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

- Inhomogeneous beam
- Systematic high-current problem
- Single aperture problem
- Aperture size increase
- Dose increase
General Performance – System Stability

• Basic test of tool stability

L-shaped single-line pattern and 21 beam burns on each arm with 1um offset along the line and 5 minutes delay between burns

Typical system drift

“Quite not bad”
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

Visible artifacts

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

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

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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

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