Electrochemical Degradation of Gas Diffusion Layers in PEM Fuel Cells

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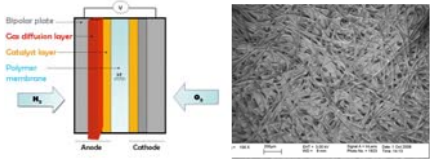
Objectives

The degradation of the components of the membrane electrode assembly is a topic of concern for the lifetime of fuel cells. Up to now, one of the components has received significantly less attention than the others: the gas diffusion layer (GDL). What if their surface properties were found to change during the lifetime of the device?

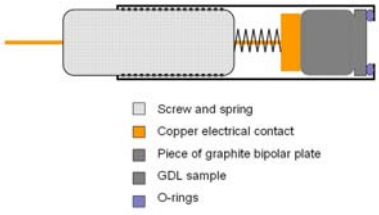


SEM Micrograph of a GDL

• Electrochemical corrosion is designed to simulate the corrosive environment of fuel cells and to give information concerning the corrosion mechanism.

•What is the impact of corrosion on the surface properties of the GDL?

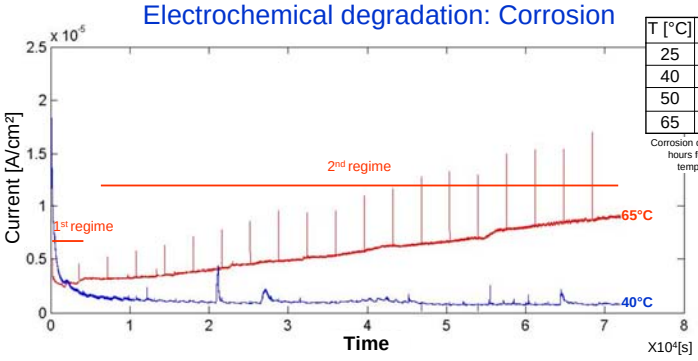
Methods



1. Potentiostatic corrosion experiments in a three electrode electrochemical cell
   - Working electrode: the GDL sample
   - Reference electrode: Silver chloride or Calomel
   - Counter electrode: Platinum rod
   - Electrolyte: 1M H_2SO_4, Potential 0.8-1.2$V_{vs\ SHE}$, Temperature: 25-65°C, Corrosion time: 10-50 hours
2. Surface analysis (SEM, XPS, EDX)

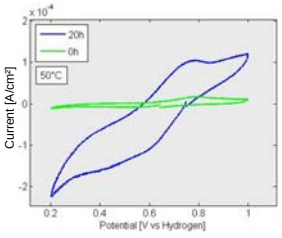
Results

Electrochemical degradation: Corrosion



T [°C]	C/cm²
25	0.022
40	0.073
50	0.25
65	0.26

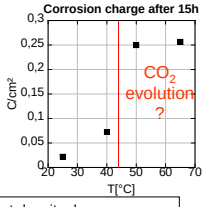
Corrosion charge after 15 hours for different temperatures



Cyclic Voltammograms allow to investigate the formation of surface oxides

•1st regime: the current density decrease, oxygen adsorption at the existing defect sites and creation of new defect sites.

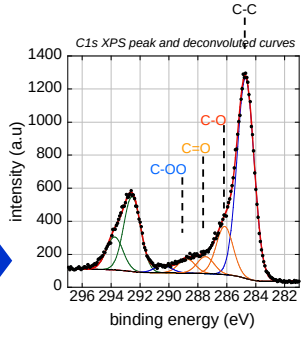
•2nd regime: the current density increase linearly as more oxygen adsorbs, causes CO_2 evolution and creates more corrosion sites.

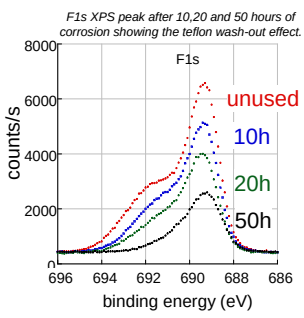


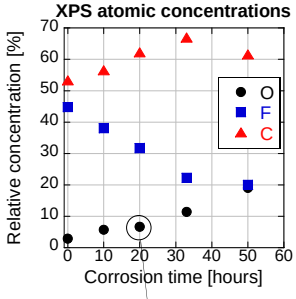
At 40°C and below, the corrosion current density decreases continuously during the whole experiment.

Above 40°C, there are 2 regimes. At first the current decreases. Secondly, the corrosion accelerates untill the end of the test.

Surface analysis: XPS







Atomic concentration evolution for corrosion experiments at 65°C, 1.2V

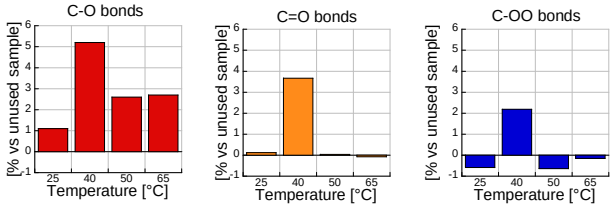
•The atomic concentration of oxygen at the surface is increased by corrosion.

•The surface concentration of fluorine decreases due to Teflon wash-out.

•The main group of surface oxides is the C-O bond.

•The surface oxide concentration is the highest at 40°C.

Surface oxides concentration after a 20h long corrosion experiment



Corrosion mechanism

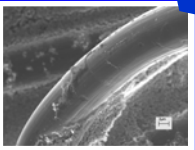
$$C + 2H_2O = CO_2 + 4H^+ + 4e^-$$

$C_x + H_2O \rightarrow C_x{-}OH + H^+ + e^-$

$C_x{-}OH \rightarrow C_x{-}O + H^+ + e^-$ ——— Electroactive species

$C_x - O + H_2O \rightarrow C_{x-1}COOH + H^+ + e^-$

$C_{x-1}COOH \rightarrow C_{x-1} + CO_2 + H^+ + e^-$ ——— Reaction of the second regime for corrosion at 50°C and 65°C



Above 40°C, the corrosion is accelerated as more oxygen adsorbs and creates more corrosion sites. At 40°C, the surface oxyde concentration is higher although the corrosion charge is clearly lower at 50°C or 65°C.

It seems that carbon dioxide formation does not occur below 40°C.

Conclusions

•Teflon wash out is already observed after 10 hours of corrosion at 1.2V and 65°C

• Two corrosion mechanisms seem to occur in parallel: surface oxide formation and carbon dioxide evolution.

•The temperature has an impact on the carbon corrosion mechanisms, a transition in the corrosion behaviour being observed around 40°C.

References

M. Matsumoto, T. Manako, H. Imai, *Journal of the Electrochemical Society*, **156**, B1208-B1211 (2009)