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GUEST EDITORIAL

Special Section Guest Editorial: Plasma Modeling and Feature Profile Simulation

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The Special Section on Plasma Modeling and Feature Profile Simulation is a collection of three review papers covering the topics of reactor scale modeling, feature scale modeling, and machine learning in low-temperature plasma modeling and simulation. The papers summarize the current state of the field for these key plasma modeling and simulation topics and provide perspectives on advances the field needs and how those advances might be accomplished.

Plasma modeling and feature profile simulation have made valuable contributions to the advancement of plasma-enabled fabrication of microelectronics devices over the past several decades. That said, advanced microelectronics manufacturing is increasingly relying on new fabrication methods, such as pulsing/cyclic techniques, which represent a nearly exponential increase in process permutations with a correspondingly exorbitant cost to characterize these permutations by traditional methods. As a result, there is both a new opportunity and a need for plasma modeling and simulation to have an industry-changing impact. Modeling and simulation can potentially help with several key challenges, including reactor design, exploration of the range of process parameters, process space reduction, process complexity reduction, and real-time control. The capability to accurately model real-world process chambers and real-world process recipes will be essential moving forward. Then leveraging that capability to clean-sheet design real-world process chambers and process recipes would be game-changing. The importance of plasma modeling and simulation and the role it will play in the future of semiconductor manufacturing is highlighted in the 2023 US Department of Energy Office of Fusion Energy Science Workshop report “Plasma Science for Microelectronics Nanofabrication: Report on Science Challenges and Research Opportunities for Plasma Applications in Microelectronics.” (https://science.osti.gov/-/media/fes/pdf/2023/DOE_FES_PlasmaScience_Semiconductors_Final.pdf)

The review paper by Kuboi et al. focuses on feature scale profile simulation, including damage distributions and film properties, in dry etching and deposition processes. Feature scale profile simulation is useful for predicting process properties and gaining insights into variation mechanisms that influence etch and deposition processes in advanced semiconductor manufacturing. This review comprehensively covers the various modeling approaches to feature scale profile simulation, including the strengths and weaknesses of each approach, and discusses the challenges to better predict and control variations in the feature scale profiles through real-time predictions combined with on-tool process monitoring and control capabilities.

The review paper by Rauf et al. focuses on modeling of plasma processing reactors. Low temperature plasma (LTP) systems can be simulated using global, fluid, and particle-based kinetic modeling techniques, as well as hybrid methods that supplement fluid plasma models with kinetic models for aspects of the plasma behavior. These techniques are discussed with an emphasis on issues that are critical for modeling industrial plasma processing systems. The industry expects plasma models to be quantitatively accurate so they can be used as an LTP system design tool. The authors highlight the benefit and need of multi-faceted plasma model validation studies where plasma sources are first characterized using a variety of complementary diagnostics, as well as the development of the plasma chemistry mechanisms and models for plasma–surface interactions.

The review paper by Trieschmann et al. focuses on the role of machine learning in advancing low-temperature plasma modeling and simulation. Many aspects of plasma modeling and simulation have benefited substantially from recent developments within the field of machine learning and data-driven modeling. The authors focus on the large variety of physical and chemical aspects of LTP processing that have so far been addressed by data-driven methods, specifically considering how data-driven plasma science can complement conventional theoretical approaches, as well as when data-driven plasma science approaches may replace classical concepts in the field of LTP modeling and simulation. The authors also provide a perspective of potential advances in plasma science and technology, possibly enabled by adaptation from other scientific disciplines.

We hope that this JM^3 Special Section on Plasma Modeling and Feature Profile Simulation will serve as a valuable reference for the LTP modeling and simulation community. We thank the authors, reviewers, editors, and SPIE staff for their contributions and tireless effort to help produce this JM3 special section.