PROJECT RESULT

Lithography

## T406: Extreme UV consortium for imaging technology (ExCITe)

# Overcoming photoresist limitations key to success of next generation lithography

**The limitations of photoresists in terms of resolution, sensitivity and line edge roughness are a critical issue in the introduction of extreme ultraviolet (EUV) photolithography, which is essential for next generation chip production. Work in ExCITe enabled European chipmakers and suppliers of materials and process equipment to gain a real understanding of the problems involved in the use of chemically amplified resists. The MEDEA+ T406 project paved the way for gaining fundamental expertise in EUV imaging process limitations and developed a basis for further EUV resist and process research.**

Photolithography is the key enabler for semiconductor fabrication in terms of technological capability but is also the major cost factor. It involves projecting the image of an electronic circuit onto a silicon wafer, and then applying a photographic process to etch details on the surface.

State-of-the-art photolithography processes use 193 nm deep ultraviolet (DUV) light for imaging but, as device dimensions shrink ever more, the capabilities of such technologies have been exhausted and process costs are becoming prohibitive.

## Golden opportunity

Extreme ultraviolet (EUV) lithography with a wavelength of 13.5 nm appears the primary choice globally to replace DUV processes for the 32 nm half pitch node and below. This is despite the emergence of alternative approaches such as maskless lithography (ML2), nanoimprint and 193 nm immersion with double patterning.

Introduction of EUV lithography will provide a golden opportunity for companies active in this field. It will enable them to gain a valuable share of the worldwide market for the sophisticated processing equipment and production materials required.

In its first phase, MEDEA+ established a series of projects dealing with EUV lithography and encouraged strong co-operation between European chipmakers, equipment suppliers and research centres. These projects covered tools, masks, illumination sources and processing.

The main objective of the MEDEA+ T406 ExCITe project was to address bottlenecks related to EUV lithographic imaging for implementing full-field patterning development, building on the results of the associated source, mask and tools projects.

Consortium partners included the major European chipmakers, process equipment and materials suppliers, and research institutes from six countries. In addition to working closely with the MEDEA+ T403 EXTATIC EUV processing equipment and T404 EXTUMASK maskmaking projects, ExCITe co-operated with the EU IST MORE MOORE project. It also contributed strongly to global EUV imaging and resist research efforts through collaboration with Sematech and the International EUV Initiative (IEUVI).

## Specific work packages

The initial focus of ExCITe was on EUV techniques for devices with 45 nm half pitch but, as new processes were already extending use of DUV to this level, the project quickly switched to 32 nm half pitch and below. Specific work packages dealt with photoresists, metrology and modelling techniques to identify and overcome roadblocks with EUV processing to enable integration into full scale manufacturing based on EUV lithographic cells.

A major issue in EUV imaging is resist sensitivity: the lower the sensitivity, the greater the source power that is needed or the longer the exposure time that is required to expose fully the resist. The lower the power levels, the more noise affects the line edge roughness (LER). The need therefore appeared to be to improve resist performance. However, ExCITe identified the lithographic uncertainty principle stating that LER, sensitivity and resolution are fundamentally linked and cannot be optimised simultaneously.

An understanding of safe levels of outgassing was developed for chemical platform selection. Flare – scattering of the light beam due to imperfections in the optics – was also identified as a constraint for process windows and LER. However, current chemically amplified resist (CAR) imaging processes were found to be limited overall by the resists themselves, not the tools.

These resist issues were shared with MORE MOORE, Sematech and the IEUVI; the global consensus was that the brick wall for current CARs will be around 32 nm half pitch. Suitable resists were selected and optimised for full-field alpha tool testing at that level. However new resist platforms will be required for 22 nm that include non CARs, molecular glass resists and main chain scission resist.

## Metrology and modelling

Assessment of process development roadblocks in EUV imaging showed scatterometry provided unique capabilities compared with scanning electron microscopy in terms of resolution capability and detection of ellipticity. Profile roughness can be measured using the same tool. And mask shadowing impact on asymmetry and overlay can be characterised by a goniometry setup.

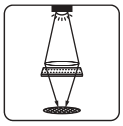
Simulation methodologies were developed and verified for imaging performance, masks and resists. Resist model were calibrated to sub-45 nm experimental data with good prediction of process window and ultimate resolution. Extendibility to 22 nm half pitch was predicted using aerial images. Simulation models were also developed to describe EUV-specific mask shadowing effects, LER and flare.

Due to lack of a mask-based exposure tool in Europe, the ExCITe consortium made use of the interferometric imaging facilities at partner Paul Scherrer Institute (PSI). Trials at PSI demonstrated clearly that resolution limitations were due to the CAR and not the exposure tools – results of this work helped boost PSI's image in the global community.

## Full-field testing

As EUV lithography is expected to be used down to at least 22 nm half pitch, full-field tools with such resolution capability are now needed to enable development of replacements for current resist materials.

Two alpha prototype tools having full-field capability will be delivered by ASML in 2006 to the IMEC research centre in Belgium and to Albany NanoTech in the USA, much ahead of any competition. Further system and integration issues will be addressed through this tool, enabling Europe to maintain its domination of this key processing technology.



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**KEY PROJECT DATES:**

Start: January 2003
End: December 2005

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