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Fully Automated Data Acquisition and Reporting for Semiconductor Dopant Analysis

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As atom probe tomography (APT) technology matures, there is a growing need to automate data collection and analysis for high throughput environments, such as semiconductor fabrication. Many instruments in a semiconductor fab take in-line measurements without the need to pull a test wafer from the production line. In-line and near-line measurements not only save cost and time but minimize risk of contaminating the sample by handling and thus altering the measurement, but at some cost to using those areas of the wafer to complete the full device. Dopant analysis in bulk semiconductors such as silicon is a critical need in the semiconductor industry and a long-standing application for APT [1-3]. APT provides the high-resolution concentration measurements localized to extremely small regions of interest, appropriate for failure analysis of a single device or routine sampling at low concentrations.

Automation of APT has made data collection and analysis much easier by allowing the user to run multiple samples sequentially without user intervention. Specimens can be run according to static data collection conditions with a recipe, or the user can dynamically change conditions throughout the analysis by writing a script. Scripted acquisitions provide the ability to run large scale design of experiments by changing acquisition conditions systematically. Additionally, information may be stored in a log file during the experiment. This minimizes the need to reconstruct and manually analyze the data to get key pieces of information, such as the concentration per million ions. The composition can be reported during or shortly after the analysis, decreasing time-to-knowledge for results. Consistency can be improved with automated scripting and reporting compared to manually positioning regions of interest on a 3D dataset.

Scripted Acquisition allows the user to create acquisition scripts with a graphical user interface to change acquisition conditions dynamically in response to live experimental feedback, or load C# code directly the software. Loading a C# script provides the flexibility to create Properties, or values used in the script that can be altered without rewriting the code itself, as shown in Fig 1. This provides the advantage to conduct a design of experiments type study by systematically changing property-conditions that may be important to aspects of yield/survivability, or data quality.

Scripted Acquisition also provides the capability to log data during the acquisition process. Any data readback from the acquisition, such as composition, number of ions collected of a particular ion, acquisition time, etc., can be reported in a log file directly. In the case of composition, this enables the user to report compositional data associated with acquisition status without the need for reconstructing the data. For example, Fig. 2 shows an example of reconstructed volumes of a Si specimen intrinsically doped with Boron. In this case, the regions of interest highlighted in Fig. 2 by the boxes correspond to intervals of one million collected ions. In a scripted acquisition, compositional data is reported in the interval associated with a specific set of data acquisition conditions (e.g., temperature, laser power, laser pulse rate). Manually positioning the region of interest within a reconstructed 3D dataset has the potential to introduce errors because it is depending on how the user positions the region of interest and not the true intervals where acquisition conditions were modified. Reporting boron content via script logs enables studies to investigate how acquisition factors affect results: background content, boron concentration, etc. We demonstrate direct reporting of concentration data via script, circumventing the need for 3D reconstruction for simple doped semiconductor systems.

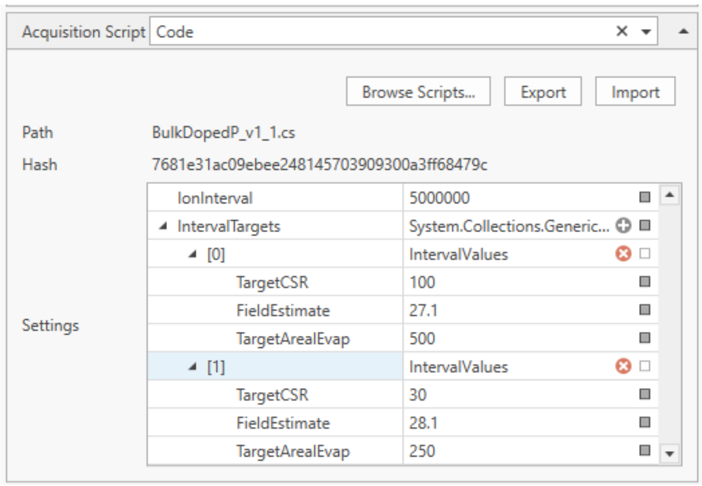

Figure 1: Code Properties in Script Browser module. These example properties were defined to enable constant charge state ratio (CSR) and target evaporation flux conditions that can be changed between experiments by modifying these property settings.

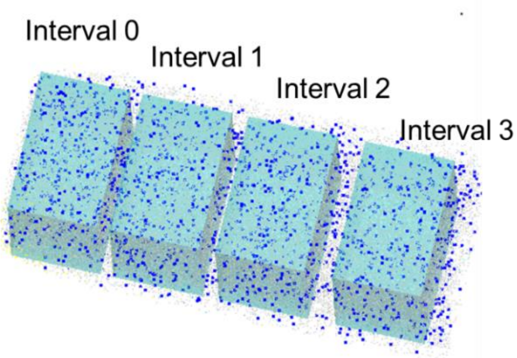

Figure 2: Reconstructed volumes acquired at different acquisition conditions (Interval 0-3) in boron (blue) doped Si (gray). Live composition information can be acquired that approximates compositions that would normally be done after acquisition and subsequent reconstruction, improving time-to-knowledge, and simplifying data reduction.

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