Measuring at the scale of a billionth of a millimetre

How do you know when an apparatus is accurately measuring down to the billionth of a millimetre? In a partnership between the Department of Precision and Microsystems Engineering and the Dutch Metrology Institute VSL, scientists built a new instrument to verify that. VSL has now made it possible for industry to use the invention.

Vulnerable

Your own eyes will do you little good in 'nanoland'. The strongest microscope is needed to check whether every layer has been put in exactly the right place and whether it has the right height, width, length or roughness. An atomic force microscope (AFM) can do that. It probes the surface with a sensitive tip that is only a dozen atoms thick.

But just like a scale or odometer, an AFM has to be calibrated at regular intervals. The tip can wear, and parts in the apparatus may start to respond differently as a result of age ('drift'). Because it involves such small distances, this can affect measurements. So occasionally you have to verify whether the nanometre measured by the AFM is indeed a nanometre long and not a couple of picometres shorter or longer.

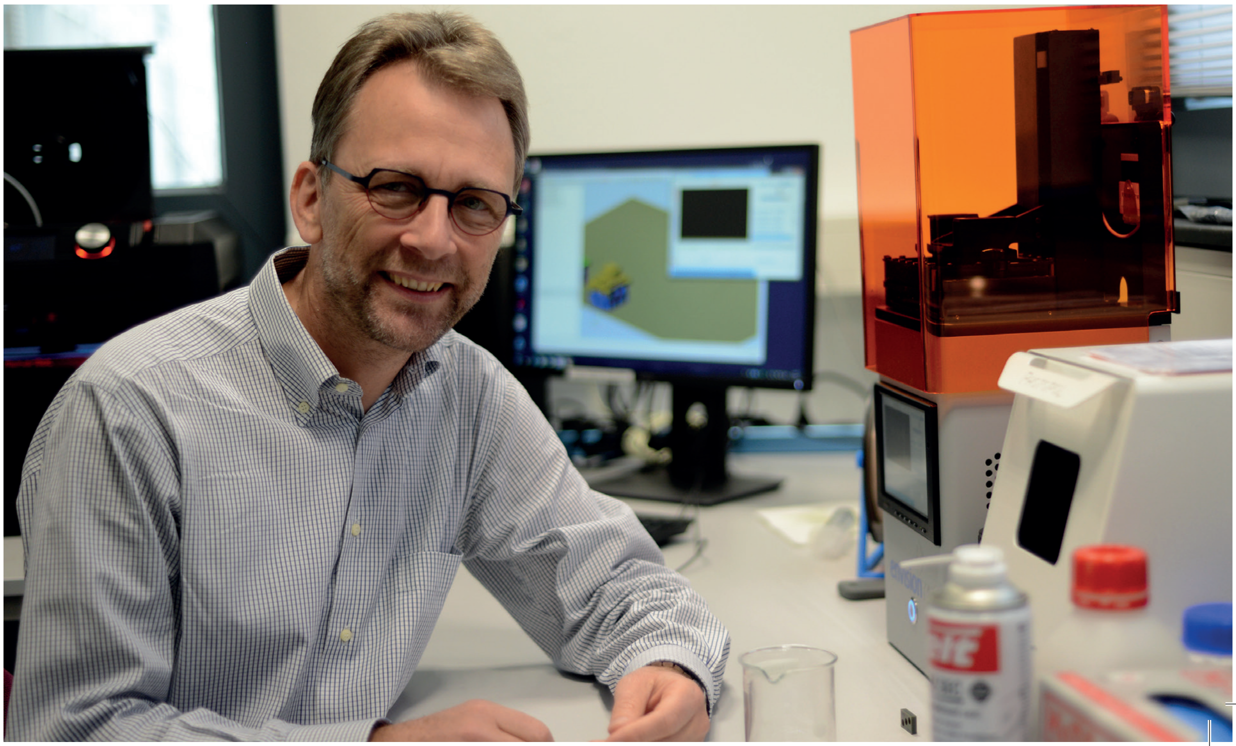
How do you do that? There is no such thing as a tape measure or a measuring stick for nanometres.

Out-of-the-box

In a partnership with TU Delft, VSL developed a solution: the 'virtual standard'. 'We use a level grating that we move very precisely vis-à-vis the AFM,' Marijn van Veghel of the Dutch metrology institute VSL says. 'The ten nanometre groove in the "classic" grating is simulated by lowering the level grating exactly ten nanometres.' This is done with the aid of a piezo – a crystal that deforms when subjected to electrical stress. We are familiar with the material's expansion properties down to the picometre, a thousandth of a nanometre. That is an out-of-the-box solution, according to Van Veghel. 'We were pleasantly surprised that it works with such precision. That was possible due to a combination of extremely precise mechatronics and the new picodrift meter, which can be used to properly calibrate this apparatus time and again. Thanks to our partnership with TU Delft we were able to further develop our findings and we can now offer them as a service to industry.'

The virtual standard is a good solution, especially

Professor Urs Staufer
u.staufer@tudelft.nl
+31 15 27 86 804



TU Delft

when companies want to analyse various thicknesses of layers or their roughness. 'The system has no trouble calibrating for distances in nanometres or hundreds of nanometres,' Van Veghel says. 'And in all dimensions.' The classical method requires multiple physical standards for that. Employing the virtual standard can be considerably less expensive. When it is not being used, it is in the VSL lab.

Picodrift

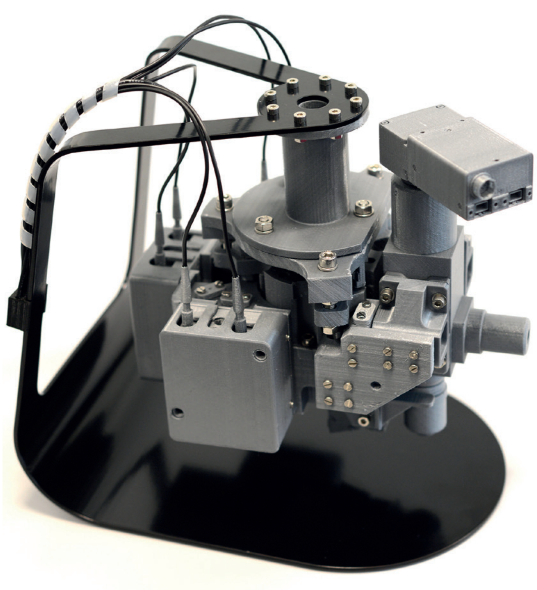
There, the standard itself can also be calibrated with the picodrift meter, another invention by TU Delft that has been further developed by VSL. The measuring device can now be used by industry to measure the long-term stability of materials, adhesive bonds and constructions. Metrologist Jo Spronck, who works at TU Delft's Department of Precision and Microsystem Engineering, coordinated the research project. 'Take an advanced telescope in a satellite, for example. It has to continue to function fifteen or preferably even forty years after being launched. But a tiny shift in one of the lenses or other components can result in a blurred image. You can use software to make some corrections from earth, but at a certain point that will dry up too.'
That means there has to be a guarantee that all parts remain extremely stable for decades. And in the world of electronics that means stable down to the nanometre. The materials themselves, and certainly the bonds between them, must not shrink, expand or shift.
How do you measure that? To solve that problem, mechanical engineer and former PhD student at TU Delft Jon Ellis came up with the picodrift meter, an apparatus that can detect movement the size of picometres, a billionth of a millimetre. Thanks to this high precision, you can now study changes that usually take years in days or weeks.
The picodrift meter is now available for Dutch industry too. 'The picodrift meter was built and is suitable for measuring picodrift,' Van Veghel says. 'But we are now using it to calibrate our virtual standard as well.' His point being that anyone struggling to measure a millionth of a millimetre could benefit from this. Indeed, VSL will be presenting the picodrift meter and the virtual AFM standards in the near future at various high-tech fairs in order to give more publicity to the new possibilities at the scale of a millionth of a millimetre.

Measuring undisturbed

More and more products are 'nano'. Computer chips, of course, but also solar cells and flexible screens owe their functioning to nanolayers. And nanoparticles can be found in cosmetics and medicines. But measuring nanostructures at regular production sites is a real challenge as a result of dust and vibrations. The European project aim4np (automated in-line metrology for nanoscale production, 2013-2016) saw TU Delft, VSL and various foreign partners join forces to develop measurement equipment that can make extremely precise measurements despite disruptions.
An advanced anti-vibration platform was built for that purpose. It ensures that the measurement instrument does not move a nanometre vis-à-vis the object that will be measured. 'The platform is not user-ready yet, but industrial partners are going to introduce parts of it onto the market next year,' says project leader Urs Staufer, professor of micro and nano engineering at Delft. 'We are also continuing to work on a new method for making accurate measurements of nano-roughness.'
The development of the above-mentioned virtual AFM standard was also part of the European aim4np-project.

Nano from lab to app

'It is great to see discoveries in nanotechnology develop into real products, says Urs Staufer. 'As a scientist, that is ultimately why you are doing it.' But that requires patience, emphasises Staufer. 'Experience shows that long-term partnerships are needed to translate excellent ideas in nanotechnology into tangible products.' That is why Delft established the Nano-Engineering Research Initiative (NERI). It is exactly this long-term partnership between universities, industry and research institutes to develop products together that is the driving force behind this initiative.



This image shows a 1:1-scale model of the actual instrument. On the right hand side, there is the white light interferometer, the three boxes to which the cables are leading are the lateral tracking sensors. The AFM is mounted at the bottom side in the center of the instrument.