Ultra-Low-Voltage Imaging Using a Miniature Electron Beam Column

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Miniature columns that are fabricated from silicon using advanced micromachining processes are a relatively new class of electron beam column. The defining characteristics of these columns are thermal field emission (TFE) sources, low voltage operation (typically < 3 keV), simple design (two lenses, no crossover), microfabricated lenses, and all electrostatic components. Current production versions of miniature columns achieve < 10 nm resolution at 1 keV, and have demonstrated < 6 nm resolution at higher beam energies.[1] The advantage provided by miniature electron beam columns is high-resolution, low-voltage performance in a compact and scalable package. Low-voltage provides opportunities for a broad range of imaging applications in non-conductive, biological and radiation sensitive samples without the need for conductive coatings which can obscure critical features. Low-voltage also improves surface sensitivity and, due to higher secondary yield, results in higher signal-to-noise in the detector chain.[2]

The production column is optimized for imaging with beam energies in the 0.5 keV to 2.0 keV, with better performance at higher beam energies. The resolution is limited by competing requirements to minimize optical aberrations, relax physical or geometric constraints (e.g. working distance, electrode-electrode distance), and maintain manufacturable mechanical tolerances of the column components (e.g., alignment, diameter, and placement). While this performance is suitable for most applications, the ability to image in the 0.1 keV to 0.5 keV range with high-resolution would address the challenge of high-resolution imaging of ultra-thin, biological, or highly energy sensitive samples. In this energy range, the secondary electron energy is comparable to the backscattered electron energy and the penetration depth can be less than the escape depth which can be of the same order of magnitude as a typical metal or semiconductor native oxide.[3] This can lead to novel contrast modes.[3]

In this paper, we investigate imaging and contrast modes in the ultra-low energy regime using a commercial field emission electron microscope with a miniature electron beam column equipped with a retarding field lens that allows imaging with < 0.5 keV electrons.

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