Ion Microscopy, Machining, and Elemental Analysis with the Cesium Low Temperature Ion Source (LoTIS)

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We present the latest results from focused ion beam and elemental analysis instruments featuring the Cs^+ Low Temperature Ion Source (LoTIS). When compared with other ion sources LoTIS can deliver very small spot sizes, high sputter rates, high yields of secondary ions, and a wide range of beam currents from pA to many nA.

The talk's first half will review applications of LoTIS tested on a single beam FIB system called FIB:ZERO. Previously we reported spot sizes as small as (2.1 ± 0.2) nm (one standard deviation) are observed with a 10 keV, 1.0 pA beam [1]. Applications include high resolution imaging, long depth-of-focus imaging, successful circuit edit operations on 10 nm node integrated circuits, high-precision machining of gold, and demonstration of the high grain-visibility imaging in copper and steel offered by LoTIS.

The talk second half will review applications to date of our new Secondary Ion Mass Spectrometry (SIMS) system called SIMS:ZERO. It is currently the highest-resolutions SIMS instrument in the world and was built in collaboration with the Luxembourg Institute of Science and Technology (LIST). SIMS:ZERO is capable of high-resolution FIB operations while also providing a new material analysis information channel through the application of SIMS. For many target materials Cs^+ generates orders or magnitude more secondary ions than other ion ions. In addition, LoTIS is can provide over 100x more current into a given spot than alternative Cs^+ ion sources.

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[1] A. V. Steele, A. Schwarzkopf, J. J. McClelland, and B. Knuffman. *Nano Futures*. **1**, 015005 (2017).

Figure 1: FIB:ZERO focused ion beam system equipped with a cesium low temperature ion source. This system is installed at the University of Kaiserslautern.

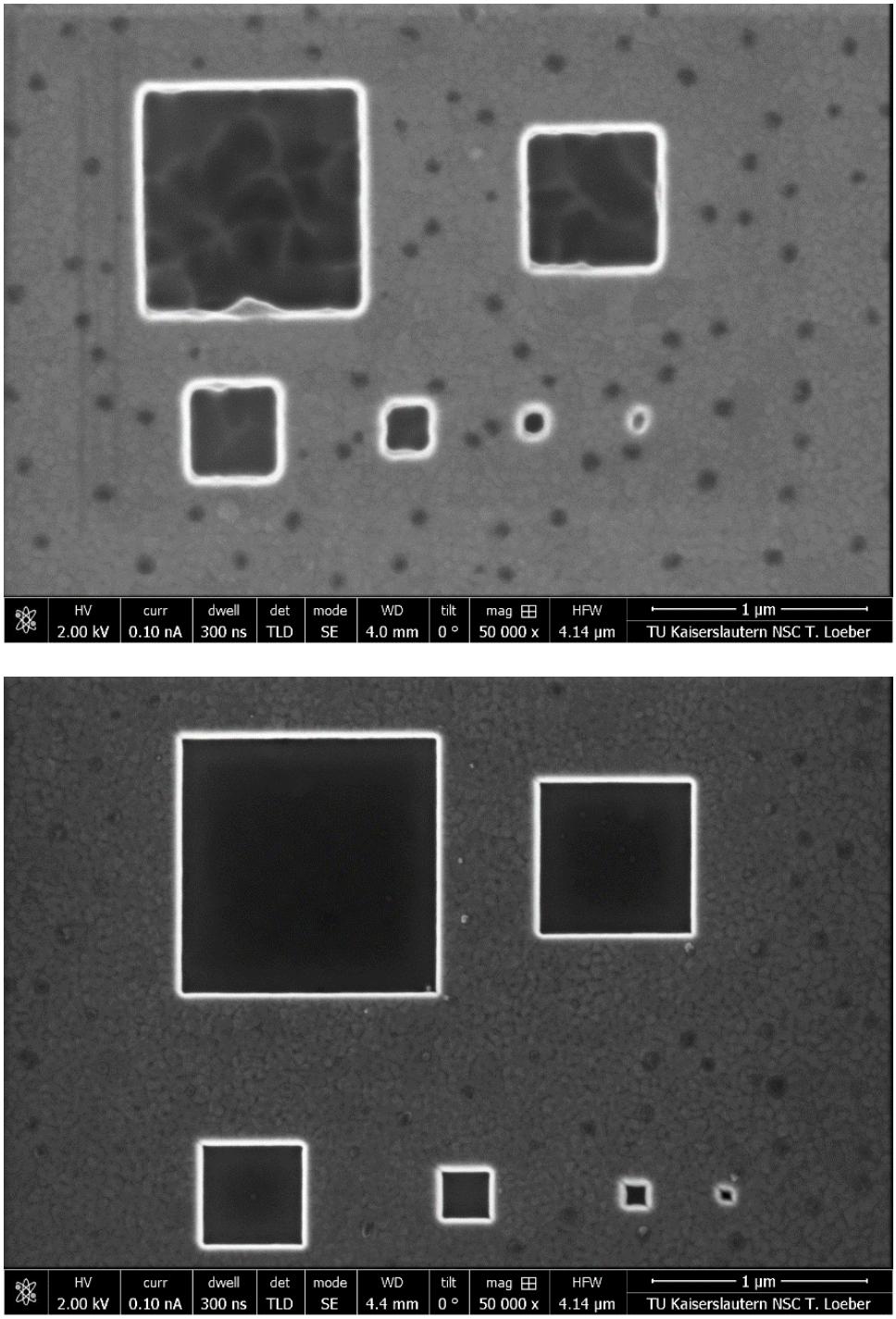

Figure 2: Ga LMIS vs Cs LoTIS Precision Milling of Gold: Boxes were milled in 110 nm thick Au on Si samples. Boxes are 1, 0.6, 0.4, 0.2, 0.1, and 0.05 µm. Imaging performed with an SEM. (Upper) Milling with a Thermo-Fisher Ga^+ LMIS. (Lower) Performed with a Cs+ LoTIS-FIB system. LoTIS demonstrates superior sharper corners and clean touchdown. Image produced in collaboration with Technical University of Kaiserslautern; thanks to Thomas Lober, Bert Lagel, and Sandra Wolff.

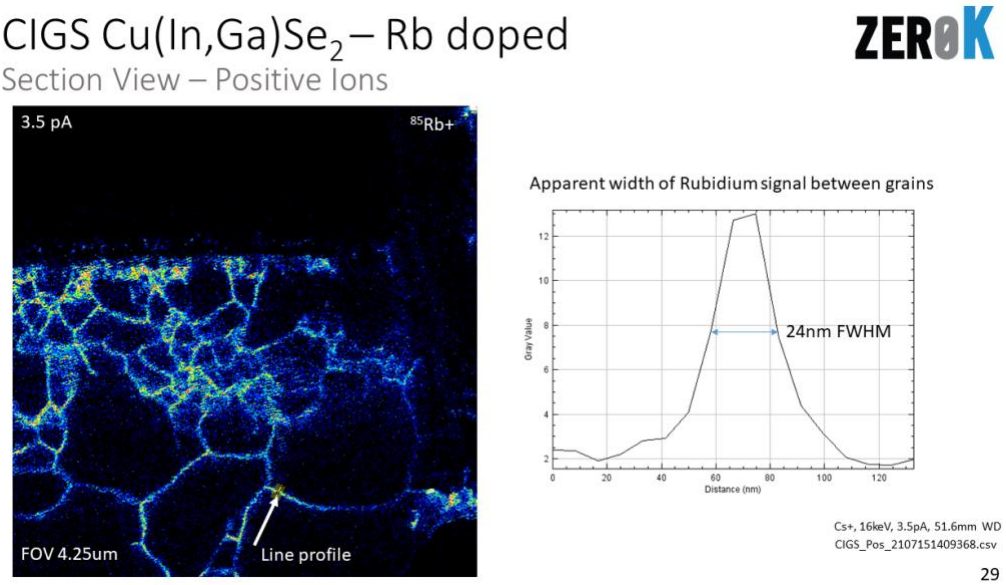

Figure 3: High-resolution elemental mapping of rubidium In a CIGS solar-cell with SIMS:ZERO. A CIGS solar cell material was sectioned at 52 degrees, then the locations of rubidium where mapped by sputtering at normal incidence and collecting the secondary ions with our double-focusing magnetic sector mass-spectrometer. Rubidium was found to agglomerate at the grain boundaries and can be located with few-nm precision.