

Industrial Decision Support Systems For Semiconductor Test and Manufacturing

AN ENTIRELY NEW APPROACH TO OPERATIONAL INTELLIGENCE AND DATA ANALYTICS

Abstract – This paper describes the motivation for, and the industrial implementation of, a collaborative, cloud based, analytics and decision support platforms for high-volume test and manufacturing data.

Within semiconductor manufacturing operations, it is business critical to be able to realise steep production ramps, improve manufacturing yields, control product quality and realize operational excellence at an increasingly fast pace. This is particularly the case in environments in which manufacturing processes and supply chains are increasingly complex, and where additional constraints such as process variability, capacity management, and worldwide logistics are crucial.

During test and manufacturing operations, hundreds of different types of measurements are done that generate thousands of data points every second, resulting in Gigabytes of data per manufactured product, per day. These data result in continuous high-volume data streams that contain the answers to many of the issues industrial managers and engineers are struggling with - such as yield, quality, cost, throughput, performance etc. Massive amounts of data therefore need to be stored and systematically analysed for operational monitoring and for management and engineering decisions.

In these industrial environments, an efficient usage of continuously increasing volumes of sensor and measurement data, gathered throughout the supply chains, is a key factor to obtain excellent operational visibility, and full control on product competitiveness.

Keywords—Test and manufacturing data analysis, data mining, yield, test and product engineering, cloud, industrial Internet, big data analytics, operational intelligence.

TODAY'S METHODS - A LACK OF OPERATIONAL EFFICIENCY

Test and manufacturing and supply chains generate massive amounts of sensor and equipment data that today remain largely under-utilised.

The semiconductor manufacturing processes have over 300 complex processing steps and several test and burn-in

stages. Process variability in terms of electrical parameters and also physical defects need to be controlled continuously, analysed and fine-tuned to guarantee final product functionality, as well as performance and quality over its lifetime. This is an activity that involves continuous data gathering on all manufacturing equipment as well as large teams of engineers and data analysis specialists to interpret the results.

At all the steps of the manufacturing supply chain, hundreds of different types of measurements that generate thousands of data points every ten milliseconds are done, resulting in Gigabytes of data per product, per day. These data result in continuous high-volume data streams that need to be stored and systematically analysed for operational monitoring as well as to make engineering decisions for continuous yield and quality improvement.

In most cases, the data is stored on hard disks, only to be made use of occasionally in case there is an immediate issue or an excursion. At the same time, when properly mined and analyzed, this sea-of-data contains the key to valuable information that is necessary to improve operational KPIs.

Classic Data Analysis Workflow – Iterative / Non-Exhaustive

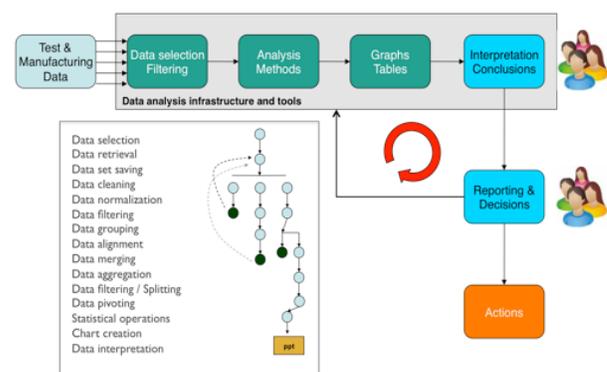


Figure 1: Today's existing approach: Time & Resource-Consuming, Iterative Data Analysis Flow

Today's data analysis infrastructures are based on classic database technologies combined with a combination of in-house and standalone, local dispersed analysis tools. In such legacy tools, the automatic data alignment, aggregation and

pre-processing that is required for obtaining coherent and accurate analysis results are costly, and in most cases even impossible. Consequently, large teams of engineers and data analysts are spending long hours on identification and root cause analysis of issues that persist already for a long periods of time. Inadequate visibility on their supply chain causes them to constantly mine through vast amounts of data, using inefficient and time-consuming methods.

AN ENTIRELY NEW APPROACH: REAL-TIME MANUFACTURING AWARENESS

QUALTERA invented and developed a purpose-built centralized big data infrastructure and analytics system that automatically integrates large streams of data from worldwide test and manufacturing operations.

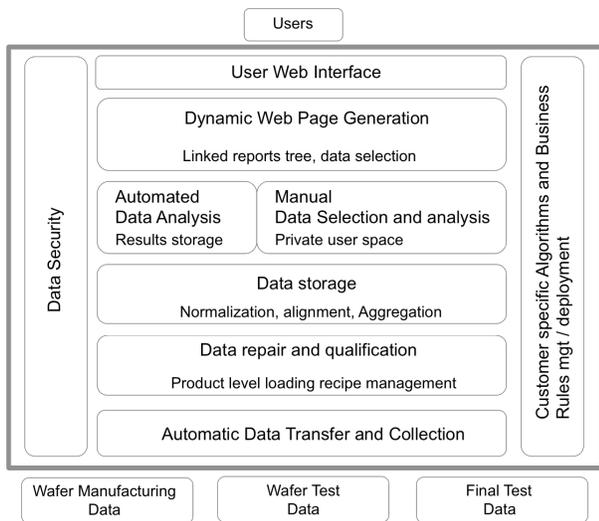


Figure 2: System application layers

The system is called Silicondash. It is centrally hosted and delivered as a combination of Platform as a Service (PaaS) and Software as a Service (SaaS). The application can be securely accessed by an unlimited amount of authorized users using a thin client via a web browser. This allows users to run scalable and powerful platforms without the costs of building and maintaining the complex infrastructures typically associated with data analytics across worldwide operations.

The Silicondash operational intelligence engines continuously monitor and analyze high-velocity, high-volume big data streams. Central compute engines are automatically triggered by incoming data to run queries along with a large set of advanced detection, classification

and correlation algorithms against streaming data feeds and manufacturing event data. As a result, Silicondash delivers real-time analytic results that can be made available to the end-users or equipment in the form of stored -meta- data, reports, textual conclusions, alert signals, chart images, API's and emails.

Silicondash provides users with real-time visibility and insight into high-volume data streams from complex manufacturing and test operations. Organizations obtain the ability to instantly make decisions on incoming data and immediately act on analytic insights, through manual or automated actions.

Automatically generated reporting infrastructures, traffic light dashboards, and custom reports give aggregated information and metrics at a glance, and empower people to make quick and informed decisions to manage corporate operational performance. In addition, these metrics act as the starting point for engineering analysis - quickly drilling down into details, performing root cause analysis, what-if-scenarios, modeling and tying anomalies to specific transactions in manufacturing and test activities.

Customers are able to drastically reduce the time needed to detect manufacturing issues and identify their root causes (10-50X reduction), improving their operational excellence, manufacturing yields and product quality while enhancing cost efficiency.

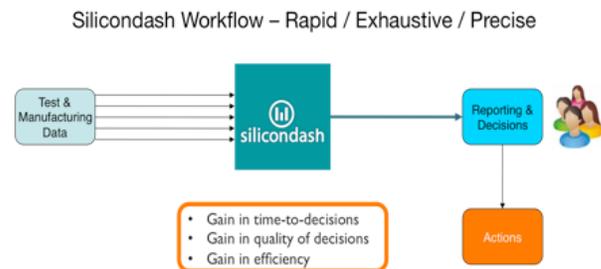


Figure 3: Today's existing approach: Time & Resource-Consuming, Iterative Data Analysis Flow

Instead of using classic database structures to search for signals iteratively, making data-queries, using spread sheets, scripts and so on, Silicondash stores data analysis results already processed and loaded, and make them instantly accessible. Anyone in a worldwide manufacturing organisation may look at the results, and share, the same key information, drill-down if necessary - and act on it with focus, speed and confidence.

SILICONDASH IMPLEMENTATION IN THE MANUFACTURING CHAIN

The figure below represents the semiconductor manufacturing supply chain and the corresponding positioning of Silicondash.

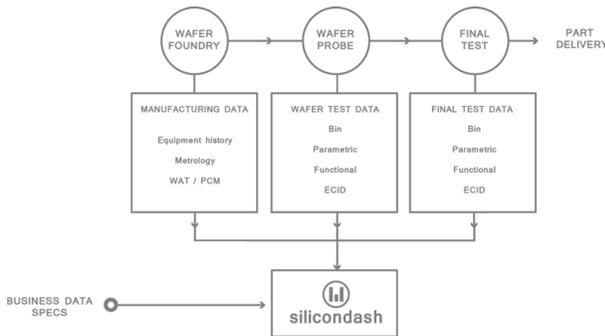


Figure 4: Silicondash connects to all data sources in any semiconductor manufacturing chain and fully automatically aligns data across different test and manufacturing stages.

The industrial readiness of the Silicondash system has been demonstrated in business situations in high-volume production at several customer types. The system is currently running in volume production at major semiconductor companies and is shown to be able to handle very large volumes of data while answering to the performance requirements for automatic analysis and fast data access for the user.

CHARACTERISTICS AND BENEFITS OF SILICONDASH – “a game changer” –

Characteristics of the Silicondash Analytics Platform	
Massive Scalability	Silicondash architecture is designed to be horizontally scalable to handle small- and very large volumes of manufacturing data – up to millions of wafers. Existing solutions either fit for small volumes only, or have difficulty adapting to varying data volumes, once installed.
Uptime and reliability	Silicondash is built using modern cloud-based technologies that are intrinsically designed for maximum uptime and reliability. Existing solutions are mostly using the classic hard and software technologies for which it is not possible or very costly to be able to commit to industry level uptime requirements.
Data security	Silicondash is built using modern technologies that are intrinsically designed for maximum data security. In contrast with the existing solutions, with Silicondash it is not necessary to transfer large volumes of

	confidential measurement data to the local environment of users that perform analysis.
Data Quality Part level Traceability Alerts signals with low false positive rates	Silicondash incorporates a unique stream computing infrastructure that enables real-time storage of manufacturing data that complies with the highest possible data-quality requirements - essential for fully automatic data alignment, aggregation and correlation of all tests and parameters throughout the entire supply chain. It also guarantees high-volume part-level traceability and accuracy for reproducible analysis results and alert signals that can be trusted.
Analysis exhaustiveness	Since Silicondash supports high internal data quality and uses centralized big data infrastructures for its massive compute engines, the generation of (intermediate) analysis results can be massive and highly automated; Analysis results cover the entire data volume of a complete manufacturing supply chain. Existing solutions can only handle the available data on a limited sampled basis with a high probability of leaving key signals undetected.
Custom Analysis Automation	Many statistical algorithms are built-in to enable the detection and quantification of all yield / quality issues occurring in entire the manufacturing chain. Output can be used for analysis, reporting or generating feed-forward or feed-backward signals for automatic corrective action in the down or upstream of the supply chain. Users can also use the Silicondash Analysis Language to build proprietary algorithms.

SILICONDASH INFRASTRUCTURE

Figure 4 shows the positioning of the system in a centralized data centre, between multiple data sources located at different manufacturing facilities and users that connect to the system from anywhere on the globe.

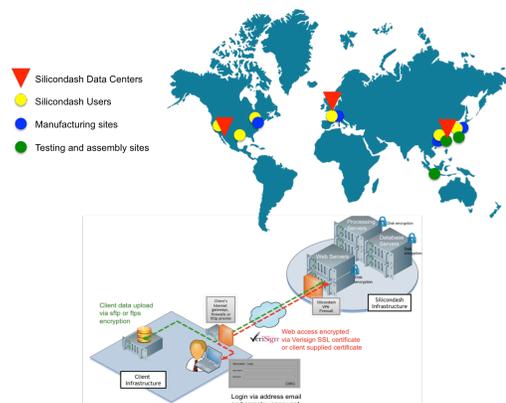


Figure 5: Worldwide Silicondash deployment and accessibility

AUTOMATIC TRANSFORMATION OF LARGE DATA SETS INTO BUSINESS CRITICAL INFORMATION AND CONCLUSIONS

Although analytics in the semiconductor industry has existed for years, the industrial application of cloud-based big data analytics in the semiconductor environments is almost non-existent. Today, most companies still rely on classical on-site database systems consisting of distributed data collection and storage, complemented with stand-alone spreadsheets and manual analysis tools. With Silicondash, modern cloud technologies are used. These technologies are the building blocks and key enablers of QUALTERA's proprietary patented- technologies and infrastructures that enable the pre-processing of massive amounts of data and the generation of pre-calculated analysis results, conclusions and meta-data for fast visualization. They also have unique capabilities in terms of enabling secure and reliable central data storage while providing very powerful infrastructures for automatic data processing. The transformation of large data sets into business critical information and actionable conclusions becomes easy and fast.

DYNAMIC VISUALIZATION OF MANUFACTURING INSIGHTS

In order to provide users with a modern and extremely rapid access to data and analysis results, a new way of visualizing and selecting data has been implemented. The platform contains hundreds of unique, carefully chosen, web pages, called "Views", that each, address specific data mining and analysis use cases. See figure below that shows an example of a single Silicondash View.

Views are web-based reports that visualize any user-selected data-scope under investigation. Each View allows the user to investigate data under different viewing angles, and draw conclusions on the data scope it contains. The data scopes of the Views and its charts contain very detailed information on die level, as well as highly aggregated data from many thousands of wafers. Views are linked to each other based on their context and data content allowing users to navigate through a complete "View Tree".



Figure 6: Silicondash end-user web- user interface

REAL-TIME HIGH-VOLUME TRAFFIC LIGHT DASHBOARDS

The high-volume data alignment and aggregation engines enable automatically generated reporting, such as real-time traffic light dashboards, and other custom reports that provide operational and business metrics at a glance. Such overviews empower managers and engineers to make quick and informed decisions to manage operational performance. In addition, these metrics act as the starting point for engineering analysis - quickly drilling down into details, performing root cause analysis, what-if-scenarios, modeling and tying anomalies to specific transactions in manufacturing and test activities.

CONCLUSION

Most semiconductor companies operate complex supply chains using multiple test and manufacturing sites that are geographically spread-out across the different continents. The associated data volumes being generated continue to increase at an exponential rate. Current solutions for collection, storage and effective mining of those data are falling behind while the needs with respect to worldwide accessibility and massive data mining are rapidly evolving. Silicondash offers an entirely new approach in tackling those issues, and is becoming the worlds most advanced and powerful data analytics tools for end-to-end data analytics and business intelligence. Currently Silicondash covers multiple high-volume supply chains in order to drive towards world-class manufacturing excellence and efficiency.

ABOUT QUALTERA

QUALTERA is an ISO 9001 and ISO 27001 certified company, that operates worldwide at fabless companies, IDMs, foundries and OSATs and provides next-generation industrial big data solutions. QUALTERA is an Operational Intelligence (OI) Company that applies massive real-time statistical methods and artificial intelligence to end-to-end data streams from worldwide manufacturing chains. OI provides both broad and deep insight into the manufacturing and test events and changes fundamentally the way executives and engineers approach data analytics for product - test - yield - and quality engineering in high-volume manufacturing. Customers gain competitive advantage and profitability by acceleration of their product and technology ramps, and improvement of manufacturing excellence, yields and IC quality.

Qualtera products and services consist of Software-as-a-Service, software licenses, and consultancy.

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