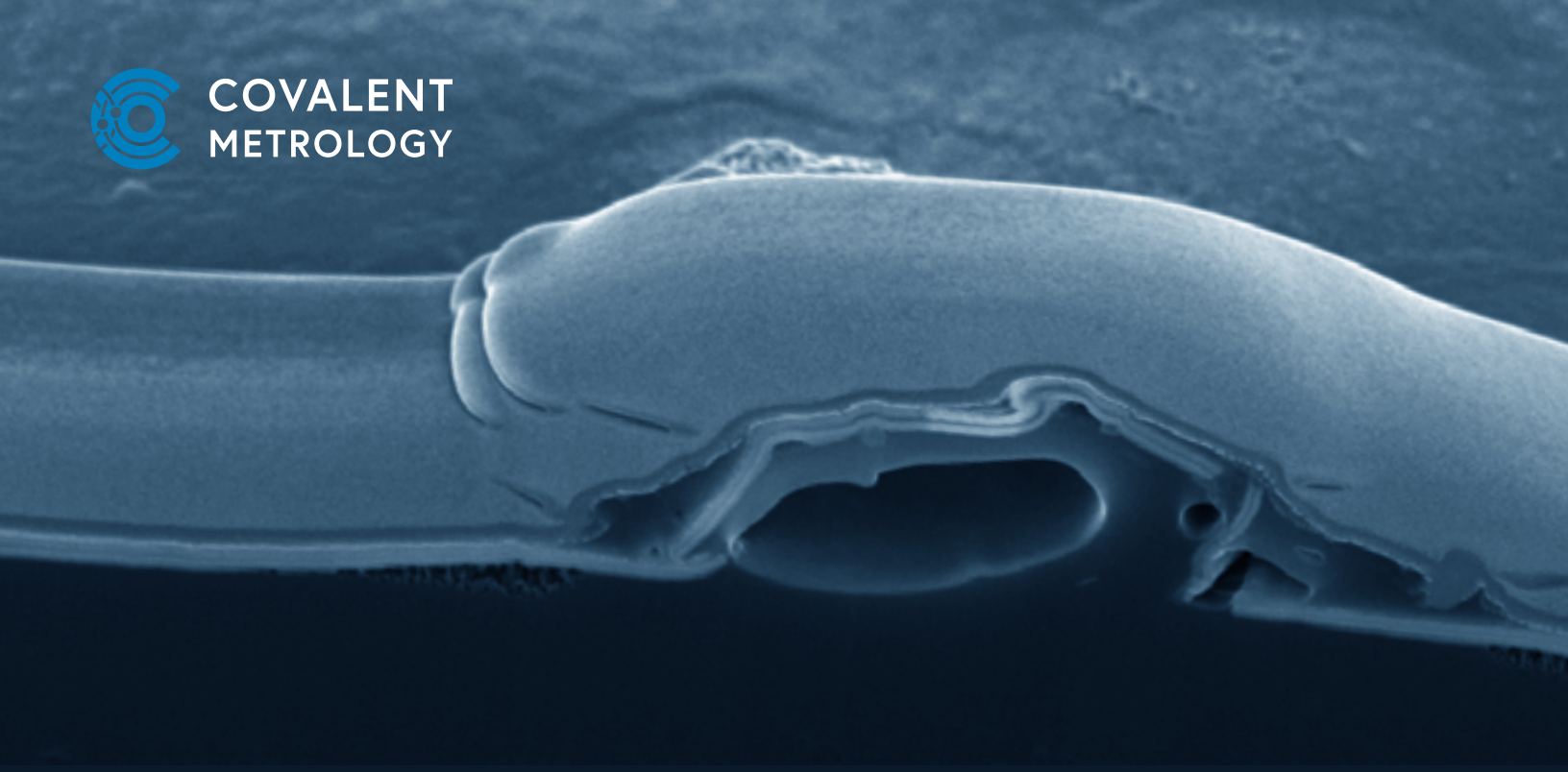


COVALENT ACADEMY Q&A

Episode 19: 3D Tomography Using the Dualbeam (SEM-FIB) – Imaging, EDS and EBSD

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01

If the 3D tomography is performed purely by software, could it take input from any source, e.g., a TEM? That way, you can get 3D images that have very fine resolution (order of nm).

FIB/SEM 3D tomography is a two-steps process involving the use of two softwares: one to run the instrument and collect the data, i.e. 2D images, known as "slice and view", and the second, "Avizo, or Amira", is a 3D visualization and analysis software that processes the collected 2D images and generates 3D images. So yes, series of 2D images from any input could be used to generate 3D images through the 3D visualization and analysis software. Tilt-series data (e.g. TEM) needs to be reconstructed using a non-Avizo SW (e.g. Inspect 3D). Once reconstructed, Avizo can be used to visualize the data.

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02 What is the maximum sample dimensions for 3D tomography in the SEM? What is the resolution of 3D tomography in the SEM? I am asking for a detectable minimum defect size. No pixel resolution.

The maximum dimension for 3D tomography depends on the ion column being utilized to collect the data. A plasma FIB can acquire data from an area as wide as 1 mm (x-axis), 200-300 um deep (y-axis/mill depth), and generally 50-100 um "back" (z-axis). Laser systems can create larger volumes, while gallium systems are an order of magnitude smaller. The resolution is ~ 0.6 to 1nm.

03 Are their any sample restrictions in terms of physical dimensions and/or properties?

For the FIB/SEM system that we have in house, the main requirements relates to: 1) the dimensions of the sample, i.e. it has to fit inside the chamber with a maximum sample size of 6 inches (~150 mm) full rotation and tilt range from -10 to 60 degrees, 2) the sample has to be vacuum compatible (e.g. wet samples), and 3) not requiring cryogenic conditions for milling (e.g. very soft materials and biological samples, etc.)

04 What is the lowest voxel size and resolution possible at Covalent?

The voxel size can be infinitesimally small. The slice thickness is the limiting factor, which can be as small as 1 nm. The voxel should be as close to equal on all sides, with x and y defined by the image pixel resolution and the z defined by the slice thickness.

05 In 3D Tomography, For each slice, how can you be sure that each voxel is milled at same rate? The material may have different milling rate elements in the matrix.

Sputter rates vary for different materials. These variations can lead to imaging artifacts in the x-y 2D images. These can be in the form of curtains, pores, redeposition, and unmilled material. These are taken into account when setting up the data acquisition, with the user defining the optimal beam settings to minimize these artifacts. When they cannot be eliminated, post processing in the 3D reconstruction software can be used to filter the data, minimizing or removing the impact of the artifacts.

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06 What is the largest sample you can apply SEM-FIB to? If it is material dependent, I'd like to know an example for minerals such as shale.

See Answer to question # 2

07 In EBSD surface quality (crystal quality) is important for signal quality. Does Gallium milling process make surface amorphous? Or is there any other material you use not to make surface amorphous?

For most materials the EBSD probe size is bigger than the depth of amorphous damage so a clear EBSD pattern is achieved at the highest FIB kV milling. For materials that are more sensitive, ASV automation can include a low kV FIB cleanup step

08 Regarding imaging the topography of the upper surface of a sample: how about laying down a protective coating, then slicing? Is it better to slice perpendicular to the coating or for better x,y pixel resolution, slice parallel to the protective coating? Then do the 3D reconstruction, then figure out how to "evaporate" the Pt-C protective coating and then reveal the 3D upper surface topography.

When the top surface is of specific interest, using a capping with a material that has a high contrast relative to the surface material allows for easy segmentation when the data is reconstructed.

09 What is the quality difference between cross sections and lift-out samples fabricated with different ion sources? How would that affect 3D tomography images quality?

Studies have shown that Ga, Xe, Ar, and O can all be used to create high quality TEM lamella. Considerations for each source are factored into the sample preparation process to optimize the results. With the proper technique, it can be difficult to impossible to discern the difference between lamella prepared using the different ion species.

10 Can you measure the actual slice thickness, if the sample is drifting?

The automated process utilizes drift control features to maintain a consistent milling performance.

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11 **When you talk about the ultimate resolution, is that influenced by the conducticity of the sample? Like in semiconductor industry - as you have metallic wires embedded in SiO2 for example - do you still get the ultimate 1-5 nm resolution?**

The material and the matrix of multiple materials can affect the overall results and ultimate achievable resolution. These can be minimized with the proper considerations for sputter rate differences, charging, composition, etc., but some material-type can be incompatible with this technique.

12 **How much time will it take to generate a tomography reconstruction for a 1 micron cube space with 100nm slice thickness?**

It would take roughly 4-5 hours to prepare the sample, collect the data, and process it to generate 3D reconstruction

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