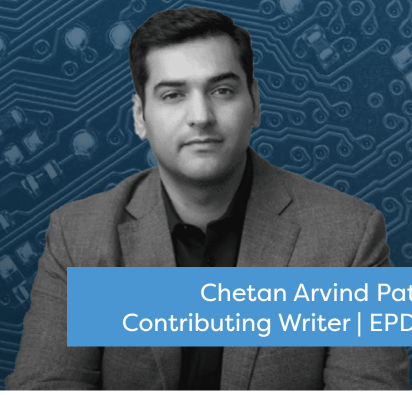
Assistive AI to Speed Up Semiconductor Test Program Development



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The semiconductor industry has grown to a scale we've never seen before - over a trillion chips were sold worldwide last year alone. These chips are at the core of almost everything we use today - from the smartphones in our pockets to the vehicles we drive. However, with the rise of advanced technologies like artificial intelligence (AI) and 6G communication, the intricacy and number of semiconductor devices are both skyrocketing. And here's the reality: no chip makes it to market without undergoing rigorous testing to ensure it performs reliably under specified conditions.

Semiconductor testing is absolutely critical. Even the tiniest defect in a chip can lead to significant consequences, especially in safety-critical applications (like automotive, medical, etc.). Thus, each chip has to pass through multiple rounds of testing (from initial design checks to wafer-level and system-level evaluations). But testing does not come cheap. In fact, it's one of the most expensive stages of semiconductor manufacturing. Modern chips are packed with billions of transistors, each needing thorough testing, which means more test patterns, cycles and complexity. The equipment and skilled engineers required for this are costly, with any inefficiencies (whether in test duration, power consumption, or debugging) adding to the expense.

The challenge continues beyond there. As chips become more advanced, the amount of test data generated explodes - making it harder to analyse effectively. On top of that, the industry faces a shortage of experienced test engineers, creating even more pressure. There's an opportunity for automation and AI to help maintain or even improve testing thoroughness without burdening engineering teams.

In such a competitive industry, testing delays will hold up getting products to market, thereby impacting on a company's bottom line. Testing has become more than just a quality checkpoint - it's a critical business function. As testing grows more complicated/expensive, AI is emerging as a way for companies to more efficiently conduct such activities.

Current test program development challenges

In semiconductor test program development, modern chip complexity presents some pressing challenges. As process nodes shrink below 3nm, unprecedented transistor numbers are being incorporated into devices. A typical high-performance system-on-chip (SoC) designed for advanced computing applications may contain >10 billion transistors. Testing such densely packed implementations requires millions of test vectors to assure functional correctness, electrical performance and reliability. Each test vector must account for process variations, flip-flips, voltage levels, boundary conditions, operating temperatures, etc. Thus, a massive amount of data generated during testing must be dealt with. Cutting-edge automated test equipment (ATE) platforms, such as Advantest's V93000 or Teradyne's UltraFlex, can produce TBytes of test data daily - placing significant strain on data storage, analysis and test program optimisation.

On the other side, test programs have also grown in size and become more convoluted. Engineers typically write these programs using specialised languages and methods like ATPG. Such programs must be carefully tailored to address a wide range of conditions. For example, a typical SoC test program might focus on digital logic verification through design for test (DFT) techniques and include tests for mixed-signal components (such as data converters) or power management circuits. The need for different testing and coding types adds to development process time and engineering resource allocation.

Apart from test program development, a crucial aspect of semiconductor testing is the need to debug and optimise these programs to minimise test time, while still achieving adequate coverage. In many cases, engineers must manually review test results (which can involve hundreds of thousands of test codes and vectors) to pinpoint failures or optimise sequences. Even with advanced ATE platforms, reducing test cycle times from ms to µs can significantly impact production throughput. For example, trimming just 100ms off each test cycle in a high-volume environment will result in substantial cost savings.

Beyond the technical challenges, variability in semiconductor manufacturing adds further difficulties. Differences in wafer fabrication

can cause variations in device performance, meaning adaptive test programs are required for real-time adjustment based on individual device behaviour. Engineers must continuously tweak their test programs to accommodate these variations - which can differ not just from lot to lot, but even from wafer to wafer.

Finally, there's an acute scarcity of skilled engineers capable of writing, optimising and maintaining test programs. This puts additional pressure on companies to streamline processes, as well as underscoring the urgent need for automation and AI-driven solutions.

AI's role in enhancing test efficiency

As semiconductor device complexity increases, traditional methods of developing/running test programs are reaching their limits. The volume of data involved is turning these methods into bottlenecks. To solve this, AI is stepping in - helping engineers optimise everything from test development to execution and analysis. By harnessing machine learning and data analytics, AI can automate significant portions of the test program development process, thereby reducing time-to-market without compromising quality.

Within semiconductor testing, AI's impact areas are very broad. However, it's essential to understand that AI isn't just an overlay of existing processes. It's fundamentally changing how semiconductor testing is approached. Historically, test engineers had to manually sift through vast datasets, make educated guesses about potential coverage gaps and spend countless hours refining test programs. These methods were acceptable back then, but they can no longer keep pace with modern semiconductor industry demands.

AI introduces a different approach that's driven by data, speed and precision. Instead of relying on engineers painstakingly fine-tuning each part of a test program, AI models can help by learning from historical data and dynamically generating tests that account for variables engineers might need more time to consider. These models will also predict, and that's a massive shift in the industry's mentality.

AI isn't just pushing the boundaries of real-time optimisation; it's reshaping the future of test programs. These programs were largely static in the past, remaining the same once written. Now, with AI's ability to process data instantaneously, they can evolve during production, responding to any changes in chip binder

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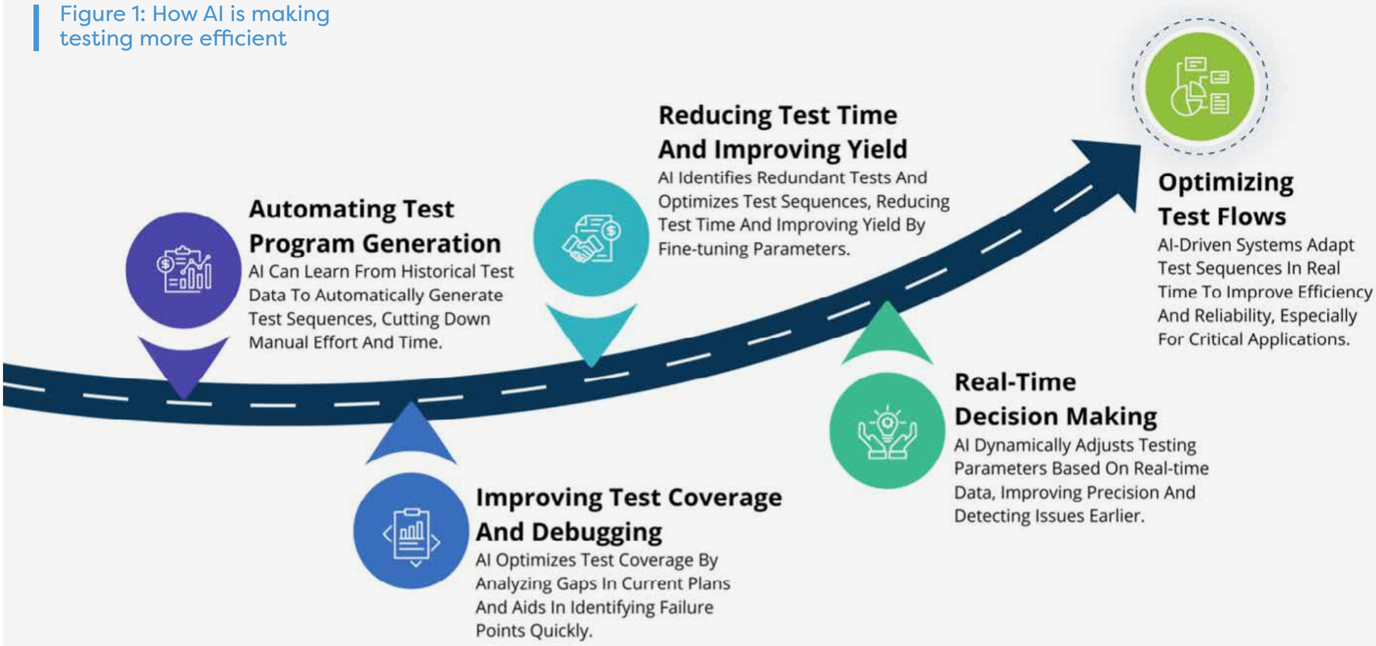
Figure 1: How AI is making testing more efficient



performance or environmental factors. Via this kind of adaptability, fabs can improve their yields and operational efficiencies.

Beyond just automating repetitive tasks, AI is altering test engineers' jobs too. Instead of troubleshooting issues or running exhaustive trial-and-error sequences, they can now focus on more strategic tasks - like tweaking AI algorithms or developing new testing methodologies incorporating AI insights. In the context of semiconductor testing or test program development, AI isn't designed to replace the test engineer. Instead, it's here to augment their capabilities, so they can work smarter rather than harder.

Key considerations for adopting AI in testing

Like any transformative technology, adopting AI comes with its own set of challenges, which companies need to navigate carefully. To fully unlock its potential, they must address some critical technical and strategic considerations, particularly in data security, model accuracy and infrastructure integration. Data security is among the biggest concerns when integrating AI into semiconductor testing. Fabs generate vast amounts of sensitive test data tied to proprietary chip designs and intellectual property (IP). This data must be protected from cyber threats, unauthorised access, or potential leaks, especially as devices become more interconnected and reliant on AI-powered processes. AI models often require large datasets for training/optimisation, which raises questions about how this data is managed. Making certain only authorised entities can access and act upon test data, particularly when shared across different parts of the supply chain or handled in real time by edge computing platforms, is paramount.

Another critical aspect is ensuring AI model accuracy and reliability. Poorly trained or overfitted models could result in false positives/negatives, with costly outcomes. If, for example, an AI-powered optimisation tool incorrectly skips specific test vectors, defective chips could pass through undetected. To avoid this, semiconductor companies should invest in building robust AI models that are thoroughly validated and generalise well across different chip designs and manufacturing nodes. Additionally, it's crucial to keep AI models up to date as new technologies and chip architectures emerge.

Scalability is a further key factor to consider. AI solutions need to be flexible enough to handle different production environments. Whether it's high-mix/low-volume or constantly altering heavy-volume scenarios, AI must adapt quickly to new test programs. At the same time, in large-scale fabs, AI's ability to optimise test sequences in real time is essential for maintaining elevated throughput and superior quality. For companies with global operations, AI systems must scale across multiple sites, enabling seamless communication and data sharing while upholding the highest security standards.

Before fully embracing AI-driven solutions, semiconductor companies must conduct meticulous cost-benefit studies. While the long-term benefits are evident - faster test times, reduced operational costs and improved yields - initial AI investments can be substantial. These include the cost of upgrading ATE platforms, training personnel to use AI tools, plus development of robust AI models. Comprehensive return-on-investment (RoI) analysis, balancing immediate costs with long-term gains (such as quicker time-to-market and higher product quality), is crucial for making well-informed decisions on AI adoption.

As AI continues to evolve, its contribution to semiconductor testing will undoubtedly increase. However, for manufacturers to truly capitalise on its potential, they must be strategic. By effectively addressing the challenges around data security, model accuracy, integration with legacy systems and scalability, they can position themselves to fully benefit from what AI has to offer in testing and beyond.