NANOMECHANICS, INC

KE CHIEH Tech Limited Company

And

National Center for Research on Earthquake Engineering

2017 International Nanomechanical Science and Technology Forum, Taipei

Time	March 13, 2017	Speaker	Chair
1230-1300	Registration		
1300-1310	Opening Ceremony	Prof. Chun-Shan David Chen	Dr. Yujie Meng
1310-1330	Nanomechanics: Unbridled Innovation	Dr. Yujie Meng	
1330-1415	Measurement of Power Law Creep Parameters by Nanoindentation (Webinar)	Prof. George M. Pharr	
1415-1500	Characterization of Mechanical Properties of Zr-Ti-Cu-Nd Metallic Glass Ribbons Using Nanoindentation	Prof. Chun-Hway Hsueh	
1500-1515	Coffee Break		
1515-1600	Recent Advances in Materials Characterization Using Instrumented Indentation Tests.	Prof. Warren C. Oliver	Prof. Chun-Shan David Chen
1600-1645	Atomistic Study and Theoretical Model for Nanoindentation Size Effects	Prof.: Chuin-Shan, David, Chen	
1645-1730	Dynamic Nanoindentation: State of the Art Experimental Methods(Webinar)	Prof. Erik G. Herbert	
1730	Closing Ceremony		

NCREE Room.101, No. 200, Sec. 3, HsinHai Rd., Taipei 106, Taiwan(R.O.C)

Nanomechanics: Unbridled Innovation

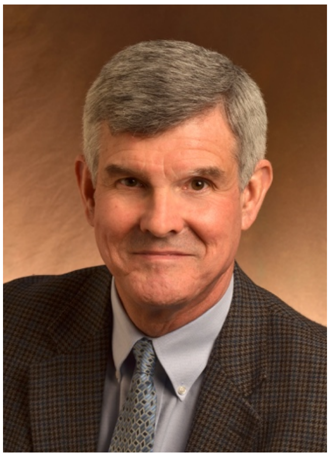
In this presentation, I will give a brief introduction of Nanomechanics, Inc., a high technology instrument company that is comprised of world- class scientists and engineers with unparalleled expertise in materials science, precision mechanical design and advanced instrumentation software. How our products, key technologies, and technical expertise could benefit your research will be discussed. In addition, a wide range of applications will be introduced.

Dr.Yujie Meng is the Business Development Manager, Asia at Nanomechanics, Inc. She enrolled in College of Materials Sciences and Technology at Nanjing Forestry University, Jiangsu, China in 2003 and obtained her BS in 2007. She moved to the States and joined Center for Renewable Carbon at University of Tennessee to pursue her M.S. degree in 2008. She worked on nanoindentation characterization on soft material and polymer composite interphase projects using various techniques (nano DMA, modulus mapping, testing at elevated temperature, testing in liquid and micro compression testing etc.). She continued her education by obtained a Ph.D. in Natural Resources with a concentration in Bio-based Products and Wood Science & Technology and a dual MS in Statistics from University of Tennessee in 2015. During the pursue of her PhD, she visited Oak Ridge National Laboratory and worked as research assistant in Material Science and Technology Division from 2013 to 2015, where she was involved in the carbon nanostructure and nanoporous carbons research.

Yujie has research experience on multi-materials including fiber-reinforced polymer composites, lignocellulose material, nano reinforced adhesive, bio nanocomposites, aerogel, bio-based carbon material and biomass-based films. She has authored or co-authored more than 20 journal publications. She also has extensive hands-on experiences on small scale mechanical characterization (Nanoindentation, AFM etc.) She is a member of Forest Products Society and Society of Wood Science & Technology.

Measurement of Power Law Creep Parameters by Nanoindentation

Over the past decade, great progress has been made in making small-scale mechanical property measurements by nanoindentation at elevated temperatures; in fact, several systems for doing so are now commercially available. The advances have paved the way for studying and measuring the material parameters that describe power law creep behavior, e.g., the stress exponent for creep, n, and the activation energy for creep, qc, using small-scale experiments. Making such measurements with nanoindentation provides for high point-to-point spatial mapping as well as the characterization of thin films and thin surface layers. However, serious experimental difficulties are often encountered, particularly those associated with thermal drift, and how one converts the data obtained in nanoindentation testing to the parameters used to characterize uniaxial creep is not at all straightforward. In this presentation, we discuss recent progress in making meaningful measurements of power law creep parameters by nanoindentation. Special attention is given to the models and data analysis procedures needed to convert nanoindentation load-displacement-time data to the parameters normally measured in uniaxial tension or compression testing.



George M. Pharr is TEES Distinguished Research Professor in the Department of Materials Science and at Texas A&M University, College Station, TX. He received his BS in Mechanical Engineering at Rice University in 1975 and Ph.D. in Materials Science and Engineering from Stanford in 1979. After one year of postdoctoral study at the University of Cambridge, England, he returned to Rice in 1980 as a faculty member in the Department of Mechanical Engineering and Materials Science. He moved to the Department of Materials Science and Engineering at the University of Tennessee (UT) in 1998, where he served he as Chancellor's Professor and McKamey Professor of Engineering. While at UT, he also held a Joint Faculty Appointment at the Oak Ridge National Laboratory (ORNL), was Head of the UT Materials Science and Engineering Department during the period 2006-2011, and served as the Director of the UT/ORNL *Joint Institute for Advanced Materials* from 2009 to 2016. He moved to his current position at Texas A&M in January 2017.

Dr. Pharr received ASM International's *Bradley Stoughton Award for Young Teachers of Metallurgy* in 1985. His honors also include the Amoco Award for Superior Teaching at Rice University in 1994, a *Humboldt Senior Scientist Award* in 2007, the Materials Research Society's inaugural *Innovation in Materials Characterization Award* in 2010, and the University of Tennessee *Macebearer Award* in 2015. He is a member of the National Academy of Engineering (2014) and a Fellow of ASM International (1995), the Materials Research Society (2012), and TMS (2016). Dr. Pharr has been an Associate Editor of the *Journal of the American Ceramic Society* since 1990 and Principal Editor of the *Journal of Materials Research* since 2012. He is an author or co-author of more than 200 scientific publications, including 4 book chapters. His research focuses on mechanisms of plasticity and fracture in solids, especially at small scales.

Characterization of Mechanical Properties of Zr-Ti-Cu-Nd Metallic Glass Ribbons Using Nanoindentation

The mechanical properties of Zr-Ti-Cu-Nd metallic glass ribbons were analyzed using both the nanoindenter and the picoindenter in the present study. Different amounts of Nd were doped in Zr-Ti-Cu to fabricate Zr-Ti-Cu-Nd metallic glass ribbons using melt-spinning and both the microstructure and mechanical properties were examined. Because of the different mixing enthalpies between elements, liquid-phase-separation occurs during the cooling process. While Nd separated from Zr and Ti, it precipitated with Cu. This was verified using energy-dispersive X-ray spectroscopy. Also, the cooling rate varied through the thickness of the ribbon during melt-spinning which, in turn, would result in different microstructures. While the ribbon was fully amorphous on the roller side, it had fine and coarse precipitates, respectively, on the surface side and in the middle thickness of the ribbon. Using modulus mapping (Hysitron TI 950 TriboIndenter), the matrix showed the higher storage modulus than the precipitates while the precipitates had the higher loss modulus. The micro-pillar compression tests performed by picoindenter (Hysitron PI 85 SEM PicoIndenter) showed the enhanced ductility of the metallic glass ribbon with Nd doping, and the micrographs showed abundant shear bands and shear-cutting of precipitates by the shear band after compression.

Chun-Hway Hsueh is a Distinguished Professor in the Department of Materials Science and Engineering, National Taiwan University. He received his BS in Physics from National Taiwan University in 1976, his MS in Materials Science and Engineering from National Tsing Hua University in 1978, and his PhD degree in Materials Science and Engineering from University of California, Berkeley in 1981. Before joining National Taiwan University in 2010 as a Distinguished Professor, he was a Distinguished R&D Staff at Oak Ridge National Laboratory. Professor Hsueh's area of expertise is to develop analytical models and to derive closed-form solutions to describe the thermomechanical properties and performance of materials as functions of the essential parameters. This would provide guidelines for materials design. He has authored or coauthored more than 230 scientific journal papers. He was listed as an ISI highly cited researcher in Materials Science. Since joining National Taiwan University, his research has been extended from theoretical to applied work. His current research work includes metallic glasses, shape memory alloys, nanoindentation, surface-enhanced Raman scattering, and plasmonics nanodevices. Professor Hsueh is a Fellow of the American Society for Metals (ASM), the American Ceramic Society (ACerS), and the World Innovation Foundation (WIF). Currently, he serves as Associate Editor of seven international journals.

Recent Advances in Materials Characterization Using Instrumented Indentation Tests

Three new instrumented indentation testing techniques will be discussed. They include high temperature, high strain rate and two dimensional testing.

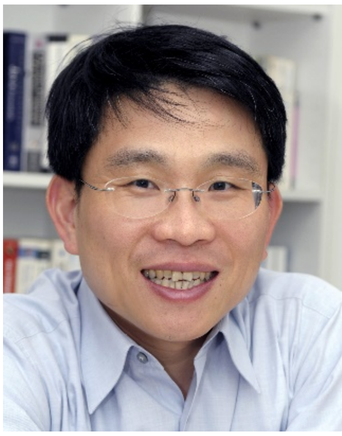
Instrumented indentation testing provides unique opportunities to study strain rate effects on the strength materials. In situ high temperature indentation testing to measure the relationships between temperature, strain rate and strength has received considerable interest in recent times. In this regard, data from in situ dynamic nanoindentation testing up to 550 C on commercial purity aluminum will be presented and compared to the values from literature. The same concepts can be applied to measure properties at high strain rates. High strain rate indentation testing results will be presented and compared to macroscopic literature results.

Finally, the first results from a new system which retains the high performance measurement capabilities in the direction normal to the surface of the sample and adds the equivalent signals parallel to the surface will be presented. The same sensitivity, range and dynamic performance (including frequency specific experiments) are available simultaneously and continuously in both directions. The ability to measure not only load and displacement but stiffness and phase angle at specific frequencies parallel to the surface continuously and simultaneously with THESE SAME MEASUREMENTS in the normal direction has resulted in entirely new results concerning the onset of sliding between two bodies in contact. Unique new data concerning the initiation of slip at micro asperities, friction and wear, lubrication, scanning surface topology, mechanical property mapping and multidimensional characterization of structures can now be investigated.

Warren C. Oliver obtained his BS in Materials Science from the University of Tennessee in 1976, and his MS and PhD in Materials Science in 1981 from Stanford University, studying with Professor W.D. Nix. Dr. Oliver spent one year on a postdoctoral appointment at Brown, Boveri and Co., Ltd. followed by two years (1982-1984) at the United Technologies Research Center. He then returned to Tennessee for a position at Oak Ridge National Laboratory for ten years until 1994 at which time he left to spend full time directing Nano Instruments, a company he helped to found in 1984. In 1998, Nano Instruments was acquired by MTS Corporation, and in 2008, the group was acquired by Agilent Technologies. During the course of his research career, Dr. Oliver has made notable contributions to the area of intermetallic alloy development and the mechanical characterization of materials and structures on the micro and nano scale. In particular, he has contributed to the development and commercialization of nanoindentation equipment and techniques.

Atomistic Study and Theoretical Model for Nanoindentation Size Effects

Indentation experiments are the commonly used method to probe the strength of materials at the nanoscale. When indentation depth decreases to micro meters, the hardness increases as the indentation depth decreases. This is known as the indentation size effect. A seminal theoretical model by Nix and Gao has successfully to explain the indentation size effect in microindentation. However, it significantly overestimates the hardness in nanoindentation. In this study, atomistic simulations and a theoretical model are presented to predict and characterize indentation size effects at the nanoscale. Atomistic simulations with spherical indenters are conducted. A method is developed to calculate the dislocation density directly from atomistic simulation. We found that the theoretical model by Nix and Gao underestimates the geometrically necessary dislocation density. However, the model by Nix and Gao can accurately predict the hardness size effects in nanoindentation if it uses the geometrically necessary dislocation density directly calculated from the atomistic simulation. Inspired by the results of atomistic simulations, we construct a new gradient-based theoretical model taken into account of surface effects to predict indentation size effects at the nanoscale. Size-dependent hardness properties predicted from the theoretical model compare well with those obtained directly from atomistic simulations. The theoretical model reduces to the model by Nix and Gao when the scale increases to micro meters.



Prof. Chuin-Shan (David) Chen received his B.S. degree from National Taiwan University, Taiwan, and M.S. from Cornell University under the supervision of Profs. W. McGuire and G. G. Deierlein and Ph.D. under the supervision of Prof. Anthony R. Ingraffea. He worked as a research associate at the Cornell Theory Center under the supervision of Prof. James P. Sethna (Physics Department, Cornell University) before he joined National Taiwan University. He is now Professor of Department of Civil Engineering, National Taiwan University. His research interests are associated with mechanics and physics of materials at the nanometer and micrometer scales. He has made significant contributions on the area of multiscale computational methods and their applications to nanomechanics, materials modeling and biosensor simulation. Prof. Chen is a Fellow of International Association for Computational Mechanics (IACM), a General Council Member of Asia-Pacific Association for Computational Mechanics (APACM) and an Executive Council Member of the International Chinese Association for Computational Mechanics (ICACM). He is one of the Editors-in-Chief of Interaction and Multiscale Mechanics, An International Journal (IMMIJ), and has received numerous awards, including International Association for Computational Mechanics (IACM) Fellow Award, International Chinese Association for Computational Mechanics (ICACM) Computational Mechanics Award, National Taiwan University Distinguished Teaching Award, National Science Council Distinguished Young Investigator Award, Distinguished Young Scholar from Society of Theoretical and Applied Mechanics, among others.

Dynamic Nanoindentation: State of the Art Experimental Methods

The viscoelastic functions and depth dependent mechanical properties measured by dynamic nanoindentation are coupled in complex ways to the measurement system's time constants, phase shifts created by the instrument's electronics, the actuator's dynamics, the instrument's load frame stiffness and requisite modeling assumptions. The ways in which these factors potentially affect measured parameters will be discussed in the context of experiments performed in both the time and frequency domains. Highlights of the transformation from time to frequency will be presented to clearly illustrate the technique's ability to reliably characterize linear viscoelasticity. Observations of depth dependence in the phase angle of 10 m diameter polyethylene fibers will be used to illustrate the critical and often overlooked role of the actuator dynamics. Finally, pure lithium films will be used to elucidate fundamental assumptions of the dynamic technique, identify important limitations and illustrate the amazing utility of the Hay-Crawford thin film model.1 Through this framework, the seminar provides direct insight into the development of state-of-the-art dynamic nanoindentation methods, examines potential experimental pitfalls and directly addresses the key criteria required to generate data consistent with the techniques requisite modeling assumptions.

Dr. Erik G. Herbert is an Assistant Professor in Materials Science & Engineering (MSE) at Michigan Technological University (MTU). He has worked directly in the field of small-scale mechanical characterization and nanoindentation for the past 20 years. His MS and PhD degrees, both in MSE, were earned in 2006 & 2008, respectively, at the University of Tennessee (UT) under the guidance of Drs. George M. Pharr and Warren C. Oliver, both of whom are international pioneers and visionaries in the field of small-scale mechanical characterization. Dr. Herbert currently has 33 publications, 1400+ citations and holds 1 US patent. Prior joining MTU in 2015, Dr. Herbert spent 4 years as a Research Assistant Professor in MSE at UT and Oak Ridge National Laboratory, 1 year as a post-doctoral researcher at UT and a visiting scientist at the Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN) at Trinity College in Dublin, Ireland, and 12 years working in industry at Nano Instruments Inc., which eventually became part of the MTS Systems Corporation in 1998 and then Agilent Technologies in 2008. Dr. Herbert's expertise includes state-of-the-art ambient, non-ambient, in-operando and in-situ mechanical testing of materials at nanometer and micrometer length scales. He is a member of the Materials Research Society, the Society of Experimental Mechanics and a Principal Editor for the Journal of Materials Research.