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Cycle time management during production ramp-up

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Abstract

Aggressive capacity ramp rate of a semiconductor wafer fabrication is vital for the commercial success of the enterprise. Basic requirements are short and stable production cycle times to timely qualify equipment and to provide acceptable yield. Therefore, in the ramp-up environment which is characterized by high variability and uncertainty, an adequate methodology is required to properly manage the conflict of short cycle times and fast throughput increase. This paper presents a methodology to manage cycle time by closely monitoring and limiting the work in process (WIP), by means of the so-called ''WIP caps''. Used consequently, this methodology allows the ramp rate to accelerate as soon as the factory performance enables this while keeping cycle times under control.

1. Importance of cycle times during ramp-up

''Ramp-up'' is the process of increasing production rate of a factory from the first lot to full volume. This occurs when a new product is introduced into a factory. The speed of the ramp-up strongly impacts the time-to-volume of a product and by that its financial success. On the one hand, product prices are at their highest early in the life cycle. On the other hand, the ramp-up phase itself may take already a considerable part of the products life cycle, since the life cycles of many products (especially within the semiconductor industry) are shortening and product generations are being replaced faster and faster.

During the life cycle of a factory, ramp phases reoccur with each new product and product generation. But the initial ramp-up is the most difficult and challenging. Tools, technology and manufacturing processes have to be timely installed, qualified and matured to provide acceptable yield. All of those tasks are directly affected by the cycle time.

Yield: An acceptable product yield is a prerequisite for volume production. On the one hand, it strongly influences the manufacturing costs; on the other hand, it limits the output of quality products and by that the revenue. Yield is also an indicator for process maturity. As long as the yield is low, extensive activities are required to improve the knowledge concerning the process. Thereby, learning is driven by two effects: Designed experiments help to solve specific problems, while the rate of production increases production experience [1]. Both effects strongly depend on cycle time because in many cases the analysis can only be done after finalizing the full process. The cycle time defines the duration of learning cycles and by that impacts heavily the learning speed.

Product qualification: For most markets, products need to be formally qualified to be accepted from customers and to realize reasonable market prices. Therefore, extensive experiments with the products are carried out. Their results also provide detailed knowledge about the process and reduce the manufacturing risk. Basis for qualification is a certain number of lots manufactured with the same process flow and a reasonable yield. Therefore, after an initiating learning phase a number of lots has to run fast through the line with a frozen process. Cycle time sets the speed of qualification.

Equipment qualification: During ramp-up new equipment needs to be delivered, hooked-up and installed with the right process. In particular, if it is released first time for production, detailed experiments and analyses are required to prove the process capability. Only when the equipment is released to production, its capacity can be used. But already with the arrival at the factory the equipment starts to accumulate costs, such as:

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deprecation, facilities and engineering. Short qualification times speed up the throughput ramp and reduce manufacturing costs. But the qualification of most critical tools depends on test lots which need a certain cycle time to get to analysis.

All key aspects of an initial ramp-up are driven by short cycle times. They directly impact the economical success of the factory. In addition to these ramp-specific facts, all the generic arguments for short cycle times are valid, such as low-inventory costs, improved transparency and short reaction times.

2. Characteristics of material flow during ramp

In order to limit unexpected impacts on the ramp-up, usually it is aimed to use as many as possible well-known elements for a new factory: Only one product which possibly runs already in another factory, equipment which is matured and copied from another site, and experienced people. But with the accelerating speed of technology changes, more and more often this ideal conditions are not given.

Therefore, during ramp-up sources of variability, such as breakdowns, test lots or process stops, have to be managed, which impact the material flow more than in a mature volume factory. In addition to the variability, during ramp-up also a major uncertainty of capacity forecasts and the characteristics of the ramp itself have to be considered.

2.1. Volume-ramp-specific characteristics

Because of technical and economical reasons, a wafer fabrication cannot be operated with full volume from the beginning. Instead of that a ramp rate of up to 1000 weekly wafer starts per quarter is typical. Therefore, a production facility with a capacity of 8000 wafer starts per week takes approximately 2 years to ramp completely.

On the other hand, typical cycle times are between 30 and 60 days. That is why also during one cycle time the throughput increases significantly and at the same time, steps located at the end of the process need to perform significantly lower throughput than earlier steps. With that throughput ramp the amount of material in the line also , the work in process "WIP" increases. Therefore, at the beginning of the line, the WIP levels are higher than at its end.

While throughput and WIP levels are constantly increasing, the production line is characterized by being extremely unbalanced during ramp-up. This effect of unbalanced capacities is caused by the different quantities of tools which are required per process step for the full volume of the factory. If only few machines are required in total, the capacity increases with big steps. Overcapacity is provided at the affected steps as long as the overall line throughput is limited by other machine groups. Additionally, the first two machines of a kind are usually installed in parallel, to lower the dependence from one specific machine. That enhances the effect of overcapacities during the first time of the ramp-up. Therefore, during the ramp-up some process steps are still low utilized, while the utilization of others is already high. This situation of unbalanced capacities can support short cycle times but has to be managed.

2.2. Impacts of variability in product, processes, equipment and people

Variability of manufacturing processes causes material to wait temporarily and by that extends cycle times. During ramp-up there are many sources of variability. Engineers get to know the product better and improve manufacturing processes. In parallel new equipment is installed and people are trained. All this impacts the material flow and by that cycle times.

Product: Until a new product is finally integrated with the tool set, adaptations of the process flow need to be implemented. Therefore, manufacturing experiments are necessary which require additional measurements and analyses. In worst case, production has to be stopped at single processes until the process offers acceptable results.

Unit process technology: Until processes are optimized and production procedures are developed, interruptions of production and considerable engineering times occur, especially if new tool types are used. For the release of a process on an additional parallel tool, a matching of the process with the already operated tools has to be verified. The process on the new tool is released only if remaining differences are proven not to influence the yield. Delays impact not only variability but also capacity.

Equipment: When equipment is released to production for the first time, in many cases it will show teething troubles. These are accompanied by a limited uptime and long repair times. As long as only few machines are released to production, this missing reliability impacts the material flow heavily.

People: Accompanying the volume ramp, the co-operation of people and departments as well as production procedures still develop. With ramping throughput, targets are reset and habits need to be changed from the first steps in a pilot environment to volume production.

2.3. The fact of uncertainty

All these aspects result in a high degree of uncertainty during the ramp. Uncertainty exists in qualification dates of tools and processes and there in uncertainty