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The Potential of Electron Beam Technology for Microfabrication

by

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An automated electron beam system has been developed for the fabrication of microcircuits. The system provides high resolution and high speed lithographic capability for pattern linewidths in the micron and submicron ranges. The primary objectives are directed at the direct exposure of advanced silicon devices and magnetic bubble devices, and at the fabrication of masks for x-ray, conformable mask and other high resolution parallel printing techniques. The application of the system to the fabrication of masks for use with conventional ultraviolet printing has also been explored.

The main features of the system consists of a special purpose electron optical column with a lanthanum hexaboride gun, a precision X-Y workstage and a comprehensive computer controlled automation system. Pattern generation is based on the vector scan technique in which the electron beam addresses only the pattern areas requiring exposure. This method of pattern writing provides several interesting and important possibilities for key areas of the system. One of these areas involves preparation of the pattern data. The vector scan technique offers the significant advantage of a high level of data compaction and as a result, the data throughput requirement during exposure is substantially reduced. With regard to flexibility, the vector scan technique allows the exposure rate to be conveniently controlled over the pattern area. This is particularly important when patterns require proximity effect corrections, and it can also contribute to improving the exposure speed. In the area of pattern writing efficiency, the vector scan approach is most efficient from a pattern area coverage point of view. Experience has shown that the overall average of pattern area coverage for typical multi-level microcircuits may fall in the region of 10 to 20 percent of total chip area as compared with the 30 to 50 percent value commonly assumed.

The system exposes a wafer or a mask in a step and repeat mode of operation which involves the following major steps: pattern write, stage movement and registration. The throughput of the system is therefore measured by the speed in which each of these steps are performed. Of special interest is the speed it takes to write a given pattern. The factors governing the writing are manifold. First, the electron optical system has to provide a sufficiently intense beam to allow the resist coating to be adequately exposed. Second, the deflection system has to be sufficiently responsive to fast deflection rates without at the

same time introducing beam position errors or excessive noise. Third, various contributions to system overhead have to be minimized. These include pattern data transmission time, logical operations of the digital control hardware, and the settling time of the deflection system for jumps between pattern elements. Experimental evaluations of these factors have been performed and their results will be presented.

Alignment of overlaid microcircuit patterns are obtained with a registration system that can be operated either in a manual mode or in a automatic mode. Improvements to signal to noise of the registration signals have been achieved using a digital signal enhancement technique under program control of the computer. Accurate registration of approximately $\pm 0.1\mu$ between two patterns levels have been achieved in experiments. One important application of the automatic registration system is for the stitching of small fields together to form one large chip by sharing registration marks between the adjacent fields.

The system has been operational over a length of time and various aspects of the system performance have been evaluated. This paper will attempt to bring into proper perspective the potential of the scanning type of electron beam system as a general lithography tool.