AUTONOMOUS
VEHICLE TECHNOLOGY

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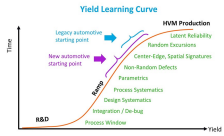
The reliability challenge with automotive semiconductors

Jay Rathert, Senior Director of Strategic Collaborations, KLA Corp., addresses one of the biggest challenges in manufacturing of new, leading-edge applications.

Jay Rathert, Senior Director of Strategic Collaborations, and a 25-year veteran of KLA Corp., currently is a leader in the semiconductor yield and quality collaborations across the automotive and mobile ecosystems.



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Consumers have increasingly high expectations for their cars, driving new requirements for convenience, automation, performance, and connectivity. Carmakers are turning to semiconductor devices as the source of innovation to meet these requirements, but the proliferation of advanced chips brings challenges to the vehicle's reliability and functional safety, factors that are the top priority for consumer and auto manufacturers.

Most automotive semiconductor devices are from mature designs with stable manufacturing processes using design-rule nodes of 40 nm and above. However, the extensive computational requirements for new applications like advanced driver assistance system (ADAS) sensor data fusion, 5G networking, and cockpit infotainment systems have created a growing demand for advanced semiconductors. Leading-edge 10- and 7-nm semiconductor chips are specified in vehicle designs today, and 5-nm designs are in planning stages. As adoption of autonomous capabilities increases, the appetite for these advanced semiconductors continues to grow.

Process maturity and reliability

Most advanced semiconductor chips originate in the consumer market where a part-per-million failure rate and a life of two to five years is adequate. Achieving the required automotive part-per-billion failure rates across a 15-year life requires a different approach. Individual component reliability is a foundation of overall system reliability. Using mature devices that have been fully debugged by their manufacturers has been one way to boost individual component reliability and achieve the aggregate automotive reliability target.

Tier 1 and OEM manufacturers now find themselves needing new advanced semiconductors to meet performance requirements, while recognizing the inherent risk in putting less mature devices into mission and safety critical roles. German OEM **BMW** says the maturity "comfort zone" is shrinking from several years to months as these advanced design-rule parts are rushed from the consumer market into automotive designs.

The semiconductor industry has historically relied on a final electrical test of the completed chip to determine its fitness for shipment. However, an electrical test can only examine a chip's present quality, not its longer-term reliability in the field. Additionally, the testing process of advanced design-rule devices, containing billions of transistors, suffers from incomplete coverage, untestable gap areas, and "latent defects" that are not detectable. Therefore, one test alone cannot eliminate the escape of low reliability devices into customer vehicles.

Fab defects

Increasingly, the supply chain is focusing on the problem closer to the source of many of the reliability defects, the manufacturing fab. A closer look reveals the complexity of this challenge.

As a new semiconductor process node moves from R&D into manufacturing, the percentage of working devices, known as yield, tends to improve with time. This relationship, known as the yield curve, is shown in Figure 3. The strong correlation of a semiconductor's reliability to the manufacturer's fab yield is well established (by C. Glenn Shirley at **Intel**); those fabs that produce a higher percentage of working chips also have higher quality and reliability.

When an automotive designer specifies a device with mature yields, the reliability failures that are traced back to the fab are typically caused by random process variation, tool failures, or latent defects. When a new device with a less mature process is specified, the user intersects the yield curve at a lower point where a broader and more challenging problem-set still exists. An increasing quantity of so-called "systematic" defects related to subtle interactions from the design and manufacturing process are likely to remain. These issues may not yet be fully recognized, and their contributing sources not yet debugged.

Addressing the challenges

Semiconductor chip suppliers accustomed to making advanced design-rule parts for the consumer market can address these challenges in three ways:

Steepen the yield learning curve: Fab yield management teams should plan to aggressively accelerate process maturity by focusing on yield learning. Moving up the yield curve faster reduces the sources of reliability risk for the new devices. For complex process nodes less than 10 nm, which have several hundred manufacturing steps, this challenging task will require additional inspection and metrology measurements to provide information about "defectivity" levels and process variations. Additional proactive methods to reveal systematic weaknesses in the device design and manufacturing process must be used.

Break down data silos: Semiconductor defect screening data gathered during manufacturing adds valuable context to the final electrical test go/no-go decision for each chip. Examining 100% of the devices at a few key steps, in conjunction with statistical defect outlier analysis, helps identify chips with potential reliability concerns. Devices that contain an unusual quantity of manufacturing defects that narrowly pass the final electrical test are especially at-risk for reliability issues that would otherwise escape into the supply chain.

Standardize the approach: Device manufacturers and their automotive customers rely on a process known as Safe Launch to assess a device's readiness for high-volume manufacturing. While the concept is strong, the implementation across suppliers is highly variable. Additional governing standards would allow automotive customers to effectively audit and assess the fab's risk reduction activities before potentially allowing a problem to proliferate in volume production.

Looking ahead

The increased adoption of advanced semiconductors brings many exciting and innovative capabilities to automobiles. Proactive measures to accelerate yield learning and screen outlier devices in the fabs, coupled with data sharing across the fab manufacturing and testing domains, can help remove some of the risk of using devices from less mature process nodes. Beyond inspection and metrology equipment, KLA offers collaboration, expertise, and best-known methods across the automotive ecosystem in support of this industry goal.

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