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Electron Image Projection

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Ever since the time when integrated circuits were first produced there has been a continuous decrease in the dimensions of the transistors and other circuit elements used. There is a strong incentive for this diminution in size as the cost is closely related to the number of elements that can be packed onto the silicon wafer and most circuit characteristics are improved by reduced dimensions. It is clear that this decrease in dimensions will continue for some time yet before any superable technological or any more fundamental barrier is reached.

Throughout the world great efforts are being devoted to exploring possible ways of achieving features in the region of 1μm in a practical manner. Optical projection with 1:1 magnification is being extended into the deep UV. Several demagnifying step-and-repeat systems working directly on the silicon are appearing on the market, and a number of teams are working on direct slice writing with electron beams. Replication using X-rays is being pursued in many laboratories.

Relatively little attention has been devoted to the method of 1:1 electron image projection originally demonstrated by O'Keefe Vine and Handy in 1969. This system uses a mask coated with a photocathode material so that, when illuminated by UV from behind, electrons are emitted from all clear areas of the mask. These electrons are focussed by axial magnetic and electric fields onto the silicon wafer held parallel to the mask.

Development of this basic system has included the addition of an automatic alignment system, relying on X-ray emission from special markers on the silicon. The main advantages offered by the electron image projector are:

(1) high speed - 20 second exposures are possible with only modest UV intensity and an insensitive resist,

(2) high resolution - certainly submicron,

(3) large depth of focus - at least 50μm for 0.1μ edge movement,

(4) fast automatic alignment to ± 0.1μm,

(5) the potential to correct for wafer expansion or contraction.

Against these desirable features there are a number of difficulties, the most significant of which is image distortion. This arises from the fact that the electric field cannot be perfectly uniform since part of the positive electrode is the silicon wafer itself. A slight discontinuity is inevitable at the edges and any wafer bowing that occurs will also result in some distortion of the image. It is this problem that has probably deterred many people from taking electron image projection seriously. However the problem should be seen in perspective. In the best examples integrated circuits are already being made with registration tolerances of less than 1μm everywhere on the wafer, and this registration tolerance includes many factors in addition to image distortion. There are still a number of improvements that can be introduced to ameliorate the problems including an electrostatic chuck and automatic magnification control. Another problem is electron scattering. The same proximity effect that is encountered with scanning electron beam systems occurs in the projector but it is supplemented by a longer range effect due to electrons that leave the surface and are returned to it by the electric field. It is impractical to use the projector in the extreme case of a mask with isolated small features on a clear background, but in the majority of circuits the effects are quite tolerable. Overall there appear to be no fundamental difficulties that would prevent the electron image projector from becoming an economic method for making very high packing density large scale integrated circuits.