Achieving Zero Defect Manufacturing Part 3: Prevention of Defects

By Prasad Bachiraju,
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The concept of zero defect manufacturing has been around for decades, arising first in the aerospace and defense industry. Since then, this manufacturing approach has been adopted by the automotive industry, and it has only grown in importance as the sector transitions to electric vehicles. Given the role semiconductors play in today's vehicles, and will play in the future, it is no surprise the industry has adopted a zero defect approach.

However, the quest for zero defect manufacturing goes well beyond the aerospace, defense and automotive industries. Many companies that have started or are planning digital transformations are pursuing zero defect manufacturing. Accomplishing this requires using data from a wide range of sources, including materials, products, processes, factory subsystems and equipment. When all of this data is properly integrated, and fabs are able to take complete advantage of the analytics from their monitoring systems, the goal of a zero defect manufacturing environment is achievable.

Before we go any further, we should get one thing out of the way: zero defect manufacturing does not promise zero defects. It is a commitment to properly identifying defects and sources, giving manufacturers the opportunity to detect dormant failures early on and make proactive corrections.

We first began to dive into the subject of zero defect manufacturing with our blog "Achieving Zero Defect Manufacturing Part 1: Detect & Classify." In it, we examined real-time defect classification at the defect, die and wafer level. Moving on to the next blog, "Achieving Zero Defect Manufacturing Part 2: Finding Defect Sources," we discussed how to use root cause analysis to determine the source of defects. As for this installment, the last in our three-part series, we will discuss how to prevent defects. In particular, we will discuss dormant defects caused by micro cracks, variations in copper seed thickness following deposition, and a case where monitoring equipment health led to the discovery of defects resulting from the spin coater process.

Dormant Defects

Fabs already employ many of the best practices for achieving zero defect manufacturing. They have adopted measures including dynamic part average testing, rules-based binning and others. In addition, many fabs employ machine learning-based techniques for signatures and apply good die in bad neighborhood rules. In this zero defect quest, manufacturers have to find a balance, one that sufficiently addresses their customers' needs while meeting the requirements of their own production goals.

Consider this example of a fab pursuing a zero defect initiative and how software rules were used to reduce bad die. For starters, the fab examined a 15-wafer lot, and in that lot, they found micro cracks within the same die or cluster of dies across seven wafers in the lot. As for the remaining eight wafers, they were unable to identify defects within this same area. In other words, just a little under half of the wafers had a micro crack in a similar location; the rest appeared to be fine. However, many of these die could be defective for the same reasons the dies in those seven wafers were. In other words, these die might have dormant defects.

As we know, micro cracks can cause potential failures. To address this, the fab in this example applied a lot-level guard banding rule to bin all defects within the same die or cluster of dies. This decreases the possibility that die with potential micro cracks may move on to the next stage of the process.

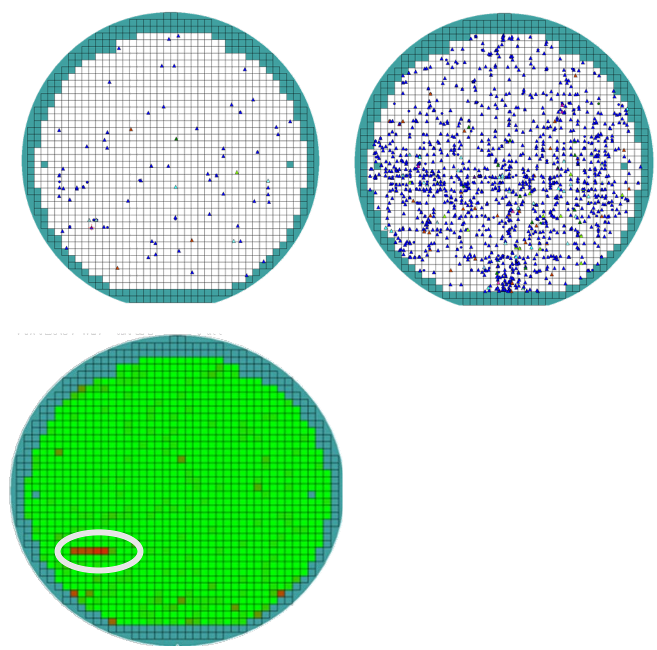

Figure 1: a) Defect map (top left); b) Stacked defect map (top right); c) Stacked probe map, micro cracks (bottom left)

Feedback and feedforward

Run to run (R2R) software has been providing advanced process control to the semiconductor industry for more than 25 years. By implementing R2R control across the entire manufacturing process, customers gain efficiency and reduce maintenance and improvement costs. To give you

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a better idea of how R2R models can be employed in pursuit of zero defect manufacturing, we offer the following scenario involving deposition control in the process chamber.

As you may know, defectivity and out of control thickness variations are often linked to strong variations in the deposition rate. With this in mind, we took feedback from copper seed layers using delta offset corrections generated by yield analytics and data from fault detection and classification (FDC) software. With this information, we recalculated the dynamic deposition rate. By applying this recalculated rate of deposition, we were able to reduce out of control defect events by 40%, decrease dispersion by 32% and increase overall chamber lifetime by 15%.

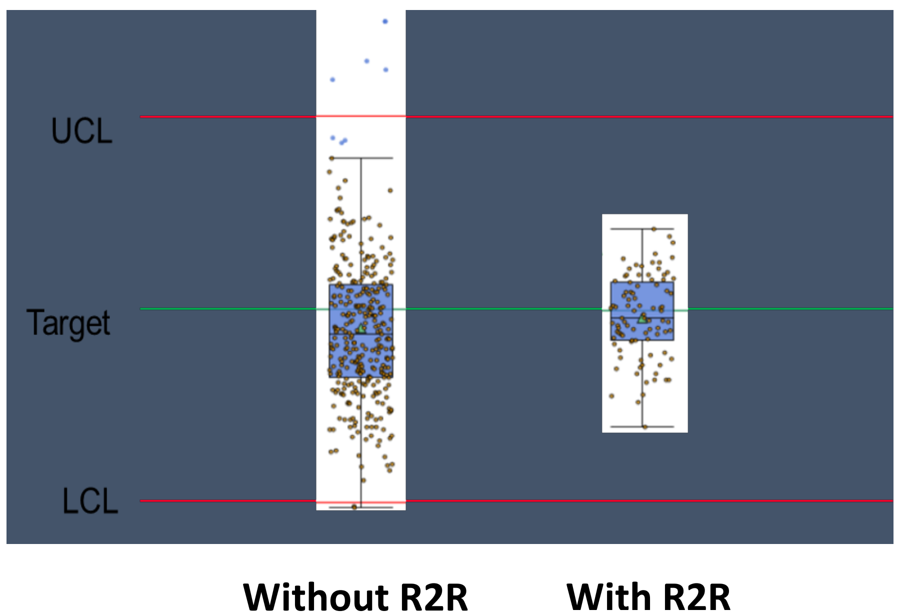

Figure 2: *Enabling dynamic deposition rate control throughout the lifetime of the process chamber.*

Monitoring equipment health

In terms of equipment control, tool sensor monitoring is always important. Using various inputs, customers can create health scores for an entire fleet of tools — at the component level, module level and tool level.

With this information, we can better understand process control trends, particularly whenever a tool or process step begins to deliver abnormal

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data. In that case, we can apply machine learning models to quickly determine the causes of issues. The following is an example of how we took data from a spin coater exhaust flow sensor and used that information to proactively increase quality and yield.

At various times, analytics showed the occurrence of an out of control event involving a spin coater. In this case, liquid from the spin coater was overflowing and randomly exposing the under bump metallization layer. By looking at the data, and the timing of the out-of-control events, we determined the tool was being impacted by a loss of suction involving the spin coater exhaust vent. This resulted in the overflowing liquid. With this knowledge in hand, we were able to take full advantage of all sensor data, build models to monitor equipment health and take actions appropriately, creating additional fab efficiency and remedying the issue.

Conclusion

Modern semiconductor manufacturing processes have become unimaginably complex. By adopting an integrated approach involving tools and analytical software, feedback and optimization, this complexity can be better understood and managed, positioning fabs to catch defects early on and identify efficiencies, including those that eliminate redundant steps or reduce time of operation. With this feedback in hand, fabs can not only improve device quality, but they can also reduce energy consumption and lower manufacturing costs. In other words, connected thinking drives fab efficiencies and fosters an environment of zero defect manufacturing.

In this three-part blog series, we have outlined a number of ways fabs can use run to run and FDC software, along with other tools, to meet their zero defect manufacturing goals. We hope that this three-part blog series plays a part in showcasing some of the ways this approach can be beneficial.

About the author

Prasad Bachiraju is senior director of sales and product marketing at Onto Innovation. He began his career in the semiconductor industry as a software engineer. Over the past two decades, he has worked extensively in developing and supporting defect analysis and yield management systems