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Performance Improvements of Local Electrodes from In-situ Plasma Cleaning

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The local electrode (LE) component in a Local Electrode Atom Probe (LEAP®) provides significant performance advantages over a traditional atom probe and enables unique and efficient focused ion beam-based sample preparation that has enabled a host of new applications, but it is also a consumable and must be replaced or repaired when it becomes damaged [1-3]. Damage of a local electrode can be caused by contamination, physical contact, or by sample failure and electrical discharges during analysis[1]. The performance of an LE can be easily and quickly tested using a simple test set-up at typical operation distance to a conducting flat surface and applying voltage sufficient to cause electron field emission from the LE [4]. The voltage at which emission occurs provides a direct measure and predictor of the LE performance when used for samples of interest. Recently, an integrated in-situ plasma cleaner system has become available for LEAP systems. The system creates a low-power radio frequency driven air plasma. Intended use is for automated treatment of local electrodes to improve performance, but removal of contamination from samples inspected by electron microscopy is also possible [5].

Performance data and lifetime of local electrodes was monitored during several months of analysis for a variety of sample types known to contribute to premature failure of local electrodes. Local Electrodes suspected of being damaged were evaluated for electron emission with the test described above and subjected to treatment in the LEAP load-lock chamber. A plasma power of approximately 12 W at approximately 10^{-2} Torr was applied for a variety of durations. Generally, treatment times of greater than 2 h were required to see improvement in performance, while times greater than 12 h did not further improve the performance. Performance improvements were quite variable. The mean improvement was 3.6 kV with a maximum improvement of 10kV. The practical lifetime of an LE can be defined as the number of experiments where the LE can be returned to greater than 11 kV performance via plasma treatment. Plasma treated electrodes showed a ten-fold increase in lifetime.

One obvious mechanism for improved performance is the blunting of sharp points on the LE that act as field concentrators and low-voltage electron emission points. This mechanism is difficult to confirm because SEM reviews of electrodes before and after plasma cleaning do not show any clear physical changes. Another mechanism may be surface modification causing an increase in the surface work-function resulting in decreased electron emission. Tests to measure such a change have not been attempted and further work remains to understand the mechanisms and improve local electrode performance.

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[6] The authors would like to thank the Fraunhofer Center Nanoelectronic Technologies, Dresden Germany, for contributions of local electrode usage data and careful documentation.

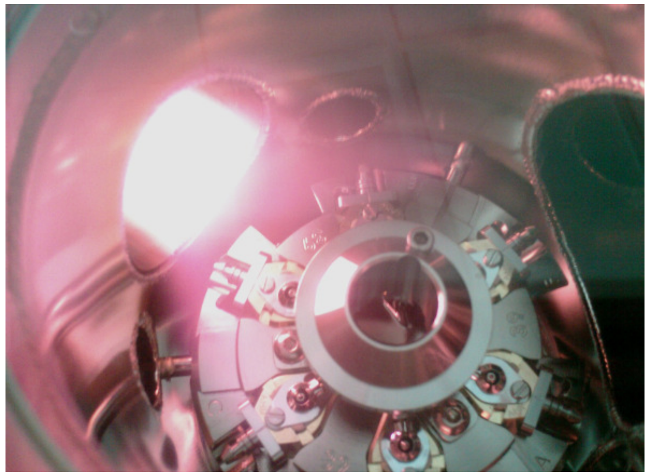

FIG. 1. Local electrodes inside a LEAP system load-lock chamber during plasma treatment.

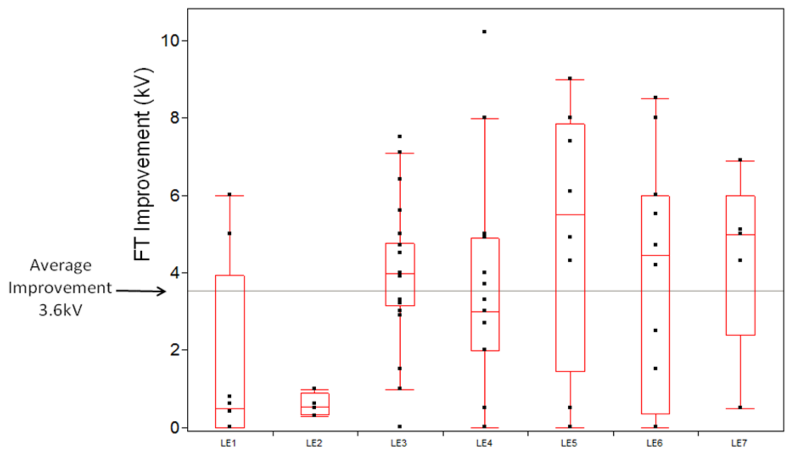

FIG. 2. Improvement in local electrode performance from selected local electrodes due to repeated treatment, usage and re-treatment as measured by the electron emission voltage in a standard test. Average improvement over all tests is 3.6kV with a large spread in improvement achieved.

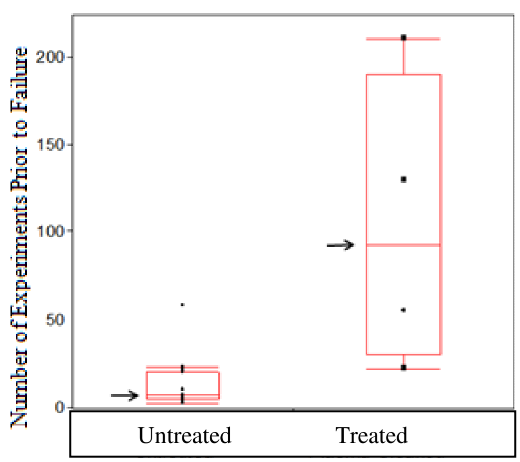

FIG. 3. Mean life-time improvement of electrodes that received repeated plasma treatments during periods of use on samples known to cause frequent local electrode damage.

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