In association with Queen Mary University of London and NanoForce Ltd

Anton Paar

Queen Mary University of London

NANOforce

# Instrumented Indentation Short Course

## Dates: 15-17 April 2015

Location: NanoForce Technologies Ltd,
Queen Mary University of London,
Mile End Campus, London E1 4NS

**Limited to 12 participants**

# COURSE SUMMARY

Practical indentation testing of materials to measure their mechanical properties has been in common use for over 100 years. Over that time there have been many developments, the most recent being the use of Instrumented Indentation, where load and depth are simultaneously monitored during indentation in order to exploit the resultant curve and calculate mechanical properties. Instrumented indentation has superseded many conventional indentation techniques (Vickers, Rockwell, Knoop, etc..) owing to its ease of use and better accuracy at low depths where conventional techniques would be either impossible to use or would produce large inaccuracies.

Many current engineers and researchers were schooled in the art of conventional indentation testing and perhaps lack the knowledge and experience required for instrumented indentation. In many current industrial applications, e.g., the automotive industry, an engineer is faced with measuring the mechanical properties of a 3 µm thick diamond-like carbon (DLC) coating on a steel component but he/she only learnt about Rockwell indentation at college, a method which is completely unsuited for such an application.

The traditionally trained engineer tends to treat mechanical properties as a “textbook value” where he/she assumes that the property, e.g., hardness, is the same throughout the material. This course sets out to shatter this myth and show by practical experimentation that most surface mechanical properties can vary greatly, especially close to the surface where they may have been influenced by machining, heat treatment, chemical exposure, or oxidation.

This course is therefore focused on providing the “bridge” from conventional techniques to the current state-of-the-art. It is designed to introduce instrumented indentation as a logical extension to traditional techniques and it combines theory with practical experimentation.

The course will include both theoretical and practical instruction from two leading experts from academia and an instrument manufacturer (Anton Paar). Understanding of the underlying principles and practical measurement issues will be presented.

The two and half day schedule includes a minimum of two and a half hours of practical hands-on training using two commercially available nanoindenters where the attendees are split into two groups of 6 and a range of experiments are designed and executed with group input encouraged.

# LEARNING OBJECTIVES

- Understand the basics of instrumented indentation testing and its use in relationship to conventional indentation techniques.
- Ability to design and perform indentation experiments which are suited to the sample material and its surface characteristics.
- Recognize unusual material behaviors and understand how to adapt experimental parameters.
- Interpret indentation data in order to extract meaningful and valid values of mechanical properties with a high level of confidence.
- Identify potential measurement artefacts and adapt test parameters accordingly.
- Understand measurement uncertainties and how to minimize them.
- Appreciate the variation of surface mechanical properties as a function of depth or spatial distribution and understand how to focus on specific layers, phases or inclusions in a heterogeneous material.
- Be able to interpret relevant applications and case studies, such as: common coating-substrate combinations, multiphase materials, composites, surface-modified layers, and Micro Electro Mechanical Systems (MEMS) devices.
- Recognize currently applicable industrial standards and be able to adapt such test methodologies to own specific application.

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# WHO SHOULD ATTEND?

This course is intended for current nanoindentation users who want to gain the experience and knowledge required to extract useful data from challenging sample materials. It is also intended for users of conventional indentation methods (Vickers, Rockwell, Knoop, etc..) who are thinking of adding instrumented indentation to their portfolio of practical test techniques.

The course could also be very useful to current nanoindentation users who have some prior experience but have encountered practical problems related to test parameters, sample preparation or data interpretation.

The content of the course is as equally applicable to research personnel developing specifically-adapted indentation methodologies, as to industrial test engineers who need to integrate such techniques into their internal Quality Control (QC) programme.

# COURSE OUTLINE

**Introduction**
Course overview, Introduction to Indentation, Basic Indentation Theory

**Basic Experimental**
Selection of Test Parameters, Conception of Basic Experiments, Data Interpretation (Basic), Practical experimentation of Creep and Fatigue Properties

**Advanced Experimental**
Unusual Behaviours (Cracking, Phase Transformations, etc.), Potential Pitfalls, Strategies for different materials (thin films, time dependent materials, etc.), Data Interpretation (Advanced)

**Research Methods**
Mapping of properties across surfaces, Testing in liquids, High Temperature Testing, Evaluating properties of Micro Electro Mechanical Devices (MEMS) such as accelerometers, beams, microswitches, etc.

**Applications of Instrumented Indentation**
Specific strategies for testing metals, polymers and ceramics, Measurement of soft materials, Advanced experiments on multiphase materials (metals and composites)

**Comparison of Techniques**
Differences between methodologies (e.g., Vickers vs. Martens hardness), Variations in analysis of the load-depth curve, Alternative ways of calculating properties (e.g., work of indentation)

**Overview of Industrial Standards**
Practical ways to implement ISO 14577 in the research lab as well as on the production floor

**Testing of Coatings**
Introduction to testing of coatings, Advanced testing of coatings, Practical experiments on different coating-substrate combinations, Data interpretation

# INSTRUCTORS

**Dr. Andy Bushby** is Reader (Associate Professor) in Materials Science at Queen Mary University of London. Both his BSc and PhD were obtained at Queen Mary where he specialized in mechanical characterization of materials ranging from fracture mechanics of brittle matrix composites to high temperature fatigue and creep in ceramics. As a Post-doctoral Research Fellow at the University of Sydney in 1993 he was introduced to the (then new) technique of nanoindentation, working on calibration of spherical indenter tip shapes and plasticity in ceramics. Returning to Queen Mary in 1995 he established the nanomechanics laboratory at Queen Mary as one of the leading facilities in the UK, contributing to international nanoindentation programs such as FASTE and INDICOAT and more recently MeProVisc. As a member of ISO working groups he developed ISO 14577 part 4 for measurement of coatings and ISO 29381 for determination of tensile test parameters from indentation.

As a leading academic in micro-mechanical testing Dr. Bushby has taught nanoindentation at Masters level for the past 15 years and supervised over 20 PhD students. He has published more than 50 scientific papers on nanoindentation and is particularly well-known for applications of spherical indenter tip geometry, test methods and calibration techniques and for his work on plasticity size effects. He has investigated a diverse range of materials systems from polymers and hydrated solids, to bones and teeth, functional ceramics and peizoelectric thin films, to irradiated materials for nuclear fusion reactors. He has given over 20 invited talks at international conferences such as the Materials Research Society ICMCTF, TMS, and Gordon Research Conferences and has previously organized 7 international nanoindentation workshops or conferences. He has been elected chair of the 2018 Gordon Research Conference on ‘Thin film and small scale mechanical behavior’.

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**Dr. Nicholas Randall** is a Chartered Engineer (CEng MIM) and holds a B.Sc. in Materials Science from Brunel University (London, UK) 1994 and a Ph.D. from Neuchatel University (Neuchatel, Switzerland) 1997. His PhD Thesis entitled, "Development & Application of a Multi-functional Nanotribological Tool" consisted of developing the first combined system for nano-indentation and Scanning Force Microscopy (SFM). This system has now been commercially available since 1997.

From 1997 to 2002 he served as the Customer Services Manager with CSM Instruments in Switzerland. He was responsible for after-sales service, technical documentation, installations, training, and contract testing laboratory service. From 2002 to 2014, he was the Vice-President of Business Development at CSM Instruments and was responsible for setting-up the US subsidiary of CSM Instruments in Boston, MA. This office provides sales, support and contract testing for North America, Canada and Mexico. He is currently Lead Scientist and Head of Business Development with Anton Paar Tritec, following the acquisition of CSM Instruments by Anton Paar in 2013.

Dr. Randall has published extensively in the field of surface mechanical properties testing, especially related to scratch (adhesion) testing, nanoindentation and tribology testing. He is chairman of ASTM committee G02.40, responsible for developing tribological test standards for non-abrasive wear. He has recently written a chapter on tribological testing of biomaterials for the ASM Handbook on Biomaterials Testing and a chapter on Experimental Methods in Tribology for the Springer book Tribology for Scientists and Engineers.

He is a member of MRS, ASM, ASTM, STLE and The Institute of Materials (UK). He is a regular reviewer for Surface & Coatings Technology, Thin Solid Films, Wear, Tribology International, Materials Chemistry & Physics, Materials Letters and Journal of Materials Research. He is a member of the Editorial Committees of Surface & Coatings Technology and Industrial Lubrication and Tribology. He also runs a biannual course on Reliability and Test of MEMS and Microsystems as part of FSRM (Swiss Federation for Research in Microtechnology). In addition, he lectures annually at the University of Cambridge Tribology Course and the MIT Professional Education Course on Tribology.

# COURSE LOCATION AND SCHEDULE

**The course will take place at NanoForce Technology Ltd:**

Nanoforce Technology Ltd
Queen Mary, University of London
Joseph Priestley Building
Mile End Road
London E1 4NS
+44 (0) 207 882 2773
info@nanoforce.co.uk
www.nanoforce.co.uk

The class runs from
1.30pm – 5.30pm on Wed,
9.00am – 5.30pm on Thursday and
9.00am – 3.30pm on Friday.

**Registration is 11.30am – 12.30pm on the Wednesday.**

The course dinner will take place on the Thursday evening in the Morgan Arms pub in Mile End (www.morganarmsbow.com)

**Course Registration**

The course tuition cost is £1500 plus VAT

The course fee includes lunches on all three days, coffee breaks and the course dinner.

The course enrollment is limited to 12 attendees in order to give adequate „hands-on" experience. It is highly recommended that you apply at least 6-8 weeks before the start date to guarantee a spot. After that date, or if course capacity has been reached, you may be placed on a waiting list and/or recommended for a subsequent course. If minimum enrollment is not met the course may be cancelled up to 4 weeks before the start date.

Accomodation may be available on the QMUL campus. Please contact the administrator for more details.

**Registration can be done online through the course website:** http://www.nanoforce.co.uk/instrumented-indentation-course-0415.html

**Course Administrator**
Sanam Ghaffari
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## Cancellations

Bookings cancelled less than 7 working days prior to the course will be charged in full. Substitutions may be made in specific cases.

We reserve the right to modify the content and/or programme of the course up to the day of the event.

In exceptional circumstances, it may be necessary to cancel or rearrange an event at short notice. Anton Paar, QMUL and NanoForce can accept no liability for loss caused by cancellation or rearrangement. Its liability is limited to refund of the registration fee if the event is cancelled.

## Course Accreditation

This event has been approved for Professional Development by the Institute of Materials, Minerals and Mining.

IOM3 PD APPROVED

The Institute of Materials, Minerals and Mining

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