Finding Critical Defects Before They Become Costly Failures: Process Control for Hybrid Bonding and Advanced Packaging

By Yong Gao,
Onto Innovation

Content as published on
Semiconductor Engineering blog post, October 2026.

In advanced packaging, value accumulates layer by layer, component by component, and process step by process step. By the time chiplets, high-bandwidth memory stacks, or hybrid-bonded devices reach assembly, manufacturers have invested substantial material and processing resources in those devices. An undetected defect at this stage can place the larger assembly at risk.

Compounding this challenge, shrinking package features are bringing advanced packaging requirements closer to the tolerances historically associated with front-end fabrication. Going forward, manufacturers will face increasing pressure to detect smaller defects and characterize increasingly complex structures.

However, the challenge extends beyond smaller surface defects.

Advanced packaging processes can present surface, sidewall and subsurface inspection challenges, including particles, cracks, embedded defects, microbump irregularities and bonding voids. They also require precise measurements of bump height and surface profile. As defect types and process control requirements become more diverse, manufacturers need the flexibility to apply complementary inspection and metrology techniques within a unified workflow.

Manufacturers consequently need process control strategies that can address the specific risk at each layer. High-sensitivity 2D inspection can identify surface particles and pattern-related anomalies, while high-speed infrared sub-surface inspection can reveal voids and embedded defects that otherwise remain hidden. 3D metrology can measure critical microbump height and surface profiles, helping manufacturers characterize advanced packaging structures more completely. The objective is to give process engineers the information they need at the point where a manufacturing decision must be made.

Sensitivity, however, cannot come at the expense of productivity. As features shrink, inspection must detect smaller and subtler defects while maintaining the throughput required for high-volume manufacturing. If an inspection throughput is too low, it can become a bottleneck in an already capital-intensive production flow.

Advanced optical architectures, multiple illumination angles, and purpose-built imaging techniques can help improve the visibility of difficult defects. Multi-angle illumination can improve the visibility of sidewall and low-contrast defects that may be difficult to detect with conventional brightfield or darkfield inspection. But greater visibility is only part of the challenge.

Finding Critical Defects Before They Become Costly Failures: Process Control for Hybrid Bonding and Advanced Packaging

By Yong Gao,
Onto Innovation

Content as published on
Semiconductor Engineering blog post, October 2026.

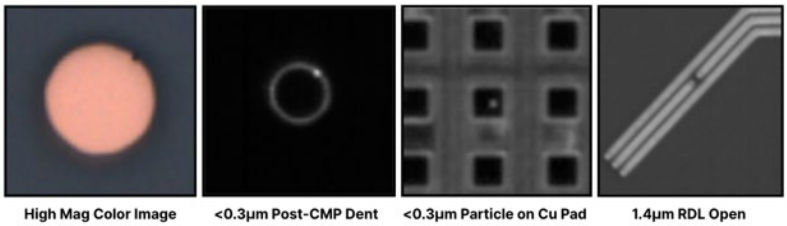


Figure 1: Manufacturers must align inspection and metrology capabilities with the specific risks and decision points associated with that layer.

Each layer presents distinct process control requirements. Manufacturers must align inspection and metrology capabilities with the specific risks and decision points associated with that layer (Figure 1). The chemical mechanical planarization (CMP) step used to prepare surfaces for hybrid bonding illustrates this challenge. Because the prepared surfaces must meet stringent requirements, even a small imperfection can become yield limiting. As bond pitches shrink, manufacturers need greater inspection sensitivity and tighter process control at this critical stage.

Greater sensitivity creates another challenge: determining which defects require action. Since advanced packaging combines varied materials, structures and surface conditions, increasing the number and diversity of detected events, engineers can spend valuable time reviewing nuisance or low-priority detections without effective classification. More detections do not automatically lead to better decisions. Manufacturers need more than a defect map. Effective classification helps separate likely yield-relevant defects from nuisance defects and turns inspection results into actionable process information.

Earlier, More Confident Decisions

Advanced packaging manufacturers must protect growing device value while detecting smaller defects and distinguishing among a wider range of defect types. Ultimately, a production-worthy process control strategy should help manufacturers answer five questions:

- Should this device continue to the next process step?
- Is the process beginning to drift?
- Which defects are most likely to affect yield?
- Can those defects be found without slowing production?
- Can the inspection strategy adapt as structures and requirements change?

Today's manufacturers need a flexible, integrated platform that brings together complementary inspection and metrology capabilities to answer these questions across the process flow.

Bringing these capabilities together on a single platform gives manufacturers the flexibility to address varied process requirements within a unified workflow while improving cost of ownership and making more efficient use of valuable fab floor space.

By finding relevant defects, prioritizing their potential impact, and delivering actionable information before compromised devices move downstream, manufacturers can make earlier disposition decisions, respond more effectively to process variation, and better protect yield.

In our next blog in this series, we will examine how manufacturers can extend this integrated approach into front-end process control, connecting information from the wafer surface, edge, and backside to support better manufacturing decisions.
We hope you will join us.

Finding Critical Defects Before They Become Costly Failures: Process Control for Hybrid Bonding and Advanced Packaging

By Yong Gao,
Onto Innovation

Content as published on
Semiconductor Engineering blog post, October 2026.

Biography

Yong Gao is a Senior Director of Product Marketing at Onto Innovation.