PROJECT PROFILE

T404: Extreme UV lithography masks (EXTUMASK)

LITHOGRAPHY

Partners:

Alcatel Vacuum Technology
CEA-LETI
GREMI
IMS-CHIPS
Incam-Solutions
Infineon Technologies
Leica Microsystems
Philips Semiconductors
Sagem
Schott Glas
Schott Lithotec
SESO
Sopra
Uni Marseille
Xenocs

Project leader:

Jenspeter Rau,
Infineon Technologies

Key project dates:

Start: November 2001
End: October 2004

Countries involved:

France
Germany
The Netherlands

Extreme ultraviolet (EUV) lithography is now considered to be the route most likely to be followed for the reproduction of deep-submicron integrated circuit patterns when optical lithography reaches its practical limit at a wavelength of 157 nm. A changeover to new-generation lithography will be required when circuit feature sizes shrink to 50 nm and smaller before the end of the present decade. As one of several related MEDEA+ projects addressing various aspects of this need, EXTUMASK is developing a complete process to make the masks required for EUV exposure at 13.4 nm. This involves a totally different technological approach, based on beam reflection rather than today's transmission optics.

Sustained growth in the electronics industry and associated application sectors derives from the fact that, since the 1970s, decreases in device feature size have provided progressively improving functionality at ever-lower cost. Critical dimensions reduced at about 70% every three years for most of the industry's history – with acceleration to a two-year cycle in recent years. Cost per function has decreased at an average of about 25 to 30% per year per function. Optical lithography, long established as the key enabling technology behind this remarkable progress, should be applicable to the 100 nm and 70 nm nodes, by employing tools designed respectively to operate with illumination at 193 nm and 157 nm wavelengths. However, reduction of feature sizes to 50 nm and below requires new-generation lithography systems.

Consensus essential

While lithography development is complex and expensive, the leverage it provides is key to the continued growth of the semiconductor industry. The cost of developing a total solution through to a commercially available tool and infrastructure could approach € 1 billion. Consequently, a narrowing of the options is essential to ensure a timely continuation of cost-effective manufacture. Achieving a general consensus on an affordable 'post-optical' technology is vital.

With the globalisation of the IC industry in the 1990s, leading chipmakers and their business partners have established manufacturing or assembly facilities around the world. And they have set up alliances and joint ventures – as have suppliers of equipment, materials, and software. An important forum for co-operation is International SEMATECH, members of which collaborate in pre-competitive research at shared cost and risk.

One of the activities of International SEMATECH is to organise global discussions on the technology roadmap. There is a yearly workshop on next generation lithography, which indicates that extreme ultraviolet (EUV) lithography is the main candidate estimated to have the capability of pattern transfer down to 15 nm. R&D on EUV in Europe is now being pursued in MEDEA+. Ion projection lithography is also supported as an alternative, but has a much lower level of market acceptance.

Untried technologies

EUV lithography is expected to move quickly from R&D into commercial development. Alongside the quest for a new exposure tool, illumination sources and the area resist process, mask making based on untried principles and materials constitutes the fourth critical facet of its implementation.

Laboratories in Europe and the USA already have programmes to develop mask-making technology for EUV, but no industrial solutions have so far emerged. The development of materials, equipment and process modules with the potential for industrialisation is at an early stage. Even less clear is the situation regarding inspection, metrology and mask repair.

The key issue of how the different elements can be combined into a viable overall process meeting mask specifications in terms of reflectivity, critical dimension performance, placement accuracy and defectivity remains open. In most cases, even the tools and procedures to assess these criteria are not yet available. One of the most crucial issues is whether and how mask performance can be maintained in an industrial environment under exposure to comparatively high-energy photons.

Standard optical lithography masks function now with light transmitted through a quartz plate covered by absorbing structures. Because of the ultra-short wavelength used in EUV, future optics from the source to the exposure system will comprise reflective elements alone. Accordingly, masks will be based on a highly reflecting multilayer mirror placed between a substrate and the masking layer.

The tight specifications of the target technology will require a large number of new techniques, because:

- The thermal expansion of the substrate material must be reduced to near-zero, and flatness improved by a factor of 10 to 100;
- A move to reflective masks requires an additional defect-free multilayer mirror between substrate and masking layer;
- A usable resolution of 100 to 150 nm is necessary for mask patterning and characterisation purposes; and
- Defect size limits of 50 nm and below must be achieved and maintained without pellicle protection.

To achieve these results, the whole multi-sandwich structure has to be specified, materials and coating techniques developed, and the process and its final results monitored with appropriate metrology tools. Simulation tools must be developed and tested to allow modelling of the complex layer sequence. Suitable handling and transportation procedures and tools are also required.

Strong team

To meet its targets, EXTUMASK is fielding a strong consortium of European companies and institutes. Co-ordinated by Infineon, this combines the competence and experience of leading semiconductor manufacturers, materials specialists and equipment makers from three countries. It draws on knowledge from previous activities such as the European Commission ESPRIT programme EUCLIDES project and the French national PREUVE project, and maintains links to the other MEDEA+ EUV cluster projects.

Chipmakers Infineon and Philips are defining the specifications and will evaluate the final products. Material specialists Schott Glas and Xenocs will provide substrate and multilayer materials. SESO, Schott Lithothec and Sagem, which specialise in high-end optical components and preparation, will carry out mask blank processing. Infineon will work on process development and simulation, together with research institutes IMS Stuttgart and LETI. Sopra and Leica will provide tooling for mask metrology while Incam and Alcatel will focus on mask handling.

Although not a formal member of the consortium, lithography systems manufacturer ASML – as the co-ordinator of the MEDEA+ EXTATIC project (development of an EUV exposure system) – will support EXTUMASK with requirement specifications and general guidance to keep the two initiatives closely aligned. This is expected to ensure delivery of the first mask samples midway through the project, and of qualified masks by its end.

The overall goal is to prove the manufacturability of EUV masks by identifying a solution in each of the problems areas or narrowing the choice of options for future research. Additionally, the consortium will provide sample masks to its partners as well as to related projects, in particular to EXTATIC, making a major contribution to the R&D infrastructure in Europe.

In summary, EXTUMASK will combine the necessary forces and develop means to provide an infrastructure for experimental EUV masks in Europe by 2004, which will be necessary for the industrial development expected to start at around that time.

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