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A High Multiple Hits Correction Factor for Atom Probe Tomography

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Microchannel plate transducer amplifiers, used to detect ions in atom probe tomography (APT), have a reduced detection efficiency for multiple ion impacts (i.e. multiple ions that impact the detector within a very small period in time and space). These effects are typically referred to as "multiple hits" [1,2], and may cause "ion pile up" [3,4]. For the technologically relevant case of boron in silicon [4–6], this can be a significant problem. Evidence of this issue is seen in secondary ion mass spectrometry (SIMS) versus APT depth profiles that have been corrected using known standard values, Fig. 1, for the NIST standard reference material SRM-2137. Although several factors may contribute to this discrepancy, it has been shown that multiple ion events at high boron concentration underlie this issue [4,7], as prior work shows boron concentrations lower than excepted, particularly for highly doped samples [4]. The shape of the boron APT profile in Fig. 1 matches well with the SIMS data, but the absolute APT concentration is lower than the SIMS data. This difference appears to scale with boron concentration, suggesting a direct dependence on multiple events. The current work uses a boron implanted sample described previously [8] to develop a simple correction factor) similar to the relative-sensitivity factor (RSF) typically used to calibrate SIMS data [9]).

In Fig. 2 we present SIMS (7f-auto, CAMECA) data and APT (LEAP 4000XR, CAMECA) data for the boron implant sample of ref. [8]. Noting that the boron discrepancy again appears to scale with concentration, we find that multiple hits vs. depth data shows a generally decreasing trend (Fig. 3) similar to the dependence of a boron RSF created by dividing the SIMS data by APT data (not shown). These two correction factors, as a function of boron concentration (Fig. 4), show a very similar dependence. Applying a fourth order polynomial fit to the SIMS correction to our original data (Fig. 1), Fig. 5, now shows good matching between APT and SIMS. This correction, although derived from the original SIMS vs APT comparison, may be independently applied to other boron analyses. Fig. 6 shows the correction factor as applied to the APT boron data shown in Fig. 2, again with an obvious improvement in accuracy.

This simple correction factor, based upon the assumption that boron deficiency is a function of boron multiple hits, is a simple scaling factor easily applied to any previously calculated boron concentration using APT. Future work will be directed toward understanding the physics of multi-hit processes, so that corrections can be derived from the APT data itself.

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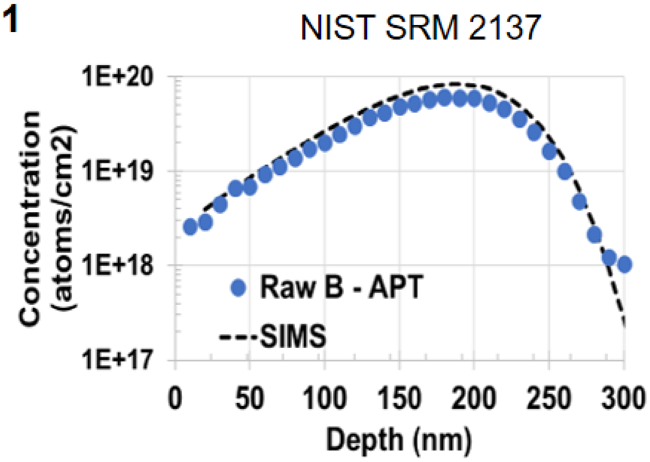

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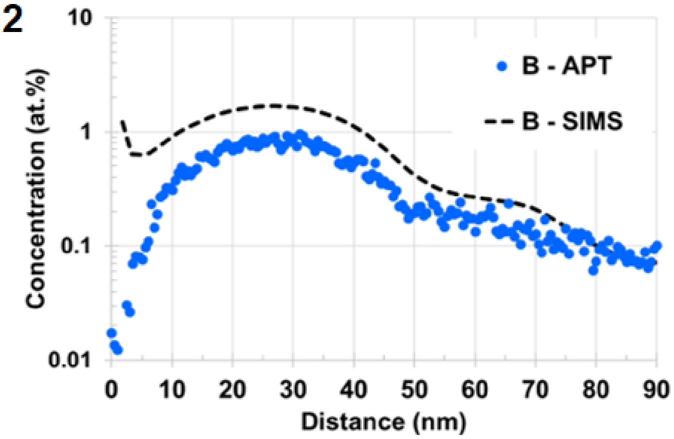

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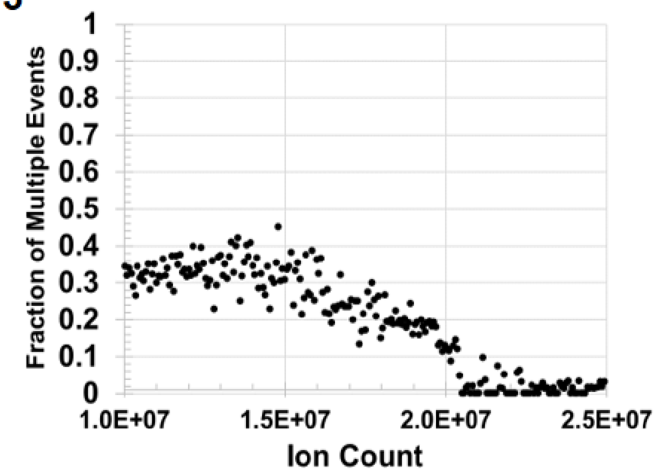

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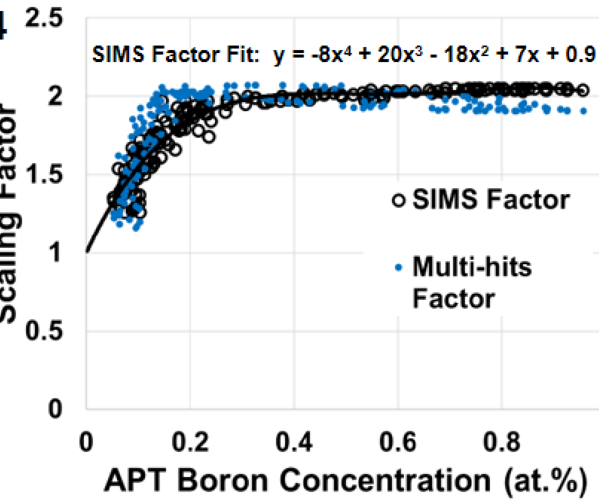

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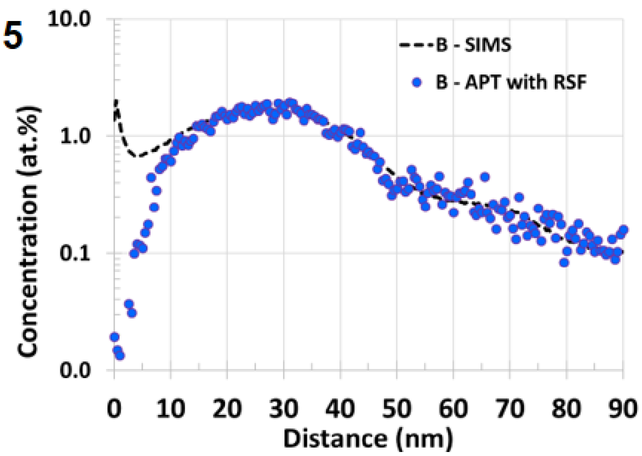

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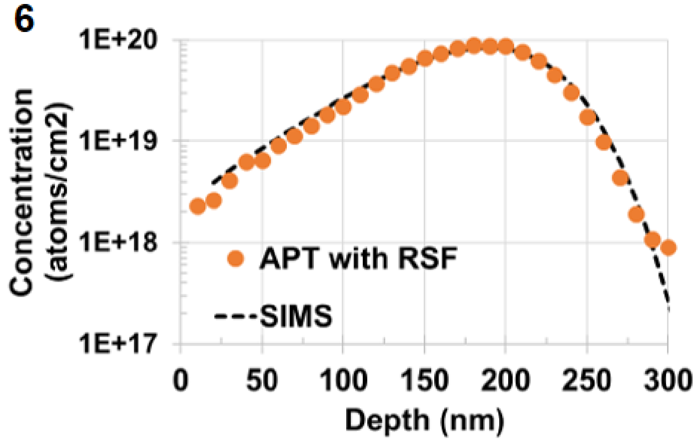

Fig. 1. SIMS vs. APT comparison for B profiles in NIST standard reference material 2137.
Fig. 2. SIMS vs. APT comparison for B profiles in high concentration boron sample of reference [8].
Fig. 3. Multiple hits (boron) vs. ion count for the data from Fig. 2.
Fig. 4. Correction factors based on SIMS and on multiple hits as a function of boron concentration.
Fig. 5. SIMS vs. APT data from Fig. 2 but with SIMS-based correction function shown in Fig. 4.
Fig. 6. SIMS vs. APT data from Fig. 1 but with SIMS-based correction function shown in Fig. 4.

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