



Nanostrain

Providing highly accurate measurement of strain in nanoscale systems to drive innovation



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Welcome

Welcome to the first edition of the quarterly EMRP Nanostrain project newsletter. Over the next three years and 12 issues this newsletter will provide you with everything you need to know on the latest project developments, as well as interviews with global industry leaders and a summary of upcoming global events and academic conferences on the exciting technological area of nanoscale piezoelectrics.



Project news

Scientists at the **National Physical Laboratory** have been working to correct decades of errors in the characterising of piezoelectric films using their own scanning vibrometer. Their aim is to measure the tiny sub-nanometre changes of thickness seen in these films in response to charge whilst removing the influence of bending in the substrate that supports them that has affected the accuracy of previous metrology analysis.

Their new technique described in a paper currently under development uses a scanning vibrometer that allows them to measure changes in thickness across the whole sample simultaneously. By taking a reference point the team can calculate the impact of the bending substrate, a value which is then eliminated from the overall analysis to give a more accurate measurement of the change in thickness.

"It's not the whole story," admits NPL's Dr Mark Stewart, "but it's a step forward and something of real interest to anyone working on the development or application of these films."

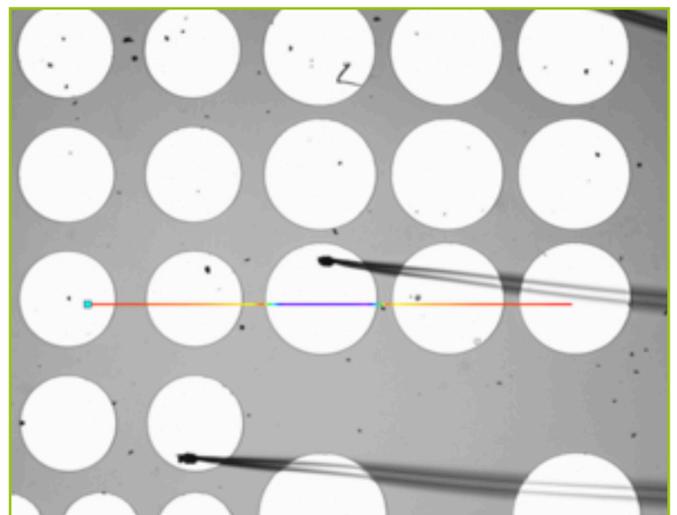


Figure 1. Vibrometer measurement of an electroded PZT film. The line shows the displacement profile across the active electrode (diameter 0.7mm) at the centre of the image, showing a maximum displacement of 30pm



Martin Hýtch from **Le Centre national de la recherche scientifique** (CNRS) is looking forward to the first use of his pioneering Dark Field Electron Holography technique to study the piezoelectric materials under investigation within the EMRP Nanostrain project.

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A vital tool for mapping strain in nanostructures, its development was rooted in Martin's previous work with electron microscopy to investigate stress induced distortion at the atomic scale that became widely used in the semiconductor industry.

Then came IBM's first strain silicon transistor which significantly boosted performance and before long everyone was using strain in transistors. "Suddenly my technique became quite important and I started to apply it to looking at transistors," says Martin.

However he soon realised that though the technique gave good results it wasn't quite what was needed in terms of mapping out the strain. It turned out the atomic level was actually too small for useful analysis.

At the time Martin was also working with electronic holography to look at magnetic materials and it occurred to him that the same technique could also be used to measure strain. After the first experiments gave positive results the technique was patented in 2007 and the accompanying paper published in Nature in 2008.

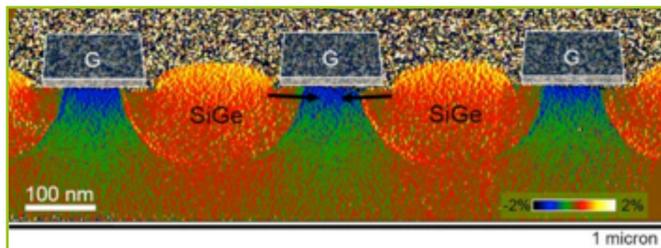


Figure 2. Strain map in the silicon devices

Since then Martin and his team have been using the technique, later named Dark field Electron Holography, with the semiconductor industry including ST microelectronics and IBM, and Martin believes it can have a major role to play in the Nanostrain project.

"With holography we can look at both electric and magnetic fields. It will be very exciting to use this to measure strain and at the same time take more traditional measurements of the electric field, all *in-situ* in the microscope," says Martin.

Upcoming events

ICONSEA 2013 (International Conference on Nanoscience)

Hyderabad, India

10-11th December 2013

SETCOR International Conference in Smart Materials and Surfaces

Bangkok, Thailand

4-6th February 2014

5th International Conference on Nanostructures

Kish Island, Iran

6-9th March 2014

Nanomaterials for industry 2014- energy, environment, products

San Diego, USA

7-9th April 2014

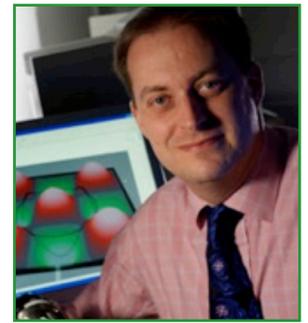
NanoLondon

London, UK

17-19th June 2014

Big Interview:

Prof Markys Cain, Science Leader, Functional Materials at the National Physical Laboratory



What are the goals of the Nanostrain project?

Fundamentally it's about accurately measuring strain at the nano-scale in piezoelectric materials. At the end of the three-year project we hope to have developed a suite of methodologies enabling the accurate and traceable measurement of strain, including various material's properties under strain, and the resulting effect on the frequency of the applied electric field, over a range of sample length scales and geometries.

If we are successful we believe these findings can support commercial attempts to overcome a decade of stagnation in semiconductor transistors performance. This plateauing has seen computational processing power fail to increase by more than a few percent since 2003. We believe there is the potential within the consortium of expertise assembled under Nanostrain to deliver a significant commercial advantage to industry, reducing time to market in this highly competitive technological area.

What do you think makes piezoelectrics the materials to overcome this decade of inertia?

Efforts to develop silicon based computer components at higher speeds have reached a ceiling. Of course there are other solutions out there. A number of companies are working on other material based computing solutions such as carbon nanotubes and graphene. However, research into the application of these more recent candidates is some way behind the more established field of Piezo technology. The fact is whilst piezoelectrics have been known about for 100 years, graphene has been known for just three.

As a result piezoelectrics benefit from a far greater foundation of scientific understanding which commercial research and development teams are starting to take advantage of with significant investment to increase their use and performance

in all sorts of electronic products. With so much market potential it seems critical that this work is underpinned by robust and traceable measurements of their fundamental properties that will determine the true effectiveness and optimum criteria for the application of these valuable materials.

What areas will the project focus on?

We have six work packages in total. These include three research based programmes that will develop links between traceable meso-scale strain metrology and crystallographic strain via in-situ interferometry and synchrotron x-ray. They will also advance techniques for ultra-high spatial resolution optical strain metrology with micro-Raman and Scanning Near Field Optical Microscopy, and extend traceable validation of macro-scale strain metrology to destructive methods such as Transmission Electron Microscopy (TEM), novel holographic TEM and Scanning Electron Microscopy. Alongside these technical streams there is also a management programme to oversee the research, a modelling package to underpin it and an impact package to communicate it, incorporating media communications, event presentations, paper publication and the newsletter you are reading.

What does the current level of metrology look like in this area?

This emerging new technology area is not currently supported by an infrastructure of traceable metrology. The expected maximum strains in thin films of piezoelectric materials are of the order of 0.1-1 %. Therefore the resolution of strain measurement required is in the range of 10-100 ppm. However, when this fractional change in length is measured on a micro or nano-scale object we find that the only currently commercially available techniques capable of performing at this level are destructive testing techniques that are not suitable for metrology in real devices.

What makes the project well positioned to tackle these issues?

Success in technological development depends on fostering innovation across a wide range of sectors, and that is something that cannot be achieved by any individual commercial organisation. Also, the infra-structural nature of the proposed work and the focus on new technologies that are still in development mean that it would not be possible to fund the research entirely from industry.

A European-wide approach ensures greater collaboration, building on existing infrastructure such as the Piezo Institute. The proposed research is highly multidisciplinary and the experts in this field are distributed throughout Europe. No national or commercial funding mechanism would be able to assemble this team, which is why this project at a European level will be both timely and highly effective.

What could these developments mean to the average consumer?

If the metrology from the Nanostrain project helps bring forward the new technologies currently in development, the average computer or laptop user could enjoy a wealth of benefits that accompany greater processing power. These include faster internet access, reduced device weight, longer battery life and lower energy consumption.

And what about commercial users?

As well as these performance improvements, for large industry users there is also the potential to make significant inroads into the carbon footprint of data farms, dramatically improving their green credentials. These farms of servers currently account for 1 % of total global energy usage. With the energy efficiency potential on offer in the coming decade from these nano-straining piezoelectric materials, the opportunity is there to cut this energy consumption by a factor of five or even more.

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Are there other industrial sectors outside computer processors which could benefit?

Absolutely. There are a number of major emerging industrial applications of these new materials including ultra-high speed and resolution printing, configurable chemical and optical sensors, and electromagnetic telecommunications devices.

The medical sector is another potential adopter moving forward and there are also studies looking at their potential use in flow sensors and cochlea implants. However in all of these examples the same major hurdle can be found around the lack of metrology capable of non-destructive measurement of nanoscale strain.

How will the work of the project benefit European industry in particular?

The European electronics sector represents 13 % of value added by total manufacturing. By working to deliver the next step change in computational electronics and processing power, the Nanostrain project will ensure the underlying intellectual property and knowledge is centred in Europe institutions.

Not only will this knowledge be kept in Europe it will also be made freely and publically available allowing the creation and application of new measurement techniques and tools that can be used as commercial entities or supporting commercial R&D by European industry.

Europe is particularly well positioned to benefit from new electronic components such as transistors and memory devices based on nano-scale functional materials due to its strong technology-driven manufacturing sector and a vibrant community of innovative companies able to develop new technologies for global markets.

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