

AOARD REPORT

The Photomask Japan '94 Held 22 April 94 at Kawasaki Science
Park, Kanagawa, Japan

22 April 1994
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AOARD



The Photomask Japan '94 symposium, the first photomask meeting in the Far East, was held 22 Apr 94 in Kanagawa, Japan. In this one day meeting, 54 papers were presented covering such topics as mask fabrication, phase shift mask, x-ray and electron-beam masks, and metrology and equipment. In this report, selected papers on the development of sub 0.5 micrometer size masks are discussed.

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I. Introduction

For the first time, the photomask technology symposium called the Photomask Japan '94 was held in the Far East on 22 April 94 at Kawasaki Science Park, Kanagawa, Japan. This one-day symposium was sponsored by the Japan Chapter of SPIE and co-sponsored by BACUS and SPIE. Altogether there were 54 papers presented, consisting of 21 oral and 33 poster papers. Topics covered in four oral sessions were mask fabrication, phase shift mask, masks for x-ray and electron-beam, and metrology and equipment. The poster session, which followed 30 minutes after the end of oral sessions, lasted for 2 1/2 hours. In the poster session, there were additional topics not covered in oral sessions. They were "cleaning and pelliclization", and "design automation." Along with technical sessions, exhibition booths were set up just outside the conference hall, displaying the photomask-related products of 20 Japanese companies. It was a part of companies' show-and-tell marketing strategy to introduce their product lines to the public in the areas of photomask and x-ray mask technologies. It was very helpful to receive pamphlets which contained brief descriptions of all the products exhibited by all the participating companies at the time of registration.

II. Technical Papers

Reflecting the strong research activities in mask technology by Japanese and US companies, most of the papers presented in oral sessions were submitted by Japanese and US industrial researchers. The whole list of oral papers is shown in Attachment 1.

The first invited paper was given by Dr F. C. Lo of Intel Corporation, USA. He presented the ever increasing role of mask technology in deep sub-micro lithography as silicon technology has moved into the sub 0.5 micrometer regime. He described the role of mask technology in the sub 0.5 micron lithography regime by examining the technology roadmap, specification requirements, and the mask impact on lithographic performance. He pointed out that there are several possible lithography methods being considered in industry. They include DUV, phase-shifting mask, oblique illumination, optical proximity correction, and some combination of these methods. Each method is faced with major technical challenges that need to be solved in order to satisfy ever tightening mask requirements keeping up with the advancement of silicon technology. Nowadays, masks using sub 0.5 micron lithography is becoming more of an integral part of the front end silicon technology development. In the near future more and more importance is placed in the development of 0.25 and 0.35 micron mask fabrication technologies.

Following the talk by Dr Lo, there were three papers presented by Japanese companies in the area of mask fabrication. Hitachi Ltd reported the successful development of the phase-shift mask method for making 0.35 micron memory devices. Matsushita Electronics Corporation reported the use of the optical proximity correction mask method for fabricating a 1.0 micron square contact pad with 0.6 micron spacing. The third paper, which was presented by Fujitsu Ltd., introduced the new method called the "interactive dry etching" to reduce the influence of proximity effects for manufacturing 64Mbit-DRAM reticles (0.35 micron design rule). These methods showed that defect density and pattern accuracy can be improved significantly to the point where it is good enough for many of today's practical applications. In particular, it is interesting to note that by using this new method the yield for manufactured goods went up by 23%. Fujitsu is continuing their research efforts to achieve even a higher yield level in the future.

The current status of x-ray lithography was presented by Dr Tadahito Matsuda, NTT LSI laboratory. He pointed out that x-ray lithography is superior to optical lithography for spatial resolution and process latitude. In the future it is a good candidate to replace optical lithography once the reliable is improved and the effective x-ray mask fabrication technique is proven. At present, x-ray technology has advanced to the level where it is possible to fabricate deep submicron large scale integration devices. To show the current level of successful research efforts in x-ray mask technology, there were three papers presented in the x-ray mask session to show the promising outlook for the future. The first paper, presented by Yohsio Yamashita, SORTEC Corp, Japan, reported the stability of x-ray masks from mechanical and optical damages due to the strong synchrotron radiation exposure for SiO₂ coated SiN mask films. Stability tests were carried out for SiO₂ coated and non coated SiN films. The comparison of test results showed that SiO₂ coating helped to maintain the pattern displacement to within 30nm even after a synchrotron radiation dose of 100MJ/cm³. On the other hand, the non SiO₂ coated film resulted in a large pattern displacement value of 100nm at a relatively small synchrotron radiation dose of 6.5 MJ/cm³. The second paper, presented by H. Noguchi, Shin-Etsu Chemical Co., Ltd., reported the successful fabrication of bonding Si-substrates to Si-frames by using the bonded Silicon-on-Insulator technique to create Si frame-mounting x-ray masks. As compared to the conventional x-ray mask, which consisted of Si-substrates on Pyrex-frame, the Si frame-mounting x-ray mask was found to be not susceptible to the curving effect of the mask surface due to the difference in thermal expansion coefficients of substrate and frame materials. When the x-ray mask was tested for flatness before and after the back etching process, the difference was found to be 0.3 micrometer for a 25mm square membrane. The third paper, presented by Y. Saitoh, NTT LSI laboratories, reported the effect of organic defects on an x-ray mask by analyzing the amount of organic defects that can be printed as functions of size and shape of organic defects and radiation dose.

In the area of electron-beam lithography, H. Satoh et al., Hitachi Ltd., reported the fabrication of a novel silicon shaping mask using the electron beam cell projection lithography technique. Based on this technique it is possible to create patterns down to 0.2 micrometers. To achieve this much of fine accuracy, Satoh used the HL-800 system, which is the first commercially available system developed for ultra large scale integration device manufacturing.

In the metrology and equipment session, one of the interesting papers was by NTT LSI laboratories. They reported the commercial use of an accurate x-ray mask writer, which created a featured pattern size of 0.2 micrometers with an accuracy of 50 nanometers (3 sigma). When used with an optimizer, the accuracy was reduced to 33 nanometers (3 sigma). The writing speed was increased to about 10 times that of a conventional point-beam exposure system. The writer was developed with an intention of modifying NTT's existing EB60 variable-shaped electron-beam system in order to get improved accuracy and high-throughput. The improvement in the beam positioning resolution by a factor of four has been reported for the new writer.

Another paper which I thought interesting in x-ray mask technology was the development of a mask repair system by making use of the focused ion beam. Using the repair system, it became possible to repair proximity print x-ray masks with features as

small as 0.25 micrometers defects. The paper was presented by Diane Stewart of Micrion Corporation, Peabody, MA, USA.

IV. Concluding Remark

The Photomask Japan '94 symposium was very successful one with many participants coming from the US, Israel, Germany, Russia, Korea, Taiwan, and of course Japan. Reflecting the interest in the future of photomask and x-ray mask technologies, almost all of the participants came from industrial sector.

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**Attachment 1
(Oral Presentations)**

Session A: Mask Fabrication

- A-1. The Ever Increasing Role of Mask Technology in Deep Sub-micron Lithography,
F.C. Lo et al., Intel, USA
- A-2. Practical Method of Phase-Shifting Mask Fabrication,
M. Hoga et al., Hitachi, Japan
- A-3. Masks for 0.25 Micrometer Lithography,
W. Maurer and D. Samuels, Siemens and IBM, USA
- A-4. The New Method of VD Control for 64 Mbit-DAM Reticles,
M. Uruguchi et al., Fujitsu, Japan
- A-5. Fabrication and Pattern Transfer of Optical Proximity Correction (OPC) Mask,
E. Sugiura et al., Matsushita Electronics, Japan

Session B: Phase Shift Mask

- B-1. Attenuated Phase Shift Mask Blanks with Oxide or Oxi-Nitride of Cr or MoSi
Absorptive Shifter,
Y. Saito et al., ULCOAT, Japan
- B-2. Attenuated Phase Shifting Photomasks Fabricated From Cr-Based Embedded Shifter
Blanks,
F.D. Kalk et al., DuPont, USA
- B-3. Development of Novel W/Si Materials for the Single-Layers Attenuated
Phase-shifting Mask,
H. Mitsui et al., Hoya, Japan
- B-4. Large Area Optical Design Rule Checker for Logic PSM Application,
J. L. Nistler et al., Advanced Micro Devices, USA

Session C: Masks for X-Ray and E-Beam

- C-1. Current Status and Issues of X-Ray Masks,
T. Matsuda, NTT, Japan
- C-2. SR Irradiation Stability of X-Ray Masks,
Y. Yamashita et al., Sortec, Japan
- C-3. Development of Si Frame-Mounting X-Ray Masks,
H. Noguchi et al., Sin-Etsu Chemical, Japan
- C-4. Printability of Organic Defects on an X-Ray Mask,
Y. Saitoh et al., NTT, Japan
- C-5. Silicon Shaping Masks for Electron-Beam Cell Projection Lithography,
H. Satoh et al., Hitachi, Japan

Session D: Metrology and Equipment

- D-1. Reticle Quality Inspection for ≥ 0.35 Micrometer Lithography,
J. N. Wiley, KLA, USA
- D-2. Supporting 256Mb and 1Gb DRAM Mask Making Requirements with the Lepton
EBES4 E-Beam Reticle Generator
C.M. Rose et al., Lepton, USA
- D-3. EB-X1: An Accurate X-Ray Mask Write Using a Variable-Shaped Beam,
N. Shimizu et al., NTT, Japan
- D-4. Next Generation Mask Coordinate Measuring Technology,
T. Ototake and M. Iwasaki, Nikon, Japan
- D-5. Focused Ion Beams for X-Ray Mask Repair,
D. Stewart and T. Olson, Micrion, USA
- D-6. A New Phase Shift Mask Aerial Image Measurement and Evaluation Tool, the
Microlithography Simulation Microscope,
R.A. Budd et al., IBM, USA
- D-7. Improvement of Phase Measurements in Phase-Shift Masks with a Differential
Heterodyne Interferometer,
T. Ode, Lasertec, Japan