Editorial

The Next Decade of Optical Lithography

For the last four decades, Moore's law, prescribing a doubling of the number of transistors per chip each 2 years, held and was even outperformed. This remarkable achievement required a joint effort of the whole semiconductor industry from the material suppliers up to packaging and was secured and enabled by the jointly agreed ITRS roadmap. From the current perspective, the semiconductor industry is likely to follow Moore's law for another decade.

With the 193-nm immersion lithography as the current workhorse, the industry follows basically three basic paths for a further increase in the level of integration of the ICS: aggressive use of the resolution enhancement techniques in connection with double patterning, further wavelength reduction by use of EUV lithography, and 3D integration. Here, EUV lithography is definitely the highest investment with the promise to open the door to the well-known path of new lithography tools with gradually increasing NA.

With this special issue of *Advanced Optical Technologies*, we intended to compile a snapshot of the current state of the art together with the future perspectives of this fascinating field of cutting edge technology. We are happy to present to you a collection of papers that are written by absolute experts in that field ranging from industry (Cymer, IBM, Luminescent, Nikon, Zeiss) to research institutions (Sematech, EIDEC).

The topical part of this issue starts with the tutorial, "Calculation and uses of the lithographic aerial image" about the principles and the state-of-the-art of optical lithography by Donis G. Flagello and Daniel G. Smith, which is a valuable reference for anybody active in that field and should be helpful as a kind of an introduction, in particular, for these readers who are not yet familiar with the scope of the technologies and applicative demands of the optical lithography process.

Computation lithography modeling is the subject of a thorough review paper by Kafai Lai with the title, "Review of computational lithography modeling: focusing on extending optical lithography and design-technology co-optimization", discussing current modeling practices in optics, mask, resist, and etching, leading to the predictive modeling of the entire patterning process, a technique that he calls "virtual fab".

The review paper, "Development of core technologies on EUV mask and resist for sub-20-nm half pitch generation", by Soichi Inoue et al. reports on the current status of the key infrastructure elements of EUV lithography. An EUV infrastructure element of particular interest is the light source of which the current status is the topic of the paper, "Advances in EUV light sources", by Nigel R. Farrar et al.

With decreasing structure size, the mask becomes a more and more critical element of the whole process. The paper, "Aerial imaging technology for photomask qualification: from a microscope to a metrology tool", by Anthony Garetto et al. gives a closer insight into the AIMS mask inspection tool, which enables a hardware simulation of the wafer-level image of a real mask, up to the currently developed EUV-AIMS. "Computational metrology and inspection (CMI) in mask inspection, metrology, review, and repair" is the subject of a paper of Linyong Pang et al. addressing the technology challenges for mask inspection arising from their increasing complexity due to aggressive OPC, source mask optimization, and inverse lithography. The status and prospects of the source mask optimization itself are discussed in the paper, "Imaging optics on scanner for SMO generation process", by Tomoyuki Matsuyama et al.

The technology decision approaching the semiconductor industry about how to do leading edge lithography for the 22-nm node is a big issue of the ITRS roadmap as reported and discussed in the paper, "ITRS lithography roadmap: status and challenges", by Mark Neisser and Stefan Wurm in the VIEWS section of the issue.

Finally, we, the guest editors of the issue, want to thank the AOT team and, in particular, all authors for their contribution to this issue, despite their demanding professional duties. We enjoyed the cooperation with them in the course of the preparation of this collection. After all, this is a decisive time of optical lithography. We do hope that you, the reader, will share this joy and feel some of the thrill that optical lithography provides for the scientific and technical mind.

Michael Totzeck, Kafai Lai and Daniel Smith

Michael Totzeck received his PhD in physics from the Technical University of Berlin in 1989. After heading a group on quantitative, high resolution microscopy at the University of Stuttgart he joined Carl Zeiss in 2002. He is a Senior Principal in the Central Research Department of Carl Zeiss. His research interests comprise, besides lithography, high-NA imaging, high-resolution metrology, diffractive optics, polarization-optics and numerical simulation.

Kafai Lai, PhD is a Senior Scientist/Engineer in the Semiconductor Research and Development Center at IBM, and has been investigating lithography in the mainstream lithography area for over 16 years. His broad research interest involves optical imaging modeling and lens characterization, exposure tooling analysis, OPC model improvement, and lithography/RET development, Source Mask optimization and recently on Design Technology Co-optimization and Emergent Lithography. He is the co-chair of the SPIE Optical Microlithography conference 2012/13 and has been a member of the technical program committee since 2005. He has also been the symposium chair for the CSTIC conference in Shanghai China since 2009.

Daniel G. Smith received his PhD from Optical Sciences Center and has been working as an optical designer in the field of Microlithography at Nikon Research Corporation of America since 2004.