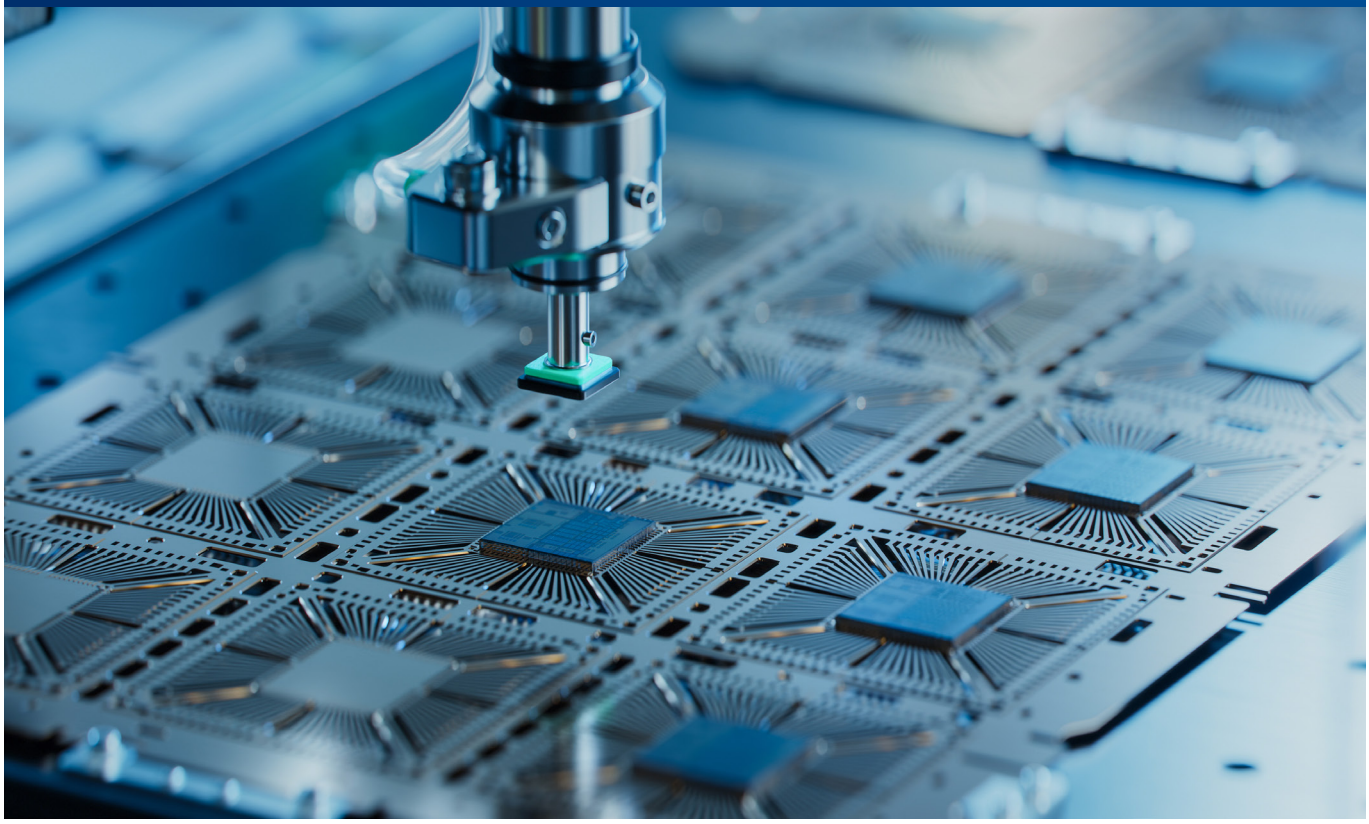
NPL
National Physical Laboratory

NPL measurement expertise helps redesign inspection instrument to target £100m+ opportunity in semiconductor market

Semiconductors – essential to the world's microchips – become more efficient and powerful each year, in part thanks to ever-smaller transistor designs that pack nanometre-scale features into increasingly dense chips.

Because these are such complex and high-value items, manufacturers want to regularly check them for defects along the production process, so they can control quality early. This has typically been done with Scanning Electron Microscopes (SEM), but these now struggle with the complex 3D features on the newest chips. Some chipmakers are turning their attention to Atomic Force Microscopy (AFM), which uses a physical probe to map surfaces with atomic-scale accuracy.

The challenge with AFM is that it is slow – too slow to use routinely in quality control. To address this, Infinitesima Limited, a venture capital funded startup, has developed the Metron 3D™, an AFM tool that can measure 100 times faster than most AFMs on the market.



Challenge

AFM maps semiconductor features by measuring the changing height of the probe as it runs over 3D features, calculating the height or depth of those features. Infinitesima's advantage comes from not relying on the slow control loop available with piezoelectric based AFM devices instead using faster laser interferometry - in which a laser beam is reflected from the probe to determine its precise position by measuring laser interference.

Obtaining accurate laser interferometry measurements relies on multiple advanced components and carefully aligned setups. Infinitesima's setup worked well for many semiconductor measurements, but improvements were required to achieve the required accuracy when measuring deep etched features of the type found in the most advanced semiconductors, and to be able to sell to this most valuable market.

Solution

Infinitesima had already engaged NPL on a couple of smaller projects, so the NPL team already had a relationship and an understanding of the device.

Building on this, in 2023 NPL replicated the device design and performed measurements using standard artefacts to test for inconsistencies. Combining test data, modelling, and decades of accumulated interferometry measurement expertise, NPL systematically worked through the various optical interferometry components and measurement processes used in the device, to understand how the accuracy of deep structure measurements could be improved.

"They took a really rigorous approach, looking at every aspect of the design." says Patrick Hole, Senior Director of Development and Engineering at Infinitesima, "They ruled out some areas we thought might be an issue to improving deep measurement accuracy, such as internal reflections – instead confirming these were not causing an issue – and quickly homed in on the areas that were impacting the measurement result".

The project identified two technical points which could be improved: beam positioning and design inefficiencies within the interferometer block – and provided a report to Infinitesima outlining the issues. NPL tested and validated a new design for the interferometer block – an essential component of interferometry – which would improve accuracy and Infinitesima have since improved their build process to better control for the beam positioning.

Impact

"The knowledge of our product design that we have gained from the project is now helping us make critical design improvements that will deliver the accuracy needed for our most advanced use cases," says Patrick Hole.

In particular, this will make the system viable for use in quality control for new FinFET transistors, which use complex 3D structures and deep channels to deliver more processing power in a smaller space. This is one of three key semiconductor markets that Infinitesima is targeting, which it estimates could be worth £100 million in sales.

The project also provided rigorous design and validation data, which can be requested by Infinitesima's more exacting customers.

Whilst the product is still in customer trials, it could have huge potential in the semiconductor industry.

“Semiconductor manufacturing is incredibly high value and probably the most exacting of any modern industry,” says Patrick. “They can go through thousands of manufacturing steps to etch in nanoscale features, and tiny errors in any one of these can mean whole batches get thrown out at great expense.”

“The semiconductor industry is dying for practical measurement tools that they can insert along the process to monitor and control processes. SEM is no longer fit for purpose, and AFM has until now taken too long for in-line quality checks. Our new approach to AFM provides both speed and accuracy. Thanks to NPL, we have now been able to fully understand the physics behind our instrument, optimise the design to resolve errors that occurred when it was pushed to its limits, and gather validation data to assure customers. That’s good for us, and will be good for the global semiconductor industry, and the growing number of companies that rely on its cutting-edge chips”.

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