INTELLIGENT DEFECT ANALYSIS, FRAMEWORK FOR INTEGRATED DATA MANAGEMENT

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Abstract

Spatial signature analysis (SSA) is one of the key technologies that semiconductor manufacturers will begin to deploy into their manufacturing processes in order to improve yield learning. In order to perform rapid root cause analysis of process excursions the defect signature information derived from SSA must be integrated with other data bases in the fab. However, some of the fundamental impediments to integrated data management identified in the 2003 Sematech International Technology Roadmap for Semiconductors (ITRS) are a lack of standards on which to base system communications, standard data formats, and a common software interface between data depositories. "The ability to automate the retrieval of data from a variety of database sources, such as based on statistical process control charts and other system cues will be required to efficiently reduce these data sources to process-related information in a timely manner. To close the loop on defect and fault sourcing capabilities, methods must be established for integrating workflow information (such as WIP data) with the DMS, particularly in commercial DMS systems."

SiGlaz has introduced a spatial signature analysis product called Intelligent Defect Analysis (IDA) that automatically assimilates manufacturing process data collected from inspection equipment and other fab databases to determine the root-cause of a process excursion. IDA incorporates an advanced system framework that facilitates communication between dissimilar databases and moves beyond the operator-driven paradigm that is currently used in the fab to an event-driven paradigm that is emerging in advanced process control systems. SiGlaz uses artificial intelligence methods that combine both spatial and temporal elements in its signature analysis. The method deploys a teaching algorithm and data mining to emulate the domain expert in recognizing anomalies occurring during the wafer manufacturing process. This paper will describe both the architecture and components of this automated process control technique.

Service-Oriented Architecture

Intelligent Defect Analysis is designed around an event-driven methodology, as represented by the learning cycle diagram shown in Figure 1. The steps of the learning cycle can be applied to any inspection process that takes place in the fab; from optimizing process results on a single piece of equipment to managing equipment maintenance schedules. The fundamental point as it applies to IDA is that the architecture allows the data taken by the inspection equipment leads immediately and automatically to information through knowledge discovery and root cause analysis with little or no need for trained staff to bridge various software systems to create the information. Likewise, IDA software automatically organizes the information to trigger an action that closes the learning cycle. Some examples of the actions that could be taken are: an email to alert the fabrication engineer to a probable yield loss condition; or an instant wireless message to call support for unscheduled preventive maintenance.

As the industry moves toward advanced process control (APC) it is also possible the IDA could issue a feedback or feed-forward command via "Interface A" to optimize a process tool. The SEMI Equipment Data Acquisition (EDA) specifications, also known as "Interface A" (published in March 2005), provide the semiconductor manufacturing industry with a complete suite of software interface definitions that support the guidelines, and define the next generation of data acquisition for the equipment. IDA framework deploys the same industry standards designed to simplify the connection and integration of systems.

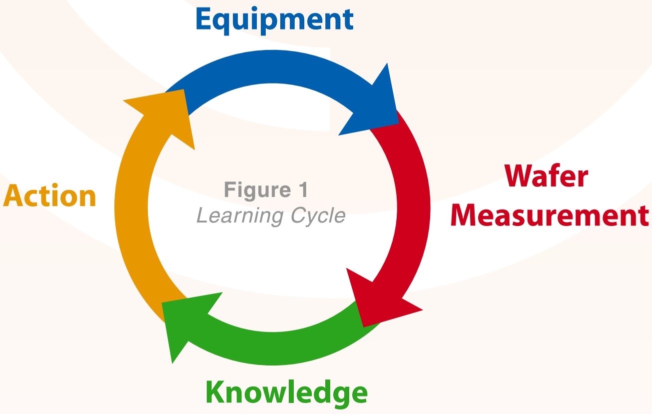

Figure 1 *Learning Cycle*

In order to deploy the event-driven methodology in the fab, it is important to consider the advantages of a service-centered architecture that is the essential to modern distributed systems. Over the past several years, the system development process has evolved from a process-centric paradigm to a period of data-centrism, and finally, to the new service-centric view of information management. The service-centric paradigm has a significant advantage over the traditional methods in the sharing and re-using of the software components for different processes and for different data models.

IDA is a suite of products that has been designed from the ground up with a clear service-oriented architecture. It provides a scaleable, reliable, secure interface for both external and internal systems. There are four primary service-centric functions: 1) Analysis Services; 2) Construction Services; 3) Deployment Services; and 4) Report Services. Analysis services provide the fundamental autonomous software algorithms to analyze and characterize spatial signatures and to classify and train known defect signatures for use in pattern recognition. Construction services contribute all components for the assembly of a neural network or workflow for an analysis job. Deployment services provide all components for launching and monitoring process analysis jobs in a safe and recoverable environment on the manufacturing floor. The Report services provide all functionality relating to extraction, transformation and loading of spatial and temporal data collected during manufacturing into the data warehouse, including the construction of multi-dimensional cubes for using in advance queries and reporting and the data mining services

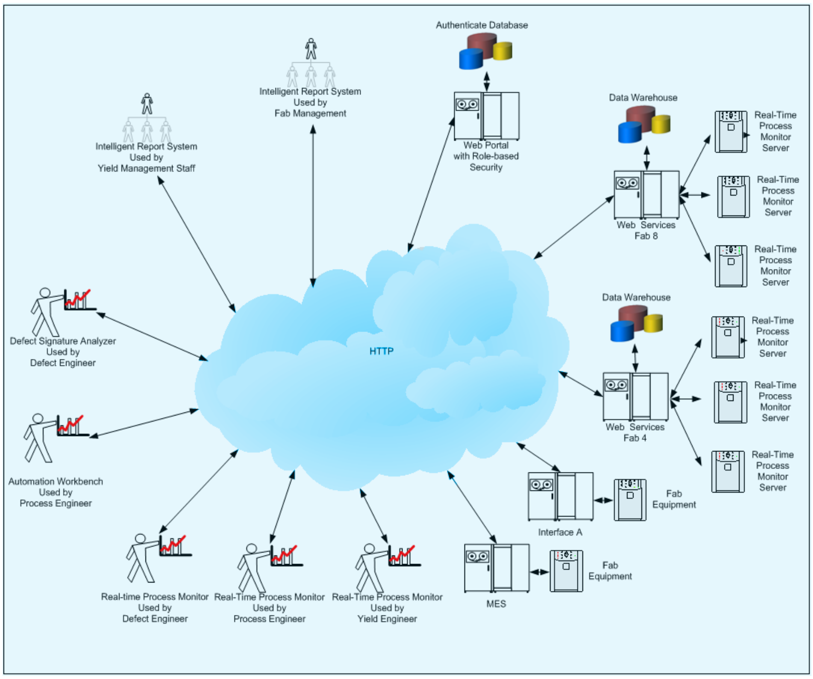

Figure 2 *Integrating IDA Architecture into a fab environment*

IDA Framework

IDA is composed of four applications modules:

- *Defect Signature Analyzer* provides yield engineers with a wide range of analysis and visualization tools with which to develop and optimize the signature analysis methodology and to train the defect signature library.

- *Automation Workbench* allows engineers to automate the signature analysis methodology to run the recipe in either batch mode or continuous monitor mode.

- *Real-Time Process Monitor* schedules, executes and monitors multiple AWB recipes in a production environment. A dashboard-type display indicates the status and real-time results from each of the operating recipes.

- *Intelligent Reporting System* generates a data base of analysis results. It uses On Line Analysis Process (OLAP) to analyze signature analysis results over an extended time period in order to identify cyclical trends in production data.

All four applications modules share the same components and services; DSA uses only one type of service while RPM uses all four services.

Getting legacy platforms to work together is one of the major tasks of the Information Technology group in every fab. Adding a new capability, such as spatial signature analysis, is often seen as desirable from a yield learning perspective, but is often seen as impractical from an integrated data management perspective. One of the key features of SiGlaz IDA is its ease-of-integration into a cross platform manufacturing environment. The fundamental requirement is to adopt a framework that enables the many different operating systems and databases to communicate with each other in a seamless, reliable and efficient manner. Figure 2 shows how IDA may be integrated into a fab environment using the .NET framework.

SiGlaz has adopted the Microsoft .NET Framework for its IDA product. The .NET Framework is a development and execution environment that allows different programming languages and libraries to work together seamlessly to create Windows-based applications that are easier to build, manage, deploy, and integrate with other networks and operating systems.

The .NET Framework provides the basic infrastructure that SiGlaz IDA applications require in order to make the connection of information, people, systems, and devices a reality:

- **Support for standard networking protocols & specifications**: The .NET Framework uses standard Internet protocols and specifications, like TCP/IP, SOAP, XML, & HTTP, to allow a broad range of information, people, systems, and devices to be interconnected

- Support for different programming languages: The .NET Framework supports a variety of different programming languages so developers can select the language that is best suited for their application

- Support for programming libraries developed in different languages: The .NET Framework provides a consistent programming model for using prepackaged units of functionality (libraries) which makes application development faster, easier & cheaper

- Support for different platforms: The .NET Framework is available for a variety of platforms, which allows people, systems, and devices to be connected using different computing platforms.

The .NET Framework consists of two primary components:

- The Common Language Runtime (CLR): A language-neutral development & execution environment that provides services to help "manage" application execution

- The Framework Class Libraries (FCL): A consistent, object-oriented library of prepackaged functionality

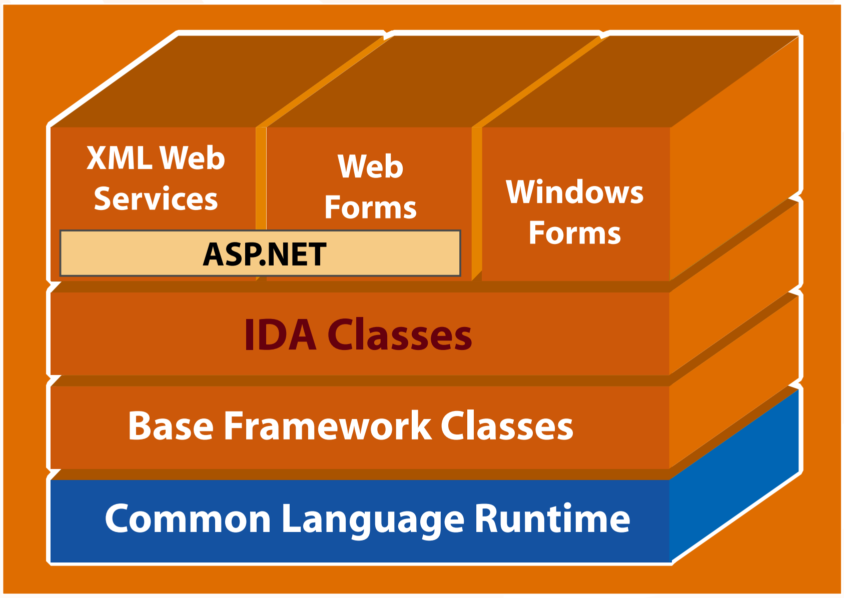

Figure 3 *.NET Framework*

Figure 3 shows that IDA classes are integrated with the .NET Framework to work with different interfaces, providing a growth path to higher levels of fab integration; IDA classes are the re-usable software components that collaborate to provide the services to support SiGlaz applications modules.

The first generation of IDA software is designed in the .NET framework around the "Windows Forms" architecture. In this traditional desktop architecture, the operating system components that manage windows and controls have been assembled as the first level of hierarchy in the .NET framework. The next generation of IDA software will leverage the .NET architecture by using the "Web Forms" architecture, which utilizes the internet and http protocol to provide more distributed interfaces using thin client. As "Interface A" becomes more widely adopted by semiconductor equipment vendors, the "XML Web Services" architecture will enable IDA to collaborate with other systems, equipment and applications in the fab using its web services.

IDA is built with the SEMI Equipment Data Acquisition (EDA) specifications in mind, also known as "Interface A". The specifications are based on Web Services technologies. Web Services are emerging as the industry standards designed to simplify the connection and integration of systems. Web services enable the deployment of secure, discoverable, platform-independent data collection and management services that operate independently of the job control interface to equipments, and which can provide a quick way to access data.

Web Services will become the "lingua franca" or universal language in the future fab for data exchange. The first generation of IDA will alarm or notify fab personnel via email, pager or PDA when a process excursion is detected. The next generation of spatial signature software will be able to collaborate with other equipment in sequence to create a more complex root-cause analysis strategy, including automatically exchanging knowledge to self-correct using web services as the vehicle of exchange. The following steps illustrate a typical scenario for automated root cause analysis in a future fab:

1. Detect spatial signature that indicates a process excursion has occurred.
2. Send request to various equipment involved in the process using web services.
3. Receive parametric data related to equipment health via web services data exchange
4. Determine the root-cause and prescribes corrective actions.

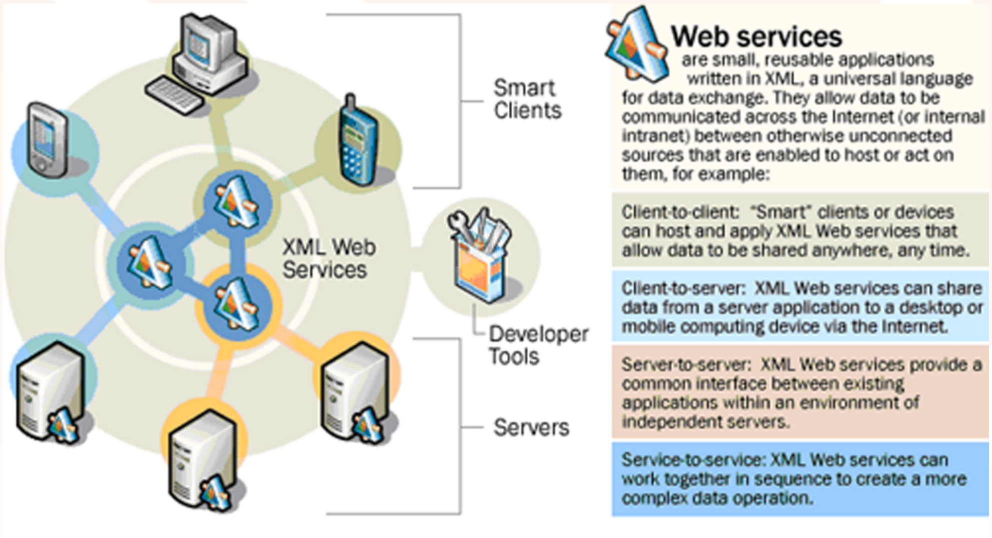

Figure 3 *.NET Framework*

Open Data Integration

The IDA architecture has been designed to operate in a cross-platform environment using an open data integration platform. It is an unbiased and tool-neutral system makes use of heterogeneous data collected from every step of the manufacturing process. The input data for IDA may be accessed directly from an inspection or process tool or from a data base management system. See Figure 5.

As semiconductor fabrication processes continue to increase in complexity, the IDA open data integration platform can be adapted to handle the increased volume and complexity of the data. For example, as new defect detection tools with higher resolution are introduced into the process, the number of pixels per unit area of wafer and the number of process levels to be inspected will result in a major increase in the volume of the data. As high resolution digital images from e-beam and x-ray inspection systems introduce additional complexity into the process of extracting and recognizing spatial signatures. Increased use of integrated metrology and integrated inspection systems will generate so much data that it can no longer be analyzed manually.

Integrated data management applications like automated process control and equipment sustaining operations are critically dependent on timely access to equipment parametric data. SiGlaz has designed its system to enable improved access to fine-grained equipment process and operational data.

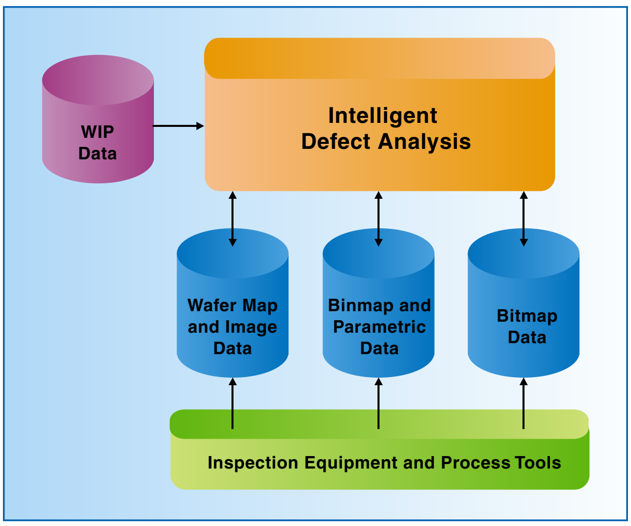

Figure 5 *Heterogeneous data sources*

Data Warehouse

During the course of monitor and analyzing wafer inspection results files, IDA correlates the defect signature information that has been extracted from results files (metadata) with other manufacturing data. To utilize this information to support yield enhancement and rapid yield learning it is important that these data be consolidated and organized in a data warehouse. The data warehouse contains the living history of the wafer processing steps within the fab. The data may be collected from a variety o f heterogeneous sources such as spatial analysis results from IDA (See Figure 5), defect data from defect detection tools, WIP, equipments, bin data, electrical test, SPC and MES. A data warehouse combines this data, cleanses it for accuracy, conforms the data to dimensions, and organizes it for ease and efficiency of querying.

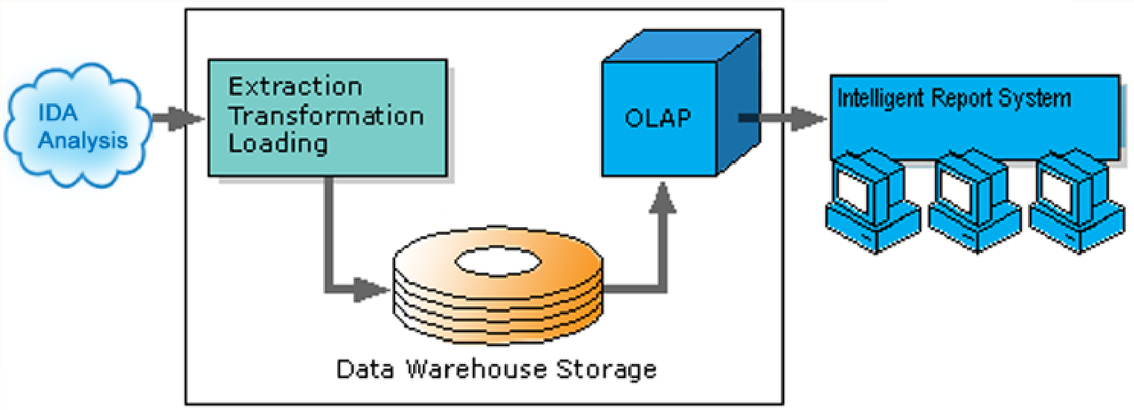

Figure 6 *Data Warehouse and OLAP*

After the data warehouse is populated with data, yield and defect engineers can mine the data to support yield learning. One of the SiGlaz IDA software modules, called Intelligent Reporting System, performs spatial and temporal analysis of the IDA metadata base to reveal trends in the process. Online Analytic Process (OLAP) is a popular tool for both temporal and multi-variable analysis. OLAP technology enables signature or spatial map data to be used effectively for online analysis, providing rapid responses to iterative complex analytical queries. OLAP's multidimensional data model and data aggregation techniques organize and summarize large amounts of data so it can be evaluated quickly using online analysis and graphical tools. The answer to a query into historical yield data often leads to subsequent queries as the analyst searches for answers or explores possibilities. OLAP systems provide the speed and flexibility to support the analyst in real time.

Cubes are the main objects in online analytic processing (OLAP), a technology that provides fast access to data in a data warehouse. A cube is a set of data that is usually constructed from a subset of a data warehouse and is organized and summarized into a multidimensional structure defined by a set of dimensions and measures. See the table below.

Sample Analysis Cube		
Column	**Name Description**	**Type**
STEPID	This field will store the process step in the Fab	Dimension
DEVICEID	The name for the product being inspected	Dimension
LOTID	Lot identification	Dimension
WAFERID	Wafer identification	Dimension
SLOTID	Slot Identification	Dimension
RESULTDATE	Date of the inspection that produced this results	Dimension
RESULTTIME	Time of the inspection that produced this results	Dimension
MAPTYPE	Signature; Scratch; Repeater; Micro-Scratch	Dimension
MAPSUBTYPE	User Defined Signature name; Scratch name	Dimension
NDIE	Number of all inspected dies in wafer	Measure
NDEFECT	Number of all defects in wafer	Measure
NDEFDIE	Number of defected dies	Measure
NDEFECTMAP	Number of defects in map type	Measure
NDEFDIEMAP	Number of defect dies in map type	Measure

1. Dimensions are a structural attribute of cubes. They are organized hierarchies of categories and (levels) that describe data in the fact table (spatial signature map). These categories and levels describe similar sets of members upon which the user wants to base an analysis.

2. In a cube, a measure is a set of values that are based on a column in the cube's fact table and are usually numeric. In addition, measures are the central values of a cube that are analyzed. That is, measures are the numeric data of primary interest to end users browsing a cube. The measures you select depend on the types of information end users request. Some common measures are number of defects, number of defected dies…See Figure 6.

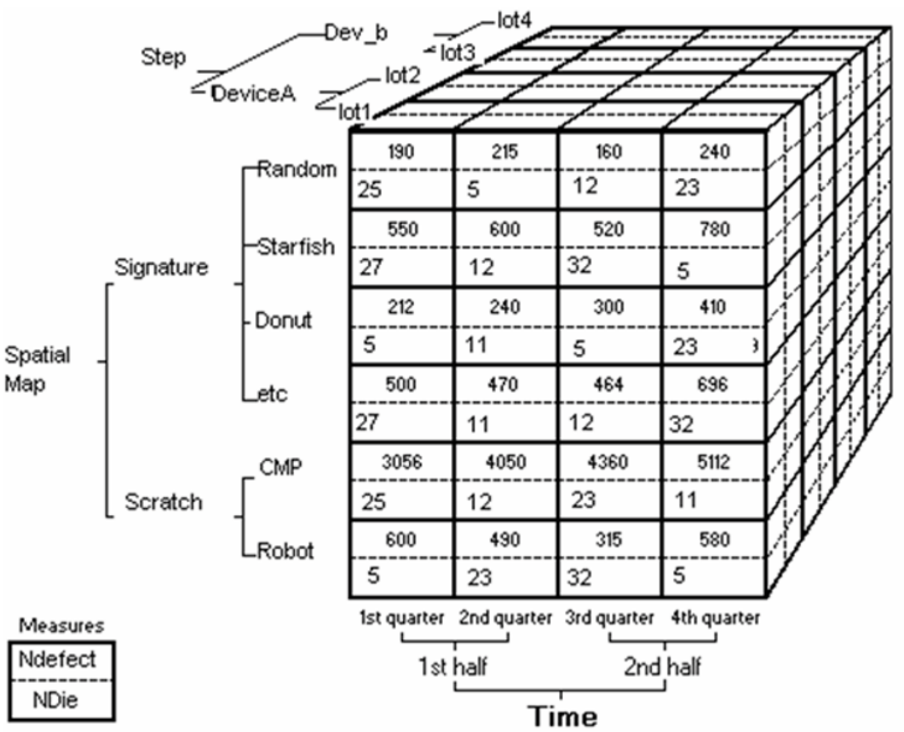

Figure 7 *OLAP Cube with Dimensions and Measures*

Conclusion

Automated yield enhancement tools that perform rapid manufacturing defect sourcing to identify the root cause of a process excursion are becoming a requirement as semiconductor devices and processes are become more complex. By merging spatial signature analysis, data warehouse and data mining into a single package, SiGlaz Intelligent Defect Analysis software provides a fully integrated solution to spatial and temporal signature defect analysis. IDA has been designed from the ground up to meet both current and future fab requirements for integrated data management. Its open data architecture integrates easily with all other systems and equipment on the manufacturing floor and it supports the advanced requirements of Interface A. A service-oriented architecture and .NET Framework have positioned it to meet future fab needs as the requirement to handle increasingly higher data volumes and more complex data formats. It is an architecture that will support advanced requirements for integrated data management well into the future.

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