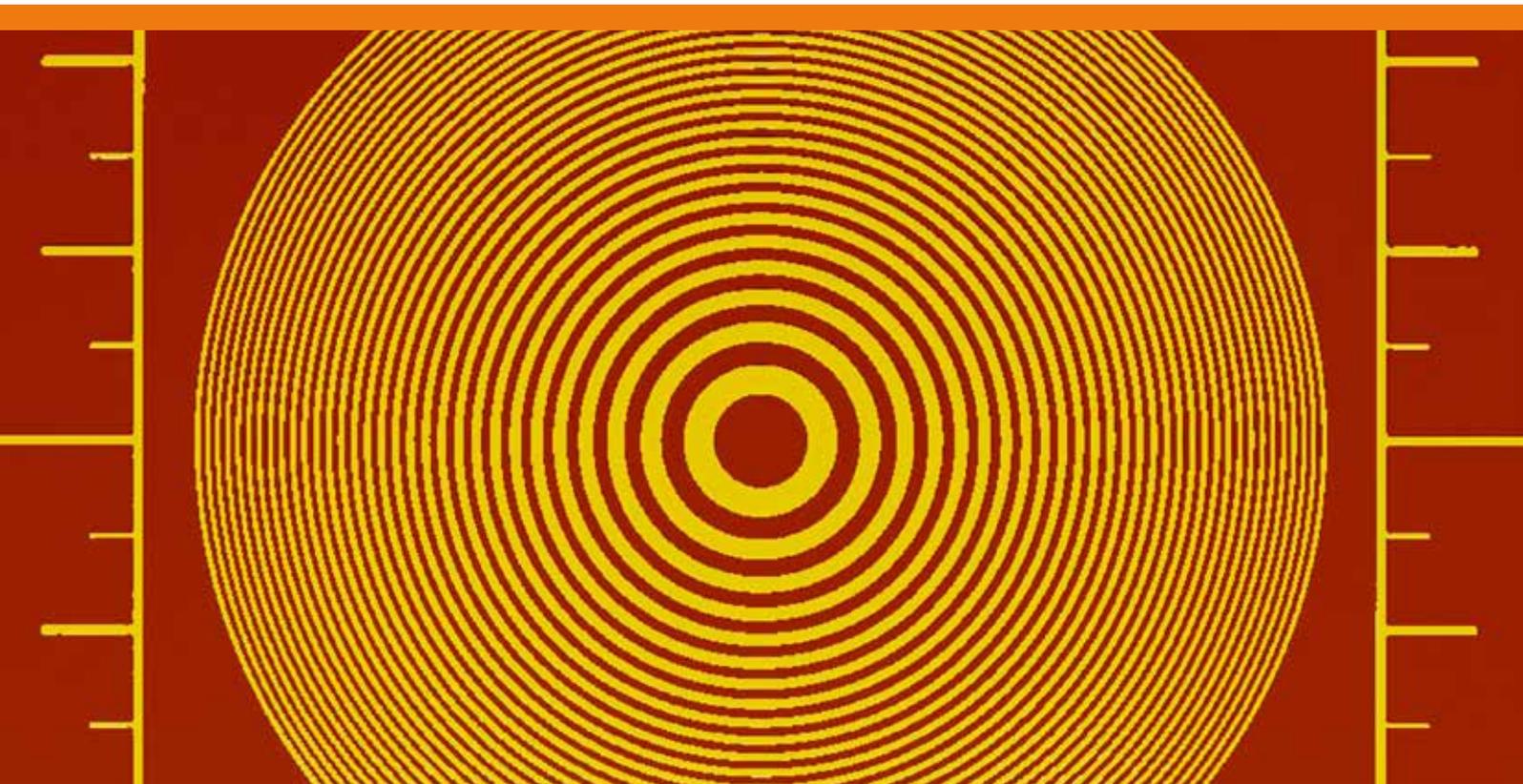


European Metrology
Programme for Innovation
and Research

Delivering Impact



A new standard for better 3D chips

To reduce the size of electronic products and increase processing power 3D silicon chips, where components are assembled on top of each other, are being introduced. Correct alignment of each of these constituents is essential for function which requires the precise measurement of surface features. Optical analysis methods currently offer the best solution, but the standards required for accurate measurements at this nanometre scale are not yet available.

Europe's National Measurement Institutes working together

The European Metrology Programme for Innovation and Research (EMPIR) has been developed as part of Horizon 2020, the EU Framework Programme for Research and Innovation. EMPIR funding is drawn from 28 participating EURAMET member states to support collaborative research between Measurement Institutes, academia and industry both within and outside Europe to address key metrology challenges and ensure that measurement science meets the future.

Challenge

The processing power of traditional silicon chips, or integrated circuits, is now reaching its limit. To address this, and the demand for smaller devices, manufacturers are introducing '3D' chips where parts are assembled on top of each other. This additional level of architecture requires new types of measurements to verify that components are correctly aligned to ensure appliances function as intended. A commonly used method is 'stylus profiling' where the movement of a stylus over a surface maps its features, but this process can damage delicate parts and is relatively slow, unsuited to high-throughput manufacturing.

Optical measurements using 3D microscopes are an attractive alternative as they are non-contact, rapid and can measure larger areas but several problems require addressing before these can be routinely used. 3D chips contain 'high-aspect-ratio' components, which are tall but have a small surface area, and feature sharp edges that are hard to detect accurately using light microscopes. Furthermore, these chips contain sub-micron elements often at the resolution level of these instruments.

Accurate, traceable measurements require that these factors must be accounted for, but instrument calibration standards are not available, limiting this approach.

Solution

Within the EMPIR project *Metrology for manufacturing 3D stacked integrated circuits* the National Metrology Institute of Germany (PTB) developed a new standard using advanced electron-beam lithography and reactive ion etching techniques to enable a state-of-the-art characterisation of 3D microscopes. The surface contains nanometre sized, sharp-edged, circular concentric 'rings' which give the standard innovative design features. Made to precise dimensions with known measurement accuracies the spacing, or distribution frequency, between each 'groove' form a geometric pattern termed a 'chirp'. This type of pattern is ideal for characterising a microscope's Instrument Transfer Function (ITF) which indicates the lateral resolving power of optical instruments for making 3D surface measurements. The rotational symmetric patterns of the rings are designed to detect angular-dependent asymmetries and their depth informs on an instruments performance at detecting the height of nanometre sized structures. As a result, optical measurements can be accurately assessed at the nanometre scale.

Impact

Following the end of the project the Zygo Corporation, a global leader in the design and manufacture of advanced optical measurement systems, used the standard to assess the performance of their products. These include a range of 3D microscopes, sensors and precision optical components and are used in a wide range of markets, from consumer electronics to the aerospace and biotechnology industries.

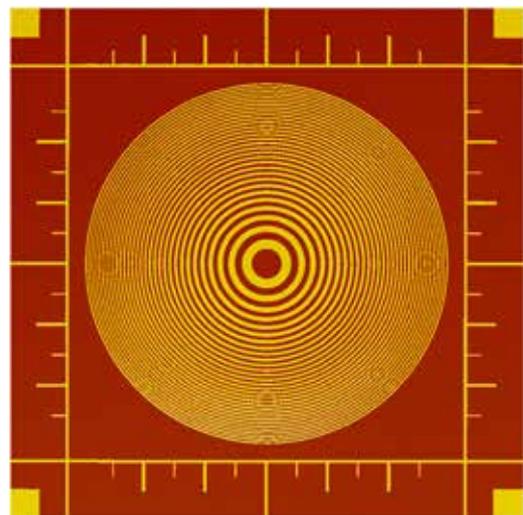
With its Nexview™ advanced optical surface profiler, the Company was able to measure the new standard's challenging features within the specified accuracies. This has helped Zygo establish the best approach to measure features with dimensions approaching the resolution level of the most advanced optical microscopes, knowledge they can now pass on to their customers facing

similar measurement issues. Zygo considers that the use of the standard helped them improve the results of fine-structure surface measurements and provided demonstrable data of the superior performance of their instruments relative to competitors.

Increased measurement precision for high-aspect-ratio components will allow a greater confidence in the use of optical microscope for the rapid, inline detection of defects in the 3D chips as well as in other industries that use submicron components.

A new standard for better 3D chips

The EMPIR project *Metrology for manufacturing 3D stacked integrated circuits*, developed techniques and methodologies to enable the traceable and accurate characterisation of the next generation of 3D silicon chips where components are assembled on top of each other. Using a battery of techniques, the project addressed the problems of measuring component alignment and dimensional properties. The project also developed novel tools to detect defects and areas of the chips where overheating can occur. Reference materials, calibration standards and four guides have been produced and made available. All these results will give more confidence in the assessment of key dimensional parameters like curvature, roughness, flatness and alignment which are necessary for the control of the 3D chip assembly and bonding processes, crucial for the implementation of this technology.



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