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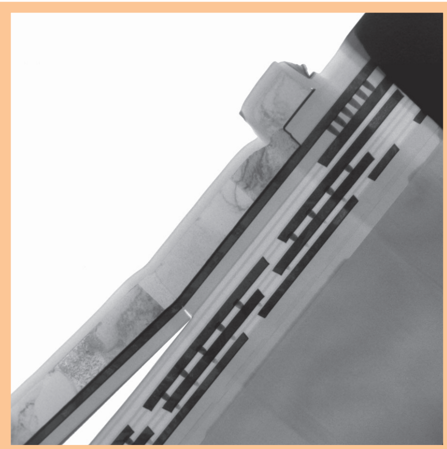
12 Reasons Every TEM Sample Preparation Lab Needs In Situ Lift-Out

The FIB in situ lift-out method for TEM sample preparation was developed in the mid to late-90's primarily as a way to improve throughput. Over the years it has been adopted across many industries and is now the leading sample preparation approach for high quality TEM samples. Here are 12 reasons that every TEM sample preparation lab needs in situ lift-out.

1. In situ lift-out is fast. Lift-out times range typically from 15 to 30 minutes [1-3], depending on user experience and sample size. Traditional methods like cleaving, sawing, and polishing require special equipment, take more time, require breaking the sample, and can induce sample damage.

2. In situ lift-out samples are flexible. The TEM tilt-angle limitation of traditional FIB "H-Bar" samples is avoided [4], and unlike ex situ lift-out specimens, rethinning is easily accommodated [5].

3. In situ lift-out is ideal for fragile samples. In situ lift-out avoids harsh mechanical processes and water or other liquids, so samples with cracks, delaminations, or other weaknesses will not be further damaged and artifact creation is minimized [6]. Fragile semiconductor samples exposed to high assembly stresses or reliability testing are easily prepared [7].



4. In situ lift-out is ideal for site-specific preparation of complex samples. A desired target of a complex or heterogeneous specimen, such as a crack tip, the grain boundary of a solar cell, or an electrically shorted region of a capacitor [8, 9] can be identified within the FIB/SEM and immediately extracted for subsequent FIB thinning and TEM inspection.

5. In situ lift-out creates samples ideal for ultra-high resolution TEM, where angstrom resolution is required. There is no membrane between the sample and detector to hinder viewing, and novel lift-out approaches enable the creation of ultra-thin lamella [10, 11].

6. In situ lift-out creates superior samples for TEM holography. Holography is a demanding application that requires samples with smooth surfaces (roughness less than 20nm variation). The lift-out technique produces samples easily oriented for backside or sideways milling, which can eliminate curtaining artifacts and produce samples of the required smoothness [12, 13].

7. In situ lift-out rapidly creates plan-view samples. Plan-view samples are desired for providing an alternate view and a large area for examination. This is often used to identify a feature which is then further processed for standard cross-section viewing. The lift-out approach easily creates plan-view samples by combining both the stage and probe shaft rotations to achieve the desired orientation [14]. The same strategy enables sideways thinning, which can improve sample quality [13].

8. In situ lift-out is ideal for small samples. Nanowires and nanoparticles can be easily attached to a probe tip, but may be too small for subsequent welding to a TEM grid. Several approaches are available to go directly from the needle to the TEM or other analytical tool such as atom probe [15].

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12 Reasons (cont.)

9. In situ lift-out is ideal for large samples. Since the in situ approach minimizes redeposition during thinning [16] and fast milling schemes exist for rapid extraction, large samples (>50um in length) can be excised quickly for FIB thinning or other types of analysis, such as EDS or FIB tomography. This is especially true when using today's newer ion columns.

10. In situ lift-out improves atom probe, TEM and FIB tomography. By creating a micropillar-shaped lift-out sample on a suitable holder, tomography with minimized "missing wedge" artifacts is enabled [17-19]. Sharpened further, the sample becomes suitable for atom probe and amenable to correlative TEM/atom probe analysis [15]. FIB tomography provides 3D information at a larger length scale and is complementary to TEM tomography. Better quality results can be obtained with an extracted sample [17].

11. In situ lift-out samples promote higher quality EDS/EBSD data. Lift-out samples are free of noise that is normally contributed by the bulk sample. Non-welding [12] or carbon deposition methods of attachment are available if necessary to further minimize contributions from extraneous sources. On a thin lift-out sample, EDS resolution below 100nm can be achieved, and analysis can be dropped considerably below 100 nm, even at high accelerating voltages [20]. The use of thin samples also improves the spatial resolution of EBSD, which can approach 10nm [21].

12. In situ lift-out is ideal for rare samples. The extremely high success rate of >95% [9] means valuable samples will not be lost during processing. It is THE method of choice used by labs to evaluate comet particles collected during the 6 year, 2.88 billion mile round-trip journey for NASA's stardust program [22-24].

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