Systematics and Key Performance Indicators to Control a GaAs Volume Production

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Introduction

The steep increase in demand for GaAs devices has pushed the manufacturing fabs to high volume production. New 6" fabs have already been build in the past few years and further plan for tranfer from 4" to 6" production are publicised. A few of these completed transfers have already been presented in the last years on MANTECH Conferences.

In this paper we want to describe how the Infineon AG 6" fab is controlling the various aspects of volume production. The method applied here is fully embedded in the systematics used for all the Infineon wafer fabrication and backend assembly sites. These cover highest volume DRAM fabrication on 200 and 300mm wafer, logic products, bipolar, BICMOS Ics, Silicon Discretes and GaAs devices. The number of masks required for these products range from 3 for diodes up to 35 for BICMOS.

The systematics derived here is based on measures that are derived from production and commercial data in the fabs to agreed methods. The basic data is supplied by an automated process out of the fabs and stored in a central Data WareHouse.

With these standardised production performance indicators the tracking of goal fulfilment is possible so that the trend is not influenced by the way of calculation of the performance indicators.

These measures give the change to the management to control, improve and optimise the fab performances on certain strategies required for the business.

Key Performance Indicators

The key performance indicators can be grouped into the following categories:

Cost: **cost/manufactured layer**

Efficiencies: **capital efficiency**
         Total capital expenditures for
            the fab related to the manu-
            factured layers
         personal efficiency
total time spent in the manufacturing by operators relative to manufactured layers

Line perf.:   **dyn.FF** dynamic Flow Fac.
         α variability

Yields: **YF**   fab yield
                  (wafer out / wafer in)
         YA   area yield
                  (test yield / wafer)

Delivery: **CVP**   confirmed volume prod
                  measure for order
                  fulfilment/backlog

For all these figures agreed plans and internal stretched goals are fixed. The figures are reported routinely on weekly / monthly basis.

In the following we will concentrate on the Production Performance Indicators.

Before we start in depth with the PPI's let us first consider the real workflow in wafer production facilities. Production facilities are wafer fabrication, wafer test, assembly or device test areas. In the production we are dealing with equipments, cluster tools, test systems etc. that are qualified for a specific operation with the purpose of meeting repeatable states of process conditions and processing a production unit. The production environment is multi dimensional. The production is made of multiple customer orders multiple process technologies and multiple mask sets. Each operation is valid for different products. A production route sequences a set of operations, which can include several process steps. Work centres are process modules that comprise of several pieces of equipment.

To meet the logistical targets of production, scheduling is a complex task in the organisation. Therefore the overall schedule is structured in hierarchical levels.
The general purpose is to manage utilisation, cycle time, delivery reliability and inventory without altering existing resources. It leads into a dilemma since these four subjects of optimisation may have contradicting goals. Therefore the actual importance of individual

goals has to be defined and compromise has to be effected by scheduling activities.

Definitions:
GR   Going Rate (through put rate) is the quantity of product units that have completed a production process in a defined time.
WIP   Work in Process
CT   Cycle Time. CT is the length of time spent by a product unit to complete a specified process or set of processes on one or a set of equipment.
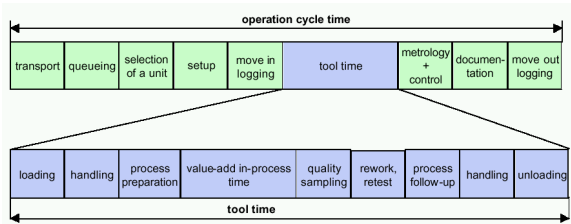

Figure: 1   Sequences of operation cycle time and tool time

DCT   Dynamic Cycle Time.   DCT represents a statistically probable value for predicting future behaviour assuming an unchanged environment.
There is a fundamental relationship between dynamic cycle time, WIP and GR reflected in

$$DCT = \frac{WIP}{DGR}$$ **Little's Law**

RPT   Raw Process Time.   RPT is the planned average cycle time need to complete the process sequences required to meet the final performance criteria for the product under optimum conditions, i.e. without queuing and process inefficiencies, based on the average lot size. RPT is planned based on the sequences of operation cycle time and includes the time segments as shown below.

FF   Flow Factor. FF is the factor indicating that the average cycle time in increased compared to the raw process time. It allows comparing different RPTs and CTs.
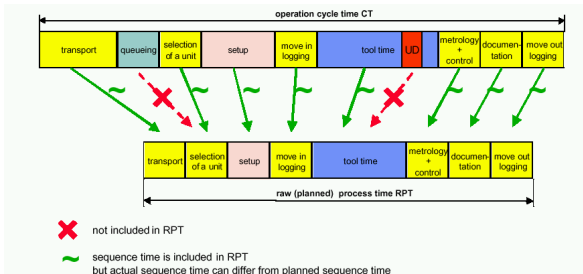

Figure 2.: Components of raw process time.

DFF   Dynamic Flow Factor. DFF same as FF but calculated from dynamic CT.

$$FF = \frac{CT}{RPT}$$

UUm   Manufacturing Utilisation. UUm is the percentage of capacity of a tool used to produce saleable, non-defective products.
Capa   Capacity. Capa refers to the capacity of the production unit, or production segment.
α: Variability. The variability of a system indicates its manufacturing performance.

Variability is the quality of non-uniformity off processing times, occurrence of tool downs, occurrence of rework, operator availability, equipment set-ups, transport strategies, product mix, number of lots on hold etc. The lower the variability the better the manufacturing performance. The variability is calculated from the flow factor and the utilisation for all tools.

The variability is also the curvature of the resulting operating curve. It is valid for all production lines and can be applied to single tool, equipment group, a line, or an entire plant as long as the quantities are measured in consistent units.
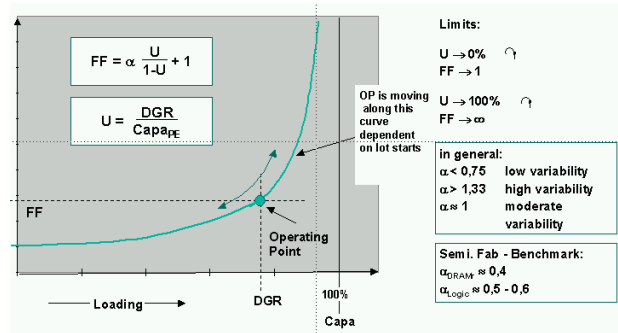

Figure 3: Operating Curve

Moving the operating point on a fixed operating curve is achieved by reducing or increasing the wafer starts. The overall performance of the production line is not improved. The dynamic performance of the production line can only be improved by moving to a new optimised operating curve.
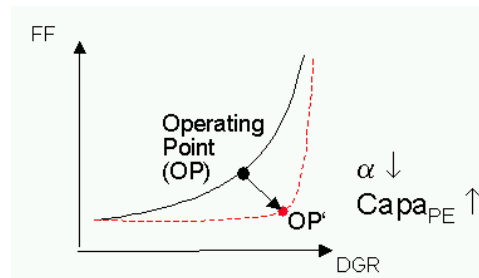

Figure 4: optimised operating curve

It is the major goal of the productivity improvement to reduce variability in a production line.

The dynamic of a production line can be described by 6 figures.

DCT, DGR and WIP these dynamic parameters can be changed on short hand basis.

RPT, Capa and α: These parameters can only be changed mid / long-term. The six parameters are not independent but connected via two equations Little's Law and the operating curve. As a consequence they cannot be chosen independently.

Optimisation of the Line Performance

Basically there are two different extremal points to plan and run a wafer fab:

a) Low utilisation around 50 to 70% and assure a very low and stable flow or FF <3 and allow a high number of very fast development lots. This allows for example margins in serviceability and short time to market for new products at the price of a poor capital efficiency.

b) High utilisation, focus on capital efficiency, reducing the number of development lots and accept a high FF >>3

Infineons strategy is to assure a FF target of 3 and simultaneously drive fabs with capital efficiency targets leading to overall utilisations of 80%.

Having these settings in mind we follow a series of methods to optimise the performance.

1. Synchronising the 4 M's in production.

The focus is the structured analysis to synchronises the simultaneous availability of

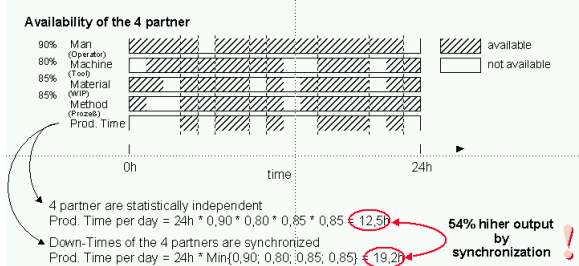| Man	personnel, operators
Machine	OEE, focus capacity exploitation without invest
Method	process availability, unit process stability
Material	WIP management implementation of supply chain management

Figure 5: Synchronisation of the 4 M', example

As can be seen from the primitive example this synchronisation can result in a very effective lever-arm to improve performance.

Furthermore, a very popular tool is the tact chart showing GR on an hourly basis. This gives clear indications for missed synchronisation during shift changes, meal times, trial runs during day shift, etc. as a drop in the tact chart.

In more complex situations a multi observation study (MOS) can be performed. In a MOS the situation in a line or part of the line is monitored on a regular time basis e.g. each 20 min and the status is recorded in detail. That means operator tasks (loading, unloading a tool, transporting WIP, documentation etc.), equipment status is recorded in detail. The analysis afterwards normally shows the clear points for further improvements.

In order to support an effective WIP logistics process a set of tools has been developed to visualise the line status from which clear and timely objectives for the manufacturing are derived interactively. This set of tools has enabled us to implement a scheduling system by work centre, by operation or by tool. The whole manufacturing performance commitment and controlling process based on these tools are tact rate, and target value of wafer moves per day are calculated using an algorithm which allows to adopt the objectives to the real situation. The line monitor works similar to the Range System (IBM consulting group,(1) implemented in IBM Burlington Fab and ALTIS IBM/IFX joint venture). It reduces the 200+ operations, usually having different length, to an acceptable and useful level of complexity. One range has the work content of one day. The line monitor is used to assure an optimum line balancing within the ranges which means that each range is filled with (and only with) the appropriate amount of WIP. Only a perfect line balancing allows a high utilisation at low WIP levels.
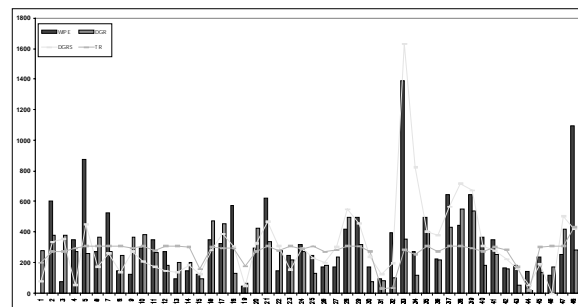

Figure 6: Line Monitor

The major blocking point of semiconductor lines turn out to be the occurrence of operational bottlenecks which not only are limited to singular tools (rolling bottlenecks). This is a consequence of low contingency and product variance. The management structure we

have chosen to get this issue under control is a daily capacity verification using OEE (Overall Equipment Efficiency) methodology. This is implemented work centre chart that is used in a daily line briefing by verifying the achieved results of the day before (moves at a work centre against OEE values (theoretical capability of the workcentre). At the same time, commitments for the actual day are derived from the WIP and machine status. The work centres are thus focussed on reacting to differences between theoretical capacity and achieved results by a detailed 4-partner analysis. Their task is then to implement appropriate operational improvements for the "rolling bottleneck". An other important advantage is that the list can be sorted by different criteria. These are e.g. CT deviations, missed moves etc. This tool together with the right procedure allows us to very quickly find degradations in process speed.

Data Supply

The basis for all the tools and actions derived to control and improve the line is consistent and reliable data. In our case we are supported from the IFX central IT teams. They have derived a Data Warehouse system. This is a database that is isolated from the operational IT systems and acts as an IFX wide data basis for the management support systems. It is subject oriented (IFX products, customers suppliers MES data), integrated with unified structure and formats, time variant and non-volatile. It contains the relevant data that is required for making decisions.
It gets snapshots from the MES (Manufacturing Execution System) on an hourly basis. The DWH also contains historical data.
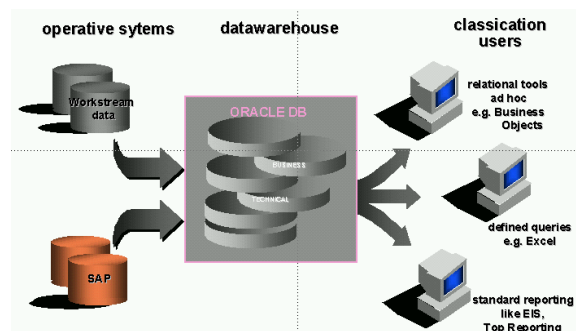
Figure 7: Data WareHouse

This system brings together data from wide spread sources into a single information resource. With the open access the user is able to generate queries, analysis and reports against the stored data.
The evaluation from the data warehouse has been extremely simplified for the end user. A set of programs is supplied that gives access to reports that have the same format through out IFX. This is our focus.perlach information (un)limited. The WinNT surface is given in
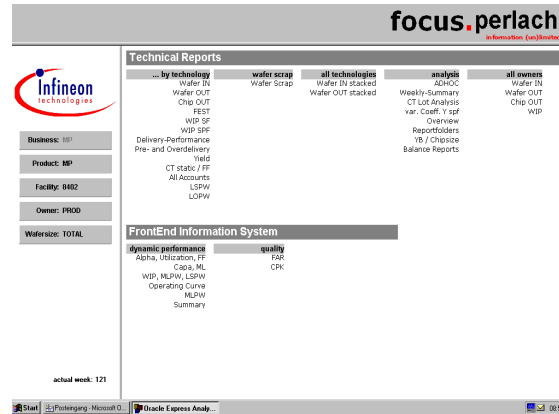
Fig8.

Figure 8: focus.perlach information (un)limited

The last tool we want to show is our devils dog tool CERBEUS. This gives the user the possibility to extract his own queries and reports out of the DWH by feeding in his specific search and selection criteria. The reports are shown by numbers or are directly transferred to figures. Both tools support the data export by mouse click into standard PowerPoint presentations or Excel sheets.
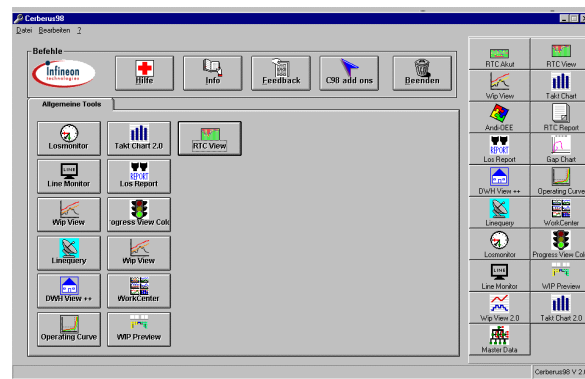
Figure 9: CERBERUS DWH Query tool

Conclusion

In this paper we have shown the tool set and some of the performance improving strategies that IFX is following. They are transferred from the volume Si fabs to the GaAs fab. It turns out that the same rules and strategies can also be applied to GaAs also some of the key performance figures have different values compared to Si.
But: Competing with larger Fabs will remain a challenge, but these challenges are the prerequisite for success.

1) H.Jauss, The IBM/CFM Range Management System, ASPICS 1986