A High-Current Miniature Column for a High Volume Manufacturing Multi-Column Wafer Inspection System

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Commercial e-beam inspection systems have been available for some time, but have been limited to a supporting role because the competing optical systems are much faster.[1, 2] The primary reasons for the relatively low throughput of commercial e-beam system are bandwidth limitations inherent in the architecture and Coulomb repulsion effects in the electron beam.[3] An obvious alternative to the single e-beam system is a multiple-column system. We have demonstrated that the miniature electron beam columns currently in production are capable of locating and resolving patterned defects at the 22nm design node. The technologies developed to manufacture these miniature columns have been leveraged to manufacture multicolumn arrays that demonstrated simultaneous multi-beam lithography at the 45nm node.[4] The feasibility of scaling the multicolumn arrays to address future mask writing nodes has been published.[5]

We have investigated the development of a high performance multi-column wafer inspection system capable of detecting small defects at speeds compatible with High Volume Manufacturing (HVM).[6] Miniature columns offer a significant advantage over conventional systems due to the short electron interaction length.
The miniature columns in production, however, are designed and optimized for high resolution imaging and would require modification to the lenses and architecture to produce the beam current and spot size needed to meet the acquisition speed requirements. Figure 1 shows the current at the sample as a function of extractor voltage. This column has a beam half angle of 6 mrad and 10 nm spot size. The inset shows the production column assembly. The length of the column in the assembly is 11 mm. Using the result shown in Fig. 1, we designed a column for high current operation and simulated the performance. Figure 2 is the spot diagram resulting from Monte Carlo simulations of that column at 25nA. The predicted spot size of 17 nm results in current density of over 8,000 A/cm^2 at 1keV, which is exceptionally high for any electron optical system.[7] The Coulomb repulsion effects are very small and are not the major impediment to higher beam current.

[1] D. Hendricks, *et al.*, Proc. SPIE 2439, 174 (1995)
[2] P. Sandland, *et al.,* J. Vac. Sci. Technol. B 9(6), 3005 (1991)
[3] A. D. Brodie, *et al.*, Microelectronics Engineering, Vol. 17, 399 (1992)
[4] C. S. Silver, *et al*., J. Vac Sci Technol. B 25(6), Nov/Dec 2007
[5] J. P. Spallas, *et al*., J. Vac Sci Technol. B 24(6), Nov/Dec 2006
[6] Yield Enhancement, Int. Technol. Roadmap for Semiconductors (2013)
[7] W. D. Meisburger, *et al*., J. Vac. Technol. B 10, 2804 (1992)

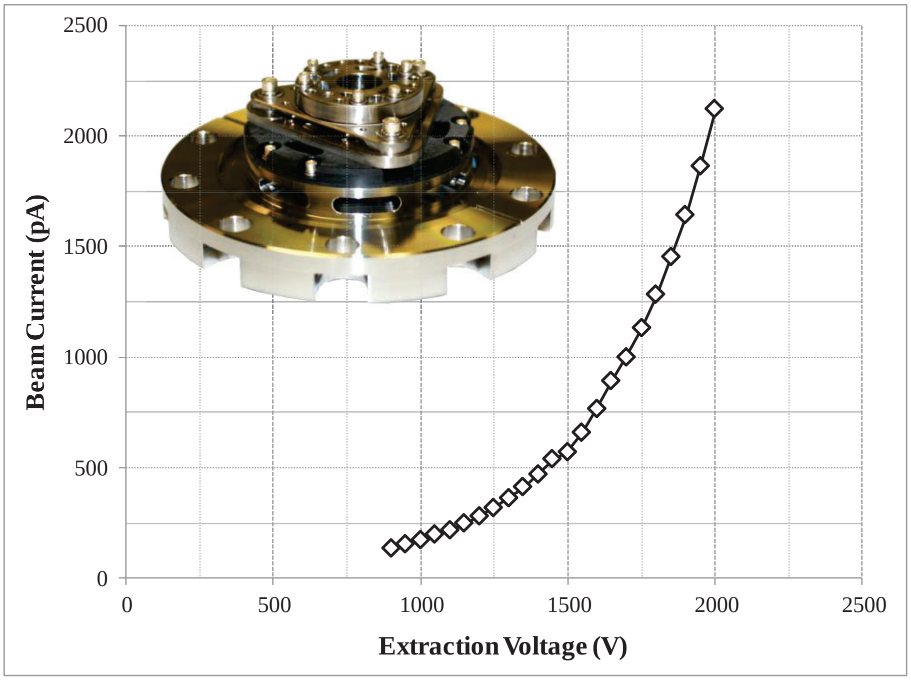

Figure 1. The current measured at the sample as a function of the extraction. The column tested is currently in production. The beam half angle is 6 mrad and the beam energy is 1keV. The spot size with a 2 kV extraction is 10 nm. The inset shows the production column assembly. The length of the column in this assembly is 11mm.

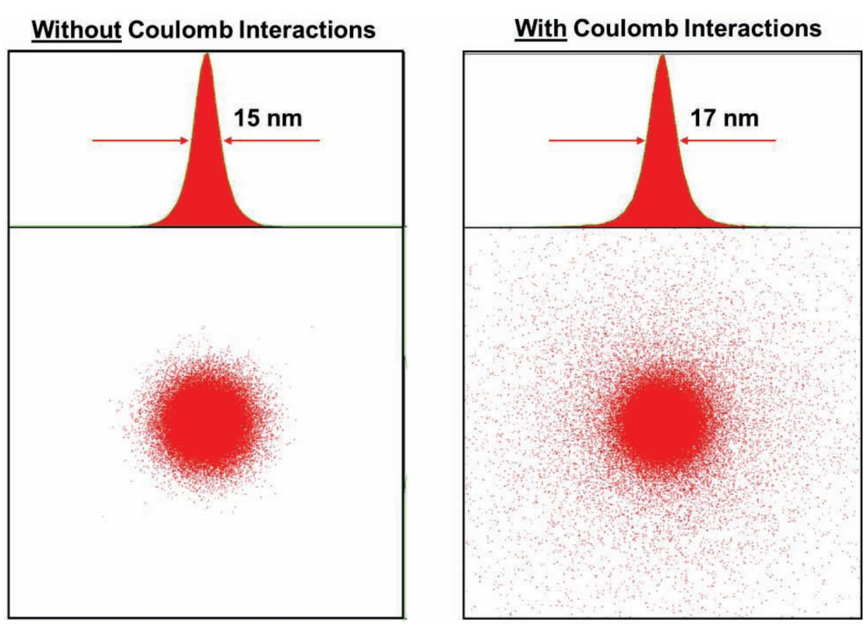

Figure 2: Simulated spot diagram of a miniature column under high current conditions. The effect of electron-electron interactions has been included for the histogram on the right, but ignored for the one on the left. The predicted spot size of 17 nm at 25 nA results in current density of over 8,000 A/cm^2 at 1keV.