Focused Ion Beam Implantation of Li^+ in WO_3 Using A Magneto-Optical Trap Ion Source

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With the advent of the magneto-optical trap ion source (MOTIS), new possibilities have arisen for controlled, nanoscale implantation of ions. At a low beam energy of 2 keV this source has demonstrated a focal spot of 27 nm and a current of approximately 1 pA using Li^+ ions,[1] a level of performance not seen with other ion sources. In addition to enabling new imaging and nanoscale milling modalities, this capability introduces opportunities for implanting optically and/or electrically active ions into materials with nanoscale precision. Such spatially-controlled implantation suggests new prospects for optical and electrical device fabrication, and also enables detailed studies of dopant diffusion in various materials.

As a demonstration of some of the capabilities of the MOTIS, we have conducted a series of experiments implanting Li^+ in WO_3. Li^+ ions are well known to produce an electrochromic effect in WO_3, changing its optical properties dramatically and altering its conductivity.[2] Using focused ion beam pattern generation software, we implanted Li^+ in 35 nm thick amorphous WO_3 films grown by reactive sputtering on a transparent substrate. Implantation doses were chosen to result in an ion density of approximately 1.6×10^{27} ions m^{-3}, or 0.5 ions per W atom. The expected range of 2 keV Li^+ ions in WO_3 is about 17 nm. The resulting implantations were examined optically by illuminating with light at a wavelength of 750 nm and observing in an optical microscope. Clear patterns were seen, corresponding to increased absorption where Li^+ was implanted (Fig. 1). For electrical measurements, 6 μm × 27 μm rectangles were implanted across gold/titanium electrodes patterned on the WO_3 films by lift-off (Fig. 2). I-V curves were measured, showing increased conductivity of the junctions as a result of the ion implantation.

These experiments suggest that focused implantation of Li^+ can be a useful tool for creating new materials with optical properties patterned on the sub-wavelength scale, e.g., metamaterials, as well as new electrical devices that take advantage of localized conductivity structuring.

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

[2] G.A. Niklasson and C.G. Granqvist, J. Mater. Chem. **17**, 127-156 (2007).

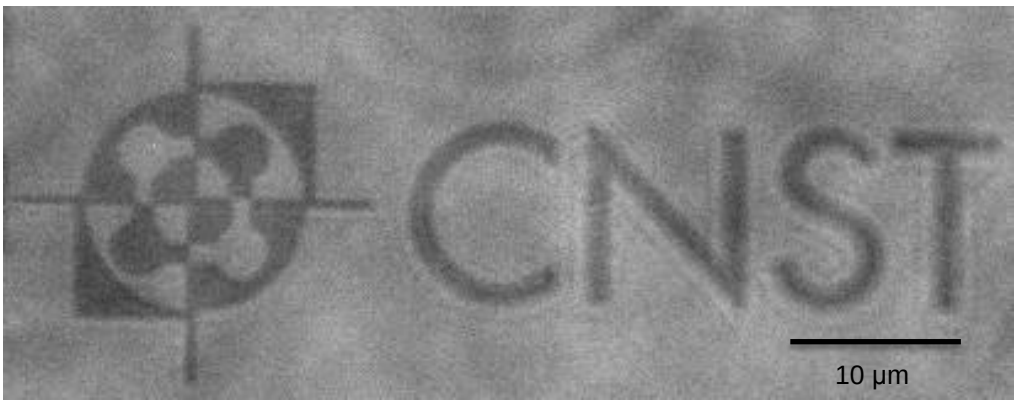

Figure 1: Optical Image of Li^+-Implanted WO_3 Film: 2 keV Li^+ ions implanted using a magneto-optical trap ion source create localized optical absorption. Image acquired with 750 nm light.

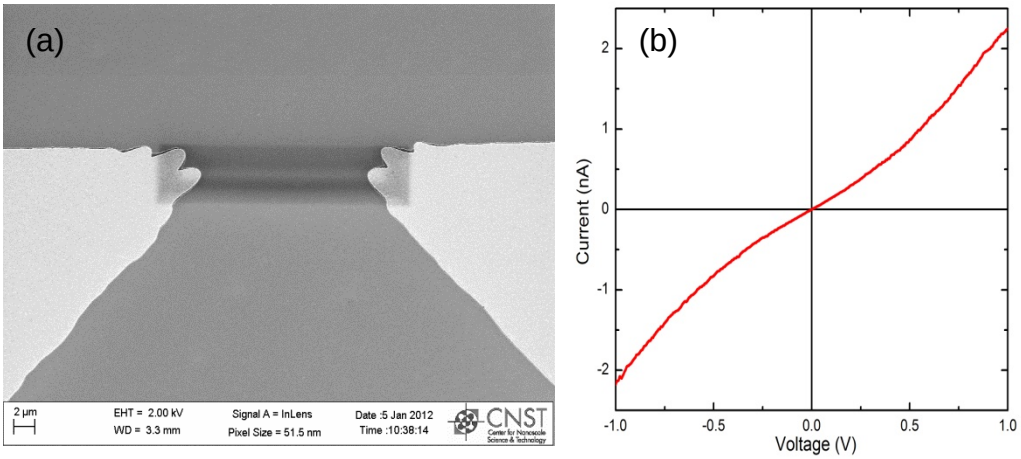

Figure 2: Conductivity in Li^+-implanted WO_3: (a) Scanning electron microscope image of junction implanted with 2 keV Li^+ ions. (b) I-V curve, showing clear conductivity.