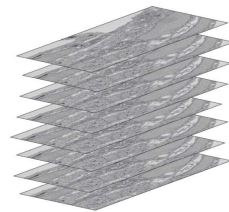


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Version 1

Sample preparation and data collection for Serial Block Face Scanning Electron Microscopy of Mammalian Cell Monolayers V.1



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We use this protocol and it's working

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Abstract

Serial block face scanning electron microscopy (SBF-SEM) is volume EM technique used to study biological samples including tissue and cellular samples. Here we describe detailed protocols for two sample embedding methods for in vitro tissue culture cells intended to be studied using SBF-SEM. The first protocol focuses on cell pellet embedding and the second on en face embedding. En face embedding can be combined with light microscopy, and this CLEM workflow can be used to identify specific biological events in a light microscope, which can then be imaged using SBF-SEM. We systematically outline the steps necessary to fix, stain, embed and image adherent tissue culture cell monolayers by SBF-SEM. Users experienced with electron microscopy sample preparation methodology will be able to complete this protocol in 10-11 days from initial seeding of cells in tissue culture to image acquisition.

Attachments



[Figures.pdf](#)

2.9MB



[Troubleshooting.pdf](#)

37KB



[Table 1.pdf](#)

30KB

Image Attribution

Guidelines

Sample preparation

Mammalian cell culture for cell pellets: Adherent cells can be grown on regular tissue culture dishes and suspension cells can be grown in flasks prior to sample staining and embedding.

Mammalian cell culture for *en face* samples for CLEM: Adherent mammalian cells must be grown on a gridded coverslip, for example, a 35 mm dish with a gridded coverslip (MatTek Cat no. P35G-1.5-14-CGRD). Cell seeding densities for CLEM should be optimized to prevent the growth of dense cell monolayers, which will obscure the underlying grid numbers during light microscopy (step 3). It is important that the grid numbers are visible for identifying the relevant region of interest during SBF-SEM imaging.

Selecting a Fixation Method: When selecting a sample fixation method, it is important to consider the type of biological event being evaluated as well as sample size. In general, a chemical fixation that combines different ratios of aldehydes (2-4% PFA and 1-5% glutaraldehyde) should meet the majority of fixation requirements. However, cryo fixation with high pressure freezing and freeze substitution is recommended when trying to capture rapid biological events, or when it is especially important to preserve specific biological structures.

En bloc staining: Depending on each project, a different combination of heavy metal stains may be optimal. For example, osmium tetroxide is an essential heavy metal stain with biological materials as it stains unsaturated lipids on the plasma membrane. Additionally, combining osmium tetroxide staining with thiocarbohydrazide helps increase not only the contrast, but also the conductivity of most biological samples. However, osmium tetroxide is not always suitable particularly when trying to preserve biological structures like the cytoskeleton. In such cases, using heavy metals like potassium ferri- or ferrocyanide might be preferred. Alternatively, the addition of heavy metals like uranyl acetate, lead aspartate and tannic acid can also be considered when trying to improve the contrast of biological samples.

Dehydration and embedding: A graded series of organic solvents such as ethanol or acetone are used to replace the water in biological samples through dehydration during sample preparation. Acetone is a stronger organic solvent and mixes well with epoxy resin, however, it is not an ideal solvent for *en face* embedding and sample processing as it will dissolve the plastic dish. There are several epoxy resins that can be chosen for SBF-SEM sample embedding, such as Durcupan, hard EMBED² 812 and Spurr. We do not recommend EMBED² 812 resin for *en face* samples as it might dissolve the plastic dish thereby compromising sample recovery.

Sample trimming and mounting: Either manual or machine trimming can be used when removing excess resin. For cell pellet samples, the removal of excess resin is important to expose both the top surface of the sample (blockface that will be imaged) as well as the bottom surface, if possible, which is glued to the 3View pin stub. The use of a silver conductive epoxy glue during this process allows for improved charge dissipation during SEM imaging by grounding the sample to the 3View pin. For *en face* embedded CLEM samples, removing as much excess resin from the non-sample side that is glued to the 3View pin is critical for successful SBF-SEM imaging as it grounds the sample and helps with charge dissipation (Figure 1). Specimens should be inspected for the quality of sample preservation and the presence of any preparation artifacts such as sample deformation or changes in organelle ultrastructure via TEM. For *en face* samples, users will likely need to

sacrifice a cell or region of interest in order to verify the quality of sample staining and the preservation of organelle ultrastructure.

SBF-SEM instrumentation

SBF-SEM uses an in situ ultramicrotome (diamond knife) mounted inside an SEM chamber to cut thin sections of the sample block (Figure 2). Following each cutting event, the sample block is raised by a specified distance (z slice thickness) and imaged. This cutting and imaging cycle repeats automatically until the desired volume is collected. Achieving the proper resolution for most biological events requires a scanning electron microscope equipped with a field emission gun, and backscattered and secondary electron detectors designed for imaging at low accelerating voltages (1 - 2 keV). SBF-SEM collections can run for hours, weeks or months, depending on the volume and resolution being collected for a given project. Given the duration of these imaging experiments, the microscope requires anti-vibration hardware, magnetic field cancellation systems and minimal ambient temperature fluctuations.

Preparation for SBF-SEM: After the sample is loaded into the SEM, the sample should be manually approached with the ultramicrotome, similar to TEM sectioning. For CLEM, the light microscopy images should be used as guidelines to select the area of interest for imaging.

Considerations for SBF-SEM Data Acquisition and Interpretation: Important considerations before SBF-SEM imaging include 1) image pixel size (resolution in x-y), 2) the z resolution (thickness of each slice) and 3) the volume (total number of slices) being collected. x-y dimensions can range from 20 μm to 80 μm , providing a maximum area of 80 μm x 80 μm . Multiple areas of interest can be collected sequentially for cell pellet samples. Depending on the biological questions being asked, a set of image acquisition parameters should be chosen including the accelerating voltage, probe current, pixel size, dwell time and scan speed (Supplementary table 1). Generally, a 5 - 6 nm pixel size is sufficient for resolving cell organelle ultrastructure. Monitor imaging periodically to adjust any focus drift that may occur during acquisition. Once data is collected, the serial images can be aligned and segmented using either open source or commercial software.

TIMING

This protocol can be performed over multiple days. Once samples are embedded in resin they are stable at room temperature indefinitely once infiltrated by and polymerized in resin.

Step 1: Culturing mammalian cells, plus an additional 24 - 48 h for cells to grow

Step 2: Brightfield or fluorescence microscopy for CLEM workflow with *en face* samples, 1 - 2 h

Steps 3-5: 2 h fixation at room temperature plus an additional 24 h at 4 °C.

Step 6-19: Sample staining, embedding and polymerization, 5 days plus any additional time for reagent setup and clean up.

Step 20-28: Cell pellet sample trimming and mounting, 2 h plus any additional time for epoxy polymerization, reagent setup and clean up.



Steps 29-47: *en face* sample trimming and mounting, 4 h plus any additional time for epoxy polymerization, reagent setup and clean up.

Steps 48-49: sample loading on the SBF-SEM, 1 h plus an additional 12 h to let the system equilibrate.

Steps 50-62: sample imaging, several hours to days depending on the number of ROIs being collected, the volume assigned as well as pixel size and dwell time.

Materials

Biological materials

In this protocol we use Vero cells (African green monkey epithelial) infected with *Encephalitozoon intestinalis*, a microsporidian parasite.

Reagents

- Dulbecco's Modified Eagle Medium, high glucose (DMEM:HG) (ThermoFisher Scientific, Cat no. 11995065)
- Dulbecco's phosphate-buffered saline (DPBS) (ThermoFisher Scientific, Cat no. 14190144)
- Trypsin-EDTA (ThermoFisher Scientific, Cat no. MT25053CI)
- Trypan Blue (ThermoFisher Scientific T10282)
- Fetal Bovine Serum (VWR 89510-188)
- 100X Non essential amino acids (Fisher Scientific 11-140-050)
- Milli Q water
- 16% paraformaldehyde (Electron Microscopy Sciences, EMS, Cat no. 15700)
- 25% glutaraldehyde (Electron Microscopy Sciences, Cat no. 16019)
- 0.4 M sodium cacodylate buffer, pH 7.2 (Electron Microscopy Sciences, Cat no. 11654)
- 4% Osmium Tetroxide (Electron Microscopy Sciences, Cat no. 19150)
- Thiocarbonylhydrazide (TCH)
- L-aspartic acid (Sigma-Aldrich)
- Lead nitrate (Ted Pella Inc., Cat no. 19321)
- Ethanol, 200 proof (Electron Microscopy Sciences, Cat no. 15056)
- Durcupan ACM Epoxy (Electron Microscopy Science, Cat no. 14040)
- EMBED 812 Embedding Kit (Electron Microscopy Science, Cat no. 14121)
- Silver conductive epoxy (Chemtronics CW2400 Epoxy)

Equipment

- Biosafety cabinet
- CO2 incubator (Heracell CO2 Incubators, ThermoFisher Scientific)
- Inverted light microscope to check confluence of cells (Carl Zeiss Microscopy LLC)
- Countess II Cell Counter (ThermoFisher Scientific)
- Invitrogen Countess Cell Counting Chamber Slides (ThermoFisher Scientific, Cat no. C10312)
- Ibitreat, 35 mm tissue culture treated dish (Ibidi, Cat no. 81156)
- 35 mm tissue culture dish; No. 1.5 Gridded Coverslip; 14 mm Glass Diameter (MatTek Corporation, Cat no. P35G-1.5-14-CGRD)
- Cell scraper (VWR 10062-904)
- Wood Applicator Sticks (Solon, Cat no. FBH00360)
- Embedding mold (PELCO, Cat no. 10535)
- Pipette and pipette tips
- Chemical hoods
- Razor (EMS Cat# 72000-WA)
- Formar Support Copper Slot Grid (Electron Microscopy Science, Cat no. FF2010)

Specific equipment

- 3View SEM pin stub: 1.4 mm flat, 2 mm pin, 12 mm height (EMS catalog# 75959-02)
- 3View SEM pin stub: 2.4 mm flat, 2 mm Pin, 12.5 mm height (EMS Cat# 75959-03)
- Diatome Histo Diamond Knife (Diatome, Cat no. DH4540)
- Leica EM UC6 Ultramicrotome (Leica microsystems)
- Zeiss Gemini300 Field Emission Scanning Electron Microscopy with Gatan 3View (Carl Zeiss Microscopy GmbH) and a second generation FCC or relevant volume electron microscope

Software

- DigitalMicrograph (Gatan)
- Fiji

Reagent setup

- Complete DMEM: HG media containing 10% fetal bovine serum and 1X non essential amino acids.
- Complete DMEM: HG media containing 3% fetal bovine serum and 1X non essential amino acids.
- Fixation solution: 2.5% Glutaraldehyde, 2% paraformaldehyde in 0.1M Sodium Cacodylate Buffer (pH 7.2-7.4)
- TCH solution: 0.1g TCH to 10 mL ddH₂O and place in a 60 °C oven for 1 h, agitate by swirling gently every 10 mins to facilitate dissolving. Filter solution through a 0.22 µm filter right before use.
- 2% Osmium in ddH₂O
- 1% Uranyl acetate in ddH₂O
- Aspartic acid stock solution: dissolve 0.998 g of L-aspartic acid in 250 mL ddH₂O water. Note: aspartic acid dissolves more readily at pH 3.8. The solution is stable for 1-2 months at 4 °C.
- Walton's lead aspartate solution¹: dissolve 0.066g lead nitrate in 10 mL of the aspartic acid stock solution. Adjust the pH of the solution to 5.5 with 1M KOH.
- Durcupan ACM: Epoxy resin/ A (11.4 g); 964 hardener/ B (10 g); 964 accelerator/ C (0.3 g); Dibutyl phthalate / D (0.05-0.1 g)
- Hard Epon: EMbed² 812 (5 mL); DDSA (2.25 mL); NMA (3 mL); BDMA (0.3 mL)

Safety warnings



Caution steps in the protocol have been indicated. Please refer to the material safety data sheet of the compound to ensure its careful handling.

Culturing mammalian cells and sample fixation

- 1 Culture adherent mammalian cells for 24 - 48 h in a 60 mm or 100 mm tissue culture dish for cell pellet samples, or 35 mm tissue culture dish with a gridded glass bottom for CLEM samples (final density $3\text{--}6 \times 10^5$ cells) according to the standard protocol for the cell line. In our experiments, Vero cells were cultured in complete DMEM:HG media.
- 1.1 Note: For cell pellet samples, the cells can be collected when they reach 90% confluence. This ensures that there are enough cells to form a large cell pellet. For CLEM, the cells should be at 70% confluence or less, as this will allow you to track the position of a cell of interest by both light and electron microscopy.
- 2 For *en face* embedding of cells, proceed with light microscopy to identify specific cells of interest. Depending on the biological event being studied, you can use brightfield or fluorescence microscopy to identify cells of interest. For cell pellet samples, proceed directly to step 4.
- 2.1 Critical step: 1) Image cells in an environmental chamber where temperature, humidity and CO₂ concentrations are maintained 2) Capture images at high magnification (40X or 60X) and low magnification (5X or 10X) of multiple regions of interest using DIC and fluorescence imaging, as appropriate, to identify cells of interest. Images collected at high magnification will allow you to record both the cell shape and a more precise position relative to the surrounding cells. From images collected at low magnification, a map of the cell location showing the gridded lines, numbers or letters can be used as a marker when trimming the EM sample block, and searching the target cell of interest under EM. We recommend selecting 2 - 4 regions of interest per sample, that are located far apart from each other on the dish. This ensures that each region of interest will be reliably recovered during the subsequent processing steps when the sample is physically cut away from the polymerized resin.
- 3 Discard tissue culture media, and gently pipette 2 mL of fixative (2% PFA and 2.5% glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2)) to fix the cells. For cell lines that are more sensitive, add 1 mL of pre-warmed 2x fixative (4% PFA and 5% glutaraldehyde in 0.2M sodium cacodylate buffer pH 7.2) directly into the dish with 1 mL of culture media.
- 3.1 Critical step: fixative solution should be freshly prepared



- 3.2 Note: the cells can be fixed first before light microscopy imaging. The fixative can be replaced with PBS, and imaging can be done under the light microscope without an environmental chamber.
- 4 For cell pellet sample fixation, after 1 min of fixation with 2% paraformaldehyde and 2.5% glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2), detach cells from the cell culture dish using a cell scraper. Transfer the cells into a 1.5 mL tube, and centrifuge immediately at 2400 xg for 2 min. Rotate the tube 180 ° and centrifuge at 2400 xg for an additional 2 min. Cells should be observed as a pellet at the bottom of the tube.
- 4.1 Critical step: 1) Scrape cells in a single direction, such that you observe a sheet of cells coming off the dish. 2) In-dish fixation should be limited to less than 3 mins to avoid disintegration of the cell monolayer which can make recovery of the dense cell pellet during centrifugation tough. 3) For cell pellet samples, avoid centrifugation moving forward and pellet samples by gravity.
- 5 Replace with 1 mL fresh fixative (2% paraformaldehyde and 2.5% glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2)) and continue to fix the cells overnight at 4 °C.



Sample staining and embedding

- 6 Discard fixative and add 1 mL 0.1 M cacodylate buffer for 10 min at room temperature. Repeat this buffer rinsing step two more times.
- 7 Discard remaining buffer and incubate the sample in freshly made 200 μ L reduced osmium solution that contains 2% osmium, 1.5% potassium ferrocyanide in 0.1 M sodium cacodylate buffer, for 1.5 h at room temperature in the dark.
- 7.1 Caution: do not disturb the cell pellet during all sample processing steps.
- 8 Wash the sample in 1 mL ddH₂O for 3 min at room temperature. Repeat this wash step four more times
- 9 Incubate the sample in freshly prepared 1 mL TCH (thiocarbohydrazide) solution (1%) for 20 min at room temperature.





- 10 Wash the sample in 1 mL ddH₂O for 3 min at room temperature. Repeat this wash step four more times
- 11 Incubate the sample in 200 µL 2% Osmium in ddH₂O for 40 min at room temperature.
- 12 Wash the sample in 1 mL ddH₂O for 3 min at room temperature. Repeat this wash step four more times
- 13 Incubate the sample in 0.5 mL 1% uranyl acetate in aqueous solution, overnight at 4 °C in the dark
- 14 Wash the sample in 1 mL ddH₂O for 3 min at room temperature. Repeat this wash step four more times
- 15 Incubate samples in 1 mL of *En bloc* Walton's lead aspartate solution¹, staining for 30 min inside a 60 °C oven.
- 15.1 Critical step: Walton's lead aspartate solution should be prewarmed at 60 °C for 30 min. Avoid precipitate formation.
- 16 Wash the sample in 1 mL ddH₂O for 3 min at room temperature. Repeat this wash step four more times
- 17 Carry out sample dehydration in a graded ethanol series as follows (1 mL per 1.5 mL tube, or 2 mL per 35 mm dish):
 - 30% ethanol in ddH₂O; 1X for 10 min at 4 °C
 - 50% ethanol in ddH₂O; 1X for 10 min at 4 °C
 - 70% ethanol in ddH₂O; 1X for 10 min at 4 °C
 - 85% ethanol in ddH₂O; 1X for 10 min at 4 °C
 - 95% ethanol in ddH₂O; 1X for 10 min at 4 °C
 - 100% ethanol; 1X for 10 min at 4 °C
 - 100% ethanol; 2X for 10 min at room temperature
- 18 Carry out resin infiltration of the sample using a graded Durcupan resin series as follows (0.5 mL per 1.5 mL tube, or 1 mL per 35 mm dish):
 - 25% Durcupan in ethanol; 1X for 4 h at room temperature
 - 50% Durcupan in ethanol; 1X for overnight at room temperature
 - 75% Durcupan in ethanol; 1X for 2 h at room temperature
 - 100% Durcupan; 1X for 2 h at room temperature



100% Durcupan; 2X for 1 h at room temperature

- 18.1 Note: For cell pellet sample embedding, a hard formulation of EMBED² can replace Durcupan, which is easier for sectioning with an ultramicrotome. However, EMBED will dissolve the cell culture dish, and therefore is not appropriate for an *en face* CLEM project.
- 19 For sample embedding of *en face* samples, tilt the dish at a 45 ° angle in order to discard as much leftover resin from the dish as possible. Add a thin layer of 100% Durcupan resin (~100 µl) directly onto the glass coverslip. For cell pellet samples, there are two options when sample embedding: 1) use a wood applicator stick to transfer the sample to an embedding mold, or 2) directly embed the sample inside the tube if the cell pellet is very small. With either sample embedding method, add 100% Durcupan to fill the embedding mold or ~200 µL to the tube if directly embedding the sample inside the tube. Place embedded samples in a 60 °C oven for 48 - 60 h to allow resin-infiltrated samples to polymerize and harden.
- 19.1 Critical step: 1) for *en face* samples, be sure to add a requisite volume of 100% Durcupan (one or two drops) that will cover just the glass coverslip and not the surrounding areas of the dish and 2) for cell pellet samples in which the sample is very small, sample embedding directly in the tube is recommended.
- 19.2 Note: Annotate samples clearly to prevent any confusion downstream when working with multiple samples. For *en face* samples, write down a sample number on a piece of paper and place it on the plastic area of the dish, so that any leftover resin will stick the number tightly to the dish. For cell pellet samples, put a sample number into an embedding mold, preventing overlap with the sample; alternatively, stick it to the inner wall of the tube.



Sample trimming and mounting: cell pellet samples

- 20 Bend the sample embedding mold, or cut open a tube using a razor blade to take out a polymerized sample block.
- 21 Lock the sample block on the specimen holder of the microtome, then trim the sample block under the microtome. Trim one edge of the sample block containing the cell pellet using a razor blade to expose the cell sample.
- 22 Place the sample block in the specimen arc of the ultramicrotome and section the exposed sample surface using a Diatome Histo Diamond knife to create the blockface. The knife holder and specimen arc angles should be set to zero.

- 23 Take the sample block out of the specimen arc. Using a razor blade, trim the remaining edges of the sample block into a pillar. 
- 23.1 Critical step: While trimming the sample block edges, ensure that: 1) the excess resin is trimmed away on the remaining edges in order to expose the sample and 2) each side of the pillar is of an equal dimension relative to the block face
- 24 Place the sample block under a stereomicroscope and cut away the newly created 3View sample blockface pillar with a razor blade.
- 24.1 Note: Laying the block flat and protecting the pillar with scotch tape before cutting will help to ensure that the pillar is not lost. Doing so on a piece of white paper will contrast the osmium-darkened sample, making the pillar easier to see.
- 25 Glue the pillar to a 3View SEM pin stub (EMS Cat# 75959-02) using silver conductive epoxy. 
- 25.1 Critical step: While gluing the sample, ensure that 1) the sample block face created using a Diatome Histo Diamond knife is glued directly to the surface of the 3View SEM pin stub, with the side cut away from the sample block facing up and 2) each side of the pillar is also covered by silver epoxy.
- 26 Place the 3View pin stub in a 60 °C oven overnight to polymerize the epoxy.
- 27 Place the pin stub in the specimen arc of the ultramicrotome and section the exposed sample surface using a Diatome Histo Diamond knife, where both the knife holder and specimen arc are set to angles of zero.
- 28 Remove the pin stub from the ultramicrotome and trim away any excess epoxy from the sides of the pillar.

Sample trimming and mounting: *en face* samples

- 29 Freeze the dish with the resin embedded sample in liquid nitrogen to carefully separate the glass coverslip from the polymerized cell monolayer. Repeat these freeze thaw cycles if necessary. 
- 29.1 Critical step: Immediately after freezing, use a very sharp razor blade to separate the perimeter of the circular coverslip from the dish, by lodging the razor edge between

the perimeter of the coverslip and dish while rotating the dish.

- 30 Identify the region of interest (ROI) and its respective, letter-number location square within the location-based grid on the sample side of the polymerized monolayer (Figure 1A).
- 31 On the sample side mark off a square around the letter-number location containing the ROI, using a razor blade (Figure 1B). 
- 31.1 Critical step: Take care not to damage the surface of the monolayer-ROI during this and all subsequent steps, as it is no longer protected by the glass coverslip; simply touching it may destroy the sample and/or its respective location-specific letter/number.
- 32 Turn over the polymerized sample monolayer and mark the location of the ROI with an "X" on the non-sample side of the resin; use the square marked by a razor on the sample side as a reference in doing this (Figure 1B).
- 33 Using a stereomicroscope, confirm that the "X" on the non-sample side aligns with the ROI on the sample side (Figure 1B).
- 34 Carefully place a 1 × 2 mm slot grid over the ROI on the sample side. Ensure that the ROI is centered within the slot. Using a razor blade, place marks at the sides of the slot grid so that the marks are parallel to the 2 mm side of the slot. These marks, in combination with the marks made in step 31, should create a rectangle equal to the diameter of the slot grid (Figure 1B).
- 35 Using a razor separate this rectangle, one side at a time, from the larger polymerized monolayer (Figure 1B). 
- 35.1 Critical step: Confirm that the non-sample side of the rectangular resin piece contains the centered "X" from step 30 (Figure 1B).
- 36 Set the rectangular resin piece aside, either in a microcentrifuge tube or a small gelatin capsule, so as not to lose the sample during subsequent steps.
- 37 Using a conductive silver epoxy, glue two slot grids one on top of the other to the top of a 3View SEM pin stub (EMS Cat# 75959-03) (Figure 1B).

- 37.1 Note: Make sure that the slots of both slot grids are aligned
- 38 Place the 3View SEM slot grid-pin stub into a 60°C oven overnight to polymerize the epoxy.
- 38.1 Note: Once dried, remove the now polymerized, excess silver epoxy from the interior of the superimposed slots using the edge of a razor or scalpel.
- 39 Glue the ends of the rectangular resin piece to the broader parts of the slot grid, sample side down, using the same conductive epoxy. 
- 39.1 Critical step: Ensure that the ROI target is centered in the slot of the slot grid and that the "X" marked on the non-sample side in Step 30 faces up. Be very careful to avoid getting epoxy on the ROI itself by placing a piece of tape on the sample side.
- 40 Allow the glue between the 3View SEM-slot grid pin stub and the rectangular resin piece to fully polymerize. Leave samples in a 60 °C oven overnight.
- 41 Place the 3View SEM-slot grid pin stub into the specimen arc of the ultramicrotome, taking care to ensure that both the specimen arc and knife holder are at zero °.
- 42 Using a Diatome Histo Diamond knife, section the now exposed non-sample side, at 500 nm section thickness and speed 1 mm/second. Continue to section until most of the resin from the non-sample side is removed and the rectangle is as thin as possible. 
- 42.1 Critical step: Thinning the non-sample side of the rectangular resin piece not only removes excess resin in order to increase the conductivity of the sample, but also ensures that the sample is parallel to the 3View SEM pin stub surface.
- 43 Using a sharp razor, very carefully remove the thinned resin rectangle from the 3View SEM-slot grid pin stub.
- 44 Under a stereomicroscope, cut the ends of the rectangle away so that the resin piece becomes a square with the ROI centered.
- 45 Glue this final square resin piece to the 3View SEM pin stub (EMS Cat# 75959-02), sample side up, using a conductive silver epoxy (Figure 1B).

46 Place the 3View pin stub in a 60 °C oven overnight, to polymerize the epoxy.



46.1 Critical step: Sample on 3View pin stub can be baked in a 100 °C oven for 1 h before sputter coating to increase the stability of the sample during SBF-SEM cutting.

47 Load the sample pin stub into a sputter coater. A layer of gold, 15 nm thick is sputtered onto the sample block faces. This improves conductivity and the reflective surface aids in the manual sample approach detailed in step 53.

Sample loading

48 Slot and secure the sample pin stub into the 3View microtome chuck by tightening a set screw. The sample is first rotated inside of the chuck such that the leading face of the block is rotated 90 ° clockwise from the set screw. This is done with the assistance of a stereo microscope.

49 Check that the sample is loaded and secured into the microtome. Shift the diamond knife laterally and adjust the cutting window position to center over the span of the block face. Using a stereo microscope and the reflection of the knife edge on the block face, manually approach the sample to the cutting plane.



49.1 Critical step: Care should be taken to avoid contact between the block face and the knife edge, as this will leave an imprint several microns deep. A practiced user should get the block face 5-10 µm away from the cutting plane.

49.2 Note: Leave the sample inside SEM chamber overnight before imaging to allow for a more thorough off-gassing and temperature equalization of the hardware and sample

Sample imaging

50 Navigate to an area of interest on the sample block face by using the stage controls in DigitalMicrograph software (Gatan).

51 Perform coarse cuts at 100 nm slice thickness to approach the sample blockface to the ultramicrotome knife. Acquire low magnification reference scans after every other coarse cut to confirm that the sample block is in the cutting plane of the knife.

- 52 For cell pellet embedded samples, acquire a low resolution scan that captures the sample blockface. Proceed directly to step 55.
- 53 For *en face* embedded samples, acquire an image with the secondary electron detector. This provides a clearer view of the sample blockface surface and makes visible the debossed grid numbers and borders.
- 54 Use low magnification images from light microscopy and the secondary electron detector to correlate the position of the cell of interest on the block face.
- 55 Create and position an imaging tile (or tile-set) over the cell of interest.
- 56 Set the chamber pressure, aperture size and electron beam settings. Refer to parameters listed in table1.
- 57 Using the secondary electron detector, activate Beam Wobble in SmartSEM (Carl Zeiss GmbH). Adjust the aperture X and Y position to center and align the mid-lens aperture. When the aperture is centered, the image will show no side-to-side movement and Beam Wobble can be deactivated.
- 58 In Gatan Digital Micrograph, edit the image tags in the Global Info settings to assign any metadata that is not automatically generated. These tags may include sample name, lab or investigator name, sample block number (if applicable), embedding resin used, aperture size and FCC pressure. Imaging parameters such as slice thickness, pixel size, dwell time and acceleration voltage are automatically embedded in the metadata.
- 59 Assign a storage directory for the saved dataset. Each scan is saved as an individual file in the native Gatan Digital Micrograph '.dm3' file format. Multiple regions of interest are saved into their respective folders (ROI_00, ROI_01, etc.).
- 60 Begin the dataset collection. For multiple regions of interest, the software will ask to confirm the positioning of the scans. The software will also ask the user to assign a region as a "monitor stack", which allows for the storage of several sequential scans in RAM for quick viewing. This is used to monitor cutting quality, sample charge rate and to perform any focus corrections during data collection.
- 61 Adjust focus and stigmation as the first image is being acquired.





61.1 Critical step: Be sure to monitor the first scans to assess whether there are any sample charge artifacts in the image. FCC pressure can be increased to compensate for sample charge or reduced to improve image contrast if the sample is sufficiently conductive.

62 Monitor imaging periodically to adjust any focus drift that may occur during acquisition.

62.1

To manually focus the image, set the 3View collection to a Pause state. Using a continuous live image of the block-face, manually navigate to an adjacent area that does not overlap with the region of interest being imaged. Adjust the focus and stigmation manually. Fast Fourier Transform analysis of the images is available, but may provide limited utility due to the relatively low signal-to-noise in the live images. Once the focus has been adjusted, set the 3View collection to Resume. For Multi-ROI imaging mode, the stage will automatically navigate to the next ROI in the image series. For a single ROI acquisition, first manually input the stage coordinates of the collection area and then set the 3View collection to Resume.

Protocol references

1. Walton J. Lead aspartate, an en bloc contrast stain particularly useful for ultrastructural enzymology. J Histochem Cytochem. 1979;27: 1337–1342.
2. Luft JH. Improvements in epoxy resin embedding methods. J Biophys Biochem Cytol. 1961;9: 409–414.