Special Section Guest Editorial: Next Generation Light Source, Materials, and Metrology/Inspection Equipment

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In this special section, we are very pleased to present a series of excellent articles centered at the core enabling technology of the semiconductor industry – light sources. The devices that we (as an industry) make, inspect, and measure as well as the key supporting equipment and infrastructure critically rely on the wavelength, power, brightness, etendue, bandwidth, and all-around capabilities of light sources. Development of new and novel light sources, from flash lamps to focused electron beams to lasers to plasma sources, has driven not only lithography and feature scaling but also the necessary process control equipment to ensure yield and functionality. Furthermore, even as device scaling has been driven more in recent days by material developments rather than light source evolution, innovations around inspection and metrology light sources have helped to enable successful novel material introduction.

New materials set a groundwork for what to inspect and how. For example, the advent and implementation of EUV resists into high-volume manufacturing has led to increased importance in line edge roughness metrology as well as inspection for material intrinsic stochastic defects. Moreover, the increased importance of 3D-NAND led to new developments in deep-via electron beam and optical metrology. Characteristically, new materials and new integration schemes are invariably tied to the development of new metrology tools to answer the control questions posed by these integrations.

Light source and metrology capability evolution are inevitably tied together. On one hand, power and brightness improve speed and capability in systems. On the other, capability improvements with flexible sources spanning into the infrared and deep ultraviolet (even the extreme ultraviolet) ranges create new opportunities in metrology. Likewise, power (and potentially wavelength/polarization) driven performance changes for EUV lithography open the door for a "final era" of lithography tooling, allowing the patterning of features below 10 nm.

In this special section of JM^3, we have curated a selection of nine papers spanning the critical areas of next generation light source development, which will support the future of the semiconductor industry through patterning, inspection, and metrology. Core metrology opportunities enabling next generation nanosheet architectures are explored in the papers by Schmidt et al. and Breton et al., while emerging opportunities for optical metrology can be found in the paper by Yoon et al., describing the development of hyperspectral imaging to provide both spectral and 3D spatial characterization. Characterization of 3D structures is further explored in the work by Shomrat et al., delving into the scanning transmission electron microscopy tomography of sub-20 nm patterns, and Fumani et al., where mid-infrared ellipsometer is demonstrated in the measurement of high-aspect ration channel hole patterns for 3D NAND.

For EUV-related topics, Juschkin and Wack explore the critical EUV mask inspection source requirements, highlighting the parameters critical for imaging defects at relevant nodal dimensions, while the necessary CD-SEM resist metrology for high-NA EUV lithography is described in the paper by Severi et al., where the challenge of ultrathin film measurement is confronted. Moreover, the metrology of EUV resists is further explored through EUV reflectometry in the paper by Schröder et al. to characterize the latent image. Lastly, the paper by Kawata et al. explores the potential of free-electron lasers as a high-average power light source for EUV lithography.

We, the guest editors, are very grateful to the authors for their scholarly contribution to this special section, without which we would most certainly be left in the dark. Moreover, we would like to thank the various referees who tirelessly reviewed these articles at length on top of their

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day-to-day activities and responsibilities. Their feedback and suggestions were an invaluable contribution to the community. Lastly, we are especially thankful for the ever-constant guidance and support of the SPIE editorial staff to help bring this special section to fruition, and certainly not least we would like to thank JM^3 Editor-in-Chief Harry Levinson for his persistence in seeing this special section come to life. We hope that you enjoy the articles contributed here, and we would certainly welcome any comments or feedback to further the discussion