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Preparing High-Quality Cross-Section Surfaces by Ultrashort Pulse Laser Ablation and Plasma FIB

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In recent years ultra-short pulse lasers (USP-L) have been integrated with Focused Ion Beam (FIB) and Plasma Focused Ion Beam (PFIB) instruments. With this combined technology it is possible to gain sub-surface access quickly, cut millimeter size cross-sections for scanning electron microscopy (SEM) imaging and perform large 3D (analytical) serial sections. [1] Materials that are perceived as more difficult to process on FIBs such as: beam sensitive, non-conductive and carbon-based material can be rapidly removed by a USP Laser. [2]

When cross-sections are prepared for high quality imaging or analytics, surface artifacts need to be minimized. Without laser parameter optimization laser cut surface artifacts can be seen, such as: shockwave damage, melting, debris, curtains and laser induced periodic surface structures (LIPSS). Minimizing these surface artifacts can be tedious due to the wide parameter space available for laser processing. Accessible laser parameters typically include wavelengths, repetition rates, power, pulse energies, scan speeds and different scan strategies (shapes, dimensions, x & y pitch, number of passes).

Earlier laser processing studies provide some directions to reduce some of the artifacts seen.
The heat affected zone (HAZ) of USP lasers is small compared to nano- or pico second lasers. By working close to the ablation threshold, the USP laser HAZ can be minimized. [4,5]. LIPSS can be reduced by limiting the number of pulses per spot. [3]

Here we present the most recent findings on laser parameter optimization where we separately focus on the cross-section cleanup process by using both optimized laser parameters and low energy Plasma FIB. (figure 1) Optimized laser parameters were systematically determined for the following materials: steel, copper, aluminum, glass and polymer resins. Low energy Plasma FIB was used to remove the remaining texture and debris. The results were inspected by high resolution SEM and analytics when possible. Removal rates and depth of damage have been quantified for the materials mentioned.

The cross-section surface cleaning steps applied result in significantly less surface artifacts on large surface areas, which result in faster time to data and higher quality image- and analytical data.

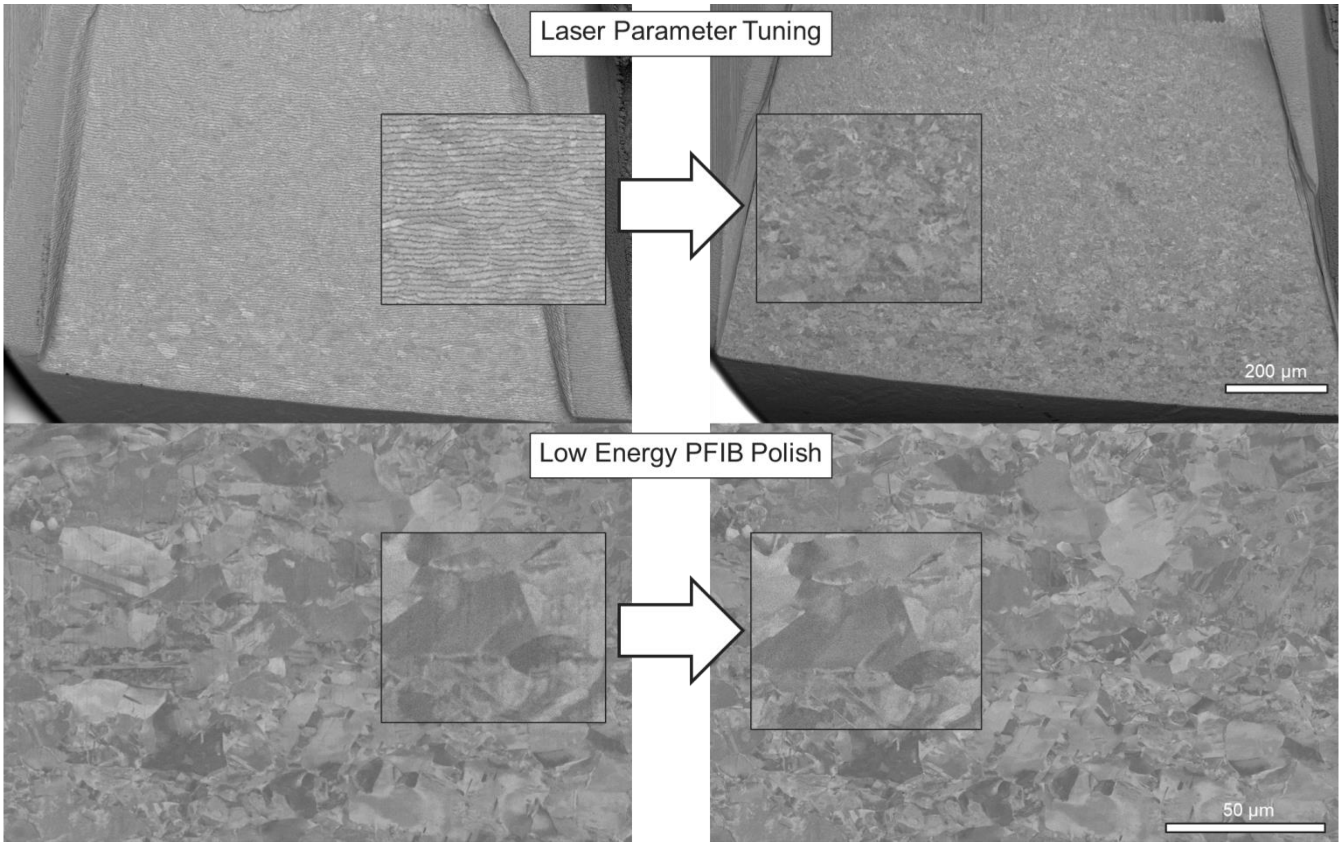

Figure 1. A cross-section of 1200 um wide was milled in copper at high power and by scanning fast (λ=1030nm, 30kHz, E_{pulse}=25µJ, 8 passes, 1µs dwelltime, coarse mode), after this the laser milling process was optimized (λ=515nm, 30kHz, E_{pulse}=16µJ, 8 passes, fine mode), any laser induced periodic surface structures and debris were removed (top). Finally, the surface was gently polished for 2 minutes by Plasma FIB at 5keV 60nA (bottom).

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