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Opportunities and Challenges of Ultra Short Pulsed Lasers with Dual Focused Ion Beams for Characterization of Full-Scale Electronic Devices

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Destructive characterization of devices without direct disassembly of parts is critical to understanding core structure-property relationships that drive ultimate behavior and failure. One such approach, serial sectioning, enables characterization of interfacial phenomena such as stress voiding and structural defects that are not otherwise observable by preserving the assembled configuration of various components in heterogeneously integrated parts, such as batteries and electronics. However, for many of these devices, the large imaging areas required for characterization preclude the use of conventional Ga^+ focused ion beams (FIB), where the associated milling rates limit the amount of area that can be characterized to at most 40x40x40 μm^3. Xe plasma FIBs have gained traction as an alternative to the Ga^+ FIB as they can routinely characterize 3D volumes up to 200x200x200 μm^3, but this is not enough for many applications such as battery coin cells and capacitors with relevant features on the order of millimeters in length.

The recent introduction of the laser plasma FIB from Thermofischer Scientific opens the possibility of characterization of volumes up to 2000x2000x1000 μm^3, which is particularly advantageous for such applications because it characterizes components without taking apart the important packaging, avoiding disturbance of delicate interfaces [1]. In this contribution, we present on 2D and 3D characterization opportunities and challenges with the laser plasma FIB. Specifically, we highlight cryogenic work over large areas with battery cells – work only recently made possible. [2] [3] An image of such a cell is shown in Figure 1 with a total area of close to 0.1 mm^2. Challenges to obtaining these types of images include: (1) keeping the cell frozen such that it does not short circuit during testing, which can be difficult with organic electrolytes and/or large parts; (2) frost formation during loading or changing out the glass slide that protects the microscope from FIB debris, which can be mitigated by refilling the chamber with dry nitrogen and enclosing the chamber with a glove bag; (3) charging during imaging; and (4) optimizing angles and imaging parameters to remove debris such as redeposition of metals and obtain clean images. The potential for even larger-area cross-sectioning has also been investigated by leveraging microscope automation packages. By combining multiple laser-cutting operations, sectioning of a commercial tantalum capacitor component in its original packaging was achieved with imaging widths in excess of 4 mm (Figure 2). Development of optimized slice and view imaging protocols to enable 3D reconstructions for a wide variety of materials and devices will also be discussed.

†This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

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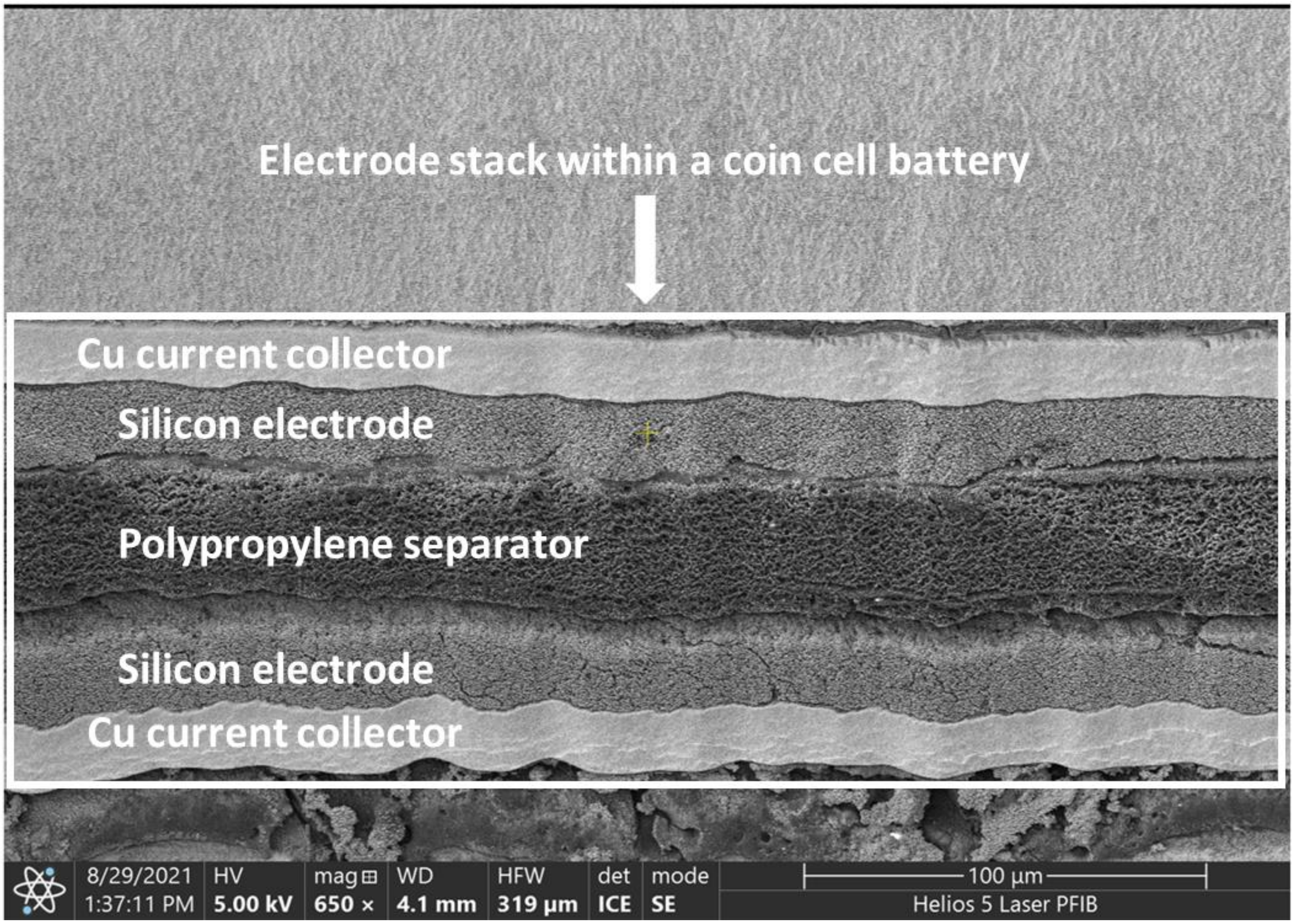

Figure 1. Battery device sectioned at cryogenic temperatures with the femtosecond laser.

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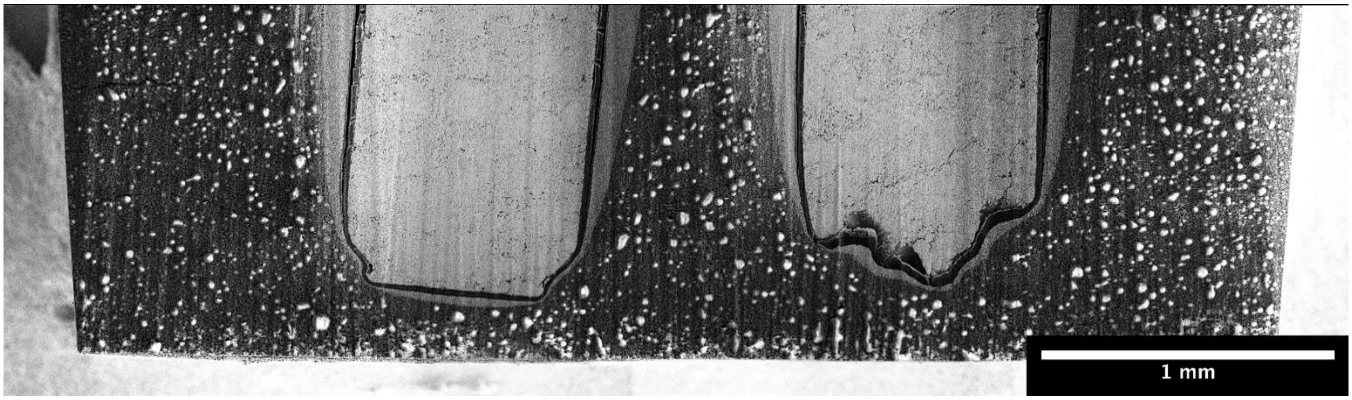

Figure 2. Composite image of a tantalum capacitor from serial sectioning with the femtosecond laser.

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