Abstract

High precision levels and low costs are required in the micro-electronics industry. As the technology advances, smaller parts and assemblies are needed. Analytical study of processes characteristics is done to increase precision and reduce costs. Continues improvement is one of the foundations of the Total Quality Management approach. Process improvement should include all of the quality components: quality assurance, variance reduction, employees’ training, performing experiments and cycle time reduction. Analyzing can be made using statistical and graphic tools such as: flow chart, cause and effect analysis, Pareto diagram, scattering plot, controlled design of experiments, etc.

This research was made at a facility’s production line for the micro-electronics accessories industry. The manufacturer is a leader in its field and holds over a half of the market share. Its clients are all market leaders in their respective fields. The product itself is a small ceramic needle through which a metallic wire is threaded. The production line performance is measured by Final-Yield level and types of scrap sorted by Pareto Diagram. The research is focused on two main contributors to organization’s profitability: shortening cycle time and minimizing scrap rate. Throughout the years, the main scrap reason was non-functionality of the product due to geometry reasons.

The research was performed over a six years period. The goal was to show methods of process analyzing and finding opportunities to improve quality. This research focus on two improvement teams: The first team had a task to reduce cycle time, whiles the other focused on increasing the yield without extra costs. The first stage was a preliminary analysis in which 15 potential topics for improvements were defined. Both teams worked tight with outsourcing consultants. During the next stage the first team defined 13 time & process barriers. These barriers were ranked by influence and effort. At the last stage, the second team performed controlled experiments. This team had 26 different issues discussed. The recommendations were on various subjects: process tests, tooling & maintenance, raw materials quality, working environment and standardization. These two teams were focused and efficient. Flow chart, process mapping, Pareto diagram and fish-bone diagram were used in order to emphasize the improvement potential of the production line process.

It was very clear that the work of the two improvement teams increased the yield (about 20% more) and reduced the cycle time (about 25% less). By doing so, both teams accomplished the tasks they were assigned to. One of the major conclusions of the teams was proving a tight connection between raw material quality, employees’ skills and following procedures and the yield level. More improvements were made in the following years; most of them were based on the recommendations given by these two improvement teams. Further improvement can be made based on analyzing process parameters such as First-Time-Yield and Variance, which are currently not collected. It would also be wise to establish a knowledge management mechanism, perform additional control tests at the process beginning and conduct more controlled experiments.

Introduction

The micro-electronics industry is a competitive market and the secret to success is profit over time. The assembly process is precise, sophisticated and consists of many stages until the product gets its final form as a hardware chip. Micro-electronics companies understood long ago that profit is achieved easier by maintaining quality standards. That can be done by using continuous improvement and not only by corrective and preventive actions occasionally. As part of total quality management attitude, not only the producer should be qualified to quality standardizations, but also his suppliers. This article is focused on one supplier in the micro electronics industry, a leader in its field.

The facility is part of world’s cooperative which its center is at the USA. It has over 30 years of world class reputation in supplying wide range of unique products that comply with its costumes needs. 85% of sales are intending to the south-east Asia market. Among its departments, there are the research &
development, engineering, production, marketing, human resources and more. The quality manager
reports to the general manager and is responsible to qualifications, procedures and actions concerning
quality towards external customers. On the beginning of year 1997, the facility has moved to a new
location. The production line as described later on has internal customers and it is the first stage in the
manufacturing. The final product is an end-tool used by the bonding machine. The dimensions are 12 mm
long with diameter of 1.5 mm. it is a small ceramic needle through which a metallic wire is threaded
[Rofe, ‘05]. The production process of ceramic component starts from extra fine ceramic powder. After
mixing with additives, the slurry is inserted into a mold to form a “green” body. The “green” body is
being sintered (heat treatment that burns the additives and form a hard unit that shrinks about 20% from
its initial volume). Once the sintering is complete, grinding and polishing can be done. The key
parameters in aspect of building quality into the product are: slurry preparation, forming “green” body
and sintering [ACerS, web; Ortech, web].

Leading this competitive market is possible due to total quality approach which exists in the facility.
Without the international ISO standards, there was no option to sale the products. These standards are
available since 1994 and as of today, the facility has ISO 9001-2000 and ISO 14001.

The goal of this study was to show methods of process analyzing used to find opportunities to improve
quality. It will discuss the time period of six years ago compared to current status at the production line.
The analyzing included several aspects such as: process tests, tooling & maintenance, raw materials
quality, working environment and standardization, as well as recommendations for further improvements.
All based on interviews with managers and raw data.

**Literature Study**

Increasing the yield and reducing the cycle time can both contribute to improve profit of an organization
and hence increase its odds to survive in the competitive market such as the micro-electronics industry.
Focus on prevention can lower the costs of poor quality such as appraisal and failure costs [Huli, ‘01;
Kloppenborg & Patrick, ‘02; Globerzon & Shtaub, ‘04].

The quality components in the production stage are:

- Quality control and quality assurance, including stabilizing processes and statistical process analysis.
- Variance reduction and solution for chronic problems.
- Employee’s guidance & qualification.
- Performing designed experiments in order to improve production’s process.
- Reduce total cycle time (from purchase order to delivery). [Shor, ‘92].

As part of quality management, there is a need for analytical analysis of processes in order to have clear
conclusions regarding the improvements needed to be implemented. One of the ways to obtain an
improvement is by means of focused projects. The base of all projects is as followed:

1. Concept Stage - analysis of demands and search for solution.
2. Planning Stage – translate the solution to specifications, required resources and schedules.
3. Operational stage - execution according to the plan.
4. Conclusion Stage – comparison of the products vs. specifications, on the basis of quality estimators
   and usefulness.

Not always all quality estimators are noticed at final results. Here are the main estimators: Effectiveness
(ability of doing right things, result-oriented, e.g. FY = Final Yield); Efficiency (ability of doing the right
things right, process oriented, e.g. FTY = First Time Yield); Availability (e.g. downtime due to
malfucntions); Quality (e.g. meeting standards, match between design and characterization); Reliability
(e.g. MTBF = Mean Time between Failures); Compatability; Adaptability; Life Span; Simplicity; Safety;
Commonality; Maintainability; Friendliness (Ease Of Use); Robustness; Service; Aesthetics [Gordon,
‘95; Globerzon & Shtaeb, ‘92 & ‘04].

Continuous improvement is one of the basic elements of quality management; the main steps are:

1. problem definition.
2. Analyze current state including process identification and characterization.
3. Determine solution objectives, such as variance reduction, increase output, etc.
4. Cause and effect analysis.
5. Define process performance estimators.
6. Think of ways to improve and solve the problem, concentrate on prevention. As Schunberger said: do the right thing, right, the first time and every time.
7. Program Implementation.
8. Verify the effectiveness of the estimators taken. Evaluate the results according to improvement parameters and define corrective actions.
9. Implement the corrective actions.
10. Back to process description or proceed to another project. [Shor, ’92; Globerzon & Shtaub, ’04].

Processes improvement is commonly done using statistical and graphical tools. With these tools, the process weakness and lack in efficiency can be identified. On top of that the resulting changes can be easily compared to the preliminary situation.

Statistical and graphical tools include the following [Shor, ’92; Eden & Bashan, ’01; Globerzon & Shtaub, ’04]:

- Flow charts and process mapping. Schematic overview on the entire production line. These tools can help locate redundant stages and areas to improve.
- Histogram. Demonstrate the process variance.
- Pareto plot. Shows the contribution of all causes to the problem.
- Scattering plot. Shows the connection between two causes, and includes coefficients and regression.
- Control chart. Shows the process scattering over time.
- Fish-bone diagram. Useful technique for cause identification and finding ways of solution. The causes can be classified into six groups: Machines, Personnel, Technology, Inputs, Measurements and Environment.
- Brain storming. The goal is to raise all the ideas that could be the factors to the problem. Every idea gets to be heard and discussed.
- Check lists. Table that shows the correlation between different factors such as the interconnection of machine, operator, shift. Gives a clear picture where is the source of the problem to the stunted quality.
- Design of Experiments (DOE). Destined to learn about the effects of specific factors on the process.

Results

The process analysis at the production line was done over two periods of time:

- First half of 1999 till late 2000. During this period I was a member in two improvement teams. The first team focused on cycle time and the second on yield improvements without increasing man power or capital.
- Second half of 2003 till late 2005. Describing the current situation and for comparison.

Description of the production line at first half of 1999:

On Fig. 1 there is a schematic overview of the production line. The production line consists of two organic teams. The first is responsible for shape forming, located at the upper level and the other responsible for grinding and sorting, located on the lower level.
Observing the production line overview alone, one can conclude that the material flow is not optimal. For example the material from sub-group 4 on the way to sub-group 5 is moving through the area that sub-group 3 is located.

Most of the production line is of mass production excluding two stages: formation of a “green” body and achieving desired length, which are driven by the weekly work plan. Most of the work is based on the skills of the employees and not automated.

Before the study began there was no technical support for that line. In this line there is a scrapping quality assurance which means the goods are being evaluated and sorted to prevent scrap reaching the customers. The objective was to build quality into the product.

The entire plant was on the edge of massive growth due to expected high demand. The growth was well funded; this was taken into consideration and seen as an opportunity to change the current situation.

Fig. 2 shows that the move to the new facility location reduced the yield. Two years later the yield is still poor. At the start of the study two process engineers were hired to support the line. The main objective was to close the gap in order to achieve the plant’s milestones.

The number of good products going through the production line is a multiplication of the production rate by yield. As seen at Fig. 2, there is a reverse correlation between production rate and yield. The higher the production rate, the employees dedicate less attention to each product hence the yield reduces which results in a request to increase the production rate. As Feigenbaum said, most of the production energy is wasted on scrap products that shouldn’t have been manufactured in the first place [Feigenbaum, ’91]. The production line is evaluated according to Final-Yield (FY) and scrap reasons sorted by Pareto (see Fig. 3). Preliminary analysis of the work stations produced 15 items that when improved may increase the yield. Each item was classified with process improvement importance (high/medium/low) and solution feasibility (citrine/probably/maybe). For example, storage the raw materials under controlled conditions is of high importance for the process and certainly will increase the yield.

Description of the production line at second half of 1999:

The first improvement team focused on reducing the cycle time. The time frame was 3 working days and was lead by an external consultant.

The analysis consisted of the following stages:
1. Detailed process mapping including the time it consumes.
2. Brain storming on areas of weakness and drawing of barriers based on previous knowledge without performing any experiments (total 13 barriers were defined, 8 of them were new)
3. The barriers were classified as time barriers or process barriers, a secondary classification was main vs. minor barrier.
4. Evaluating the barriers based on a cost-impact chart, while considering the possibilities to improve.
5. Lastly, priorities were defined according to the production constrains (production rate, annual budget, available human resources etc.) the usage of process mapping emphasized the opportunities to improve and reduce cycle time. This has also granted a base for process bottleneck analysis.

Barriers that could be easily handled were handled first. The rest of the barriers were not handled at all, handled partially, or it has taken a long time to be taken care of. The main reasons for that were limited human resources that could address it or limited budget. Out of the 13 barriers defined initially, 7 were addressed within a year.

The second improvement team focused on yield improvements. This team worked closely with an outsourcing consultant company. The time frame was 5 months. Meetings were held on a weekly basis. The analysis stages consisted of the following:

1. Scouting the production line.
2. General process mapping with regards to the scarp reasons and relevant quality characterizations.
3. Brain storming to identify the reasons for poor yield (summarized as fish-bone diagram/cause-and-effect chart).
4. Recommendations for conducting controlled experiments and areas for data gathering.
5. Prioritizing (High/Medium/Low) and setting responsible persons.
6. Conducting the experiments and data gathering.
7. Detailed statistical analysis of the data while using histograms, scattering charts and more.
8. Conclusions and performing additional experiments as needed.
9. Follow up. Implementation of the conclusions, reporting and publishing the results.

The external consultants were foreign factor which lead to excitement and certain significance feeling among the employees. It gave them motivation to work better then usual. Out of total of 24 recommended improvements defined by the second improvement team, 9 were new. Recommendations that could be easily implemented were handled almost immediately. The rest of the recommendations were not handled at all, since they needed excessive investments and were very similar to former recommendations. 13 recommendations were addressed within the study time frame. 3 recommendations were proven in controlled experiments as unnecessary, the rest were not handled for various reasons that were mentioned above.

Description of the production line as it was at late 2005:
Over the last several years and in spite of the increase in production capabilities, the production line did not change dramatically. The line still has 9 sub-groups which form two organic teams. The material flow and critical stages of the process are as they were. Machines, production equipment and additional man-power were added to several work stations, in order to increase production rate. The production is working in three shifts all week long. Each shift has a head-team of its own. It is clearly that there is much more to improve, since the yield is still poor. Several improvements were made over the years, even though they were not on the improvements recommendations lists.

There are several time frames that shows reverse correlation between yield and production rate. A tight connection was found between quality of raw material, employees skills and procedures strictness. Another correlation was found between yield and internal geometry of the product. Scrap reasons can be compared over time. E.g. on Fig. 2 marked with two red circles: scrap at the beginning of 1999 defined as 100% for reference, then at the beginning of 2005 it was almost as bad, with 90% respectively.
As Fig. 2 & Fig. 3 shows, the main scrap reason is non-functionality of the product which is a major cause throughout the years. The most concerning issue raising from Fig. 3 is that scrap reason "E" was minor during 1999, but increased over the years and is now the second. According to Pareto principles, it is recommended deal with non-functionality scrap first.

The list below includes improvements made by the process engineers and managers. Some of the improvements are based on recommendations given earlier in this study:

- Mechanical improvements made to machines, including increased safety. No major influence was detected on yield.
- Adding a test after forming a "green" body. Reduced scrap at later stages of process. No major influence was detected on yield, but saved resources at later stages.
- Infrastructure improvements and additional measurement equipment contribute a raise of about 10% in yield.
- Increase the raw material quality with the help of the supplier. Currently the approval of raw materials has become active, by communicating with the supplier and supervising the production process of the raw material at the supplier facility.
- Maintenance and ergonomic improvements in the production line. No influence on yield but on production rates.
- Training and guidance of all employees.
- Adding automated measurement equipment for sorting products.
- Adding minor management levels to production line. Each shift got its own head-team that was responsible for working according to procedures. This lead to a dramatic increase of yield.

There were total of 37 improvement issues. 14 of them were implemented within a year from recommendations, and contribute relatively up to 10% increase in quality (for each one in its field). For example, relative contribute of 5% in storage of raw material is actually reducing %5 in scrap as a result of storage in un-controlled environment. During the study frame-time, half of the improvement issues were implemented and 10% more were discussed and decided not to implement them. On top of that, 13 improvement issues that were not in the original list were implemented as well.

**Discussion**

According to the data gathered till late 2000, it seems that the plant was able to achieve the production goals set which were increasing the number of products supplied to customers and hence increase profit. The work done by the improvement teams contribute significantly to production capabilities and increase the number of good products to 2X.

Fig. 2 shows that till late 2000, the yield was significantly higher at the period of first half of 1999 and on, comparing to the period before that. The contributors for that were the reinforcement of technical support for the production line together with the improvement teams and partial implementation of
recommendations. The yield decreasing at the second half of year 1999 is due to learning curve of new employees and additional machines and equipment that were inserted to the line in order to increase production capacity.

The two improvement teams were active at the same time frame and were synergetic. The first improvement team has raised several issues without thinking on detailed solutions. Following this, barriers were defined and evaluated according to influence and effort. Several issues from this work were meticulously dealt by the second improvement team, mostly because it conducted controlled experiments. Both time and content scopes of the second team were wider.

I was an active participant in both teams and had the opportunity to implement several improvements. Along with other improvements that were implemented, the quality level in the production line was kept. Improvements that came from the teams work had major affect on production line capabilities on the long term even more then other improvements that were implemented at different levels. Working with external consultants is recommended as they tend to have a more neutral point of view. There is also a commitment of both sides to get faster results and conclusions, out of reputation and cost considerations.

Future recommendations for improvements:

- Data gathering. There is not central system that allows the collection of production data.
- Reducing variance.
  - Regular calibration of all the machines in the production line.
  - Reduce the number of work stations by acquiring high capacity machines.
  - Reduce production courses.
- Applying additional indicators. For example: First-Time-Yield emphasizes better efficiency of the process than Final-Yield.
- Shorten cycle time. Focus on process’ bottle-necks.
- Allocation of resources to conduct routine controlled experiments, such as raw materials, machines, equipment, man power, testing and analyzing tools. It should be done as part of the production plan.
- Perform additional control tests at the beginning process.
- Assess efficiency of improvement teams.
- Prioritization mechanism, that will help implement recommendations for improve.
- Get financial backup for leading changes, by persuading the stock holders that it is worthwhile investment in the long term.

Conclusions and Summary

There are many factors that influence the quality level of an active production line. These factors are time related variables. There is a need for drastic actions in order to raise the current quality level. There is a continuously need for raising the requirements for quality and translating them into actions, not only routine procedures. Another change which can not be ignored is the market requirements. As the technology progress, there is a need for smaller and smaller diameter hole of the product. Nevertheless, there are many factors that are not related to the requirement and still have big impact on the yield levels: man power, work plan (which is driven from purchase orders), machines and equipment, raw materials etc’.

At first stage, preliminary analysis was made and several issues of improvement were defined. More issues for improvement were defined following the work of two improvement teams. The work of these two teams was accompanied with outsourcing consultants and was efficient. This research is based on controlled experiments among other techniques and was using tools such as flow chart, process mapping, Pareto diagram and fish-bone diagram. The recommendations for improvement were in various aspects, including: process tests, tooling & maintenance, raw materials, work environment and standardization.

According to the parameters which quality is measured at the production line, it was very clear that the work of the two improvement teams increased the yield and reduced the cycle time. Today, over five years after, the condition of the production line is without any major change although some of the recommended improvements were implemented. There were no major revolutions besides increasing the production capacity at the beginning of the study time frame. Production line’s quality indicators are as they were: Final-Yield (FY) and distribution of scrap reasons. Throughout the years, the main scrap reason has stayed non-functionality of the product due to geometry reasons. There is a tight connection
between raw material quality, employees’ skills and following procedures and the yield level. More improvements were made in the following years. Most of them were based on the recommendations given by these two improvement teams and some were new. Further improvement can be made based on analyzing process parameters such as First-Time-Yield (FTY) and Variance which are currently not collected. By collecting them it can help viewing a different perspective on the process’ weak spots. It would also be wise to establish a knowledge management mechanism, perform additional control tests at the process beginning, reduce cycle time and conduct more controlled experiments.

Bibliography

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