Systematic construction and performance analysis of cluster tools using timed Petri net models

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Abstract

A cluster tool is an integrated, environmentally isolated manufacturing system consisting of process, transport, and cassette modules, mechanically linked together, used in manufacturing of semiconductor chips. Because of high throughput requirements, cluster tools perform a number of activities concurrently, for example, different wafers are processed in different chambers at the same time, and also the robotic transporter can be moving to a position required by the next step. Petri nets are formal models developed specifically for representation of concurrent activities and for their coordination. In timed nets, occurrence times are associated with transitions, representing the durations of modeled activities; this allows to study the performance characteristics of the modeled systems.

Timed Petri nets, as models of cluster tools, represent the flow of wafers through the chambers of the tool as well as sequences of actions performed by the robotic transporter. Since the durations of all activities are also represented in the model, performance characteristics can be derived for a variety of tools, including tools with multiple loadlocks, redundant chambers and multiple robots, as well as wafer routings with chamber revisiting and processing of wafers of multiple types.

Since cluster tools can be quite complex, a systematic approach to generating net models is proposed. The generated net models have a modular structure, which is used to determine the steady–state performance of the model on the basis of net invariants, without the exhaustive reachability analysis. Performance characteristics are obtained in symbolic form, in terms of modeling parameters, so different variants of cluster tools can be evaluated and compared very efficiently, without repetitive analyses of the model.