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Laser-Based Sample Preparation

Preparing TEM Specimens and Atom Probe Tips by Laser Machining

By Boris Kozminskii, Henry Spott (3D Micromac AG) and Michael Krause, Georg Schuster, Thomas Hölche (Fraunhofer IPT/IME)



Introduction
Over the past 50 years, lasers have found many applications in science and technology. The most important features of lasers are that photons are inherently free of material contamination, extremely high energy

devices can be focused to small diameters, and the laser beam can be precisely positioned using deflection mirrors. By reducing pulse lengths from a few nanoseconds down to the picosecond or femtosecond range, superficial surface heat damage from ablation can be reduced to depths of a few microns or less. Available for many decades, lasers have become extremely reliable processing tools in many areas, including the automotive industry (welding, drilling, and measuring), thin-film processing (cutting, patterning, and even reticle surgery), semiconductor fabrication (LIGA). In view of the outstanding characteristics of lasers as tools for micro machining, it is surprising that instruments for specimen preparation for state-of-the-art analytical techniques have not made use of laser technology. 3D Micromac company has developed a dedicated laser micro-machining instrument for specimen preparation. The name of this instrument indicates its purpose: *microMACH* (micro machining).

At sufficiently high power (or more precisely directed), laser radiation is able to ablate all kinds of materials. Using ultra-short pulses and high pulse energies, ablation-based tools can also process materials that are transparent to the laser's wavelength. The ablation rate of laser micro-machining is about six orders of magnitude larger than that of the carbon beam used in focused ion beam (FIB) workstations, and it is even about four orders of magnitude higher than the milling rate of the 20-nanometer FIB. Moreover, beams can be very precisely positioned on a given workpiece and straightforwardly focused using standard optical

elements. Since laser radiation consists just of photons (rather than an ion beam), which may have unwanted impregnation effects, laser work involving it does not result in contamination. This whitepaper shows how this technology can be used to produce thin lamellae for transmission electron microscopy (TEM) and sharp tips for atom probe tomography (APT).

Tasks for the laser

Specimen preparation techniques need to be fast, reliable, cost-effective, and scalable from the millimeter scale to smaller. Traditional mechanical specimen preparation and FIB systems currently dominate the TEM/APT market. However, it is accompanied by the high costs of time-consuming processes. The laser is characterized by the high costs of instrument ownership. There are a number of specific capabilities of a laser-based specimen preparation tool. Based on several patents, the tool described here has a range of laser functions, including laser cutting from the bulk, followed by local laser thinning in an almost entirely automated fashion. Making use of a rugged, ultra-short-pulsed laser source, the process is characterized by low running costs, suitability for all materials of modern microelectronics (freedom from contamination, and a precision of about one micrometer).

Instrumental setup and performance

The main components of the microMACH (M2) instrument are a 100 W laser source with 10 ns average pulse and an objective lens focusing the laser beam to a small probe (beam diameter ~10 µm). The pulse energy of up to 0.1 J enables high ablation rates compared with a focused Ar ion beam on the focused Ga or Xe ion beams used in FIB instruments. Figure 1 shows a (100 × 100 × 150) µm³ box milled by using the microMACH (M2). This specific preparation was done in less than 5 min. If a FIB were used for the same task, it would take up to 17 days. Thus the removal of bulk material can be efficiently done by means of this laser instrument, but the speed still depends on the dimensions, the tool, and the specific material to be removed.

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Preparation of electron-transparent thin specimens can be costly in terms of time and is often challenging. Laser processing is an effective method for rapidly removing significant volumes of material to reduce the total time to a finished specimen. Cost-effective, and site-specific preparation of samples for microstructure evaluation allow to overall speed up and simplify analysis processes. In addition, ultra-short-pulsed laser-based sample preparation makes possible new sample geometries.

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