A single-column, multi-beam SEM for high-resolution, high-throughput imaging

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INTRODUCTION

An increasing need for imaging of large areas of samples such as semiconductor wafers or even whole volumes of organic tissue at nm resolution calls for scanning electron microscopes (SEMs) that achieve both the required resolution and sufficient throughput. We report on the development of a multi-beam SEM that enables a considerable increase of total imaging speed compared to single beam SEMs, the scalability properties of its design, and its application to a variety of samples.

MULTI-ELECTRON BEAM TECHNOLOGY

Figure 1 (left) shows a schematic of the system layout [1]: An array of electron beams generated by a multi-beam source is focused by a lens arrangement onto the specimen. A regular pattern of 61 primary electron spots is formed on the sample, and the secondary electrons (SE) that emanate from each primary electron spot are imaged onto a multi-detector that records all beams simultaneously. A magnetic beam splitter separates primary and secondary electron beams. The bundle of electron beams is scanned over the sample (Figure 1, middle and right). One single scanning pass thus produces many images in parallel, yielding a complete image of the sample area under the primary beams that currently contains between several hundred million and one billion pixels.

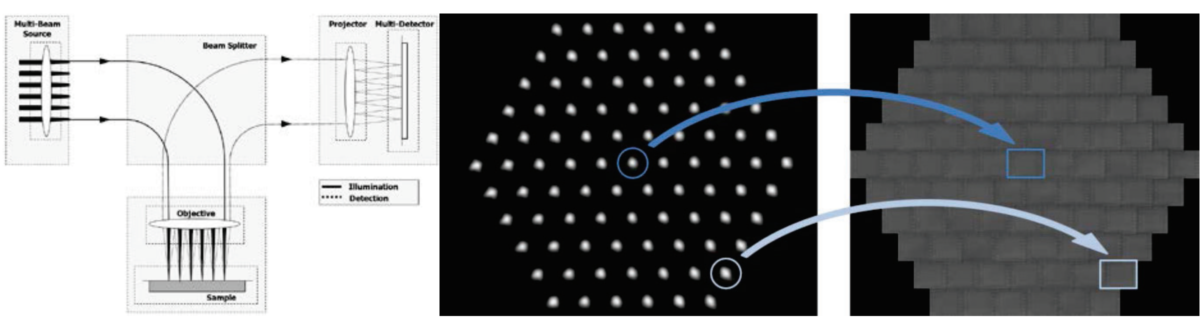

FIGURE 1. Left: Schematic drawing of the multi-beam SEM. Primary electrons (solid lines) are focused onto the sample and separated by a beam splitter from the secondary electrons (dotted lines) that are detected simultaneously in the multi-detector unit. Middle: Secondary electron spots at the plane of the multi-detector. Each spot corresponds to one emitted secondary beam acquired by one detector. All beams are scanned simultaneously. For example, the beams marked in dark and light blue simultaneously acquire the images marked in dark and light blue, respectively. Right: Stitched image of 91 single-beam images recorded in one shot with a total field of view of ~200 µm [2] (sample: etched silicon test chip)

APPLICATION EXAMPLES

Figs. 2 and 3 demonstrate that the multi-beam SEM can image a variety of samples. Fig. 2 shows a test wafer patterned with the SEMATECH AMAG6L reticle that contains test features for metrology experiments, such as line patterns with different nominal line widths and pattern recognition features [3]. Fig. 3 shows an ultrathin mouse brain section collected on capton tape [4].

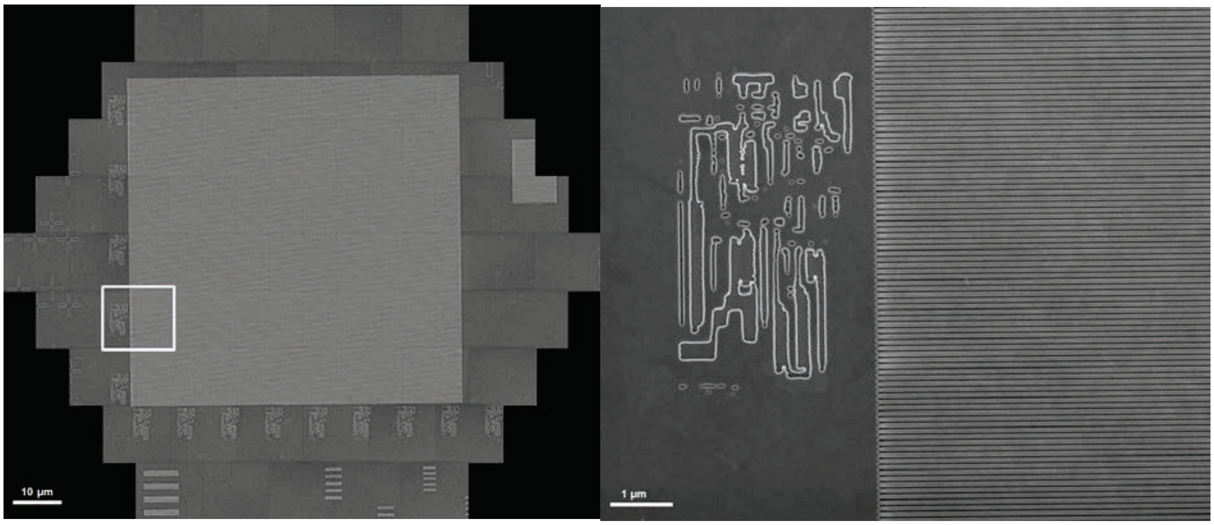

FIGURE 2. Semiconductor test sample with line patterns for metrology experiments. Right: 12 µm × 10 µm single-beam sub-image detail of the full multi-beam image (left). Sample by SEMATECH.

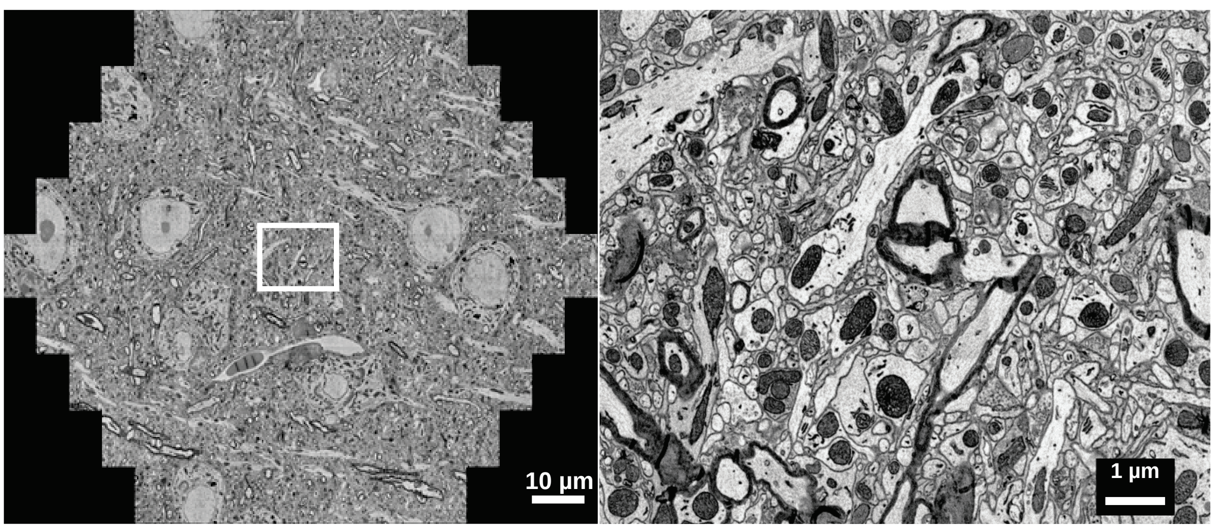

FIGURE 3. Ultrathin section of a Mouse brain. Right: 12 µm × 10 µm single-beam sub-image detail of the full multi-beam image (left). Sample by J. Lichtman, Harvard University.

DESIGN SCALABILITY

Enhancing the throughput of the multi-beam SEM is achievable by increasing the number of beams and detectors which has been demonstrated for the transition from 61 to 91 beams [2]. This demonstrates that the single-column, multiple beam concept ensures simple scalability in beam number and total current. It is thus adaptable for much higher beam numbers still [5].

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