Guest Editorial

Equipment and Operations Automation in the Semiconductor Industry

The semiconductor industry is a key element of all modern economies, contributing either directly via manufacturing of computer chips or indirectly through manufacturing of high-tech goods and the support of services. However, this value comes at a cost. Semiconductor wafer fabrication is arguably the most complex of all manufacturing processes and a state-of-the-art wafer fabrication facility can cost on the order of US $5 billion. Such facilities are highly automated and there is a need to extend the concept of automation to encompass advanced decision technologies (such as Operations Research, Artificial Intelligence, and Queueing Theory)—full automation requires the careful consideration of all decisions in such facilities. While numerous efforts have been made over the years to address issues such as production control and more recently supply chain management, there are compelling opportunities in the area of equipment automation.

As stated in [1], “the drivers of the next-generation factories...[depend] most strongly...on production equipment configurations and the supporting automation system capabilities.” This is in part due to the anticipated transition from 300 to 450 mm diameter wafers, which presents an opportunity to reconsider existing equipment designs and operations. In addition, the careful scientific consideration of the decisions made inside the automated equipment is a relatively new area with much potential and remaining work. Further, there continues to be a wealth of opportunities to improve existing operations. Informed by an ocean of data being collected from the automation systems, new concepts for automated metrology and modeling are also arising. As such, equipment and operations automation promises to lead the revolution toward the next-generation factories; it is the theme of this Special Section of the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING.

From over 30 high-quality papers submitted to the Special Section on Equipment and Operations Automation in the Semiconductor Industry, ten papers by leading researchers and practitioners were selected for publication. They are original, visionary, and practically relevant papers that we hope will be of considerable value to and guide the focus of the academic and practitioner communities in the future. There are three foci, all with a specific emphasis on semiconductor manufacturing automation: equipment automation, operations automation, and modeling.

Cluster tools are increasingly common in semiconductor wafer fabrication and consist of a collection of process modules housed in a single chassis. Wafers are moved from one process module to another via wafer transport robots. The linked photolithography scanner—by far the most expensive tool in a fab—may be considered as a connection of cluster tools, or a multicluster tool. The key facet of equipment automation considered for this Special Section is how wafers are moved from process to process within such tools. These decisions dictate the throughput of the tool and are essential for efficient operation. Throughput optimization is a burgeoning field with the potential to change the way equipment is operated; it is especially important as the cost of wafer production equipment and wafer fabricators continues to escalate. In particular, questions on the efficacy of emerging design concepts must be addressed. Chan et al. develop optimal schedules for multicluster tools consisting of two clusters. In a second work, Chan et al. extend their results to multicluster tools with tree-like topologies. Such configurations have the potential to be of increasing importance in manufacturing. In an effort to deduce the throughput implications of internal wafer buffers, Geismar et al. study dual-gripper cluster tools. They also assess the practical value of internal buffers based on work with a U.S. equipment manufacturer. In the fourth paper focusing on equipment automation, Wu et al. employ Petri net methods to address the challenging problem of scheduling cluster tools with reentrant process flows.

The automation of semiconductor manufacturing operations is ever more important as the industry evolves toward greater productivity and new fabricator designs. To wit, the International Semiconductor Manufacturing Initiative’s (ISMI) Next-Generation Factory (NGF) program targets a “30% cost reduction and 50% cycle time improvement by 2012” [3]. To address what is arguably the most important metric in semiconductor wafer fabrication, Blue and Chen propose a new method to automatically identify systematic spatial variations on wafers in an effort to improve yield. Such new methods have the potential to remake the approaches used in the industry. From the industry perspective, Said et al. discuss automated methods for the detection and classification of solder joints in processor sockets on motherboards. This contribution represents real industry implementation of automation methods and science that significantly improves existing capabilities.

While modeling of semiconductor operations is a traditional field, it remains of vital importance. The papers selected provide new directions and insights in this area. Morrison develops theory for multiclass flow lines and demonstrates how they may be used to model linked photolithography scanners. The in-
tent is to provide substantially more expressive yet computationally tractable models for use in fabricator simulation. Wu et al. develop a new approximation for the mean cycle time in batch tools; such tools are common in semiconductor fabricators. The approach corrects for errors made by common decomposition techniques and promises to improve batch tool queueing models. Neural network models for cycle time in a fabricator are developed by Kuo et al. Their approach addresses issues associated with queueing models and has been implemented at an integrated device manufacturer in Taiwan. The last paper of the Special Section is a short paper by Leachman and Ding. They develop a model relating cycle time and excursion yield loss.

We wish to extend our gratitude to all of the authors and anonymous reviewers for their excellent efforts to ensure the quality of the Special Section papers. We also wish to thank Editor-in-Chief N. Viswanadham, Editor-in-Charge of this Special Section M. Zhou, Editorial Assistant A. Chakravarty, and the additional Associate Editors for their extraordinary efforts to support this Special Section. This Special Section was developed by the IEEE Robotics and Automation Society’s Technical Committee on Semiconductor Manufacturing Automation. Please visit our website at http://xS3D.kaist.edu/tc-sma or send an e-mail to james.morrison@kaist.edu for additional information on the Technical Committee.

REFERENCES


James R. Morrison (S’97–M’00) received two B.S. degrees, one in electrical engineering and one in mathematics, from the University of Maryland, College Park, and the M.S. and Ph.D. degrees in electrical and computer engineering from the University of Illinois at Urbana–Champaign, Urbana, in 1997 and 2000, respectively.

He was with the Fab Operations Engineering Department at the IBM Corporation from 2000 to 2005. He is currently an Assistant Professor with the Department of Industrial and Systems Engineering at Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea. His research interests include semiconductor wafer fabrication and related automation, service systems, eco-design and port systems.

Dr. Morrison began a three year term as a Co-Chair of the IEEE Robotics and Automation Society’s Technical Committee on Semiconductor Manufacturing Automation in 2009. He has served on the program committee of numerous conferences including IEEE CASE 2010, SEMI/IEEE ASMC 2010 and IEEE CASE 2009. He has served as a Guest Editor for the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING. He was selected as the 2009 Best Teacher for the KAIST Department of Industrial and Systems Engineering. In 2010, he was a recipient of the three year New Professor grant from the Korea Research Foundation (KRF).
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Dr. Chien received the Outstanding Research Award and Tier 1 Principal Investigator Award from the National Science Council, the Distinguished University-Industry Collaborative Research Award from the Ministry of Education, the University Industrial Contribution Award from the Ministry of Economic Affairs, the Distinguished Young Faculty Research Award and Distinguished University-Industry Collaborative Research Award from NTHU, the Best Paper Award and the Distinguished Young Industrial Engineer Award from CIIE, the Best Engineering Paper Award from the Chinese Institute of Engineers, and the TSMC Faculty Semiconductor Research Grant Award, Taiwan.

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Milind Dawande is a Professor of Operations Management and Area Coordinator of the Operations Management Group, School of Management, University of Texas at Dallas, Richardson. His research interests are in discrete optimization problems in manufacturing and operations. His book, Throughput Optimization in Robotic Cells with N. Geismar, S. Sethi, and C. Srisankdarajah, was published in 2007. He serves as an Associate Editor for a number of journals, including Manufacturing and Service Operations Management, Production and Operations Management, IEEE Transactions, and the Journal of Scheduling.

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