doi:10.1017/S1431927619003349
Microsc. Microanal. 25 (Suppl 2), 2019

Atom Probe Tomography Productivity Enhancements

D.A. Reinhard[1*], T.R. Payne[1], E.M. Strennen[1], E. Oltman[1], B.P. Geiser[1], G.S. Sobering[1], D.R. Lenz[1], J. Mandt[1], G.A. Groth[1], D.J. Larson[1], R.M. Ulfig[1], T.J. Prosa[1]

[1.] CAMECA Instruments Inc., 5470 Nobel Drive, Madison, WI 53711 USA.
* Corresponding author: David.reinhard@ametek.com

The semiconductor industry is driven by the minimization of feature size and optimization of process time (money). The combination of these concepts is well captured in the recent literature by the statement that expectations for data are "as precise as possible" and "as fast as possible" [1]. While the atom probe tomography (APT) technique has been around for 50 years [2], only recently has there been substantial efforts toward application in the semiconductor industry (for some recent reviews see [3–5]). The interest in APT is due to its combination of analytical sensitivity and sub-nanometer spatial resolution.

One critical improvement, called for in reference [4], is faster "time-to-knowledge", which is directly related to improving "productivity". With respect to APT, improving productivity can range from removing certain individual user input requirements up to complete automation of the large processes of specimen preparation [6], data acquisition, data analysis, etc. It also means lowering barriers for comparing APT results with other more traditional and mature characterization techniques.

This work presents several new software advancements CAMECA® is introducing in order to alleviate these limitations and facilitate faster throughput for high-volume, routine measurements. Topics include a closed-loop integration of a scientific database, the ability to run automated multi-specimen acquisitions with standard or specimen specific design-of-experiment acquisition plans, automated real-time mass calibration, scripted variable data acquisition, automatic reconstruction and scripted data analysis. These developments enable a substantial reduction in overhead through improved utilization and time-to-knowledge that encourages the use of APT in manufacturing environments.

The first advance is a new project plan infrastructure which allows for recipes to be defined for portions of the APT project lifecycle where automation is possible, and for other instruction sets to be specified for non-experts to follow when automation is not possible. These plans make it easier to promote a higher level of precision for all required analysis activities. Some project planning is still done outside of the APT infrastructure using instructional best-known methods for specimen preparation and data reporting steps. For recurring sample projects, a project template can be saved to allow a new project to be created with all desired recipe plans already specified. The newly defined recipes are used as inputs to drive automated data acquisition (including real-time mass spectrum calibration) and the data reconstruction steps. Post reconstruction data analysis is semi-automated, with some aspects of the analysis improved with analyst feedback.

The next advancement in automation is the introduction of unattended data acquisition from multiple specimens. This advance builds on the project plan infrastructure and adds automation of the specimen positioning stage and the laser control software enabling sequential data acquisition from multiple specimens on a microtip array without any intervening user input (Figure 1). Unattended operation of LEAP® instruments allows for utilization during unstaffed time periods (i.e., overnight), improves productivity, and reduces time-to-knowledge for routine applications.

Another advancement under development is the inclusion of advanced acquisition scripting capabilities. Specimens incorporating complex structures can benefit from intelligent variations in acquisition conditions based on analysis of the data being acquired [7]. Examples include reduction in the detection rate when the detected ions are concentrated in one area and distinct chemical compositions are detected in two concentric circles (indicative of a layer interface and a potential failure point), or a switch to a higher detection rate and constant ion flux control when analyzing a lightly doped layer (results in lower background and better quantification of the dopants). Currently, an operator is required to be present to recognize the changes in the acquired data signaling the time to change the conditions. With advanced acquisition scripting capabilities, specimens can be analyzed with optimal settings for yield and data quality at all points within the specimen while unattended.

Taken together, these features largely automate the process of APT analysis for routine samples. Data acquisition only requires intervention for transfer of microtip arrays, while the post-acquisition data analysis can be partially automated depending on the complexity of the analysis required.

References:
[1] P. van der Heide, J. Vac. Sci. Technol. B **36** (2018), 03F105.
[2] E.W. Müller et al., Rev. Sci. Instrum. **39** (1968), p. 83.
[3] W. Vandervorst et al., Phys. Status Solidi **C11** (2014), p. 121.
[4] A.D. Giddings et al., Scr. Mater. **148** (2018), p. 82.
[5] J.P. Barnes et al., Scr. Mater. **148** (2018), p. 91.
[6] M.B. Schmidt et al., APTM 2018 Abstr. June (2018), p. 222.
[7] T.J. Prosa et al., Frontiers of Characterization and Metrology for Nanoelectronics (NIST, Gaithersburg, Md, 2013), pp. 269–272.

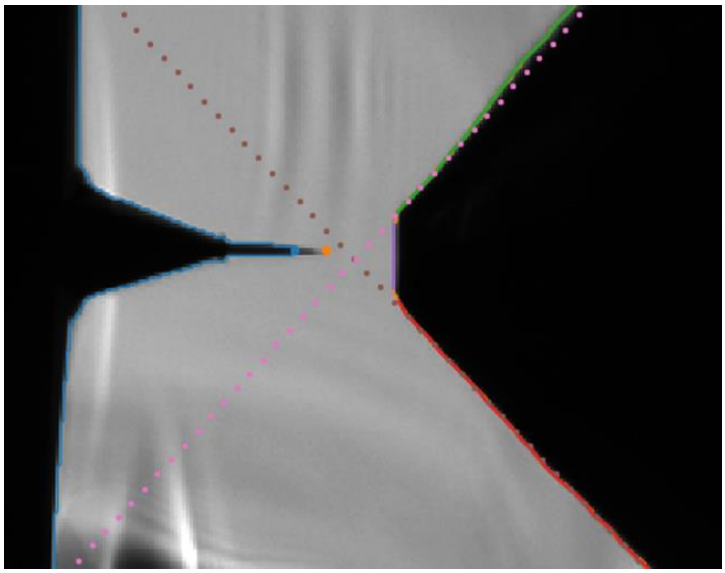

Figure 1. The specimen microtip (left) and local electrode (right) within a LEAP 5000 as processed through a machine vision algorithm. The solid blue line denotes the specimen tip while the orange dot is the estimated apex position. The solid green, red, and violet lines denote the edges of the local electrode. The dashed lines are fit to, and extrapolated from, the sloped sides of the electrode. When automatically aligning the specimen, the machine vision will position the specimen apex (orange dot) at the point at which the dashed lines cross.