A Comparison of Laboratory Based and Synchrotron Nano X-ray CT for PEFC Micro Porous Layer

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The nano-structure of the micro porous layers (MPLs) used in polymer electrolyte fuel cells (PEFC) has introduced new challenges to existing tomography techniques. A such technique, X-ray CT has fundamental abilities such as: 1) non-destructive 3D tomography, 2) high energy, enabling deeper penetration and internal imaging, and 3) strong absorption and phase contrast dependence to elemental composition. In this study, the nano structure of an MPL was analyzed by two nano X-ray CT techniques: 1) Xradia Inc. Ultra XRM-L200 laboratory based system, and 2) synchrotron radiation source at the beamline 32-ID C of the Advanced Photon Source (APS) at Argonne National Laboratory (ANL).

The Xradia Inc. Ultra XRM-L200 laboratory based nano X-ray CT system is similar to visible light microscope and uses condenser and objective lenses to respectively project the X-ray onto the sample and to magnify the X-ray images. The beam is cone shaped and includes a range of X-ray energies. Generally in micro XCT systems such as Xradia XCT-400 contrast is obtained based on absorption difference of transmitting X-ray through different materials present in the sample. Additionally, the Ultra XRM-L200 system utilizes Zernike phase contrast technique to enhance the visibility of edges and boundaries. This is important for imaging MPL since the absorption contrast of the MPL materials such as carbon, PTFE and pore is rather low. At APS, tomography is based on synchrotron radiation source, which provides high-energy monochromatic (i.e., single energy level) radiation and parallel beam. Because of high-energy flux monochromatic radiation the imaging is fast and with high resolution. Compared to cone shaped beam of the laboratory based systems, the parallel beam results in low noise, low image blur and good contrast [1].

For both systems, i.e., the laboratory based and synchrotron, there are several influential parameters to obtain high-resolution tomographic images [2]. It is necessary that the X-ray energy flux should be high enough to have sufficient number of photons for good measurement statistics. The detector should have high spatial resolution to distinguish different photon paths. Moreover, the number of projections increases with spatial resolution.

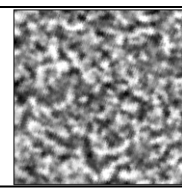
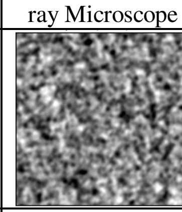
The measurement setup for the MPL 3D microstructural reconstruction using the two systems is summarized in Table 1. The same type of in-house MPL is used at both measurements. It can be seen in Table 1, a higher pixel resolution of 26.76 nm was obtained using the APS. Additionally, the scan time is much faster in case of synchrotron.

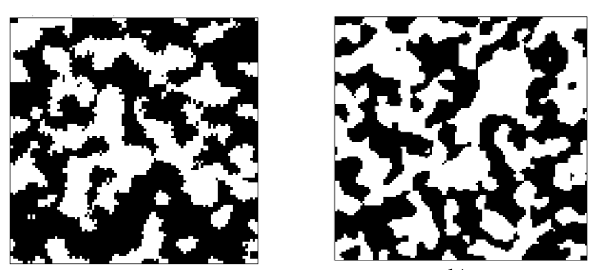
Binarization was performed on both set of data to identify solid and open pore phases of the MPL. The binarization was performed using Otsu's automatic segmentation technique. After the segmentation, further post-processing was performed to compare the measurement results obtained by these two techniques on the MPL structural and transport properties.

Figure 1 shows the segmented slices of the MPL microstructure obtained by the laboratory based and the synchrotron systems. It can be seen that using synchrotron system, a better image contrast is obtained, resulting in sharper solid edges.

Pore size distribution of the MPL was obtained with both measurements using the virtual sphere packing method [3]. The result showed smaller pore diameter with APS data. This may have resulted from higher resolution of APS data. Oxygen transport within the MPL was also investigated and the values of the oxygen diffusion coefficients within the MPL for both measurements were reported.

Table 1Measurement techniques and setup conditions

Name	Xradia Inc.	APS
Imaging equipment	Xradia Inc. Ultra XRM-L200	Xradia Inc. Transmission X-ray Microscope
Image (Example)		
Type of system	Cone beam (Lab. source), Magnification optics	Parallel beam(32-ID-B,C), Magnification optics
Pixel resolution	32nm (object)	26.76nm (object)
FOV	15μm	25μm
Energy	40 kV, Tube current 30 mA	32 kV, $1x10^{-4}$ Ph/s
Scan rate	33 hours / scan	Less than 1 hour / scan



a) b)

Figure 1 2D slice of the MPL obtained by a) Xradia Inc. Ultra XRM-L200, and b) APS synchrotron source

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