## **Supporting information**

# Along the Channel Gradients Impact on the Spatioactivity of Gas Diffusion Electrodes at High Conversions during CO<sub>2</sub> Electroreduction

Recep Kas<sup>a,b\*</sup>, Andrew G. Star<sup>a</sup>, Kailun Yang<sup>d</sup>, Tim Van Cleve<sup>a</sup>, Kenneth C. Neyerlin<sup>a</sup>, Wilson A. Smith<sup>a,b,c,d\*</sup>,

<sup>a</sup>National Renewable Energy Laboratory, Golden, Colorado 80401, United States

<sup>b</sup> Renewable and Sustainable Energy Institute (RASEI), University of Colorado Boulder, Boulder, CO 80303, USA

<sup>c</sup> Department of Chemical and Biological Engineering, University of Colorado Boulder, Boulder, CO 80303, USA

<sup>d</sup> Materials for Energy Conversion and Storage (MECS), Department of Chemical Engineering, Faculty of Applied Sciences, Delft University of Technology, van der Maasweg 9, 2629 HZ Delft, The Netherlands

Corresponding Authors: <a href="mailto:recep.kas@colorado.edu">recep.kas@colorado.edu</a>, <a href="mailto:wilson.smith@colorado.edu">wilson.smith@colorado.edu</a>,

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## **1.Model description**

Cathode compartment of a PEM based CO<sub>2</sub> electrolyzer with a flowing catholyte configuration was modeled at the steady state with 2-D finite element approach. Following sections describe the modelling approach by introducing source terms, governing equations and boundary and initial conditions. Determination of some key parameters, assumptions and simplification of the model are discussed along each section. A schematic depiction of the model layout is shown with the dimensions of the flow channels and GDE in Figure SI1 and all the model and material parameters are summarized in Table SI2. The computational model is composed of 4 domains including a gas channel, gas diffusion layer (GDL), catalyst layer and catholyte channel. x(horizontal) and y(vertical) axis in the model represent directions that are perpendicular and parallel to the flow channels, respectively. Aqueous 1 M bicarbonate solution and gas phase CO<sub>2</sub> at atmospheric pressure is fed via a rectangular 1-mm wide channel from the either side of GDE with variable flow rates. Single phase laminar flow was modelled for an incompressible and compressible fluid by using Navier-Stokes equations for gas and liquid channels, respectively ( Section 1.1 and 1.2). We assume that the flowing electrolyte ensures that the effect of reactant, product and electrolyte crossover from and towards to anode compartment on the concertation profiles is negligible. Since there are changes in the overall gas phase concentration due to neutralization of CO<sub>2</sub> by cathodically produced hydroxide and production of hydrogen, imposing a flow rate at the outlet causes convergence difficulties. Therefore, the outlets were assumed to



be atmospheric pressure. Nevertheless, the flow rate of the outlet is reported to be known to be variable depending on the current density.<sup>1</sup> No tangential and perpendicular motion of the fluid is assumed exist at the non-porous wall of the flow channels, i.e. no-slip condition. Maxwell-Stefan multi-component diffusion model was used to model the diffusion of gas phase species in the flow channel and GDE (Section 1.3). The diffusion coefficients were further modified inside the GDE to include effect of pore size (Knudsen Diffusion), porosity and tortuosity. The velocity field inside the GDE was approximated by Darcy's law for porous medium. The effective diffusion coefficients of the electrolyte ions inside the catalyst layer was approximated by Bruggeman relationship including the effects of tortuosity and porosity and the mass transport is assumed to be driven by diffusion. The gas phase CO<sub>2</sub> transfer to ionomer assumed to occur in the CL and the ionomer was assumed to be saturated with the water (Section 1.4). All the equations were solved iteratively by Newton's method at the steady state using COMSOL Multiphysics MUMPS solver.

#### 1.1. Transport in the gas flow channels

The transport in the gas channels are driven by the forced convection and diffusion. The convective flow velocity and pressure changes were computed via Navier-stokes equations and the diffusion is modelled by the mixture-averaged approximation. The flux of the gaseous species  $(N_i)$  can be written as combination of a diffusive and convective term,

$$N_i = -J_i + \rho_i u_g \tag{S1}$$

where  $J_i$  is the diffusive flux of species i,  $\rho_i$  is the density (kg/m<sup>3</sup>),  $u_g$  is the mass averaged fluid velocity (m/s). Under a forced convection the convective flux of the species might dominate the transport phenomena inside the channels depending the flow velocity and the length of the channel. The dimensionless *Pèclet number* provides a semi-quantitaive guide for the contributions of diffusion and convection on the overall mass transport,

$$Pe = \frac{\ell u_g}{D_i} \tag{S2}$$

where  $\ell$  is the length(m) of the flow channel,  $D_i$  is the diffusion coefficient. Peclet numbers varies between 5-20 for the flow rates computed here implying that the forced convective flow is the dominant mode of transport along the flow channels. Nevertheless, we included the diffusion in the gas flow channel since the x component of the velocity field inside the gas flow channel is very small and diffusion in this direction have an effect on the concentration gradient across the flow channel.

Reynold's number is most used term to predict flow patterns in fluid. Reynold's number can be written as:

$$Re = \frac{\rho_g u_g \ell}{\mu_g} \tag{S3}$$

where  $\rho_g$  is the density of the gaseous mixture and  $\mu_g$  is the viscosity. The Reynold numbers in the gas flow channel was well below 100 for all the computed flow rates, so the flows are assumed to be laminar. Single phase laminar flow was modelled in the gas flow channel for a compressible fluid by using Navier-Stokes equations. For a compressible flow, the Navier-Stokes equations read as continuity equation:

$$\nabla \cdot \left(\rho_g u_g\right) = 0 \tag{S4}$$

and momentum equation at the absence any external body force

$$\rho_g(u_g \cdot \nabla u_g) = \nabla p + \mu_g \left( \nabla u_g + \left( \nabla u_g \right)^T \right) - \frac{2}{3} \mu (\nabla \cdot u_g) I$$
(S5)

where p is the pressure. Mass fractions were dictated at the inlet as 0.995 and 0.005 for CO<sub>2</sub> and CO, respectively, with a specified volumetric flow rate while the pressure at the outlet  $(p_{out})$  of the flow channel is assumed to be at atmospheric pressure that is assumed to be equal to the normal stress component,

$$p = p_{out} \text{ and } p_{out}n = (-\rho_g I + \mu_g \left(\nabla u_g + \left(\nabla u_g\right)^T\right) - \frac{2}{3}\mu \left(\nabla \cdot u_g\right)I)n \quad (S6)$$

The gas fluid was fed from the inlet with a certain average velocity( $U_0$ ) that corresponds to desired volumetric flow rate,

$$u_g = -U_0 n \tag{S7}$$

where n is the boundary normal. Boundary conditions at the outer walls of the flow channel include no-slip and impermeable boundary

$$u_x = 0 \text{ and } u_y = 0 \tag{S8}$$

The multicomponent diffusion inside the gas flow channel was approximated by mixtureaveraged diffusion model. The mixture-averaged model assumes Fickian type approximation in which the diffusion is driven by the gradient of the mole  $(x_i)$  or mass fraction $(\omega_i)$  of individual species. The diffusive mass flux  $(J_i)$  of species i can be written,

$$J_i = \rho D_i^m \frac{\nabla x_i}{x_i} \tag{S9}$$

and this equation, in terms of mass fraction and average molar mass of the gaseous mixture  $(M_n)$ , can be written as

$$J_i = \rho D_i^m \nabla \omega_i + \rho D_i^m \omega_i \frac{\nabla M_n}{M_n}$$
(S10)

where  $D_i^m$  is the mass averaged diffusion coefficient and  $\omega_i^m$  mass fraction of species i,  $M_n$  is avarage molar mass of the gaseous mixture.  $M_n$  and  $D_i^m$  can be written as for a multicomponent mixture,

$$M_n = \left(\sum_i \frac{\omega_i}{M_i}\right)^{-1} \tag{S11}$$

and

$$D_i^m = \frac{1 - \omega_i}{\sum_{i \neq k} \frac{x_k}{D_{ik}}}$$
(S12)

Where  $x_k$  and  $M_i$  mass fraction and molar mass of the species.

#### 1.2. Transport in the electrolyte flow channel

The molar flux  $(N_j)$  of the electrolyte species inside the flow channels can be written as combination of a diffusive  $(J_i)$  and convective term

$$N_j = -J_j + c_j u_e \tag{S13}$$

The convective mass transport terms were calculated by modelling the liquid electrolyte flow via Navier-Stokes equations. The flow rates of the liquid electrolytes and pressure differences that are relevant to electrolysis cells usually allows an assumption of incompressibility. Further, the density gradients that might form as a result of concentrations gradients is assumed to be negligible and the continuity equation reads,

$$\nabla \cdot u_e = 0 \tag{S14}$$

The second viscous term in equation S5 can be removed since the divergence of the velocity is zero,

$$\rho(u_e \cdot \nabla)u_e = \nabla p + \mu \left(\nabla u_e + (\nabla u_e)^T\right)$$
(S15)

The diffusive term in equation S13 was computed by Fick's law,

$$J_i = D_i \nabla c_i \tag{S16}$$

Where  $D_j$  and  $c_j$  are the diffusion coefficients and concentration of species j in the bulk electrolyte solution. A reactive transport model was used to compete the concentration of the species in the flow channel. The flow of the electrolyte was assumed to be fully developed before entering the flow channel. At the channel inlet,

$$u_x = 0 \tag{S17}$$

while the pressure at the outlet  $(p_{outlet})$  of the flow channel is assumed to be at atmospheric pressure which is assumed to be equal to the normal stress component.

$$p = p_{outlet} and p_{outlet} n = (-pl + \mu_e (\nabla u_e + (\nabla u_e)^T))n$$
(S18)

Boundary conditions at the outer walls of the flow channels include no-slip and impermeable boundary,

$$u_x = 0 \text{ and } u_y = 0 \tag{S19}$$

#### 1.3 Gas phase transport in the GDL and CL

The flux of the gas phase molecules  $(N_k)$  can be written as a combination of diffusive term $(J_k)$  and convective term.

$$N_i = -J_i + \rho_i u_g \tag{S20}$$

Unlike the flow channels the diffusion plays an important (or major) role for the transport of the gas molecules in and of the GDE. In addition, now the diffusion coefficients, in addition to the mixture-averaged diffusion model, are needed to be modified based on the porosity, tortuosity and pore size. The mixture-averaged diffusive flux of molecules can be written as

$$J_i = \rho D_i^{eff} \nabla \omega_i + \rho D_i^{eff} \omega_i \frac{\nabla M_n}{M_n}$$
(S21)

 $D_i^{eff}$  is the effective diffusion coefficient corrected for porosity( $\epsilon_m$ ) and tortuosity( $\tau_m$ ) by using Bruggeman relationship,

$$D_i^{eff} = D_i \frac{\varepsilon_m}{\tau_m} \tag{S22}$$

Where  $\tau_m = \varepsilon_m^{-1/2}$ . The diffusion coefficient  $(D_i)$  can be written as combination of Knudsen diffusivity  $D_i^K$  and Maxwell-Stefan Diffusivity  $D_i^M$ ,

$$\frac{1}{D_i} = \frac{1}{D_i^K} + \frac{1}{D_i^M}$$
(S23)

 $D_k^K$  is can be written in terms of mean free path  $(\lambda)$ ,

$$D_i^K = \frac{\lambda}{3} \sqrt{\frac{8RT}{\pi M_k}}$$
(S24)

Where R is the gas constant ,T is the temperature  $M_k$  is the molar mass of the species k. Mean free path of the molecules were assumed be equal to the average pore diameter of the medium  $(d_p^m)$ . The Maxwell-Stefan Diffusivity in equation S23 is,

$$D_i^M = \frac{1 - \omega_i}{\sum_{i \neq k} \frac{x_k}{D_{ik}}}$$
(S25)

The velocity in the convective term of equation S20 was computed by Darcy's law.

$$u_g = \frac{\kappa_m}{\mu_g} \nabla p \tag{S26}$$

Where  $\kappa_m$  is the permiability of the medium and  $\mu_g$  is the viscosity. The total flux inside the GDE was computed by using the distinct parameters for CL and GDL that are given in Table SI2.

#### 1.4 Charge and Phase transfers in the CL

At the catalyst layer, the  $CO_2$  is transported to the ionomer phase and reacts at the electrode surface,

$$CO_2 + H_2O + 2e^- \longrightarrow CO + 2OH^-$$
(R1)

The competing hydrogen evolution can be written as,

$$2H_2O + 2 e^- \longrightarrow H_2 + 2OH^- \tag{R2}$$

The electrochemical reaction rate of R1 was assumed to follow concentration dependent Volmer-Butler kinetics,

$$i_{CO} = -i_{CO}^{0} \frac{c_{CO_2}}{c_{CO}^{ref}} \alpha_{H_2O} e^{-\frac{\alpha_{CO_2}F}{RT}\eta_{CO}}$$
(S27)

where  $i_{CO}$  is partial current density of CO,  $i_{CO}^0$  is exchange current density,  $c_{CO_2}$  and concentration of CO<sub>2</sub> in the ionomer,  $\alpha_{H_2O}$  is the activity of the water and  $\alpha_{co}$  is the cathodic transfer coeffcient.  $C_{CO_2}^{ref}$  are the concentration of the CO<sub>2</sub> in the ionomer at a partial pressure of 1 atm. The anodic exponential term becomes negligible compared to cathodic term at potentials evaluated in here. The rate of phase transfer in and out the ionomer was approximated via the following equation by assuming the gaseous CO<sub>2</sub> in the catalyst layer is in equilibrium with CO<sub>2</sub> in the ionomer-gas phase interface,

$$S_{PT} = a_v M_i \frac{D_j^{eff}}{d_l} (c_g^l - c_j)$$
(S28)

Where  $c_g^I$  is the equilibrium concentration at the interface of the ionomer and the gas phase for a given partial pressure

$$c_g^I = p_g x_i S_g^I \tag{S29}$$

Where  $p_g$  and  $x_i$  is the total gas pressure and mole fraction of gas specie i in the CL and  $S_g^I$  is the solubility of the gas in the ionomer. The solubility of the gases can be related to the diffusion coefficients  $(D_g^I)$  and permeability of the ionomer $(\epsilon_g^I)$ 

$$\epsilon_g^I = D_g^I S_g^I \tag{S30}$$

For the ionomer phase the diffusion coefficients were assumed the follow the Bruggeman relationship,

$$D_j^{eff} = D_g^I \frac{\varepsilon_m}{\tau_m} \tag{S31}$$

Where  $\tau_m = \varepsilon_m^{-1/2}$ . Since the electrolyte species are transported through the ionomer, the porosity  $\varepsilon_m$ , in here, is referring here ionomer volume fraction that is given in Table SI2. HER is assumed to take place via water reduction and water in the catholyte in assumed to be always in equilibrium with ionomer phase. The reaction rate was assumed to follow,

$$i_{H_2} = -i_{H_2}^0 (\alpha_{H_2O} e^{-\frac{\alpha_{H_2}F}{RT}\eta_{H_2}})$$
(S32)

The overpotential( $n_j$ ) for reactions 21 and 26 are given by the applied potential difference between the electric potential of GDE ( $\phi_s$ ) and solution ( $\phi_l$ ).

$$n_j = (\phi_s - \phi_l) - (E_i^o - 0.059^* \text{pH})$$
(S33)

 $\phi_s$  of the electrode was varied between -0.8 V and -2.0 V vs RHE at the GDL-gas flow channel interface while  $\phi_l$  was set to zero as a reference at the CL-electrolyte flow channel interface. The current-voltage relation across the solid phase of obeys the ohms law,

$$i_s = \sigma_m^{eff} \nabla \phi_s \tag{S34}$$

with conservation of current,

$$\nabla \cdot i_s = \alpha_v \sum_k i_k \tag{S35}$$

where  $i_s$  denotes the current density vector in the electrode,  $\sigma_m^{eff}$  denotes the effective conductivity and  $i_k$  is local partial current density for the reaction k. The conductivity ( $\sigma_m$ ) of the medium corrected with Bruggeman relationship.

$$\sigma_m^{eff} = \sigma_m \frac{\varepsilon_i}{\tau_i} \tag{S36}$$

Where  $\varepsilon_i$  is the solid or liquid fraction of the porous medium i. Impermeable boundary for the gaseous species and charge insulation at the outer walls of the GDE were specified. The charge transfer reactions contribute to the source terms ( $S_{CT,j}$ ) in the electrolyte phase for CO<sub>2</sub>, CO and OH<sup>-</sup> and in the gas phase for H<sub>2</sub> via the equation,

$$S_{CT} = -M_j \sum_k \frac{v_{j,k} \alpha_v i_k}{n_k F}$$
(S37)

Where  $v_{j,k}$  is the stoichimetric coefficient and  $n_k$  is the number of electrons transferred for reaction k.

#### 1.5 Homogenous Reactions and Transport of electrolyte species

Homogenous reactions take place in the solution and ionomer phase since the bicarbonate solution not only serves as an electrolyte but also a buffer. When CO<sub>2</sub> is introduced into the solution, the following series of equilibrium reactions takes place,

$$CO_2 \xrightarrow{H_2O} H_2CO_3 \xrightarrow{H_2O} HCO_3^- + H_3O^+$$
 (R3)

$$HCO_3^- \xrightarrow{H_2O} CO_3^{2-} + H_3O^+$$
(R4)

The reactions of water with  $CO_2$  and bicarbonate ions are relatively slow when compared to the reaction of hydroxyl ions with  $CO_2$  and bicarbonate ion. Therefore, the following reactions are assumed to dominate the overall pH near the electrode surface,

$$CO_2 + OH^- \rightleftharpoons_{k_1^b}^{k_1^f} \Longrightarrow HCO_3^-$$
 (R5)

$$HCO_3^- + OH^- \iff^{k_2^f}_{k_2^b} \Longrightarrow CO_3^{2-} + H_2O$$
(R6)

The forward and backward kinetic expressions were used in the flow channel and CL to calculate the reaction rates

$$S_{HR} = k_j^f \prod_{i=react} c_j^{\nu_{ij}} - k_j^b \prod_{i=prod} c_j^{\nu_{ij}}$$
(S38)

and the equilibrium concentrations were dictated by the equilibrium at the inlet

$$K_{eq}^{j} = \frac{\prod_{i=prod} c_{i}^{\nu_{ij}}}{\prod_{i=react} c_{i}^{\nu_{ij}}}$$
(S39)

Where stoichiometric coefficients are denoted by  $v_{ij}$ , forward and backward reaction constants are  $k_j^f$  and  $k_j^b$ . The equilibrium constant  $(K_{eq}^j)$  for a reaction j is given by,

$$K_{eq}^{j} = \frac{k_{j}^{f}}{k_{i}^{b}}$$
(S40)

The flowing electrolyte was not saturated with  $CO_2$  since most of the experimental studies utilized an unsaturated electrolyte in flow cells containing a GDE. Note that some of the dissolved  $CO_2$  in the CL, supplied from the gas channel, is in equilibrium with the electrolyte as shown in Figure SI1. Therefore, the electrolyte next to the CL contains considerable amount of  $CO_2$  during the operation depending on the partial pressure of  $CO_{2(g)}$  in the CL. The reactions rates and equilibrium constants of the homogenous reactions were assumed to be same in the ionomer and aqueous catholyte.<sup>2</sup>

The flux of the species inside the catalyst layer was assumed to be driven by diffusion,

$$J_j = D_j^{eff} \nabla c_j \tag{S41}$$

We note that even though the convective flow in the catholyte channel do not supply direct convective transport in the CL, the boundary layer thickness of the ions, extending to the flow

channel, is effected by the flow of the catholyte. The mass balance of the species in the gas phase can be written in terms of volumetric source and mass flux,

$$\nabla \cdot \mathbf{N}_i = S_{PT,i} + S_{CT,i} \tag{S42}$$

Where  $S_{PT,i}$  and  $S_{CT,i}$  are given by the equations S28 and S37, respectively. The mass balance of the species in the electrolyte phase can be written as

$$\nabla \cdot \mathbf{N}_j = S_{PT,j} + S_{CT,j} + S_{HR,j} \tag{S43}$$

Where  $S_{HR,j}$  is given by the equation S38,

#### **1.5 Conversion and Consumption**

The single-pass conversion was calculated by the following equation,

$$X_{CO_2} = \frac{R_{CO,out}}{F_m} \times 100 \tag{S44}$$

Where  $R_{Co,out}$  is the rate of CO production and  $F_m$  is the molar flow rate of the CO<sub>2</sub>. The consumption ( $W_{CO_2}$ ) was calculated by,

$$W_{CO_2} = \frac{R_{CO2OH}}{F_m} \times 100$$
 (S45)

Where  $R_{CO2OH}$  is net reaction rate of reaction R5.

Ji	Mass Flux of species i	kg m <sup>-2</sup> s <sup>-1</sup>
N <sub>i</sub>	Total mass flux of species i	kg m <sup>-2</sup> s <sup>-1</sup>
$ ho_i$	Density of gaseous species i	kg m⁻³
ug	Mass averaged fluid velocity	m s <sup>-1</sup>
Pe	Pèclet number	
l	Channel length	m
Lm	Thickness of the medium	m
D <sub>i</sub>	Diffusion coefficient of gaseous species i	m <sup>2</sup> s <sup>-1</sup>
Re	Reynolds number	
$ ho_g$	Average density of gas mixture	kg m <sup>-3</sup>
$\mu_g$	Viscosity of the gas mixture	Pa s
$x_i$	Mole fraction of gaseous species i	
$\omega_i$	Weight fraction of gaseous species i	

Table S1: List of Symbols

$D_i^m$	Mass averaged diffusion coefficient of gaseous	m <sup>2</sup> s <sup>-1</sup>
	species i	
M <sub>n</sub>	Average molar mass of the gaseous mixture	kg mol <sup>-1</sup>
M <sub>i</sub>	Molar mass of the gaseous species i	kg mol⁻¹
Cj	Concentration of species j	mol m⁻³
$\varepsilon_m$	Porosity of the medium	
$ au_m$	Tortuosity of the medium	
$D_i^K$	Knudsen Diffusion coefficient	
$D_i^M$	Maxwell-Stefan Diffusion coefficient	
R	Gas constant	J K <sup>-1</sup> mol <sup>-1</sup>
Т	Temperature	К
κ <sub>m</sub>	Permeability of the medium	m <sup>-2</sup>
$D_j$	Diffusion coefficient of electrolyte species j	m <sup>2</sup> s <sup>-1</sup>
λ	mean free path	m
$d_p^m$	Average pore size diameter	М
i <sub>co</sub>	Partial current density of CO	A m <sup>-2</sup>
<i>i</i> <sub><i>H</i><sub>2</sub></sub>	Partial current density of H <sub>2</sub>	A m <sup>-2</sup>
$i_{CO}^0$	Exchange current density of CO	A m <sup>-2</sup>
$\alpha_{co}$	Transfer coefficient of CO formation	
$\alpha_{H_2}$	Transfer coefficient of H <sub>2</sub> formation	
$R_{PT}$	Phase transfer rate to ionomer	kg m⁻³s
F	Faraday Constant	s A mol⁻¹
$\eta_{H_2}$	Overpotential for the formation of $H_2$	V
$\eta_{co}$	Overpotential for the formation of CO	V
$E_i^o$	Standard electrode potential for reaction i	V
$a_v$	Specific surface area	m <sup>3</sup> m <sup>-2</sup>
$d_I$	Thickness of the ionomer	Μ
$p_g$	Total gas pressure	Ра
$S_g^I$	Solubility of the gaseous species in the ionomer	mol m <sup>-3</sup> Pa <sup>-1</sup>
$\epsilon_g^I$	permeability of the ionomer for the gaseous species	mol m <sup>-1</sup> s <sup>-1</sup> Pa <sup>-1</sup>
$D_g^I$	Diffusion coefficient inside the ionomer	m²s
$\phi_s$	electric potential of the solid phase	V
$\phi_l$	electric potential of the liquid phase	V
$\sigma_m^{eff}$	effective conductivity of the porous medium	S m <sup>-1</sup>
$\sigma_m$	conductivity of the medium	S m <sup>-1</sup>
i <sub>s</sub>	Total current density	A m <sup>-2</sup>
i <sub>k</sub>	Local partial current density for the reaction k	A m <sup>-2</sup>
$k_i^f$	forward rate constant for reaction j	
$k_j^b$	backward rate constant for reaction j	

$K_{eq}^{j}$	Equilibrium Constant for reaction j	
X <sub>CO2</sub>	Electrochemical Conversion of CO <sub>2</sub>	
R <sub>Co,out</sub>	Rate of CO formation	mol s <sup>-1</sup>
F <sub>m</sub>	Molar flow rate	mol s <sup>-1</sup>
W <sub>CO<sub>2</sub></sub>	Homogenous consumption of CO <sub>2</sub>	

## Table S2: List of parameters

$L_{\sf FC}$	1 x 10 <sup>-3</sup>	m	
$L_{GDL}$	3 x 10 <sup>-4</sup>	m	3
$L_{CL}$	3 x 10 <sup>-6</sup>	m	4
$D_{CO_2-H_2}$	6.46 x 10 <sup>-5</sup>	m <sup>2</sup> s <sup>-1</sup>	5
$D_{CO-H_2}$	7.43 x 10 <sup>-5</sup>	m <sup>2</sup> s <sup>-1</sup>	5
$D_{CO_2-CO}$	1.52 x 10 <sup>-5</sup>	m <sup>2</sup> s <sup>-1</sup>	5
$\mu_{g}$	1.5 x 10 <sup>-5</sup>	Pa s	
M <sub>CO<sub>2</sub></sub>	0.044	kg mol <sup>-1</sup>	
M <sub>CO</sub>	0.028	kg mol <sup>-1</sup>	
$M_{H_2}$	0.002	kg mol <sup>-1</sup>	
R	8.3145	J K <sup>-1</sup> mol <sup>-1</sup>	
Т	293.15	К	
$\kappa_{GDL}$	3.5 x 10 <sup>-12</sup>	m <sup>-2</sup>	6
$\kappa_{CL}$	1.0 x 10 <sup>-15</sup>	m <sup>-2</sup>	7
$d_p^{GDL}$	2 x 10 <sup>-6</sup>	m	2
$d_p^{CL}$	5 x 10 <sup>-6</sup>	m	2
ε <sub>m</sub>	0.75		
l	1 x 10 <sup>-2</sup>	m	
$i_{CO}^0$	3.3 x 10 <sup>-4</sup>	A m <sup>-2</sup>	8
$i_{H_2}^0$	3.4 x 10 <sup>-6</sup>	A m <sup>-2</sup>	9
$\alpha_{co}$	0.33		10
$\alpha_{H_2}$	0.33		9
$E_{H_2}^o$	0.0	V	
$E_{CO}^{o}$	-0.11	V	
$a_v$	1.0 x 10 <sup>7</sup>	m³m⁻²	3
$d_I$	10 <sup>-8</sup> nm	m	2
$S_{CO_2}^I$	3.97 x 10 <sup>-4</sup>	mol m <sup>-3</sup> Pa <sup>-1</sup>	11
$S_{CO}^{I}$	2.52 x 10 <sup>-4</sup>	mol m <sup>-3</sup> Pa <sup>-1</sup>	12
$D_{CO_2}^{I}$	2.4 x 10 <sup>-10</sup>	m <sup>2</sup> s <sup>-1</sup>	11
$D_{CO}^{I}$	1.15 x 10 <sup>-11</sup>	m <sup>2</sup> s <sup>-1</sup>	12
$\sigma_{CL}$	25	S m <sup>-1</sup>	6
$\sigma_{GDL}$	80	S m <sup>-1</sup>	6

$k_1^f$	5.93 x 10 <sup>-3</sup>	m <sup>3</sup> s <sup>-1</sup> mol <sup>-1</sup>	13
$k_1^b$	1.34 x 10 <sup>-4</sup>	S <sup>-1</sup>	13
$k_2^f$	1.0 X 10 <sup>-8</sup>	m <sup>3</sup> s <sup>-1</sup> mol <sup>-1</sup>	13
$k_2^b$	2.15 X 10 <sup>-4</sup>	S <sup>-1</sup>	13
$D_{HCO_3^-}$	9.23 X 10 <sup>-10</sup>	m <sup>2</sup> s <sup>-1</sup>	13
$D_{CO_{3}^{2-}}$	1.19 X 10 <sup>-9</sup>	m <sup>2</sup> s <sup>-1</sup>	13
D <sub>OH</sub> -	5.27 x 10 <sup>-9</sup>	m <sup>2</sup> s <sup>-1</sup>	13



















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