NPL
National Physical Laboratory

Engineering *Precisely*

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Watt's Next

To aid the international effort to redefine the kilogram, NPL is taking steps to improve the performance of its watt balance.

The International System of Units (SI) is founded on seven base units; the second, the metre, the kilogram, the ampere, the kelvin, the mole, and the candela. Of these, only the kilogram is still defined in terms of an artefact (the International Prototype of the Kilogram, held at the Bureau International des Poids et Mesures (BIPM) in Sèvres near Paris). An artefact definition presents a number of metrological problems, and NPL, along with several other National Measurement Institutes (NMIs) around the world, is working towards a fundamental realisation of the kilogram.

The work at NPL involves the realisation of the kilogram via electrical units (the volt and the ampere) by balancing electrical and mechanical power using an apparatus called the watt balance. Recent improvements to the performance of the watt balance have yielded a result with an uncertainty of 70 parts per billion (ppb) and a plan is in place to reach a 20 ppb uncertainty. To redefine the kilogram a minimum of three independent realisations are required, with at least one having an uncertainty of 20 ppb or better. The National Institute of Science and Technology (NIST), the American NMI, also has a watt balance experiment which has recently produced a result with an uncertainty of 36 ppb. Unfortunately the NIST result disagrees with the NPL result by 300 ppb, much greater than the combined uncertainties of the two experiments.

Results from the International Avogadro Project only add to the controversy. This project aims to define the kilogram in terms of a fixed number of atoms of pure silicon. At present the uncertainty of this experiment is 300 ppb, but the result disagrees with the watt balance realisations by 1100 ppb! A new sample of very pure single isotope silicon will improve this uncertainty and, hopefully, the agreement with the watt balance results.

Both the NPL and NIST watt balance projects are making major strides towards the target uncertainty of 20 ppb. and it is hoped that improvements in their respective apparatus will diminish the discrepancy between these results. Watt balances are also being developed by the Swiss and French NMIs (METAS and LNE) and by the BIPM. In time these should all contribute to the redefinition.

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NPL Swing Arm Profilometer delivered to Optic Technium, Wales

Extremely Large Telescopes are required for tasks such as extra-solar planet detection, but the large, curved surfaces of their primary mirrors can be especially hard to calibrate. NPL and University College London have designed and constructed a prototype Swing Arm Profilometer for the measurement of surfaces up to 1 m diameter.

In the optics industry, calibration of spherical surfaces can be performed using traditional interferometry and low uncertainties can be achieved. However, when the surface to be measured is aspherical, techniques such as optical interferometry become much more difficult. This is especially the case when the optic to be measured is quite large. In order to start to address these problems, NPL has been involved in several collaborative projects associated with the manufacture and measurement of aspheric surfaces. Under a project that was recently completed, NPL and UCL (University College London) have been working on a prototype Swing Arm Profilometer for the measurement of surfaces up to 1 m diameter. The instrument uses the alignment principles of cup-wheel grinding, however it works not as a manufacturing tool, but rather as a precision instrument for measuring surface profile.

NPL staff and three PhD students at UCL have been busy with the design and construction of this instrument, which was completed in early summer 2007 and was then dismantled and transported to the National Centre for Ultra-Precision Surfaces at Technium OpTIC, St Asaph, Wales. The instrument now sits alongside several state of the art optics manufacturing machines including a Zeeko Ultra Precision 7 axes free abrasive polishing system, a Cranfield Ultra Precision fixed abrasive machining system and a soon-to-be-installed RAPT re-active atom plasma surface figuring system. The NPL instrument is one of the metrology tools used for measuring optical surfaces, and it can be used at various stages of the process. The collaborative work on the Swing Arm was funded by the DTI's NMS Programme on Engineering Measurement and the supply of the manufacturing equipment was made possible by a £3.526m grant from the UK Joint Research Council's Basic Technology Programme. Together, the manufacturing and metrology equipment form a unique cluster of technologies aimed at addressing the economical manufacture (and testing) of large optics, particularly aspheric optics. This next generation of optical manufacturing processing will be necessary if the UK is to take a lead role in the provision of primary optical surfaces for new Extremely Large Telescopes. These telescopes, with primary mirrors ranging from 30 m to 50 m diameter, are required for science missions such as extra-solar planet detection.

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NPL dimensional measurement training framework

The NPL framework for dimensional measurement training is now firmly established and providing significant benefit to the organisations of the first stream of candidates. NPL, in the role of certification body, develops and maintains the course content and monitors the performance of organisations such as Mitutoyo, Hexagon Metrology and Coventry University Enterprise to ensure a consistent high standard of delivery.

"The programme will enable the participants to make better manufacturing decisions and take a more consistent approach to problem solving and process capability improvements."

Dr. Hamid Mughal, Director of Manufacturing Engineering, Rolls-Royce

Good measurement supports the technical infrastructure, which leads to new and competitive products with efficient processes. However, knowing how to use a measurement tool is not the same as knowing how to use measurement as a tool. Measurement is a science to be applied with skill, not a manual.

Understanding the principles of measurement can lead to better decisions on product purchasing, a reduced need for expensive technical support and reduced operational mistakes that can have expensive consequences. A better understanding of measurement will reduce these risks to businesses.

NPL-Training brings together the measurement community into a framework, ensuring a consistent, credible measurement qualification applicable across industries.

The framework offers practical, application-based training courses supported by workshops and seminars designed to improve skills and competencies in measurement and related areas. The modular framework enables the training to be completed alongside existing work commitments.

The programme takes candidates up from the basics, revisiting foundation measurement skills and identifying how they should be used in practice. Throughout all training, the emphasis is on the practical application of relevant measurement practice and standards in the workplace.

NPL is already progressing plans to develop the syllabus to cover additional needs across industry and commerce; for Materials Characterisation, Optical, Temperature, Radiation and Electrical Measurements.

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Thermal metrology thrusts ultra-efficient jet engine forward

The production of gas turbine blades is dependent upon heat treatment, which is controlled by noble metal thermocouples. Thanks to a joint programme of research between NPL, CCPI Europe Ltd. and Bodycote Heat Treatments, the calibration of noble metal thermocouples with world-beating uncertainties is now possible at CCPI Europe.

Improvement of energy efficiency of jet aircraft is achieved by operating gas turbine engines at higher temperatures. To facilitate this, gas turbine engine manufacturers are continuously developing new alloys for hot zone turbine blades that will withstand the increased in-service temperatures. A critical part of the manufacture of these blades is heat treatment to ensure that they attain the necessary metallurgical characteristics. Turbine blades for the next generation of engines undergo heat treatment at over 1310 °C to attain these required properties. The heat treatment, which is controlled by noble metal thermocouples, is performed at Bodycote Heat Treatments (Derby). This process has exacting control requirements (±3 °C), at the limits of the lowest accredited uncertainty currently available from thermocouple manufacturers. With conventionally calibrated thermocouples, the heat treatment process is limited by available uncertainties, and additional detailed inspection is required to verify the process efficacy. Bodycote wish to attain ±1 °C temperature uncertainty in-process, but until recently this was not possible at the industrial level.

However, thanks to a joint programme of research between NPL, thermocouple manufacturer CCPI Europe Ltd. (Rotherham) and Bodycote, the calibration of noble metal thermocouples with world-beating uncertainties of better than ±1 °C is now possible at CCPI Europe. NPL has enabled this by implementing a novel high temperature fixed point into CCPI Europe's calibration chain. These novel high temperature fixed points mark a watershed in high temperature metrology and have extended the range of reference fixed points from the previous limit of 1084 °C (copper) to approximately 3200 °C. Their development has been the subject of vigorous research at NPL for the last 3-4 years.

The ideal candidate for this aerospace application is the Co-C eutectic, which melts at 1324 °C, very close to the heat treatment temperatures required. The resulting improvement in process control should yield an increase in effectiveness of the heat treatment process at Bodycote, allowing them to respond effectively to the increasingly stringent demands of engine manufacturers.

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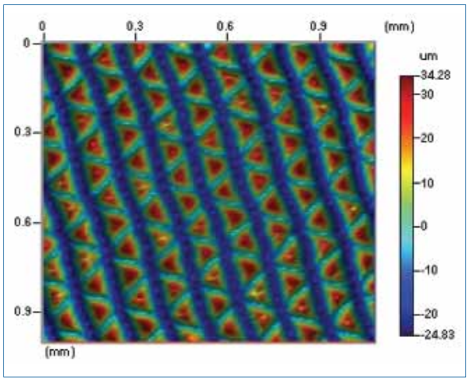
Areal surface texture is just around the corner – are you ready?

The modern trend in advanced manufacturing is to use three-dimensional surface topography to alter the functionality of products. NPL is leading the way for three-dimensional surface topography measurements with good practice guides, instrumentation and artefacts to transfer traceability of measurements to industry.

There is soon to be a step-change in the way that we measure and characterise surface texture or topography as we move from two-dimensional (also known as profile) measurements, into three-dimensional (also known as areal) measurements. Over the past one hundred years or so, engineers and scientists have been measuring surface texture to gain information on how the surface was manufactured or how it will function in use. The most popular method for many years has been the use of a stylus that physically contacts the surface. The stylus, or object being measured, is moved in a lateral direction and the surface heights are recorded as the stylus traverses the surface topography, resulting in a two-dimensional measurement. In many manufacturing operations, only a line scan using a stylus instrument (a profile) is required to hunt for changes in the manufacturing process or for parts that are not in tolerance. However, the modern trend in advanced manufacturing is to attempt to control the functionality of a part by the use of three-dimensional patterning. By patterning or functionalising a surface, its optical, thermal, mechanical, electrical, rheological and biological function, for example, can be controlled. To accurately control the three-dimensional nature of a surface requires a three-dimensional measurement.

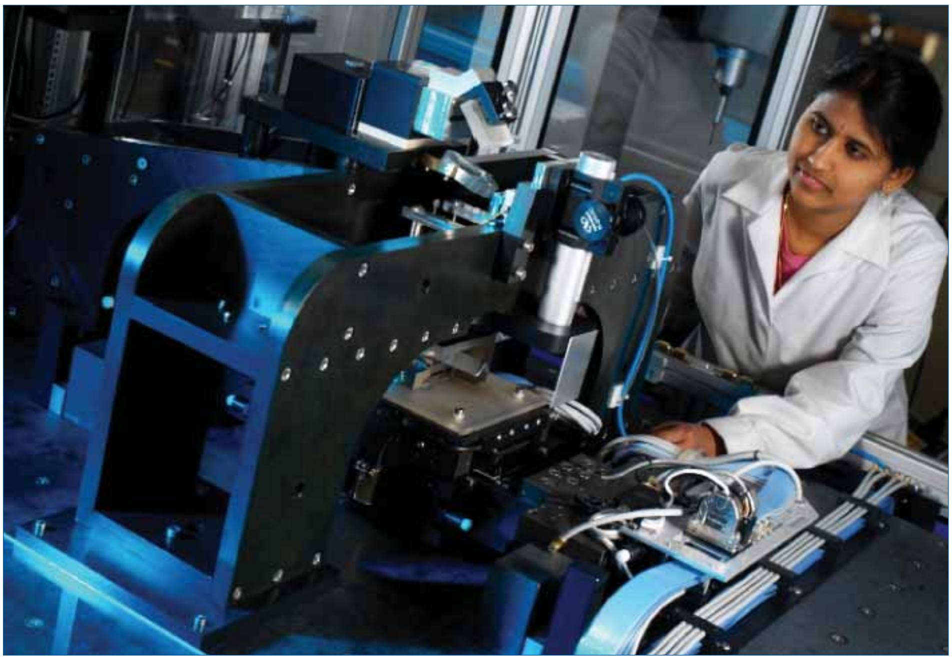
To measure three-dimensional or areal topography, a stylus can be scanned in a raster fashion to produce an area grid of measured points. However, such methods can be very time consuming and can sometimes damage the surface. Alternatively, there is also a range of non-contact optical instruments available commercially that can measure areal surface topography, which are usually based on a microscope. Optical instruments can make areal measurements very quickly, over a range dictated by the numerical aperture of the instrument. To increase the lateral measurement range a two-axis translation stage can be used, and sets of areal measurement data "stitched" together; although incurring a corresponding increase in measurement time and uncertainty.



An Areal scan of a 3M TRIZAC abrasive surface

Despite their popularity, optical instruments can sometimes give very different results to those from stylus instruments. So, which is correct? The answer is neither, and both! To truly compare the measurements from the two types of instrument one must have an exact knowledge of the bandwidth and other limitations of each instrument, and the way in which it is used. This is a rare luxury, especially with commercial instruments. For this reason it is essential that impartial good practice guidance is given on the use of all instruments. NPL has addressed this need by producing a good practice guide for stylus instruments operating in profile mode (Leach, 2001 – see below), and is looking to produce guidance on the use and limitations of some optical instruments.

Whilst a stylus instrument operating in a profile measuring mode has the support of an international standards infrastructure, the measurement of areal surface topography and the use of optical instruments are not yet covered by standards. The International Organization for Standardization's ISO 213 working group 16 is in the process of drafting a suite of standards for areal measurement and the first specification standards are expected to be published in the next two years. An important aspect of the draft standards is the new set of areal surface texture parameters that are being developed. In some cases these "S-parameters" are three-dimensional equivalents of the standardised profile



The NPL Areal Instrument

parameters (the most popular being Ra). However, the areal parameters are much more powerful than the two-dimensional parameters, in that they can be used to characterise functional aspects of a surface topography.

So, what is NPL doing to support the imminent introduction and use of areal topography? Currently there are no standardised, or widely accepted, methods for calibrating areal surface measuring instruments. Whilst the methodologies for calibrating such instruments are being developed in ISO 213, there is no primary instrumentation that can be used to transfer traceability of measurements to industry. To address this need NPL has developed a scanning stylus instrument, the NPL Areal Instrument, that can measure areal surface topography in an 8 mm x 8 mm x 0.1 mm range, with nanometres of accuracy. The instrument uses laser interferometers to measure the position of the stylus in three axes, and obtains traceability to the SI metre via the laser sources. The instrument is currently being tested before an areal surface topography measurement service is launched. NPL has also developed areal transfer artefacts that can be measured using the NPL Areal Instrument, and then used in industry and academia. Taylor Hobson has recently delivered the latest in its range of scanning white light interferometers to NPL, so that the issues of areal traceability for optical instruments can be addressed. The instrument has a lateral scanning range of 150 mm x 150 mm and a vertical resolution of less than one nanometre.

There is still some way to go before all the issues around areal measurements are resolved. Reference software needs to be developed to filter measurement data and calculate the new areal parameters, and research is required to investigate the uncertainties associated with areal measurements. All these developments put NPL are at the forefront of world research into areal surface topography measurement, and will help to stand UK industry in a firm position to reap the rewards of advanced manufacturing.

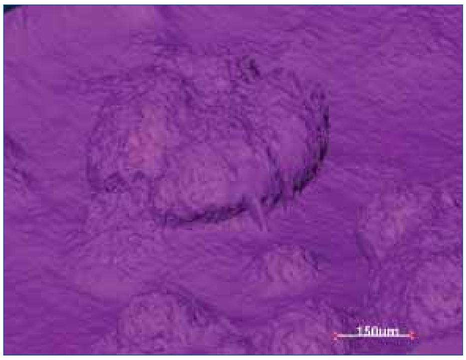
Leach R K 2001 The measurement of surface texture using stylus instruments Measurement Good Practice Guide No. 37 (available from National Physical Laboratory)

For further information, please contact Richard Leach on 020 8943 6303 or e-mail richard.leach@npl.co.uk

X-ray tomography revolution in the study of crack evolution

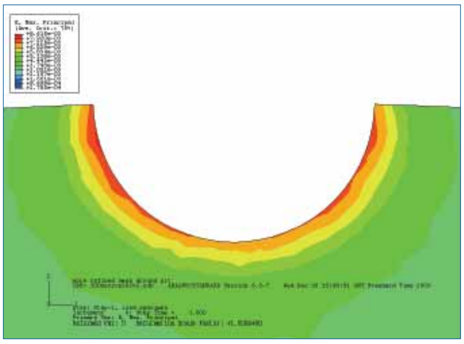
Novel X-ray-tomographic imaging of the evolution of stress corrosion cracks from corrosion pits has challenged conceptual ideas about crack evolution, and questioned the relevance of predictive models for damage development in service.

Pitting corrosion is the precursor to stress corrosion cracking in many engineering applications. A single pit of 100 µm can lead to failure, costing millions of pounds and impinging on plant safety. There has been considerable effort to understand and to model the evolution of damage in practical systems. Such models, incorporating pit initiation, pit growth, the transition from a pit to a crack, short crack growth and long crack growth leading to fracture, are continuum-based with the crack assumed to develop uniformly around the pit. However, the detail of how a stress corrosion crack actually emerges from a pitting corrosion precursor has never been clarified. In collaboration with the University of Birmingham, X-ray tomography has been used to investigate the 3-D morphology of pits and cracks in steam turbine steel exposed to simulated steam condensate at different exposure times. Transmission X-ray images were acquired over 180° of rotation of the specimen with an 11 second exposure per projection and a 0.9° rotation step, creating 200 2D transmission X-ray images in total. Tomographical reconstruction was then performed to create a 3D representation of the internal corrosion and cracking features.



X-ray tomography image of pit with incipient crack as viewed from “inside” specimen.

The unique images obtained suggest that, for stresses relevant to the service application, cracks develop predominantly at the shoulder of the pit at or below the pit-surface interface. In support of that perspective, finite element analysis of hemispherical and bullet-shaped pits (to reflect different stages of pit development) has indicated that the strain is a maximum just below the pit mouth.



Maximum principal strain of 100 µm pit in cylindrical specimen viewed in cross-section showing localisation of strain to just below the pit mouth.

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3-D MEMS motion characterisation keeps moving on

NPL has upgraded the vacuum-compatible micro-scanning vibrometer used for characterising MEMS (Micro Electro-Mechanical) devices. It now has the capability to characterise both in- and out-of-plane motion of MEMS, over a wide frequency range.

As MEMS devices become more intricate and offer greater functionality (within products ranging from inkjet printers to motion detection in games consoles), it is essential that their properties are fully understood. Laser Doppler Vibrometry (LDV) offers a non-contact method for collecting information about movement of MEMS. The vibrometer measures the Doppler shift of a moving part, relative to a stationary reference, and this is then translated into a displacement.

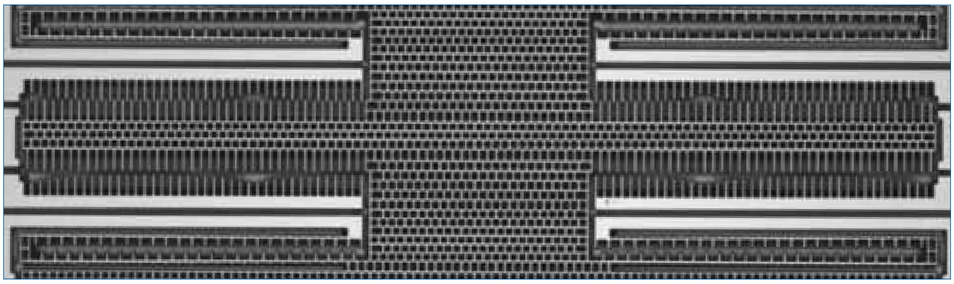
As reported previously in Engineering Precisely (Measuring MEMS motion - Issue 2, Winter 2005), by coupling a commercial vibrometer system with an environmental chamber developed at NPL, the out-of-plane displacement was measured and mapped at differing pressures, from atmospheric pressure down to 10^{-5} mbar. Now as part of CEMMNT (The Centre of Excellence in Metrology for Micro and Nano Technologies), the vibrometer has been replaced by a micro-systems analyser (Polytec MSA-400-PM2-D), providing analysis of both in- and out-of plane dynamic measurements of MEMS devices.

Out-of-plane vibrational information is gathered using conventional vibrometry. A two-beam differential fibre vibrometer allows for a measurement beam to be positioned on the moving part, with a reference beam placed on a separate region of the sample, typically a stationary substrate. In this way, unwanted vibrations of the system can be corrected for. The system can measure vibrations with a resolution < 5 pm, with a lateral resolution down to 1 µm. Vibration frequencies from near-DC up to 1.5 MHz can be measured.

The new LDV scanning system increases stability against spurious vibrations, and minimises external vibration effects, whilst it maintains excellent shielding against electrical noise. This system is able to quickly scan across the surface with mirrors to control the laser position, and to acquire a frequency range, up to 1 MHz, using a fast Fourier transform (FFT) algorithm, cutting total acquisition times from as long as several hours down to several minutes.

The micro-systems analyser uses a stroboscopic technique to obtain in-plane dynamic measurements. Several images are recorded at each frequency to generate a smooth profile of the device undergoing lateral motion. Within these measurements, NPL scientists are able to hone in on a smaller frequency range of interest - from examination of the out-of-plane vibrometry data.

The ability to produce both in- and out-of-plane displacement profiles opens up the possibility of gaining a greater understanding of how MEMS devices operate. Combining this measurement capability with the option of scanning under different environmental conditions has equipped NPL with a truly unique characterisation tool.



MEMS accelerometer, floating middle section honeycombed for reduced inertial mass. Overall image size 0.9 mm by 0.6 mm.

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For more information on MEMS and Polytec please visit www.polytec.com/mems

Photovoltaics to deliver power from the Sun that won’t cost the Earth

The cost of delivered solar generated electricity needs to be reduced by a factor of between 5 and 10 for solar power harnessed by photovoltaic cells to be competitive. NPL is developing a measurement platform to enable accelerated development of emerging photovoltaic technologies and increase the competitiveness of existing technologies.

Solar energy is available the world over, in practical terms it is inexhaustible, and is by far the largest energy source available to mankind. Photovoltaic (PV) cells are semiconductor devices used to convert light energy into electrical energy and hence a key way to tap into solar energy for energy generation. PV cells provide a carbon-neutral, sustainable form of energy generation, which is portable, free from geopolitical instability and can provide energy at the point of use – albeit at a higher cost compared to conventional means. Due to this cost electricity provided by PV cells only accounts for less than 1% of global consumption – a step change in PV technology (with respect to light capture, energy conversion and storage) is needed for it to be competitive, estimated as a reduction by a factor of 5-10 in the cost per watt of delivered solar generated electricity.

In order to meet this challenge, new materials and device architectures are being explored that could potentially hold the key to a revolution in the way that PV cells are conceived, designed, implemented, and manufactured.

NPL is developing a measurement and testing platform to support UK development, competitiveness, and exploitation of existing and emerging PV technologies. Consequently, NPL has established links with key PV academic and industrial players in the UK. In addition, NPL is supporting an EPSRC CASE award for a PhD on dye

sensitised nanocrystalline solar cells with the University of Bath to start in the next academic year.

Research at NPL is focusing on providing solutions to the crucial measurement issues that are limiting PV technology and encompass all three generations of photovoltaic materials and devices. Specifically, interest lies in studying the structure-activity link in PV systems, i.e. relating material properties from the macro- to the nano- scale with the local and bulk optical characteristics.

Techniques to be used include electron microscopies, scan probe techniques, local electrochemical techniques and spatial mapping of PV conversion efficiency as a function of specific wavelengths, incident angle and irradiance using wavelength-tuneable monochromatic radiation (which can be generated across the UV, visible and infra-red).

For more information, please contact Dr Patrick Nicholson on 020 8943 6179 or e-mail patrick.nicholson@npl.co.uk

Nanoscale Surface Analysis of Hair Fibres

NPL is developing novel techniques for the characterisation of fibres such as human hair, using surface analysis techniques to determine the impact of surface treatments found in products such as shampoo.

Within a typical bottle of shampoo there is a lengthy list of chemical ingredients, including surfactants, foaming agents, moisturisers, anti-static agents, amino acids, stabilisers and perfumes. The market for haircare products is worth a massive £1bn each year, and the technology behind them is fast changing, challenging and increasingly reliant on nano-scale surface properties.

NPL, with Unilever, Intertek Measurement Science Group and the University of Sheffield, are working together on a DTI funded Micro and Nano-Technology project to develop nano-scale analysis of microfibres, including cottons, synthetics and human hair.

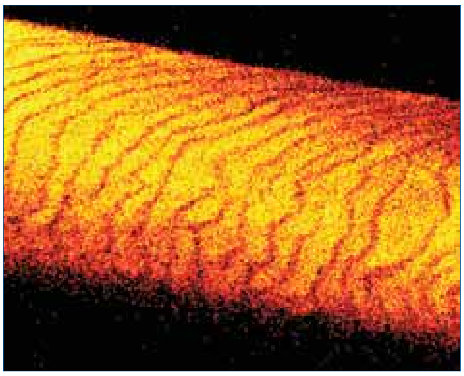
Quantitative characterisation of fibre surfaces at the nano-scale remains a massive challenge due to their extreme curvature, topography, and lack of systematic and validated measurement methods.

By developing the application and data interpretation of popular surface analysis techniques, such as atomic force microscopy (AFM), secondary ion mass spectrometry (SIMS) and x-ray photoelectron spectroscopy (XPS), NPL aims to address the enormous technical challenges confronting scientists in the formulation of innovative treatments for fibre surfaces.

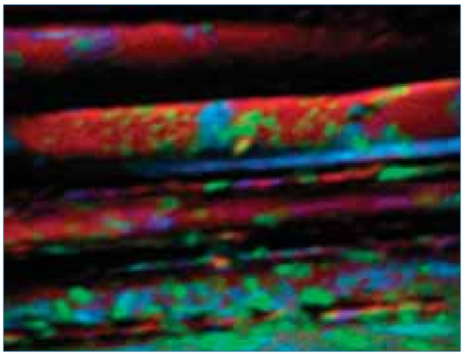
Through the development of analytical methods, NPL are able to integrate nanoscale properties with compositional information to yield novel information on the impact of surface treatments. This allows rapid understanding of the chemical mechanisms that influence product performance. For example, measurements of the adsorption behaviour of active ingredients will lead to the production of more efficient and environmentally friendly products.

Together with our partners, NPL is developing robust and powerful methods to obtain physiochemical properties of nanoscale fibre surfaces and quantitative measurements of product performance. This will lead to wider use of novel surface techniques and enable the formulation of products with improved environmental and economic benefits.

For further information, contact Joanna Lee, Nanoanalysis Group, NPL on 020 8943 6202 or e-mail joanna.lee@npl.co.uk or visit our website http://www.npl.co.uk/nanoanalysis



Above: Secondary Ion Mass Spectrometry (SIMS) image of an individual hair fibre, showing the cuticles. Below: False colour image of the distribution of three chemicals on hair fibres with a multi-component formulated treatment. Images taken by Dr Ian Fletcher (Intertek Measurement Science Group).



Laying the foundations for the next generation of Structural Health Monitoring

The first step towards creating a simple to understand Structural Health Monitoring systems is being taken by NPL – the development of industrial demonstrators for renewable energy and civil engineering structures.

There is a wide industrial need for predictive systems that can monitor structures and inform the asset holders on their state of structural health. These structures include bridges, buildings, power plants, aircraft, chemical plants and more - all of great economic importance to the UK. Even just considering bridges, a simple and clear indication of the structural health will provide substantial economic benefits since there are over 10,000 bridges worth more than £1M each in the UK alone.

This project (Enabling the Next Generation of Structural Health Monitoring: Demonstrator, Validation and Best Practice) is a first step in the measurement grand challenge of creating an SHM (Structural Health Monitoring) system as simple to understand as a traffic light system. This system could provide early warning of potential problems and be a sophisticated indicator of the structure's current lifetime. This would lead to cheaper maintenance, lower running costs and provide advanced warning of failure, leading to enhanced safety.

The purpose of this project is to accelerate the uptake of combined and multi-modal monitoring methods that support total life-cycle management of user-critical devices, structures and systems. This will be achieved by developing industrial demonstrators for renewable energy (wind turbines) and civil engineering structures (e.g. bridges, buildings). The selection of the demonstrators has been influenced by NPL's ability to cover several different material systems, including metallic, composite, and concrete. Sensor types will include full field displacement measurements provided by Digital Image Correlation (DIC) and embedded sensors such as fibre Bragg gratings and wireless sensing.

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Updating the definition of the kelvin

An updated definition of the kelvin, currently being discussed in the International Committee for Weights and Measures, will allow for improvement in the accuracy of temperature measurement.

The international measurement community, through the International Committee for Weights and Measures, is considering updating the International System of Units (SI). This update (to probably occur in 2011) will redefine the kilogram, the ampere and the kelvin in terms of fundamental physical constants. The kelvin, instead of being defined by the triple point of water, as it is currently, will be defined by assigning an exact numerical value to Boltzmann's constant. This change would generalise the definition, making it independent of any material substance, measurement technique, and temperature range, ensuring the long-term stability of the unit.

For the typical user of temperature measurements, the redefinition will pass unnoticed; 0 °C will still be the temperature at which water freezes, and thermometers calibrated before the change will continue to indicate the correct temperature. The immediate benefits of the redefinition will be to encourage the use of direct measurements of thermodynamic temperatures in parallel with the methods described in the International Temperature Scale.

In the longer term, the new definition will allow the accuracy of temperature measurements to gradually improve without the limitations associated with the manufacture and use of the triple point of water cells. For some temperature ranges, true thermodynamic methods are expected to eventually replace the International Temperature Scale as the primary standard of temperature.

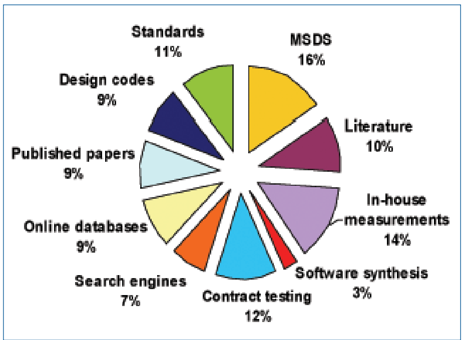
For further information, please contact Graham Machin on 020 8943 6742 or e-mail graham.machin@npl.co.uk

or visit http://www.bipm.org/wg/CCT/TG-SI/Allowed/Documents/Report_to_CIPM_2.pdf

NPL actively supporting Materials UK

Materials are essential to everything we do – in supporting our quality of life, our infrastructure and our competitiveness. The government has recently undertaken Innovation and Growth Team (IGT) reports on many industry sectors, often in conjunction with a trade body for that sector (e.g. SBAC for aerospace). The most recent IGT report was on the materials "community" and involved several NPL staff. A major recommendation was to establish a representative body – Materials UK – in the absence of a suitable trade federation (see http://www.matuk.co.uk for more details).

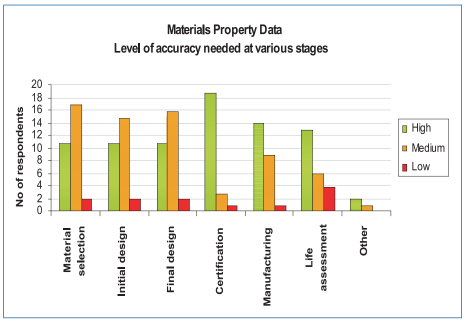
Materials UK is a partnership between industry, academia, policy stakeholders, and employee organisations, and commands a strong interest from Government Departments. It works with the materials community to deliver essential activities, such as the optimisation of the UK's R&D asset base, the provision of a validated database of materials property for designers, producers and users, and knowledge transfer to support the development of materials, manufacturing and new applications. It looks for opportunities where the community, working together, can seize global advantage for the benefit of companies operating in the UK.



Data sources used

NPL continues to be active in the work of Materials UK, for example participating in the Materials in Energy, Materials in Construction, and Science and Technology Working Groups.

NPL recently conducted a survey on design data and life cycle data needs as a precursor to an initiative on a materials property validation centre or network. Half of the respondents maintained material property databases and 70% would support availability of an on-line data facility. A wide range of data sources were being used by respondents. Approximately half of the correspondents had unsatisfied data needs. They also required data at better than 10% accuracy (medium + high), and in several cases - certification, manufacture and life prediction - better than 5% accuracy (high). Two-thirds of respondents needed data for life-cycle-analysis (LCA) within the next 5 years.



For further Information please contact Graham Sims on 020 8943 6564 or e-mail graham.sims@npl.co.uk

Expanding territory for Terahertz: security & non-destructive testing

Advances in the use of frequencies in the Terahertz part of the electromagnetic spectrum have allowed this area to flourish in the last ten years. NPL is using its terahertz knowledge and instrumentation to develop materials imaging, biological testing and security scanning.

Terahertz waves are located between mobile phone emissions and visible light. They have the ability to penetrate through materials and provide high-resolution imaging. A further feature of terahertz waves is their ability to differentiate between material types. The UK has led the terahertz field academically and following a number of successful spin-out companies, the UK is an international leader in terahertz instrumentation and applications. The most successful applications have been in the security and materials testing markets, with a number of airport personnel scanners and pharmaceutical testing instruments already in common use.

The work at NPL supports metrology standards for terahertz frequencies and also looks to develop new applications and technologies in this field. Metrology support focuses on the provision of wavelength, power and the penetration of terahertz into materials. In particular the metrology of scattering and spatial resolution at depth within materials is key to understanding multi-layer materials, and to the verification of measurements.

NPL has a comprehensive instrumentation range and knowledge in terahertz material testing, and is involved with a number of projects, including biological testing, security scanning, counterfeit identification and pharmaceutical monitoring applications. An exciting development in this sector is near-field microscopy, which focuses energy below normal limits, allowing 100 nm features to be spectroscopically measured. The technique is at the research stage, but has not only the potential to measure very small-scale material features, but also the dynamics of bio-molecular systems such as proteins. NPL is now starting a programme of work on terahertz near-field microscopy with a number of UK Universities.

For further information please contact Richard Dudley on 020 8943 7020 or e-mail richard.dudley@npl.co.uk

VAMAS embraces wider global role at 25th birthday celebration

The VAMAS G7 (Versailles Project on Advanced Materials and Standards) pre-normative organisation celebrated 25 years of existence at a special seminar at LNE (Laboratoire National d'Essais), Paris on 23rd May 2007. Countries outside of the founding members and EC are now being encouraged to join the Steering Committee.

The seminar was organised by NPL on behalf of the current USA Secretariat. LNE were responsible for local arrangements, including the Gala Dinner at the Arts and Metiers Museum. The Seminar consisted of an overview of the last 25 years by the current Secretary, Steve Freiman (NIST - National Institute of Standards and Technology), with much of the material supplied by NPL resident historian, Colin Lea, a past VAMAS chairman. Cedric Powell (NIST), the co-chairman with Martin Seah (NPL), gave a review of the very successful TWA2 (technical working area 2) on Surface Chemical Analysis, as an example of the technical work undertaken in a TWA. A forward look given by Graham Sims (NPL) included the proposed globalisation of VAMAS membership (outside G7/8 + EC) and the likely outcomes of the interactions on materials metrology with CIPM (Comité International des Poids et Mesures) and ILAC (International Laboratory Accreditation Cooperation). The significant measurement and standards challenges in the new areas of nanomaterials and biomaterials were well described by David Mendels (NPL) and Paul Tomlins (NPL), respectively.

At the annual Steering Committee (SC) meeting held concurrently, VAMAS agreed a new Memorandum of Understanding (MoU) that will allow the VAMAS SC membership to be expanded outside the founding G7 + EC membership to a wider global participation. Although participation in the technical work had been open to all countries, with 15% being outside the founding members, membership of the Steering Committee has been the same throughout the 25-year life of VAMAS.

Countries likely to join include Australia, Brazil, China, India, South Korea, Mexico and South Africa. All these countries are of increasing global economic importance, and have the scientific capability to support the VAMAS work on international pre-normalisation activities in the materials field. Representatives from NMIs (National Measurement Institutes) in most of these countries have been involved already in the CIPM ad-hoc Working Group on

metrology related to materials property measurement, being led by Seton Bennett (International Director) and Graham Sims (past VAMAS Chairman) at NPL.

For further Information please contact Graham Sims on 020 8943 6564 or e-mail graham.sims@npl.co.uk

New NMS Innovation R&D Programme

Restructuring of the National Measurement System (NMS) has brought about the creation of the Innovation R&D programme, which builds on the Measurement for Emerging Technologies (MET) programme at the end of March 2008.

In April 2007, the NMS projects funded by the former DTI (now DIUS) were rearranged into a new set of programmes, following the recommendation of the NMS Review in 2005-2006. With a simplified structure of fewer and larger programmes that group together projects with similar objectives, timescales and impacts, the programmes will be more efficient to operate and manage.

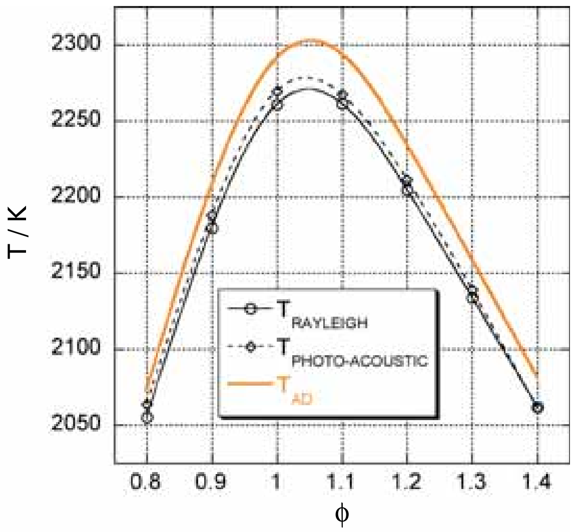
The NMS Innovation R&D programme within the NMS portfolio builds on the Measurement for Emerging Technologies programme, which comes to a close at the end of March 2008. It will have a new scope, in line with the new NMS structure, focussing on developing new measurement capabilities in the government's Technology Strategy priority areas of advanced manufacturing, information and communication technologies, healthcare, security, transport, energy and the environment.

For further information on the NMS please contact the NPL Helpline on 020 8943 6880 or e-mail enquiry@npl.co.uk

Trailblazing: Flame temperature measurement paper wins award

The 2007 Rayleigh award (presented for an NPL paper, published in a scientific journal, that demonstrates science excellence, creativity, impact, clarity and accessibility to a non-specialist scientist) has been won by Gavin Sutton and Andrew Levick for their paper "A combustion temperature and species standard for the calibration of laser diagnostic techniques." Optimising combustion temperature is extremely important to many industries. NPL can now provide a standard flame with a temperature known to an accuracy of better than 1% to aid this process.

In the Spring 2006 issue of Engineering Precisely (Issue 3), an article was published detailing the NPL project (lead by Gavin Sutton) to develop a standard flame. Making use of a standard metrological burner - well known to the combustion community, and calibrating it with Rayleigh scattering and photoacoustic thermometry techniques, the temperature of the flame was measured to an unprecedented accuracy. Rayleigh scattering thermometry measures the brightness of a scattered laser beam and if the flame composition is known, the temperature can be accurately measured. Photoacoustic thermometry measures the speed of sound in the flame, which is related to temperature.



Temperature of the portable standard flame versus equivalence ratio Φ: comparison of measurements using the Rayleigh and photoacoustic techniques. *T_{AD} is the theoretical maximum flame temperature if there were no heat loses (never achieved in practice). The two independent methods agree to better than 0.5% of temperature.*

The article (Temperature measurement of flames: the most accurate temperature measurements in the world!) highlighted future developments, including a portable standard flame. This fully portable standard flame has now been commissioned, removing a major barrier to organisations hoping to exploit this leap forward in calibration and validation.

Photograph showing the Rayleigh scattering experiment in the Standard flame – a green laser beam can be seen. The portable square burner is used.

The new portable flame (a square shaped Hencken diffusion burner) has digital flow meters for better accuracy, stand-alone computer control and is able to produce a standard flame that has a highly reproducible temperature and gas composition. By careful adjustment of the ratio of propane to air, the flame temperature can be varied from 1780 °C to 2000 °C. Temperatures measured by the Rayleigh scattering and photoacoustic techniques now agree to better than a hugely impressive 0.5% – despite the two techniques being based on different physical phenomena.

These improvements will benefit UK businesses that have technically complex, non-contact flame measurement systems, which need to be calibrated and validated - now the standard flame has the potential be transported to their facilities.

Rayleigh Award winning paper:

Gavin Sutton and Andrew Levick's award winning paper describes the implementation of Rayleigh scattering for the determination of flame temperatures with an unprecedented precision of better than 1%.

G. Sutton and A. Levick. A combustion temperature and species standard for the calibration of laser diagnostic techniques. *Combustion and Flame* 147 (2006) 39-48.

For further information contact Gavin Sutton on 020 8943 6712 or e-mail gavin.sutton@npl.co.uk

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Regional Measurement Surgery

24 January 2008, 11 am to 6 pm
Coventry Metrology Centre, Coventry University Technology Park, CV1 2TT

The ability to make consistent and reliable measurements is an intrinsic part of overcoming the challenges of operating in both engineering and manufacturing industries. It facilitates innovation and product development, supports efficient manufacturing, ensures product quality and demonstrates product specification and adherence to legislation.

Talk to the Experts

This regional surgery offers you the chance to review your measurement needs on a one-to-one basis with a member of the National Physical Laboratory team.

NPL has several DIUS funded initiatives to assist UK industry solve measurement problems. These include:

- 4 days free expert assistance
- Secondments either into or out of NPL
- Joint industry and studio research and development projects

To find out how NPL can help you get the most from better measurement practice, and to register for the regional surgery please e-mail engineering@npl.co.uk

Forthcoming events

Improving UK Competitiveness in MNT Gas Sensing
30 October 2007
NPL, Teddington
Contact: louise.dean@npl.co.uk

Large Volume Metrology Conference
6 to 7 November
Aintree Racecourse, Liverpool
http://www.lvmc.org.uk/index.shtml

EMAN / NPL @ GTMA "Make Measurement Matter" Roadshow
14 November 2007
RAF Cosford, Shropshire
Contact: leanne.gardener@npl.co.uk

EMAN: Thermal Effects on Machine Tools - an Update
21 November 2007,
University of Huddersfield, Huddersfield
Contact: leanne.gardener@npl.co.uk

Joint Time and Frequency Club Meeting
27 November 2007
NPL, Teddington
Contact: npl_clubs@npl.co.uk

UKAS Electrical Day @ NPL
28 November 2007
NPL, Teddington
http://www.npl.co.uk/electromagnetic/clubs/

EM Day 2007
29 November 2007
NPL, Teddington
http://www.npl.co.uk/electromagnetic/clubs/

Regional Measurement Surgery
24 January 2008, 11 am to 6 pm
Coventry Metrology Centre, Coventry University Technology Park
Contact: engineering@npl.co.uk

CEM 2008 - Seventh International Conference on Computation in Electromagnetics
7 to 10 April 2008
Quality Hotel, Brighton
http://conferences.theiet.org/cem

For information on Engineering Precisely, event details and contacts visit the website: www.npl.co.uk

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