Contrast-to-Noise Ratio Evaluation for X-ray Computed Tomographic Imaging of Water in Polymer Electrolyte Fuel Cells

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Background & Challenges

➢ **Background:**

- **Water management** is crucial to the performance of polymer electrolyte fuel cell (PEFC)[1]; Optimal operation is needed to maintain the humidity of membrane and reduce the degree of saturation in gas diffusion layer (GDL);
- Operando X-ray tomographic imaging is a promising technique for investigating of water transient phenomena[2] .

➢ **Challenges:**

- **Sub-second** tomographic imaging is required to study water dynamics[2] ;
- Reduction of scan time limited by water segmentation which requires suitable image quality.

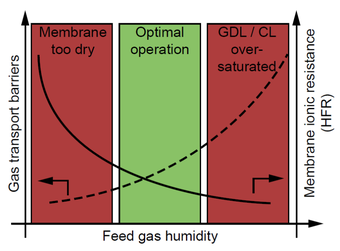
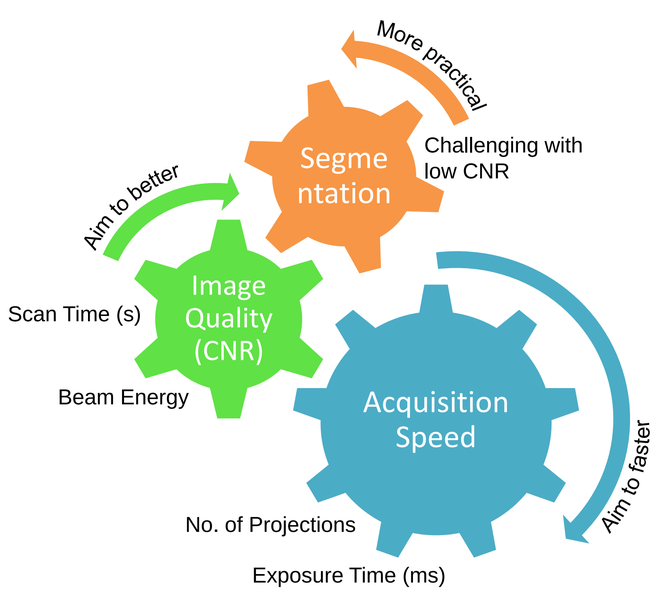
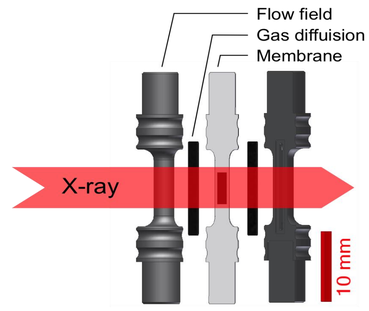


Image Source: J. Eller, ETH Dissertation, 2013

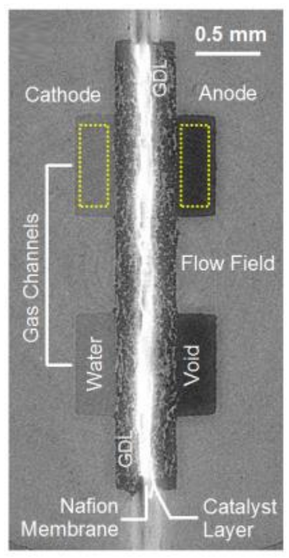


PEFC Experimental Setup

- Double channel polymer electrolyte fuel cell (PEFC) [2];
- Gas diffusion layer: SGL 24BC;
- Catalyst coated membrane (CCM): SolviCore H400;
- Cathode channels filled with water;
- The dashed yellow rectangles indicate the sampling area for CNR calculation.



- *Schematic of cell components*

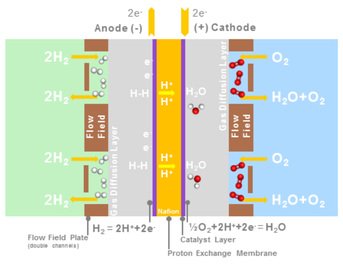


- *X-ray tomographic through-plain slice of PEFC*

PEFC Basics

➢ **PEFC conditions:**

- Wide operation temperature range with current densities up to 2 ~3 A/cm^2;
- Water is generated at the cathode therefore insulates the transports of gases especially oxygen.



- *Principle of PEFC*

Contrast-to-Noise Ratio (CNR)

➢ **Indicator for image quality:**

- Contrast-to-Noise Ratio (CNR);
- Define as:

$$CNR(A/B) = \frac{|Mean(A) - Mean(B)|}{StdDEV(B)}$$

- CNR(H_2O/Void) between cathode (water) and anode (void) channels represents for the contrast between water and void in GDL.

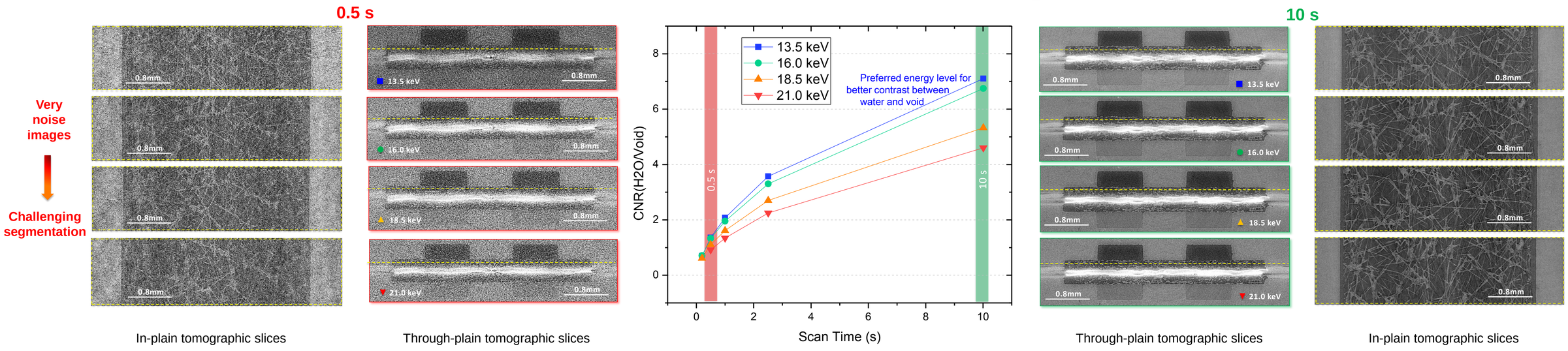
X-ray Tomographic Imaging

➢ **X-ray tomographic imaging settings:**

- Performed at TOMCAT beamline of Swiss Light Source;
- Energy range: 13.5-21.0 keV (monochromatic beam, ΔE/E=2~3%);
- Flux densities: 10^{11}~10^{12} photons /(s·cm^2);
- Output: 3D-grey images with 3 μm voxel size;
- Absorption contrast reconstruction.

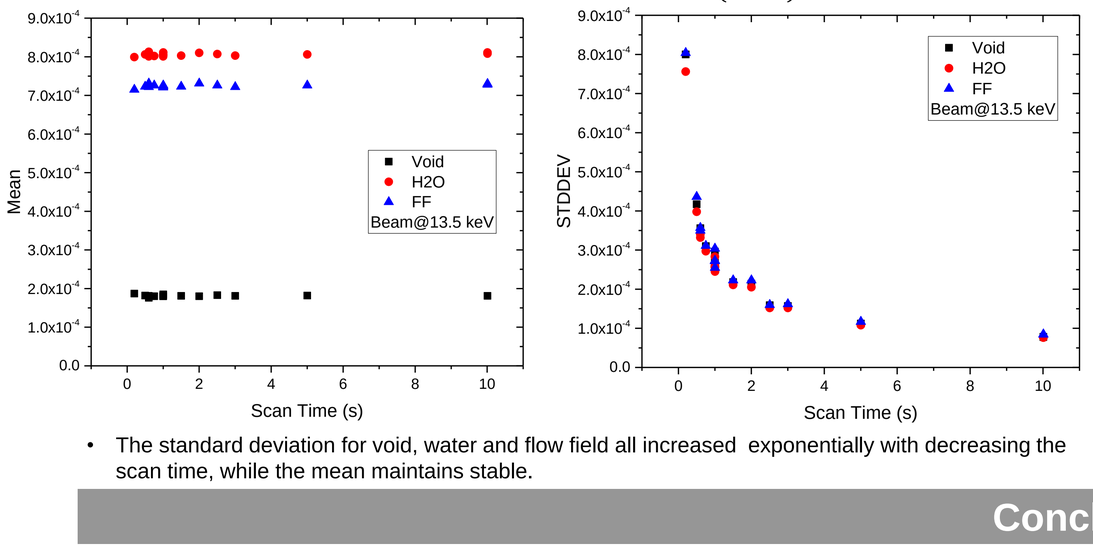
CNR Evaluation & Analysis

- Influence of **Beam Energy** on contrast-to-noise ratio of water versus void [CNR(H_2O/Void)] in PEFC channels



- Influence of **Mean & StdDEV** on CNR

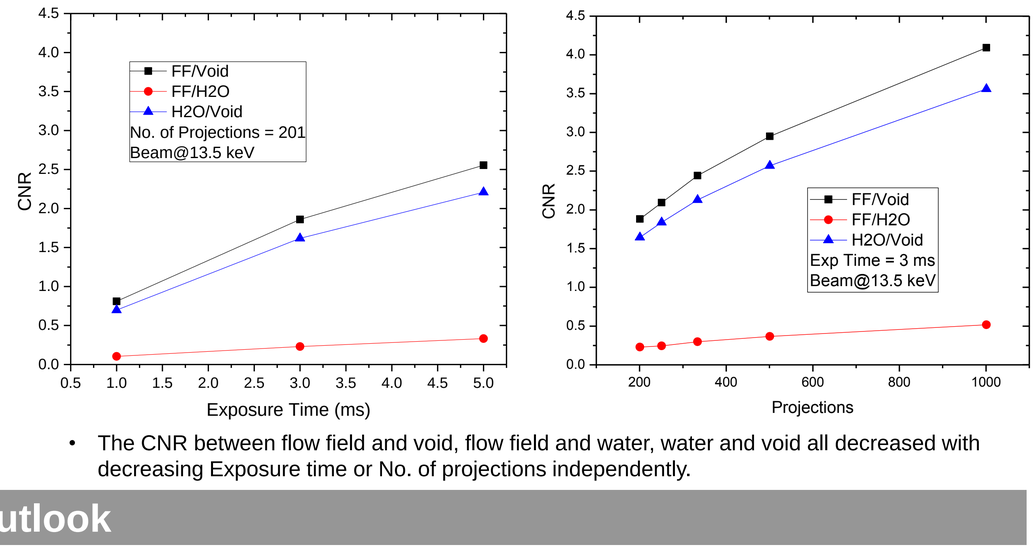
$$CNR(H_2O/Void) = \frac{|Mean(H_2O) - Mean(Void)|}{StdDEV(Void)}$$



- The standard deviation for void, water and flow field all increased exponentially with decreasing the scan time, while the mean maintains stable.

- Influence of **Exp Time & No. of Projections** on CNR

$$Scan\ Time = Exposure\ Time \times No.\ of\ Projections$$



- The CNR between flow field and void, flow field and water, water and void all decreased with decreasing Exposure time or No. of projections independently.

Conclusions & Outlook

- Double channel PEFC with cathode channels filled with liquid water has been investigated using synchrotron X-ray tomographic imaging.
- Dependency of CNR on beam energy was studied both qualitatively and quantitatively: 13.5 keV is the preferred energy in terms of CNR (H_2O/Void).
- Standard deviation dominates the value of CNR; Decreasing exposure time or No. of projections reduces the CNR independently.
- Next step is studying the influence of the imaging parameters on water segmentation and feature detectability in GDL.

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References

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[2] J. Eller, F. Marone and F. N. Büchi, “Operando sub¬second tomographic imaging of water in PEFC gas diffusion layers.” ECS Trans. 69(17), 523–531, 2015.
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