Skyworks Solutions Six Inch GaAs Conversion

Glenn Hafer

Skyworks Solutions, Inc
2427 West Hillcrest Drive, Newbury Park, CA 91320
Tel: (805) 480-4355, Email: glenn.hafer@skyworksinc.com

Keyword: Conversion, HBT, Project Management

Abstract

Skyworks Solutions' GaAs facility located in Newbury Park, California recently converted its entire high volume wafer fabrication from a four to six inch wafer size. This was accomplished while running full production volume throughout the entire conversion. It was critical that the execution of the six inch conversion was seamless to the customer and the business. The people who put their heart and soul into the wafer size conversion were the primary reason for success. Project management skills, meticulous planning, system implementation, team work and precision execution were required to meet company goals and convert the factory per schedule and within budget.

INTRODUCTION

The Skyworks' Newbury Park team was given the challenge to transfer their entire GaAs HBT and BiFET wafer fabrication facility from a four inch to a six inch wafer size in two years. There were several difficult constraints. First, the conversion had to occur in the existing and fully consumed cleanroom space. Second, it needed to be done while running a completely full factory. And, third, it was not an option to disrupt our customer deliveries. To the outside world, the conversion was seamless and hardly noticeable. However, for the people conducting the wafer size conversion, it was very intense and required 10X more activities each day in addition to sustaining a four inch wafer production in parallel.

The first step was to carve out and create a one of a kind six inch toolset to provide the capability for recipe development. The existing four inch HBT and BiFET processes were transferred to new six inch recipes. Although many of the tool platforms remained the same, substantial process development work was still required to ensure the six inch recipes were robust, and would meet the four inch uniformity specs. Even more time consuming new processes were developed on three new equipment sets since the older four inch platforms would be phased out. Every six inch process module needed to be developed and validated through an internal qualification, then endorsed by external customer qualifications. The next step was to exercise the six inch pilot line with live production to build experience running a six inch line. Once this was demonstrated successfully, the team methodically converted existing four inch tooling to augment the six inch line capacity. During this phase of the project it was critical to increase the total four inch equivalent output to support customer demand. The project was exceptionally complex but was accomplished with minimal additional human resources and no adverse impact on customers or the company's financial performance. This paper will discuss several aspects of how this project was planned and executed on time rather than focus on the technical six inch process development point of view.

PLANNING

In order to be successful with any project there must be a project plan and schedule. Two approaches were used to accomplish this task. Initially, a high level top down project plan was developed to identify the critical phases of the conversion to see how it would fit into a two year time span. The plan started out at a very high level defining each of the major phases and duration which ultimately led to the final end state in a specified period of time, as shown in Figure 1.

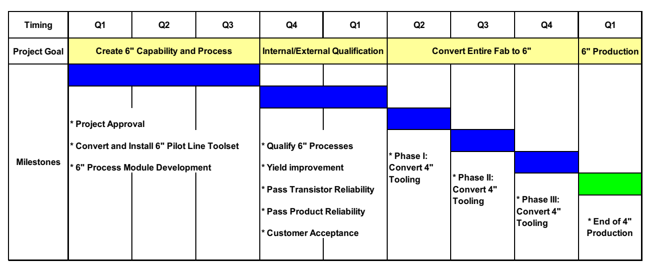

Figure 1. High Level Plan for the Wafer Size Conversion

It was then necessary to perform a ground up analysis that identified every task required to complete the wafer size conversion. This was a critical step that collected input from every engineer responsible for their respective tool and process. When this analysis was completed, the next step was to fit the collection of tasks back into the high level timeline. Of course the ground up analysis told us that the project would take longer than the required two year time frame. An iterative process of revising the duration for each task and moving tasks from serial to parallel activities was carried out until the schedule fit into the allotted time.

The outcome of merging the high level timeline with the ground up analysis produced a list of critical milestones that were used to monitor and measure our ability to execute, as shown in Figure 2.

Milestone Name	Baseline	Schedule	Actual	Status
Project Approved	Q1	Q1	Q1	Complete
Pilot Line	Q3	Q3	Q3	Complete
Process Module Development	Q4	Q4	Q4	Complete
6" Process Qualification	Q1	Q1	Q1	Complete
Last 4" Wafer Start	Q1	Q1	Q1	Complete
Last 4" Out of the Factory	Q1	Q1	Q1	Complete

Figure 2. Six Inch Conversion Project Milestones

Another critical planning component was to understand the factory capacity. The Industrial Engineering department developed a very detailed capacity model that estimated six inch capacity for each toolset. This provided the foundation to develop a plan to run a six inch pilot line in parallel with four inch production. The tool set capacity was used to determine what tools to pull from the four inch line and convert to the six inch line. This ultimately developed a plan to ramp down the four inch line while ramping up the six inch line in parallel in order to meet the increased demand for equivalent output, as depicted in Figure 3 below.

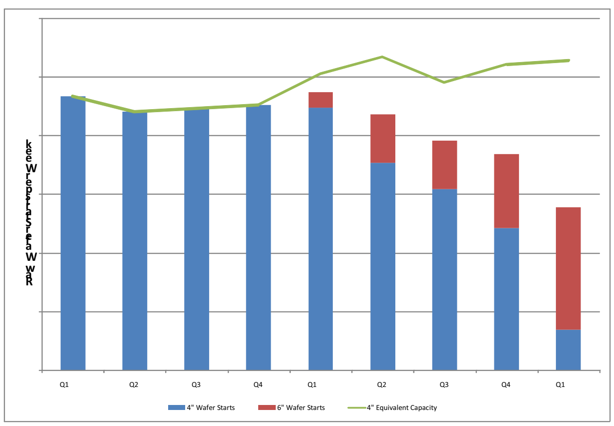

Figure 3. Wafer Starts per Quarter and Total Capacity

It was very important to understand the bottlenecks for both the four and six inch lines throughout the conversion. In addition, single points of failure were created as four inch tools were pulled to increase six inch capacity. Figure 4 shows bottlenecks and single points of failure by quarter. Managing the factory bottlenecks was critical to meet the required factory output on a weekly basis.

Bottlenecks

	Q4	Q1	Q2	Q3	Q4	Q1
4"	1	4	3	6	0	0
6"	0	0	2	3	5	4

Single Points of Failure

	Q4	Q1	Q2	Q3	Q4	Q1
4" Total	3	3	3	6	0	0
4" %	2%	2%	3%	7%	0%	0%
6" Total	28	26	22	18	8	0
6" %	64%	59%	49%	30%	17%	0%

Figure 4. Factory Bottlenecks and Single Points of Failure

PROGRAM MANAGEMENT STRUCTURE

A Program Management structure was implemented to support each phase of the wafer size conversion. Each phase had a logical set of activities grouped together. To ensure the success of the entire conversion, a project manager was selected to be responsible for each specific "part" of the conversion. Each part would be considered a major project for any given wafer fab. Having a project manager for each part resulted in a reasonable scope to manage, streamlined focus and better attention to detail. Figure 5 shows the management structure used to support the wafer size conversion.

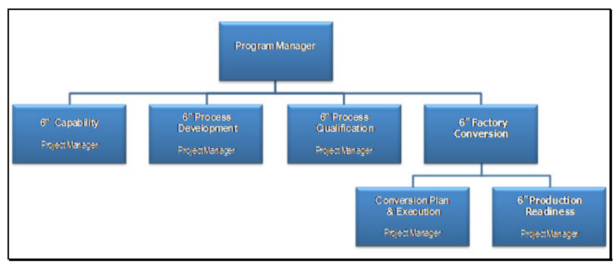

Figure 5. Program Management Structure

COMMUNICATION

Communicating the plan required many different channels due to the complexity of a multi-functional team involved in the wafer-size conversion. The communication was covered at all levels in the facility. The day to day activities could change rapidly based on program conditions as well as resource impacts due to sustaining four inch production for customer shipments. At the beginning of the conversion a project communication plan was established so that the proper flow of information was disseminated and collected at every level in the organization.

Upon defining the high level conversion plan, a kick-off meeting was held to clarify the purpose of the conversion, to provide the high level plan and to motivate the entire team. Throughout the conversion multiple team meetings took place ranging from daily to bi-weekly meetings. There was a bi-weekly meeting with upper management to report overall project status. Cross functional core teams for each manufacturing area (etch, photo, etc.) met weekly to handle area specific details and execute to schedule. The program manager met weekly with the project managers to ensure all parts of the conversion were integrated well. The Industrial Engineering group was the planning hub of the conversion and they met weekly to ensure current activities were on schedule. In addition, the Industrial Engineers had to stay two quarters ahead from a planning standpoint to ensure a clear path was developed and ready to roll out to the entire team. The daily production meeting was modified to include a wafer size conversion update on the last and next 24 hours of activity. This was efficiently conducted in 15 minutes each day.

One of the most critical meetings was the daily "9:00 a.m. Six Inch Meeting". The purpose of this team was to ensure that the plan for the day was well understood and that the complicated logistics were communicated to the appropriate resources. In addition, the team would monitor progress and balance daily competing demands between four inch and six inch WIP. This team was formed with Production, Industrial Engineering, Equipment Engineering and Process Engineering managers and a high level production lead. The group had the authority and obligation to get with the appropriate people following the meeting to ensure all action items were completed. Each activity for the day was discussed in detail and decisions were made that would best optimize the desired outcome for both the wafer size conversion and the production floor. In addition, the team would anticipate any problems and develop contingency plans to avoid a negative impact to the schedule. Taking the time to optimize a plan daily led to an extremely efficient project execution, and was critical to the success of the wafer size conversion.

SYSTEMS

As the wafer size conversion progressed, critical systems were identified and implemented to best support the prolonged activity. The wafer size conversion had many elements of starting up a new six inch wafer fab from starting material to a finished product, but, in this case, was done all within an existing four inch line. Many systems were created and a few key ones will be discussed.

The first system developed was a weekly capacity look ahead that showed how four inch production would be impacted as a result of the wafer size conversion activity. This allowed the Program Manager, Production Manager and Industrial Engineering Manager to make decisions to best handle the fab's current running condition and to decide when to perform a tool conversion within the required timeline.

Another system created to support tool qualifications was the "Qual. Bible". The Process Engineering team had to continually evaluate the requirements to qualify and ramp a newly converted tool into production. As data was gathered from the first set of tool conversions, the level of risk was re-evaluated and qualification requirements were modified to best support schedule requirements while still ensuring a high level of quality. The "Qual. Bible" was used to communicate requirements in many day to day activities as well as the weekly core teams and daily 9:00 a.m. Six Inch Meetings. The whole wafer size conversion was completed without any major yield events due to insufficient qual. requirements.

Another vital system was created to communicate the status of a tool's wafer size and qualified recipes for the production floor. Due to the large quantity of tools converted and released to the production floor, it was necessary for a person walking up to the tool to understand if it was six inch capable and what recipes could be used to process lots. Since the conversion was done within an existing wafer fab, there could be a six inch tool right next to a four inch tool. In addition, some tools were converted back and forth between four and six inches on a daily or weekly basis. A Web based solution was implemented to distinguish what wafer size the tool supported. The operator could click on that tool in the Web environment and see a list of recipes that were qualified to run four inch or six inch wafers, as shown in Figure 6.

Figure 6. Tool Wafer Size and Qualified Recipe

The recipes that were checked as qualified would then be fed back into the Manufacturing Execution System. When the operator tracked the six inch lot to the next process step, the MES would provide a list of available six inch tools to run that qualified recipe. This was invaluable and proved to be an important tool for the production floor that eliminated the possibility of running either a four or six inch lot on the wrong or unqualified tool.

TRACKING EXECUTION

It was imperative that the all aspects of the conversion included documented plans and schedules in order to track progress over time. Executing the wafer conversion on time was critical to meeting customer demand as well as meeting Skyworks' business goals. A methodology was adopted on how to identify, classify, document, track and report each problem or risk. Capturing risks and developing options to deal with potential concerns helped to proactively avoid problems.

Most projects use schedules to track the ability to complete a task by a specific baseline date. In general, the summation of the completed tasks provided an overall level of the projects status. Another important aspect was to measure the human effort required to complete a specific task. Engineers had a finite amount of time divided between sustaining a four inch factory and the six inch wafer size conversion. A method was used to capture the level of effort measured in hours for each task and track progress over time. This was a very unique and successful way to track the progress of the process module development as shown in Figure 7.

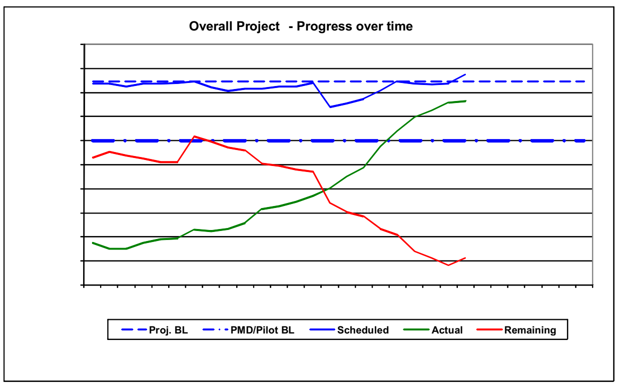

Figure 7. Process Module Development Effort over Time

Another interesting method was developed to track the status of six inch recipe development that ranged from no capability to low through high level of confidence, as shown in Figure 8. This information was provided to upper management, to communicate the team's level of confidence in the pilot line as the first six inch lots moved through the fab.

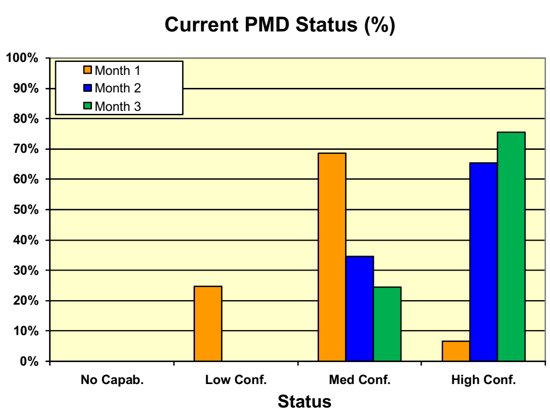

Figure 8. Increasing Confidence in 6" Pilot Line

Finally, detailed timelines for all conversions and qualifications were developed for each tool, and listed by month needed to support the required capacity. Qualifications that would not meet the required schedule were identified in red, as shown in Figure 9.

Tool	Delivery	Install (Facilities)	Conversion (EES)	Recipe Development	Qualify	Ramp
CAN09	N/A	2/2 – 2/6	2/9 – 3/6	3/9 – 3/9	3/10 – 3/14	3/10 – 3/14
PLSH51	10/30	11/3 – 12/12	12/12 – 12/18	1/8 – 1/16	1/16 – 1/27	1/28 – 2/25
TEG11	11/17	N/A	12/1 – 12/5	12/8 – 1/7	1/8 – 2/23	2/22 – 9/21
DSAS02	1/5	N/A	2/11 – 2/12	2/13 – 2/20	2/20 – 5/6	5/6 – 9/26
EVAP08	1/12	N/A	1/12 – 1/26	1/26 – 2/9	1/28 – 3/14	3/30 – 6/26
PLSH101 – BP	1/31	N/A	4/6 – 4/10	4/13 – 4/17	4/29 – 5/27	5/27 – 6/18
PLSH7	8/11	N/A	8/11 – 8/12	8/13 – 8/15	8/18 – 9/17	9/17 – 11/14
PRB42	10/10	N/A	10/10 – 10/10	10/13 – 10/13	10/14 – 10/14	10/15 – 11/11
SCRB01	10/8	N/A	10/8 – 10/10	1/14– 1/27	1/20 – 2/4	2/4 – 3/4
WAXMT03	10/10	N/A	10/10 – 10/13	10/14 – 10/16	10/17 – 11/21	11/21 – 11/22

Figure 9. Example Scheduled Tool Conversions

Mitigation and expedited plans were then created for each of these tools to ensure the deadlines could be met.

CONCLUSIONS

In summary, Skyworks Solutions conversion of the Newbury Park fab to a six inch wafer size was very successful. Output was increased throughout the program, customer deliveries were not impacted and Skyworks gross margin continued to improve. The critical component to the success of the conversion was the people who worked so hard to make this a reality. The Newbury Park site has a great team of dedicated people who are willing to go the extra mile to ensure Skyworks' success.

ACKNOWLEDGEMENTS

The Newbury Park Team would like to thank the entire Senior Management Team for their support. The author would also like to thank Heather Knoedler, Ravi Ramanathan and Juan Veleasquez for reviewing this paper and their valuable inputs.

ACRONYMS

HBT: Heterojunction Bipolar Transistor
BiFET: Bipolar Field-Effect Transistor
MES: Manufacturing Execution System