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Invited

SOR X-Ray Lithography

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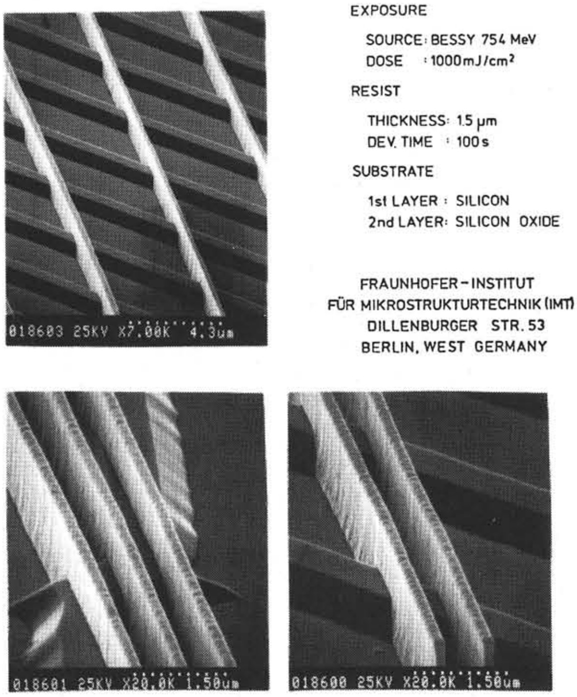
The complexities of future VLSI circuits such as a 64 Mbit DRAM will require a tremendous performance on the lithography process. The combination between the expected chip area (14 x 28 mm) and the required feature size down to 1/4 micron makes it rather doubtful that optical means can cope with those requirements. In order to achieve a reasonable throughput even in the sub half micron regime, very high pixel transfer rates are necessary, which will probably rule out serial writing processes. Besides the resolution and throughput, a large process latitude and defect tolerance become more and more important for those extremely high complexities.

Soft x-rays provide due to their low defraction limit a superior resolution down to approximately 0.1 microns. There is no reflection from the substrate surface and no scattering within the resist. These properties combined with the low absorption in the resist material lead to a very high process latitude concerning the exposure/development process and the control of the resist thickness as well. In general, the low absorption in low z-materials leaves most of the dust particels transparent to the soft x-rays. The parallel synchrotron orbit radiation (SOR) in particular avoids all the geometrical distortions (blurring/run out) connected with alternative x-ray sources (x-ray tube, plasma source). Therefore, only SOR lithography provides the ultimate resolution connected with a very high depth focus. Figure 1 reveals the resolution capability and the large depth of focus in synchrotron lithography. The SEM picture shows 0.2 μm wide resist bars running over 1 μm high SiO_2 bars on a silicon substrate without changing their dimensions. The high process latitude of the SOR lithography is demonstrated in Figure 2 showing rather unfavorable material combinations connected with a tremendous wafer topography. The 0.4 μm



EXPOSURE

SOURCE: BESSY 754 MeV
DOSE : 1000 mJ/cm²

RESIST

THICKNESS: 1.5 µm
DEV. TIME : 100 s

SUBSTRATE

1st LAYER : SILICON
2nd LAYER: SILICON OXIDE

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Fig. 1: 0.2 micron wide resist bars (HPR 204) running over SiO_2 Bessy 754 MeV bars (1 micron high) on a silicon substrate. Exposure:

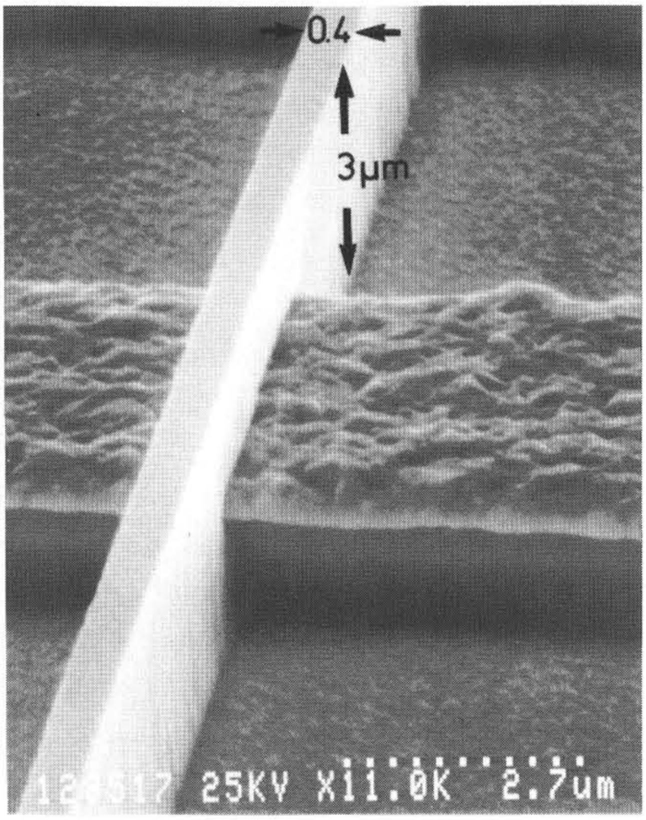

Fig. 2: One-layer resist lines (3 micron thick) running over electroplated gold bars on a nickel surface

wide resist bar (thickness 3 µm) is running over electroplated Au bars on a grainy Ni surface without any change in the critical dimension.

The specific problems in using soft x-rays arise mainly from mask technology and from the availability of a suitable x-ray source. The R + D activities entail additionally new resist materials and special designed x-ray steppers. The paper presents the actual state in the development of the topics addressed above with special emphasis on the mask technology and the development of a compact electron storage ring.

The system silicon (membrane) / gold (absorbers), which reflects the most advanced stage in mask technology, allows the patterning of 0.2 micron structures by means of electroplating with high structure fidelity. The properties of the system W/SiC which could provide a superior mask technology in future will be discussed shortly. In conjunction with the mask technology new methods for defect repair with focused ion beams are necessary as well.

First tests with the compact storage ring 'COSY' being built at BESSY in Berlin show that the expected final specifications will be achieved with a very high probability at the beginning of next year. The superconducting storage ring 'COSY' will provide the same features concerning radiation power and spectrum as the huge electron storage ring BESSY with dramatic reduced physical dimensions and costs as well.

The first prototype x-ray steppers operating vertically on at BESSY reveal overlay capabilities below 0.2 microns (3 σ).

New resist developments based upon Novolack resins show already results concerning resolution, sensitivity and process stability which make them applicable as a one-layer resist system in 1/4 micron lithography.

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