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Fine Pitch Probing of Micro-Bumps for Advanced Packages

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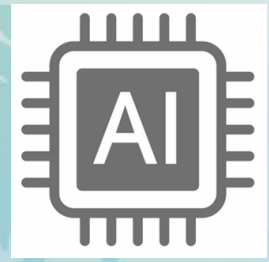
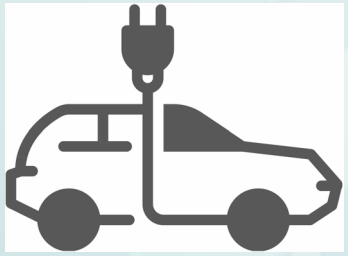
Outline

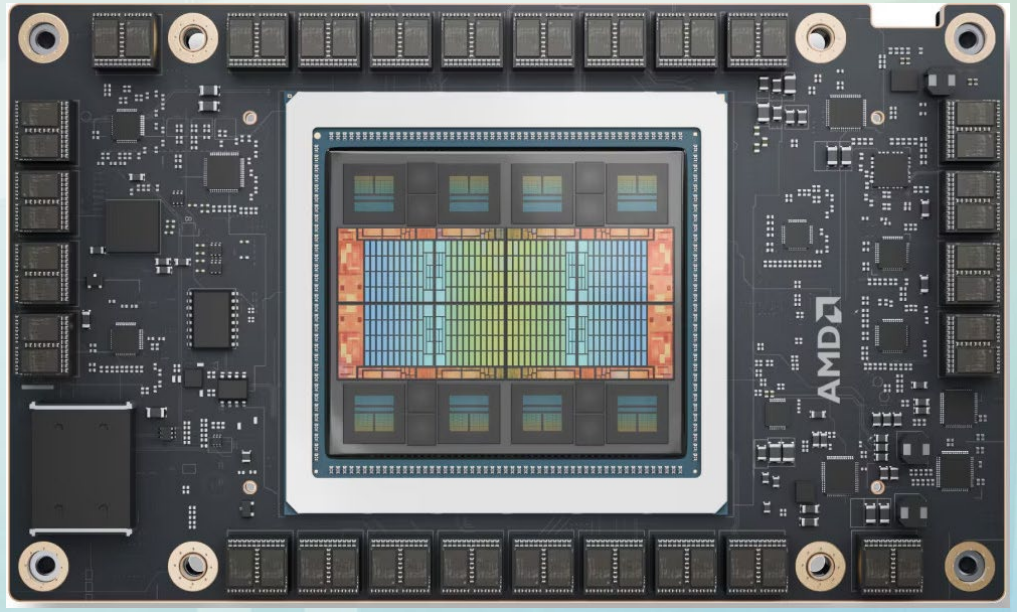
- The market opportunity
- Significance of the problem
- Fine pitch probe cards and the heterogeneous integration test system (HITS™)
- Test results and challenges
- Summary

What is Advanced Packaging?

Advanced semiconductor packaging combines multiple chips into a single package, offering increased functionality, performance, miniaturization, and is crucial for emerging technologies like AI, 5G, autonomous vehicles, and datacenters







The Market Opportunity

- Advanced packaging is becoming increasingly important in the semiconductor industry due to the limitations of traditional scaling methods (Moore's Law)
- Market opportunity driven by megatrends in AI, 5G, autonomous vehicles and datacenters
- The projected 2029 revenues for advanced packaging is $ 79B with a CAGR of 10.7%

[1] Yole intelligence, "Advanced packaging pushing the boundaries of semiconductor probe card market," SWTest 2024

Significance of the Problem

- Chipmakers and integrators cannot afford to integrate faulty chiplets[2] and interposers into a package. A faulty chiplet or interposer could render an entire expensive package useless at significant cost, time, and effort.
- Thus, a probe card is required to test the functionality of chiplets and interposers prior to and after assembly.
- However, there is lack of fine-pitch probe cards for testing chiplets and interposers with fine pitch micro-bumps, copper pillars, and hybrid bond pads.

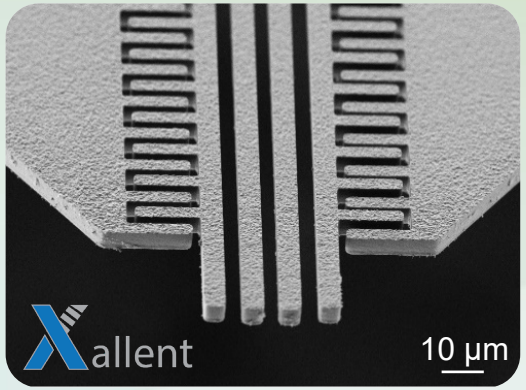
[2] A chiplet represents a miniature integrated circuit (IC) with distinct set of functions.

Limitations of Conventional Probe Cards

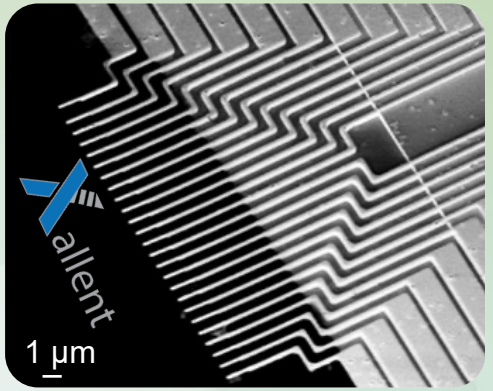
- Traditional probe cards, often based on cantilever or vertical probe technologies face limitations when applied to fine-pitch micro-bump (µbump) probing.
- Limitations include:
  - Inadequate spatial resolution making it difficult to accurately contact very small µbumps
  - High contact forces which could damage the delicate µbumps
  - Poor planarity control leading to uneven contact and inaccurate measurements

Fine Pitch Probe Cards for Advanced Package Tests

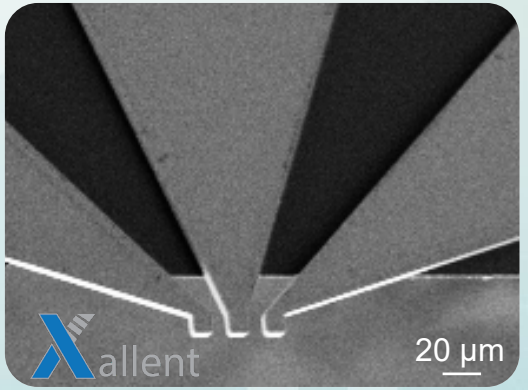
- Fine pitch probe cards enable the testing of current and future chiplets and advanced packages
- Improve packaging yields by proactively determining known-good-chiplets (KGC) and interposers
- Shorten manufacturing and packaging iterations



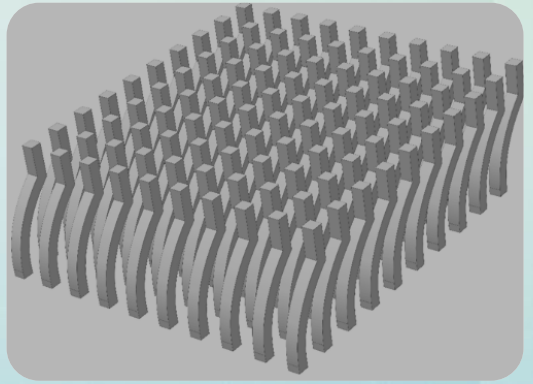
Kelvin Probe



Ultrafine Pitch Probe



RF/High Frequency Probe



Grid Array Probes (Early-Stage Dev)

The Heterogeneous Integration Test System (HITS) Provides the Insights

Reduced Capex with a single test system for multiple test applications

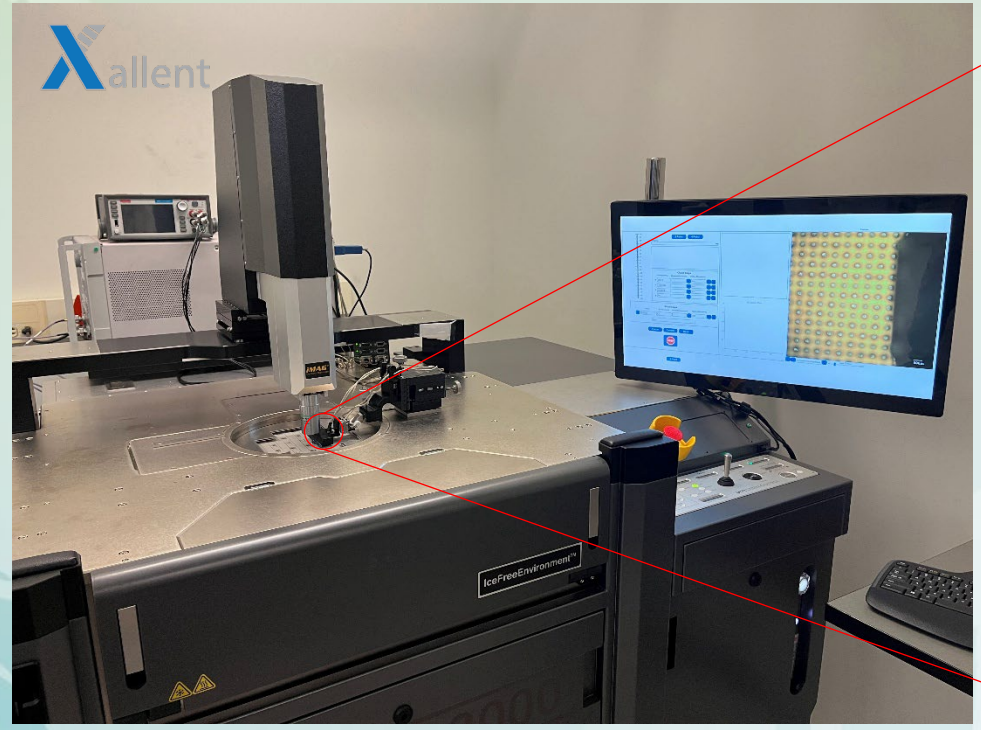
System leverages Xallent fine pitch probe cards for electrical, mechanical, and photonics tests

Test system replaces machines up to 5X the price and occupying 5X the lab space.

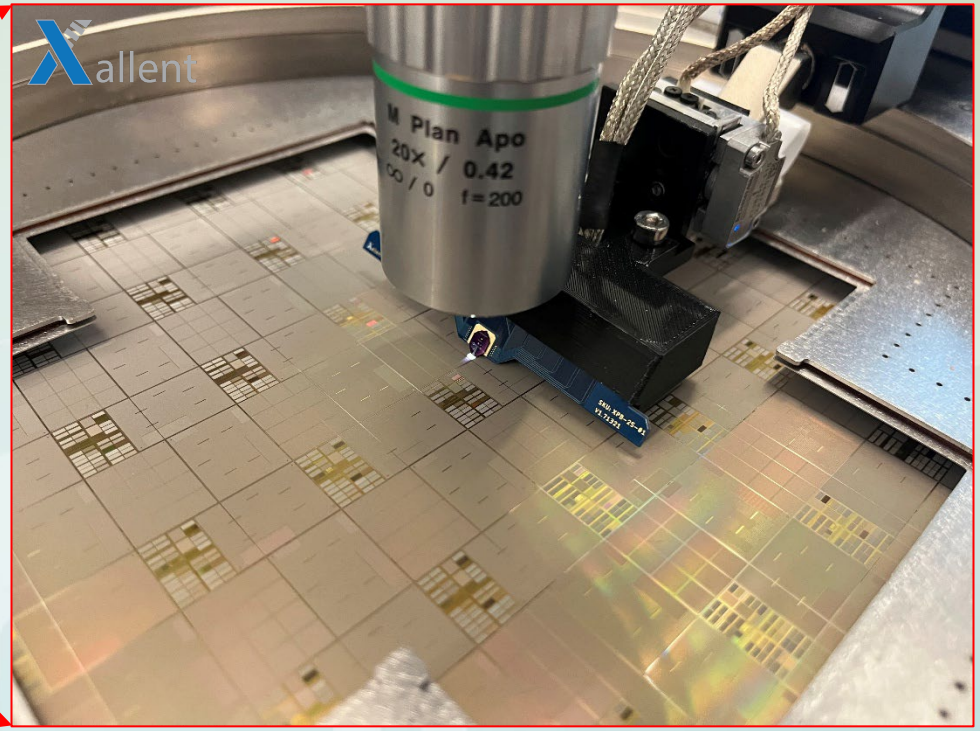
Case Study: Micro-bumping Process Verification

- Objective: Perform wafer acceptance tests (WAT) to determine the integrity of micro-bumping processes
- Platform: Leverage a custom fine pitch Kelvin probe and HITS™
- Data: Measure the Kelvin resistance of 3-µbump test structures and display results and statistics as a heatmap

Measurement Setup

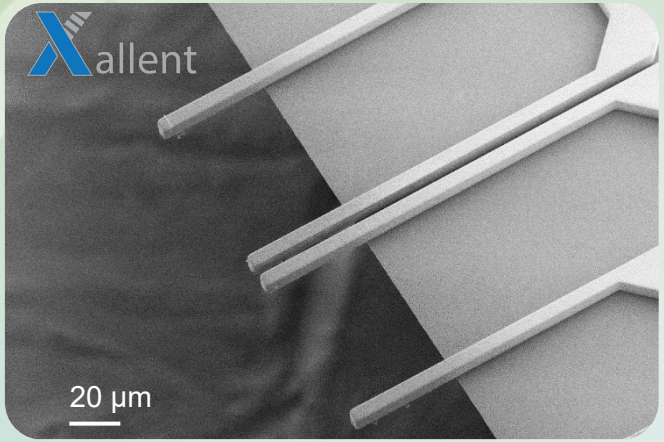


HITS™



Probe tips in contact with 300 mm µbump wafer

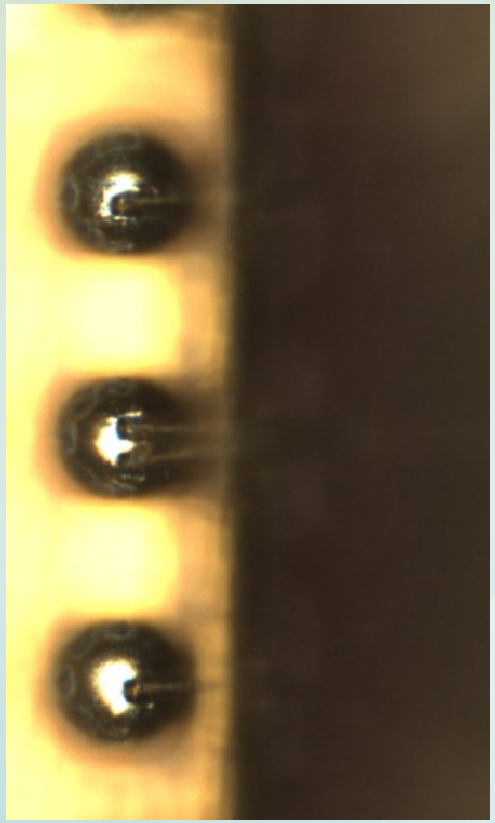
Fine Pitch Probe Specifications



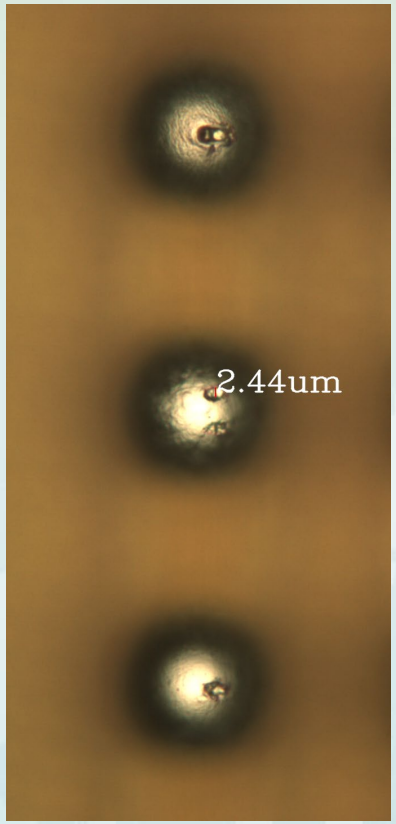
Parameter	Value
Number of tips	4
Arrangement	Inline
Probe 1 & 2 spacing	65 µm
Probe 2 & 3 spacing	5 µm
Probe 3 & 4 spacing	65 µm
Probe thickness	8 µm ±2 µm
Probe-to-probe leakage current	~500 pA @ 5 V
Current carrying capacity	100 mA

Kelvin Resistance Measurements

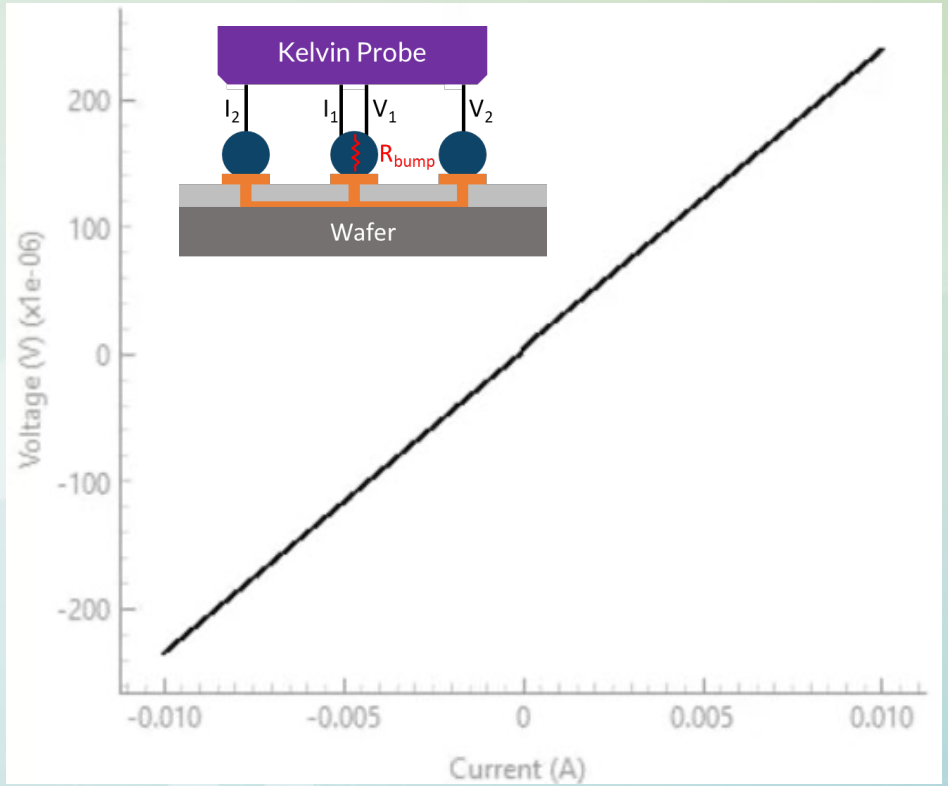
Virgin µbumps



Probes in contact with µbumps

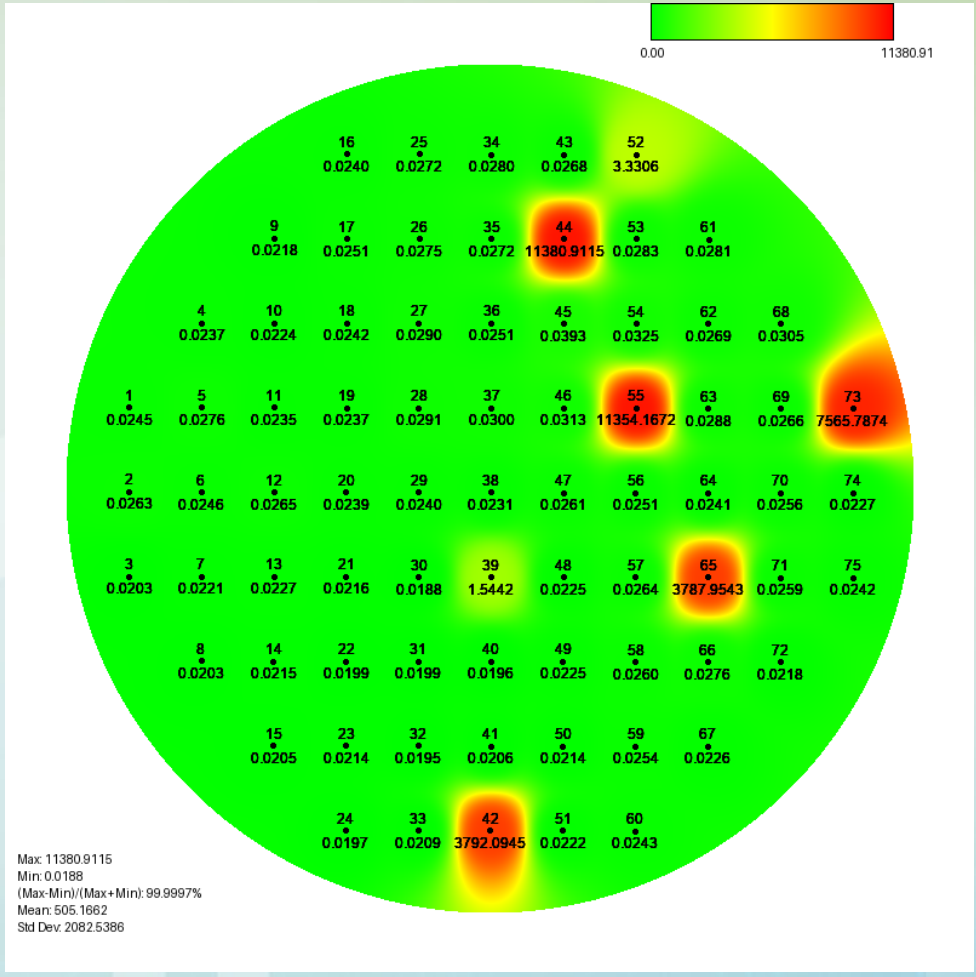


Probed µbumps



Kelvin Resistance Measurements

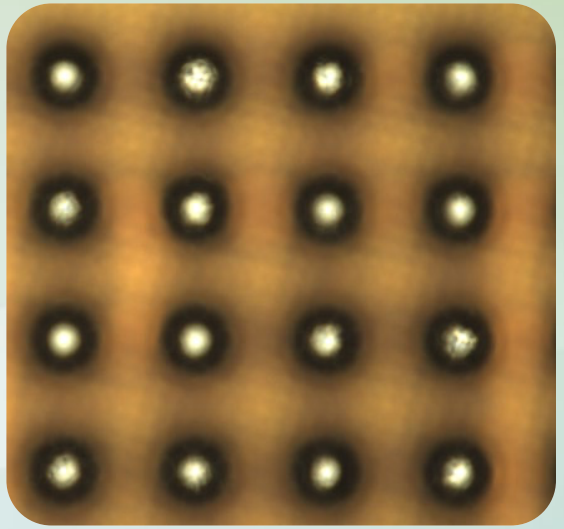
- 75 dice on a 300 mm wafer were tested
- A single 3-µbump test structure was tested per die
- The median Kelvin resistance was 25 mΩ with minimum and maximum resistance values of 18.8 mΩ and 11.38 kΩ respectively



Challenges of Micro-bump Probing

- **Auto-focusing of µbumps**

Leverage advanced algorithms for auto-focusing



- **Accurate alignment between probe tips and µbumps**

Utilize high precision stages and automation software

- **Maintaining constant contact force**

Utilize force feedback probes to continuously monitor contact force during probing

Summary

- Fine pitch probing is crucial for ensuring the reliability and performance of advanced packages, enabling the development of next-generation high performance computing (HPC) and high bandwidth memory (HBM) chips
- Our experiments demonstrate the effectiveness of our fine-pitch probing solution for accurate characterization of micro-bumping processes
- Reliable and repeatable measurements of Kelvin resistance, a key wafer acceptance test (WAT) parameter were achieved

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- Frank Fehrmann

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