Big data analytics in semiconductor manufacturing: An analysis of state-of-the-art methods

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1 Introduction

Nowadays, the advent of Industry 4.0 and the explosive development of big data analytics, give rise to novel forms of industrial practices, based on the integration of physical and digital dimensions. This paper focuses on the recent advancements of big data analytics in the semiconductor manufacturing industry, subject to a continuous exponential growth of facility-wide data volumes [3].

The increase of low-cost and heterogeneous demand for integrated circuits heavily drives technological advances and high levels of automation in semiconductor manufacturing. A high level of automation and the complexity of product routes, including hundreds of tools and process steps and re-entrant flows, make semiconductor manufacturing the most complex manufacturing process. To cope with these challenges, the Advanced Process Control (APC), a family of facility (called fab for short) operation analytics, has been introduced in the 1990s as a tool for a competitive edge, and became a requirement in the early 2000s [3]. The emergence of big data analytics in semiconductor manufacturing provides promises not only to improve the existing APC capabilities, but also to create new high value-added capabilities. Even if many challenges still abound, a number of improved and new capabilities have been found in the literature in virtual metrology, predictive maintenance and predictive scheduling [1, 6].

Being written in the complementarity of the existing related surveys [2, 5, 3], this paper seeks to review and analyze the capabilities and the industrial competitiveness of the state-of-the-art big-data analytics approaches, and to discuss their implications on managerial decision making. Based on extensive computational experiments, a number of research avenues will be derived to support the big data analytics development in semiconductor manufacturing.

2 Analysis of state-of-the-art methods

For the sake of rigor, this literature review is conducted according to the following approach:

- **Providing the related definitions and the scope of APC:** This stage includes both the basic APC components (fault detection, classification and prediction, run-to-run control, statistical process control), and extended APC components (equipment health monitoring, predictive maintenance and scheduling, virtual metrology, yield prediction).

- **Identifying, implementing and analyzing big-data analytics methods:** In accordance with the nature of the studied APC component, statistical process control methods, regression methods and machine learning approaches are under investigation in this paper.

- **Quantifing analytics capabilities:** The analytics capabilities have been studied through the prism of six levels of control and diagnostics proposed in [4]: supervision, prediction, correlation, dynamics, state, and Subject Matter Expertise (SME) knowledge. Based on real-life instances, extensive numerical experiments are in progress to evaluate the capabilities, and the industrial soundness and tractability of big-data analytics approaches.
- **Deriving managerial implications of big-data analytics:** Extended APC components are both consumers of outputs from basic APC systems, and suppliers for management systems (see FIG. 1). The impact of predictive analytics of extended APC on the incoming and outgoing flows of data will be discussed at the fab-wide level.

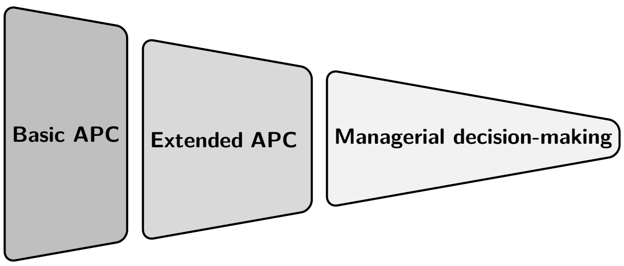

FIG. 1: From basic APC to managerial decision-making

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References

[1] K. Dongil, k. Pilsung, C. Sungzoon, L. Hyoung-joo, and D. Seungyong. Machine learning-based novelty detection for faulty wafer detection in semiconductor manufacturing. *Expert Systems with Applications*, 39(4):4075 – 4083, 2012.

[2] T. Edgar, S. Butler, W. Campbell, C. Pfeiffer, C. Bode, S.B. Hwang, K.S. Balakrishnan, and J. Hahn. Automatic control in microelectronics manufacturing: Practices, challenges, and possibilities. *Automatica*, 36(11):1567 – 1603, 2000.

[3] J. Moyne and J. Iskandar. Big data analytics for smart manufacturing: Case studies in semiconductor manufacturing. *Processes*, 5(3):39, 2017.

[4] J. Moyne, J. Samantaray, and M. Armacost. Big data capabilities applied to semiconductor manufacturing advanced process control. *IEEE Transactions on Semiconductor Manufacturing*, 29(4):283–291, 2016.

[5] J. Moynes, J. Samantaray, and M. Armacost. Big data capabilities applied to semiconductor manufacturing advanced process control. *IEEE transactions on semiconductor manufacturing*, 29(4):283–291, 2016.

[6] W. Yang, J. Blue, A. Roussy, J. Pinaton, and M. S. Reis. A structure data-driven framework for virtual metrology modeling. *IEEE Transactions on Automation Science and Engineering*, pages 1–10, 2019.