



Yield Analysis in the Semiconductor Industry

Analysis Challenges in the Semiconductor Industry and How the PV-WAVE Family of Products Delivers Solutions

A Business White Paper by
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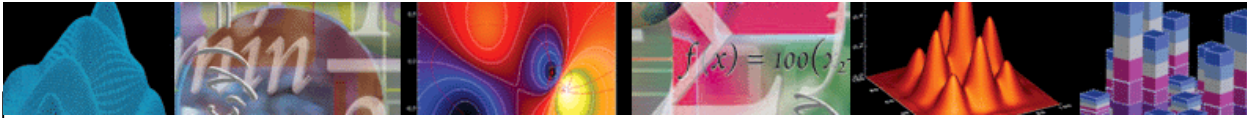


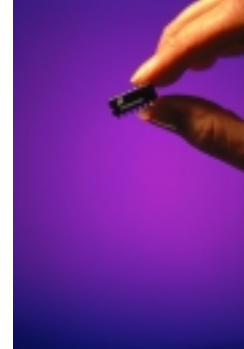
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Introduction

The Semiconductor industry includes manufacturers and engineering data analysis solution providers interested in yield management solutions. Semiconductor companies are faced with tremendous time to market pressures due to product cycles getting shorter and shorter with each new generation of wafer technology and selling prices declining rapidly after new products are introduced.



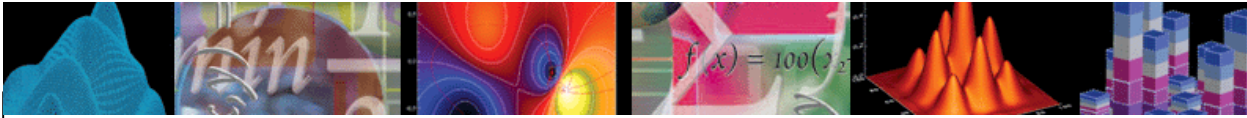
To remain competitive, companies need to send their products quickly to market with the highest yield production possible. To achieve this, yield management has emerged as an area of increased importance and plays a significant role in technology development and continuous manufacturing process improvements. One extremely important component of yield management is effective yield analysis in order to achieve accurate yield prediction and ensure the right level of work in progress (WIP).

The PV-WAVE family – PV-WAVE, JWAVE, and TS-WAVE – as well as our customizable yield analysis technical frameworks and strong consulting expertise in the semiconductor market offer tailored made solutions particularly suited to meeting the yield analysis challenges of the semiconductor industry.

Yield Analysis Requirements in the Semiconductor Industry

Effective yield analysis is an integral component in driving quality products to market as quickly as possible with optimal yield output — which maximizes revenue. Once a product is in production, continuous improvement to the process can further increase quality yield output. Rapid data collection and reliable analysis reduces the response time to yield and process problems.

Whether you need to improved **time to volume**, **quickly identify yield issues**, **improve yield visibility**, **analyze split lot or lot quality**, **perform outlier or trend analysis** or **accelerate your yield learning curve**, the ability to quickly, consistently, and flexibly analyze and visualize specialized data from your wafer manufacturing processes significantly keeps operational costs down and increases your return on investment (ROI).



Yield analysis is a vital component to yield management. Effective yield analysis includes the following key components and allows accurate yield prediction and ensures the right level of work in progress (WIP).



Accurate and Reliable

High quality statistical techniques, statistical charting methods and wafer maps are needed to meet the demanding requirements of a yield analysis solution. Robust, reliable numerical algorithms are essential to achieving accurate results from yield analysis efforts.

Flexible, Easy to Use, and Customizable

A packaged solution seldom meets all of a user's requirements. A custom solution for yield analysis allows each organization to have an integrated analysis environment tailored to their unique requirements. It is important to have technology that not only addresses immediate needs and, is also is easy to use, flexible, customizable, and scalable to meet unanticipated future requirements.

Web-enabled for Collaboration and Sharing

With outsourcing and global companies access to information quickly from anywhere in the world is increasingly important. A web-based solution allows engineers to access engineering data in a collaborative environment. The Internet speeds the flow of vital analysis to all interested parties.

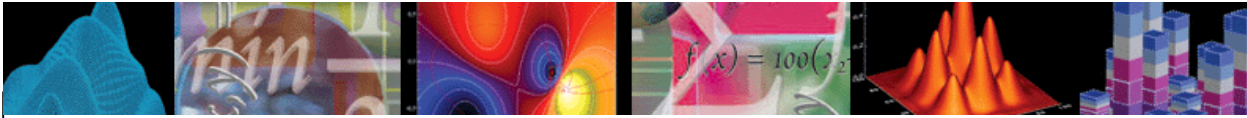
Integration with various architectures and systems

Modern semiconductor companies, like other large high-tech organization often employ enterprise-wide information architectures for managing their data requirements. To provide the best productivity gains the yield analysis function must work within the corporate information architecture. Data needs to be gathered from diverse sources for analysis by the engineers. The analysis environment must be capable of working in a wide variety of information architectures and bring the data into the analysis system quickly and easily.

Challenges in Yield Analysis in the Semiconductor Industry

Yield analysts in the Semiconductor industry face manufacturing processes that are highly specialized and unique in several significant ways:

- The process to build a semiconductor wafer is very long and complicated and the amount of data collected in the modern fab is growing rapidly.



The manufacturing process for a wafers involves hundreds of steps and can take from days to weeks. With fabs running 24 hours a day 7 days a week, rapid detection of yield problems is crucial.

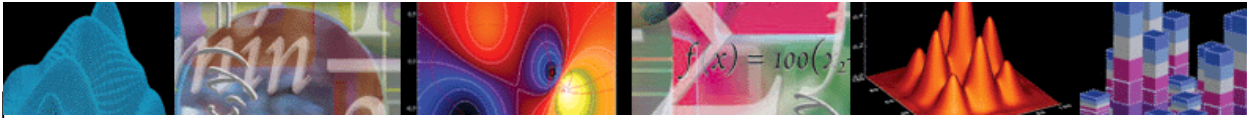
- The data generated by a modern fab is rapidly increasing as the metrology instrumentation improves in speed and capability. Further, factory throughput is continually increasing and this is another factor for the generation of massive amounts of data.
- The process of building a semiconductor is often a global activity with outsourcing occurring at many stages. Rapid analysis and information flow to all participants in the design and manufacturing process is critical.
- Due to increasingly intense competition, many semiconductor companies are making significant changes in their supply chain with increased outsourcing and fabless integrated device manufacturing – to achieve optimal production efficiencies.
- Traditional supply chain management products and techniques ignore the vital and important area of yield analysis as part of the semiconductor manufacturing process.
- Time to market pressures result in manufacturers using new chip designs prematurely – before bugs are completing addressed – making it difficult to achieve predictable yield output of quality wafers or chips.

Accurate yield analysis increases yield predictability, ensures quick response time to yield problems, and reduces die loss. In addition, the right analysis tools will allow manufacturers to monitor process tool performance, improve maintenance schedules, and enhance control of process modules.

The Solution – the PV-WAVE Family of Products

The PV-WAVE family of products by Visual Numerics — PV-WAVE, JWAVE, and TS-WAVE — delivers yield analysts specialized analysis and visualization tools to optimize their custom manufacturing environments. Additionally, our team of consultants has strong expertise across various industries including the semiconductor market, and with your yield analysts, can build the most optimal, custom solution tailored to meet your specific needs.

The PV-WAVE family of development solutions allows analysts to rapidly import, manipulate, analyze and visualize your data. And, PV-WAVE Advantage includes a sophisticated set of analysis routines based on the IMSL libraries. For over 30 years, the IMSL libraries with its industry standard mathematical and

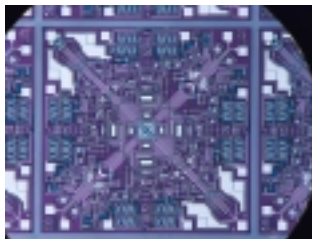


statistical functionality have provided robust and reliable numerical analysis across several industries including the semiconductor market.

JWAVE provides a web enabled solution that allows teams to collaborate across the enterprise and quickly access and understand what the yield data means, from anywhere, at anytime. Using JWAVE and/or our Visual Numerics' highly specialized consulting team with our customizable yield analysis technical frameworks, we can quickly address your specific requirements in the wafer manufacturing process.

TS-WAVE delivers an extensible, off-the-shelf solution that allows for custom interactive time-series data analysis. It allows you to read, transform and plot data in time history plots, tabular data views, X-Y plots, and contour plots. Through a point and click interface you can customize the plots extensively by modifying many plot attributes and adding annotation. It has built-in report generation features and allows batch processing.

How the PV-WAVE Family Meets the Needs of the Semiconductor Industry



The process becomes streamlined, operationally efficient, and fast

Wafer fabrication is a complex, time consuming and often costly process. Using the statistical methods provided by the IMSL libraries to analyze yield data and make adjustments to the process as quickly as possible can save fabs thousands of dollars per batch.

Massive amounts of data can be managed and analyzed more effectively

PV-WAVE provides the tools necessary for gathering and analyzing large amounts of data quickly and easily. PV-WAVE provides all of the tools necessary to extract data from a database or read in textual or binary data files. The array-oriented language makes working with the data simple. The charting techniques allow the engineers to use visual analysis to help direct their statistical investigation of the yield data.

Management of global activities through web-based solutions is possible

Using JWAVE to build a web-based application allows the engineers to have a common interface to the data no matter what the platform or location. The results of the analysis can be quickly and easily made available to other



departments in the organization without time-consuming data transmission and report generation.

Effective yield analysis results in higher predictability and profitability

As chip designs are pushed to production faster and faster and the designs become even more complex, effective analysis tools are vital. Yield analysis must be sophisticated enough to meet the needs of the engineers in order to fully understand all of the components of yield and defect detection. Using the IMSL libraries for the analysis allows the application designers to expand the yield analysis to new techniques without costly algorithm development. Using the IMSL libraries through the PV-WAVE scripting language makes the development of new application features a simple process. This rapid application development environment allows the developers and the engineers to collaborate on the development of a new technique and iterate to the optimal solution for their unique environment and conditions.

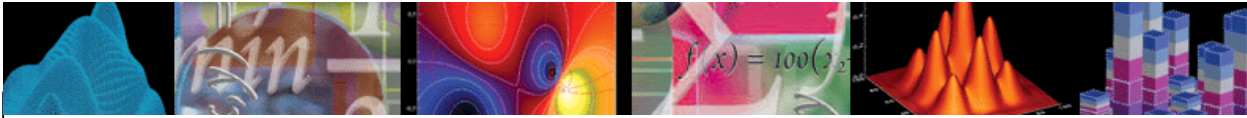
How PV-WAVE Meets Yield Analysis Requirements in the Semiconductor Industry

The PV-WAVE Family provides solutions that are robust, flexible, scalable, and easy to use in order to meet immediate needs quickly as well as address unanticipated data analysis and visualization needs in the future. Several flagship customers around the world use PV-WAVE as the one stop shop solution for all their data analysis and visualization requirements.

With JWAVE and our Visual Numerics' highly specialized consulting team, we can quickly address your specific requirements for a customized yield analysis solution. Further, our consulting experts have developed technical frameworks based upon JWAVE that can quickly address your needs in the wafer manufacturing process.



The PV-WAVE scripting language is easy-to-use and its application specific analysis algorithms and charting techniques can be leverage to build programs quickly. Using automated metrology tools and testing equipment, data can be generated at an astonishing rate. Collected data has no value if it cannot be easily retrieved and analyzed. PV-WAVE provides a wide variety of data import techniques, allowing data to come from databases or raw data files.



Data Analysis and Visualization

Trend analysis requires that data be filtered on a variety of criteria selected by the user. Trend analysis can quickly identify what processes are driving high yield results and what issues and problem areas might exist with low yield results. The PV-WAVE language provides an easy methodology for working with the parameters and quickly filtering the data sets for analysis.

Statistical and visual correlation is an important aspect of yield and failure analysis. Analysis tools need to provide visual representations of the correlation results. With sufficient data, graphical analysis can identify major failure modes and identification of specific failure mechanisms.

For statistical analysis, PV-WAVE utilizes the reliable and trusted IMSL libraries. PV-WAVE Advantage delivers powerful data analysis capabilities that include the industry standard IMSL libraries of over 370 proven mathematical and statistical routines. Yield analysts interested in effective yield management in the semiconductor industry will routinely use IMSL for regression, correlation, ANOVA, categorical analysis, nonparametric statistics and multivariate analysis.

For visual data analysis, the PV-WAVE Family delivers customizable analysis and visualization functionality that can optimize yield analysis efforts leading to operational efficiencies for higher productivity and profitability. PV-WAVE's easy-to-use, interactive 2D, 3D, and OpenGL display capabilities along with JWAVE's web-enabling functionality allow yield analysts to access, share, and obtain meaningful insights to their data quickly and accurately.

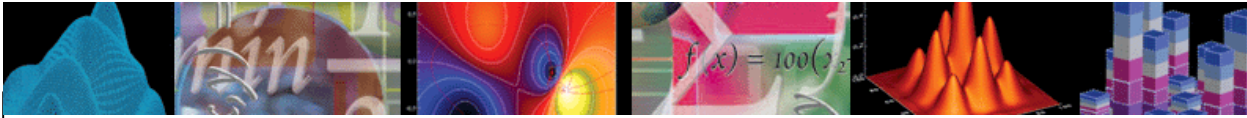
Sample Charts and Mapping for Effective Yield Analysis

Effective Yield Analysis achieves accurate yield prediction and ensures the right level of work in progress (WIP). Following is a brief overview of some of the charting techniques available with the PV-WAVE Family that easily provide the right analysis framework to increase yield predictability, ensure a quick response time to yield problems, monitor process tool performance, improve maintenance schedules, and reduce die loss.

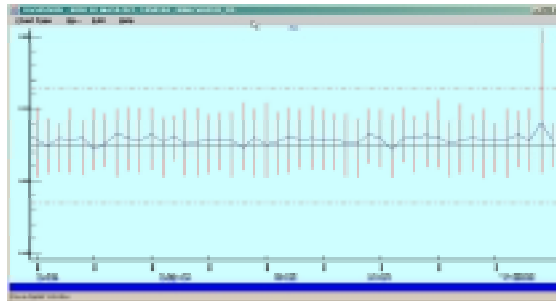
Lot Quality Control

An important aspect of yield analysis is the statistical analysis of yield parameters. A simple, intuitive interface tailored to your unique requirements allows your analysts to focus on critical yield management improvements and not spend valuable time on how to run applications or get the data.

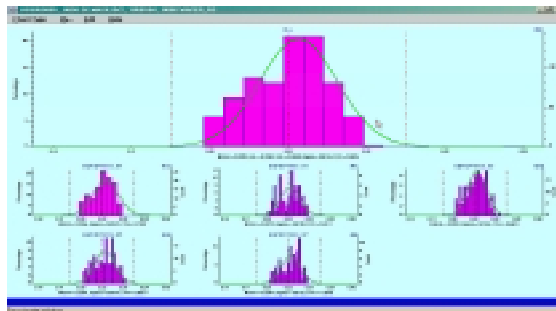
- **Trend charts** – This type of chart gives you a graphical and statistical overview of the selected lot data. The blue line shows the mean values



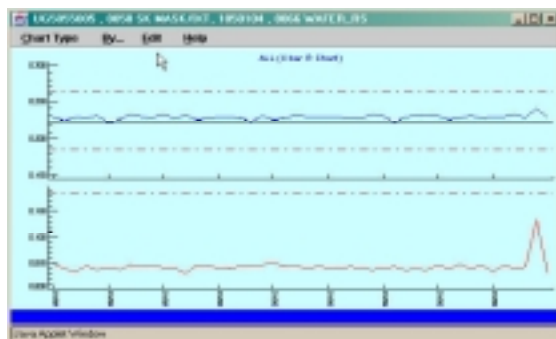
for each lot. Each bar shows the min, max, and range for a single lot. The Upper Specification Limit (USL), the Lower Specification Limit (LSL) and the target values identify specification values. The bottom of the chart shows the statistical values: Cp, Cpk, Max, Min, and Avg.

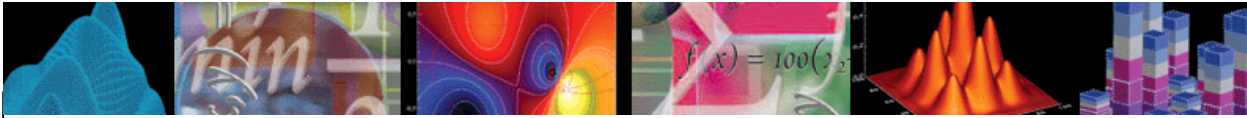


- Histogram** -- The upper chart shows the histogram for all process IDs and the lower charts depict individual process IDs. Showing the total and component histograms in the same window helps highlight variations and which equipment (Process ID) could be affecting yield.

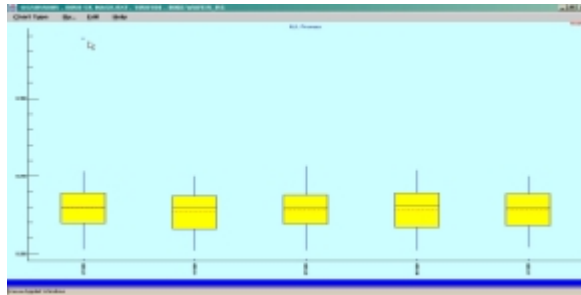


- Xbar-R and Xbar-S Charts** -- The X bar R chart allows you to compare variation in the data by displaying the mean and the range in a single display. As with the trend chart the Upper Specification Limit, the Lower Specification Limit, and the target are displayed.





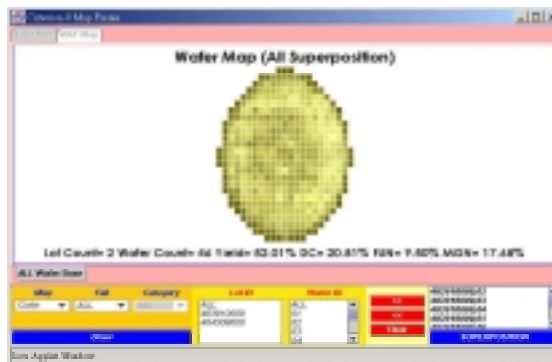
- Box Plot** -- A box plot provides an excellent visual summary of many important aspects of lot value distribution. With this chart, we can see the distribution is similar for all Process IDs (x axis labels) and you can delve deeper into outlier data for the problem process ID.

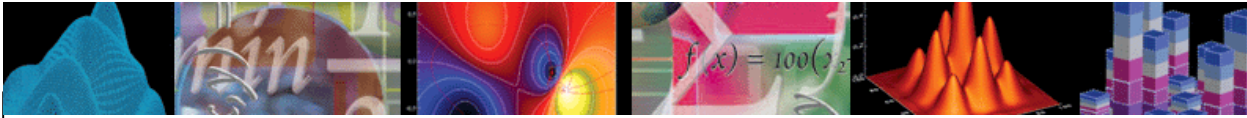


Wafer Mapping

Looking at wafer maps is another technique for finding yield problems and understanding defect patterns. With wafer maps, your analysts can drill down to individual wafer to look at specific failures or look at composite maps to identify meaningful trends and insights that can significantly improve the operational efficiencies of the wafer manufacturing process.

- Wafer Map** -- The Wafer Map display shows the defects for all of the selected lots superimposed. At the bottom of the wafer map are the yield percentages. You can subset the data and look at a single lot or a group of wafers. Or, you can subset the data by failure conditions. In this example, we can see that the DC failure rate is the highest, so this keeps the analysis focused on DC failures.

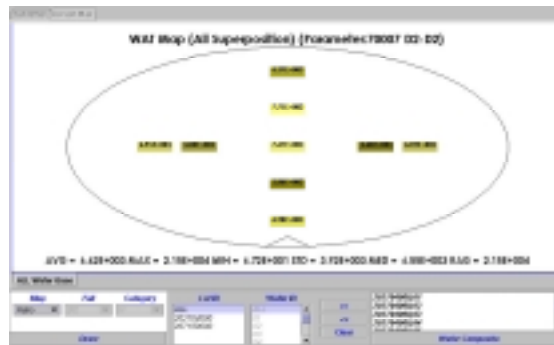


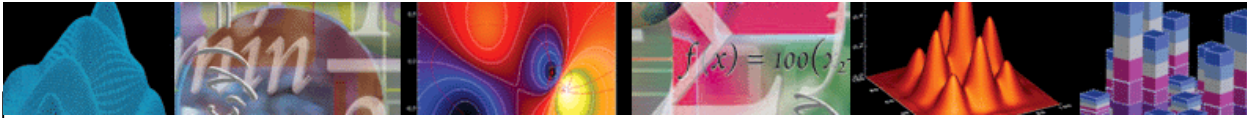


- Failure Map** – More detail is available on any one of the failure causes. Looking at the DC, most of the failures are around the edges, with a concentration in the lower left area. This interactive chart allows you to quickly and easily find the category causing the most defects.



- WAT Map** – This display allows you to take a look at WAT parameters. A simple right click on the display will change the parameter easily.

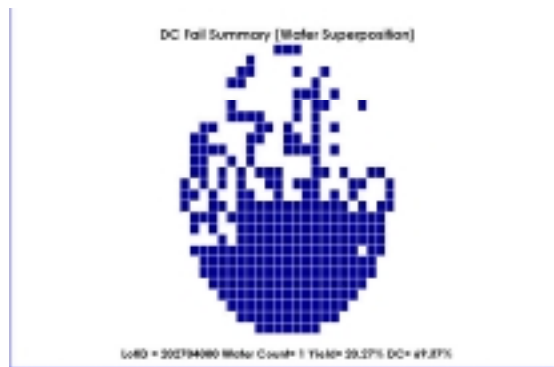


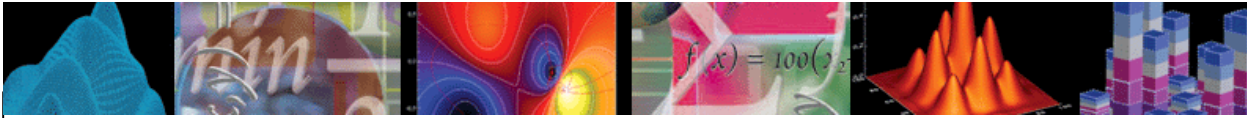


- **Yield Map** – The yield detail map allows you to show failure causes for each die on the wafer and all the wafers in the lot at the same time. With this interface, you can change failure and category conditions.



- **Failure Detail Map** -- You can display the wafer detail for the selected failure and category for any wafer by simply double clicking on that particular section of the yield map.





Customer Success Stories

Customer: ICSI – Integrated Circuits Design Company

Situation: ICSI required a web-based data analysis system that would allow them to meet specific statistical and visual data analysis needs and significantly increase performance and productivity. Engineers were downloading the wafer acceptance test (WAT) or yield data to their computers and then analyzing individual data using programs such as Excel, which are not economical especially in terms of time, efficiency and performance.

Solution: Using JWAVE, ICSI quickly built a sophisticated web-based data analysis system meeting analysis and visual requirements and allowing engineers to carry out real-time data and visualization analysis.

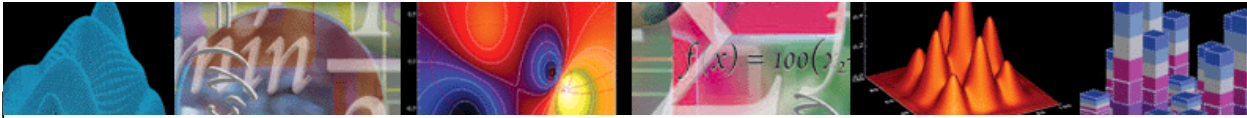
Benefit: The JWAVE solution allows engineers to carry out real time analysis and quickly find the accurate yield parameters to send to the fab. ICSI states that JWAVE has provided tremendous savings in time and increased productivity -- saving more than 50% in time and efficiency.

Customer: Winbond

Situation: Winbond had requirements to enhance their existing engineering data analysis system. Upgrades were necessary to accomplish faster processing of large amounts of data and graphics, improve operational efficiencies, meet corporate e-strategy needs, and build a web-based user interface.

Solution: Using JWAVE and customizable yield analysis technical frameworks, Visual Numerics' expert consultants developed a new custom-built, interactive yield management system. Using JWAVE's web-enabled architecture, Winbond is now able to integrate several modules under a single web portal including Lot QC (LQC), yield-yield map, wafer acceptance test (WAT), correlation, defect, work in progress (WIP), machine QC (MQC), and others. Engineers can now use differently modules concurrently to carry out interactive data analysis.

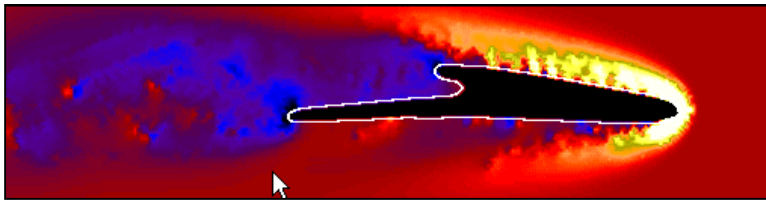
Benefit: Using JWAVE, Winbond now take advantage of a web-enabled solution with advanced technology for custom yield analysis. Winbond can now use new streamlined methods for yield data collection as well as quickly and easily determine factors affecting yield. With the custom solution build upon JWAVE, Winbond has improved the overall efficiency of yield analysis and significantly increased the yield output of quality products.



Visual Numerics - A Partner not Just a Vendor

Visual Numerics has provided Trusted Numerics and Scientific Graphic tools to many users in the semiconductor industry for years. The PV-WAVE Family has the functionality you need now and in the future, including an open software environment to allow your investment to be integrated with new technologies.

Visual Numerics is your partner, not just a software vendor. We have unparalleled technical support that can answer the hard questions fast, and consulting that can provide in-depth expertise and fast delivery of time-critical solutions. Long time users can attest to the quality of support provided by Visual Numerics, which can be very important when you have difficult problems or tight schedules to meet. If you need specific expertise that is beyond what you have available in-house, or need to rapidly develop a solution and do not have the resources to develop it in-house, then the Technical Resources Group is available for contract development and are there to make sure you are successful.



PV-WAVE has been an important tool for yield analysis for years. We work closely with many customers and are responsive to their

particular needs and to the needs of the semiconductor industry. The PV-WAVE Family provides you with standardized software that can provide rapid, high quality, cost-effective solutions for many kinds of problems, and deliver a positive return on your investment through maximizing your productivity.



PV-WAVE