QUANTIFIABLE COMPARATIVE EVALUATION OF FIB/SEM INSTRUMENTS

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Outline

- Challenges of FIB/SEM equipment evaluation
- Quantifiable comparative testing approach
- Design of tests targeting intended applications
- Practical Examples
- Summary

Challenges of Evaluating FIB/SEM Instruments

- Complexity of translating application needs into instrumentation requirements and evaluation criteria
- There are no “bad” instruments out there
- OEM engineers are highly skilled with demonstrations
  - Outcome of same operation for average user could be very different
- “Canned Demo” approach by OEMs
  - Designed to demonstrate strong sides
- Art of crafting specifications – “specsmanship”
- Critical (for your application) performance parameters could be “confidential”
  - Sometimes for a reason of not being known, defined, or ever tested

Quantifiable Comparative Testing Approach

- Identify range of applications for intended usage
  - Translate application goals into instrumentation requirements
- Design comparative tests, define evaluation criteria
  - Test descriptions and samples to all vendors as early as possible
- Comprehensive evaluation based for intended use:
  - Quantifiable testing of critical performance parameters
    - Based on pre-defined evaluation criteria
  - Applications demo
    - Overall performance in 3D applications, TEM lamella prep, etc…
- Two-day evaluation is reasonable to get all the data

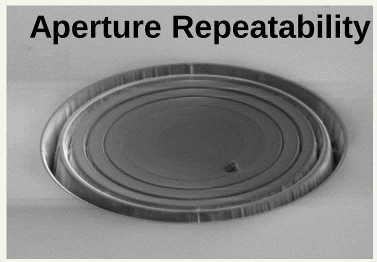
Tests targeting intended applications

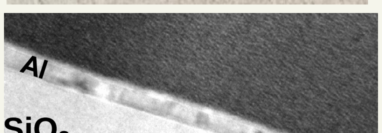
- General Performance
  - Beam quality; System stability; Aperture repeatability
- Patterning
  - Beam placement; Etching fidelity; Beam drifts and shifts
- TEM lamella preparation
  - Throughput; Thickness uniformity; Ease of use; Automation; Endpoint
- FIB Tomography 3D slice-n-view
  - Unattended runtime; Image quality; Throughput; Ease of use; Drift Correction; Focus Tracking; Slice thickness uniformity; EDS integration
- Imaging
  - SEM SE, SEM BSE, STEM BF, STEM DF, FIB SE, FIB SI…..

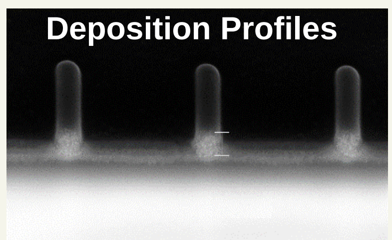
Samples for comparative evaluation

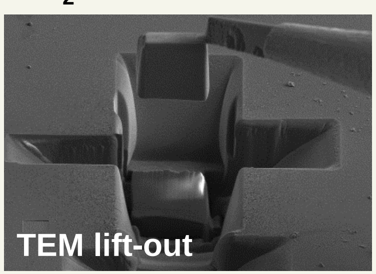
- Performance Testing

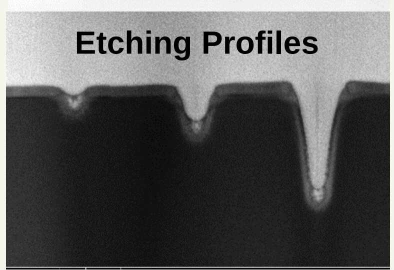
SiO_2 optical flat, ~24nm evaporated Al coating, silver paint around perimeter





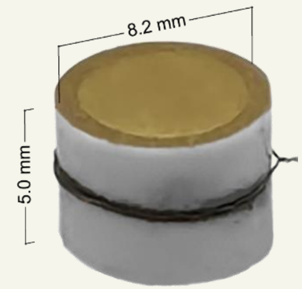


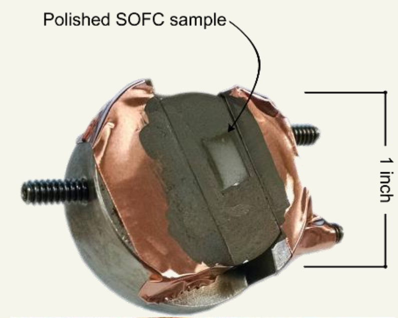


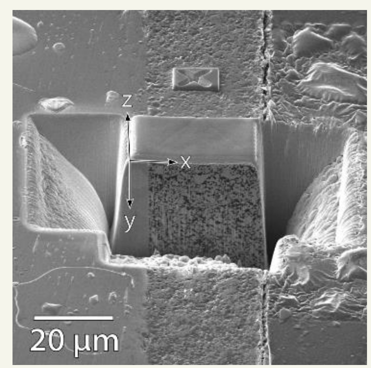


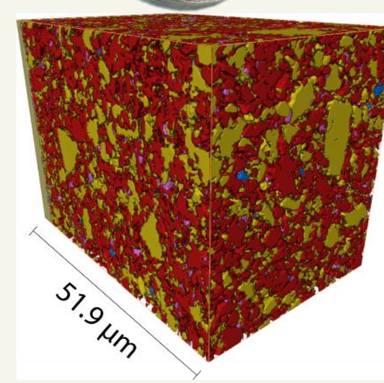
- Application Testing

Epoxy-impregnated Solid Electrolyte Fuel Cell (SOFC), 2-phase ceramic





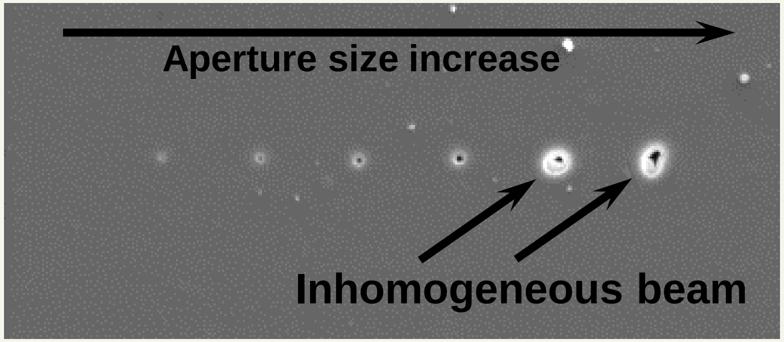


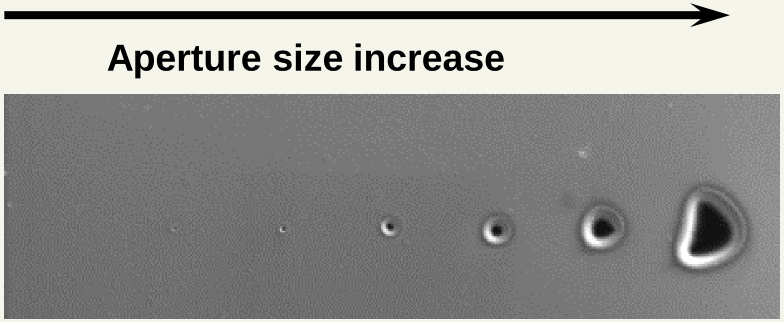


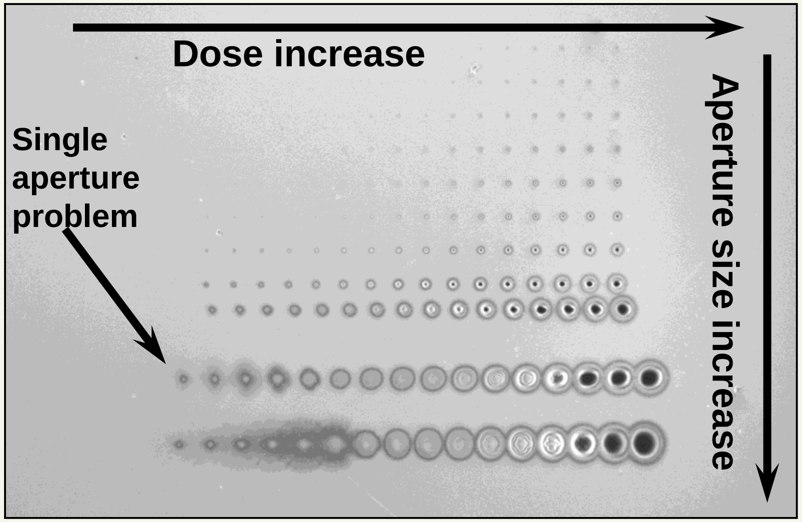
Same sample(s) to all vendors, require return of test sample(s) for independent analysis

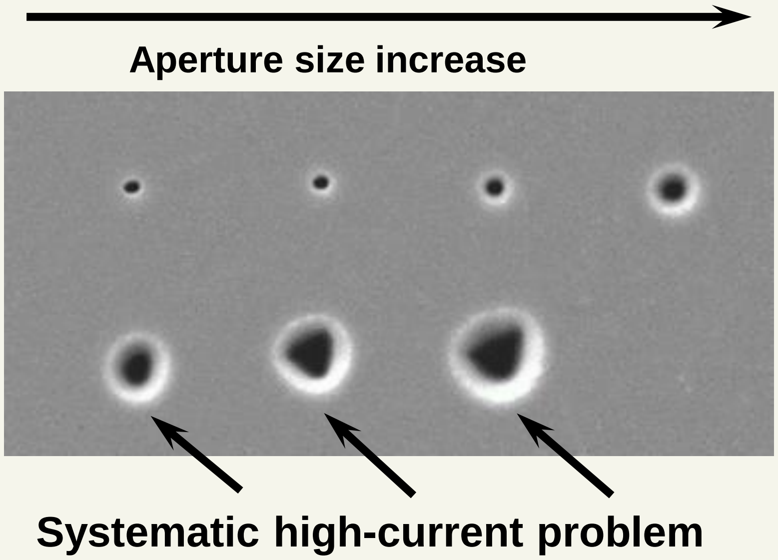
General Performance – Beam Quality

- Basic test of ion beam quality: shape and homogeneity



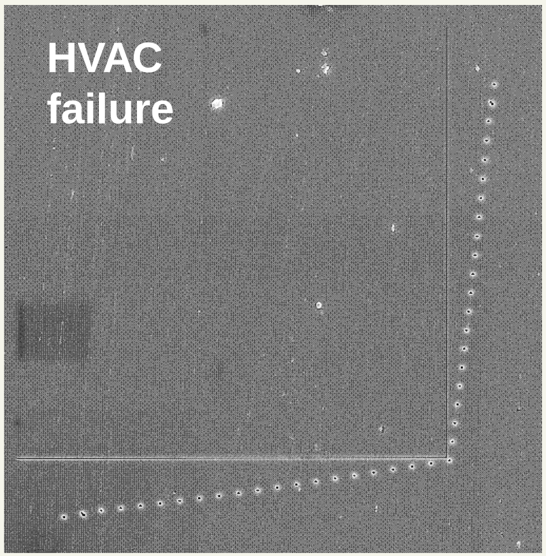


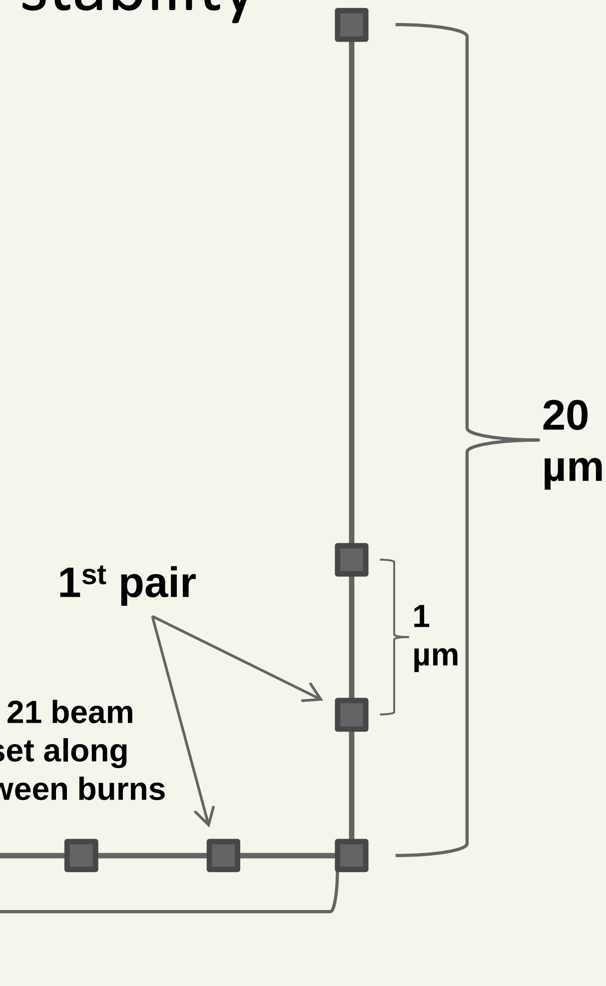


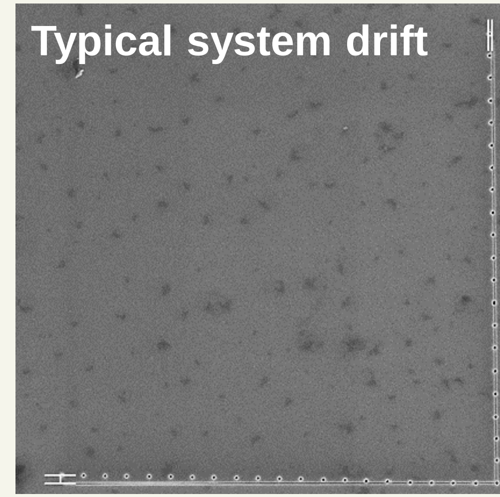


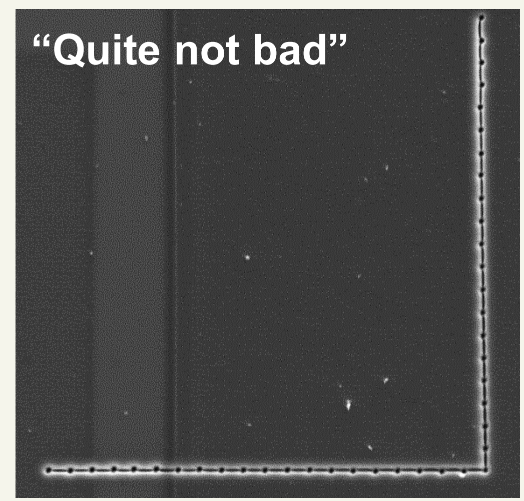
General Performance – System Stability

- Basic test of tool stability

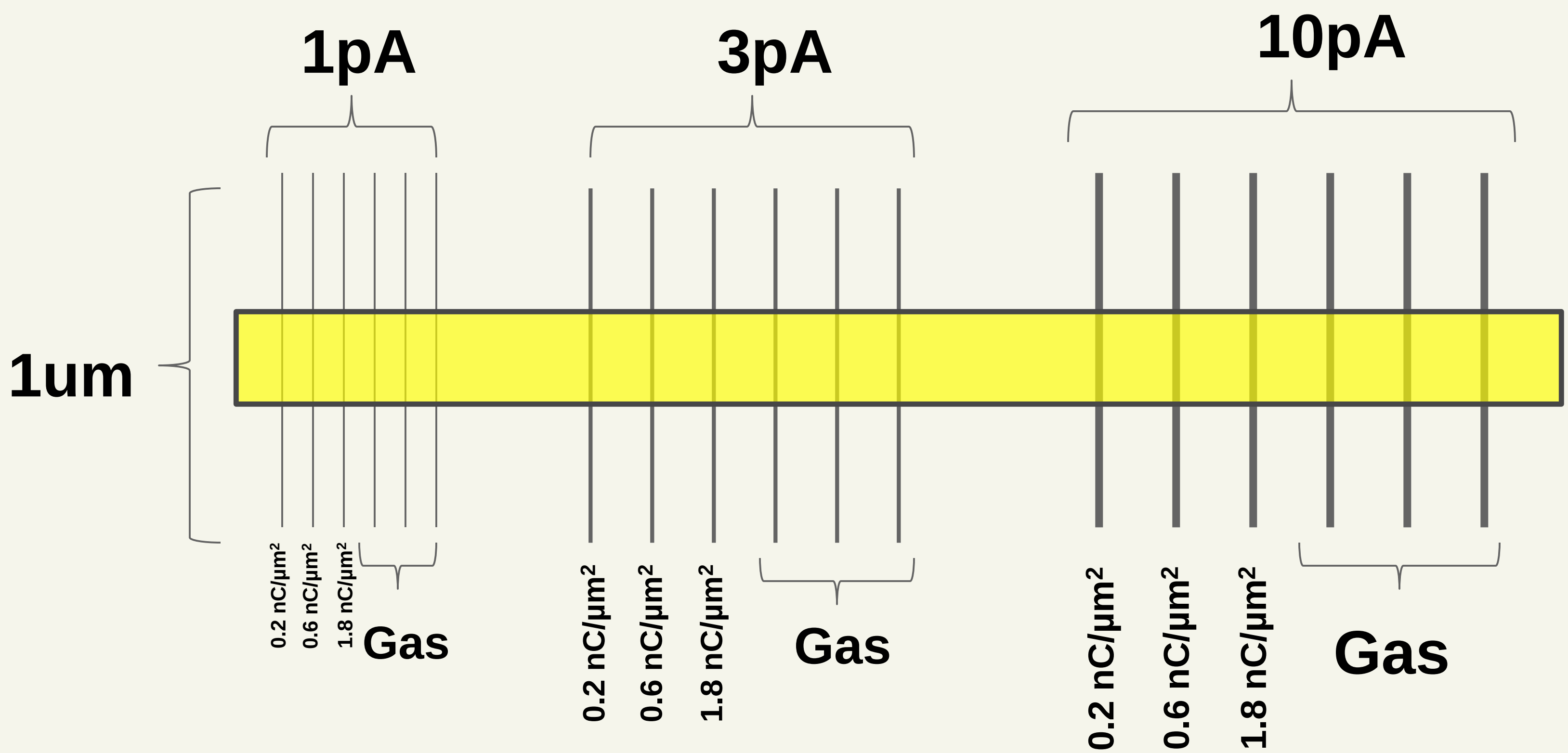








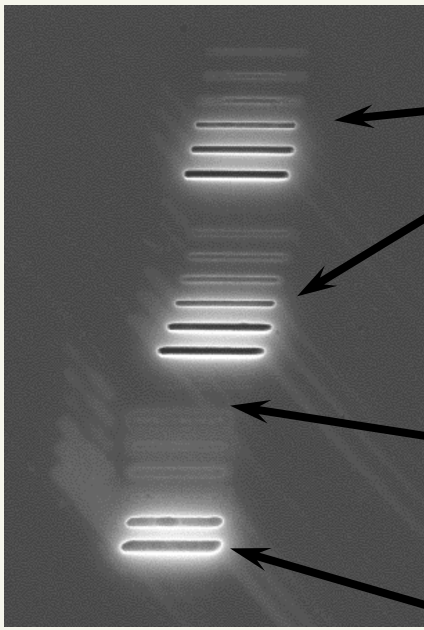
Critical Performance – Etch Placement & Fidelity



Shortest dwell time, -20% pixel overlap, x2 pattern repeats: (a) sputtering/GAE (XeF_2) and (b) sputtering/depo (C, Pt, W)

Critical Performance – Etching Placement

- Patterning where intended with/without gas injection



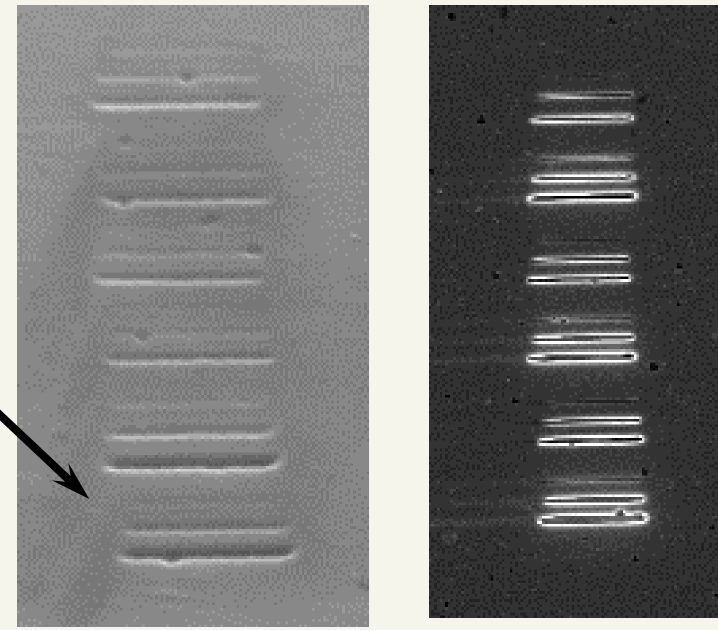
Drift after aperture change
Problem for automatic patterning

Shift due to gas
problem for site-specific deposition and GAE

Aperture change shift
problem for multiple-current patterning

Drift during line exposure

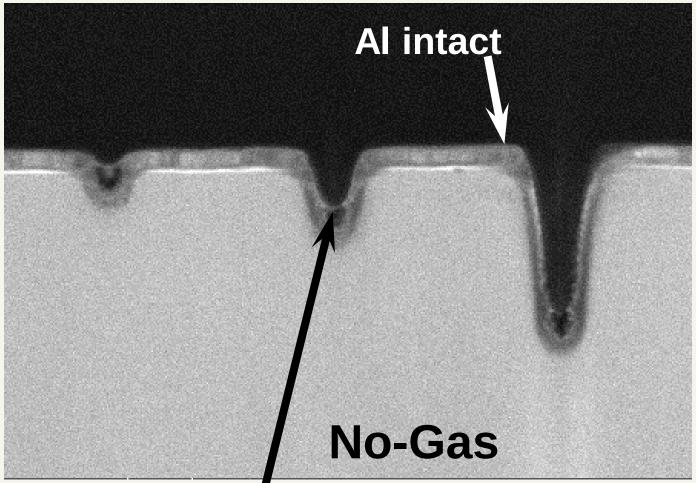
Visible artifacts



Expected performance

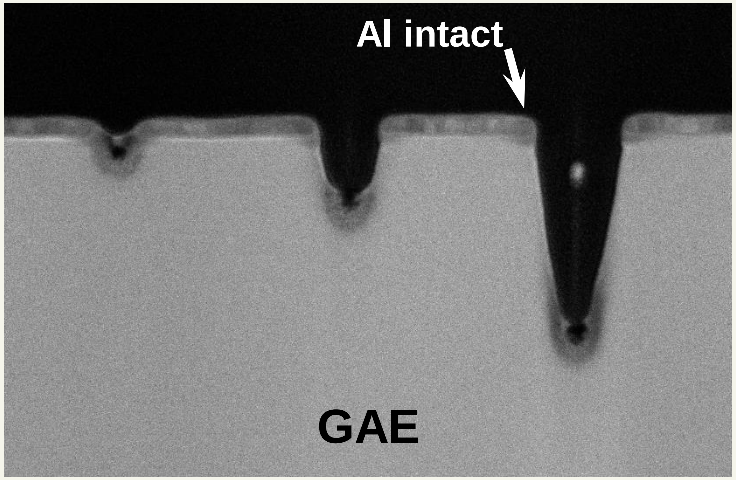
- C or Pt stripe e-beam deposited across lines, TEM lamella prepared and STEM-imaged as part of application testing

Critical Performance – Etching Fidelity



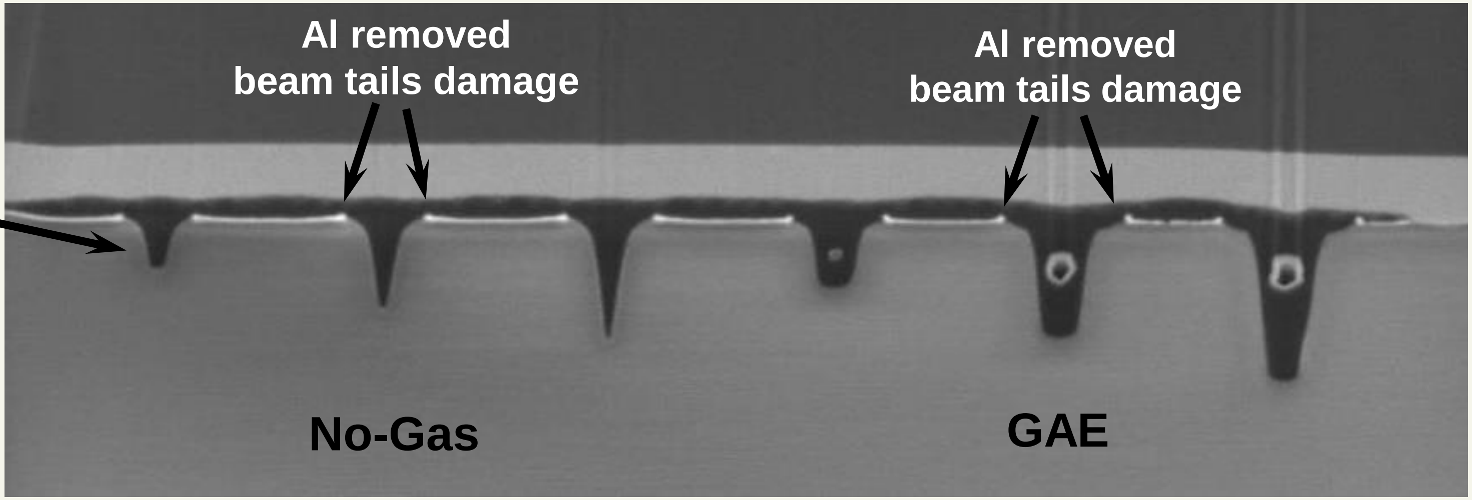
Sidewall slope and No-Gas profile aspect ratio define polishing efficiency

Al layer removal indicates beam tails damage to surface



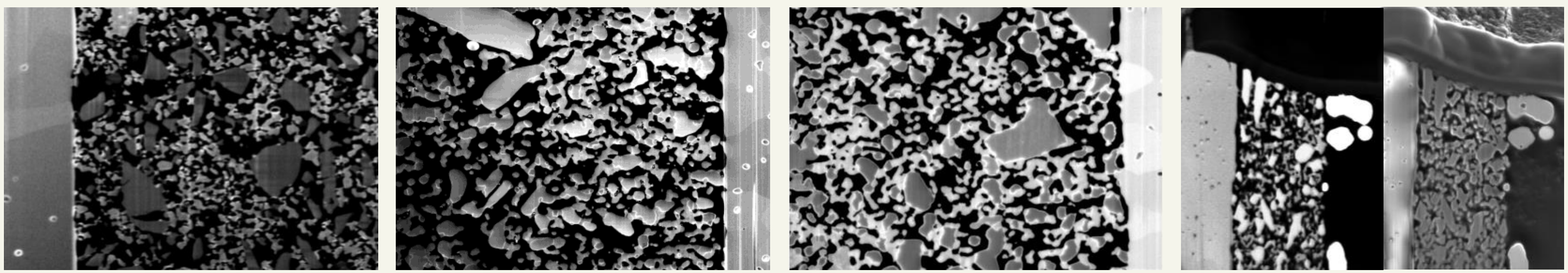
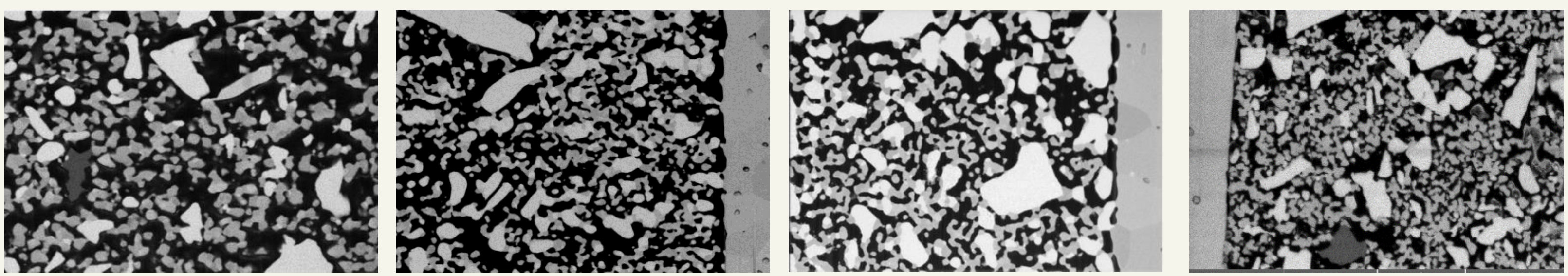
Narrowest cut defined by width of a tip of No-Gas etching profile

No-Gas to GAE profile area ratio defines GAE enhancement



Application Testing – SOFC imaging

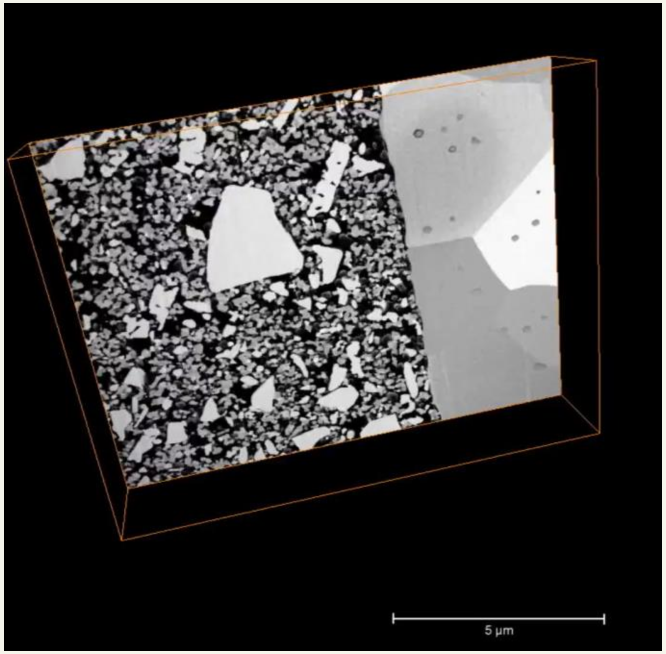
- Side-by-side comparison of same sample imaging

SE	
BSE	

Application Testing – 3D Reconstruction

- Fix experimental parameters between vendors:
  - Run overnight, if possible
- Results to evaluate:
  - Total running time (limited by stability)
  - Usable acquisition volume/hour
  - Acquired image quality
  - Output/ease of use of 3D visualization software

Slice thickness	Detector settings
Image resolution	Dwell time



Example of vendor visualization output

Summary

- Quantifiable testing approach enables comparative evaluation of FIB/SEM instruments by collecting performance data under controlled conditions
    - Careful sample preparation, thorough test design, and demo planning
- Seamless integration of performance tests with applications demo facilitates comprehensive evaluation
    - providing OEMs opportunity to showcase strong features of the equipment
    - while allowing side-by-side comparison of critical performance parameters
- There are no “bad” tools, but nobody is perfect either
    - Interpret test results in context of realistic application requirements