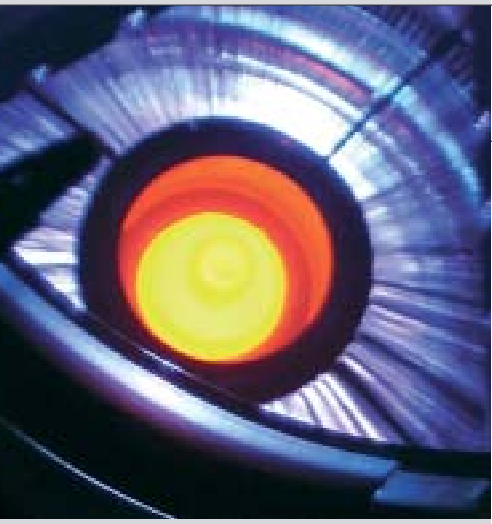
PROJECT RESULT

Lithography



T405: EUV sources development (EUV Sources)

Gas-discharge plasma EUV sources lead way to next generation wafer-fabrication processes

The rapid decrease of circuit structure size in microelectronics devices has required a concerted effort by European industry to develop new photolithographic technologies for future chip processing. The EUV Sources project focused on a key component in the lithographic tool - the EUV light source. Achievements included world record level high power output and development of optimised debris-mitigation processes, making it possible to guarantee much longer lifetimes for light collector and illumination optics. Initial models are integrated in the first operational full field alpha EUV tools.

Photolithography plays a key role in the production of semiconductor chips, accounting for over a third of wafer-processing costs, and increasing with each technology node. An image of the circuit required is projected onto the silicon wafer using a photomask. The wafer is coated with a photoresist which reacts to the light projected. Exposed areas are washed away and the wafer etched. This process is repeated many times in the integrated circuit manufacturing process.

Lithography is key to dimension reduction. As circuit structures continue to shrink, the wavelength of the light for this photographic process has to reduce as well. Current technologies use 193 nm deep ultraviolet (DUV) sources but future generations will need much shorter wavelengths, in the extreme ultraviolet (EUV). While there has been interest in moving to an intermediate DUV wavelength, the global consensus for high volume production and small feature sizes of 32 nm and below is now on a switch to EUV with a wavelength of 13.5 nm, introducing new challenges in technologies and equipment.

MEDEA+ anticipated this with a cluster of projects covering the main elements of EUV lithography: illumination sources, masks, tools and processing. This brought together Europe's leading companies and research centres in wafer steppers, light sources, imaging systems and mask manufacturing as well as equipment and subsystems suppliers to help win the global race for next generation solutions.

High power essential

Availability of high power lithography sources will long remain a critical issue. The MEDEA+ T405 EUV Sources project investigated a solution that included characterisation and interfacing to alpha-level lithographic tools. It focused specifically on high power sources, but also studied low power sources for metrology applications.

High power outputs are essential to increase wafer throughput and reduce the cost of ownership. To be cost effective, the final production tool has to be able to handle at least 80 wafers an hour, requiring a minimum power of 100 W in the intermediate focus – a factor of ten more than possible at the start of the project. The need was to develop collector optics and reliable sources to meet these requirements.

At the EUV level, optics are no longer transparent. Illumination systems therefore incorporate optical elements consisting of grazing incidence mirrors made from 40 alternating thin films of silicon and molybdenum, both with a reflectivity optimised for the 13.5 nm wavelength.

There are various methods to generate radiation at this level. The EUV Sources project investigated several alternatives with the objective of drastically increasing the effective output power of the resulting source.
As there had been no application that used this type of source before the project started, development was still in its infancy. A high source power was required due to the low sensitivity of photoresist and to the significant reflection losses in the optical system with its many surfaces.

Two main approaches

EUV Sources looked at two main approaches: one involving laser excitation of the plasma that emits the radiation; and the other making use of gas-discharge plasma sources. Some work was performed on laser-produced systems to demonstrate feasibility, and interesting results were achieved. But the laser-based solution proved to have a higher cost of ownership. Therefore, the focus was on gas discharge.
The main challenges for gas-discharge sources were reliability and lifetime of both source components and associated optics. Particularly good progress was made on debris mitigation – a century-old problem with gas-discharge sources. Particles from the discharge system gather on the integrated optics surface, reducing light output markedly. Optimisation of gas flows and geometries of debris-mitigation devices and addition of halogen in the tube led to a more than a one thousand times improvement in lifetimes.
Large increases have also been achieved in power outputs: initially it was only possible to provide output powers of several watts but, by the end of the project, a world record 800 W output over 2πsr had been achieved in laboratory conditions – more than a hundred times better. To achieve similar outputs in full-scale process conditions requires further development of the collector optics.

Work to continue

This was a global development in concert with potential customers in Europe, the USA and Japan. The project included investigation and development of metrology for EUV source characterisation to meet international standards. There was a broad approach in Europe at the beginning of the project but this narrowed rapidly as several companies pulled out of the market as they could not find partners or the correct technical solutions.
Working as part of the MEDEA+ EUV lithography cluster meant the EUV Sources consortium had clear specifications on power requirements and timing for European equipment suppliers. As a direct result of EUV Sources, two high power sources are being delivered to ASML – the leading European equipment supplier in this field – for integration into full field alpha excitation tools to allow further equipment and process developments.
The overall results of all four of the initial EUV cluster projects, together with those of the EU Sixth Framework Programme (FP6) MORE MOORE project, are now being used as the basis for the 'EAGLE' project in the second phase of MEDEA+. EAGLE covers all elements of the EUV lithographic platform, compatible with high volume production requirements at the 32 nm node and below.

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