Highlights from 2016 EUV Source Workshop

Work on Conversion Efficiency of EUV Sources and Continued Progress in Source Technology

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The 2016 Source Workshop was held Nov 7-9, 2016 at ARCNL, Amsterdam, The Netherlands. During the workshop we received new information about EUV source power, updating what we learned at the EUVL Workshop in June. ASML now has 125 W sources in field with their uptime improving, and 210 W dose controlled sources in lab, with 5.5 % conversion efficiency (CE). This leads me to predict that we will be able to have 250 W in field by 2018, which will be needed to support manufacturing at 125 wafers per hour. Another piece of good news on the high power source front is the continued solid progress by the second-largest supplier of HVM EUV sources, Gigaphoton. They now have 100 W @ 5% CE, with 95% duty cycle for 5 hours of continuous operation.

There were reports of continued progress on EUV metrology sources, but they are still years away from being integrated into the next generation of mask defect inspection tools. In the workshop, I heard that Zeiss is now working closely with suppliers to evaluate their EUV metrology sources for their next generation AIMS tool. We also need patterned mask inspection (PMI) tools to be ready sooner than later, and I was happy to see a presentation by KT on the status of the source for their PMI tool. However, when and if this tool will become reality is still unknown, while these tools will be needed at 5 nm application of EUVL in fabs.

This year there were several papers (experimental and theoretical) on how to increase CE of sources by looking deeper into the working of EUV sources. In EUV sources, the laser energy (which is at 10 micron wavelength) is converted into 13.5 nm photon. Current reported CE is 5.5 to 6%. Can we can get more efficient?

We learned, via plasma measurements, how we can better tweak the delay and shape of laser pre-pulses (Kyushu University papers) and were told about development of pre-pulse lasers to enable the delivery of those optimum pulses (work from HiLase).

I found interesting the work of Hanneke Gelderblom, Univ. of Twente and Dmitry Kurilovich, ARCNL. They are using “water drops as scale model for tin” to understand the scalability of hydrodynamic stability of droplets interacting with lasers. They found that they can adjust parameters to work in regions to avoid drop breakups during interaction of laser with droplets, while looking for greater laser absorption to increase CE. It was a good example of how we can use learnings from other disciplines to improve the functionality of EUV sources.

Gerry O'Sullivan of UCD pointed to the need for maximizing the line emission by reducing opacity and reducing recombination. He noted that plasma density has a "sweet spot" for a maximum CE and optimized CE. He also described his wedged target colliding plasma that can be better matched to CO2 for increasing CE.

A most interesting CE paper to me was one by Mikhail Basko. He pointed out that in principal, 20% CE is possible (based on 40% spectral efficiency calculations) but in reality only 9% CE can be achieved. He pointed that 2.5% of CE is lost as the kinetic energy of plasma flow, while rest of CE is dissipated due to non-uniformity of temperature across the "working" zone and in-band reabsorption. We need to find ways to achieve this optimum density profile in our tin targets to get to 9%.

There were several interesting papers on modeling efforts to improve CE (LLNL, ISAN, Cymer) and generation of fundamental data to improve modeling. Such efforts are going to be important as we run out of knobs readily available to us today to improve CE, and we must look deeper into the working of plasma sources to squeeze those additional EUV photons out of plasma and search for stable operational modes for sources that can be sustained in factories around the clock.

We had many excellent papers on XUV sources and their applications to support manufacturing in the semiconductor industry and beyond. Hans Hertz in his keynote speech described his water window microscope, which with a 200 W laser of 600 picosecond pulse operating at 2 kHz gives an early synchrotron level of brightness. It can now do 3D tomography with a 10s exposure. These developments were possible due to a new multilayer mirror with >4% reflectivity (optiXfab) at water window wavelengths. He had reported the development of these new multilayer mirrors in last year's source workshop, and decided to incorporate them in his tool to achieve this progress.

This year's workshop had the highest attendance ever. I was happy to see continued work by the research community and suppliers to better understand the working of EUV sources, so that we can achieve those 500+ W sources that can operate 24/7 in fabs with 80-90% uptime.