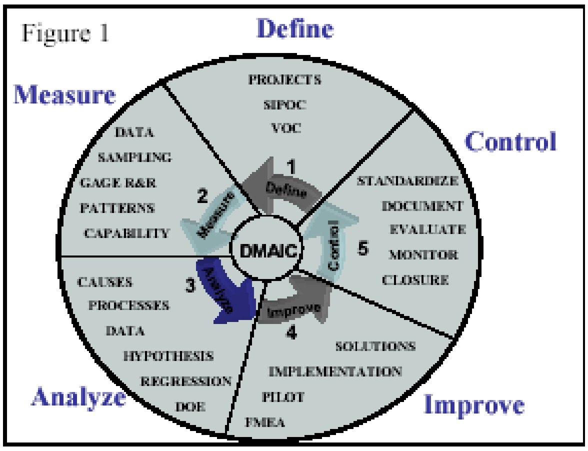
Using the Six-Sigma Methodology to Improve Wafer Fab Productivity

Abstract:

In today's economy and highly competitive market companies are seeking to maximize their asset utilization. For those Fabs that still operate in the US it is essential that asset utilization is maximized to generate the best possible cost and to take advantage of increased capacity to capture market share. Intersil is a global leader in the design and manufacture of high-performance, analog, semiconductor solutions featuring flat panel displays, optical storage (CD and DVD recordable) and power management.

As a result of consolidation of operations and significantly increased production requirements, Intersil's main Fab was facing bottlenecks in supply versus demand. Intersil enlisted Tefen USA first to support identifying the Fab bottleneck, and then to develop a comprehensive roadmap for capacity and cycle time improvements. A team composed of Tefen USA and Intersil members conducted a short assessment to confirm that the Photo area was the bottleneck, and then initiated an aggressive and focused cross-functional improvement team. The improvement team combined their extensive experience in semiconductor manufacturing with the DMAIC methodology to systematically Define, Measure, Analyze, Improve, and Control the Photo performance. In the next six months after the initial assessment photo cycle time dropped by 60%, while Photo and overall Fab production increased to record levels (a 40% increase). In the following article, we will highlight how we used the Six-Sigma DMAIC approach and other tools to eliminate the bottleneck, and ultimately to control and sustain the change.



Given the sensitive and proprietary nature of the semiconductor environment, in the following article we will focus on the DMAIC methodology, its application at Intersil, and normalized performance indicators (not the specific performance indicators that were so key to the DMAIC method). In this article we will highlight how the DMAIC method guided our activity, were we made concessions and why, the improvements and solutions the team developed, and the types of results we were able to achieve.

In the Fall of 2002 it became clear to Intersil that they did not have the production capacity to meet their market demand. They were forecasting a need to increase the number of wafer starts per week 37%. The required increase in wafer starts could drive an increase in Lithography output of 43%, depending on the product mix. In addition to the demand requirements, increasing cycle times were causing scheduling and commitment issues.

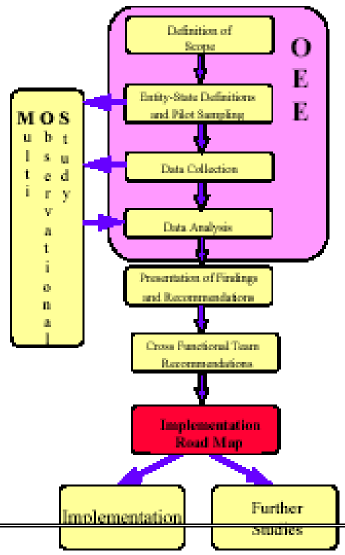
Intersil was aware of several of the problems and had several projects underway to address some of the issues. But, their capacity planning forecasted a shortfall between the capacity increases expected from current projects and the capacity they needed to meet ramp plans. As

a result, they determined that they may benefit from external resources with the proper expertise. At this point, Tefen was engaged to help them focus on the right problems, and then aggressively develop and implement solutions.

The first step in the DMAIC methodology it to “Define” the scope and focus of the project. You don’t want to try to boil the ocean, so you need to scope the project such that you can achieve results in an acceptable time span. The definition process started with a short on-site assessment of the fab operations. Based on Intersil’s current capacity data and performance indicators it became clear that the Photo area (Coat, Expose, Develop, Measure) was the primary bottleneck out of all the major areas (other areas being Dry Etch, Diffusion, Ion Implant, Deposition, and Wet Etch). A tour of the Fab confirmed what the data was indicating. The Photo area was inundated with WIP at every station and tool, this excessive WIP was contributing to operational inefficiencies by impeding scheduling, staging, staffing, etc.

At this point the scope and focus of the project became much clearer. At a high level, the Photo area was the bottleneck, constraining capacity needed for output and cycle time. Given the relatively small size of the entire Photo area, the integration of staffing between all areas, the flow of WIP between these areas, and the general interdependency between the Photo areas, it was determined that the Photo areas needed to be addressed as a whole (i.e., starting with Coat, then to Expose, to Develop, to Measure). Intersil already had tool installation projects underway that should net 15%-20% additional capacity. Therefore, Tefen was challenged with finding an

Figure 2: MOS Methodology



additional 20%-25% capacity to enable Intersil to meet its demand targets.

Another pivotal decision made at this early stage of the project, was the creation of a Steering Committee. For any project of this scope to be successful, there must be clear support and quick decisions by management and stake holders. From the outset of the project, Intersil and Tefen organized a weekly meeting to review progress, activities, plans, schedules, and problems. The Steering Committee was composed of high-level management and engineering leaders, who were capable of assessing the project activities, progress, and direction, and making all needed decisions. This Steering Committee was essential to the timely implementation of solutions throughout the project.

Given the project scope of the Photo area, the next step in the DMAIC is "Measure". The measure step has four main objectives:

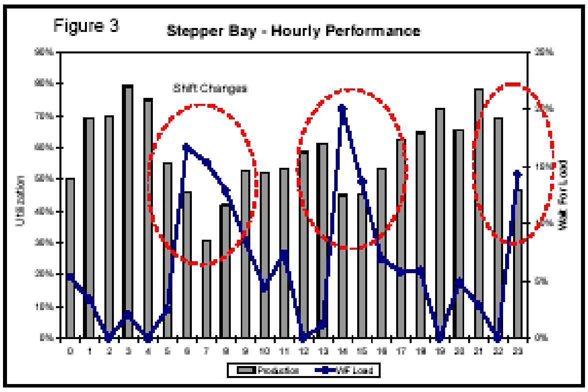
1. More specifically define the scope of the project and delineate the required improvement activities.

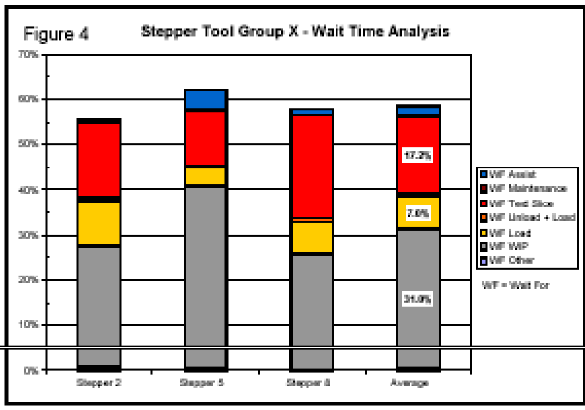
2. Gather data to qualify the opportunities for improvement and quantify their potential for improvement.

3. Gather data to quantify the current state performance and create a baseline from which improvement can be measured.

4. Based on the data analysis provide insight into what the root causes are for the problems identified.

Even if a client has automated data collection and analysis (which was the case at Intersil), it is important to validate the data prior to using it, understand how the data is collected, and how the performance indicators are generated. To this end, Tefen performed an extensive observation study (referred to as an MOS, which stands for Multi-Observation Study). In this case, Tefen performed an abbreviated MOS, which entailed sampling of the equipment and personnel states 24 hours a day over four days. Four days of sampling enabled observation of all five





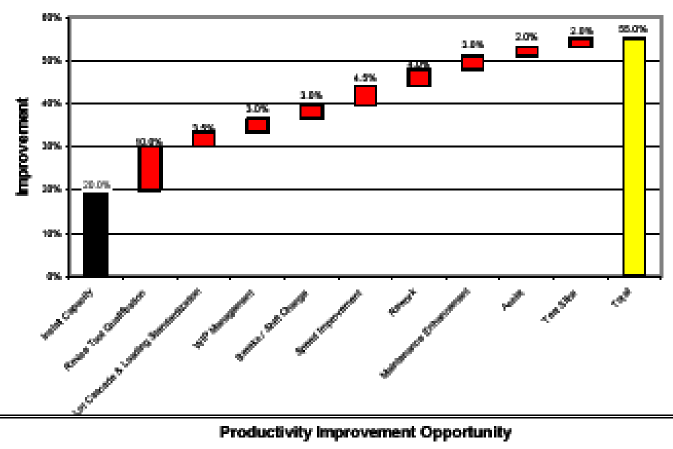
shift teams. The end result was about 400 observations per entity (e.g., Coat Tool #1, Operator X, Measurement Tool #4, etc.) specifying production activity, idle activity, unavailable activity, etc. The MOS data collection technique (see MOS Methodology in Figure 2) has proved to be a very accurate method for validating the client's data, and is detailed enough to allow for sophisticated data analysis (see Figures 3 and 4) of the performance of the production resources. The MOS also provides a valuable opportunity for Tefen to spend extensive time in the production environment to better understand where the problems are and what their root cause(s) could be.

The MOS results allowed us to refine the scope of the project to focus on addressing a set of primary activities. For example, Figure 4 illustrates the non-productive, idle activities for an Exposure tool set and their potential improvement to capacity. The combination of MOS data and Intersil's automated data provided a clear baseline from which improvement could be measured. In addition, by establishing a baseline we were able to calculate and target the specific performance numbers needed by Intersil to meet production goals. At a high level, the baseline performance and capacity was expressed through a combination of area output and cycle time, and was trended weekly throughout the project. At this point we progressed quickly to the next step of the DMAIC process, and began to "Analyze" what the root causes were to the capacity detractors. Using the list of improvement opportunities previously identified by the MOS, we created four focus teams to tackle the problems in parallel. To ensure progress and communication, the Focus teams were responsible for reporting to Management at the weekly Steering Committee meetings.

Given the areas of opportunity we created cross-functional focus teams to concentrate on four main areas:

1. **Work Methods** – Assess affects of on-floor operator work methods on area performance, isolate problem areas, determine best methods, standardize, and create new work methods to improve performance. For example, given the drop in tool activity during shift changes (see Fig. 3), one task this team had was to analyze what happens at shift change that causes this drop, understand the root causes, and improve the shift change process.

Figure 5



2. **Dispatching and Scheduling** – Assess the affects of the interaction and instruction of the MES on the area performance, identify any detractors to

optimize throughput and cycle time, and make any necessary changes to improve the performance. The Dispatch Team also accepted responsibility for redesigning the prioritization strategy and algorithms which would be applied first in the Photo area, and then expanded across the Fab. For example, most Photo area tools have flush-and-fill speed detractors, so one task of this team was to understand what information the operators need to optimally stage product to minimize the speed loss from product-type changeovers, and ensure this information is presented to the operators in an effective and efficient manner on the real-time dispatch lists used to run the areas.

3. **Capacity Planning** – Create a detailed strategic, capacity planning tool to better understand and predict tool capacity requirements, create detailed speed models of tools to more accurately model tool throughput, and identify opportunities for improving tool performance. For example, during the course of creating a speed model (spreadsheet that calculates tool performance under varying operating scenarios, based on measured data of tool performance) of a tool, we identified an alternative tool configuration that would nearly double the tool output without increasing the tool footprint or causing yield problems, and worked with Intersil maintenance and vendors to design and implement the upgrade.

4. **Training** – Tasked with documenting and formalizing the changes and improvements, creating SOP's (standard operating procedures) when appropriate, and incorporating changes into training practices. The essential objective of this team was to take the changes and improvements from the other teams and incorporate them into future training programs to ensure the operational changes are sustained.

The impetus for dividing our resources into several, cross-functional focus teams was primarily to partition the vast amount of work that needed to be done in analyzing the operations and to allow for parallel implementation of improvements and solutions. Ideally, changes and improvements would be made in a controlled manner, with key performance indicators to monitor the magnitude of the effects. However, due to the market demand and capacity constraints, time was of the essence, and as is frequently the case in the real-world, concessions had to be made for the sake of getting results as quickly as possible. The area where we saved time at the expense of information was during the next DMAIC phase, "Improve".

Given the extensive work that was completed during the first three phases of the DMAIC process, we felt confident in implementing

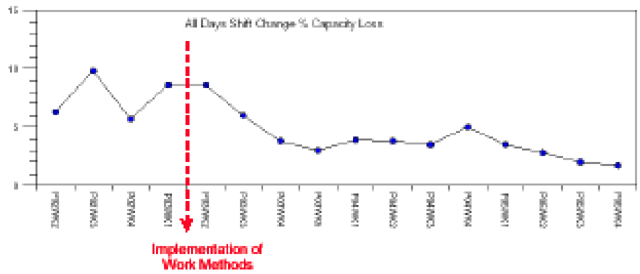
Figure 6

	ISSUE	DESCRIPTION	ACTIVITY
1	**Inconsistent Staffing strategies**	Each shift had a different staffing strategy (Area vs Tool Type)	Implemented **Work Zones** to standardize staffing strategies across shifts
2	**Poor Area Coordination**	No formal means of communication between different areas of Photo	Created roles of a **Dispatcher & Zone Coordinators**
3	**Poor Shift to Shift Communication**	No formal means of communication between shifts	Implemented a **Passdown Procedure**
4	**Poor Bottleneck Management**	Certain Steppers were starving, while others had excess WIP	Implemented a **Pull System** with a visual, kanban-style WIP rack
5	**Mask Availability**	Stepper operators spend a lot of time creating lists of masks that need to be brought into the Fab.	Created a **Mask Report** (Mask DLIS) for the Mask Runner
6	**Flatness Test**	Flatness tests for all Steppers were being done at the start of each shift. This is one of the reasons for lost production at shift change.	Created a **Flatness Test Schedule** to stagger the tests
7	**Test Slice Management**	What happened to test slices and where they accrued CT could not be determined due to current operating and measurement methods.	Developed a system for processing, tracking, and managing test slices at each stage of handling.

our improvement activities. Our position at this point was that if we did our job well during the first three phases, our improvement activities will be successful. At this point we could have taken more time and effort to design experiments and KPI's to more accurately quantify the impact of each improvement activity. But, instead we kept our sites on more general bottom line KPI's that indicate improvement at a higher level (e.g., tool availability, output, cycle time, etc.) and KPI's specific enough to indicate improvements regarding our initial opportunities.

For example, Figure 6 summarizes some results from the Work Methods team. The first three issues outlined in Figure 6 will all affect the performance of the operators during the shift change. Implementing improvements to all three of these issues in parallel makes it very difficult to determine the magnitude of the effect each has on the problems at shift change. However, a KPI that monitors the tool performance at shift change will indicate from a "bottom line" perspective if we are addressing the opportunity we initially identified. Our initial data collection indicated that about 3% of the total area capacity is lost through inefficiencies at shift change and breaks. We developed a KPI to track the tool performance at shift change for the Exposure tool sets. As the trend line in Figure 7 illustrates, the desired results were achieved. Prior to implementing any changes, the capacity loss at shift change for the Exposure tools averaged about 8% with a wide variation from week to week. Soon after implementing the first three work methods improvements, the capacity loss decreased to about 3%, the week-to-week variation decreased significantly, and the improvements were sustained.

Figure 7



Once improvement and implementation activity is underway, consideration must be given to the last step in the DMAIC process, "Control". To successfully control the improvement to the business consideration must be made to create a process that facilitates both the monitoring of the implementation activities and the embedding of the changes permanently into the organization. In our case, the execution of this phase of the process took two forms:

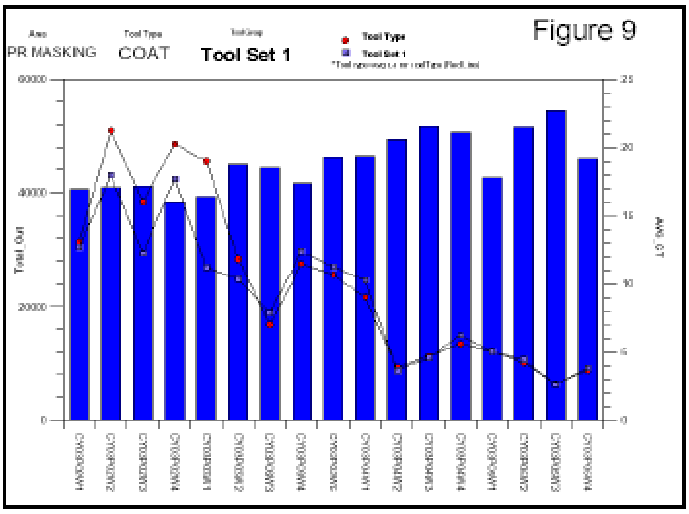
1. Creation of several new KPI's to track both detailed tool and area performance and high-level KPI's to track the

Figure 8

	SHIFT 1	SHIFT 2	SHIFT 3	SHIFT 4A	SHIFT 4P	MOVES (total)
TOTAL:	880	980	1135	0	0	2995
ZONE-4						
Metrology 1	0	0	0	0	0	0
Metrology 2	0	0	0	0	0	0
Metrology 3	3327	4062	3774	0	0	11163
SEM 1	462	669	513	0	0	1644
SEM 2	24	118	0	0	0	142
TOTAL:	3813	4849	4287	0	0	12949

overall Photo area performance with respect to output and cycle time.

2. A cross-functional Training Team to incorporate the operational changes into documentation and SOP's for use by the Intersil Training Department and the Operations management teams. Our approach to measuring and characterizing performance is hierarchical. The changes and improvements initiated by the focus teams engaged personnel at all levels of the Intersil Fab, and as a result, different levels of detail and context are required for a KPI to have the intended clarity and meaning. For example, at the most basic level the operators and area supervisors need to know very specifically and in real-time how an area or tool is performing to gauge if daily output targets will be met. This required level of information necessitated the building of a daily performance chart (see Fig. 8) that provided real-time feedback to the user on the output of each work zone by team/shift.



Another step up in generalization is to create a historical performance chart that provides information regarding the trends in performance. This type of KPI provides that invaluable view of whether or not improvement is taking place, and if improvement is being sustained. For example, Fig. 9 illustrates the improvement in cycle time performance (dotted lines) in a set of Coat tools after the implementation of improvements. This chart is a good illustration for everyone of how well this cycle-time improvement is being maintained week to week, given that output has been consistent or increased at the same time that cycle time is being reduced. Monitoring performance at the highest level was done with KPI's that tracked the entire area output and performance. The "bottom line", so to speak, was to improve area capacity 40%. Through a combination of output increases and cycle-time reduction, overall capacity was shown to exceed this target. The high-level KPI's, like Fig.10 (lines indicates output), were critical to monitoring this improvement in capacity, and to ensuring that the Fab performance is sustained at a high level of productivity.

Actual Photo area output increased 35% and was sustained at this level. Simultaneously with this increase in output, actual cycle time was reduced over 60% (see Fig. 10). This reduction in cycle time was maintained at this low level. Given that capacity can be used for output or for cycle time, increases in capacity will not always be indicated by output measurements alone. Likewise, cycle time measurements will not always indicate improvement in capacity, if output is increasing. As a result, Poisson based performance curves were used to estimate increases in capacity resulting from cycle time reductions. Performance curves are informative KPI's, because output or utilization can be graphed together with cycle time to indicate overall capacity. Graphing output and cycle time together in a performance curve can indicate how capacity increases are being utilized, i.e. for output, or for cycle time, or for some combination of both.

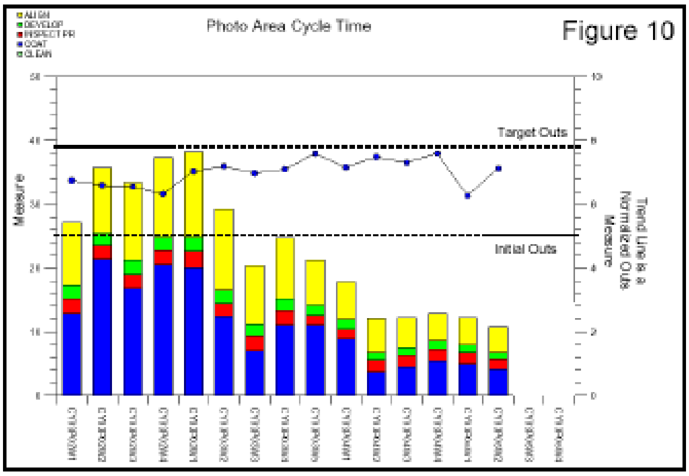


Figure 10

Using a Poisson system, an operating curve based on cycle time and equipment (i.e., server) utilization can be created. Cycle time was normalized to an X-factor parameter, where "x" is the time one unit spends in the system. The performance curve in Figure 11 combines the improvements in output and cycle time to estimate a total capacity improvement of 47%, thereby exceeding the original targets.

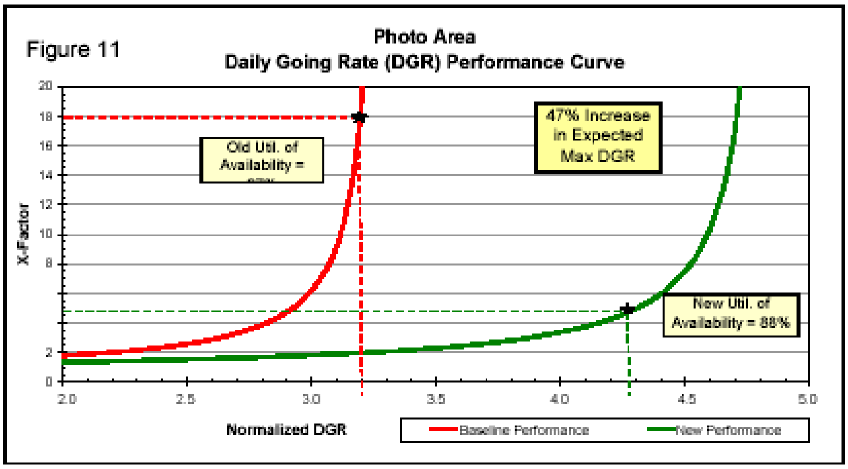


Figure 11

In summation, the Six-Sigma DMAIC approach is a proven and effective method for understanding problems and creating improvement to an operation. As with any tool, there are many ways to use it and apply it successfully.

For more information, please email us at info@tefen.com

About Tefen

Tefen is a publicly traded, international operations consulting firm with seven offices in United States, Europe and Israel. The firm has over twenty years of experience in improving the overall operational effectiveness of Fortune 500 clients around the world. Tefen designs and implements solutions that enhance operational performance throughout an organization. The main areas of focus include operational excellence, manufacturing, quality, customer service, research and development, and supply chain management. All of Tefen's support programs are ISO 9001 and TCS (Total Customer Satisfaction) certified. Our hands-on approach has achieved success in delivering quantifiable and value-driven results. The company has remained profitable since its inception and currently employs over 250 professionals worldwide, 40 of whom are certified Six Sigma Black Belts.

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