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EVALUATION OF LOT RELEASE POLICIES FOR CYCLE TIME IMPROVEMENT IN SEMICONDUCTOR MANUFACTURING SYSTEMS: A PETRI NET APPROACH

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ABSTRACT

We present a framework to approximate and improve the cycle time of semiconductor manufacturing fabs. We model the system as a generalized stochastic Petri-net and compare it to previous approaches, evaluate the advantages and consider this framework as an alternative to simulation models for practitioners. Using this framework the effect of applying certain control rules can be examined. These rules are often implicit and informal and are applied based on experience of operation managers with the goal of cycle time reduction. The present framework can provide the means to examine the effectiveness of such rules and help the operation managers make informed decisions regarding the application of such control rules.

INTRODUCTION

Semiconductor manufacturing is a highly competitive industry, where high service levels are demanded by customers. The time elapsed between the setting of an order and the delivery of the finished product to the customer facilities has to be short enough so the desired service level can be accomplished. Therefore, cycle time (CT) becomes a key focus for decision making in semiconductor manufacturing systems (SMS). However, cycle time depends on the complicated process flows of SMS (Shanthikumar, Ding, & Zhang, 2007): raw material must go through several steps whose time of completion is variable, before finishing the whole process (Kempf, 2011). Some of those steps include re-entrant flows to stations where tools are unreliable and are subject to preventive maintenance and random emergency repairs. This phenomena introduces an increase of cycle time length, variability, and estimation difficulty (Shanthikumar, Ding, & Zhang, 2007).

In order to help semiconductor manufacturers to improve their performance measures, several operative policies have been suggested (Sandell & Srinivasan, 1996). An operational policy gives a set of decisions to follow, given the status of certain variables in the system (Winston, 2004). Sequencing, scheduling, lot sizing and lot release policies are among the operational policies proposed in the literature. In this work, we focus on a lot release policy, more specifically, on a workload regulating policy.

Given the characterization of SMS and the high operating costs, testing operational policies on actual semiconductor manufacturing factories implies the risk of dropping performance, incurring in high costs and underachieving client demands. Hence such policies must be tested on models of real-life SMS. Different tools exist such that they take into account the stochastic nature of the SMS, including discrete-event simulation, queueing theory and statistics, among others. These approaches have their strengths and weaknesses that have to be considered in order to meet practitioners' requirements.

We compare a discrete-event simulation approach to analytical stochastic modeling, more specifically, Markov models and Generalized Stochastic Petri Nets (GSPN). Simulation and Markov models have

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been evaluated in a previous work by Ruiz and Akhavan (2011), in which the suggested policy succeeded in reducing cycle time. In this work we want to evaluate the effectiveness of GSPN as a modeling tool in terms of computational time, modeling complexity and consistency with results obtained by the previous study.

The Markovian nature of both the Markov models and GSPN requires the underlying distributions to be exponential. However, this can be far from the reality of SMS. To relax this requirement an approximation method in order to fit a proper Hyper-Erlang distribution to the non-exponential distributions is suggested. However, this can result in the expansion of the state-space, hence making the solution procedure long and inefficient. For the case of Markov chains, effective solution algorithms developed for Quasi Birth-Death Processes (QBD's) apply. However this implies some knowledge in queueing theory and programming. For the case of GSPN models, this inclusion implies an increase in the computational time and renders an inefficient methodology.

Simulation seems more flexible in terms of modeling ease, but its results depend on generation of random numbers, does not allow derivation of an expression for the desired performance measures, unlike the GSPN and queueing network. Also, it is not convenient for tactical decision support as it needs long replications. Other disadvantages include the need of commercial packages for modeling big SMS factories. There is a trade-off between ease of modeling, cost, and exactitude of the estimations. Choosing a framework as a decision support tool depends on the practitioner requirements.

GSPN proved to be a really useful tool as it allows modeling different features of the system, such as synchronization, concurrent operations, and mutually exclusive relations, among others. Also, it stands between Markov models and simulation as it renders an analytical estimation of performance measures and allows a graphical visualization of the behavior of the system. For this particular case, Petri nets performed well for models with smaller state-space. For larger models, the run time was too long to be considered convenient to support short-term tactical decisions in SMS. However, as no commercial Petri net package has been developed -to our knowledge-, this framework has the potential to become a more powerful tool when more efficient algorithms to solve the steady-state are developed.

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