Simulation Optimization for the Management of Time Constraint Tunnels in Semiconductor Manufacturing

B. Anthouard[1,2], Q. Christ[2], S. Dauzère-Pérès[1], R. Roussel[2]

[1] Mines Saint-Etienne, Univ Clermont Auvergne, CNRS, UMR 6158 LIMOS, Gardanne, France
{b.anthouard, dauzere-peres}@emse.fr

[2] STMicroelectronics, Crolles, France
{quentin.christ, renaud.roussel}@st.com

Mots-clés : *Production control, Time constraints, Semiconductor manufacturing, Simulation optimization.*

1 Context, problem statement and motivation

To ensure the quality of integrated circuits, semiconductor manufacturing factories (fab) need to respect *Time Constraints* (TC). *Time constraints* are critical times not to exceed between two operations or steps in a product route. More broadly, a set of consecutive steps under at least one TC is called *Time Constraint Tunnel* (TCT). These quality requirements, added to other challenges in a High Mix/Medium Volume factory (e.g. long cycle times, re-entrant flows and heterogeneous complex machines) become stressful for operators regulating TCTs in real time. Due to the complexity of the fabs and lots competing with each other to access critical resources, managing TCTs is complex.

In the factory, operators often use simple rules based on Little's law [5] to define a maximum number of lots (WIP_{max}) that can be managed under a TC, using the duration of TCs, the throughput of the machines and a safety coefficient. However, this rule consider TCs independently which is limited in High Mix/Medium Volume factories, where lots are competing for critical machines. To take this into account, scheduling, capacity planning or production control can be considered. Scheduling seems limited in our case, as shown in [3], due to approximations and events happening in the factory (such as machine state changing), global scheduling needs to be constantly adapted or recomputed. Capacity planning and production control, usually using queuing theory, are limited as models are considering some configurations and also a steady state that is often never reached. The most promising results rely on simulation [6, 4] that explicitly model the competition between lots. Based on these previous studies, a simulation system and its decision support capabilities have been presented in [1, 2]. This abstract improves this previous work by proposing TCT entrance rules using simulation combined with optimization to manage TCTs.

2 Solution approach

With the simulation approach described in [1], relevant key performance indicators (KPIs) can be extracted to create TCT entrance rules that can then be evaluated by simulation and improved through an iterative optimization approach. The rules that are created are similar to the ones currently used in the factory by operators, defining a WIP_{max} values for a single TC or a groups of TCs. With the simulation approach and WIP_{max} defined for groups of TCs, the mix of lots and the competition between lots is considered.

The three grouping strategies below have been identified to manage TCTs.

- *Single TC:* Considering a single TC can be useful, as TCs have different critical time values and short TCs often need to be considered with additional more restrictive WIP_{max} values to be properly managed.
- *Group by critical machine:* Criticality measures for machines in terms of TCs are described in [2]. The previous iteration of the simulation defines for each TC the most critical machine. The idea here is to group TCs accessing the same critical machine and manage them together to avoid a machine to be overloaded by lots under different TCs competing with each other.
- *Group by start of TCT:* Due to the management rules of TCs in the factory, some WIP_{max} values can be exceeded. A lot entering a TCT might enter new TCs without checking the WIP_{max} values because it must continue its route in order to respect previous TCs. In this case, TCs succeeding or overlapping each other must be considered together in order to avoid exceeded WIP_{max} values. The idea is to find the critical TC of the TCT (the one being exceeded in the simulation) and manage a group that contains all TCs overlapping and succeeding from the beginning of the TCT to the critical TC.

Numerical experiments show that, in the simulation approach, WIP_{max} values and groups proposed when considering the three grouping strategies are relevant, and help to considerably reduce the number of exceeded TCs with less negatives impacts on other KPIs such as the number of respected TCs or the number of wafers being processed. A decision support tool that embeds the proposed approach is currently used by some operators to compare with the ground truth.

3 Conclusions and perspectives

Combining simulation and optimization allows TCT entrance rules to be created and evaluated. To create these rules, three grouping strategies (single TC, critical machine, beginning of TCT) have been explored and seem sufficient to manage TCTs using WIP_{max} values. A decision support tool has been created and is currently tested by operators. The results are promising, mainly on short TCs, and our current work focuses on TCs that are longer than the current simulation horizon.

References

[1] Benjamin Anthouard, Valeria Borodin, Quentin Christ, Stéphane Dauzère-Pérès, and Renaud Roussel. A simulation-based approach for operational management of time constraint tunnels in semiconductor manufacturing. In *Annual SEMI Advanced semiconductor manufacturing conference (ASMC 2022)*, 2022.

[2] Benjamin Anthouard, Valeria Borodin, Stéphane Dauzère-Pérès, Quentin Christ, and Renaud Roussel. Criticality measures for time constraint tunnels in semiconductor manufacturing. In *2022 Winter Simulation Conference (WSC)*, pages 3326–3337. IEEE, 2022.

[3] Chihyun Jung, Detlef Pabst, Myoungsoo Ham, Marcel Stehli, and Marcel Rothe. An effective problem decomposition method for scheduling of diffusion processes based on mixed integer linear programming. *IEEE Transactions on Semiconductor Manufacturing*, 27(3):357–363, 2014.

[4] Alexandre Lima, Valeria Borodin, Stéphane Dauzère-Pérès, and Philippe Vialletelle. A sampling-based approach for managing lot release in time constraint tunnels in semiconductor manufacturing. *International Journal of Production Research*, 59(3):860–884, 2021.

[5] John DC Little and Stephen C Graves. Little's law. *Building intuition: insights from basic operations management models and principles*, pages 81–100, 2008.

[6] Rezvan Sadeghi, Stéphane Dauzère-Pérès, Claude Yugma, and Guillaume Lepelletier. Production control in semiconductor manufacturing with time constraints. In *26th annual SEMI Advanced semiconductor manufacturing conference (ASMC 2015)*, pages 29–33. IEEE, 2015.