Nanoscale X-ray Computed Tomography of Solid Oxide Fuel Cell Electrodes

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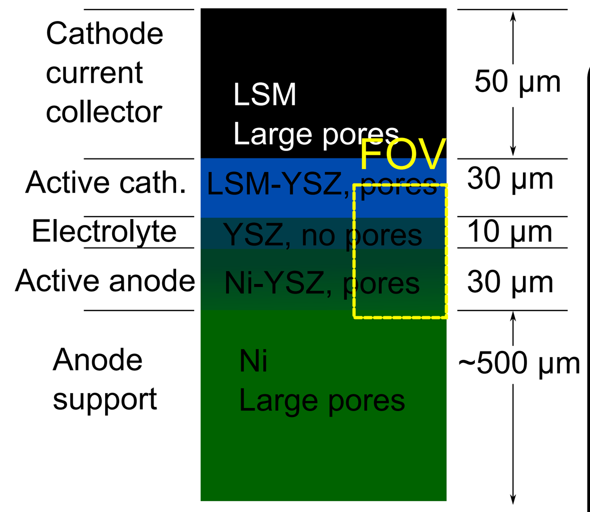
Abstract

- Understanding performance degradation in SOFCs requires an understanding of electrode microstructure
- Prior methods yield small fields of view below scale of eterogeneity present in some cells
- Nanoscale X-ray CT can yield 3D microstructure of a larger volume

Here, we present imaging, artifact removal, and analysis of the scale of heterogeneity in industrial SOFC electrodes

Nanoscale X-ray CT of Solid Oxide Fuel Cells

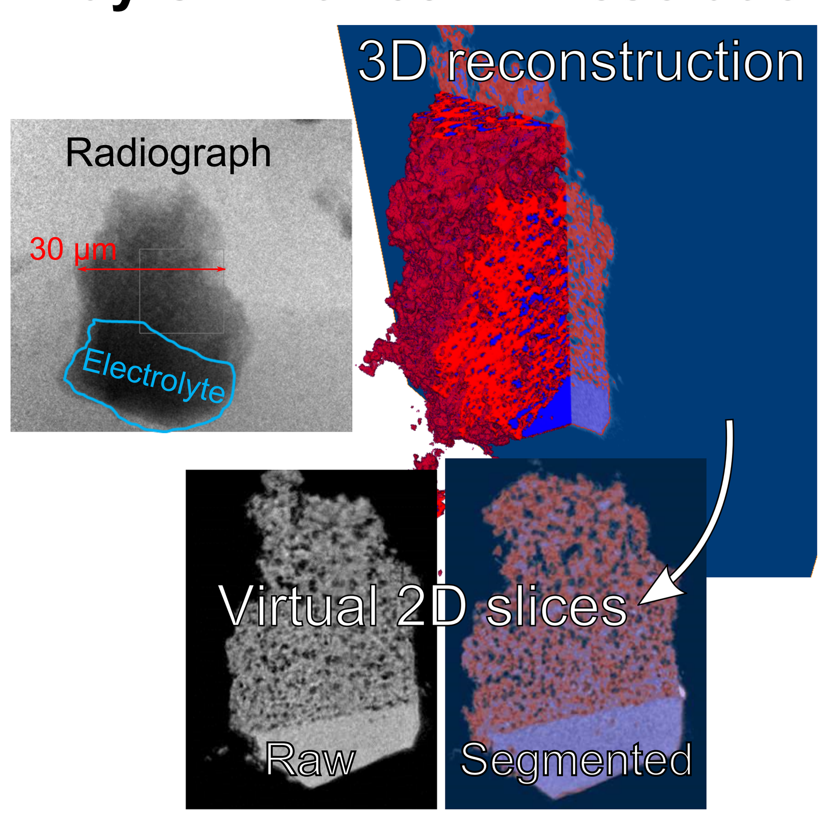


Cathode materials:

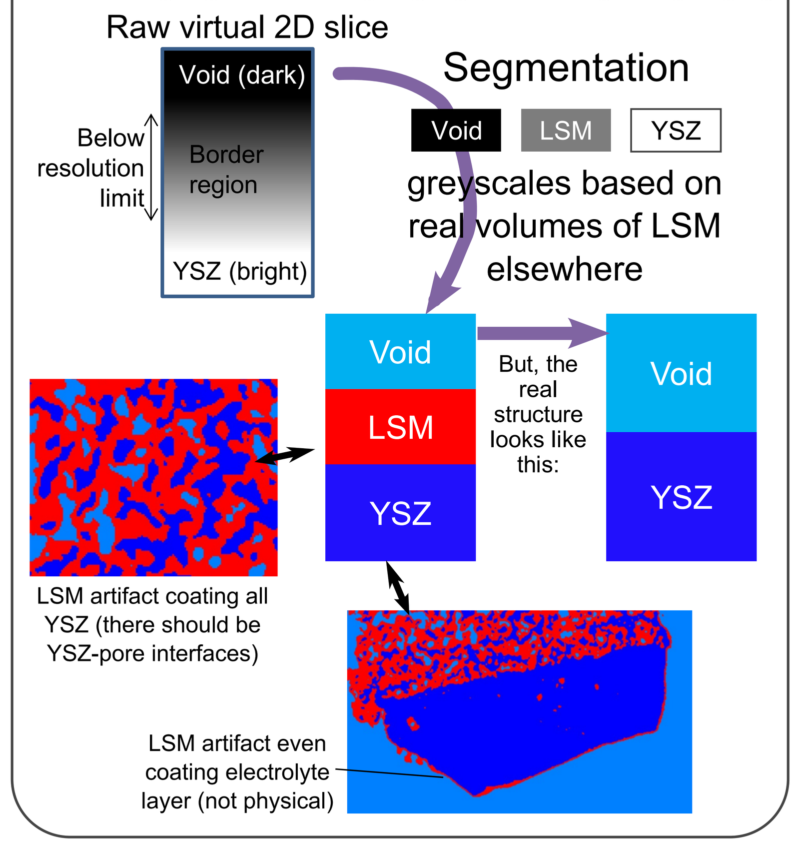
LSM
Lanthanum strontium manganate, electron conductor / catalyst

YSZ
Yttria-stabilized zirconia, oxide conductor

X-ray CT with 65 nm resolution

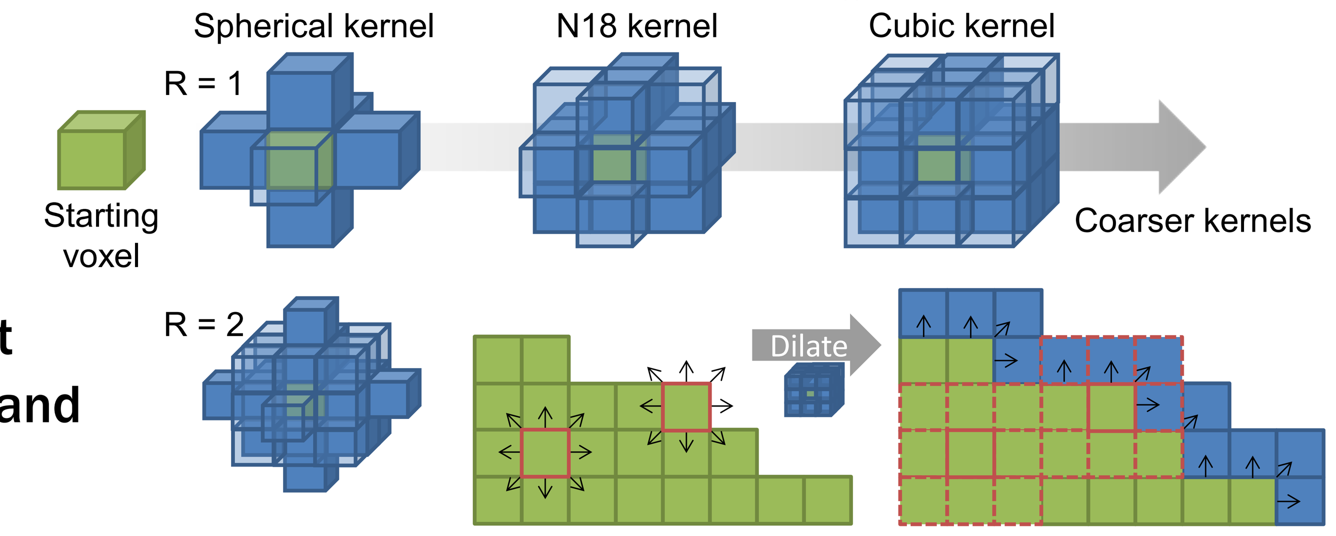


Three-Phase Artifact

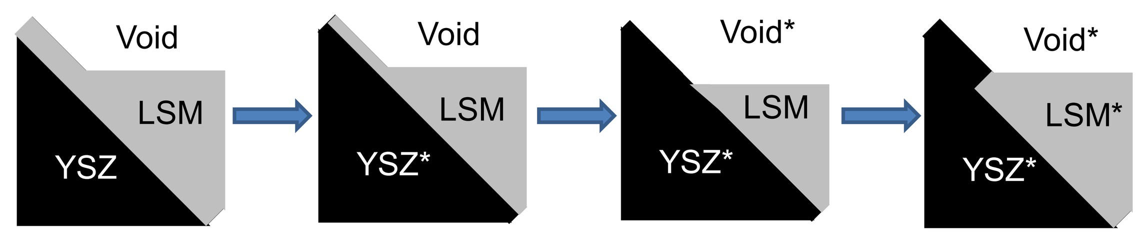


Removal Method: Morphological Dilation

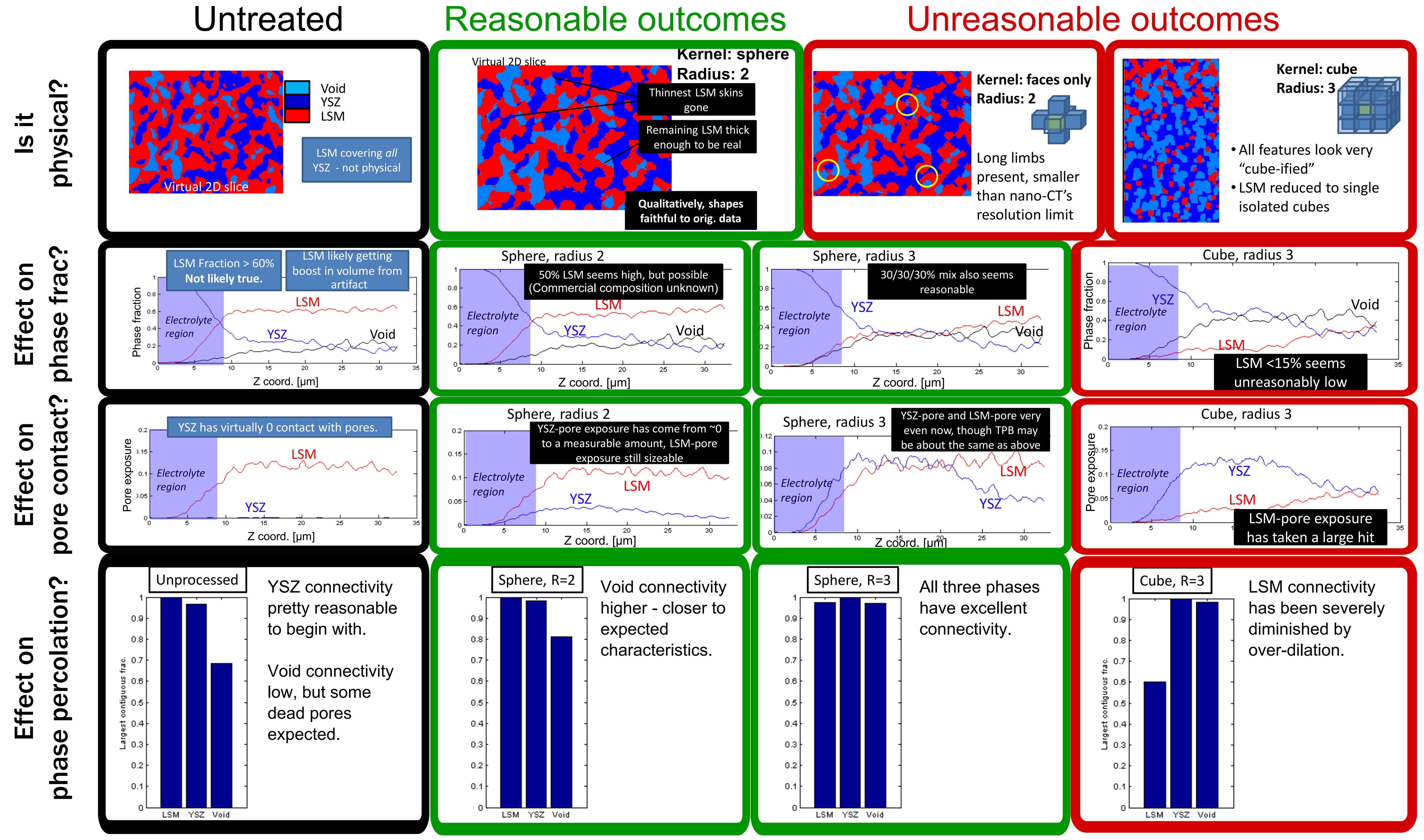
Dilation: Different kernels and sizes



Artifact removal by sequential dilation



Studying Dilation Parameters for Artifact Removal

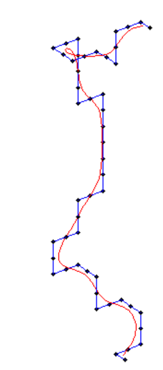


Using a Spherical Dilating Kernel of R = 2:

3D Spatial Analysis of TPB Distribution

TPBs determined vertex-by-vertex in 3D

↓



Vetices connected to orthogonal neighbors

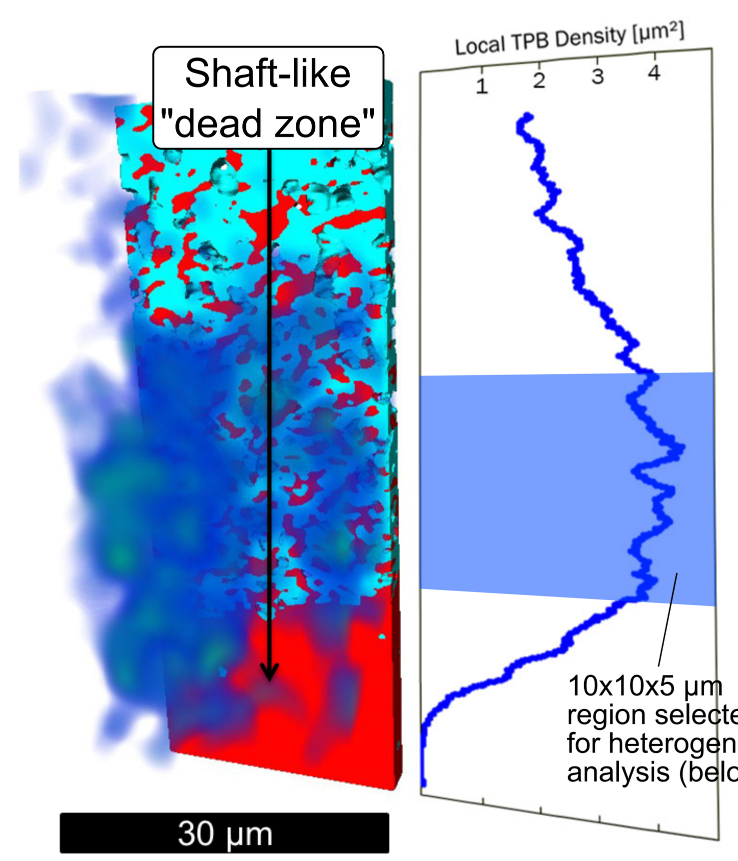
↓

Paths smoothed for accurate length measurement

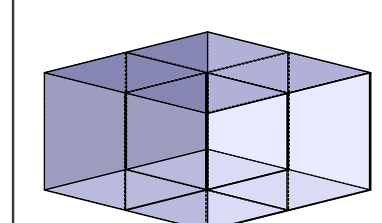
↓

Local TPB length stored on voxel-by-voxel basis for 3D spatial analysis

TPB density "cloud" visualization

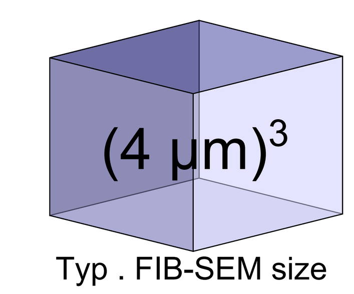


Heterogeneity Analysis

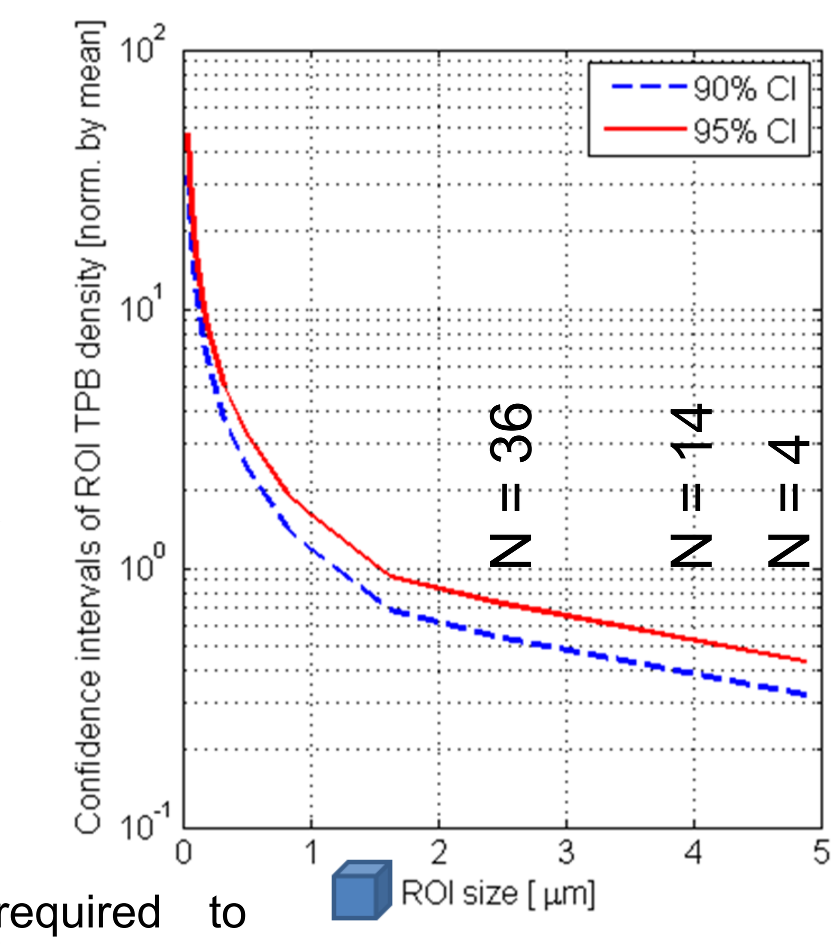


Multiple cubic ROIs placed within larger volume

How much does TBP density differ between each cube, as the cubes become smaller?

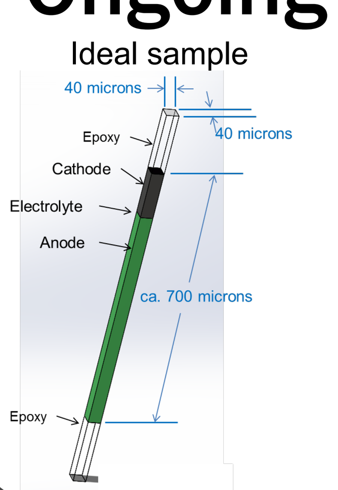


±40%
deviation from mean TPB, based on 95% confidence interval on T-distribution



Larger volumes (30+ µm) required to accurately characterize more heterogeneous industrial cells - nano-CT is capable

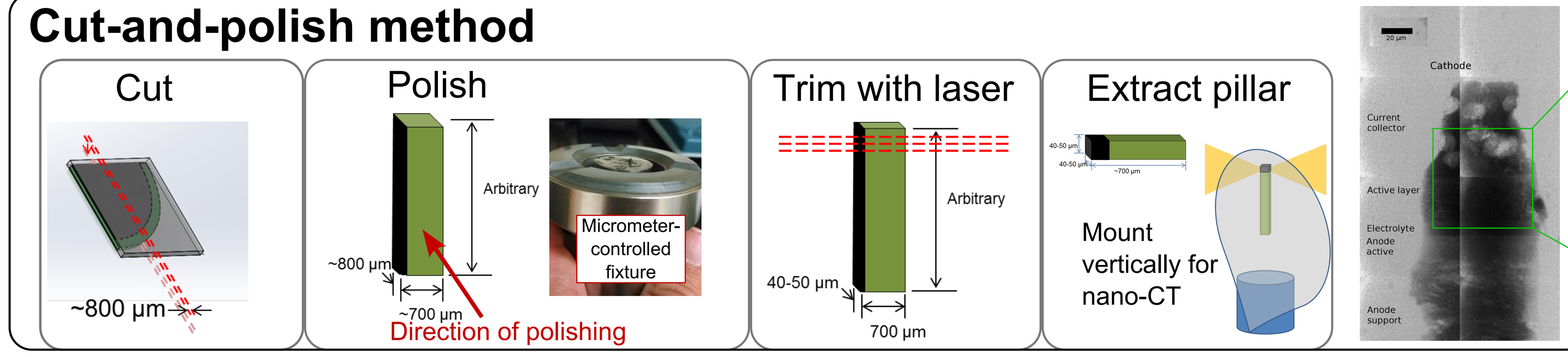
Ongoing Work: Advanced Sample Prep for Larger, More Representative Samples



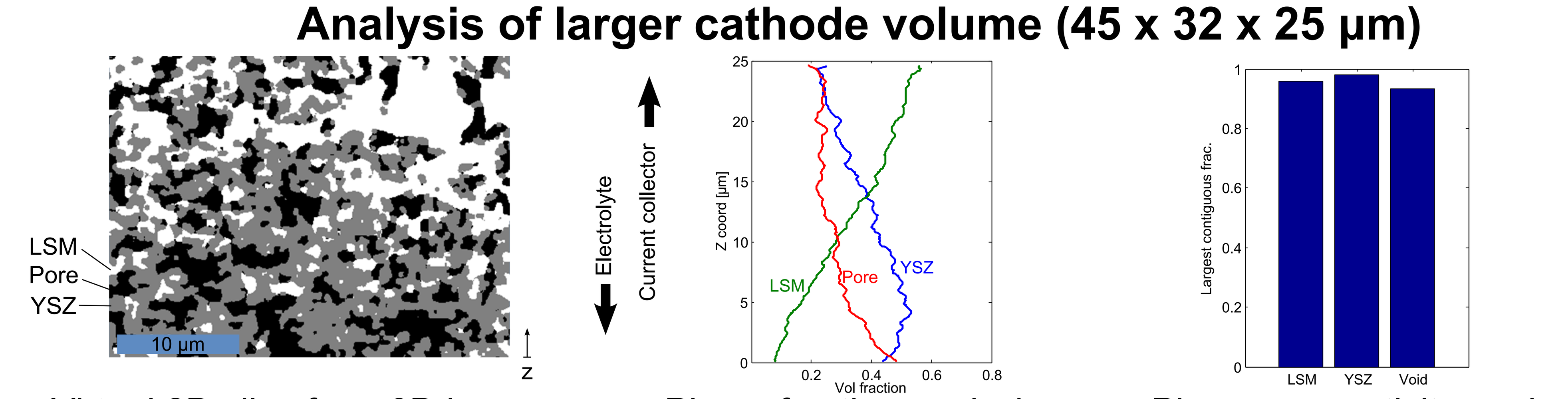
"Fracture and hope" method may favor statistically unusual samples: "why did it break there?"

In fact, this sample is more homogeneous than many other samples previously attempted in FIB-SEM, which exhibited large superpores, or 4+ µm boulders of solid material.

Cut-and-polish method



Analysis of larger cathode volume (45 x 32 x 25 µm)



Virtual 2D slice from 3D image | Phase fraction analysis | Phase connectivity analysis

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