DIGITAL INDUSTRIES SOFTWARE

Accelerated semiconductor lifecycle management

Streamline new product introductions and reduce fragmentation with end-to-end digitalization

Executive summary
Siemens Digital Industries Software's semiconductor lifecycle management (SLcM) solution is an out-of-the-box (OOTB) process and data model to manage end-to-end lifecycles for semiconductor products and help semiconductor companies advance rapidly in their digital transformation journey. This holistic solution reduces fragmentation of legacy systems with end-to-end digitalization via three modules: 1) new product introduction (NPI), 2) integrated circuit (IC) design management and intellectual property (IP) reuse and 3) IC manufacturing planning. Leveraging SLcM allows semiconductor companies to accelerate NPIs and the entire semiconductor product lifecycle using a single digital thread connecting design and planning to manufacturing.

Sankhajit Chakraborty
Solutions Director
Siemens Digital Industries Software

SIEMENS

Contents

Introduction

The Siemens SLcM solution is a complete end-to-end solution that eliminates system fragmentation barriers commonly experienced with outdated legacy systems. These fragmented legacy systems cannot provide the interoperability necessary to handle the complexity or the pace of collaboration for today's rapidly evolving semiconductor ecosystem.

Legacy systems inhibit the secure collaboration and complete traceability necessary for collaborating and competing in today's rapidly changing semiconductor ecosystem. Key stakeholders, including business leadership, IC systems engineers, design engineers, manufacturing planners, product engineers, quality engineers and many others, need an end-to-end digital solution to effectively manage all semiconductor product lifecycles. Lifecycles that range from components developed in-house to components supplied from a volatile global supply chain.

With three distinct modules, SLcM provides NPI software capabilities to help semiconductor companies launch new products faster.

The **first module** manages the NPI with automated project management templates, OOTB key performance indicators (KPIs) and metrics and a phase gate approach to manage ideation to project closure and ensure smooth product and program delivery.

The **second module**, IC design management, helps manage the die and package design objects, their artifacts and a corporate-wide enterprise IP library with the right security access as well as controls. It also ensures integration with other IP work-in-process (WIP) management systems. This creates one version of truth for IP across the enterprise. It also helps associate the IPs with each design object for devices and packages for internal and external IP.

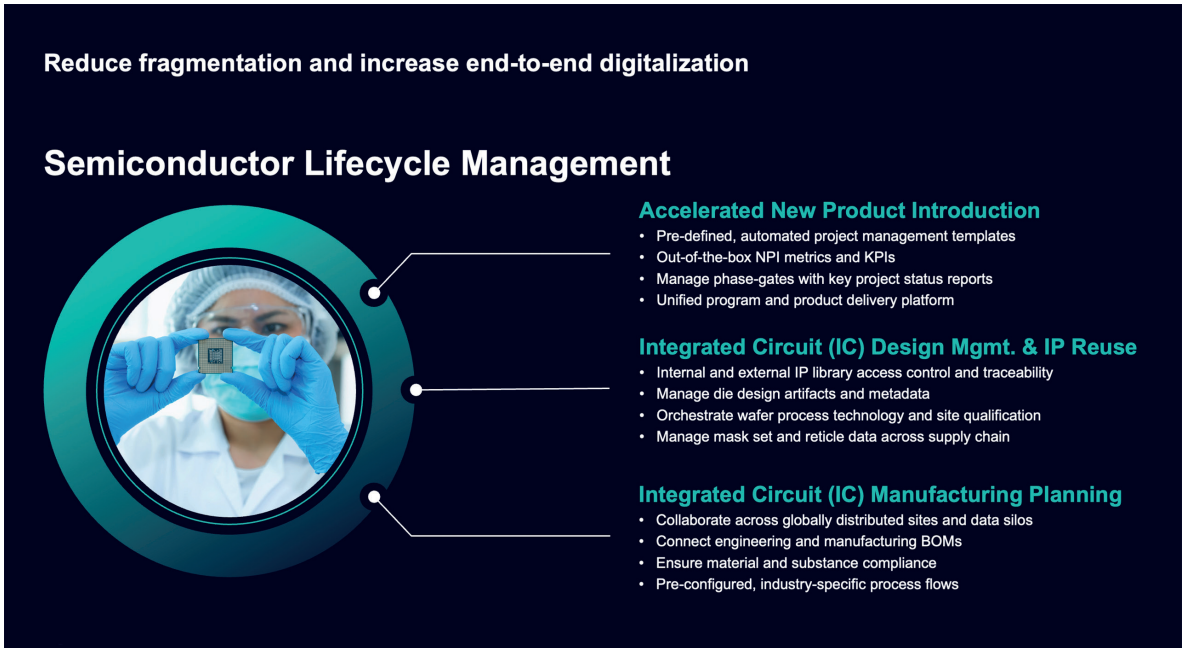

Figure 1.

The module also handles wafer process technology and various site-level qualifications to ensure the design is using the correct qualified technology. Additionally, it manages the interrelationship between the graphic design system II (GDSII), Open Artwork System Interchange Standard (OASIS), process design kit (PDK) objects, the mask set and the reticles for single and multiple project wafers along with the handover from design to manufacturing to ensure a smooth and secure transition. GDSII is a database file format representing planar geometric shapes, text labels and other information about the layout in hierarchical form and is a widely used industry standard for data exchange of IC layout artwork.

The **third module**, IC manufacturing planning, handles the bill-of-materials (BOM) and the bill-of-process (BOP) to ensure users smoothly transfer a recipe to the manufacturing systems downstream, establishing standardization across the enterprise.

This outlined solution reduces and/or eliminates fragmentation, connecting design through manufacturing with complete interoperability and accelerated workflow.

Secure end-to-end traceability and digitalization

Ensuring security with a semiconductor-specific data model, from silicon to system, is essential.

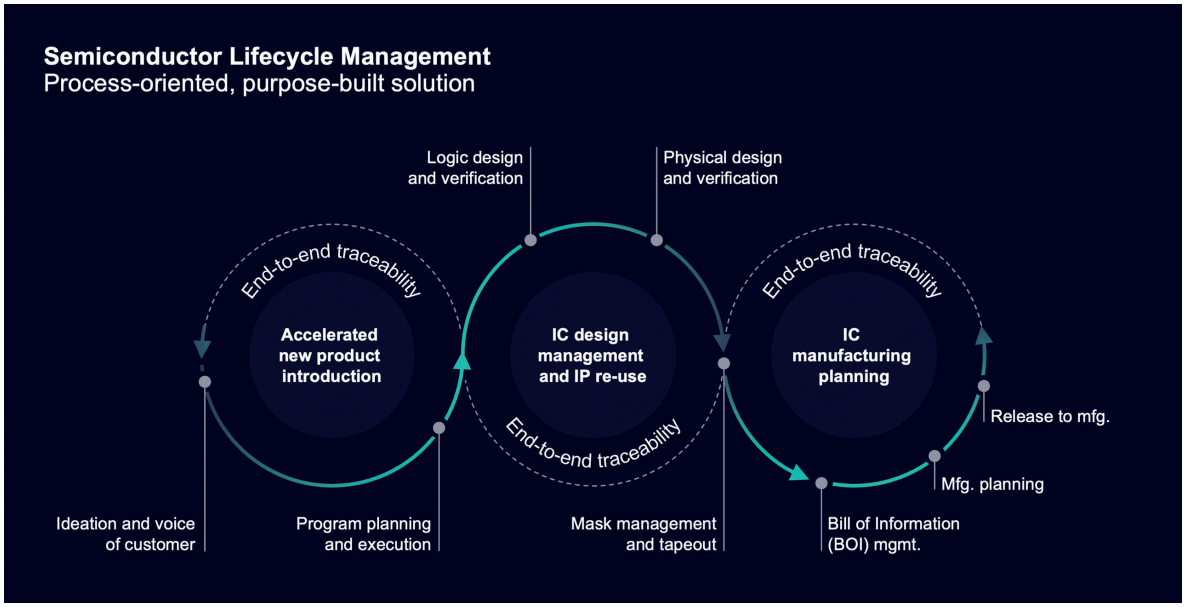

Figure 2.

When considering the value Siemens' semiconductor lifecycle management solution gives you, you can look at it as a process-oriented, purpose-built solution that empowers you to:

- Manage your entire NPI process, from introduction to final product delivery. Take control of your NPI processes using predefined semiconductor project management templates, metrics and characteristics
- Manage product design using semiconductor site qualification processes. Work with your design houses and focus on managing IC design artifacts
- Leverage manufacturing capabilities in Teamcenter® software, which is part of the Siemens Xcelerator business platform of software, hardware and services, to incorporate foundries or subcons. Focus on front-end and back-end IC manufacturing planning

Finally, since this is an integrated solution as opposed to the siloed tools currently found in the industry, you can take advantage of end-to-end traceability throughout the product lifecycle.

The details matter from design to manufacturing

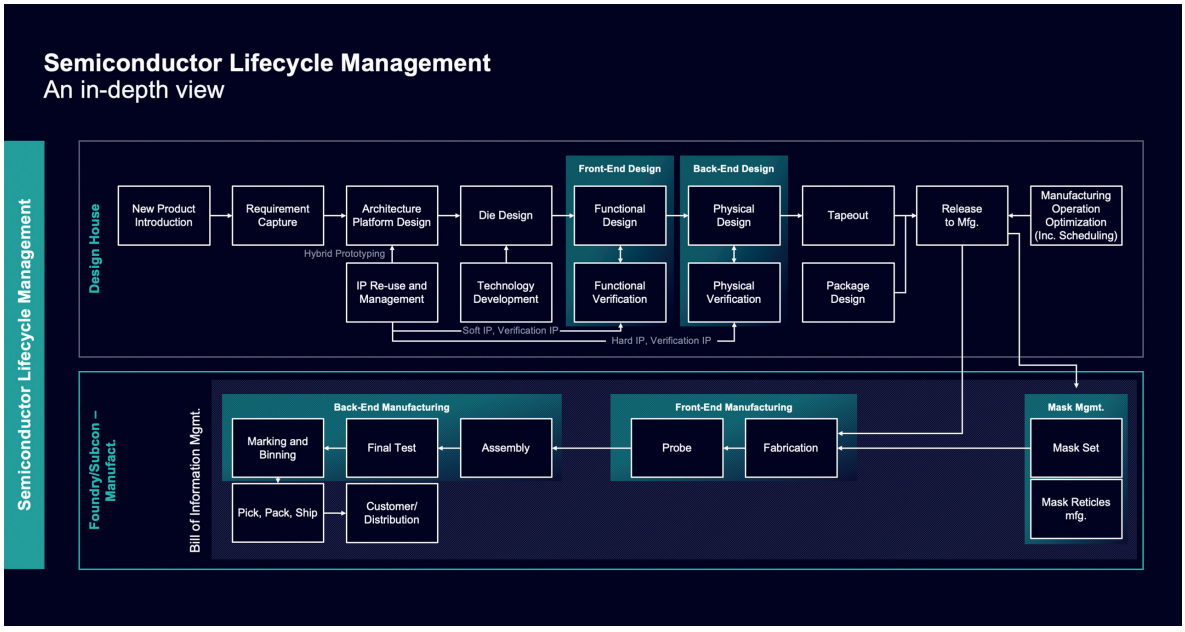

Figure 3. Overview of the semiconductor lifecycle management solution.

For a complete perspective, take a closer look at the core of our solution in figure 3.

This in-depth diagram shows a semiconductor customer's business process from design to manufacturing. The top section focuses on the design while the bottom section focuses on manufacturing.

The IC design process is extremely complex. It starts with the NPI, which includes the specification of the

new die requirements (top section). This semiconductor lifecycle management solution offers predefined project templates to assist with project realization and delivery.

After capturing the requirements, the product's design phase starts. This includes several steps:

- IP management using an external or internal library of component IPs
- Die design
  - Front-end design or functional design: Where the device specifications are programmed in a hardware description language often referred to as register transfer level (RTL) code. Users can then synthesize this code into a gate-level representation of the hardware or netlist
  - Back-end design or physical design: Where the netlist is converted into a geometric representation showing how users need to arrange the billions of transistors that will make up the die in multiple layers to satisfy product design specifications
  - Tapeout: After defining the physical layout and verifying the die, save it as a GDSII or OASIS file and release it to manufacturing

You can transfer the design to the manufacturing team (in the GDSII format) and then create the photomask set necessary to make the die (bottom section).

The die fabrication and packaging process can be split into front-end and back-end manufacturing:

- Front-end manufacturing: The multistep wafer fabrication process (WFP) where a slice of pure silicon ingot is sliced, processed and imprinted with thousands of dies via lithography. This is followed by probing, which uses special microprobes to verify the functionality of each die. The bad dies are marked on a wafer map via inkless probing to easily separate them from the good dies after cutting the wafer
- Back-end manufacturing: You can dice (singulate) the wafer to separate the dies and mount and assemble each good die in advanced packaging. The IC undergoes a final inspection followed by marking before being distributed and consumed in electronics modules
- The semiconductor lifecycle management solution integrates design and manufacturing. This is unique in the semiconductor industry, where companies typically have siloed design and manufacturing processes

Please note that, for IP reuse and management, we offer an integration with Perforce Methodics IPLM.

End-to-end traceability matters

Traceability is critical in the semiconductor industry. Coordinating revisions between design and manufacturing and ensuring end-to-end traceability throughout the process is a key differentiator of this solution.

Why is that important?

The connected world runs on semiconductors, operating everything from spacecraft to cell phones, medical devices and smart buildings. Being able to trust the data and the devices that protect our privacy, security and future matters.

In the past, customers could take a manufacturer's word for the authenticity of each semiconductor device and the integrity of the data, but that is no longer the case.

Counterfeiting, malicious code, backdoors, susceptibility to cyberattacks and critical chip shortages have made us question the supply chain to the point where we need to verify every device.

That is where secure end-to-end traceability and digitalization make a difference.

Using Siemens' SLcM solution provides secure end-to-end traceability to verify the entire genealogy of the component, the IP and as-designed specifications match as-built realities. It also provides high-performance, single-device tracking to elevate manufacturing enterprise system (MES) performance, promoting rapid verification, acceptance and delivery of semiconductor products, as well as faster time-to-market.

You can achieve this using the OOTB traceability report. This report shows some of the representative objects from design to the manufacturing site and how they interconnect. It clearly depicts the digitalization you established at the data model level, threading together the design and manufacturing objects. You can thread together the object processes (figure 4) in terms of how they are going to be consumed as process steps.

This solution can act as an end-to-end threaded ecosystem, or it can help establish digitalization for building additional structures like a digital twin and trusted traceability.

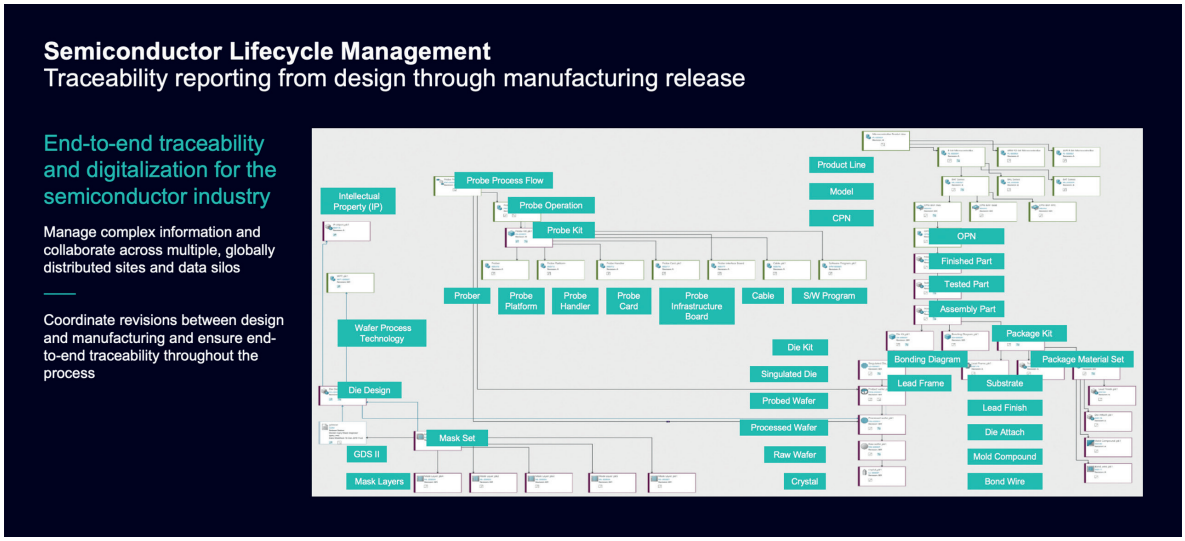

Figure 4. Achieving end-to-end traceability and digitalization.

Accelerating NPI is critical

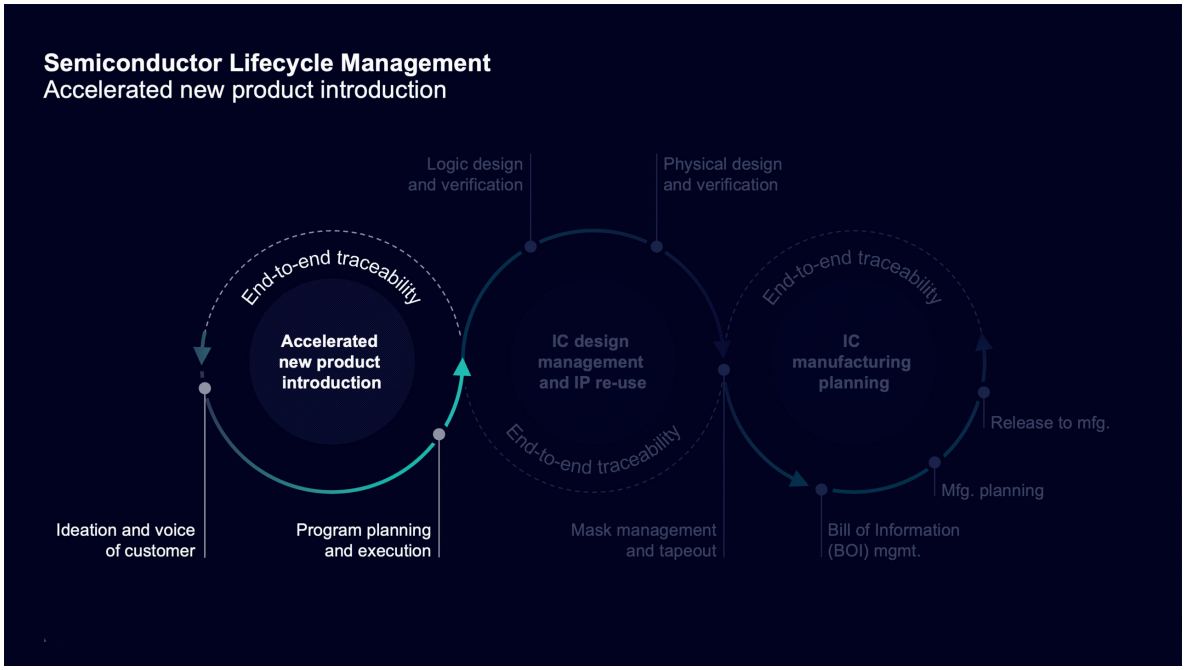

Figure 5.

This section focuses on the first step of the process: the NPI.

There is an urgent need for faster NPI cycle time across the semiconductor industry. With the pace of innovation today's semiconductor market demands, combined with a zero tolerance for defects in mission-critical applications, it is easy to see why product lifecycles might last three to five years at some companies. However, since a significant portion of lifetime profits come from the first few quarters of a new product, it is critical to accelerate NPI cycle time.

So, how do companies balance the need for faster time-to-market against a zero tolerance for defects?

Historically, the semiconductor industry used hundreds of legacy and homegrown systems. Many of these are decades-old systems and cannot scale to meet the kind of expansion and complexity required in today's rapidly changing industry.

Alternatively, the Siemens NPI solution is an end-to-end, fully integrated project management solution, created to accelerate time to value. It offers OOTB workflows based on industry best practices and leverages predefined project templates selected by default based on your new idea's characteristics.

NPI helps companies launch new products. The solution helps you manage the NPI with automated project management templates, OOTB KPIs and metrics and a phase gate approach to manage from ideation to project closure, ensuring a smooth product and profitable program delivery.

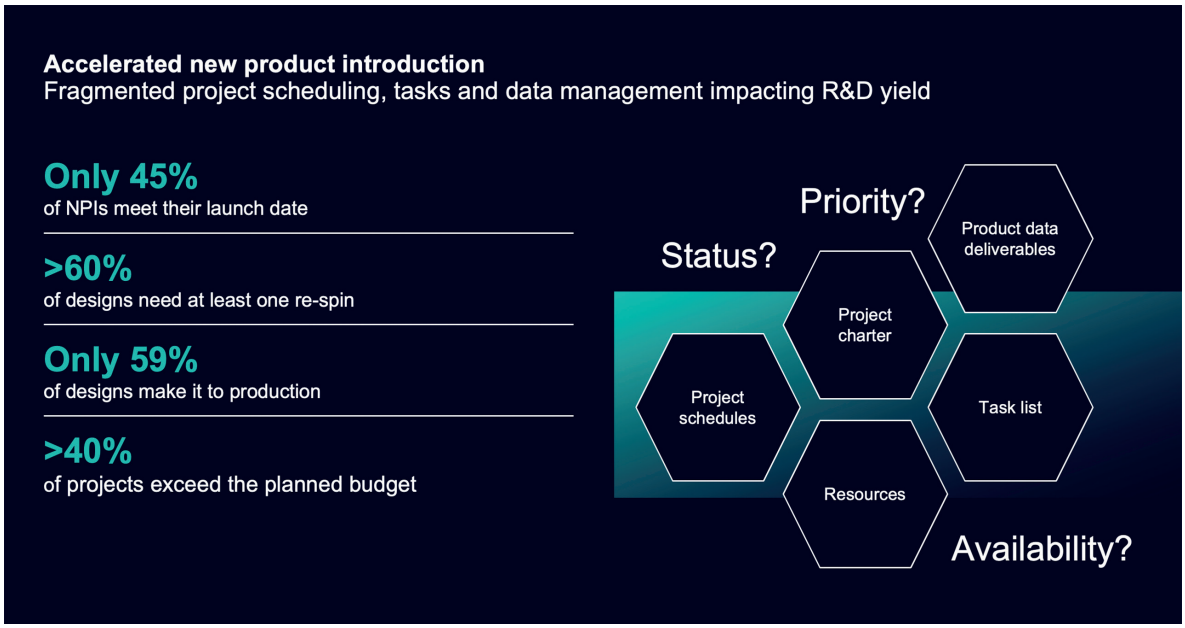

Figure 6.

Figure 6 illustrates the urgent need to upgrade NPI performance. Significant improvement is necessary since only 45 percent of NPIs currently meet their launch date, and more than 60 percent of designs fall short and require at least one design respin.[1]

In addition, there is:

- No program visibility
- Siloed concurrent development (system, chip, software and package)
- Time-consuming reporting and status update activities
- Inconsistent practices and ad hoc communication for project management typically occur across the organization

Unified lifecycle management improves NPI results

Due to fragmented project scheduling, tasks and data management, NPIs rarely meet target delivery dates without costly design respins, often resulting in the product never reaching production. Additionally, from what we know about the semiconductor market from leaders such as Syed Alam, customers expect a certain level of customization and on-demand experiences that require rapid NPI.

To manage semiconductor lifecycles, users can leverage an OOTB semiconductor NPI project management solution that can help move new products from ideation to planning and execution quickly, thus improving research and development (R&D) yields. This is possible by using predefined, automated project management templates, OOTB metrics and KPIs, project status reports and unified program and project delivery management.

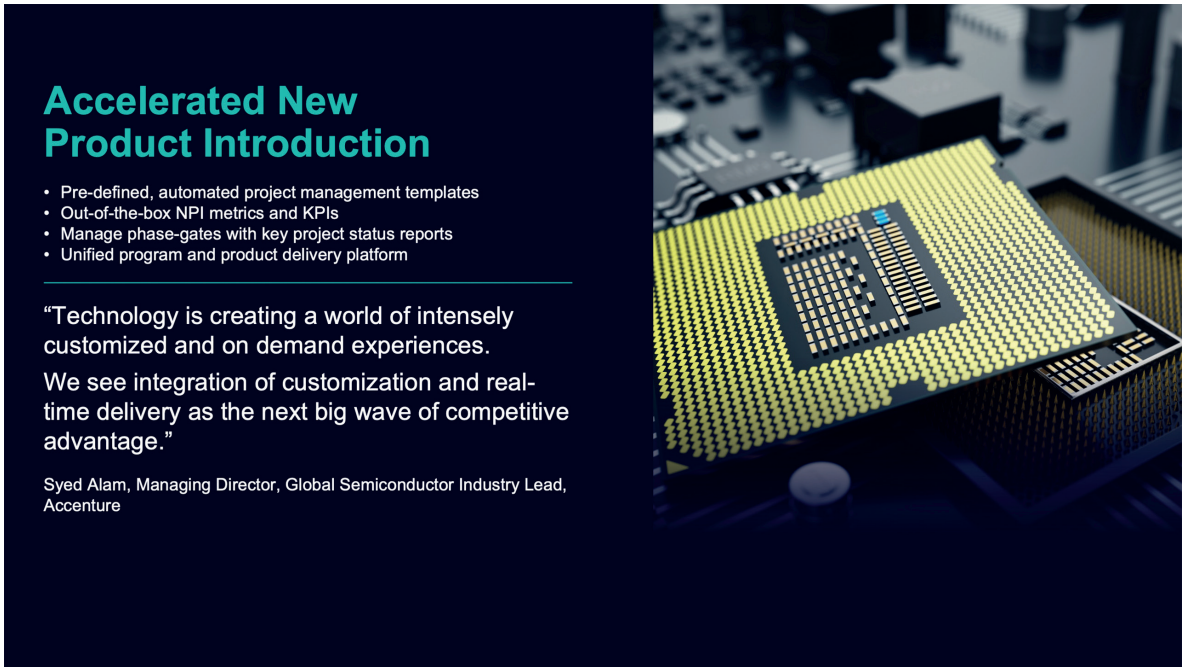

Figure 7.

NPI product management with integrated portfolio planning

Company growth is a function of introducing new products to the market that are cost-effective, timely, high-quality, meet market demands and generate significant revenue. Since companies manage multiple new products, they need a process to manage new ideas, projects and lifecycles so the most profitable and strategic projects go through the approval funnels.

With Siemens' SLcM solution, ensure project resources, schedules and risks are managed, tracked and reported. This way, companies can measure their investments to yield high-revenue products with a smooth delivery process. As the idea matures into a project, automated templates help establish the tasks, checklists and workflows specific to the type of product you are launching. With Siemens OOTB metrics, measure the progress throughout the lifecycle as it goes through the phase gate process.

The overall OOTB process and framework help smooth NPI and improve R&D yield, which is key for a semiconductor company's top-line growth. Companies can also scale the NPI framework for managing new IP introductions, technology introductions or process introductions.

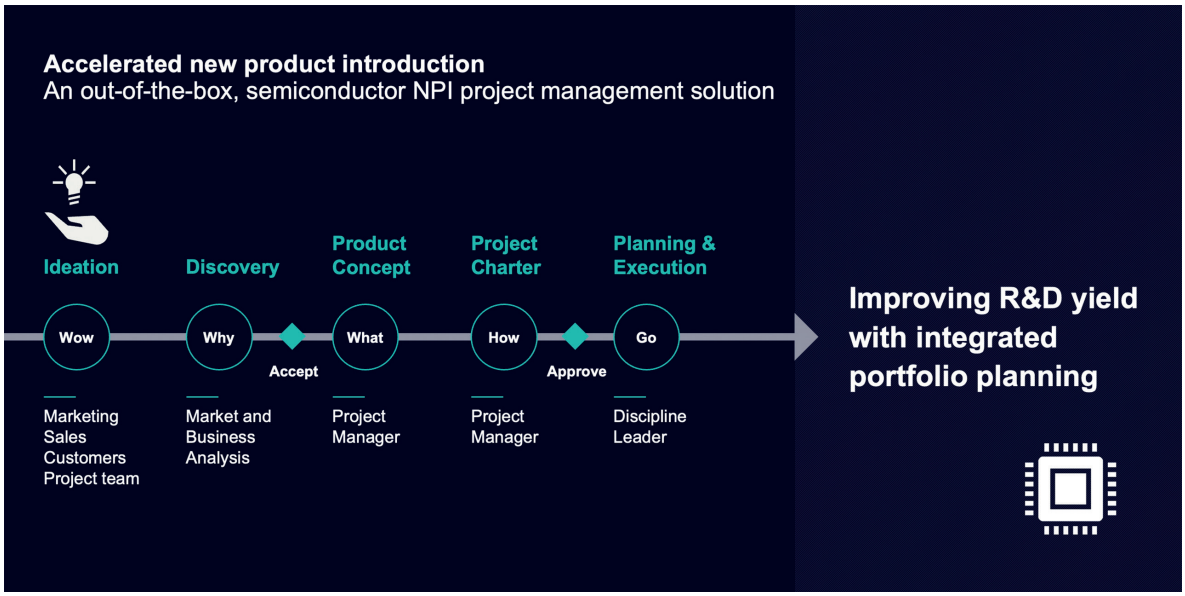

Figure 8.

Achieving visibility and control via the dashboard

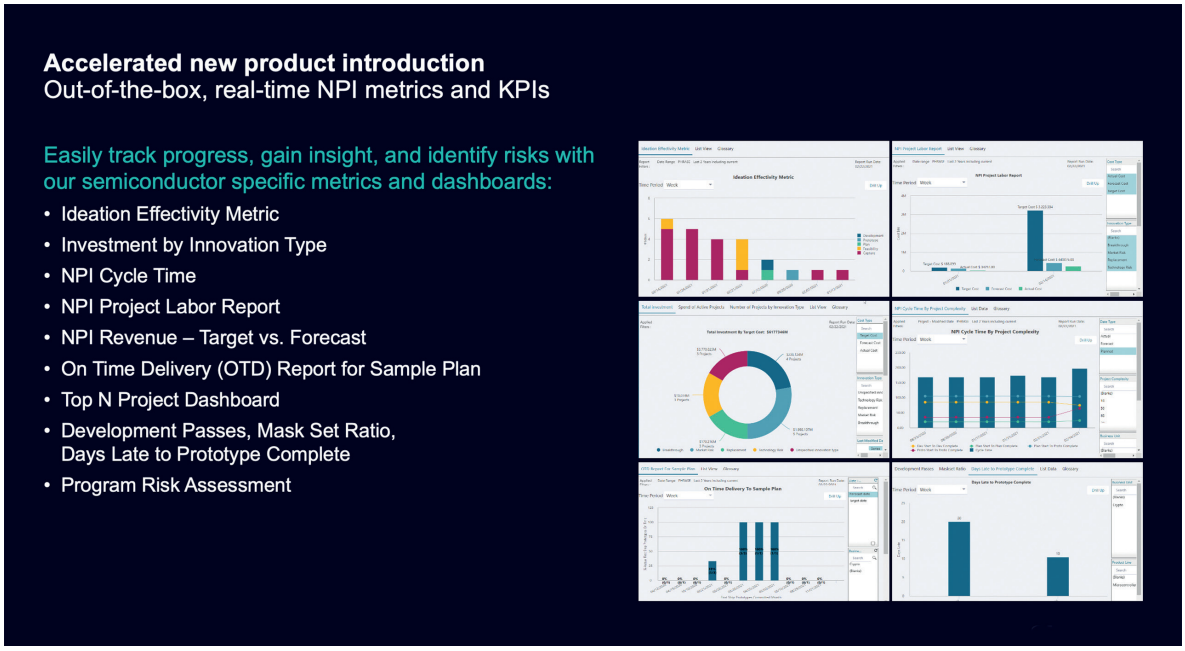

Figure 9. Accelerating NPS with NPI metrics and KPIs.

Since this semiconductor lifecycle management solution comes OOTB, we have introduced several semi-industry-specific dashboards and metrics to help you easily track progress, gain insight and recognize risks.

Track your investments by innovation type, how they are structured across the organization, cycle time report, project label report and NPI revenue. Additionally, track your targets against forecasts, measure the on-time delivery (OTD) for sample planning, measure the structure and more. View a top 10 dashboard to specify the number of projects you want to see.

Also, NPI revenue is automatically calculated and includes strategic projects, which may not be high in NPI revenue, but it is strategy for the enterprise as platform projects.

These project dashboards are rolled up, creating visibility from the chief executive officer (CEO) level to the project management level.

These metrics and reports are created using a cube reporting dashboard. This means you can slice and dice the data across multiple dimensions, for example, by organizational hierarchy or time dimension. There is also a product family dimension so you can see the data at the project manager level and a general manager level. At the CEO level, all data can be seen in real time and can be rolled up and rolled out at any desired data point.

This data display approach gives a company complete transparent visibility to the entire organization at every report level in the metrics.

These metrics also measure development passes, which is a critical factor in knowing how many development passes a product has been through to get to the product mask set ratio. Typically, companies do not want to do respins or want to have multiple mask sets.

This solution measures how many mask sets you have and will compute your average mask set ratio. It will give you that report and predict the days to prototype.

For semiconductor design, it also indicates the project delay factor, performs analytics and fact-finding to learn why a particular type of project is delayed and then drills down for more data. It can determine if the root cause for these defects is a systemic or a one-off issue. This solution includes all of the data, rolled up via OOTB metrics and dashboards.

Report breakdowns available via semiconductor lifecycle management

- Ideation efficiency metric (figure 9): The dashboard shows how many ideas move from ideation to project planning and other project phases. See how ideas are distributed across various maturity phases of an NPI project, based on selected criteria (timeframe)
- Investment by innovation type (figure 9): The dashboard shows how the company deploys investments. This report gives an overview of innovation and breakthrough projects versus continuous improvement projects. Categories include technology risk, breakthrough, replacement and market risk

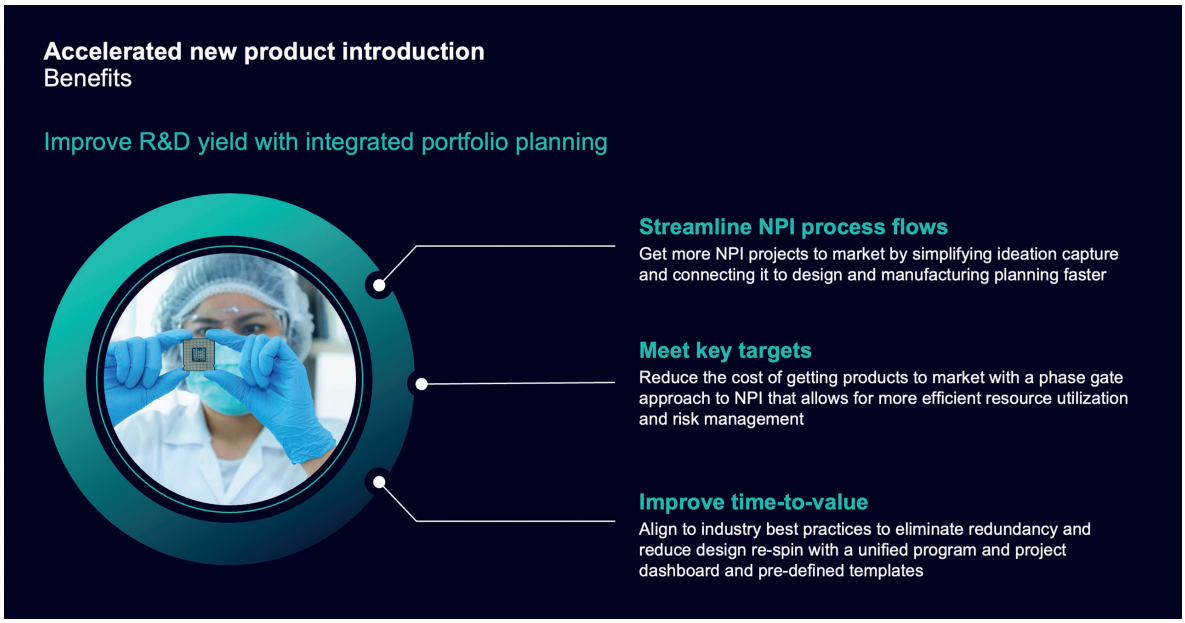

Figure 10.

- NPI cycle time: The dashboard calculates the selected project's average cycle time and the cycle time by phase
- NPI project labor report: The dashboard calculates the total money spent for labor (target versus actual) based on selected criteria (date range, business unit, innovation type) for all active projects by various categories
- NPI revenue (target versus forecast): The dashboard shows the sum of product revenue of target versus forecast revenue by project innovation type for selected projects
- OTD report for sample plans: The dashboard measures delivery to committed sample plan dates. For a given month, the metric measures how many projects were sampled the first time on time or the total number of projects due for sampling
- Top N project dashboard: The dashboard shows the default and recommended top 10 projects with the highest net present. The list also includes projects that are strategic and selected by executive management
- Development passes, mask set ratio, days late until prototype completion: The dashboard displays the tabbed report of the average development passes, mask set ratio and days late to prototype completion against the plan for a selected set of projects based on time or business unit
- Risk management section: This dashboard is modified to include a risk statement in addition to the impact score, probability, mitigation plan and contingency plan

IC design management and IP reuse

Learn how semiconductor lifecycle management helps manage IC design for better IP reuse.

You can use this second module to manage die and package design objects and their artifacts and a corporate-wide enterprise IP library with the right security access and controls, ensuring it integrates with other IP WIP management systems. This creates one version of truth for IP across the enterprise.

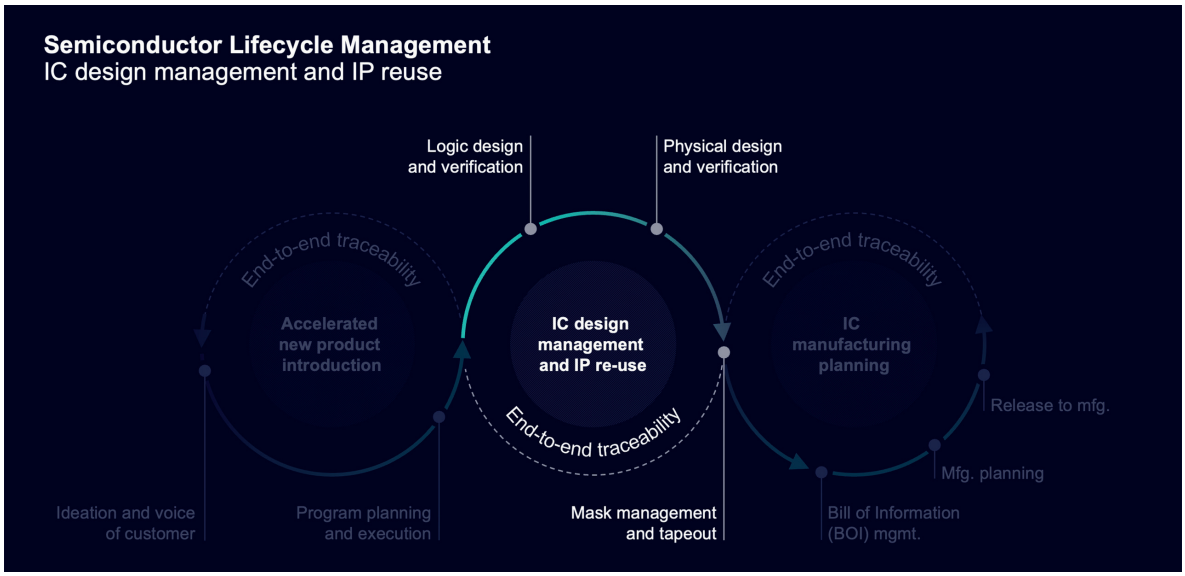

Figure 11.

It also helps associate IPs with design objects for internal and external IP devices and packages. The solution also manages wafer process technology and its site-level qualifications to ensure the design is using the correct qualified technology. You can also use the solution to manage the interrelationship between the GDSII, PDK, mask set, reticles and the handover from design to manufacturing.

Companies can manage product design using semiconductor site qualification processes and then work with design houses and focus on managing IC design artifacts.

According to the Aberdeen Group, communication and collaboration are at the center of semiconductor areas for improvement. Companies are looking toward solutions that offer "tool and process efficiency and will provide engineers with capabilities that expand their designs while stimulating their creative juices."[2]

Using a semiconductor lifecycle management solution can directly address this idea by improving design workflow efficiencies while preparing for a smooth transition to manufacturing.

With tight internal and external IP library access control and traceability, we create an end-to-end solution that manages the design from logic design and verification to physical design and verification through mask management and tapeout. This includes die design artifacts and metadata, orchestrating wafer process technology and site qualifications and managing mask set and reticle data across the supply chain for single- and multi-project wafers.

Figure 12.

OOTB IC library access, control and traceability

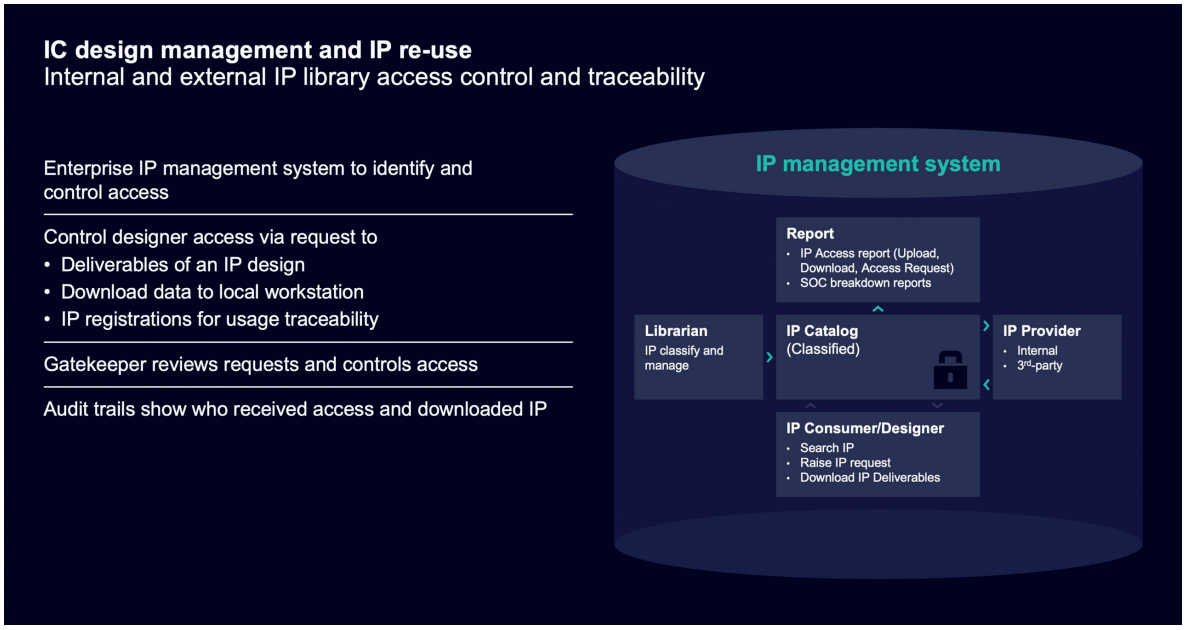

Figure 13.

The semiconductor lifecycle management solution comes with an OOTB IP management enterprise repository.

This is a secured IP library vault for the enterprise. The system ensures a secure data exchange with third-party IP providers as well as IP with data management systems and within the enterprise. This is typically managed by an IP librarian and OOTB workflows that manage the overall IP management lifecycle from creation to final consumption.

Since these workflows are OOTB, the advantage is connectivity with web data management systems like Methodics, Perforce and GIT. Thus, an enterprise during mergers and acquisitions (M&A) can have multiple WIP data management systems as well as various security controls and disaster recovery mechanisms. Companies can connect this data to their enterprise IP repository.

This provides the enterprise with powerful solutions in terms of enabling downstream use cases for planning and manufacturing. Additionally, it helps create architectural planning layouts and gives the enterprise a complete view and repository of their IP assets. Further, it includes traceability for the die, showing if the company used the proper IPs. During tapeout, you can measure what IP was or was not used, helping you prevent accounting issues.

Additionally, using Teamcenter, companies can leverage a state-of-the-art disaster recovery mechanism.

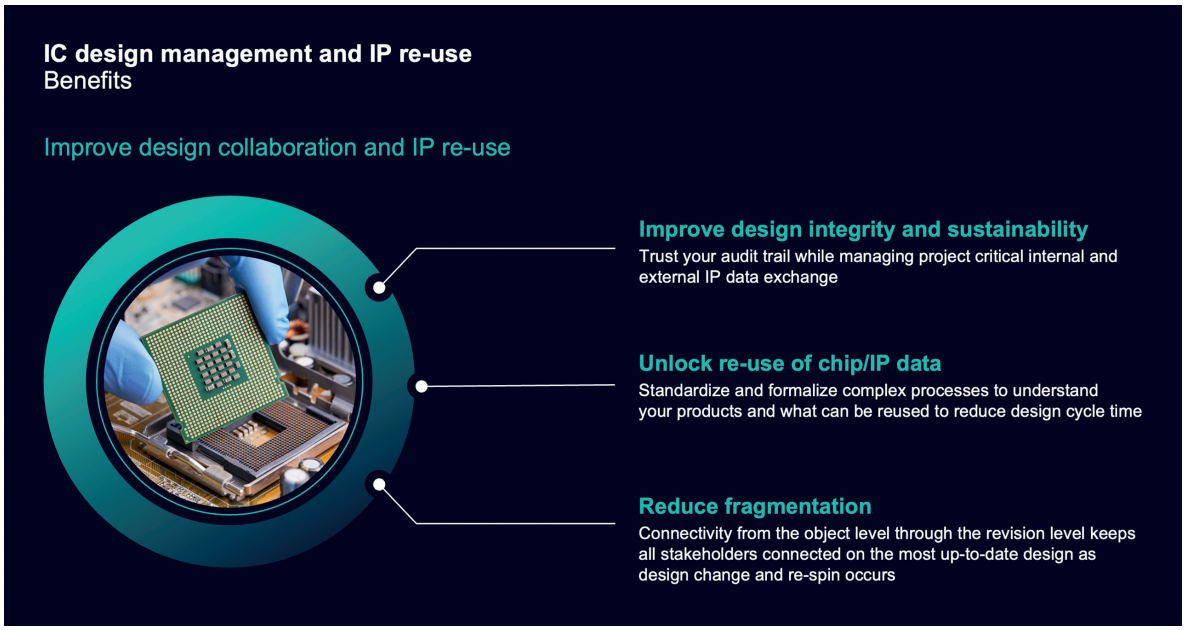

Figure 14.

IC manufacturing planning

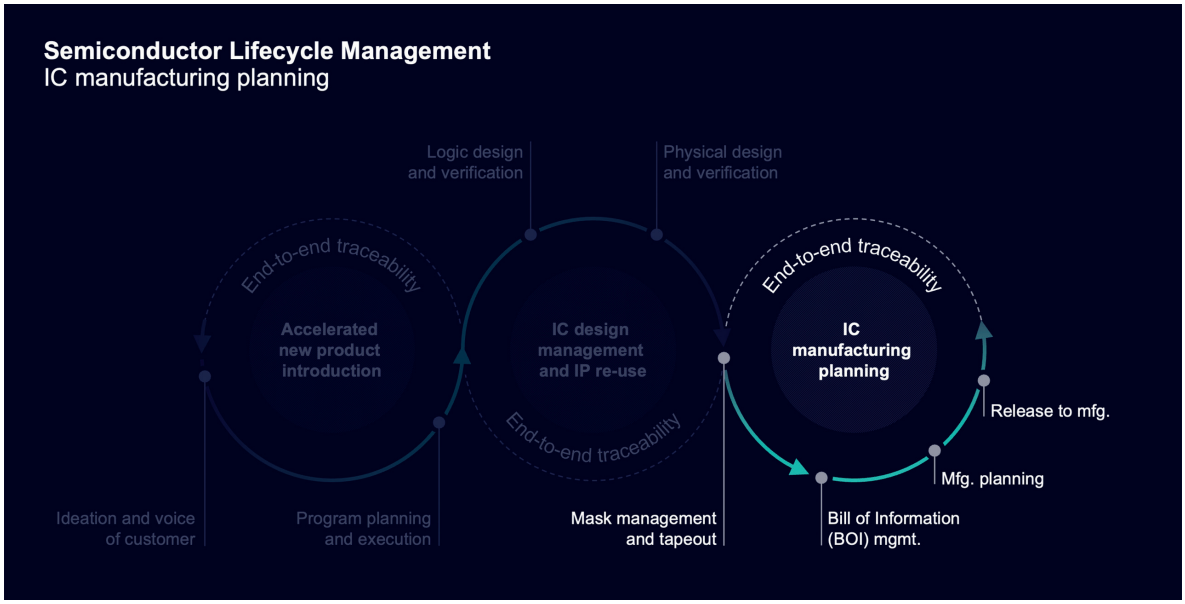

Figure 15.

The third module, IC manufacturing planning, handles the BOM and BOP to ensure the recipe transfers smoothly to the manufacturing systems downstream to establish standardization across the enterprise. This helps change management, ensuring material and substance compliance, factory transfer, product transfer, process flows and operations standardization and optimizing effective root cause analysis.

According to Alam, "Approximately two-thirds of semiconductor companies have yet to scale cloud, a technology that drives efficiency, sustainability and resiliency." Our solution aims to solve this problem by building an end-to-end digital solution to streamline the manufacturing process to be centrally administered, allowing copy exact factory model, product and factory transfers.

This semiconductor lifecycle management solution enables collaboration across globally distributed sites and former data silos by connecting engineering and manufacturing BOMs for all users. This also includes storing important material and substance compliance info companies need. With built-out, industry-specific process flows for fabrication, probing, assembly, testing, marking and packing, our solution keeps your project on track for delivery.

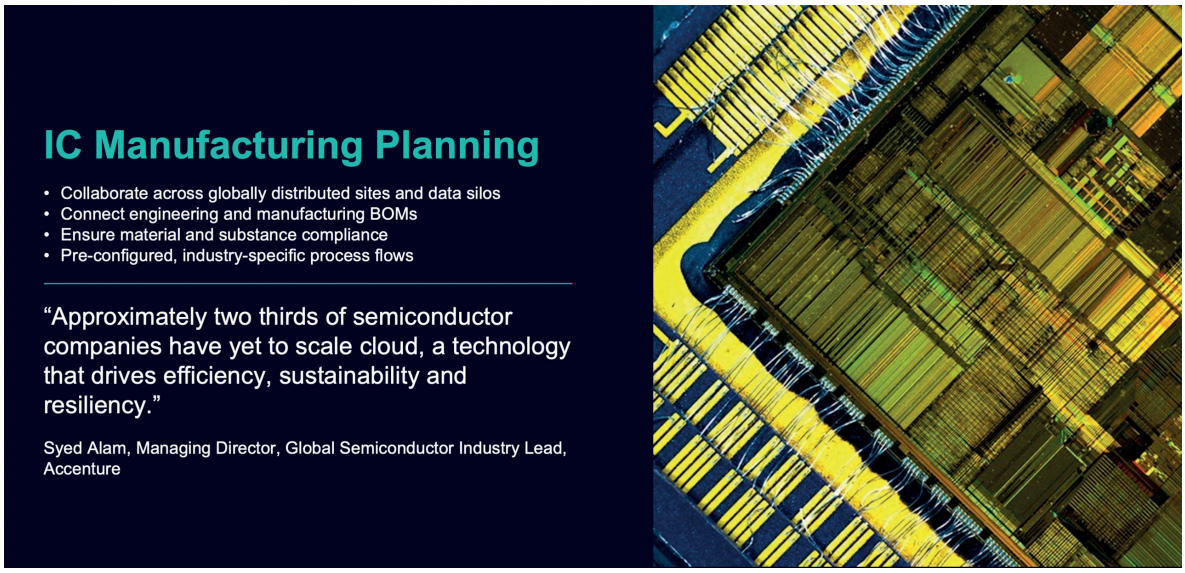

Figure 16.

IC manufacturing planning and recipe management

Figure 17 shows various process flows or recipes manufacturing requires, which are built into semiconductor lifecycle management.

After you develop and design a bill-of-information (BOI) in the system, this process helps create the recipe for building product information step-by-step.

The solution provides configurable built-in flows, tools and operations for fabrication, probe, assembly, testing and marking processes. For example, a mask shop application for a BOP flow can use the mask layers as one of the tools for photolithography or a specific tester as part of the test flow.

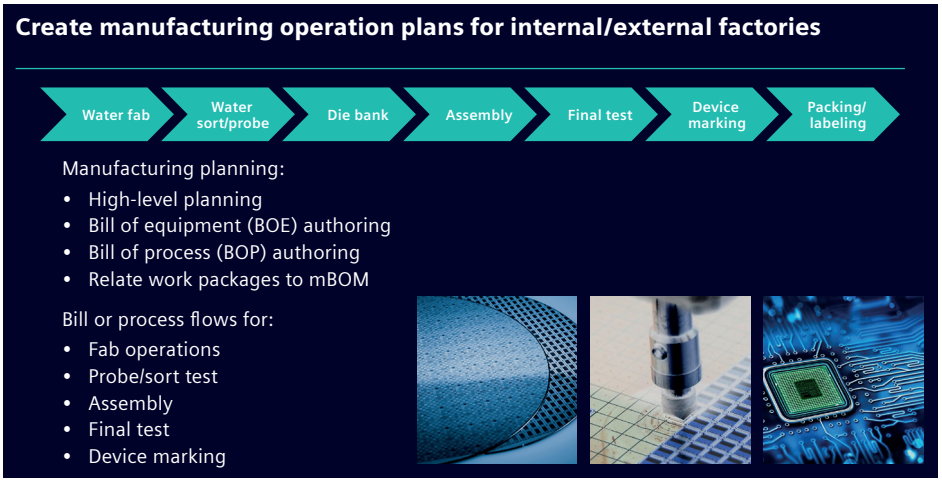

Figure 17. Industry-specific process flows for front-end and back-end manufacturing.

IC manufacturing planning and marking data management

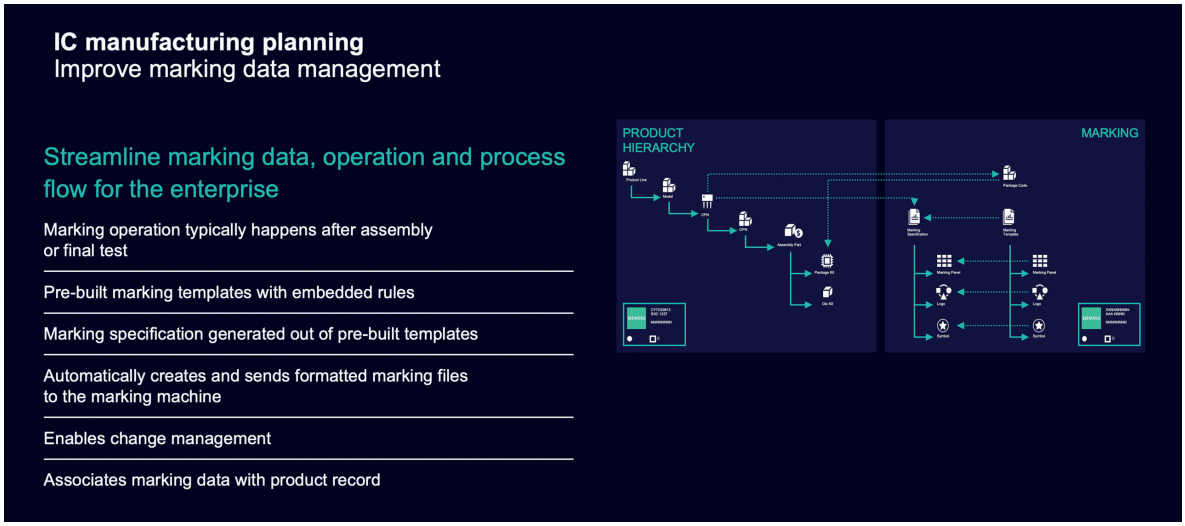

Figure 18.

Marking is a crucial step in the chip manufacturing process that occurs at the end of the manufacturing process (either at the end of assembly or the end of testing).

Companies need to mark chips with important information such as the company logo, product name, lot date code and pin start. Sometimes they can be extremely small with topside or bottom side markings, and they need to follow a particular schema.

Additionally, companies need to validate the artwork and integrate it with the marking machines. This way there is no manual handoff during the process. This is extremely crucial when you have to manage upwards of thousands of finished goods.

To solve these major industry issues, our SLcM solution sends the marking object as a manufacturing recipe step or operation to the marking machine. This way, everything is sequenced, structured and tracked. With this structure, it eliminates the chances of error that can happen in this vital step. Secondly, the change management function helps manage information like logo changes. If the company decides to use a different logo because of M&A or any other reason, change management in the marking template helps to automatically create new specifications and applies the change to all future designs.

Figure 19.

Conclusion

Siemens SLcM solution is a complete end-to-end solution that eliminates the barriers of system fragmentation commonly experienced with outdated legacy systems. With SLcM, you can accelerate NPIs and significantly reduce fragmentation with end-to-end digitalization.

This solution provides the interoperability required to handle the complexity and pace of collaboration and innovation companies need to compete in today's rapidly evolving semiconductor ecosystem.

Key stakeholders, from business leaders to IC systems engineers and design engineers to manufacturing planners to product engineers and quality engineers, need an end-to-end digital solution for effectively managing semiconductor product lifecycles.

With three distinct modules, SLcM provides NPI software capabilities to help semiconductor companies launch new products faster. The first module manages the NPI with cost-effective, automated project management templates, OOTB KPIs and metrics and a phase gate approach to manage ideation to project closure, ensuring smooth product and program delivery.

The second module, IC design management, helps manage the die and package design objects, their artifacts and a corporate-wide enterprise IP library with the right security access as well as controls and ensures it can integrate with other IP WIP management systems. This creates one version of truth for IP across the enterprise. The solution also manages wafer process technology and various site-level qualifications to ensure the design is using the right qualified technology. Additionally, using this solution, companies can manage the interrelationship between the GDSII, the mask set and the reticles, as well as the handover from design to manufacturing for a smooth transition.

The third module, IC manufacturing planning, handles the BOM and BOP to ensure you can smoothly transfer a recipe to the manufacturing systems downstream, establishing standardization across the enterprise. This is an end-to-end solution designed to accelerate semiconductor lifecycle management. The solution is available on-premise and cloud-hosted solutions.

References

1. Poston & Dury. "Semiconductor Product Lifecycle Management," Kalypso, https://teeyonglim.wordpress.com/2013/11/22/semiconductor-product-lifecycle-management/

2. Aberdeen, September 2019.

Siemens Digital Industries Software

Americas: 1 800 498 5351

EMEA: 00 800 70002222

Asia-Pacific: 001 800 03061910

For additional numbers, click here.

Siemens Digital Industries Software helps organizations of all sizes digitally transform using software, hardware and services from the Siemens Xcelerator business platform. Siemens' software and the comprehensive digital twin enable companies to optimize their design, engineering and manufacturing processes to turn today's ideas into the sustainable products of the future. From chips to entire systems, from product to process, across all industries, Siemens Digital Industries Software – Accelerating transformation.

siemens.com/software

86492-D3 5/25 H