ADVANTEST

ACS

UNLOCKING VALUE:
The Power of AI in Semiconductor Test

ACS White Paper

INTRODUCTION

AI (Artificial Intelligence) and data analytics empower semiconductor manufacturers to extract valuable insights from the massive amounts of data generated throughout the silicon lifecycle. By leveraging AI algorithms, semiconductor manufacturers can optimize silicon design, assembly, and testing processes. Through the analysis of vast datasets, AI can identify patterns, predict failures, and optimize quality, leading to improved yield rates, reduced production costs, and accelerated time-to-market.

Semiconductor manufacturers are actively developing data analytics applications to establish a fully integrated workflow across the semiconductor test ecosystem. A state-of-the-art data analytics solution encompasses vital features like streaming data collection and control, data feed forward, low latency, intelligent decision-making powered by ML-driven algorithms, and robust data security and integrity capabilities. This enables the end-to-end utilization of analytics throughout manufacturing and test operations.

This white paper addresses the significant semiconductor test challenges of the digital age and highlights the benefits of intelligent manufacturing solutions that drive efficiency and optimize production processes for semiconductor customers. The solutions include ACS Real-Time Data Infrastructure (RTDI) and machine learning-driven analytics solutions from Advantest and its ecosystem partners, establishing a digital highway for the seamless integration of all test data. By leveraging low-latency edge computing and analytics solutions, real-time monitoring of semiconductor test operations becomes possible, enabling prompt corrective actions. This leads to improved quality, yield, and faster time-to-market for customers.

THE STATE OF THE SEMICONDUCTOR INDUSTRY IN 2023

The semiconductor industry is fundamentally a thrilling, high-stakes game of cat and mouse. It is a world of cutting-edge technology, where the separation between science and science fiction is often blurred. It is also an industry where the biggest players hold almost all the cards, but where new players are constantly emerging to shake things up.

In the world of semiconductors, the line between success and failure is razor-thin and the future is always uncertain, but constant innovation and progress are inevitable, with new technologies such as 5G, the Internet of Things (IoT), and AI driving demand for more advanced semiconductor devices and solutions.

Integrated circuits reflect a relatively recent New World Order where the trade tensions between countries and supply-chain disruptions are constant threats and where the impact of the pandemic continues to affect the industry as well. But despite these challenges, the industry continues to push forward, driven by the relentless pursuit of innovation and progress.

The industry is constantly pushing the boundaries between what is possible and what seems impossible. It is a world of innovation and limitless possibilities, where the brightest minds and the most daring entrepreneurs can change the course of history. The risks are high, but so are the rewards, where

the future is always up for grabs, and where the only thing that's certain is that nothing is certain. Ultimately, only the strongest and the smartest will survive.

PREDICTIONS FOR THE INDUSTRY: 2023 AND BEYOND

The impact of the rapidly evolving digital superhighway is already being felt with big data and advanced technologies driving change. One projection puts the semiconductor market at approximately $1.1 trillion in 2030, with a CAGR of 9.03% from 2020 to 2030 compared to 3.96% from 2010 to 2020 (Figure 1).

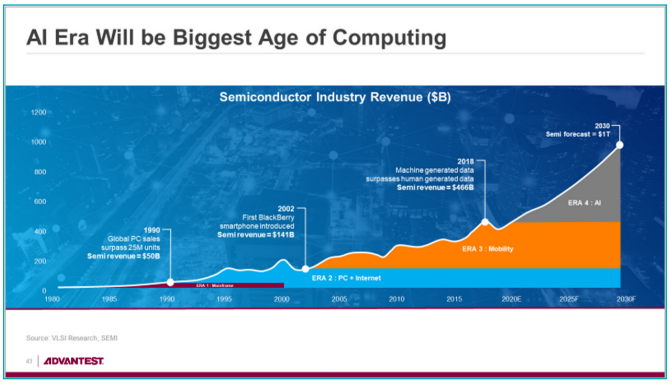

Figure 1. One projection puts semiconductor market at approximately $1 trillion in 2030.

The increase in the software content of electronics products will also have a positive impact on the growth of the semiconductor market.[1]

This rapid market growth will significantly impact test with respect to the exploding test-data volume and ways to handle that volume:

- One report says that "…roughly 2 TB of data were generated per day in 2019…" and adds, "The volume of test data jumped in the move from 10nm to 7nm, and it will increase again at each new node." The report attributes this increase in part to more chips per wafer but also to more transistors per chip, increased design complexity, and more process corners as well as new processes, tests, diagnostics, and more complex assembly.[2]
- The data explosion originates in part from the ever-growing number of test vectors necessary to test the increasing number of transistors per chip (Figure 2).[3]

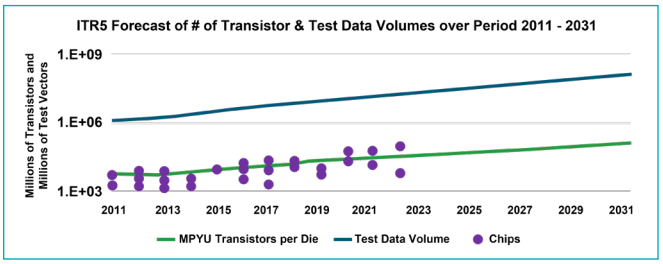

Figure 2. The growing number of transistors and the vectors needed to test them is driving the test-data explosion.

- The industry is seeing a greater focus on data analytics. The increasing amount of data generated during test will place a greater emphasis on data analytics to extract insights and improve decision-making.
- The increasing complexity of semiconductor devices will drive the increased adoption of AI and ML in semiconductor testing. AI and ML can enable more advanced testing methods and equipment to help improve efficiency, accuracy, and scalability.
- The use of data feed forward and data feed backward will become more prevalent, helping to improve the accuracy and efficiency of semiconductor testing.
- Data and Edge computing will augment semiconductor testing, allowing for more flexible and scalable testing methods.

Market growth will also increase pressure on test with regard to application areas, packaging strategies, environmental concerns related to edge applications, and cybersecurity:

- The growing demand for autonomous vehicles, IoT, and 5G devices will drive the need for more advanced semiconductor testing methods and equipment.

Increasingly widespread use of heterogeneous integration[4]—the integration of multiple technologies and materials in a semiconductor product—will lead to an increased need for testing methods that can handle it.

- Test equipment must be flexible and able to handle a wide range of environmental conditions, and test data should be available in the distributed network rather than being restricted to a centralized database.
- Devices under test will include increasing number of sensors, and the data produced by them will need to be leveraged to improve product quality, reliability, and efficacy. Also, test equipment will have more embedded sensors which will exploited to monitor and control test operations in real-time.
- As semiconductor devices become more complex and further connected, there will be a greater need to focus on cybersecurity to protect against potential cyber threats and ensure the integrity of IP during the testing process.

And finally, the semiconductor test industry will likely see the emergence of new business models, such as pay-per-use and subscription-based services, and advancements in automation and robotics will continue to be adopted more widely in semiconductor testing, helping to improve efficiency and reduce human error.

MAJOR CHALLENGES FACING THE INDUSTRY

In addition to the challenges related to heterogeneous integration, 2.5D and 3D packaging, test data volume, and service-based business models, the increasing complexity of semiconductor devices will require faster test times and higher throughput to keep pace with the rapidly increasing demand for semiconductor devices; more accurate and precise testing as semiconductor devices become denser and more complex with increasingly tighter tolerances; and flexible and open solutions to test a wide range of devices using technologies from differing sources.

Furthermore, test systems must have the ability to test multiple technologies, such as digital and analog, be on the same platform; be able to handle a larger number of device types and package sizes; can test at different temperatures and voltages; and to test new materials and structures, such as those used in 2.5D and 3D packaging. Finally, strategies must be developed to handle the challenges of data privacy, security, and compliance in the era of big data and data computing.

The challenges of big data are daunting. One estimate states that 80% or more of the data collected across the semiconductor supply chain is never looked at, from design to manufacturing and out into the field. Contractual obligations, particularly in the automotive and aerospace industries, may require archiving data for 10 or 15 years, but engineers tend

to only look at the data needed to solve a specific problem. In addition, some stored data lacks the traceability and context that would make it useful.[2]

That is not to say there is no value in the data. But the tools and infrastructure to effectively analyze the data and extract maximum value from it are currently inadequate. Everyone desperately wants to mine their data, but practically speaking they simply physically cannot make it happen.

Yet another problem is that currently, testing is typically accomplished via a file-based approach, whereby the data is not available until end of wafer or end of lot, and only then can the data be analyzed offline, often at a different location. Even though the clock is ticking, hours or days are often needed to perform analysis and corrective action.

This approach is no longer viable given the rapid pace at which the test industry is evolving. As stated, chips are becoming increasingly complex and, in many cases (including medical and automotive device test), zero defects is the goal. In other cases, even minor defects that used to be acceptable now render more sensitive and complex chips useless. Testing these more advanced chips has therefore become the challenge, along with meeting more aggressive time-to-volume goals and time-to-volume goals that ensure IC producers can remain competitive.

One company has reported success using an online infrastructure approach, which reduces latency from hours or days to milliseconds or microseconds. The approach enables on-the-fly ML scoring an decision-making while maintaining secure communication.

The approach applies neural networks to parametric prediction, taking into account dependencies on temperature, power, and other conditions, enabling significant test-time reductions with zero impact on quality.[5]

ADVANTEST ACS: THE SOLUTION TO SEMICONDUCTOR TEST CHALLENGES

With advanced analytics, including ML capabilities and future-proof, real-time, automated production control, the ecosystem addresses test challenges by integrating all data sources across the entire IC manufacturing supply chain. This ecosystem enables customers to achieve intelligent data-driven workflows and helps customers realize better yields, faster time-to-market, accelerated time-to-volume, and improved quality and reliability. As a part of Advantest's Grand Design strategy, ACS is enhancing edge and data infrastructure services, data analytics, and AI/ML solutions as a means of helping customers accomplish data-driven workflows.

Advantest's data-based products and services are based on a single scalable real-time data platform (Figure 3), which empowers customers to develop or procure market-leading solutions from Advantest and its partners. ACS uses real-time ML analytics so that customers can quickly turn insights into production-worthy actions. These rules and procedures are easy-to-use and accessible across the entire semiconductor value chain.

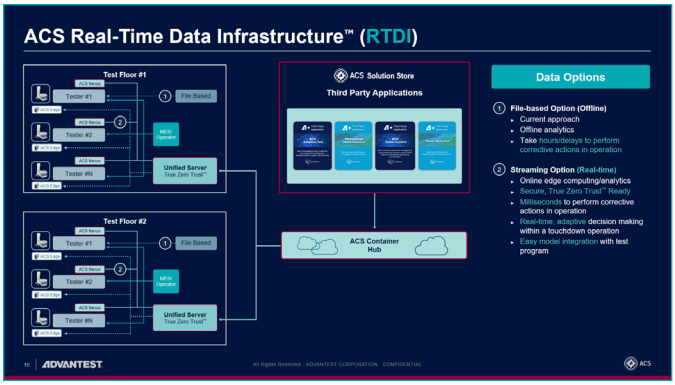

Figure 3. A real-time test-data platform can eliminate the hours or days otherwise necessary to perform corrective actions.

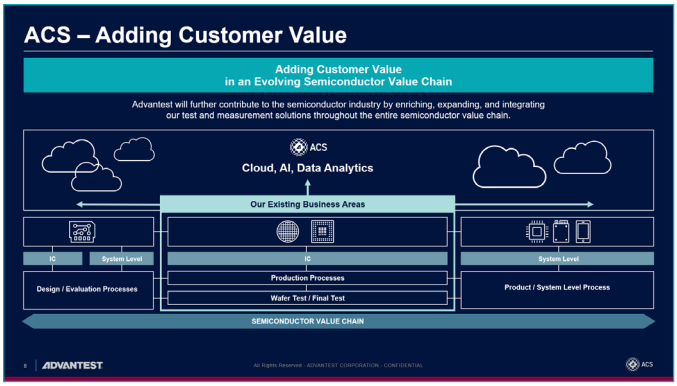

Figure 4. ACS, AI and data analytics add value to the evolving semiconductor value chain.

THE BENEFITS OF ADVANTEST ACS

Given that the current testing approach is costly, cumbersome, and time-consuming, the industry needs a new paradigm. To address this need, Advantest has created the industry's first Real-Time Data Infrastructure (RTDI)—an innovative, revolutionary approach to providing analysis and corrective analysis and action in the evolving testing environment (Figure 4). Compared to file-based analysis, online edge-computing analytics are performed in a secure, True Zero Trust™ environment that detects issues and applies corrective actions in just milliseconds. In this way, ACS RTDI provides real-time, adaptive decision-making with solutions that are also easy to integrate into any test program, and it enables customers to maximize the Advantest value chain to deliver improved yield, quality, time-to-market, and time-to-volume.

ACS RTDI acts as a communication backplane for the test floor to facilitate rapid, secure, and accurate information exchange. It supports online edge computing/analytics to enable real-time adaptive decision-making within and between touchdowns. Real-time data monitoring with intelligent data extraction and control enables the initiation of corrective actions within milliseconds.

ACS RTDI includes several specific key features and technologies:

- The ACS Container Hub™ employs container technology to enable automated software distribution for containerized apps. This product ensures easy, secure, and reliable deployment of the apps to the test fleet while ensuring seamless integration into the ACS ecosystem.
- ACS Edge™ Server, a high-performance and highly secure edge-compute and analytics solution, offers millisecond latencies to facilitate real-time adaptive decision-making during test execution.

- ACS Nexus™ provides a standard interface for real-time test-cell data streaming and inline equipment control between equipment and external clients across all Advantest platforms, enabling inline analytics capabilities, real-time control, and across different test stages. It enables applications to maximize yield, optimize throughput, and ensure test quality without increasing breakdown risk in the production line.
- ACS Unified Server supports scalable and redundant compute and storage resources to enhance workload management and minimize the risk of downtime while providing True Zero Trust™ security for the test floor and it supports data feed forward/feedback and also provides transaction-level security, cross-platform support, multi-party sharing, and data governance while enabling packet inspection and transaction logging.

Collectively, these solutions are helping customers transform data into real-time production control, delivering excellent results and improved ROI for their products. Advantest is setting a new standard in the semiconductor test equipment and test data analytics industries.

ONLINE SOLUTIONS STORE

To further support ACS's ground-breaking strategy, ACS also has an online solutions store (Figure 5) where customers can find a comprehensive collection of software designed for the digital age that address major challenges facing the semiconductor industry. The store offers a wide variety of ready-made analytics solutions from multiple providers, enabling customers to achieve higher yields, faster time-to-market, more rapid time-to-volume, improved quality and reliability. It offers a wide range of capabilities, including AI/ML use cases and big-data business cases to optimize the entire semiconductor test life cycle that can be tailored to meet the specific needs of different customers and applications.

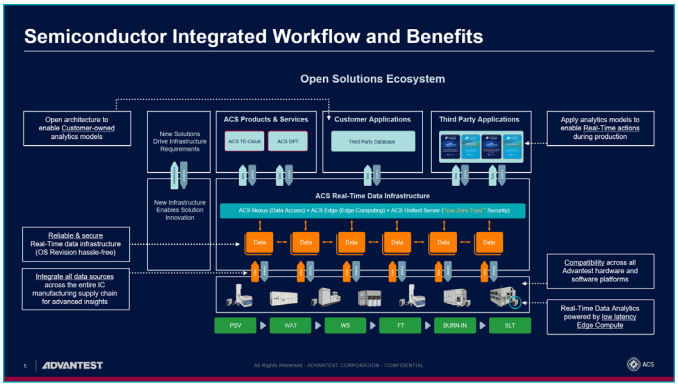

Figure 5. A solutions store is a part of the ACS ecosystem.

The solution store provides access to a variety of advanced technologies and use cases for AI and ML:

- Defect detection, with improved accuracy and efficiency compared with traditional methods.
- Test optimization, with test conditions such as voltage and temperature controlled to improve testing efficiency and accuracy.
- Yield prediction, allowing for more efficient use of resources and improved production planning.
- Test data analysis, to extract insights from and identify patterns in large amounts of data to improve the testing process.
- Parametric testing, to determine the parametric performance of semiconductor devices with regard to power consumption, frequency response, and temperature variation.

- Statistical process control, through monitoring the production process and identifying patterns that indicate a potential issue, allowing for early detection and correction of problems.
- Test time reduction, by selecting the most relevant test vectors or by optimizing the test sequence.

ACS RTDI USE CASES

ACS RTDI can serve several use cases. A fabless or IDM user, for example, could use it to make smarter real-time decisions at various insertion points: wafer sort, final test, and system-level test. As another example, an OSAT could use RTDI and its True Zero Trust™ Security to share data with fabless customers while avoiding storing data in a publicly accessible network.

Some specific functions that ACS RTDI can provide include real-time checks of trim value shifts that can indicate equipment issues and smart chiplet pairing to match the specifications of multiple chiplets in one package. ACS RTDI can also enable adaptive test time reduction to optimize cost of test without risking test escapes, and it can facilitate adaptive test flow.

CONCLUSION

Armed with these advanced analytics, including ML capabilities and future-proof, real-time, automated production control, the ACS Data Solutions ecosystem integrates all data sources across the entire IC manufacturing supply chain, a revolutionary first in the industry.

By pushing the limits of what is possible, Advantest is driving test performance to new heights by elevating its edge and data infrastructure services. Advantest is augmenting data analytics and empowering AI and machine learning solutions so customers accomplish data-driven workflows.

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