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GUEST EDITORIAL

Special Section Guest Editorial: Metrology for EUV

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As the adoption of extreme ultraviolet (EUV) lithography in high volume manufacturing continues to expand and EUV nodes continue to shrink, the application of at-wavelength metrology, inspection, and characterization is becoming increasingly critical. Several factors drive the importance of at-wavelength metrology techniques in the EUV regime, but first and foremost on the list is the fact that EUV lithography relies on the use of highly specialized Bragg coatings (multilayers). Such structures are highly chromatic by design and can only be fully characterized at the design wavelength. This fact is particularly critical in all applications related to metrology, inspection, and characterization of the mask, a topic addressed in the papers by Shen et al., Benk et al., and Sherwin et al.

Another important characteristic of EUV light is that at a photon energy of 92 eV, EUV photons are significantly more energetic than typical binding energies. The relevance of this is that EUV-induced radiation chemistry can differ significantly compared to deep UV and/or electron induced chemistry. This is important both from the radiation damage perspective as well as from the EUV resist chemistry perspective. Understanding these effects requires the use of at-wavelength characterization tools as described by Mueller et al. and Dorney et al.

Finally, from the perspective of wafer metrology, utilizing the shorter wavelengths in the EUV and soft-x-ray regime provides important resolution margin compared to DUV metrology solutions. Moreover, the chemical sensitivity in this wavelength regime provides a mechanism to measure molecular states of buried interfaces which opens up new possibilities in device characterization as addressed by Ciesielski et al.

The paper by Shen et al., "Spectral reflectometry characterization of an extreme ultraviolet attenuated phase shift mask blank," discusses how spectral reflectometry can be used to determine the real and imaginary parts of the index of refraction, n and k, along with the thickness of the layers in an EUV attenuated mask blank. Results for a platinum-tungsten (Pt-W) absorber, along with n and k, and the thicknesses of the top three layers of a sample stack are presented. Varying the wavelength and angle of incidence to access deeper layers is also discussed.

The paper by Mueller et al., "Study of electron-induced chemical transformations in polymers," describes using 20 eV to 80 eV electrons to study the mechanism of EUV exposure of photoresist. Absorption of an EUV photon in a material generates a cascade of primary, secondary, etc., electrons which are believed to be the main cause of EUV photoresist exposure. Three different pure polymer materials were examined, including poly(4-hydroxystyrene). Outgassing, thickness change and FTIR were used to compare different exposure conditions. Results indicate a strong correlation between exposure conditions and material change.

The paper by Benk et al., "Zone plate-based extreme ultraviolet mask microscope with through-pellicle imaging capability," discusses the development of a zone-plate based EUV microscope with 3 mm working distance. The large working distance is required to avoid interfering with the pellicle used to protect an EUV mask. Results demonstrate excellent image contrast, 95%, on large (60 nm) features and indicate the viability a zone-plate based EUV microscope for EUV mask metrology which works with a pellicle.

The paper by Ciesielski et al., "Interface sharpness in stacked thin film structures: a comparison of soft X-ray reflectometry and transmission electron microscopy," quantitatively

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compares soft X-ray reflectometry with scanning transmission electron microscopy and energy dispersive X-ray spectroscopy (STEM-EDX) of silicon/silicon-germanium (SiGe) thin film stacks. Results show a strong correlation between the measured layer thickness and interface properties as determined by the two methods.

The paper by Dorney et al., "Actinic inspection of the extreme ultraviolet optical parameters of lithographic materials enabled by a table-top, coherent extreme ultraviolet source," used EUV table-top sources to measure the reflectivity and absorption of a range of materials, including crystalline films, photoresist systems, and carbon nanotube membranes. Optical parameters, absorption kinetics and 2D transmission maps were determined from the measurements. This study demonstrates the utility of compact table-top EUV sources for optimizing the materials used in EUV systems.

The paper by Sherwin et al., "Understanding and measuring EUV mask 3D effects," discusses the results of using actinic scatterometry to measure various electromagnetic 3D effects on EUV masks. Image dependence on phase shift, which varies with pitch, absorber thickness and multilayer effects were evaluated combined with source angular and spectral variation. Results indicate the utility of actinic scatterometry for optimizing the 3D design of EUV masks.

We hope this special section will provide JM^3 readers with a broad-based sampling of various EUV/soft-x-ray metrology methods and applications as applied to the field of semiconductor lithography. We acknowledge that this special section only scratches the surface, but hopefully it serves as a good jumping point for our readers to dig deeper into these important and exciting topics. We thank the authors, reviewers, and the JM^3 staff for their contributions.