PROJECT PROFILE

2T304: Lithography based on quite extreme ultra high NA 193 nm optical immersion development (LIQUID)

LITHOGRAPHY

Partners:

ASML
Carl Zeiss
CEA-LETI
Freescale Semiconductors
IMEC
Infineon Technologies
JenOptik
LTM/CNRS
NXP
Photronics
Schott AG
STMicroelectronics
TuiLaser

Project leader:

Andries Hofman
ASML

Key project dates:

Start: January 2005
End: December 2008

Countries involved:

Belgium
France
Germany
The Netherlands
United Kingdom

Recent research clearly indicates the feasibility of using immersion technology to extend the existing 193 nm optical lithography platform to process microelectronics devices at the 50 nm feature level and possibly below. The LIQUID project is developing an immersion lithographic tool with optics, the masks and the processes as well as the most critical materials required for volume production from the 50 to sub-45 nm node. Success in this MEDEA+ project will enable the European lithographic industry to maintain and improve its global leadership position against tough Japanese competition as well as providing the processing infrastructure required by European semiconductor manufacturers.

Wafer-fabrication techniques have evolved continuously over the years to meet the needs for ever smaller electronic devices that consume much less energy and that have cut the cost of many of the systems that we now take for granted in our everyday lives. Improvements to photolithographic technology are no exception as it is the key – and most costly – element in integrated circuit production.

In photolithography, smaller feature sizes can be obtained either by reducing the wavelength of the light source used for projecting the image on the silicon wafer or by increasing the numerical aperture (NA) of the lens. Extensive consideration has been given to new 157 nm deep ultraviolet (DUV) and 13 nm extreme ultraviolet (EUV) for next generation lithographic processes. Now advances in the use of immersion technology have made it possible to extend the existing 193 nm optical lithography platform to the 50 nm feature level and below.

Immersion lithography involves replacing the air between the projection lens of the imaging system and the silicon wafer with a layer of fluid. This fluid refracts or bends the light, resulting in a greater resolution because the lens can be designed with a numerical aperture greater than one, making possible smaller features as the larger the aperture, the better the resolution.

While adoption of immersion technology is not an easy task, it adds significantly to the process window for 193 nm equipment. The now proven feasibility of this approach has already frozen any further developments in 157 nm processes and may delay the almost inevitable introduction of more costly EUV technology.

Industrially viable process

The MEDEA+ 2T304 LIQUID project brings together lithography equipment and optics manufacturers, materials suppliers, leading chipmakers and research institutes from across Europe to develop an industrially viable 193 nm based immersion lithographic process and equipment for the 50 to sub-45 nm mode. The project will also study the possibilities for non-water based 193 nm immersion processes usable beyond the 45 nm node. The project leader is ASML, the major manufacturer of photolithographic systems worldwide.

LIQUID will cover all the basic aspects involved:

- The lithographic exposure tool with optics;
- The masks or reticles required for imaging;
- The photoresist, wafer handling and processes concerned; and
- The metrology concerns at 50/45 nm.

Such new lithographic technology is essential to meet the deadlines identified in the International Technology Roadmap for Semiconductors (ITRS). Current 193 nm based optical lithography is already being used for volume manufacture of chips at the 65 nm node. The next generation of lithographic equipment will be required to meet needs for volume manufacture at the 45 nm node from 2010 – requiring suitable process technology two to three years earlier.

Specific processing challenges

Immersion technology itself is not new – the technique has been used in microscopy for over a century now – but it poses a number of specific challenges for lithography systems suppliers, not least in terms of ultra high numerical aperture optics. Current optical lithography has been pushed hard over the past few years but seems to have attained its cut-off point at 0.93 NA. Design of a new lens is necessary to exploit the enhancement of depth of focus possible with immersion as well as to reach new limits in terms of critical dimensions.

However, designing and manufacturing lenses with NAs beyond 1.35 is still uncharted territory. Water has been used successfully as the fluid layer between lens and wafer but modifying the liquid without major increases in light scattering and absorption and while it remains stable under the applied source is a particular challenge. It is also necessary to improve the complete illumination system in terms of tighter exposure control and in the compaction of the quartz glass in the lens itself.

LIQUID will build on work carried out in earlier projects involving many of the same partners. These focused initially on 157 nm technologies – particularly in the MEDEA+ T401 FLUOR and EU Framework Programme IST UV2Litho projects.

Extending technology use

Extending the limit of existing optical lithography technologies is essential for both the equipment suppliers and the semiconductor industry overall. The cost of ownership of the 193 nm process has been gradually reduced since initial introduction. It is now a mature technology with good availability of photoresists and reasonable reticle quality – though mask properties depend on writing problems and tests.

Therefore, by extending use of 193 nm processes over at least two more nodes will dramatically reduce the cost of introduction of new generations in the wafer-fabrication plants. Chipmakers worldwide are expecting their equipment and material suppliers to face up to the challenges involved in line with the requirements of the ITRS.

The MEDEA+ 2T304 project involves a series of subprojects focusing on: immersion-based lithographic scanner technology; materials for the optics and masks, particularly improving the laser durability of calcium fluoride (CaF_2) for the optics; low-k1 – the ratio of printed feature size and accepted wavelengths – enhancements; new immersion fluids and handling technology; and processes, defect analysis, metrology and reticles for relevant applications.

Interaction between the subprojects will be strong as materials and liquids will be required to build the optics and the lithographic scanner, and specifications for the scanner will be defined in close co-operation with participants in the applications subproject. The process to qualify the scanner will also be developed and the scanner qualified in the applications subproject.

The project is split into three stages, covering:

1. Development of an immersion infrastructure demonstrator supporting the 50 nm half pitch;
2. Development of an immersion infrastructure demonstrator supporting the 45 nm half pitch; and
3. Study of the feasibility for 193 nm immersion lithography supporting the sub-40 nm half pitch.

Benefits across the board

The successful outcome of the MEDEA+ LIQUID project will boost Europe's lithographic equipment, optics and materials industries, maintaining their world leadership in this critical area. It will also benefit the whole micro- and nanoelectronics industry by ensuring that European chipmakers will be able to manufacture competitive products well in line with consumer needs and with short times to market. And it will enable the leading European research institutes to bring together all the potential knowledge available to support this high risk area.

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