



Improving sub-nanometre accuracy

Semiconductors, bio-materials and other nanoscale innovations rely on the precise production of miniscule features. Verifying that these have been reliably reproduced requires advanced analytical instruments and highly accurate microscopes working at the forefront of measurement capabilities – an area where Europe is world leading. To maintain Europe's competitive edge, as features get even smaller, new sub-nanoscale reference standards are needed to demonstrate the accuracy of current and next generation instruments.

Europe's National Measurement Institutes working together

The European Metrology Research Programme (EMRP) brings together National Measurement Institutes in 23 countries to address key measurement challenges at a European level. It supports collaborative research to ensure that measurement science meets the future needs of industry and wider society.

Challenge

Innovations in nanotechnology are producing novel materials with unique properties, such as the functionalised surfaces that are spurring the development of a new generation of electronics. Verifying that these nanoscale innovations perform as designed relies on measuring their features with sub-nanometre accuracy.

Ultra-high-resolution Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and optical techniques such as confocal microscopy and interferometry are used to assess height changes across surfaces and distances between features with nanometre accuracy. Calibrating these instruments and confirming their performance currently relies on using reference standards with physically machined ridges, but these can only be manufactured with steps down to 6 nm. This is fine for now, but existing machining techniques cannot produce ridges small or precise enough to confirm the further advances in microscope precision that will be available in next generation nano-technologies.

New reference standards are needed based on sub-nanometre length standards to characterise microscopes with this level of precision. Using the fundamental properties of crystals, such as the distance between atoms, could provide reliable measurement standards at this scale. However, constructing such standards requires the development of reliable production and rigorous characterisation methods.

Solution

The EMRP project, *Crystalline surfaces, self-assembled structures, and nano-origami as length standards in (nano)metrology*, investigated different types of materials and assembly methods for creating sub-nanometre structures and prototype dimension standards.

This was achieved by taking advantage of fundamental properties of nature that create regular, predictable crystalline structures. In creating these standards, project researchers focussed on extending the use of low-cost production methods based on technologies routine in the semiconductor industry. By using silicon crystals, and controlling environmental conditions during crystal formation, they created small regular steps of less than 0.3 nm spacing.

The so-called 'staircase' standards are 20 times smaller and 10 times more accurate than existing reference standards. These will now undergo evaluation by the international measurement community to confirm their links to SI units, and assess their suitability for industrial use.

Impact

Sensofar, develops high-end optical measurement instruments, and was one of the first users of the project's novel step height dimension standard. The company used the staircase standard to explore the limits of its current microscopes and to support R&D for new ones.

This will help Sensofar future-proof their business, demonstrating that their products exceed client expectations, whilst also helping them create and validate a new generation of ultra-high resolution measurement tools for emerging nano-technologies. Once the staircase standard has been validated for wider industrial use, other instrument manufacturers will also benefit from being able to accurately characterise more precise instruments.

The resulting improvements in sub-nanoscale measurements will support the development of ever smaller innovations in electronics and other nanoscale applications, such as the creation of nanoparticles and carbon nanotubes, which are of great interest to the environmental and health sectors.

Improving dimensional measurement accuracy at the nanoscale

The advanced electronics industry continues to push the limits of component miniaturisation, but assessing production quality at the nanoscale requires well-calibrated test equipment capable of performing measurements accurately.

The EMRP project *Crystalline surfaces, self-assembled structures, and nano-origami as length standards in (nano)metrology* developed novel dimensional reference standards, based on self-organizing crystalline and molecular structures, for the calibration of instruments used to measure the dimensions of advanced nanoscale electronic components.

Nanostructures formed from silicon crystal lattices, polymer chains or DNA sequences were investigated, their regular lateral and step height features exploitable as nano-dimensional standards. Once fully approved for calibration purposes, manufacturers of test equipment for the electronics industry will be able to offer improved measurement accuracy at the nanoscale.



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