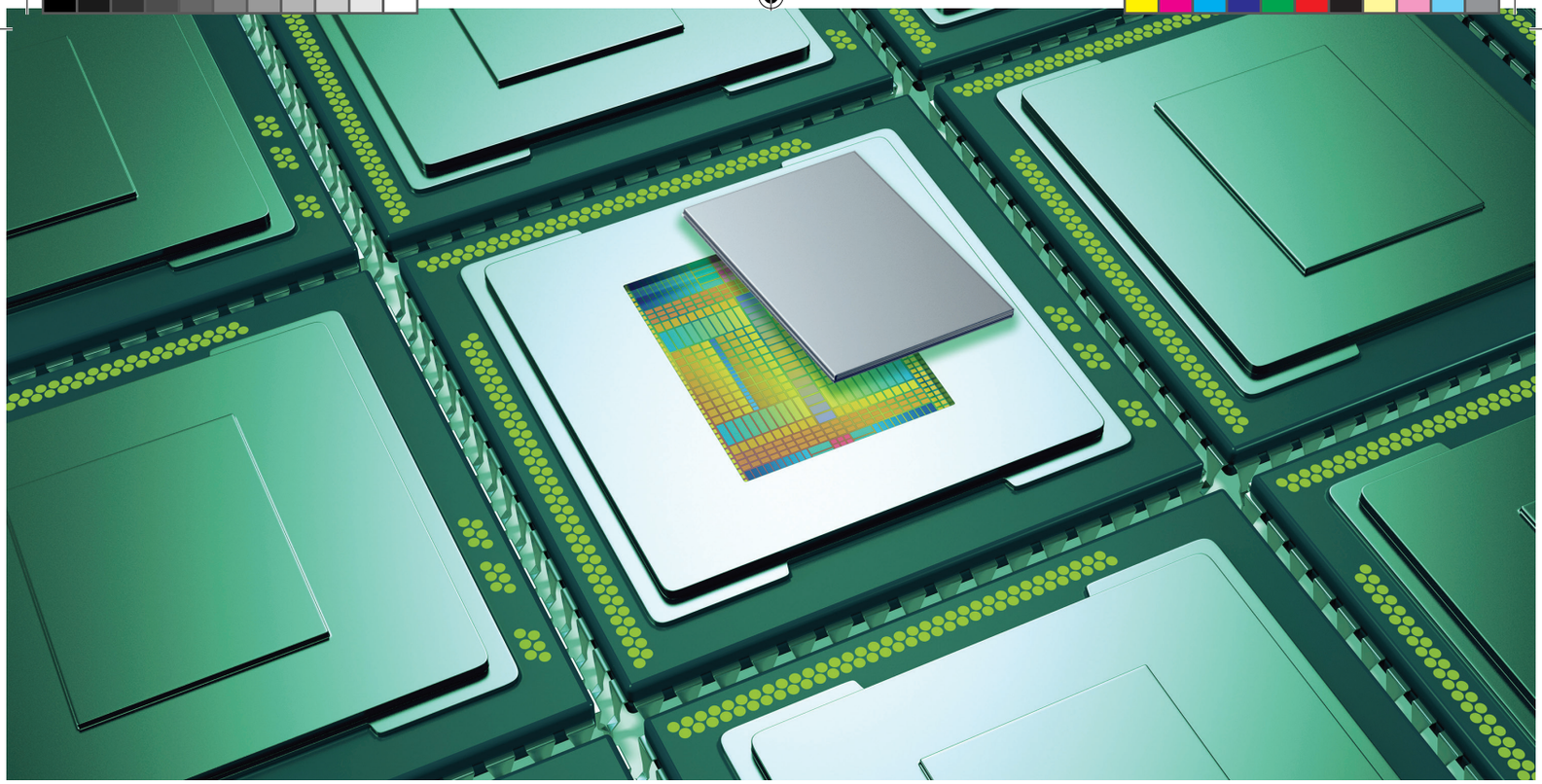

DIGITAL INDUSTRIES SOFTWARE

Single-device tracking for semiconductors

Taking a high-performance approach to streamlining data and improving control

Executive summary

Booming demand and shortages mean semiconductor production capacity is at a premium, but it will take years to expand it. Meanwhile, getting more quality products out of the factory faster is essential today. Getting more throughput means the manufacturing execution system (MES) must under no circumstances be allowed to slow down processing.

An increasing number of applications have different needs for complex multi-chip or multi-chiplet devices in small, inexpensive packages. So mixing products in a lot and performing different operations on each at some steps is crucial to maximizing utilization and profitability. Even the front-end may have unique processing per device. High-performance computing integrated with MES can support single-device forward tracking at production speed.

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Abstract

Although customers demand traceability, tracking forward motion is crucial in semiconductor production. Single-device tracking is the way to manage production and deliver data about every device and its processing history, even when single devices are processed differently. Yet most semiconductor companies cannot currently perform that tracking without unduly slowing the operation. Fortunately, a new high-performance approach is available to optimize capacity and avoid the need for additional capital. If this new tracking approach is integrated into MES, the semiconductor maker can also control how each device goes through the processes and record it effectively.

Why single-device tracking now

Market opportunity

Demand is outstripping supply and is likely to do so for sometime, so capacities are maxed out across the industry. After many years of focusing on yield, manufacturers are now looking at innovative ways to optimize utilization. Research shows that semiconductor makers consider product quality, reliability, performance, innovation, cost, product certification and internal efficiency[1] as top factors for success.

Optimizing capacity

Customer requirements for traceability include knowing the exact process conditions that every device was exposed to at every moment in its manufacturing lifecycle. Yet traceability only includes data collection; a semiconductor maker needs tracking to do different processing on each device in a batch (see sidebar later in the paper).

Tracking is the map for the operation showing exactly what's next for each individual device. Companies making multi-chip modules (MCM) – for example, central processing units (CPUs), systems in packages (SIPs), Insulated-gate bipolar transistors (IGBTs) – need to track sub-devices or chiplets as well as the final package. With their varying batch sizes at each step, tracking and monitoring each device as it proceeds through the process is essential for full traceability.

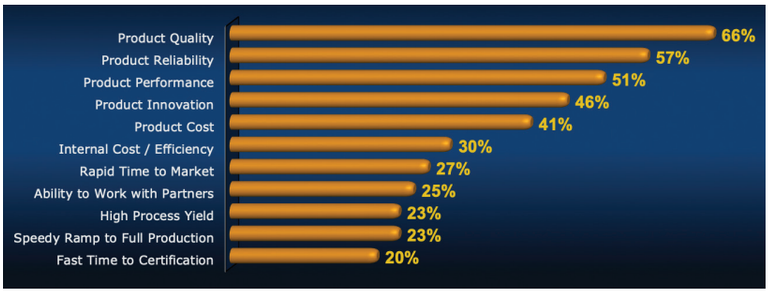


Figure 1. Important factors for company profitability and success.[1]

Complex multi-chip or multi-chiplet devices can have low yield if assembly and test are not fully process controlled. For that, tracking is an essential foundation but also needs to be connected to MES and equipment automation. Yet typical MES modeling and processing in the application layer might take seconds, which is far too slow to track the volume of individual products and subproducts in these environments.

In short, for complex products, current tracking methods are no longer adequate. Sequential data writes for single-device tracking is inefficient. Yet, companies cannot afford for data processing to slow production and limit capacity use. Parallel data writes can bog down the application server, which risks not keeping data monitoring current with the process. Some companies have developed their own systems, but these are a significant information technology (IT) burden.

More than Moore

As we reach the physical limits of single chips, they can become too complex to be cost-effective. This has led to the era of Moore and "More than Moore." Although geometries continue to shrink according to Moore's Law, most agree the industry is reaching the physical limits of single chips. MCMs are increasingly common as a "more than Moore" way to reduce costs while increasing device capability. Combining standard or specialized building block integrated circuits (ICs) into multi-chip packages enables the realization of more complex modules at lower cost, less risk and increased flexibility to meet mounting customer expectations.

Yet many applications for complex multi-chip devices require small, inexpensive packages. This means mixing products in a lot and performing different operations on each at some steps is crucial to maximizing utilization, meeting customer demand and achieving profitability.

Customer pressures

Zero defects

Customers are pushing for perfect quality and high reliability. No wonder since semiconductors are at the heart of both safety and advanced features for original equipment manufacturer (OEM) products.

The OEM's brand reputation rests on the customer experience. Most semiconductor companies are experiencing higher expectations for product quality than even their customers – 72 percent report stronger demand for quality.[1]

Nearly 4 percent of automotive warranty cost is due to a semiconductor failure.[2] As a result, customers make it expensive for semiconductor suppliers to have a quality problem that makes it to the market. Customers in other segments are adopting automotive quality standards, so all products and lines must improve quality to be profitable and avoid customer penalties or loss of position in approved vendor lists (AVLs). Stringent quality controls are becoming expensive for semiconductor companies.

Automotive warranty costs breakdown

"Analysis of the estimates from the semiconductor management group at a leading European OEM provides an estimate that ***for every $1 of warranty costs, nearly 4 cents can be attributed to the failures of semiconductors****."*

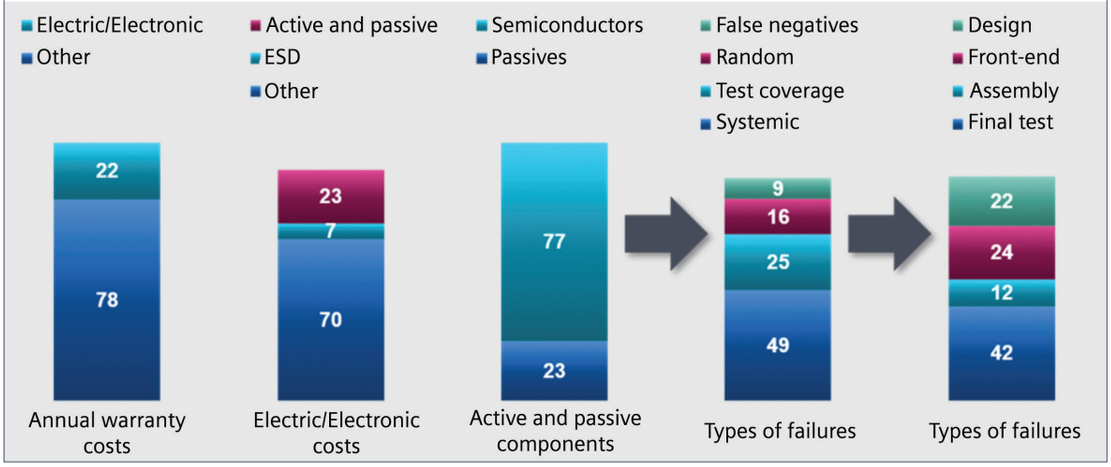


Figure 2. Annual automotive warranty costs breakdown (data presented by ELES Semiconductor at Automotive Electronics Reliability Workshop, courtesy of Semiconductor Management at BMW Group).[3]

Time pressure

Customers want products delivered in a timely manner so there is time-to-market pressure on semiconductor makers. With capacity already maxed out, companies must be innovative through every phase of production.

Beyond current products, getting new products through the process is also pressing. More than one of every three semiconductor companies report that customer pressure for faster NPI times are significantly higher than just two years previous. Only about one in five is not feeling increased pressure.[1]

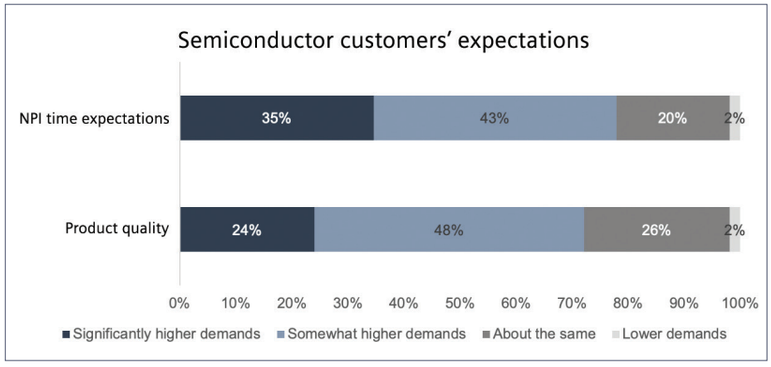


Figure 3. More than seven out of ten semiconductor companies say their customers' expectations for speed and quality are higher over the past two years.[1]

Single-device traceability

With data available for every device at every step through the entire supply chain, traceability is a way to improve quality control and reduce containment impact in the case of issues. SEMI has a task force for single-device traceability; this group developed the T23 specification for single-device traceability for the supply chain. T23 establishes a standardized approach for enabling traceable device-level ID throughout the IC manufacturing, test and assembly processes to the point of use in the final system.[3]

Traceability includes detail for the customer to trace back to see materials and processing steps, equipment and conditions for every device. However, traceability cannot meet the IC manufacturer's needs alone; chip and device makers need to both track and trace single devices (see sidebar). Often people use the terms track and trace interchangeably, but that is not correct. Both words are used in the term track and trace for a reason.

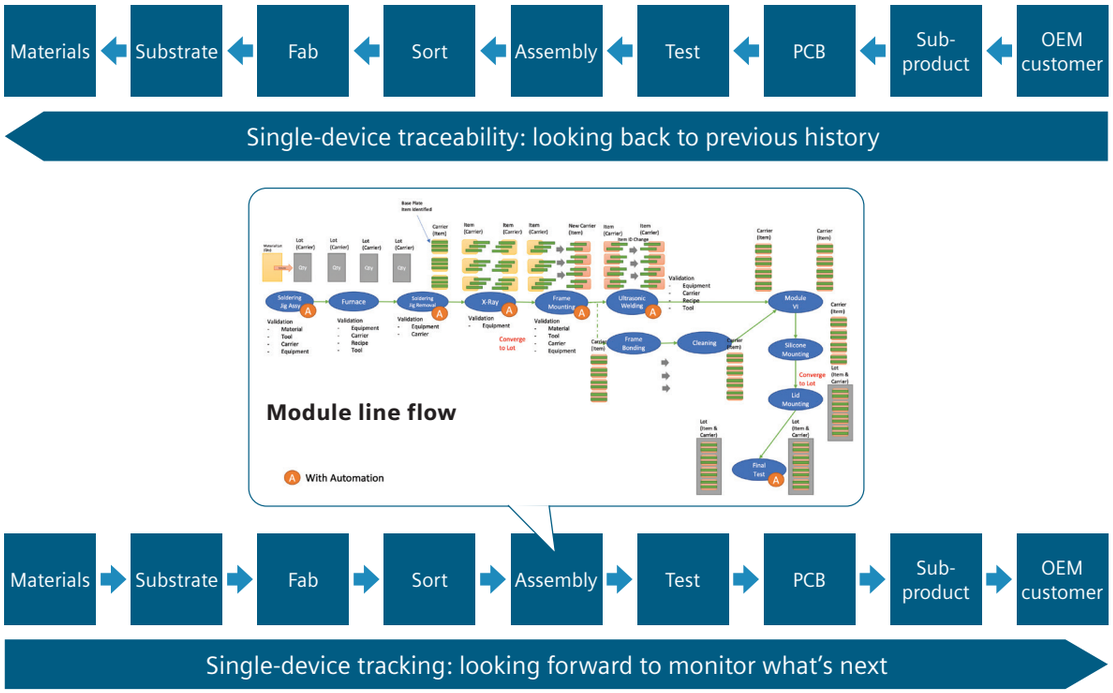


Figure 4. Single-device traceability requires single-device tracking, which can be complex at every step.

Sidebar: Track versus trace – a different direction, purpose and point in time

- **To trace:** Follow the completed path backward from its current point to where it began: for example, where a device comes from on the wafer – so this begins at the start of fab, using maps; this is backward-looking genealogy
- **To track:** Follow the emerging path forward from wherever it is currently to where it should go next, like a map: this allows different processing on each device at specific steps, the same at others, and records details and metadata associated to the individual die once cut and particular package once assembled; this is forward-looking

Semiconductor priorities

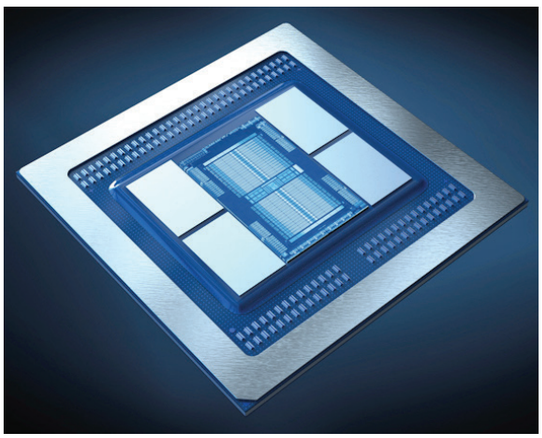
Improvement needs

Every company needs to continue rapid NPIs to meet market opportunities. With the prevalence of MCMs, the level of process innovation is unprecedented. The level of risk and complexity for production is also at an all-time high. Dozens of trackable chips or chiplets could be in each complex MCM device shipped, creating many opportunities for quality problems.

To succeed with innovation and rapidly ramp new products to maximum yield, semiconductor makers must also use data for analysis. Advanced analytics offer a clear path to understanding how to improve quality and yield and keep costs down. What's less clear is an efficient means of processing single-device tracking data about every device on its unique path going forward during processing and assembly.

Single-device tracking is the approach

Semiconductor companies face the perfect storm. The combination of complex products, a high mix and greater specs for quality, innovation and size makes it more challenging to achieve zero defects



and effectively utilize hugely expensive capital equipment and facilities. Single-device tracking is the approach to meet those customer expectations. It not only allows delivering customers detailed trace data about every device for them to use, but should there be a problem with an upcoming step, tracking allows everyone to circumvent it efficiently. In addition, potentially affected products can be identified easily and precisely.

Streamlining tracking

In tracking, parent and child lots may require two-level starts. When a shipped module has dozens of chips in it, there may be thousands of child data points to process for every lot. In a volume production facility, this is multiplied by many steps on many pieces of equipment for many lots. So the number of data transactions can add up quickly.

Today, sequential data reads into the application are so time-consuming they often slow the operation. Given capacity needs, this is unacceptable. Semiconductor companies urgently need to streamline the data processing for single-device processing.

Single-device processing and tracking basics

Semiconductors historically were processed and tracked in lots or carriers. MES typically is used to perform that lot-tracking and genealogy. However, recently, tracking single devices has become urgent to accommodate quality expectations plus complex products and portfolios for a higher mix in the back end.

Process and data discontinuity

MES typically can be used to track wafers to a lot and die to a wafer. However, sometimes, when a die is removed from a wafer, you lose information about where on the wafer the die originated. So, traceability or genealogy are not detailed enough about what happened to keep containment focused if there is a problem later.

Beyond tracking multiple wafers to a lot, knowing exactly what part of the lot each wafer is in is crucial for minimizing the containment scope when problems appear in an assembly. Containment scope creep also happens later. For example, suppose you split a lot and move some devices on one path and others on another, and then they merge again. In that case, the detail is inadequate to differentiate between which wafers were in specific operations. Should a problem occur, the result is the scope of the wafer and device containment needed grows significantly.

Beyond simple splits and merges

In increasingly high-mix fabs and backends, it is common for a single die to be part of one lot at one time and later combine with a different lot made up of multiple previous lots. These facilities may also process individual die or devices differently at the same time on the same piece of equipment at various steps and have all items in a lot processed the same way through other process steps.

Single-device tracking

Single-device tracking allows you to put all of that metadata with that single item. Even after a device is separated from the wafer processed through splits and merges, binned and graded separately, it still contains all its history and can continue through the process. Different die and individual devices each have their own information from every step moving forward with them at all times.

Single-device processing challenges

Processing single devices is essential to using fab capacity and meeting market demand for complex and high-performing semiconductors. Knowing single-device tracking is needed does not make it easy to do.

Complex processes

Complex product portfolios mean a higher mix in back ends than ever before. It is common to have single lots or carriers where individual products need unique processing at specific steps. Primarily this is for complex devices that each need different handling. Often many chips, each of which needs comprehensive track and trace, make up a finished device.

Semiconductors already involve a complex and unforgiving manufacturing process; putting each device through different processes using different parameters magnifies that challenge. It creates operational issues in the back end, particularly in a brownfield where various equipment, containers and processes are already set and do not use the same standards or carry the same number of devices. Such a situation creates the need for many splits and merges. Sometimes these splits and merges are not performed in the MES, but perhaps a strip is moved manually to the next step, leaving a gap in the digital tracking.

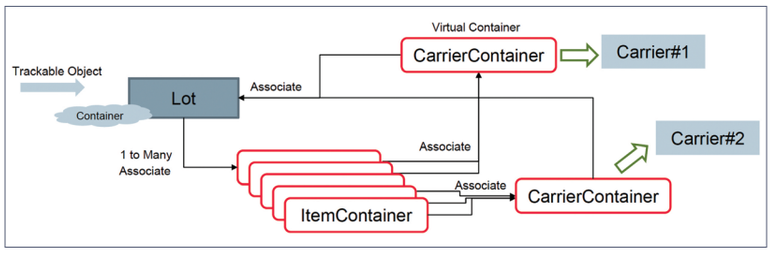


Figure 5. Relationships among carriers, lots and items are often complex.

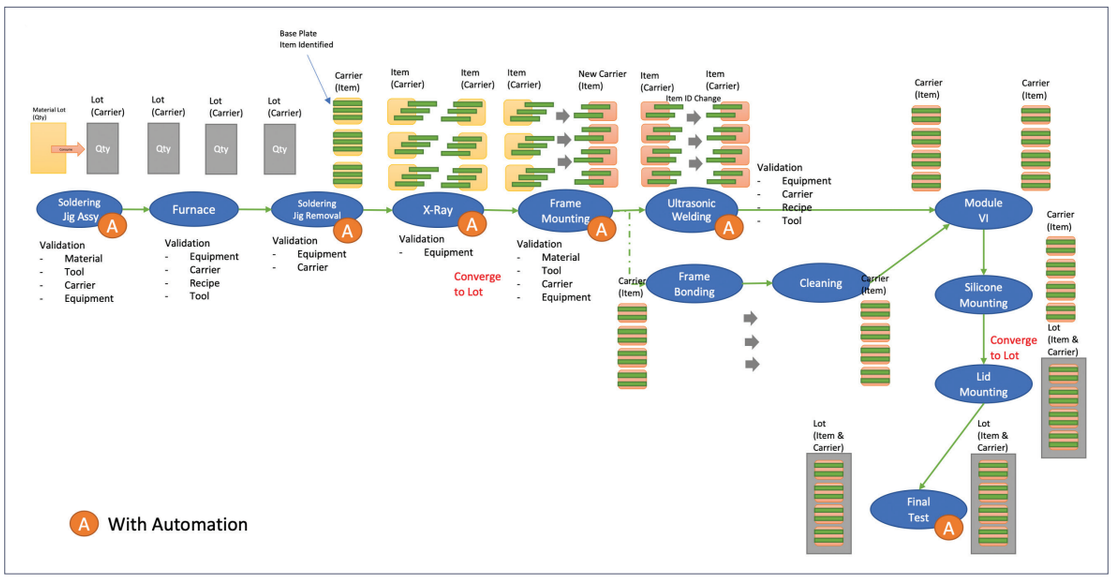


Figure 6. Typical semiconductor assembly and test process flow with a view of how complex each top-level block can be.[2]

Exponential growth in tracking data

No product can ship without genealogy or traceability data. Yet, with so many individual products and subproducts to track in each lot, the company may need to record many thousands of data points per week for single-device tracking. At specific process steps, the lot size is one single device. So, there would be 1,000 transactions at that step for a single lot of 1,000.

Sequential data processing at steps where devices are processed individually is far too slow to keep up with production: which, by definition of its function, the MES must do. Single-device tracking requires fast data handling to keep production processes moving, particularly with high volumes and unique devices. Leaders have developed ways to do this for the past decade or more, but they are homegrown and fragile methods, sometimes housed in custom databases.

A high-performance approach

Clearly, the semiconductor industry needs a new approach to single-device tracking to meet business and customer needs. High-mix, high-volume fabs need single-device tracking data to move efficiently for every component within each complex device. Fortunately, today commercial high-performance processing can support this need.

Speed and detail

Customers' expectations for complex products for new applications, zero-defect quality and single-device traceability make single-device tracking essential. To meet market demands profitably, companies must track single devices rapidly and effectively to keep running time-sensitive processes, utilizing capital and keeping IT overhead low.

Beyond data acquisition to control

Homegrown or custom-developed single-device tracking is all about data acquisition, writing into a database to record what happened to each device in a lot. Ideally, tracking can do more than record data for tracing; it allows forward monitoring. However, it does not provide forward process control, nor the ability to improve based on data analysis. Semiconductor manufacturers need this control to thrive.

Data for analytics

The continued quest for perfect quality and good capacity utilization for complex products processed in a mix means semiconductor companies need to figure out a way to continuously improve. Knock-on impacts of each step are often not readily apparent. Single-device processing requires detailed device-specific data to correlate and use in analytical efforts.

Single-device tracking as MES capability

Track and trace

The term is track and trace; companies need to do both to deliver the information customers demand while using capacity efficiently. MES has always been the system for track and trace and work-in-process (WIP) management; it was the original purpose. Yet, most MES cannot be used to model and track individual die on the wafer and individual devices rapidly through every step of the assembly and test process.

The combination of tracking to allow unique processing per device and MES for dispatching and control delivers a whole new level of capability to semiconductor manufacturers. However, most MES are not equipped to handle this volume of data and transactions. It would take most manufacturing execution systems minutes, not milliseconds, to process data from each transaction for every device in a lot.

High-performance engine

Fortunately, today's high-speed computing methods offer a breakthrough approach. Anytime a parent lot needs to break into 50 or more child transactions, a high-performance engine (HPE) will be more effective. HPE uses bulk, not sequential, data writing. This enables thousands of transactions in the database using stored procedures.

To avoid unduly slowing down the application, HPE performs these bulk writes to the database, not on the application server. Keeping writes at the database minimizes network chatter and keeps speed high. It can write database actions, parameters, statements or values.

HPE starts parent and child lots at the same time for a two-level lot start and release. There are two possibilities for launching a lot in HPE:

1. Start assuming there will be single-device processing in child lots and tracking each one from the start.
2. Start all homogeneous in bulk for faster processing when all lots in a container have the same attributes.

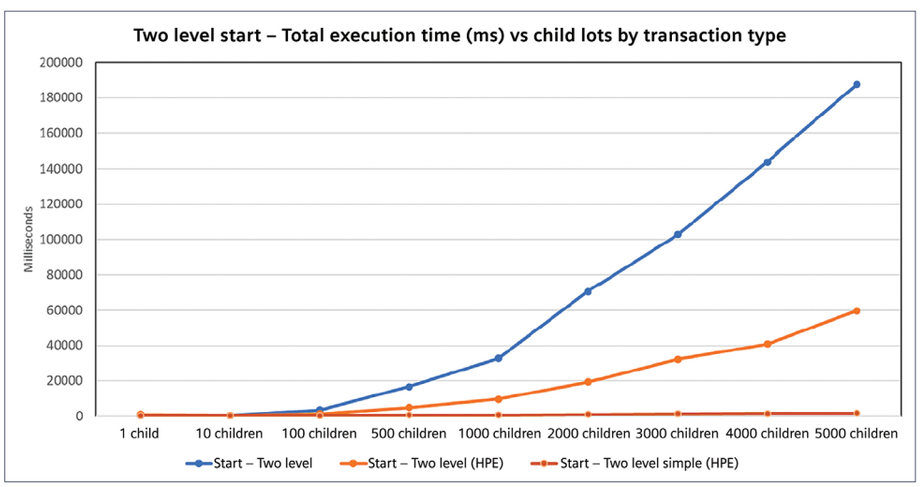


Figure 7. Standard speed of two-level start transaction comparison.

MES needs for single-device tracking

Semiconductor MES needs an array of specific functions to address single-device tracking. These include:

HPE: For rapid processing of many transactions simultaneously configured for semiconductor tracking needs.

Two-level dispatching: Two-level lot starts for parent and child lots that recognize the relationship between work order and quantity of lots.

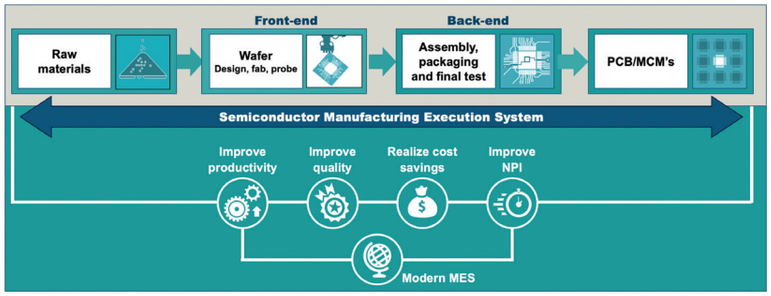


Figure 8. The modern MES for tracking, tracing and control from crystal to multi-chip modules.

Multi-dimensional carrier positions: Ability to configure 2D or 3D tracking with position availability.

Child load/unload: User interface and transactions for child container load into new positions in the carrier.

Item tracking modes: Three modes of item tracking: lot, carrier, or individual item wafers.

Verifications: Able to configure carrier-loading verification.

Automated and manual access: Supports complex flows and item tracking by carrier, whether materials movement is automated or manual.

Multi-container closure: To close or terminate multiple lots, items or carriers, ensuring child lots carry forward the correct attributes.

Boost profits from complex products

Semiconductor makers urgently need to increase variety with minimal performance degradation, even in automated operations. They also need to excel at continuous improvement as the pressure has never been higher. The need for efficient single-device tracking is not new in back-end assembly and test and also applies in advanced nontraditional front-ends where single-device processing is possible.

MES with HPE

Fortunately, today Siemens Digital Industries Software's semiconductor MES is capable of handling HPE for two-level starts to record different data for each device. And it can operate only where needed for single-item tracking. It is not needed at steps where entire lots are processed the same way. Best of all, it delivers the ability to analyze data due to the rich context of MES.

Benefits available

The HPE in MES approach to single-device tracking is already in use. It is proven to reduce capital costs and improve throughput. For example, in one case, it reduced time on the tester by 80 percent. It also increases utilization by allowing unique device processing with quality control. Beyond operations benefits, this commercially available approach can also lower the cost of custom IT to deliver single-device tracking.

By including single-device tracking in the MES, track, trace and operational transactions are in a single application, which improves:

- Accessibility and speed to product data records
- Ability to embark on detailed advanced analytics
- Confident single-device processing
- Support high-volume manufacturing facilities with rapid tracking transactions

Conclusion

Semiconductor companies can meet customers' traceability needs and comply with the SEMI standard more easily with this high-performance approach inside the MES. Companies have a new option for supporting capacity optimization and avoiding additional capital expenses. Semiconductor companies with complex single-unit processing stand to improve their profitability and ability to meet market needs dramatically with this high-performance approach to single-device tracking.

About Opcenter Execution Semiconductor

Opcenter™ Execution Semiconductor software (formerly known as the Camstar™ Semiconductor suite) is a comprehensive manufacturing execution system that enables both wafer fabrication factories and assembly and test sites to meet traceability requirements, control production and integrate the shop floor into their enterprise resource planning system and extended enterprise. It provides a high level of out-of-the-box industry functionality. Manufacturers are no longer hindered by islands of automation and disjointed systems; now they can innovate and adapt to succeed. Instant intelligence enables the user to improve quality and productivity. Opcenter Execution Semiconductor, which is part of the Xcelerator portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, addresses your needs on a configurable, scalable and modular platform for production.

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