Low-Intermediate Temperatures using a Solid Acid Membrane Cell

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Table S1. Composition of the mixture to be deposited on the carbon paper to fabricate the Pt-based or Cu-based electrode for the membrane-electrode assembly (MEA) with CsH₂PO₄. Pt (<20 μm, Sigma-Aldrich, Product #: 205915) and Cu (14-25 μm, Sigma-Aldrich, Product #: 326453) were used as the electrocatalysts.

Pt-based	Cu-based
Pt powder <20 μm (Aldrich) 0.4 mg/cm ²	Cu powder 14–25 μm (Aldrich) 0.4 mg/cm ²
+	+
CsH ₂ PO ₄ powder (synthesized) 1.2 mg/cm ²	CsH ₂ PO ₄ powder (synthesized) 1.2 mg/cm ²
+	+
2-propanol 3 mL/cm ²	2-propanol 3 mL/cm ²

Table S2. Number of electrons to produce one molecule of each product via CO₂ reduction.

CO ₂ reduction products	# of electrons to produce one molecule of the product via CO ₂ reduction
CO	$\text{CO}_2 + 2\text{H}^+ + \underline{2}\text{e}^- \rightarrow \text{CO} + \text{H}_2\text{O}$
CH ₄	$\text{CO}_2 + 8\text{H}^+ + \underline{8}\text{e}^- \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$
C ₂ H ₆	$2\text{CO}_2 + 14\text{H}^+ + \underline{14}\text{e}^- \rightarrow \text{C}_2\text{H}_6 + 4\text{H}_2\text{O}$
C ₂ H ₄	$2\text{CO}_2 + 12\text{H}^+ + \underline{12}\text{e}^- \rightarrow \text{C}_2\text{H}_4 + 4\text{H}_2\text{O}$
C ₂ H ₂	$2\text{CO}_2 + 10\text{H}^+ + \underline{10}\text{e}^- \rightarrow \text{C}_2\text{H}_2 + 4\text{H}_2\text{O}$
CH ₃ OH	$\text{CO}_2 + 6\text{H}^+ + \underline{6}\text{e}^- \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$
HCOOH	$\text{CO}_2 + 2\text{H}^+ + \underline{2}\text{e}^- \rightarrow \text{HCOOH}$

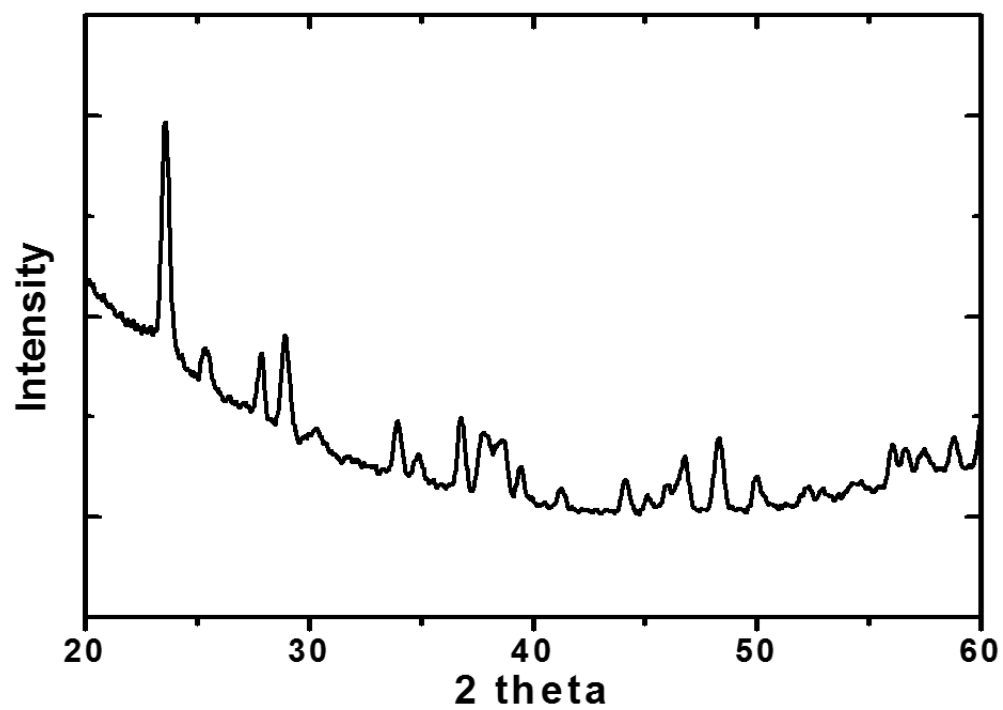


Figure S1. X-ray diffraction pattern of the synthesized CsH_2PO_4 .

Table S3. Produced concentration [$\mu\text{mol}/\text{cm}^2$] and Faradaic efficiency (F.E. [%]) of the products from the electrochemical reduction of gaseous CO_2 with the Pt- CsH_2PO_4 -Cu MEA.

[μmol] F.E. [%]	CO	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	CH ₃ OH	HCOOH
0 min		-	-	-	-	-	-
10 min	0.38 0.12	0.18 0.23	0.009 0.020	-	-	-	-
40 min	1.9 0.15	0.81 0.26	0.027 0.015	-	-	0.036 0.009	0.009 0.001
70 min	2.6 0.12	1.7 0.30	0.054 0.017	-	-	0.080 0.011	0.018 0.001
100 min	3.0 0.10	2.5 0.32	0.089 0.020	0.009 0.002	0.009 0.001	0.13 0.012	0.027 0.001
130 min	3.5 0.09	3.3 0.32	0.12 0.020	0.018 0.003	0.018 0.002	0.16 0.012	0.036 0.001

Initial gas composition in the cathode chamber: 5400 μmol CO_2 , 2100 μmol H_2O

Test conditions: Pt/ CsH_2PO_4 /Cu (surface area: 1 cm^2)

-2 V, H_2/CO_2 (0.4 atm H_2O both), 250°C

Table S4. Produced concentration [$\mu\text{mol}/\text{cm}^2$] and Faradaic efficiency (F.E. [%]) of the products from the electrochemical reduction of gaseous CO_2 with the Pt- CsH_2PO_4 -Pt MEA.

$[\mu\text{mol}]$ <i>F.E. [%]</i>	CO	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	CH ₃ OH	HCOOH
0 min		-	-	-	-	-	-
10 min	0.47 0.15	0.018 0.023	-	-	-	-	-
40 min	2.2 0.18	0.089 0.028	-	-	-	-	-
70 min	3.9 0.18	0.18 0.033	0.009 0.003	-	-	-	-
100 min	5.3 0.17	0.31 0.040	0.018 0.004	-	-	-	-
130 min	6.3 0.15	0.44 0.040	0.018 0.003	-	-	-	-

Initial gas composition in the cathode chamber: 5400 μmol CO_2 , 2100 μmol H_2O

Test conditions: Pt/ CsH_2PO_4 /Pt (surface area: 1 cm^2)

-2 V, H_2/CO_2 (0.4 atm H_2O both), 250°C

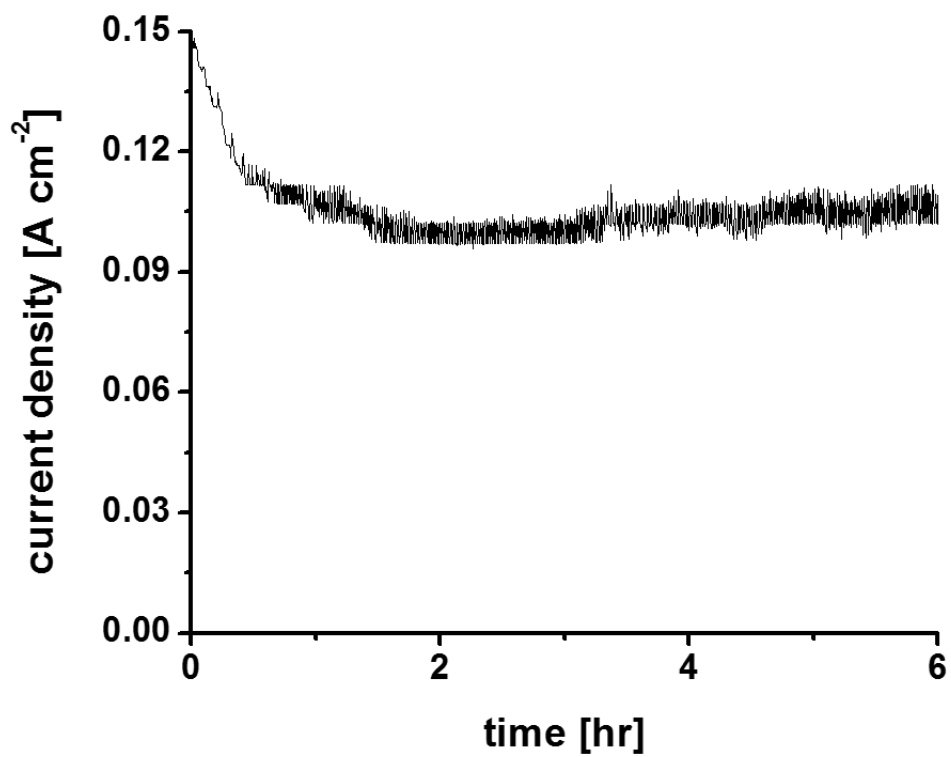


Figure S2. Current density-time curve for the Pt/CsH₂PO₄/Cu with -2 V constant cell voltage for the time duration during which CO₂ is being electrochemically reduced.