Understanding Water Transport in Compressed Gas Diffusion Layers of Polymer-Electrolyte Fuel Cells Using X-ray Computed Tomography

Iryna V. Zenyuk[1], Dilworth Y. Parkinson[2], Gisuk Hwang[3] and Adam Z. Weber[1]

[1]Electrochemical Technologies Group, [2]Advanced Light Source

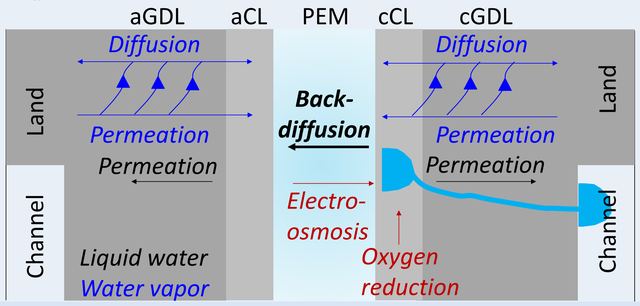
Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720, USA

[3]Wichita State University, Wichita, KS 67260, USA

ivzenyuk@lbl.gov

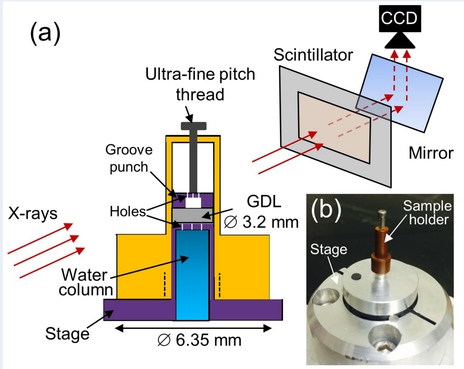
Introduction

- Optimal water management at low temperatures is one of the critical issues in commercializing polymer-electrolyte fuel cells (PEFCs)
- Design of porous carbon-fiber materials, such as gas-diffusion layers (GDLs) for maximum water permeation
- Synchrotron X-ray CT to study the morphology of GDL materials under varied compressed state, chemical treatment and banded porosity
- Correlate structure properties to transport parameters



Experimental Setup

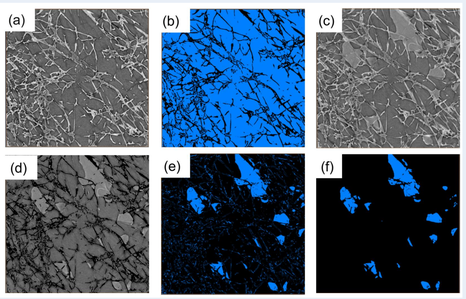
- Ultra-fine pitch thread for controlled compression
- Water imbibition through holes in aluminum stage
- Stamp has a 1 mm groove for land|channel simulation



Materials: SGL 10 BA , Toray paper

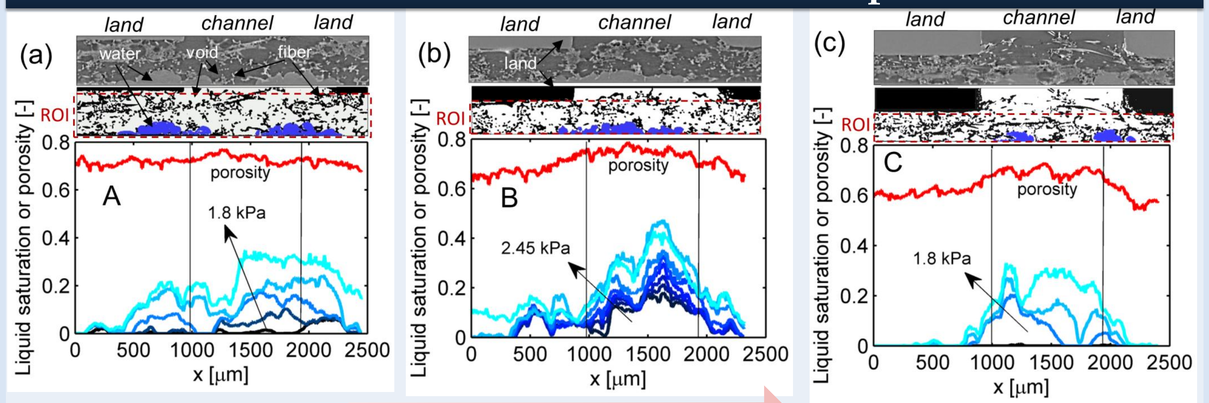
Collection of data: ALS Beamline 8.3.2, 14 keV, 500 ms exposure time, 5x lenses, 1.3 – 2.2 µm resolution, PCO. Edge and PCO.Dimax cameras

Reconstructions: MBA with Fiji and Octopus 8.5.

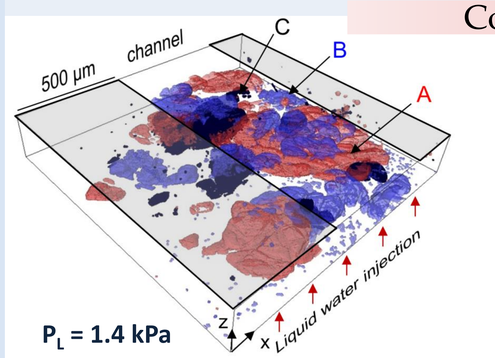


a) Dry tomograph, b) segmented, c) tomograph with water, d) reduced in two phases, e) segmented, f) morphological procedure

Three Levels of Land/Channel Compression

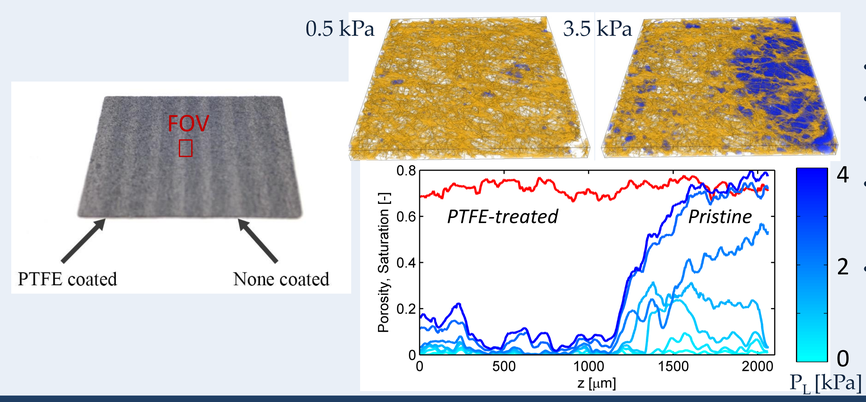


Compression



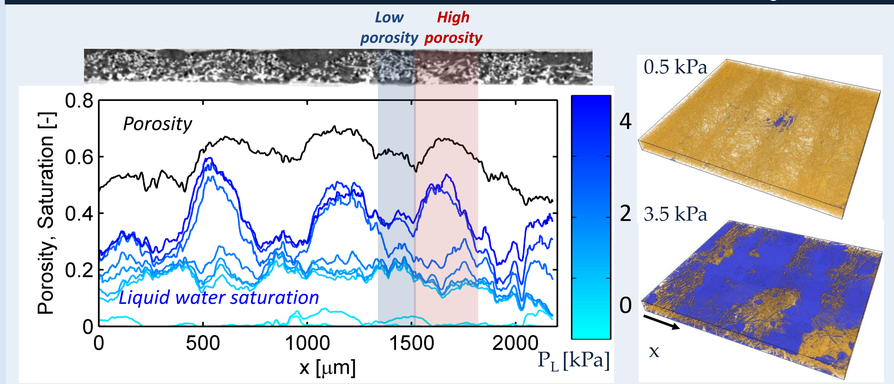
- Compressed thicknesses for A: 340 µm, B: 260 µm, C: 210 µm.,
- Higher saturation for higher pressures with non-uniform water front
- At highest compression, C, porosity under channel is higher by 0.1 compared to land
- Water front becomes narrower at higher compressions
- Size of water clusters decreases with increase in compression. From A to C it is 100 µm
- Water spreads laterally for compression A forming large clusters
- Clusters lose their connectivity at higher compressions forming smaller islands

Hydrophobic Treatment



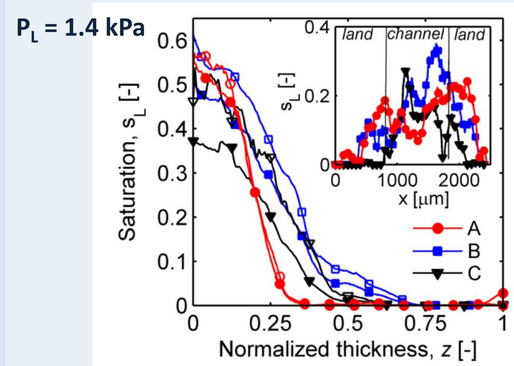
- GDL is treated with PTFE
- Sample is cut to have 50|50% of PTFE and untreated areas
- At 4 kPa 0.6 saturation difference between two regions
- Directional PTFE treatment directs water removal through pristine areas

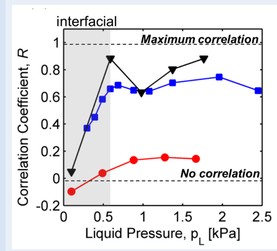
Modulated Porosity



- Porosity variation of 0.1 with fiber bands of ~500 µm
- At lower liquid pressures water front did not get to modulated bands
- At high liquid pressures saturation and porosity have the same wavy profile
- Water is preferentially removed through high-porosity bands

Water Front





- Only 20-40% of GDLs are filled by water-front, the rest is capillary fingering
- Correlation coefficient between porosity and saturation highest at highest compression
- Weak correlation between porosity and saturation for the least compressed sample

Summary

- Water front position under land|channel geometry of fuel cells depends on cell compression
- 0.1 reduction in porosity causes water to move through high porosity regions
- Three methods of directional water removal studied: land|channel compression, hydrophobic treatment and banded porosity
- In all three structures water preferentially moves through low resistance pathways
- These porous carbon design strategies can be applied to the other electrochemical devices such as electrolyzers and redox-flow batteries

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