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Investigation of carbon corrosion for HT-PEM fuel cells and development of protective start and stop procedures

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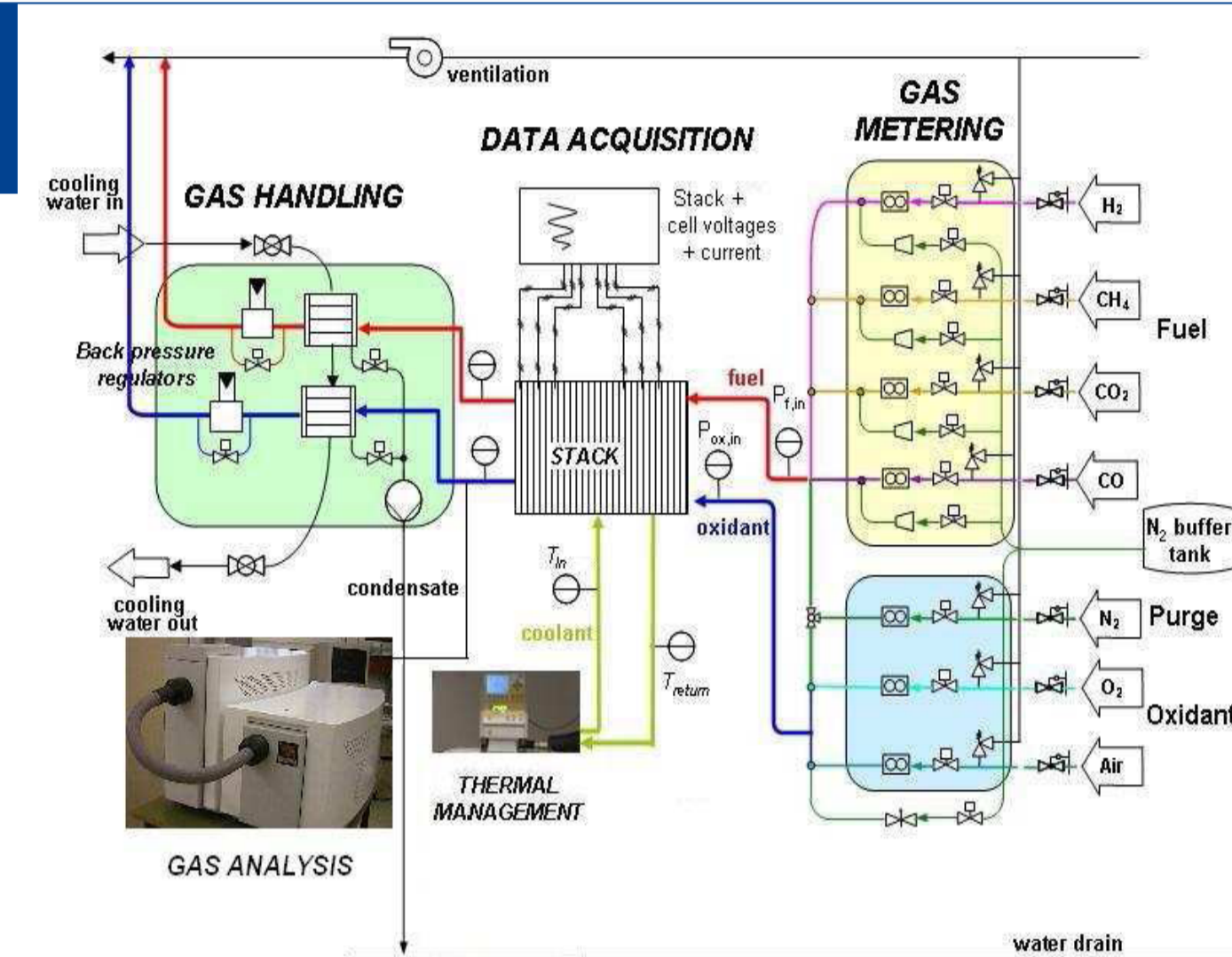
Objective

- Analyzing the HT-PEMFC cathode carbon corrosion using mass spectrometry for the detection of carbon dioxide evolution
- Lifetime prediction and identification of non stressing operating conditions with respect to degradation of the fuel cell stack

Experimental

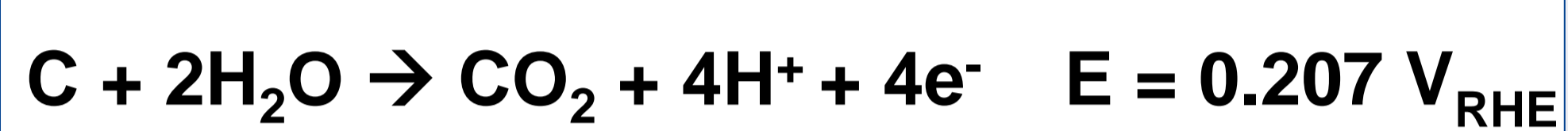
Use of commercial MEA
Carbon loading on the MEA

Electrode	Weight (mg/cm ²)	Weight (mg/electrode)	Wt/12 (Moles)
Cathode	21.34	3478.42	0.29
Anode	21.98	3582.74	0.3



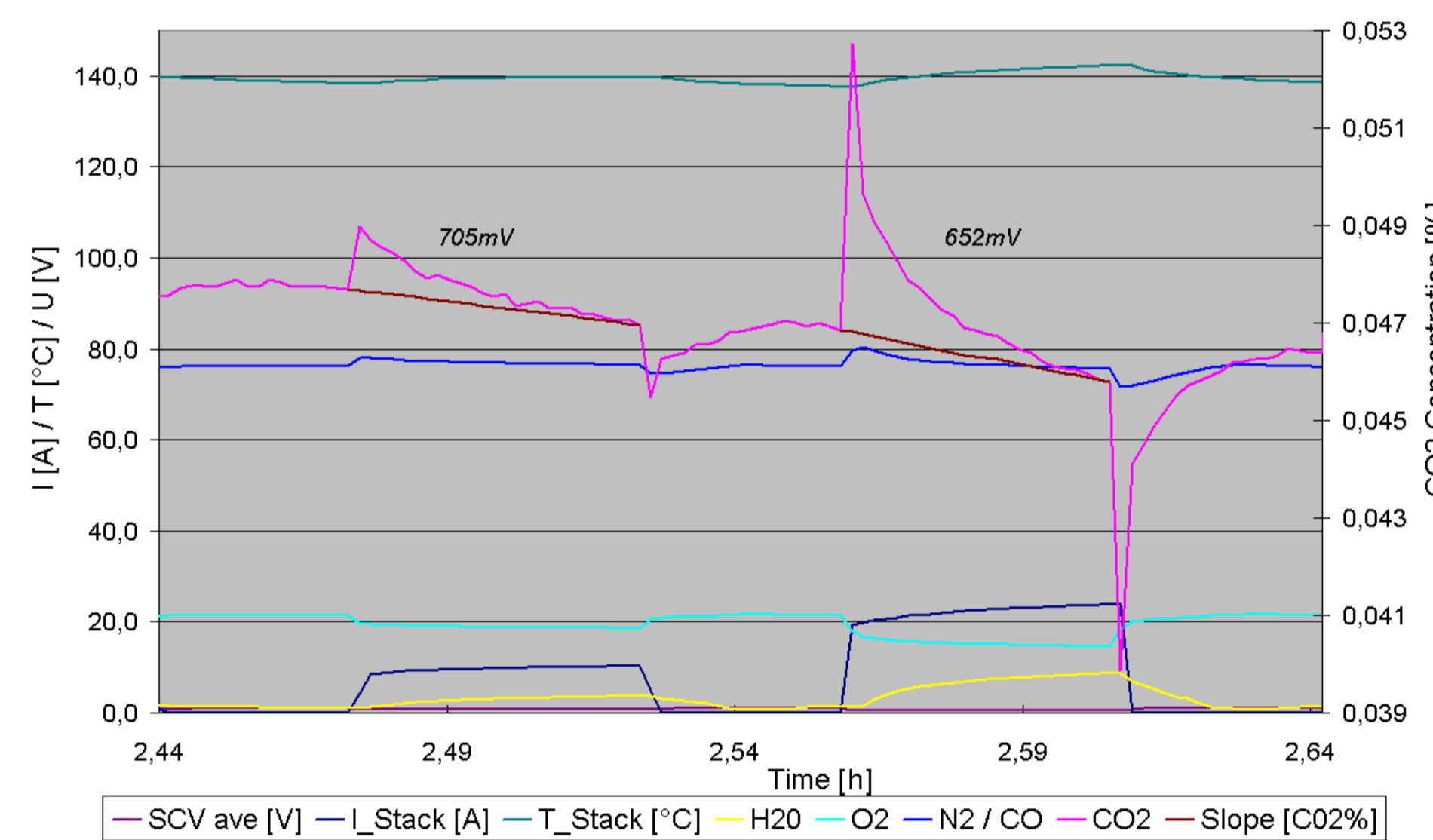
- Stack heat up ~ 2.5 K/min
- Flow set to equiv. c.d. of 0.25 A/cm²:
- Anode: 80/20 H₂/N₂, λ=1.25
- Cathode: air flow, λ=2.5

Degradation



- Potential cycling with OCV operation
- Potential cycling with 650 mV operation
- Lifetime prediction for 8% carbon loss
- Start-up and Shut down strategy

Influence of OCV



Measurement series (OCV – X – OCV)

Desorption of oxidised carbon from MEA as CO₂

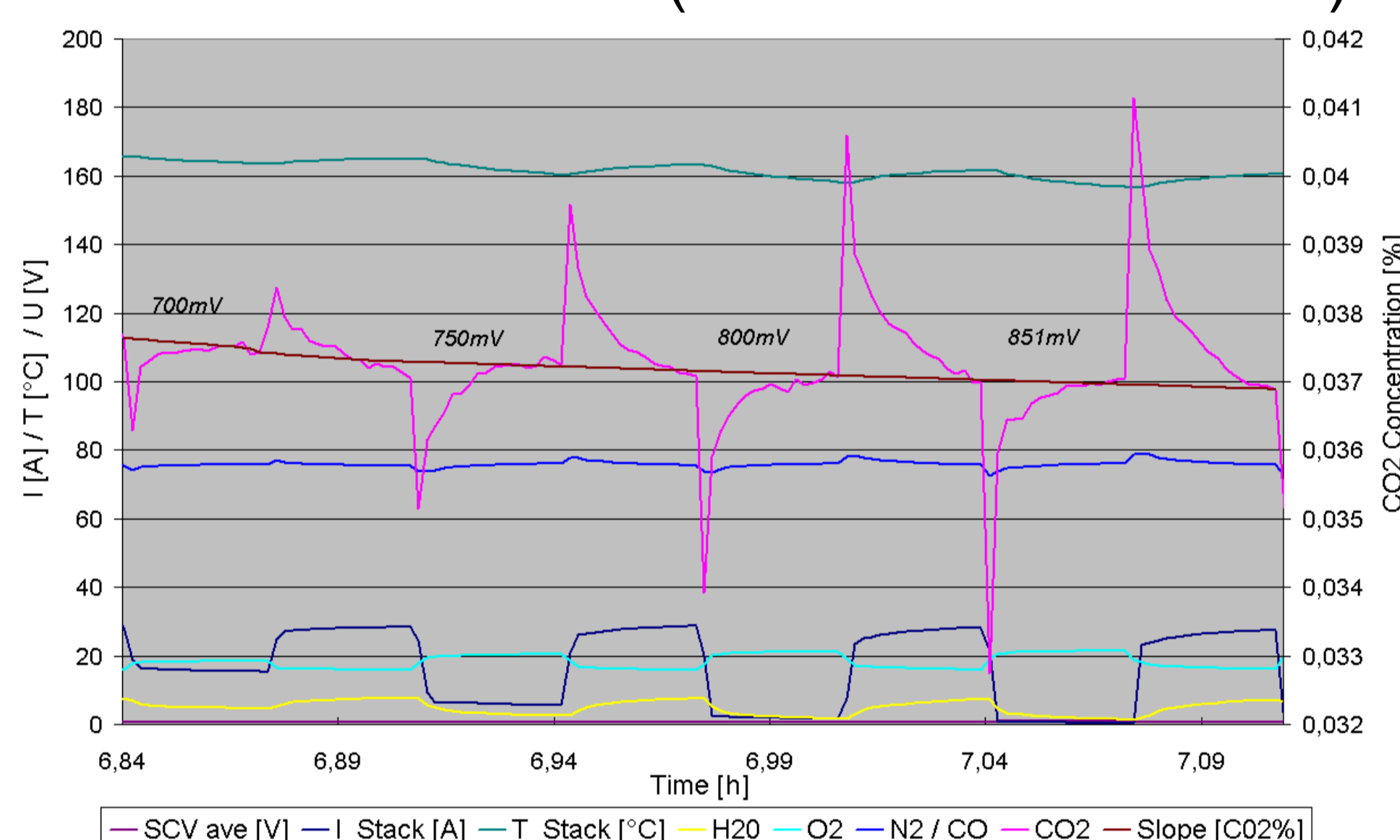
	120 °C	140 °C	160 °C
700mV			
CO ₂ [Moles]	2.42E-06	2.95E-06	3.76E-06
Factor of Life	3.8	3.12	2.45
650mV			
CO ₂ [Moles]	7.26E-06	7.83E-06	9.20E-06
Factor of Life	1.27	1.17	1

*Data provided for cycles of 2 min OCV duration

- Significant adsorption/desorption effects observed
- No full CO₂ release at 700mV
- Strong desorption at 650mV observed

Influence of Cell Voltage

Measurement series (650mV – X – 650mV)



- Significant effect of CO₂ content due to variation of potential
- Observation of strong adsorption/desorption effects depending on the cell potential
- No full CO₂ during cycle expected, only relative figures for lifetime estimation useful

Region	Potential	CO ₂ [Moles]		
		120 °C	140 °C	160 °C
Ohmic	700 mV	3.07E-07	2.64E-07	2.12E-07
	750 mV	5.41E-07	(1.11E-07)	4.15E-07
Activation	800 mV	1.11E-06	1.65E-06	1.89E-06
	850 mV	1.78E-06	2.02E-06	3.14E-06

Region	Potential	Factor of Lifetime		
		120 °C	140 °C	160 °C
Ohmic	700 mV	10.2	11.9	14.8
	750 mV	5.8	(28.2)	7.6
Activation	800 mV	2.8	1.9	1.3
	850 mV	1.8	1.6	1

** Data provided for cycles of 3 min duration

- Corrosion rate is strongly enhanced at potentials > 750 mV
- Continuous operation shall be done within 500 mV to 750 mV

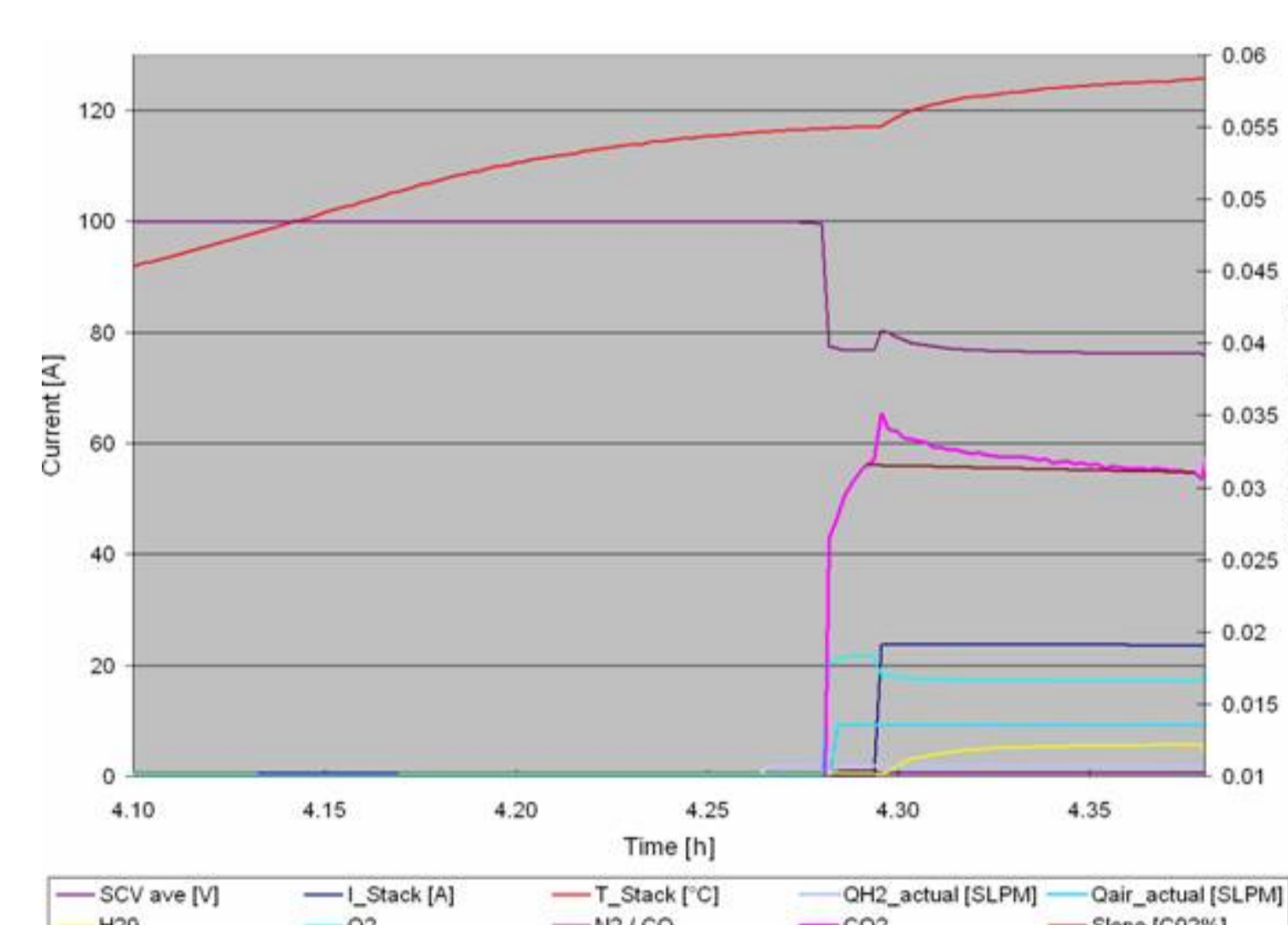
Start Stop Operation

Start up Strategy

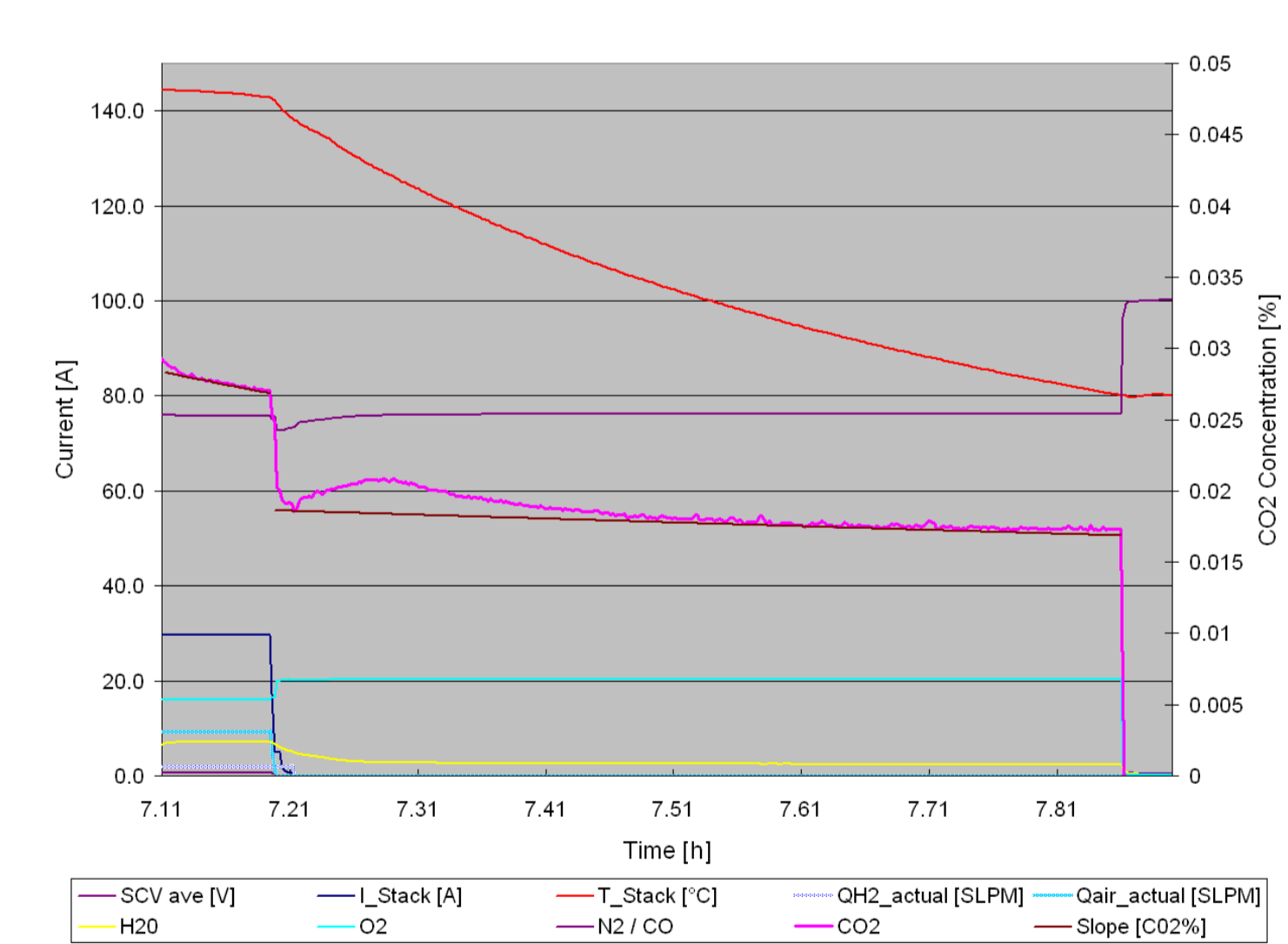
- Nitrogen as protecting gas flows through the stack.
- At 115°C, anodic fuel flow is started
- After 30 sec, air flow at the cathode is turned on,
- Stack is operated at OCV for 30 s.
- Current ramp up to 40.5 A

Shut down Strategy

- Current reduction to 5 Amps for 600 s.
- Stop air flow
- drop of current and cell voltage close to zero
- After 1 min, switch of anode flow to nitrogen
- Stack cool down (no coolant flow)



	160 °C	140 °C	120 °C
Start up			
CO ₂ [Moles]	3.21E-05	2.79E-05	1.80E-05
Lifetime [Cycles]	9045	10394	16111



	160 °C	140 °C	120 °C
Shutdown			
Current phase	4.33E-06	3.36E-06	2.80E-06
Temp phase	1.23E-05	6.15E-06	3.74E-06
Total CO ₂ [Moles]	1.66E-05	9.51E-06	6.54E-06
Lifetime [Cycles]	17470	30494	44343

Conclusion

- Lifetime of the stack is strongly affected to OCV exposure (factor of appr. 12 - 26 times between OCV and 700 mV)
- Extended operation of the stack in the activation region (> 750mV) can accelerate degradation exponentially and should be avoided to prolong the life of the fuel cells. Lifetime reduces by a factor of appr. 6 - 15 times @ 150 mV voltage increase (700 to 850 mV)
- Protective start and stop procedures were developed. An effective cooling strategy can also reduce the corrosion induced by stop cycles.