Scanning Ion Microscopy with Low Energy Lithium Ions

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Using an ion source based on photoionization of laser cooled lithium atoms in a magneto-optical trap (MOTIS)[1], we have developed a scanning ion microscope with probe sizes of a few tens of nanometers at beam energies from 500 eV to 5 keV. These beam energies are much lower than the typical operating energies of the helium ion microscope or gallium focused ion beam systems. The lithium microscope has already demonstrated high quality imaging using both secondary electrons (Figure 1) and backscattered ions (Figure 2). We will discuss applications in imaging and surface analysis where a low energy beam provides an advantage.

Low energy is preferred in ion microscopy when imaging with backscattered ions, as the interaction volume is reduced and the backscatter yield is increased. Similar to imaging with backscattered electrons in an SEM, backscattered ion imaging provides elemental contrast and is relatively insensitive to charging effects. In our energy range, backscattered ions provide information about the top 5 to 20 nm of a surface, so our technique is ideal for imaging thin films with elemental contrast.

To demonstrate an application of this imaging mode, we image the removal of a residual resist layer during plasma etching in a nano-imprint lithography (NIL) process. Figure 2(a) shows a schematic of a NIL grating test pattern after the imprint and mold release. As usual with this technique, a thin layer of residual resist remains in the spaces between the grating lines. Controlling the removal of this residual layer by plasma etching (Fig. 2[b]) is of critical importance to NIL process control. By taking lithium ion images at increasing etch times, the residual layer removal is observed, non-destructively, as a stark change in contrast when the relatively high atomic number silicon substrate becomes visible to the ion beam, compared to the low atomic number organic resist [Fig. 2(c) and (d)]. The low penetration depth of the lithium ions prevents imaging of this substrate through the thin layer of residual resist.

Low energy ions can also be used to probe the composition and structure of surfaces with high sensitivity to the topmost layers by energy analysis of the backscattered ions. This sensitivity has been exploited in the well-established field of low energy ion scattering (LEIS). We discuss the possibility of combining high resolution ion microscopy with surface-sensitive composition analysis similar to LEIS.

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

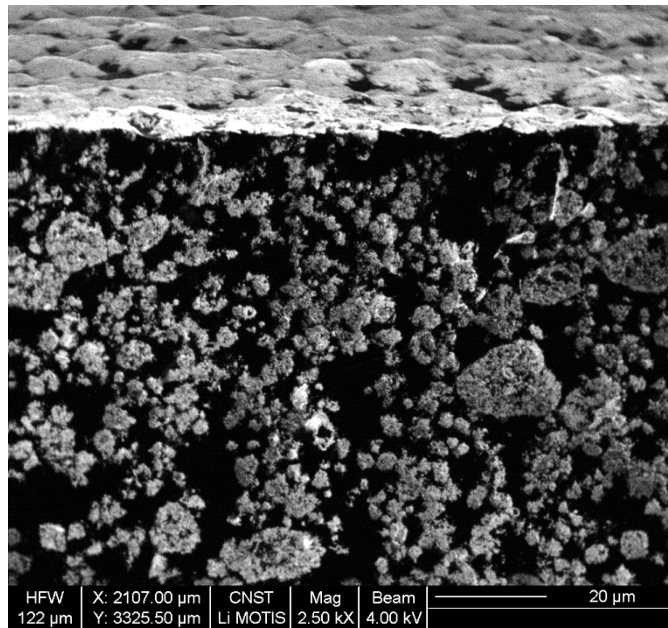

Figure 1: Secondary electron image of carbon nanotube bundles embedded in epoxy

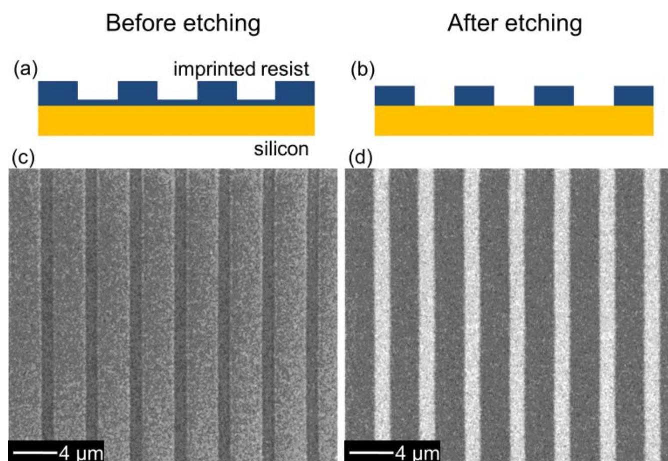

Figure 2: Backscattered ion images of a NIL grating: (a)-(b) Schematic of imprint and etching process. (c)-(d) Images before and after oxygen plasma etching. The images were taken using the same beam parameters (2 kV, 1 pA) and detector settings, and have been processed identically.