High-Resolution Compact FESEM with a Magnetic Immersion Objective Lens

J. Spallas[a,b] and L. Muray[a]
Keysight Technologies, 5301 Stevens Creek Blvd., Santa Clara, CA 91109

M. Mankos
Electron Optica, 1000 Elwell Court #110, Palo Alto, CA

[a] American Vacuum Society Member
[b] Electronic mail: james_spallas@keysight.com

Miniature all-electrostatic columns with lenses fabricated from silicon using advanced micromachining processes have many advantages for low-voltage applications.[1] Current production versions of miniature columns achieve < 10 nm resolution at 1 keV, and have demonstrated < 6nm resolution at higher beam energies.[2] This resolution is satisfactory for most applications with the additional benefits being a compact, low cost system without hysteresis effects. The best performance, however, requires a short working distance and as high beam energy as possible to minimize spherical and chromatic aberrations. Currently these are limited by the dimensions of the objective lens, and the practical aspects of SEM operation. Replacing the micromachined objective lens with a magnetic immersion lens would negate many of the advantages inherent to the all-electrostatic column, but provide a path to improved system performance and more versatile sample and detector placement.

We have designed, built and tested a prototype ultra-high resolution field emission scanning electron microscope (FESEM). The prototype is modified Keysight 8500 FESEM that is currently in production and includes a new magnetic immersion lens design. Targeted resolution is 1 nm at 5 keV and 3 nm at 1 keV. The magnetic lens is used in conjunction with the existing electrostatic lenses for optimum performance. The objective lens maximum total power is < 25 W eliminating the need for liquid cooling. A CAD drawing of the system with the magnetic lens installed shown in Fig. 1(a). The existing components are shaded. A more detailed drawing showing the immersion lens is shown in Fig. 1(b). The lens diameter is 150 mm and the height is 100 mm. The system includes two dual octupole deflectors and an in-lens detector. Figure 2 shows a SEM micrograph of gold islands from the prototype system. The beam energy was 2 keV and the field of view is < 0.7 um. The calculated resolution is 3 nm.

We will present details of the optical and mechanical design and system performance.

[1] T. Chang, D. Kern, and L. Muray, "Microminiaturization of Electron Optical Systems", J. Vac. Sci. Technol. B 8(6), 1698-1705 (1990).
[2] J. Spallas, C. Silver, L. Muray, T. Wells, and M. El Gomati, "A Manufacturable Miniature Electron Beam Column," Microelectron. Eng. 83, 984-989 (2006).

(a) (b)

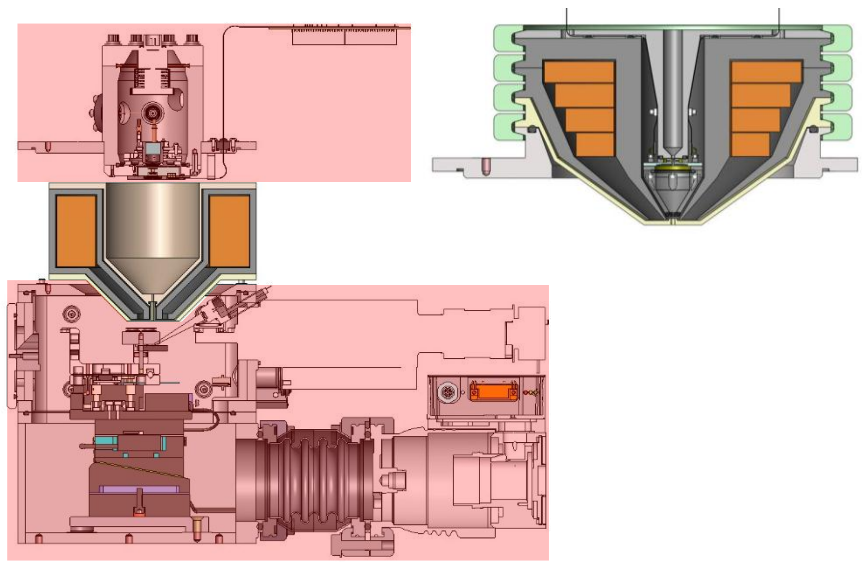

Figure 1: (a) The production FESEM instrument shown with the custom immersion lens in place. The existing components are shaded. (b) A detailed view of the immersion lens showing the unique stair-step coils and second dual octupole deflector and detector common package.

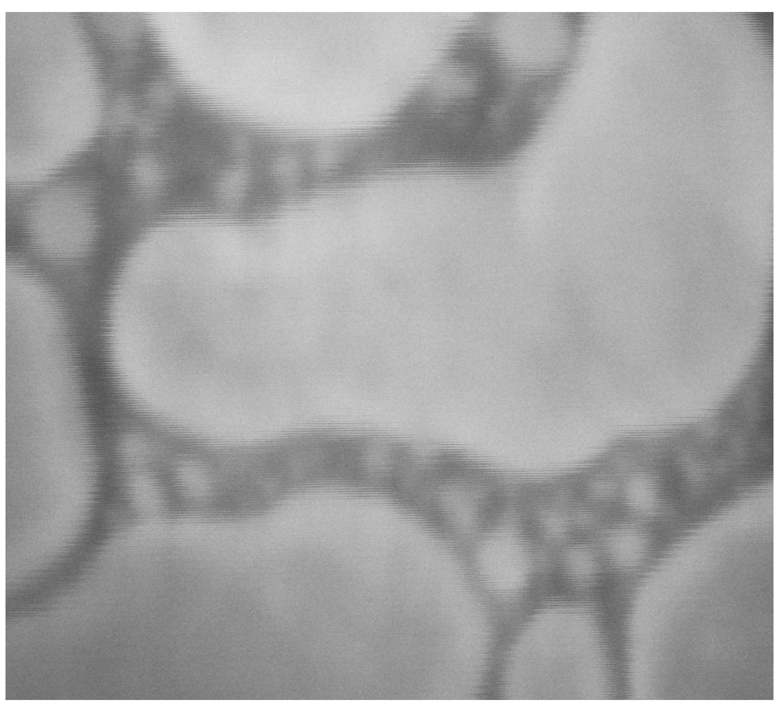

Figure 2: A high-resolution micrograph of gold islands on carbon. The field of view is < 0.7 um and the calculated resolution is 3 nm.