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Hardware and Software Advances in Commercially Available Atom Probe Tomography Systems

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Over the past 15 years, the number of peer reviewed publications referencing the use of atom probe tomography (APT) has grown by nearly a factor of five [1]. A number of factors are involved in this very rapid adoption of APT, a microscopy that has been in use since the early 1970s. The performance of the typical atom probe today is orders of magnitude better than the early systems in terms of data collection rate, field of view, mass resolving power, reliability and software. The availability of easy to use laser pulsed systems coupled with the changes in performance and availability of FIB-SEM sample preparation has dramatically opened the array of applications that can be analyzed. These advances, with the improved ease of use and availability of atom probe tomography microscopes, have changed the typical user from an expert in APT to a scientist looking for answers that other microscopies cannot provide.

Modern local electrode atom probe systems (LEAP®), can identify subnanometer, spatially resolved, 3D information of any element with up to 80% detection efficiency at millions of atoms per minute with a field of view (FOV) that can exceed 250 nm and an achievable sensitivity limit in the low parts per million range. The LEAP 5000™ from CAMECA® (Figure 1a) includes improvements in FOV and uniformity, multi-hit sensitivity, faster data acquisition, especially in voltage-pulsed mode, and a new control software platform that improves yield and the speed at which a user can optimize run conditions. Additionally, a new atom probe platform, the EIKOS™ (Figure 1b) offers dramatic improvements in the simplicity of design and operation, including a nearly 50% reduction in the cost of ownership, much in part to a novel ex-situ alignment of the specimen to the counter electrode shown in Figure 1c.

Newly available APT options from CAMECA beyond the EIKOS platform include specimen transfer at ultra-high vacuum levels (Figure 1d), with the ability to keep the specimen at cryogenic temperatures, as well as sample preparation techniques and software developed in cooperation with EDAX® to combine transmission electron backscatter diffraction and APT to provide synergistic information and improve APT data reconstruction [2]. Additionally, CAMECA has just announced the availability to upgrade LEAP 4000 systems to full LEAP 5000 capabilities.

For APT, data analysis software is critical because the information available during data acquisition is primarily used to verify the region of interest has been collected. The majority of the analytical work is done after data collection. The most recent version of the analysis software available from CAMECA is IVAS 3.8™. This version includes updates to ensure compatibility with the latest windows operating system, the ability to analyze datasets over 2B ions, as well as a number of additional updates. Recent feature updates include automatic background correction in concentration profiles, and the ability to flatten specifically designated reconstructed features to known geometrical interfaces (Figure 1e), using either low-pass or high-pass filters, to either preserve or smooth interface roughness while globally flattening known flat surfaces. Other significant features include assisted mass peak identification,

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arbitrary clipping planes, a scale bar on 2D plots, automatic pole indexing (Figure 1f), and a 2D evaporation simulator [3]. Moving forward in reconstruction developments, metrics have been developed to measure changes and improvements in reconstructions [4].

Although the most common APT applications remain metallurgical in nature, these hardware and software improvements continue to open up new applications by enabling sufficiently high yield and data quality to provide novel information. Recent new applications include, failure analysis of FinFET devices, 3D printed alloys, high entropy materials, zeolites, cryogenically preserved biomolecules, and more.

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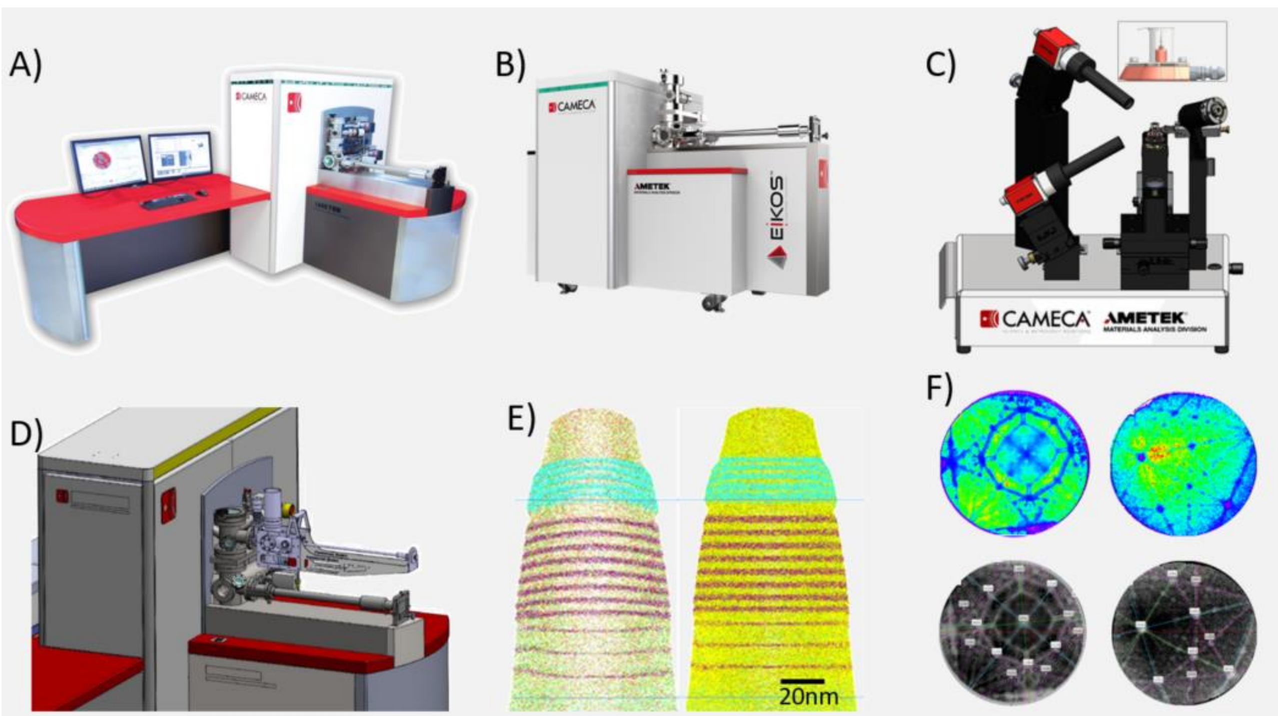

Figure 1. A) LEAP 5000 Instrument, B) EIKOS Atom Probe, C) ex-situ alignment station for pre-aligned counter electrodes, D) one implementation of a UHV-Cryo specimen transfer system attached to a LEAP 5000, E) landmark registration reconstruction for plane flattening, F) Field disorption maps of tungsten(left) and aluminum(right) with automatically determined crystallographic pole identification.

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