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EXpressLO™ for Fast and Versatile FIB Specimen Preparation

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It is generally accepted that focused ion beam (FIB) ex-situ lift out (EXLO) specimen preparation for transmission electron microscopy (TEM) and other analytical techniques has a higher throughput than in-situ lift out (INLO) methods [1]. In addition, since ex-situ lift out is performed outside of the FIB-based instrument, EXLO may save costly instrumentation time compared to INLO. The primary disadvantage to conventional EXLO is the difficulty of re-milling a specimen once the specimen is manipulated to a carbon, formvar, or holey carbon film. In addition, the carbon or formvar film supporting the specimen may preclude certain TEM methods such as electron energy loss spectroscopy (EELS) or electron holography. Porous and delicate specimens are also difficult to prepare using EXLO methods. Since EXLO specimens are supported on organic films they cannot be plasma cleaned because the film, and thus the specimen, may be removed by the process. Conventional EXLO methods consist of FIB milling a specimen completely to electron transparency prior to lift out. Since FIB milling is performed while the specimen is surrounded by trench walls, the specimen may be predisposed to redeposition artifacts [2]. Redeposition artifacts can also be problematic in confined trenches using broader ion beams that are synonymous with low energy FIB milling techniques. Using newly developed methods, EXLO may now be used to manipulate thick specimens, in any orientation, to a newly designed grid such that the specimen may be further thinned by conventional FIB methods. Fast and easy manipulation in any orientation allows e.g., backside milling to reduce curtaining artifacts [3].

Using the EXpressLO™ method, a specimen may be FIB milled to say 1-2 μm in thickness (FIG. 1a) and lifted out using a hydraulic micromanipulator or similar (FIG. 1b) as per the usual method [4]. However, the specimen is manipulated to a newly designed grid carrier which allows the specimen to be transferred back into the FIB for further milling (FIG. 1b). A smooth flat grid surface allows the FIB milled specimen to adhere to the grid carrier via surface tension forces. If desired, epoxy may be used to glue the specimen to the grid. The specimen support area contains a slit (shown in FIG. 1b) to allow for further FIB milling of both specimen surfaces if needed, or the specimen can be further thinned or directly analyzed using other methods [5]. If desired, ion beam or electron beam deposition can be used to provide additional support for the specimen to the grid. FIG. 2a shows a scanning electron micrograph of the specimen after EXpressLO™ and further FIB thinning. FIG. 2b shows a high resolution TEM lattice image of the FIB prepared Si. This EXpressLO™ method combines the high throughput of EXLO with the flexibility of INLO specimen preparation [6].

References

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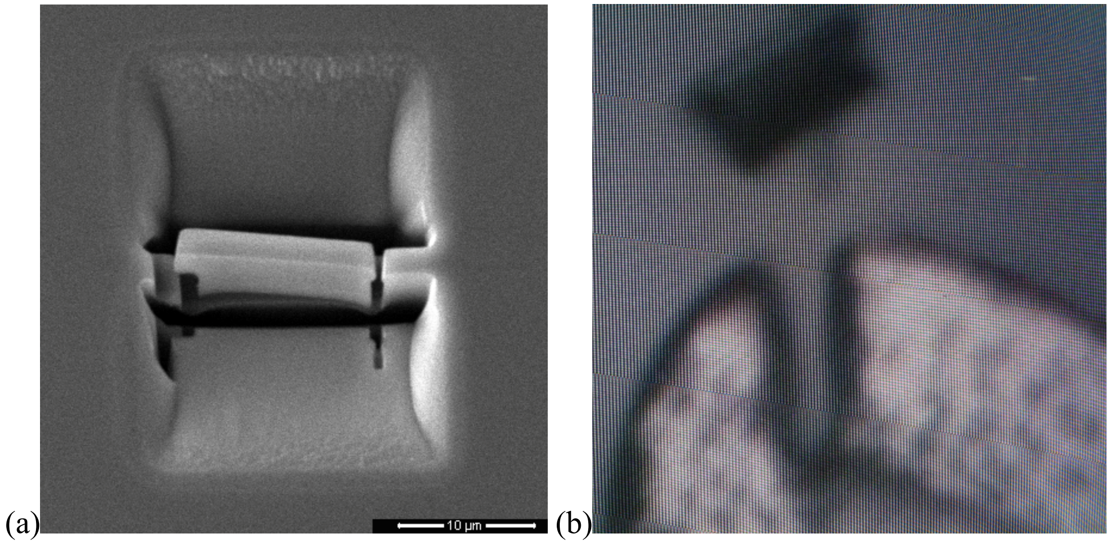

FIG. 1. (a) FIB lift out preparation of a Si specimen to 1-2 μm in thickness. (b) EXpressLO^{TM} of the thick Si specimen to a newly designed grid carrier.

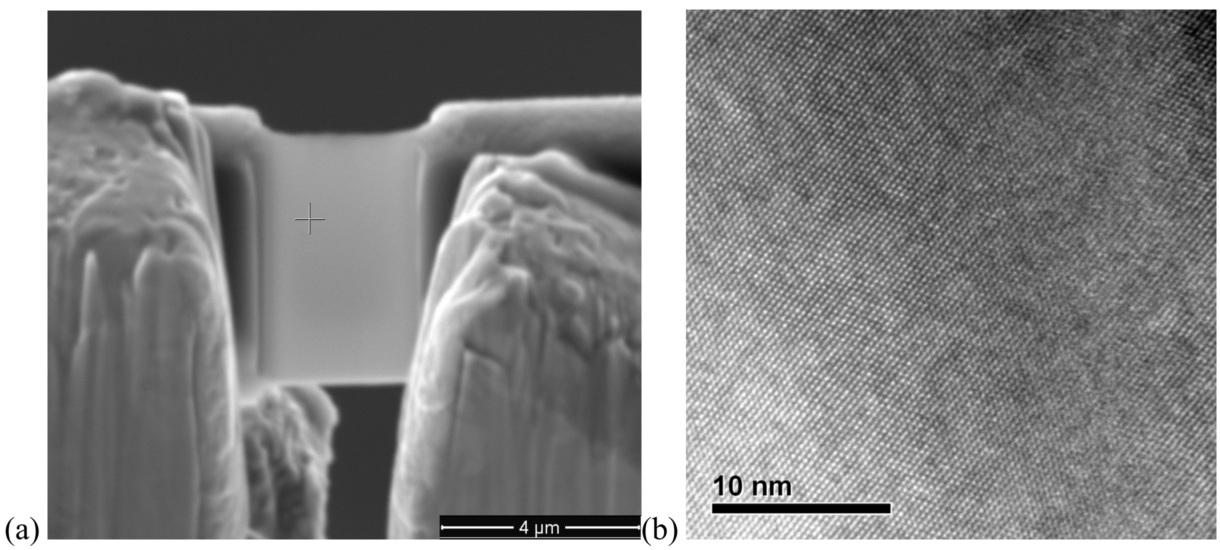

FIG. 2 (a) The specimen is FIB milled to electron transparency after EXpressLO^{TM}. (b) High resolution TEM Si lattice image of the EXpressLO^{TM} FIB prepared specimen.