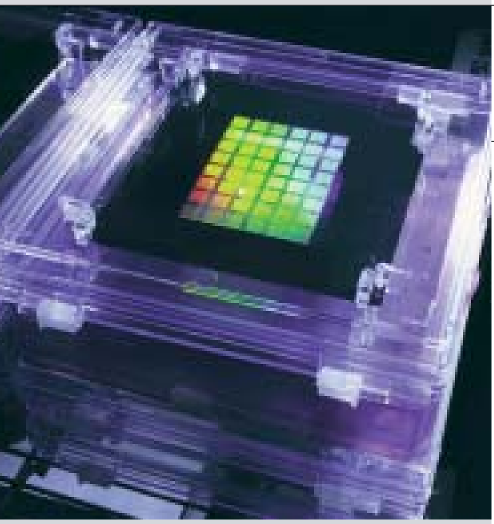
PROJECT RESULT

Lithography



T404: Extreme UV lithography masks (EXTUMASK)

Focused materials and metrology research wins global lead in EUV masks

The EXTUMASK project has set the basis for a complete infrastructure from substrate material to mask structures for EUV masks, enabling the transition from optical to EUV lithography for future generations of semiconductor chips. At the same time, new metrology tools have been developed to accompany the process. The results of the project have made Europe self-supporting in the supply of strategic EUV masks for production of 32 nm devices and below by the end of the decade. The first masks have already been made using this technology and delivered on a commercial basis for further equipment research.

Lithographic masks play an essential role in the production of semiconductor devices. In the current lithographic process, light passes through the mask, replicating circuit patterns on the photoresist-coated silicon wafers. Current processes use deep ultraviolet (DUV) light with a 193 nm wavelength. This was initially thought limited to 90 nm nodes, but immersion technology has extended its use down to 45 nm nodes. The global consensus now is that a prime candidate for sub-45 nm feature sizes is extreme ultraviolet (EUV) – actually soft X-rays – with a wavelength of 13.5 nm.

Playing catch up

The USA and Japan had already established technical advances for EUV technologies, so the MEDEA+ T404 EXTUMASK project set out initially to enable Europe to catch up. Members of the consortium included materials and subsystem suppliers, mask makers, research institutions, metrology companies and major European chipmakers.

Their original objective was to establish an infrastructure for experimental EUV masks at 70 nm nodes but this was quickly pushed to the 45 nm node with much tougher requirements than had been envisaged at the beginning.

Standard mask materials are no longer transparent at EUV wavelengths. Therefore, it was necessary to develop reflective masks using multilayer coating techniques. Material specifications were particularly demanding as the mask substrate has to achieve a high degree of flatness, excellent reflectivity and very low defect density.

While no substrate material existed at the beginning of the project with a flatness of less than 500 nm, single-sided flatness has now reached 50 nm, and levels have been achieved for double-sided flatness of 120 nm on the front and 80 nm on the back. It was also necessary to elaborate new coating techniques to structure the mask surface with a high degree of critical dimension uniformity across the complete plate.

Moreover, it was necessary to develop or adapt suitable measurement tools to verify the dimensions in the new processes, as well as to improve cleaning and handling techniques for the masks once created. Innovative vacuum handling techniques were investigated and implemented to prevent contamination during mask use and transport.

Making material advances

EXTUMASK developed new substrate materials and coating combinations to ensure the necessary high precision in reflective mode. This involved creation of a multilayer mirror using more than 40 bi-layers of molybdenum and silica.

As reflectivity of this multilayer combination is limited to 70%, the substrate has to absorb the rest of the light, demanding a low thermal expansion material that can also meet the required flatness and thickness limits. A glass ceramic has been developed and refined that can now be manufactured under reproducible conditions. Polishing techniques were adapted from methods for fused-silica glass to achieve the required flatness, and defects levels were reduced almost to the final required values.

However, the most challenging task was the multilayer deposition of the EUV mirrors. No commercial coating solution was available before the project, but it is now possible to produce multilayer depositions routinely with reflectivity of more than 65%. And an ion beam deposition tool was designed to reduce defect densities markedly.

Standard chromium absorbers are no longer suitable for mask structures below 200 nm. A tantalum nitride (TaN) absorber and silicon oxide buffer layer were therefore developed to enable dry-etch processes at the structure sizes involved in the new masks. Different dry-etch combinations were tested to obtain the best etch selectivity. The resulting mask-patterning process can now be used to create first full field masks for use in subsequent lithographic tool development.

Measuring up to the task

Metrology tools had to be adapted or developed to verify all relevant optical and physical parameters of the EUV masks. This included the development and testing of two reflectometers: one fast spectrograph with a fixed angle of incidence for further improvements of EUV mask blanks, and another with a variable angle of incidence and a scanning monochromator for R&D.

Other metrology equipment advances resulting from the MEDEA+ project included:

- A microscope station for inspection, line width and placement metrology; and
- A high resolution optical EUV microscope using a dedicated source and vibration-free turbo pumps.

In addition, several partners improved existing equipment or demonstrated existing techniques to detect or prevent unwanted particles and test the depth of the multilayer depositions.

Cluster-led co-operation

EUV is seen as the future for lithography in the microelectronics industry worldwide. Close contacts existed from the start of EXTUMASK with other projects in the MEDEA+ cluster that covered all aspects of EUV: masks, tools, sources and processes. Good links were also established with the EU IST/FP6 MORE MOORE EUV project. As a result, the MEDEA+ projects have already achieved remarkable results and Europe is now at the leading edge of global EUV technology.

The EXTUMASK project demonstrated a complete mask-making process for 45 nm circuit structures and below, based on 13.5 nm wavelength EUV. The project also developed the tools necessary for mask metrology and inspection. Moreover, the first commercial masks have already been delivered to lithography tool maker ASML following close collaboration with the MEDEA+ EXTATIC project enabling it to continue development of the next generation of process equipment to put Europe well ahead of its global competition.

Lithography

T404: Extreme UV lithography masks (EXTUMASK)

PARTNERS:

Advanced Mask Technology Center
AIS
Alcatel Vacuum Technology
CEA-LETI
IMS Chips
Incam-Solutions
IOM
Leica Microsystems
Philips
Roth&Rau
Sagem
SCHOTT
SCHOTT Lithotec
SESO
SOPRA
STMicroelectronics
Uni Orleans
Uni Marseille
Xenocs

PROJECT LEADER:

Jan Hendrik Peters
Advanced Mask Technology Center

KEY PROJECT DATES:

Start: November 2001
End: April 2005

COUNTRIES INVOLVED:

France
Germany
The Netherlands

MEDEA+ Office
140bis, Rue de Rennes
F-75006 Paris
France
Tel.: +33 1 40 64 45 60
Fax: +33 1 40 64 45 89
Email: medeaplus@medeaplus.org
http://www.medeaplus.org

EUREKA Σ!

MEDEA+ Σ!2365 is the industry-driven pan-European programme for advanced co-operative R&D in microelectronics to ensure Europe's technological and industrial competitiveness in this sector on a worldwide basis.

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