Fast Throughput Improvement Through Speed Modeling Using Tool Matching and Process Optimization.

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Abstract – Traditionally, speed models have been used in the semiconductor industry to validate machine throughput or rate in terms of units per hour (UPH), but their true value lies in their ability to increase output. The MAX Group developed a series of techniques and tools that build upon the traditional models to improve the efficiency and value of speed modeling. This paper shares the methodology and how to practically utilize "big data" to improve performance and it's application to any Compound Semiconductor Fab.

TOOLSET, TOOL AND RECIPE SELECTION

Identifying the correct tools is key to generate quick gains that effectively will increase the capacity of the fab. We developed a tool called Raw UPH Deviation (RUD) to facilitate this process. RUD takes start and end times, from the MES system, for every lot in the fab, and it generates a comparison of all the tools in a capacity group which ranks the tools from faster to slower. This analysis is done on a recipe by recipe basis; therefore, it can perform comparisons for tools that are not running the same recipe mix, and it also takes into account the total recipe usage for the entire tool-set to add additional weight to the most used recipes. This process can be easily applied to all the toolsets in the fab in a single pass, eliminating the need to analyze toolset by toolset.

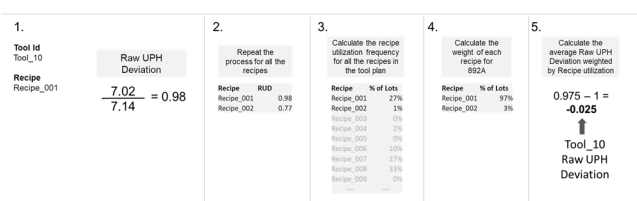

Figure 1. RUD analysis process example.

The first step to calulcate RUD is to remove outliers, generally the lowest 10th and highest 90th percentiles are removed. Then, the average speed of each tool and for each recipe are compared against the group average for that recipe. Finally those ratios are weighted using the total recipe utilization for the entire toolset.

As an example, the analysis in Figure 2 shows that there is 19% speed difference between the fastest and the slowest CVD tools. Creating this comparison for all the toolsets in the fab allows to rank the toolsets in order of potential improvement based on RUD. Combining this information with bottleneck index, or other ranking of fab importance, allows for a quick selection of important toolsets with high potential for improvement.

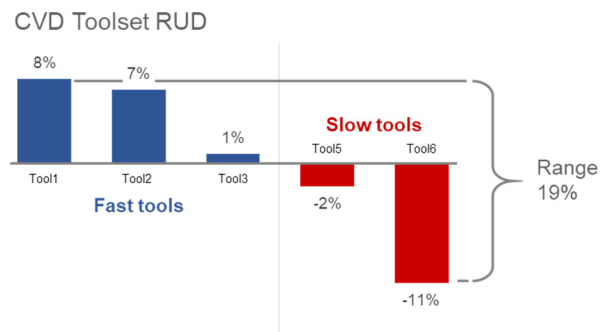

Figure 2. RUD result example – CVD toolset.

DATA MINING: TOOL LOGS AND TIME STUDIES

We use two sources of data to create the speed models: Tool logs and time studies. In many cases a combination of both is necessary.

While tool logs are generally t the preferred way, they come in many different formats and styles. Different tools from the same vendor can have completely different tool log formats. To tackle this problem, we developed a Python script that lets the user easily program the pieces of data that are valuable from a tool log. The script then can process hundreds of tool logs in minutes, and provide a table with all the information requested.

The ability to quickly process large number of tool logs opens the possibility of using "big data" to improve the value of the analysis. Processing data for significant periods of time allows for tracking of deviations on processing time due to changing conditions that affect the process. These conditions include degradation of equipment, impact of PM events, and recipe combinations or sequences. This information then can be used to reduce variability in processing times, by optimizing the frequency of PM events and combination of recipes that run in parallel or in sequence.

Our second source of data, time studies, is used when tool logs are not available or it cannot provide enough detail. This process involves watching the tool or the tool interface, while it process a particular recipe, and time the start and end of all the steps affecting the total process time of a lot. Because most tools process more than one wafer at the time, a video recording is recommended, and then time stamps are extracted from the video. Generally, this approach takes between 3 to 4 times the tool processing time; therefore, it is not pragmatic to gather the same amount of data as with tool logs.

SPEED MODEL

With the raw data extracted from tool logs or time studies, a model is created for each tool. This model displays all the steps in a process for each wafer in a Gantt chart.

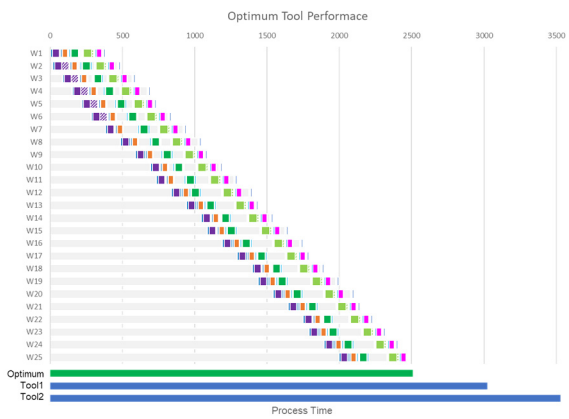

Figure 3. Gantt chart example for a CVD toolset.

The Gantt chart allows for quick identification of wafer to wafer variability, the interactions between different components and usage of bottleneck resources.

In addition to the Gantt chart, average, min, max and standard deviation are calculated for each step in the process. Using this data, a "golden" tool is created, combining the fastest process time from all tools in the fleet. This golden tool becomes the internal benchmark to standardize all the tools.

Finally a model including all the steps in the process is created to calculate the theoretical throughput of the tool. These models can be created in Excel, which allows most people in an organization to use the models to determine what if scenarios due to recipe changes, staging and cascading levels, lots and batch size and any other factor thay may impact the tool throughput.

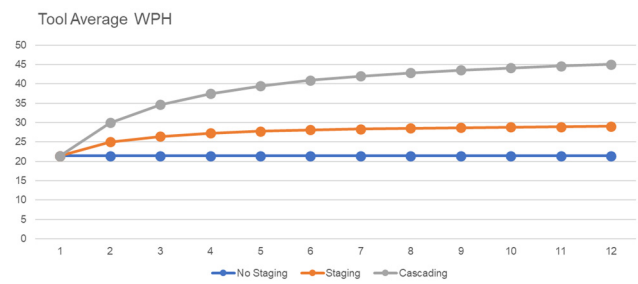

Figure 4. Example of cascading and staging levels affecting WPH.

Final output of the model, tool UPH by recipe, is then used in the capacity model.

IMPROVEMENT EXAMPLES

Figure 5 shows a Gantt chart with an example of a process sequence improvement. This tool waits until it finishes the Wafer Auto Clean (WAC) step to pick up the next wafer. To save time, picking up the next wafer should be done in parallel while the chamber does the WAC. Switching the tool to run in parallel mode increased the average tool speed by 6%.

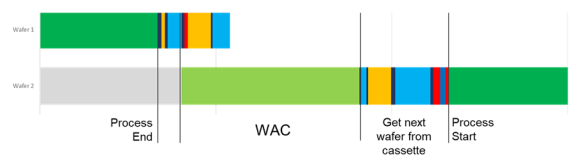

Figure 5. Step sequence in a dry etch tool.

Figure 6 shows a reduction in idle time (white space) for a bottleneck chamber by enabling a second blade in the robot. With one blade (top), the idle time between processes is 34 seconds, enabling the second blade reduced the idle time to 14 seconds, resulting in a 8% speed improvement.

Figure 6. Idle time reduction .

Figure 7 shows a reduction in process time by matching the process times in two different tools. While Tool 1 had the faster overall process time (Chamber 1 was the bottleneck process), Tool 2 had faster third and fourth steps in the process. The "Golden" tool was created using the fastest

steps from both tools and it was set up as the benchmark for tool matching.

Step	Description	Tool1	Tool2
1	Heat Up	49s	59s
2	Chamber 1 Deposition	53s	68s
3	Chamber 1 Stabilization	27s	4s
4	Chamber 2 Deposition	61s	56s
5	Chamber 2 Stabilization	12s	15s
6	Cooldown	33s	38s
7	Cooldown Stabilization – difference only observed for 1st wafer	3s	32

Figure 7. Process times comparison betwenn two tools for the most common recipe.

CONCLUSION

Speed modeling is a technique that yields multiple benefits. It provides an accurate speed that can be used to calculate capacity, including an ability to measure the impact of changes in recipe or in production environment (e.g. lot size). More importantly, it provides a guide to improve the speed performance of tools by optimizing wafer flow, robot configuration and process step matching.

This methodology can beapplied to any Compound Semiconductor manufacturer. The results yield about 10% improvement in throughput on average. This is significant for fab tools that are bottleneck toolsets. As an additional benefit, engineers gain more knowledge about the tool, after developing a speed model This new knowledge can facilitate new ideas and improvements.

References

Realizing Throughput Improvement Through Machine Rate Modeling -Mantech 2007