High throughput defect detection with multiple parallel beams

H.M.P. van Himbergen[a], M.D. Nijkerk[a], T.C. Hosman[b],
P.W.H. de Jager[a] and P. Kruit[b]
[a]TNO Science and Industry, Stieltjesweg 1, PO Box 155, 2600 AD Delft, The Netherlands
[b]Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Defect detection on wafers and masks for the semiconductor industry is mostly done using optical inspection machines. Optical machines have limited resolution. Inspection machines based on electron microscopy, that are capable of much smaller resolution, are becoming increasingly important. However, electron microscopy based inspection machines are typically at least a factor of ten slower than optical tools. This is due to the amount of current that can be used for image formation, whilst maintaining adequate resolution. An increase in current is usually accompanied by an impermissible increase in probe size due to Coulomb interactions in the electron beam and the brightness of the electron source. We have devised a technique that makes it possible to use tens of thousands of separate electron beams for image formation, arranged in such a way that these beams are distributed over an area as small as 1 square inch, without crosstalk among the detectors. Each beam has its own microscopic electron optical column. The concept is shown in figure 1. The electron optical columns consist of micro-manufactured silicon aperture arrays on a 150 µm pitch. A stack of these aperture arrays functions as a projection lens array. By imaging an array of intermediate foci the projection lens forms a small probe at the wafer and simultaneously pulls up secondary electrons through the lens onto a scintillator. The scintillator has holes to allow the primary beams to pass. It is imaged with light optics situated outside of the volume occupied by the electron optics onto a photodetector array that can resolve secondary electron light spots from individual columns. This concept has several advantages with respect to multi e-beam techniques proposed by others [1]: the high number of single, independent electron beams on a small area; the absence of a common crossover, thus minimizing coulomb interactions; optical readout simplifying high speed, parallel data transfer.

We have designed a projection lens consisting of four, 100 µm diameter aperture arrays, with thickness and spacing 200 µm, that has spherical and chromatic aberration coefficients 3 mm and 0.3 mm respectively, when used in decelerating mode from 5 kV at the intermediate focus to 500 V at the wafer. A decelerating field at the wafer is present so that secondary electrons are pulled up through the lens. Electron-optical ray-tracing simulations show that the electrons are pulled back to the scintillator with an collection efficiency on the order of 75% (figure 2). The landing energy at the wafer is chosen for high secondary electron emission. Electric fields between the apertures do not need to be higher than 20 kV/mm for this lens design, which limits the likelihood of high voltage breakdowns. In figure 3 the optimum performance of the projection lens is shown for different source brightnesses.

At the moment experiments are in progress to quantify the efficiency of the detector chain and the feasibility of promising subsystem concepts is evaluated.

[1] Electron optical column for a multicolumn, multibeam direct-write electron beam lithography system, E. Yin et al., J. Vac. Sci. Technol B 18(6) p. 3126 (2000).

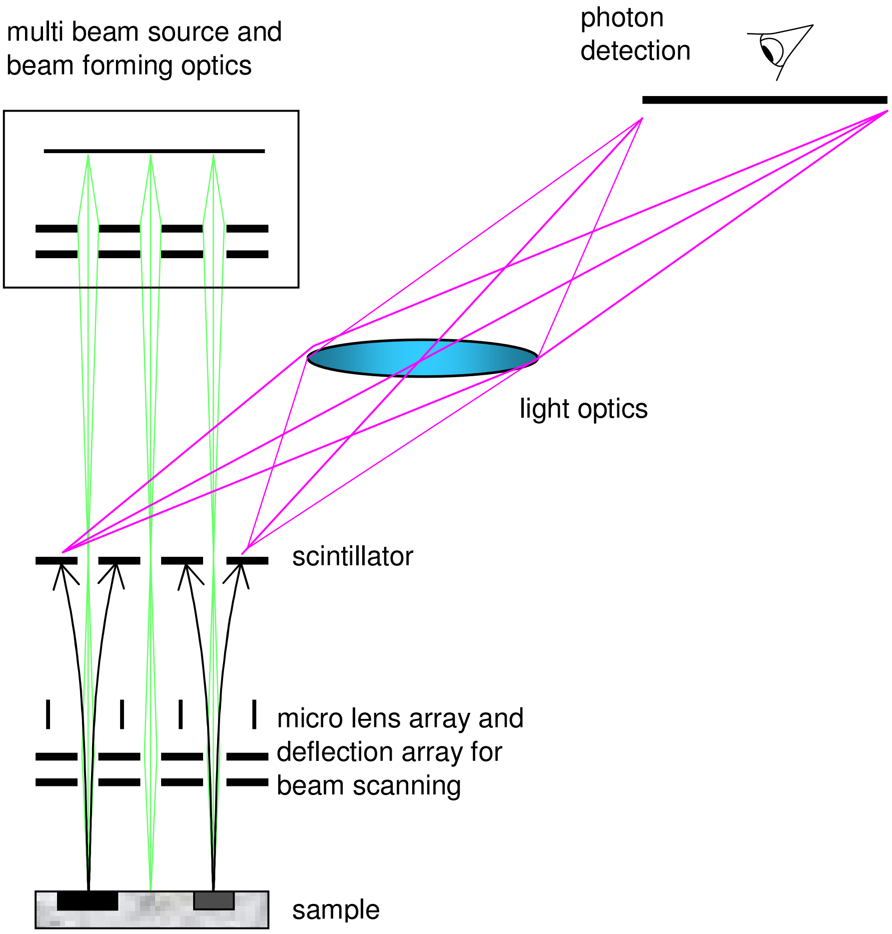

Figure 1 Schematic overview of the multi e-beam concept

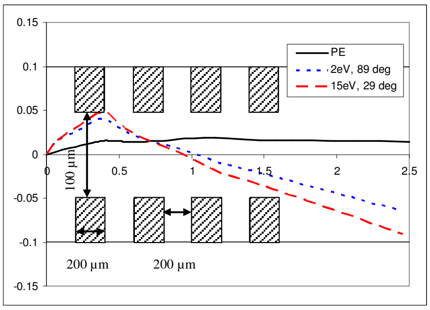

Figure 2. Projection lens design with ray traces for primary electrons (500 eV at the wafer) and secondary electrons (e.g. 2 eV and 15 eV at the wafer). Distances along the axis are in mm.

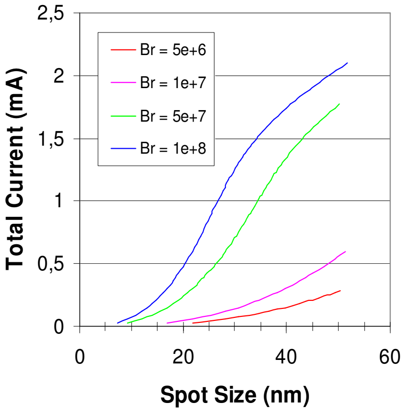

Figure 3 Total current vs. spot size characteristics for designed projection lens for three multi beam sources with a different reduced brightness (A/m^2 sr V)