Laser-cooled lithium as a bright source for focused ion beam microscopy

J. R. Gardner, W. M. McGehee, J. J. McClelland

Center for Nanoscale Science and Technology
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA
jamie.gardner@nist.gov

Progress is reported on a second-generation magneto-optical trap ion source (MOTIS) for nanoscale lithium ion microscopy. The first version of this system, reported in [1], has become an integral part of current research investigating lithium ion transport in battery electrode materials. In addition to secondary electron and ion backscatter microscopy, a lithium focused ion beam (FIB) can be used for precise ion implantation, allowing uniquely detailed studies of ion dynamics.

To construct a high-performance version of the original Li MOTIS, we focus on increasing current and reducing emittance in the beam [2]. Using a 2D magneto-optical trap (MOT) in the place of a Zeeman slower, the 3D MOT load rate is enhanced by more than an order of magnitude, to 7×10^9 atoms/s. Ionizing this entire flux yields a current over 1 nA. To reduce the size of the ionization region, we implement a novel two-photon ionization procedure [3]. Starting with ultraviolet laser light (323 nm), we resonantly excite atoms in the MOT to the $3P_{3/2}$ state, from which an IR laser (795 nm) ionizes them to the continuum with minimal effects on their kinetic energy. Focusing both ionization beams and overlapping them at the center of the MOT results in a source size approximately two orders of magnitude smaller than in the single-beam configuration. Preliminary data suggests that the ion current at this source size remains above 100 pA—significantly better than the original MOTIS.

Retrofitting this second-generation Li MOTIS onto a commercial FIBSEM with in-situ AFM capabilities will result in a powerful platform for studying nanoscale lithium ion transport in a wide variety of materials. In addition to battery electrodes, there is excellent potential for studying other ionic devices, including memristors, nonvolatile resistive memory, and neuromorphic hardware.

[1] B. Knuffman, A. V Steele, J. Orloff, and J. J. McClelland, New J. Phys. **13**, 103035 (2011).

[2] J. J. McClelland, A. V Steele, B. Knuffman, K. A. Twedt, A. Schwarzkopf, and T. M. Wilson, Appl. Phys. Rev. **3**, (2016).

[3] B. Knuffman, A. V Steele, and J. J. McClelland, J. Appl. Phys. **114**, 1 (2013).