Welcome

to today's episode:

Under the Microscope

Your Electron Microscopy Questions Answered

Meet the Experts from Covalent Metrology:

Yi Zhang

Technical Director of Electron Microscopy

Kevin Wu

Electron Microscopy Metrology Manager

Esaul Garza

Operations Director of Electron Microscopy

Valerie Brogden

Technical Operations & Marketing

Ben Buford

Technical Director of Software & Algorithms

Rigaku (former Covalent Metrology)

DEC 4, 2025

11 AM Pacific Time

COVALENT METROLOGY

COVALENT METROLOGY

Modern, digitally-empowered analytical services platform delivering quality data and expert analysis to accelerate advanced materials and device innovation.

Comprehensive Solutions Stack

50+ Cutting-edge instruments in-house, 150+ Techniques

Analytical Services

Advanced Modeling

Method Development

Custom Consulting Solutions

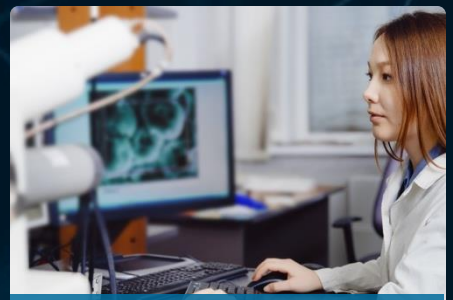
High-touch, High-Quality Services

Nexus Membership Program

Enterprise Metrology Solutions

Instant, Secure Access to Data and Reports

Expanding Toolkit in Custom Digital Platform



Flexible Business Models

LiveView™ (real-time collaboration)

Co-op and Tool-share Opportunities

Training and Certification on Instrumentation

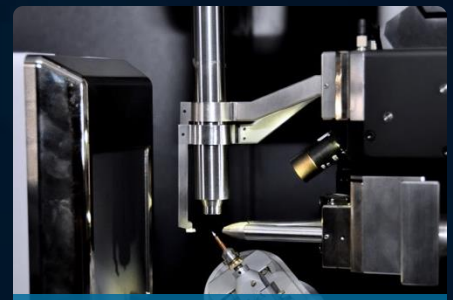
Laboratory Audits

Rich Network of Partnerships

Partner to World's Leading Instrument Manufacturers and Labs

Expanding access to Advanced Instruments and Analysis Tools

Lab Connections and Applications Learning



Who We Are, Who We Serve

80+ People, 21 PhDs

Comprehensive, Modern Analytical Capabilities

Headquarter Lab in Sunnyvale, CA

800+ Clients, 15-30 new clients / week

Covalent's Analytical Services & Technical Groups

COVALENT METROLOGY

Enterprise Metrology Solutions: Failure Analysis & EM

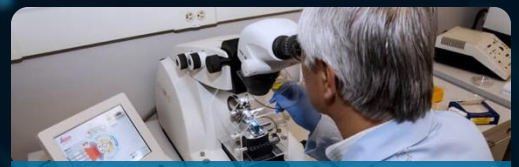
Electron Microscopy

- S/TEM
  with EDS; EELS; Electron Diffraction; SAED
- FIB-SEM & HR-SEM
  with EDS; EBSD; 3D Tomography
- Lamella Preparation
  incl. specialized lift-outs

Failure Analysis

- DPA / Mechanical X-section
- Dye & Pry Test
- EBIC / OBIC failure analysis
- Hot Spot Detection
- NIR / IR Imaging
- Emission Microscopy
- Root-Cause Failure Analysis

Materials, Chemicals, and Surfaces



Microscopy & Profilometry

- Chromatic Aberration
- Digital Optical Microscopy
- Laser Scanning Confocal Microscopy
- White Light Interferometry
- Scanning Acoustic Microscopy (SAM)

Analytical Chemistry

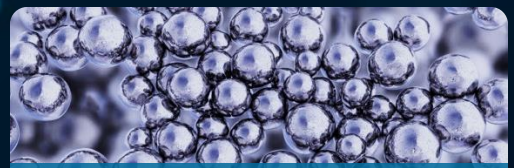
- Mass Spectroscopy: ICP-MS and LA-ICP-MS; GCMS
- ICP-OES / GDOES
- Raman
- NMR (solid / liquid + 1,2,3 nuclei)
- XPS, UPS, ISS
- SIMS, TOF-SIMS

X-ray Characterization

- X-Ray Diffraction (XRD)
- X-Ray Reflectometry (XRR)
- Micro-computed X-ray Tomography (Micro-CT)
- 2D / 2.5D / 3D X-ray Inspection & X-ray Radiography
- ED-XRF / WD-XRF

Mechanical Testing

- AFM & Advanced AFM Modes (EFM, KPFM, MFM, PFM, PiFM)
- Nano-indent / Nano-scratch
- Rheometry / Viscosity
- DMA / TMA (bend/stretch/compression)
- Tensile testing



Misc. Material Properties

- Thermal Analysis: DSC, TGA
- Surface Zeta Potential
- Porometry / Pycnometry
- Gas Adsorption / Chemisorption
- Foam Density / Skeletal Density / Tap Density
- Particle Analysis: DLS / ELS / size distribution / zeta potential

Optical Characterization

- Fourier Transformed Infrared Spectroscopy (FTIR and ATR-FTIR)
- **Spectral Ellipsometry & Advanced Optical Modeling**
- UV-Vis-NIR Spectroscopy

Introducing today's panelists

Yi Zhang
Technical Director of Electron Microscopy, Covalent Metrology

- Director of Electron Microscopy with 16-plus years of S/TEM experience
- Expert in advanced electron microscopy for diverse materials
- Ph.D. in Materials Science and Engineering, Nanjing University
- Postdoctoral work at University of Michigan and Stockholm University
- Former senior research scientist at the RENEW Institute

Kevin Wu
Electron Microscopy Metrology Manager, Covalent Metrology

- Electron Microscopy Metrology Manager with 10-plus years of materials characterization experience
- Specializes in SEM, FIB, EDS, and EBSD techniques
- Experience across semiconductors, batteries, and advanced manufacturing
- B.S. and M.S. in Materials Science and Engineering from UC Berkeley

Esaul Garza
Operations Director of Electron Microscopy, Covalent Metrology

- Operations Director of Electron Microscopy, leading TEM workflow development
- 20-plus years of experience in materials characterization and failure analysis
- Background spanning semiconductors, hard drive technologies, and display technologies

Introducing today's panelists

Valerie Brogden
Technical Operations & Marketing, Covalent Metrology

- 15-plus years in metrology, characterization, and failure analysis
- Expertise in FIB/SEM and automated TEM sample prep
- Managed a multi-instrument academic and industry lab
- Technical session chair for multiple FIB conferences
- Former graduate instructor at the University of Oregon
- Holds patents and publications in FIB/SEM innovation

Ben Buford
Technical Director of Software & Algorithms, Rigaku (former Covalent Metrology)

- Leads development of software and algorithms for x ray metrology at Rigaku
- Develops advanced data analysis methods for x ray metrology tools
- PhD in Electrical Engineering from Oregon State University
- Experience at Intel and Covalent Metrology on physics guided data analysis for TEM EDX and other metrology techniques

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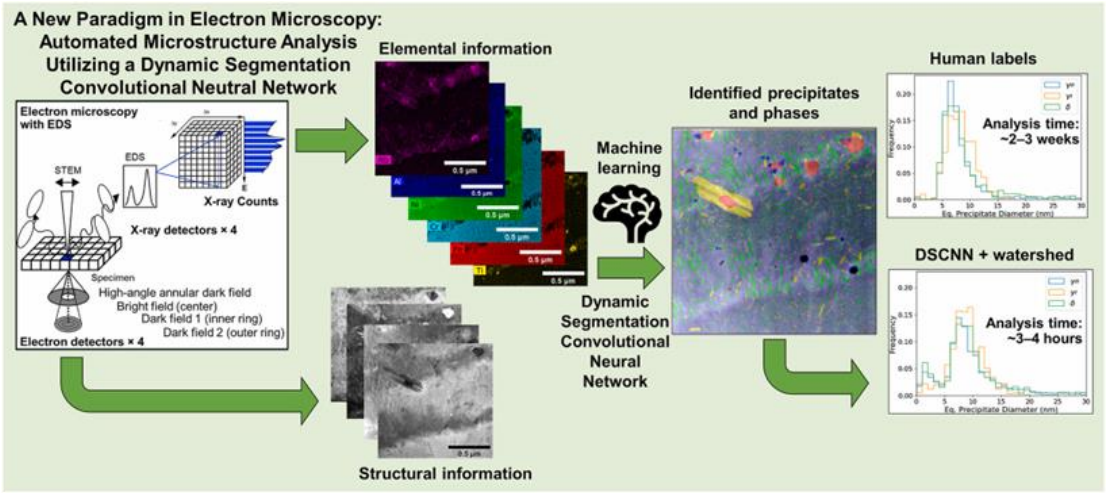
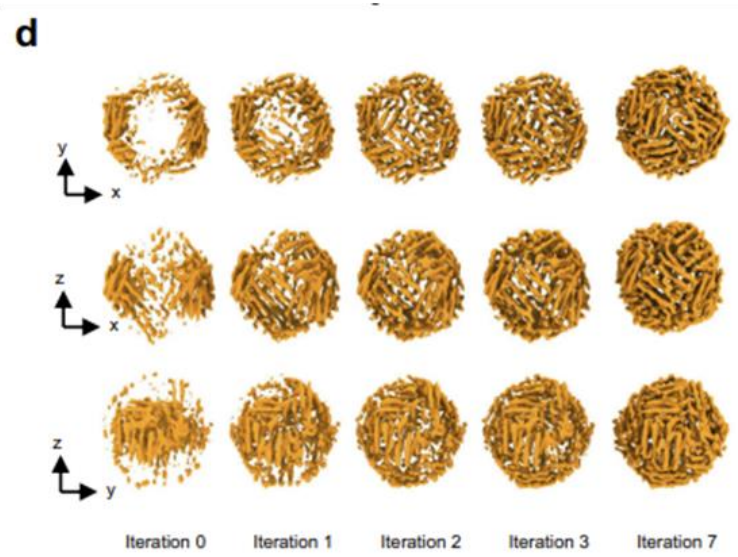
Q & A Session

- Automatic (or semi-automatic) sample prep
- Segmentation/Classification using neural networks(1)
- Final image denoising
- Tomography reconstruction
  - Missing wedge reconstruction(2)
  - Denoising
  - Automated sample alignment tracking
- ML Defect Detection
  - Esoteric workflows for specific applications

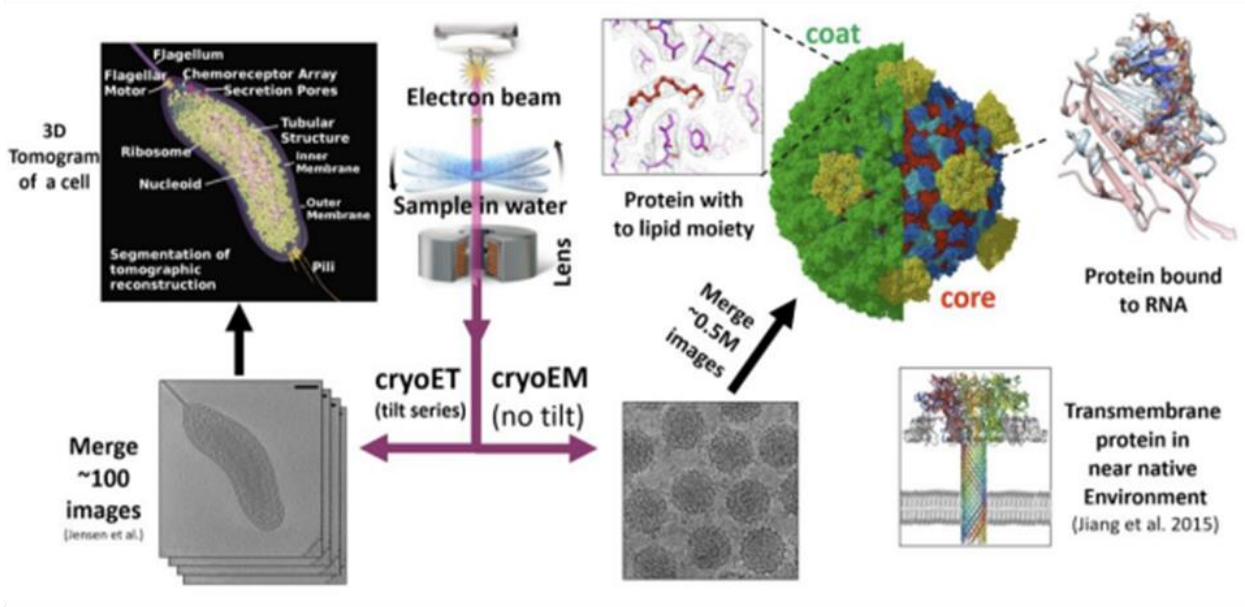




1) https://doi.org/10.1016/j.mtadv.2024.100468
2) https://doi.org/10.1038/s41467-022-33957-8

- “Distiller” from Lawrence Berkeley Nation Laboratory(1)
  - Provides scalable interface between lab equipment and cloud infrastructure
  - Enables ‘Big Data’ collection and storage, with proper metadata; a necessity for AI Developments

- Near atomic resolution imaging from CryoET/EM(2)
  - Combines 100-500k images of either tilt series, or different identical structures (with arb rotation)
  - In CryoEM:
    - ML/AI identifies identical particles
    - Identifies their relative orientations



1) https://newscenter.lbl.gov/2025/04/07/a-new-age-of-electron-microscopy-magnifying-possibilities-with-automation/
2) https://doi.org/10.48550/arXiv.2507.19565

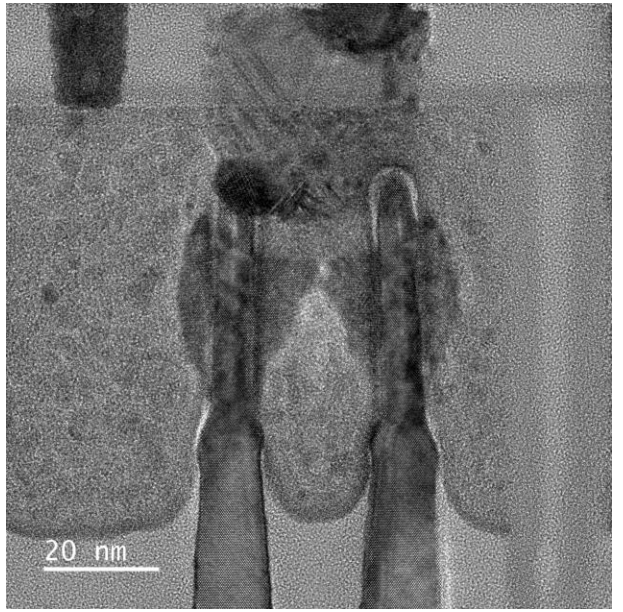
Metric	Manual	Automated	Hybrid
Speed	☑		☑
Yield	☑		☑
Flexibility	☑		
Cost		☑	☑
Quality	☑		☑

Manual:
- Single sites, one of a kind, too precious to risk
- Small RIO <40nm
- Able to adjust for milling artifacts before final polish

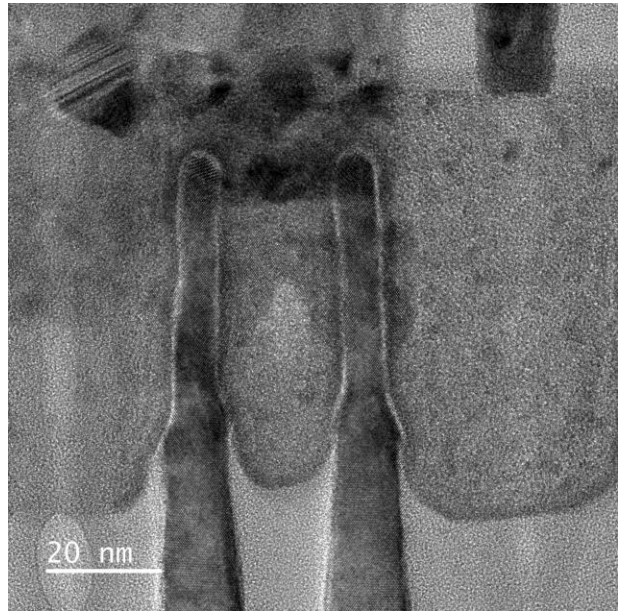
Fully Automated:
- Blankets
- Repeated Structures

Hybrid:
- Samples with backup sites
- Dissimilar materials ok
- Can be adopted for most samples, to the point of lift out with final thinning and polishing done manually

Manual



Automated



Protective Caps → Liftout → Final Thinning

Manual

Automated

Hybrid

Comparison of LMIS and Plasma FIB

In the PFIB, we have access to much larger currents with a spot size that increases linearly (not exponentially)

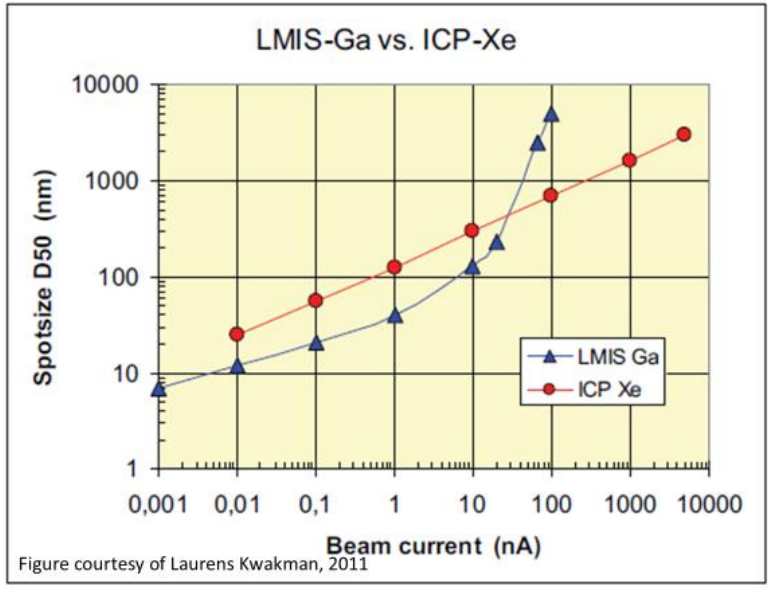
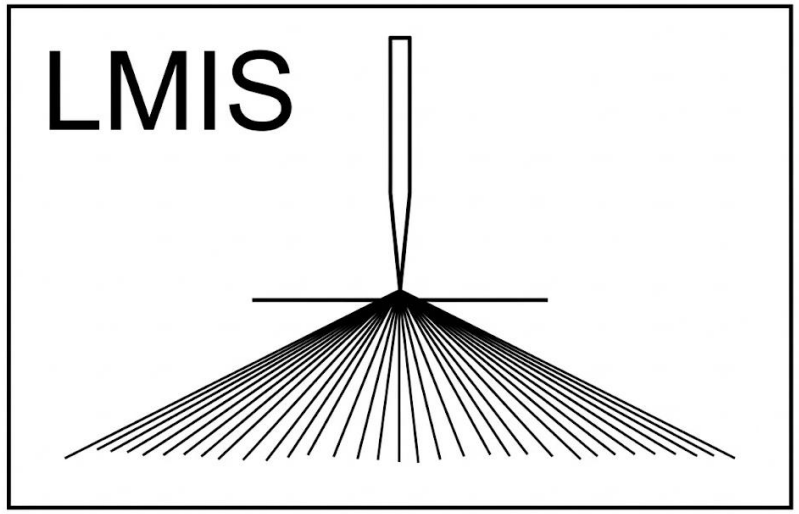


Figure courtesy of Laurens Kwakman, 2011

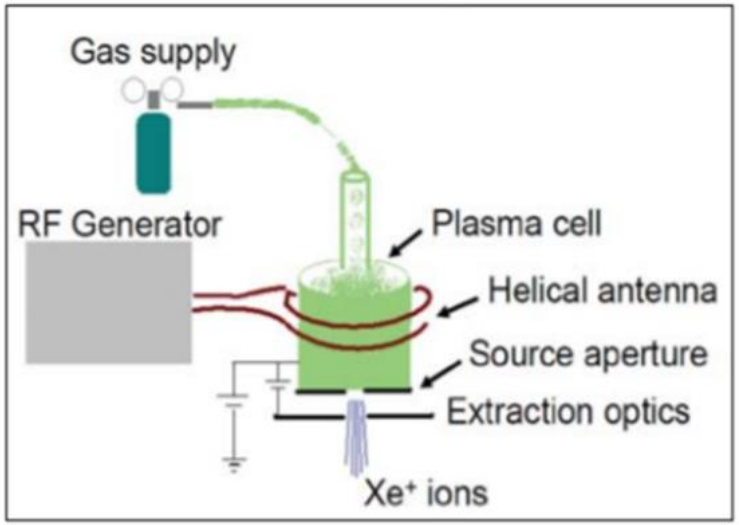
FIGURE 2. Spot size comparison of Ga-LMIS and Xe-ICP based FIB columns as a function of the ion beam current.

LMIS FIB vs PFIB

The LMIS source has a cone shaped emission. Therefore, when current is large (ie tens of nanoamps) a large aperture is needed, which beams a large spot size!



In contrast, the PFIB emission is tighter and more collimated, so the spot size does not increase so dramatically with large currents



Beam Sensitive Materials: (Minimize total electron *dose)*

- **Avoid unnecessary imaging**: locate areas at low mag or off-beam focus; focus on sacrificial nearby area, not on the region of interest.

- **Use low-dose imaging modes during the whole FIB process**: microscope low-dose settings during protective layer deposition, during sample thinning, utilize dose-fractionation (frames), beam blanking while moving.

- **Optimize TEM imaging conditions**: lower voltage and current to avoid sample shrinkage and damage. Adopt similar of region beam focus/conditioning.

Physics Limitations:
- Sample prep requirements differ between approaches
- Mismatches in interaction volumes
- Differences between elemental sensitivities

Practical Limitations:
- Alignment challenges
- Large scale features cannot practically be mapped at small scale

Commercial Limitations:
- Each tool / vendor has its own format, no standardized way of reading in all relevant data
- Methods of combining data vary significantly by application, so it's impossible to create a 'one size fits all' solution

Quick Survey + Sign-up for Free Discovery Consultations

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Want to learn more about Covalent's
Electron Microscopy services?

Speak with a Covalent Expert!

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with the link in the chat.

View On-Demand Recordings in the Covalent Academy

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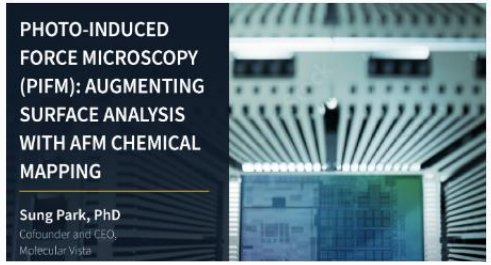

Register and start exploring at:
academy.covalentmetrology.com

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Thank you.