A multi-objective optimization model for scheduling in the photolithography area in semiconductor manufacturing

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1 Introduction

Semiconductor manufacturing includes the most complex manufacturing processes. Scheduling problems to be addressed at the operational level involve a rich set of constraints and criteria. As a result, optimization algorithms are increasingly preferred over dispatching rules, especially in complex production areas such as the photolithography area which is considered in this paper.

2 Problem description

The scheduling problem in the photolithography area consists in scheduling a set of jobs on a set of parallel photolithography machines. Each job requires an additional resource, called reticle, that can be transported from one machine to another.

Jobs. Each job needs to be processed with a given priority. Few jobs have precedence constraints (without formally considering the problem as a flexible job-shop scheduling problem), and must not exceed a maximum time lag. Engaged maximum time lag constraints when starting the schedule are modelled by assigning a deadline to each job.

Photolithography machines. Each machine is qualified to process one job at time, and may not be available before a certain date. Processing on the machine is non-preemptive and its duration depends on both the job and the machine. Finally, a machine-dependent and sequence-dependent setup time is required to start the processing of a job.

Reticles. Each job requires one reticle, which is available in a single copy. Jobs are assumed to have a competitive access to reticles (otherwise, considering them would be trivial). Besides, transporting a reticle between two machines takes a sequence-dependent duration.

3 Multi-objective scheduling model

The above scheduling problem is addressed through an Integer Linear Programming (ILP) model based on the works of [2] and [1]. Time is divided into periods of equal duration. A feasible solution is represented by binary decision variables associated with each triplet (job, machine, period). Several constraints are defined to comply with the description made in the previous section. Moreover, all jobs must be scheduled before the end of the time horizon.

Several objective functions are defined based on the factory requirements. All the criteria must be considered in the optimization problem, which makes it multi-objective. Overall, three categories of criteria are studied :

— Criteria implementing relaxed operational constraints, such as the minimization of a total risk function associated with the maximum time lag constraints and deadlines ;
— Criteria to meet production targets of the manufacturing area :
  - Minimize the sum of the completion times of jobs,
  - Maximize the number of jobs scheduled before a certain time threshold ;
— Criteria aiming at improving the industrial efficiency :
  - Minimize the total setup times of machines,
  - Minimize the total number of reticle moves.

4 Relationship between the objective functions

To reduce the number of objective functions, the relationship between the objective functions in the previous section is analytically studied. Considering two distinct objective functions f and g of the same optimization problem, let us denote by $\mathcal{X}_f^*$ and $\mathcal{X}_g^*$ their respective set of optimal solutions. Function f is said to *dominate* function g when $\mathcal{X}_f^* \subseteq \mathcal{X}_g^*$. In such a case, objective function g can be removed from the model since it is sufficient to optimize objective function f to optimize g.

Regarding the classical single-machine scheduling problem, several results have been shown. For instance, the minimization of the sum of the completion times of jobs dominates the minimization of the makespan and the maximization of the number of jobs scheduled before a time threshold. When several machines are considered, no specific relationship has been highlighted between objective functions, which proves that the selected set of criteria cannot be reduced in the general case.

5 Conclusions

The mathematical model will be presented in details in the conference, together with numerical experiments showing the limits of the model and the impacts of the different objective functions.

References

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