JM3 Journal of
Micro/Nanopatterning,
Materials, and Metrology

GUEST EDITORIAL

Special Section Guest Editorial: Direct Write Lithography

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Recent leading-edge work in semiconductor lithography tends to concentrate on EUVL and its advanced optics, masks, inspection tools, and other technologies. Meanwhile, of course, DUV lithography continues to soldier on, occupying a less-glamorous but still important part of the landscape — indeed, the laser mask-write market, as noted at a recent conference, is dominated by masks for the 180 nm node and larger. Analog electronics, chips for edge computing, single-chip unique security IDs, and heterogeneous integration are all important markets in the field.

Concurrently direct-write lithography has continued to advance. Those familiar only with the older e-beam wafer exposure tools may be surprised at the new work in the field. This Special Section on Direct Write Lithography is meant to more widely advance knowledge of the state of the art in this field. The six papers in this volume are presented by technologists from not only nonprofit research institutes and universities but also toolmakers with real upcoming products.

The paper by Laulagnet et al. discusses a method of joining electron-beam direct-write (EBDW) lithography with 193i conventional litho in a hybrid process using negative-tone resist. The idea is that the hybrid method will enable practitioners to use the high resolution and flexibility of EBDW while avoiding its disadvantages of low throughput. An example shown is that of pairing unique ID codes drawn by EBDW on circuit chips made by 193i processes. The authors discuss overlay and other practical challenges.

In the mask-writer field, multibeam systems are now taking over from variable-shape beam (VSB) systems for making curvilinear chips, or non-Manhattan layouts, due to their improved throughput. Linn et al., though, show that a VSB lithography tool can be used for unique optical printing applications in silicon photonics and in diffractive optical elements, which typically require non-Manhattan structures. They demonstrate the performance of cell-projection systems with novel algorithms for applications like diffractive axicons.

Zeitner, Banasch, and Trost continue this theme by employing a character-projection EBDW tool for writing examples like a large computer-generated hologram for testing of aspherical mirrors. They also venture into hybrid schemes by using the EBDW system to write a nanoimprint litho master for a very large meta-grating.

The paper by de Boer takes a higher-level view, comparing past EBDW systems like the MAPPER and IMS direct writer platforms in terms of throughput, resolution, and overlay. Differences in data path design, scalability, and alleviating effects of wafer heating are considered, and the author surveys these platforms with a view to future use.

Electron-beam tools are not the only way to do direct writing. A optical direct-write advance from a toolmaker is described by Watanabe et al. with their description of a 193 nm maskless wafer-exposure tool or digital scanner. In this system, a spatial light modulator acts as a pixelated phase mask, allowing exposure of wafers with fields ranging in size from the standard dies in mask-based tools to a field covering the entire wafer. The authors describe OPC and data conversion in this tool and cite potential uses in rapid prototyping, heterogeneous integration, and (like the work above) identification of chips with unique IDs for high-security purposes.

Finally, this section presents an overall historical review of the optical direct-write field by Owa, who starts with the original patents for optical direct-write systems in the 1990s and continues to the present day, discussing different data-path and optical schemes.

We hope that this special section will provide JM^3 readers with an introduction to and review of this exciting part of the field of semiconductor lithography. We thank the authors, reviewers, and the JM^3 staff for their contributions.