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3D-Printed Lift Outs For EXLO and INLO Practice and Training

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To many, the lift out step in focused ion beam (FIB) specimen preparation is nerve-racking and frequently the most difficult part to master. A suitable scanning/transmission electron microscopy (S/TEM) specimen often relies on lift out success. Whether lift out is performed outside the FIB (i.e. *ex situ* lift out or EXLO) or inside the FIB (i.e., *in situ* lift out, microsampling, or INLO), the process generally encompasses two parts: (i) removing the sample from the bulk, and (ii) manipulating the sample to a suitable carrier [1-4]. These two parts may be broken down into a smaller set of nuanced sub-steps depending on the specific lift out procedure and the ultimate requirement of the specimen preparation such as manipulation for plan view or backside milling geometries. Mastering lift out requires numerous practice sessions needing expensive FIB time to prepare the specimens. In this paper, we discuss the production and implementation of 3D-printed samples that mimic the size and shape of FIB specimens used in the lift out process. An array of 3D-printed lift out samples allows novices to train and practice either the EXLO or INLO technique with repetition required for mastery in a cost-effective and timely manner.

A Nanoscribe Photonic Professional GT system that can 3D-print structures via the process of two-photon polymerization [5] was used to additively manufacture FIB-like samples onto a Si substrate (see figure 1a). Each 3D-printed sample was centered 100 μm apart to create an array of samples as shown in figure 1b. As shown in figures 2a-c, the samples can be used for EXLO or INLO practice or training. The tabs of material holding the specimen can be FIB milled free for EXLO to either a carbon coated grid as in figure 2a, or a slotted grid as shown by the arrows in figure 2b. The 3D-printed samples can also be used for INLO as shown in figure 2c. Thus, these 3D-printed samples are FIB processing teaching aids that can help new FIB users either EXLO or INLO learn lift out steps in a timely and cost-effective manner, easily repeating lift out steps without the need for creating expensive FIB specimens [6].

References:

[1] LA Giannuzzi et al, in Introduction to Focused Ion Beams (Springer, New York), p. 201-228.
[2] T Kamino et al., in Introduction to Focused Ion Beams (Springer, New York), p. 229-246.
[3] J Mayer et al., MRS Bulletin, **32** (2007), p. 400-407.
[4] LA Giannuzzi et al., Microsc. Microanal., **21** (2015), pp. 1034-1048.
[5] S Kuwata et al., Nature, **412** (2001), p. 697–698.
[6] 3D-printed Praxis™ samples are patent pending.

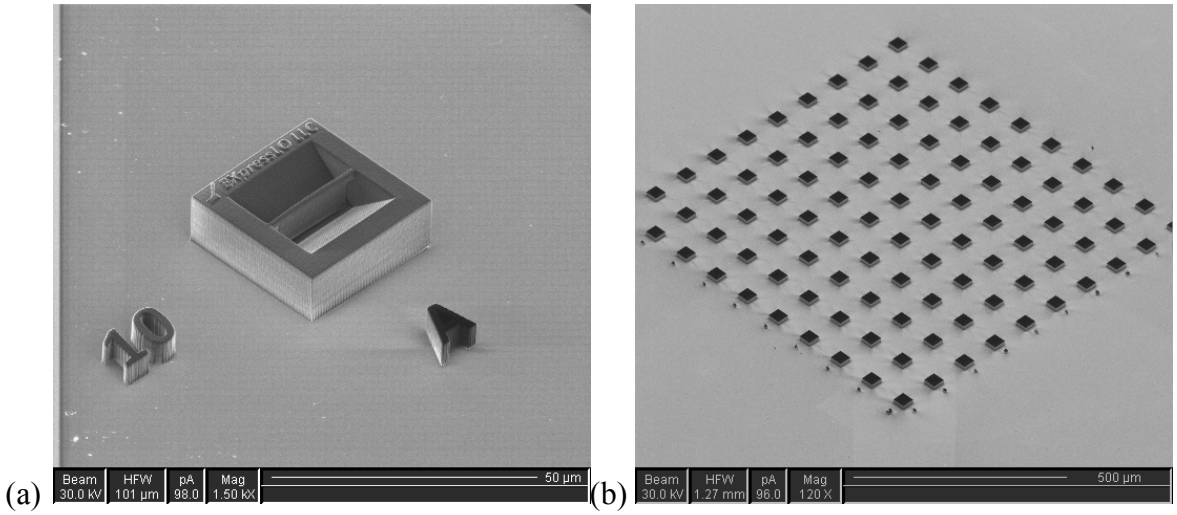

Figure 1. (a) A single 3D-printed FIB-like sample and (b) an array of 3D-printed samples.

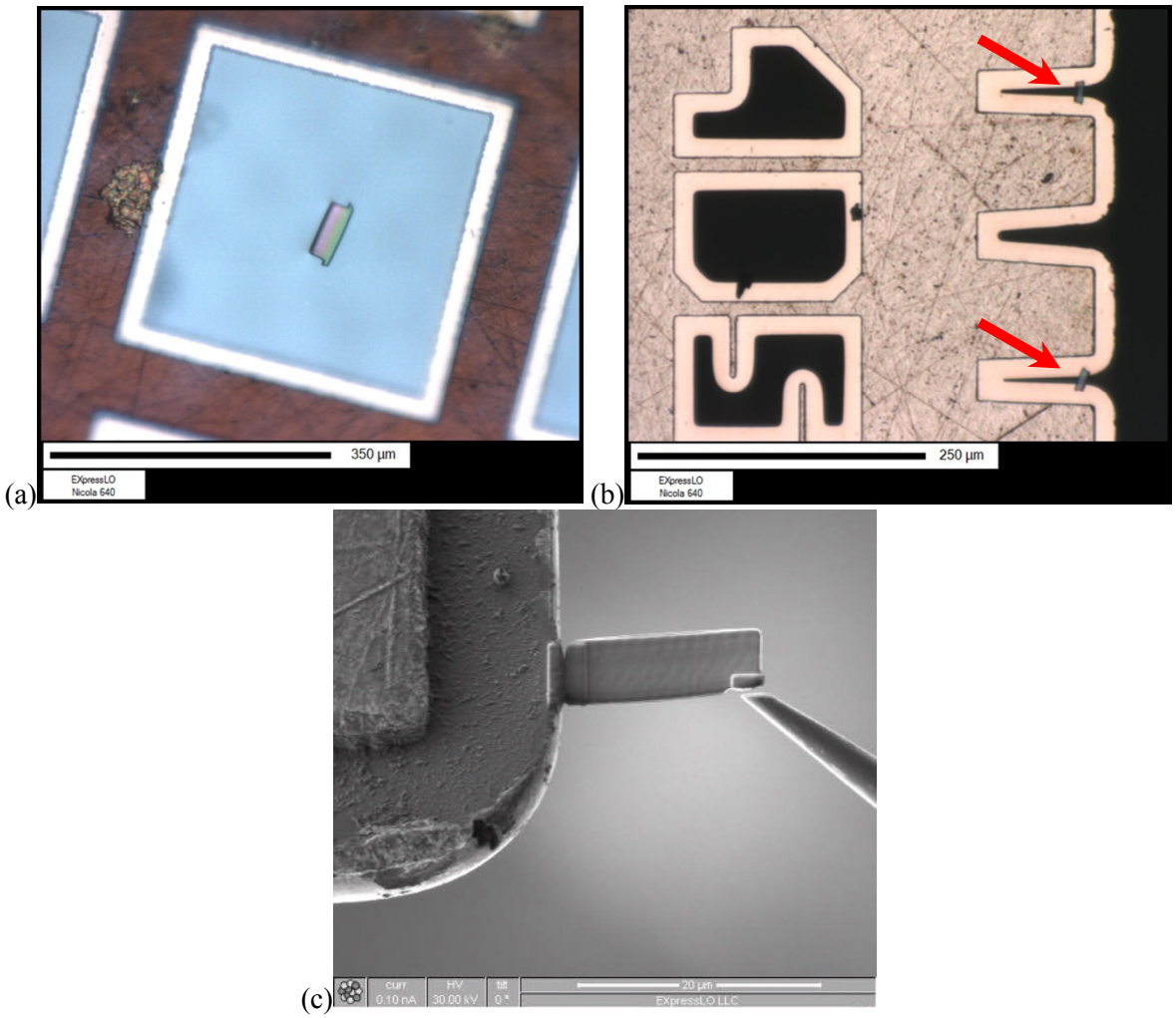

Figure 2. Lift out of the 3D-printed FIB-like sample using (a) conventional EXLO to a carbon-coated grid, (b) EXLO to a slotted grid, and (c) INLO**.**

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