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Single Image Composite Tomography Utilizing Large Scale Femtosecond Laser Cross-sectioning and Scanning Electron Microscopy

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Introduction: Femtosecond lasers have become increasingly popular for cross-sectioning applications due to their high throughput and low heat affected zones. Here a novel technique was developed which utilizes a single high-fidelity large-scale laser cross-section and a single scanning electron microscopy mosaic to reconstruct a three-dimensional tomography. This technique can be applied to any sample which has periodic or repeating structures. For demonstration purposes the technique was performed on a restructured biomedical platinum electrode. Restructured platinum electrodes have been shown to have significant improvements in electrochemical performance by improving the charge storage capacity and reduction in impedance [1]. However, to understand the driving force behind this improvement, large scale cross-sectioning for profiling and subsurface features analysis is needed [2,3]. The features range from tens of nanometers to hundreds of microns and therefore current focused ion beam methods prove to be prohibitively long to perform analysis on many of such samples.

Large Scale Cross-Sectioning: A femto-second laser system coupled with gas processing was employed to create multi millimeter cross-sections. These cross-sections where first validated and compared to focused ion beam, FIB, cross-sectioning. The system includes software and stage systems that can allow for infinite laser scan field. This infinite scan field coupled with lasers high throughput allow for a cross-section of any needed size. A major challenge when attempting a multi-millimeter to centimeter cross-section is the redeposition of the removed material. However, in this case the gas processing system completely eliminates all redeposition and buildup of material. Furthermore, a masking technique was employed to further protect the sample and increase the quality of the cross-section.

Method: Typically, cross-sections are performed perpendicular to the samples face. Here due to the periodicity of the sample in question a very slight angular cross-section was employed. This angular cross-section proceeds into the sample reveal the growth of the periodic structure. Changing the angle and length of the cross-section allow for control of the slice thickness of the tomography. This is of course not a traditional tomography, but a composite tomography of a single slice taken from multiple structures throughout the sample. One major advantage of this is that analysis can be performed to determine the variation in each periodic structure. Furthermore, the tomography is derived from a single cross-section which allows for rapid 3D analysis. Utilizing automated SEM stitching using ZEISS ATLAS software, the entire imaging process can be automated and stitched together to form a single mosaic. **Results**: Figure 1 below depicts a mosaic of a 1 mm long angular cross-section which has been imaged at a 50 nm pixel size.

Once the mosaic is obtained the image can be dissected and separated to produce slices of individual structures. Once the slices are obtained they are stacked together to form the 3D tomography. Figure 2 displays the dissection process, which will result in a 3D composite tomography.

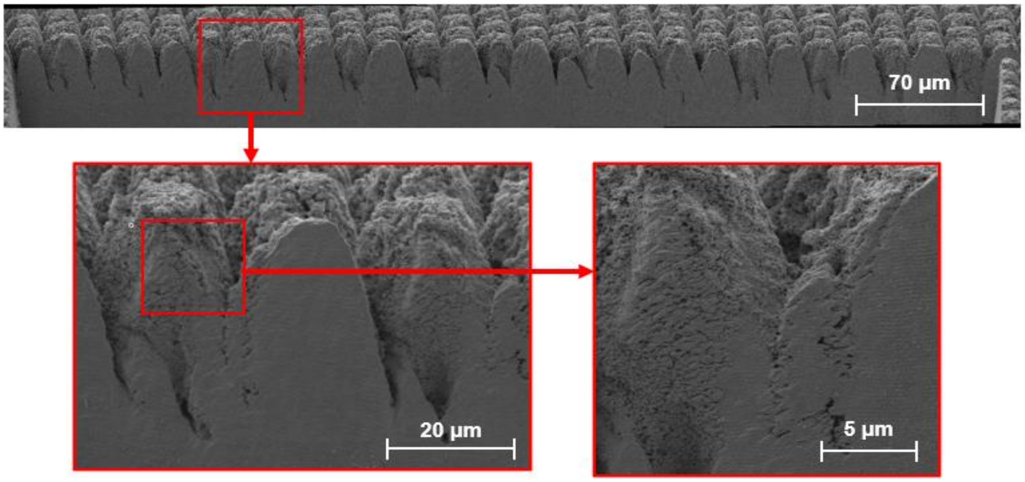

Figure 1. A stitched mosaic of 30 SEM images of a 1 mm long cross-section. A 50 nm pixel size allowing for an overall view and zooming into the data while

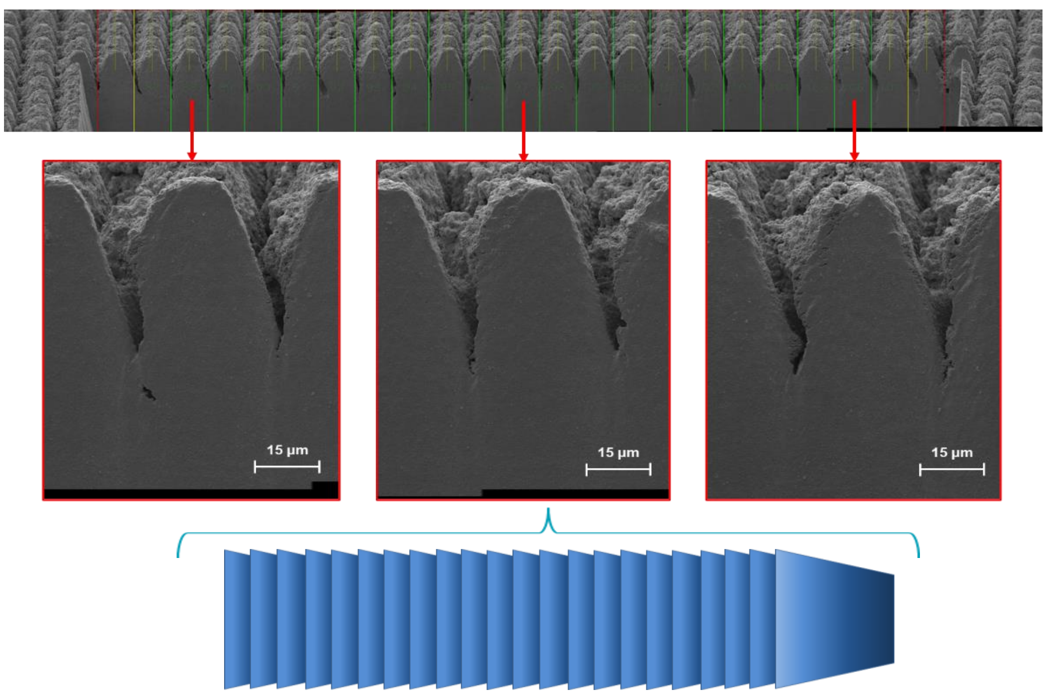

Figure 2. The mosaic is dissected into individual slices which will be stacked together to construct the 3D tomography

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