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Performance Advances in LEAP systems.

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Performance advances in Atom Probe Tomography (APT) in recent years have driven a dramatic expansion in the published literature. This expansion is evidence that easier, faster, and better three-dimensional nanoscale compositional information can enable a wide variety of research that was not reasonable to pursue even several years ago. Since the introduction of the commercially available laser-pulsed atom probe in 2006, publications reporting APT results have tripled and the variety of applications continues to expand with each year [1].

Recent years have seen continued improvements in the Local Electrode Atom Probe (LEAP®) such as data acquisition rate, signal-to-noise ratio, compositional accuracy, and yield through improved control of software and hardware [2]. These advances, including multi-hit performance, evaporation control algorithms, laser beam control, and flexibility of data acquisition, continue to improve data quality, yield, and time to knowledge.

Multi-hit detection continues to be a topic of interest in the APT community, especially with respect to certain materials systems that preferentially evaporate more than one ion per pulse [3]. Improved 'hit-finding' algorithms are being developed to maximize the amount of information that can be extracted from the raw data. For an antimony doped silicon analysis, the new algorithm finds 18% more double hit events and recovers 19% more partial hit events with no substantial loss of signal-to-noise ratio. This improvement as a function of separation on the detector is demonstrated in Figure 1.
Although maximum data collection rates have increased dramatically in the past decade, data acquisition times can still be significant (several hours or more) for complex specimens with large experimental regions of interest. In order to address this limitation, and improve specimen throughput in general, adaptive pulse frequency controls (available in both laser and voltage modes) have been developed to allow selection of a constant mass range during the entire experiment such that the pulse frequency is increased as ion flight times are reduced. This allows the acquisition speed to be increased by a factor of 3 or more in many cases.

Yield in APT is often the dominating limitation in extending the technique to new, non-traditional material systems. Advanced proportional, integral, differential (PID) control algorithms allow data collection at slower rates and with very fast response times to enable experiments to be conducted at optimal conditions to promote higher yield. Additionally, in laser mode, keeping the specimen optimally aligned with the laser spot is critical to both yield and data quality. Adaptive scan and focus algorithms with the smart PID have been shown to be especially useful in low data collection rate modes to accommodate lower signal-to-noise ratios and rapidly changing environmental conditions. Yield improvements have been demonstrated for implanted silicon/oxide/silicon samples from nominally zero to 75% as demonstrated in Figure 2.

References:
[1] D.J. Larson et al., "Local Electrode Atom Probe Tomography" (Springer, New York 2014) p. 318.
[2] M.K. Miller and R.G. Forbes, Materials Characterization **60** (2009), p. 461.
[3] F. Meisenkothen et.al., Microsc and Microanal, **20(S2),** (2014), these proceedings.

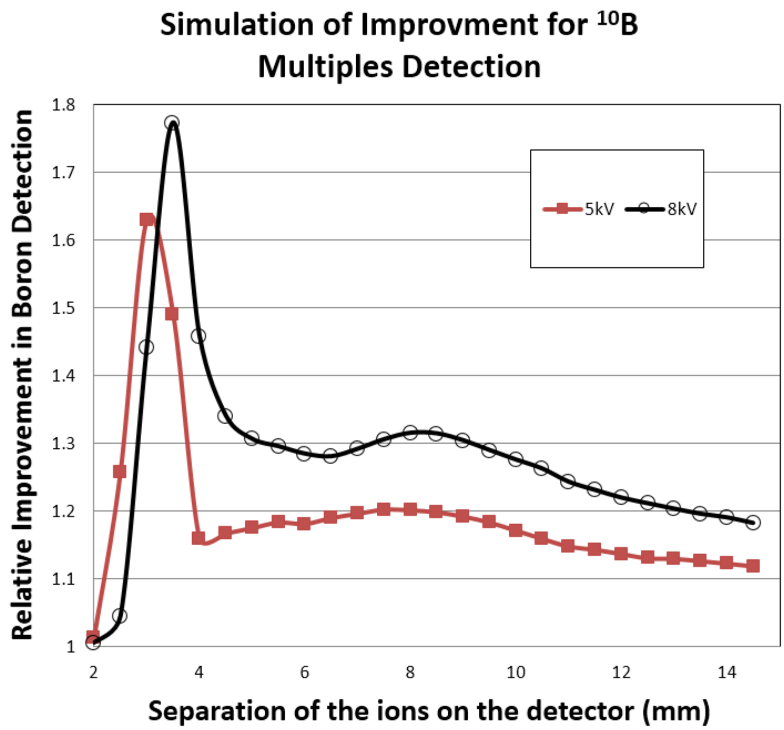

Figure 1. Multi-hit detection improvement (ratio) for mass separation of 0.5 Da as a function of distance on the detector in mm for a LEAP 4000X HR.

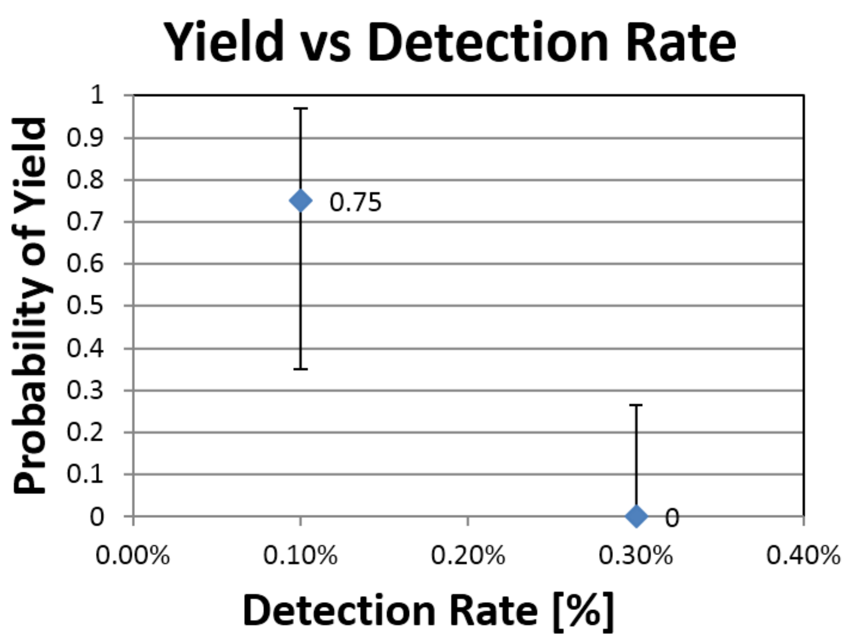

Figure 2. Yield difference between two run conditions (detection rate 0.1 and 0.3%) with Clopper-Pearson 95% confidence intervals displayed, demonstrating the clear statistical difference in yield.

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