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Simultaneous Voltage and Laser Pulsing in Atom Probe Tomography

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Concurrent voltage and laser pulsing in atom probe tomography (APT) has recently been proposed [1] and explored [2]. Advantages of such a pulsing scheme include reduction in background, potential improvement in composition determination for challenging materials (i.e, GaN) [3, 4], and the capability to filter background using kinetic energy discrimination [1]. This work presents preliminary experimental data on the application of concurrent voltage and laser pulsing to a variety of materials.

In atom probe tomography, a voltage or laser pulse (Fig. 1a) is applied onto a DC standing voltage and, in either case, the background noise is generally inversely related to the magnitude of the pulse (red arrow in Fig. 1b). Schematically shown in Fig. 2, the application of concurrent voltage and laser pulses theoretically decreases background by reducing the probability for field evaporation between pulsing events, when the specimen is being held at a constant DC voltage (blue point in Fig. 2b). In this mode, the specimen is held at the blue point during most of the analysis time. A voltage pulse increases the applied evaporation field and moves the specimen from the blue point to the green point in Fig 2b. While the voltage pulse is still applied, the specimen temperature is increased by using a laser pulse, which then moves the specimen from the green point to the right and crosses the field evaporation threshold, as shown in Fig. 2b. Background noise is inversely related to the red arrows shown in Figs. 1b and 2b and is thus reduced in the combined pulsing mode.

An example of background noise reduction produced by concurrent voltage plus laser pulsing is presented in the silicon mass specimen shown in Fig. 3a. Mass spectra containing two million ions are shown for each dataset, with a constant detection rate (normalized by specimen voltage) to ~2% and a constant charge state ratio (CSR) of ~30. The data shown in blue for the laser mode were measured to have a background level of 30 ppm/ns (see reference [5] for further details of the background units). The spectrum shown in orange for the volage-plus-laser mode had a background level of 1.6 ppm/ns, more than an order of magnitude reduction in background noise for this material. A similar analysis is shown in Fig. 3b for a common stainless steel. 1.7M ions were collected for each data set at a constant detection rate of 0.5% and a constant CSR of ~35. The data shown in blue (laser mode) were measured to have background level of 8.2 ppm/ns. Data shown in orange (volage plus laser mode) had a background level of 1.9 ppm/ns. For this material we observe a factor ~4 background noise reduction.

Fig. 4 shows a summary of the background reduction for a variety of materials, including aluminum (~8X), a stainless steel (~4X), silicon (~15X), and silicon dioxide (~2X). A sufficient voltage pulse-fraction is required in order to achieve a background noise reduction, so this reduction may vary by material. As previously observed [1], the best combination of laser amplitude, standing voltage, and voltage pulse amplitude will depend on material properties such as individual evaporation fields, electrical conductivity, thermal diffusivity, and experimental conditions such as base temperature.

[1] T. F. Kelly, Micro. Microanal. **17** (2011) 1.
[2] L. Zhao et al., Micro. Microanal. **23** (2017) 221.
[3] D. R. Diercks et al., J. Phys. Chem. C **110** (2015) 20623.
[4] R. A. Morris et al., J. Vac. Sci. Tech. B **36** (2018) 03F130.

[5] D. J. Larson et al., “Local Electrode Atom Probe: A User’s Guide” (Springer Media, 2013).

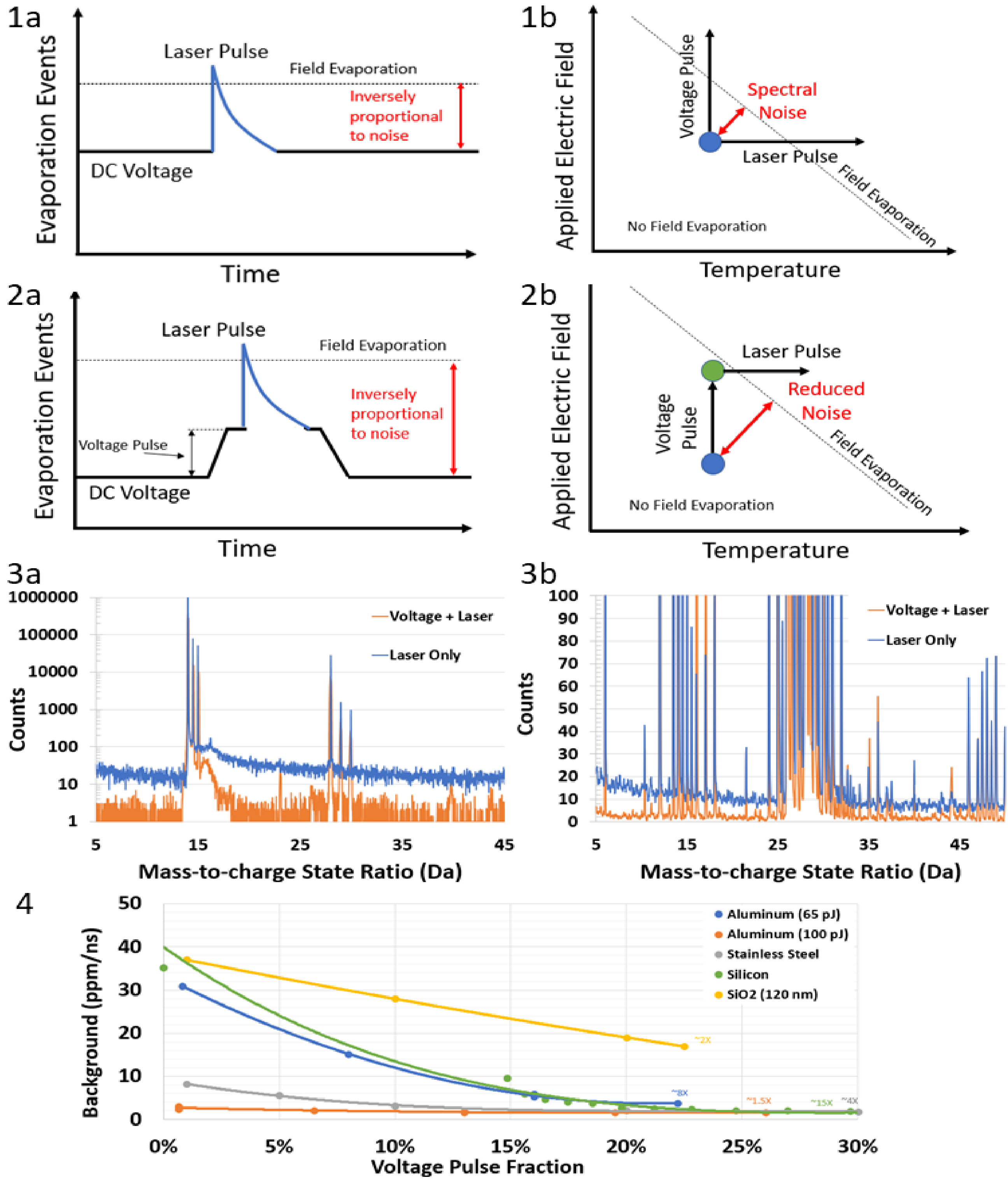

Figure. 1. Schematic representation of background noise generated in voltage or laser pulsing in APT.
Figure. 2. Theoretical background noise reduction using concurrent voltage plus laser pulsing in APT.

Figure. 3. Spectral comparisons for (a) silicon (log scale) and (b) stainless steel (linear scale) for laser-only pulsing versus voltage plus laser pulsing.

Figure. 4. Reduction in background noise with voltage pulse fraction for a variety of materials.

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