PROJECT PROFILE

MEDEA+

T401: Frontline lithography using optical refraction (FLUOR)

Over the past 30 years, optical lithography has been the semiconductor industry's accepted method for printing circuit patterns on silicon wafers. With continuing reduction in device feature size, this method is approaching the physical limits of performance. New competitors are emerging, but chipmakers are reluctant to abandon proven technology. By harnessing shorter light wavelengths in the deep ultraviolet region, and adopting advanced resolution-enhancing techniques, equipment manufacturers are continuing to prolong its viability. MEDEA+ project FLUOR aims to deliver a system operating at a wavelength of 157 nm, which could extend use of the process to the 70 nm feature level and below.

LITHOGRAPHY

Partners:

ASML
Carl Zeiss
CNRS
Honeywell
IMEC
Infineon Technologies
JenOptik
Korth
Lambda Physik
M+W Zander
Philips Semiconductors
Schott Lithotec
STMicroelectronics
Tuilaser

Project leader:

Judon Stoeldraijer,
ASML

Key project dates:

Start:January 2001
End: October 2004

Countries involved:

Belgium
France
Germany
Italy
The Netherlands

Sustained growth in the semiconductor industry depends on the fact that decreases in device size continue to provide improved functionality at a reduced cost. Optical lithography has long been a mainstream technology underpinning this trend, whereby linear feature dimensions have shrunk by around 30% every three years for most of the sector's history. In recent years, this cycle has even reduced to two years, while cost per function has simultaneously decreased at an annual average rate of 25 to 30%.

The progressive downsizing has been achieved by:

- Shortening the wavelength of the light sources used for mask exposure;
- Increasing the numerical aperture of optical systems;
- Using half-tone phase-shift masks and other resolution-enhancement technologies such as annular illumination; and
- Developing high-performance resists.

Mask-making capability and cost escalation have become major limiting factors to further progress in lithography, while compression of the roadmap timescale adds further pressure. The technology has already been pushed down to feature sizes required for the 130 and 100 nm device generations

Developing complete solution

The MEDEA+ T401 FLUOR project is working towards a complete solution for optical lithography using a wavelength of 157 nm, which will enable the industry to produce 70 nm features – and may permit extension down to 50 nm geometries. The project embraces all the basic aspects of the lithography process: development of a photolithographic tool with laser source and optics, reticles, the exposure and resist treatment processes, including the special materials required.

Led by equipment provider ASML, the FLUOR consortium includes a number of European partners that are among world leaders in their respective fields. The three participating chip makers – Infineon, Philips and STMicroelectronics – are all in the top ten. IMEC is a prominent institute for the development of integrated circuit (IC) processes, while Carl Zeiss and ASML itself are seriously challenging Japanese companies for leadership in the lithography equipment market.

With further support from specialist materials and equipment suppliers, this group is building on the results of the previous

MEDEA T656 project as well as of a German national programme on 157 nm lithography. In addition, FLUOR is fully interfaced with the complementary European Commission IST UV2LITHO project, through which several of the partners are funded.

Meeting multiple challenges

For mask making, difficult challenges common at each new technology node include controlling critical dimensions, overlay accuracy and defect density. Existing techniques for measuring sizes, positions and defects are becoming ineffective for sub 100 nm features. A new substrate material for mask blanks also has to be developed.

The toolmaker has a separate set of problems to overcome. To eliminate chromatic aberrations, it is necessary to reduce the bandwidth of the laser severely or to develop a catadioptric optical system that uses reflective but also refractive optical elements. The FLUOR team estimated the second solution to be more attractive.

Today, the only practical optical material for 157 nm refractive optics is calcium fluoride (CaF_2), available only in limited quality and quantity. A new material, barium fluoride (BaF_2), has emerged as a potential alternative only recently. Partners Schott Lithotec and Korth are carrying out in-depth evaluations of both materials. The growth furnace and post-treatment technology employed have proved capable of producing large lens blanks of a quality hitherto unattainable – and Honeywell is working on the production of very high purity CaF_2 for this purpose. Appropriate metrology systems are being established for on-going testing.

A 300 mm wafer scanner frame developed in the earlier MEDEA T601 project forms the platform for a new machine, AT1600. Several of the participants are co-operating with ASML on this aspect. Zeiss is designing the optics, with additional components provided by JenOptic. Lambda Physik is developing a laser source with a targeted 1 pm bandwidth. Since 157 nm light is absorbed by oxygen, exposure must take place in an oxygen-free atmosphere. ASML itself is researching means to keep the optical path within the scanner under very pure and dry nitrogen, while M+W Zander is focusing on the provision of an improved clean air supply unit. The challenge is to produce the world’s first industry-ready tooling for mid 2004.

Production-viable resist

Probably the most critical factor for success is the fact that a production-viable resist is not yet available for the technology. Due to the high absorption of 157 nm in organic materials, none of the currently available resists is suitable. New root components based on silicon or fluorine bonds need to be developed and synthesised.

As part of the project, materials developed by the resist industry are therefore being screened in a process facility established at IMEC.

The CARL (chemical amplification of resist lines) process developed by Infineon offers another option. This technique uses a double resist layer with a very thin top layer. After wet development of the top layer, the thick bottom layer is sililated and then structured by a dry development step in oxygen plasma. Using the very thin top layer, the absorption problem of 157 nm can be overcome.

Crucial to Europe’s future

It is clear that the market position of the major European IC manufacturers is dependent on technology and, since lithography is such an important part of the manufacturing process, production costs are also linked to advances in lithography. Therefore all European chip makers will very much benefit from the success of FLUOR by the early availability of a well evaluated exposure tool together with a complete exposure and resist process.

A successful conclusion to MEDEA+ project T401 will enable the partners to improve their competitive positions, and help the European semiconductor industry to maintain a solid growth. Moreover, continuity in employment and provision of jobs requiring high levels of education in a dynamic and interesting environment will be as important as the trade balance for Europe.

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MEDEA+ focuses on enabling technologies for the Information Society and aims to make Europe a leader in system innovation on silicon for the e-economy.