Efficiency improvements of off-line metrology job creation

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ABSTRACT

Progress of the first lot of a new design through the production line is watched very closely. All performance metrics; cycle-time, in-line measurement results and final electrical performance are critical. Rapid movement of this lot through the line has serious time-to-market implications. Having this material waiting at a metrology operation for an engineer to create a measurement job plan wastes valuable turnaround time. Further, efficient use of a metrology system is compromised by the time required to create and maintain these measurement job plans. Thus, having a method to develop metrology job plans prior to the actual running of the material through the manufacturing area can significantly improve both cycle time and overall equipment efficiency. Motorola and Schlumberger have worked together to develop and test such a system.

The Remote Job Generator (RJG™) creates job plans for new devices in a manufacturing process from an NT host or workstation, offline. This increases available system time for making production measurements, decreases turnaround time on job plan creation and editing, and improves consistency across job plans. Most importantly, this allows job plans for new devices to be available before the first wafers of the device arrive at the tool for measurement. The software also includes a data base manager which allows updates of existing job plans to incorporate measurement changes required by process changes or measurement optimization. This paper will review the results of productivity enhancements through the increased metrology utilization and decreased cycle time associated with the use of RJG™. Finally, improvements in process control through better control of Job Plans across different devices and layers will be discussed.

Keywords: Off-line job plan creation, metrology, cycle time

1. INTRODUCTION

By the end of 1998, trends in the semiconductor industry forced manufacturers to become more cost-driven, while maintaining high quality products and minimizing time-to-market. At Motorola BMC, older critical dimension (CD) and overlay optical tools are being phased out and replaced with newer metrology tools to provide the benefits of more repeatable measurements and higher throughput.

In order to integrate the new metrology tools into the production line, job plans had to be transferred from the older tools to the newer ones. Requirements for this transfer included maintaining both the integrity of the job plans and the consistency of the job plans from tool to tool. In addition, the impact on wafer in process (WIP) time required by transferring the job plans needed to be minimized.

To meet the needs of the consolidation of the fabs in a timely manner, and to minimize cycle time, an off-line job plan creation and management tool was utilized. This allowed job plans to be transferred from the older metrology tools in a very consistent manner, and required significantly less time to create the job plans than if they had to be created on the metrology tools themselves. Since the metrology tool was not required to create all of the new job plans, this provided a significant improvement in cycle time. This also ensured that job plans for new devices were available before the first wafers arrived at the metrology tool for measurement.

A study was performed to quantify the time saved by using the off-line job plan management tool. In this study, traditional methods of generating job plans on-line were compared with use of the off-line job plan generator. The results of the study included analysis of WIP time, the time reduction in generating job plans, and identification of non-quantitative issues.

2. THE METROLOGY PROCESS

Depending on the product, a typical process requires up to seven CD layers being identified as critical, or requiring metrology qualification to maintain a high yield. A prototypical measurement scheme for CD's includes measuring three wafers per lot at four measurement sites per wafer. A population of twenty-eight sites is typically measured for overlay.

The retiring of some of the metrology equipment required that the metrology needs for several devices had to be transferred to the newer, more capable tools. One of the chief concerns was that the hand-over to the new tools must provide consistent measurements across devices, in a timely manner, with as little impact to the WIP as possible. Hence, there is a need for a tool which can help with this transition - the off-line job plan manager.

3. ON-TOOL VS. OFF-LINE PROGRAMMING

When a hot lot of a new device is being processed through the production line, the time spent waiting for an engineer to be available to create a job plan for each layer can be considerable. Writing a job plan in the traditional way, on-line, requires the use of the metrology tool, a processed wafer from the production layer being measured, and the time of a trained individual to write each job plan. This involves first setting up a wafer map for the device being measured, where wafer size, die size, grid offsets, global alignment marks, and die to be measured are specified. This information is unique for each device, but can be re-used to create job plans for different layers of the same device.

A job plan for a given process layer contains a unique set of pattern recognition images to be used for global wafer alignment and at the measurement site, as well as an optimized measurement template, containing specific focus and measurement algorithms. This information can be used to create a job plan for an identical process layer of a different device.

For off-line job plan creation to be successful, the Fab must have a consistent and well-defined set of processes used to manufacture its product devices. The underlying premise of off-line job plan creation is that the same feature placed on two different devices can be measured using much of the same information. For a given process, scribe lines must be standardized, or the location of the overlay or CD targets within them must be known. The must contain identical cells of overlay and critical dimension targets, as well as features that can be used for global alignment across all devices. Golden job plans are created under these conditions and a set of optimized measurement templates for any device needs to be set up only once by a trained individual. This information can then be re-used by another person to generate a set of job plans for a new device. In this way, metrology expertise is not needed for off-line programming. The individual creating job plans off-line only needs to know the device specific information of field size and offset. Making modifications offline also allows for global changes to all devices at once instead of modifying each job plan, one at a time.

4. EXPERIMENTAL PROCEDURE

Job plans were set up on seven critical layers for the IVS-120, the metrology tool used in this study. The layers included polysilicon, nitride, and several metal layers. Initially, job plans were written in the traditional manner for all layers of several devices, and the time required was recorded. This time was then projected for 10 layers each for 10 devices.

A single job plan from each layer was then used to complete a set of golden job plans for use in the off-line job generator tool. This tool was used to create all job plans for 10 devices, and the time required to create the job plans was recorded. The job plans were then tested to ensure their performance.

In a typical fab setting, when a new device is created, the first lot will arrive at the new metrology tool, and the operator will realize that a job plan does not yet exist for that lot. The operator will then have to contact a trained engineer or technician and the lot must wait until the responsible person creates a new job plan. Each time this happens, the tool will not be available for production use while it is being used to create the new job plan. This scenario recurs for each job plan of each layer of each new device, causing significant delays in both cycle time and time-to-market.

To account for the time saved by the off-line job plan generator tool, an estimate is provided for the time required for a lot to wait for a job plan to be written and the time required to write the job plan on-line, for each layer. This time will be projected for 10 devices to compute the WIP time saved by the off-line job plan generator tool.

Since the off-line job plan tool is also a job plan manager, a process change was assumed at one layer. The job plans were changed for that layer using the conventional manner on-line, and the time required was recorded. This time was projected for each of the job plans. The same process change was then incorporated into the one golden job plan for that layer, and the change was updated for all subsequent devices using the off-line job plan management tool. The time required for this change was entered.

5. JOB CREATION RESULTS

The time required to produce a job plan on-line averaged to 9.78 minutes. For 10 job plans per device, the projected time per device would be 97.8 minutes. For 10 devices this would be 978 minutes, or 16.3 hours.

The time required to produce the golden job plans would be the same for one device, or 97.8 minutes. The average time to generate a job plan on the off-line job plan generator tool is 31 seconds. Therefore, to create 10 job plans for 10 devices each would require 51.67 minutes plus the 97.8 minutes required to create the golden job plans, or a total of 149.47 minutes or 2.49 hours.

Waiting for a job plan to be created for a lot can require almost no time if a trained engineer or technician is readily available; or it may require holding a lot for an entire weekend if a trained person is not available. On average, this was found to be 120 minutes. As stated earlier, 9.78 minutes are required on average to create a new job plan. If a device requires 10 job plans, then the lost WIP time for that lot would be:

Lost WIP time = (# job plans/device)*(average hold time + job creation time) (1)
= 10*(120 + 9.78) = 1297.8 minutes, or 21.63 hours per device

If all of the job plans had to be created on-line, this would lead to 216 1/3 hours of lost WIP time for 10 devices. Since the off-line job plan manager requires making the golden job plans on-line, this would also incur the same lost WIP time for the time required to create the golden job plans. But unlike creating the device job plans on-line, the only WIP time lost for creating the golden job plans would be equal to the lost WIP time of one device, or 21.63 hours. So the total time required for off-line creation, including holding time for the gold job plans, would consist of the lost WIP time required to generate the 10 gold job plans (21.63 hours), and the time to create the 100 job plans on the off-line job plan generator (0.86 hours), or 22.49 hours. This yields a total savings in job plan creation time of 13.81 hours, and an improvement in WIP time of 193.81 hours due to the off-line job plan generator. Table 1 provides a listing of time required and WIP time lost for on-line and off-line job plan creation.

Table 1 - Job plan creation time and lost WIP time for on-line and off-line created job plans. All times are in hours.

Number of Devices	Time to create job plans (Hours)			Lost WIP time (Hours)		
	On-line	Off-line	Time saved	On-line	Off-line	WIP Time saved
1	1.63	1.72	-0.09	21.63	21.72	-0.09
2	3.26	1.80	1.46	43.26	21.80	21.46
3	4.89	1.89	3.00	64.89	21.89	43.00
4	6.52	1.97	4.55	86.52	21.97	64.55
5	8.15	2.06	6.09	108.15	22.06	86.09
6	9.78	2.15	7.63	129.78	22.15	107.63
7	11.41	2.23	9.18	151.41	22.23	129.18
8	13.04	2.32	10.72	173.04	22.32	150.72
9	14.67	2.41	12.27	194.67	22.40	172.27
10	16.30	2.49	13.81	216.30	22.49	193.81

Based on the data listed above, a comparison of the time required to generate job plans for the 10 devices is shown in Figure 1 below. Figure 2 provides the savings in WIP time that the off-line job creator provides for each device.

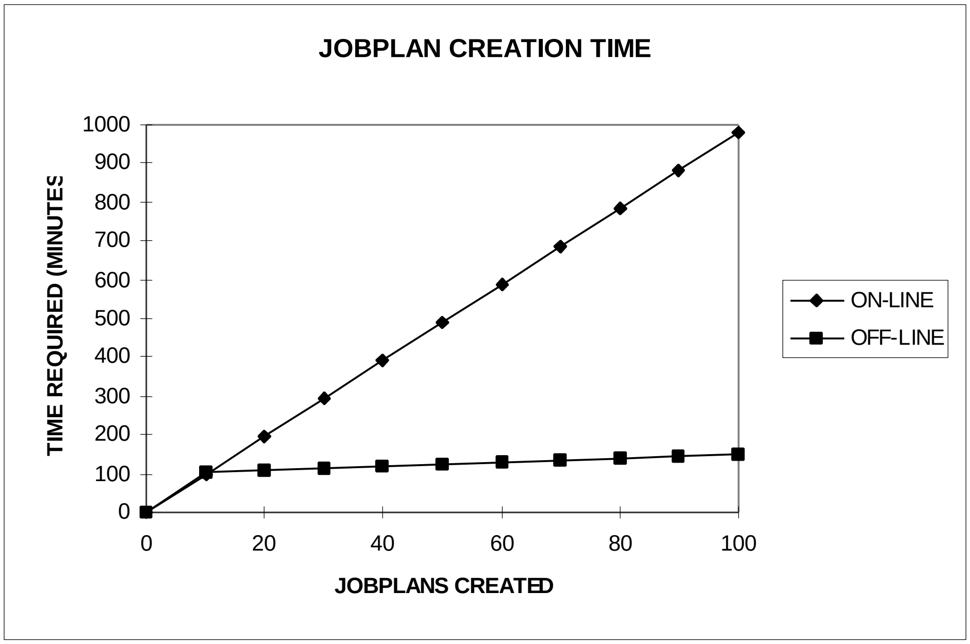

Figure 1 - Time required to create job plans on the tool vs. using the off-line job plan generator tool.

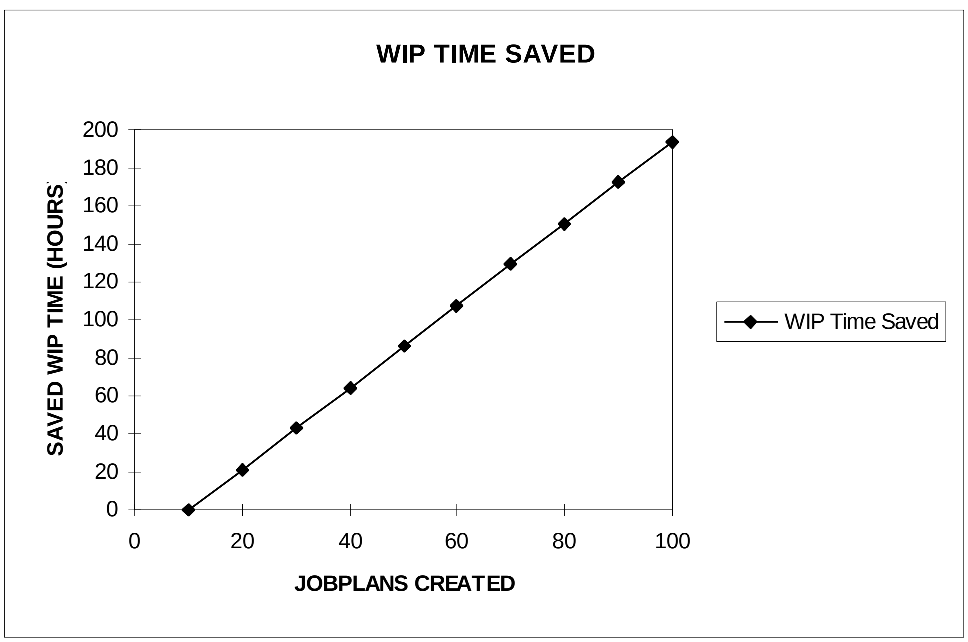

Figure 2 - WIP Time saved by creating the job plans off-line using the off-line job creator.

6. JOB MANAGEMENT RESULTS

The next point has to do with managing job plans effectively and consistently, while again minimizing WIP time. If 10 devices are being run, and a process change requires editing the job plans for one layer for each device, then the time required to create the job plans is as follows. For the on-line job plan creation an average time of 2.83 minutes was required. This change would have to be incorporated into the remaining 9 job plans, for a total time of 28.33 minutes. Since wafers would be needed for updating all of the job plans for on-line job plan creation, it could be argued that:

Lost WIP time = (# job plans)*(average hold time + job plan edit time)
(2)

= 10 * (120 + 2.83) = 1228.3 minutes, or 20.47 hours

For the off-line job plan generator tool, the same amount of time would be required to update the golden job plan. To incorporate this change into the existing job plans would require 55 seconds total for all 10 job plans. Since the layer had to be updated once, this would require an additional 2.83 minutes. Therefore, the savings in WIP time would be 1228.3 – (122.83 + 0.92), or 1104.55 minutes or 18.41 hours for the 10 job plans. In addition, the changes in all the job plans for that layer would be assured of being consistent, since they all rely on the golden job plan. The only additional WIP time lost is for holding and editing one lot, or 2.05 hours. Table 2 provides a comparison of time required and WIP time lost for editing a job plan for 1 layer for 10 devices. Figure 3 indicates the difference in time between updating job plans off-line compared to on the tool, and Figure 4 provides the WIP time required for on-line and off-line updating, as well as the savings in WIP time using off-line updating.

Table 2 – Comparison of job plan editing time and lost WIP time for on-line and off-line updating of job plans. All times are in hours.

Number of Devices	Time required to update device (Hours)			Lost WIP time (Hours)		
	On-line	Off-line	Time saved	On-line	Off-line	WIP Time saved
1	0.047	0.062	-0.015	2.047	2.062	-0.015
2	0.094	0.062	0.032	4.094	2.062	2.032
3	0.142	0.062	0.080	6.142	2.062	4.080
4	0.189	0.062	0.127	8.189	2.062	6.127
5	0.236	0.062	0.174	10.236	2.062	8.174
6	0.283	0.062	0.221	12.283	2.062	10.221
7	0.330	0.062	0.268	14.330	2.062	12.268
8	0.377	0.062	0.315	16.377	2.062	14.315
9	0.425	0.062	0.363	18.425	2.062	16.363
10	0.472	0.062	0.410	20.472	2.062	18.410

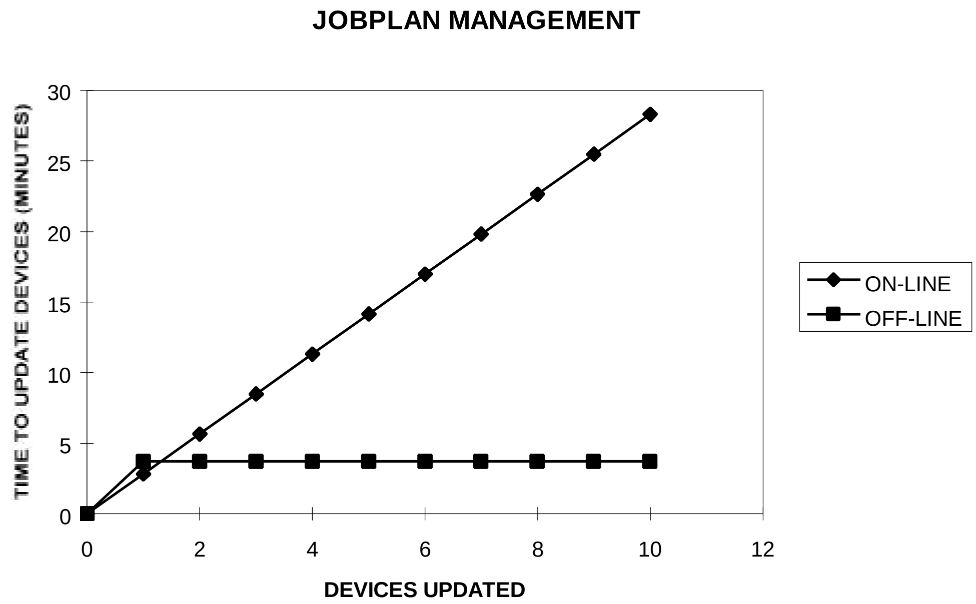

Figure 3 – Time required to update a layer in all of the devices using on-line and off-line job plan editing.

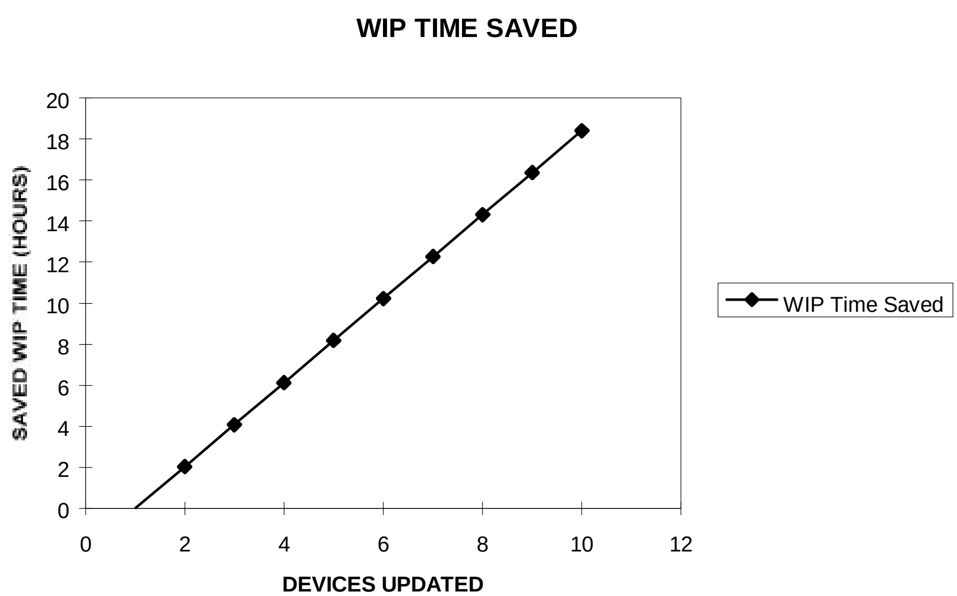

Figure 4 – WIP time lost updating the devices, and the WIP time saved using off-line job plan updating.

7. CONCLUSIONS

At Motorola BMC, to maintain the integrity of their products, fabs are phasing in new generation metrology tools to meet their higher quality expectations. To assist in this strategy, job plans will have to be transferred from older tools to the newer tools while maintaining the integrity of the job plans, and minimizing the impact on WIP time. An off-line job plan generator tool was developed in expectation of achieving these goals, and a study was performed to evaluate whether the tool could help meet them.

The study showed that the off-line job plan generator tool not only requires 8.26 minutes less time per job plan, but also saves an average of 116.3 minutes of WIP time per job plan, or a total of 193.81 hours for 10 devices with 10 job plans each. The method used to generate job plans off-line is similar to the work of R. Schiessl[1] from Siemens, which also attests to some of the advantages of off-line job plan creation. The results of this study are similar to those found by K. Lamers, et. al.[2] from Hewlett-Packard. The database management capabilities of the tool also showed a savings of 24.54 minutes of job plan creation time for one layer on 10 devices, and an improvement of 18.41 hours of WIP time for the editing required for a process change.

The off-line job plan manager also will provide a significant benefit to the fabs by maintaining a high level of consistency across job plans for each manufacturing process. As the fabs now house several different technologies, more and more job plans will have to be transferred to the metrology tools. The use of an off-line job plan manager could allow the fabs to better control the quality of job plans by incorporating a process change only in a single golden job plan, and then copying the same change to all other devices which require that job plan. This minimizes inconsistencies across similar job plans of different devices due to training issues or lack of consistency among individuals editing job plans.

The study shows that the off-line job plan generator tool was successful. It was shown to reduce job plan creation time by 89.6%, and save 193.81 hours of WIP time. In addition, it eliminates lot holding time because job plans can be ready before first wafers arrive, and provides a means of maintaining a consistent set of job plans regardless of operator skill level. It also allows subsequent job plan creation to be performed outside of the cleanroom at a time that is convenient to the process engineer rather than when a hot lot requires immediate attention.

8. REFERENCES

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