



Preface – Virtual special issue on nanomechanical testing in materials research and development

The Editors and Guest Editor at *Materials & Design* are pleased to present the Virtual Special Issue (VSI) on *Nanomechanical Testing in Materials Research and Development*.

Nano- and micromechanical testing has become an established field that continues to develop apace, making a strong contribution to materials research and development. A key breakthrough in the field has been the development of nanoindentation, also called instrumented indentation testing, which enables precise control and monitoring of forces and/or displacements at the nanoscale. Besides indentation, the nano- and micromechanical methods in use presently include compression, tension and bending tests, thin film testing methods, different *in situ* testing techniques as for example micro-bending experiments, combined with diffraction methods using electrons (EBSD), or micro-beam X-rays. Moreover, fatigue loading and fracture mechanical experiments are performed at small length scales to study the deformation processes and determine the local mechanical properties. These nano- and micromechanical testing techniques open the way to the development of new design concepts for novel engineered materials systems based on their fine scale mechanical properties.

The samples for these test methods are prepared by various techniques, ranging from focused ion beam (FIB) milling to lithography, etching of thin films, femtosecond laser processing, or growth of micro/nano-objects (whiskers, rods, spheres, etc.). Recently, these preparation methods were reported to attain the theoretical strength of nanowires, opening the way to fabricate samples to investigate unprecedented stress states in metals or semi-conductors. Further new developments are being reported in achieving local testing at high strain rates and elevated as well as low temperatures.

This virtual special issue (VSI) represents a snapshot of the state-of-the-art in the field of nanomechanical testing, built around and including some of the presentations made at the 2017 Nanomechanical Testing in Materials Research and Development VI meeting in Dubrovnik, Croatia (Fig. 1). In the meeting, 127 participants enjoyed the opportunity to exchange information in 10 oral and 2 poster sessions regarding the latest developments and research advances in the field of nanomechanics of materials. In numerous *ad hoc* discussions, new contacts were made and old collaborations fostered to explore new research avenues and exciting possibilities. Special attention was paid to poster presentations and tutorials, including on high temperature indentation testing and industrial applications. This helped contribute to building the future community in nanomechanical testing.

The Virtual Special Issue opens up with two focus review articles that present detailed landscape views of the recent advances in small-scale fracture experimentation and analysis. The first review

article by Ast et al. is dedicated to the 40th anniversary of publication of *Materials & Design* [1]. It is devoted to the experimental challenges and the principal micro-scale fracture toughness measurement methods that are outlined and critically reviewed. In the second review article by Pippan et al. [2], the fundamental concepts of fracture mechanics are revisited in the context of their applicability to miniature scale experiments.

This is followed by the articles based on the presentations at the meeting and a variety of full research articles [3–26] reporting the recent challenges and achievements in small-scale mechanical testing, as well as their applications for improving the process-structure-property correlations in thin films and nanostructured materials.

The Editors are particularly pleased to include in this VSI the contributions from **young scientists – winners of Best Poster awards** during the conference:

1. The contribution from Lisa Krämer and co-workers on the “Activation volume and energy of bulk metallic glasses determined by nano-indentation” [3];
2. The paper from Raphael Soler and co-workers on “Fracture toughness of Mo₂BC thin films: Intrinsic toughness versus system toughening” [4];
3. The article from Markus Alfreider and co-workers on “In-situ elastic-plastic fracture mechanics on the microscale by means of continuous dynamical testing” [5].

Other examples include small scale plasticity studies in crystalline and amorphous metallic alloys [6–10], high-temperature nanomechanical testing [11–14], micro-scale fracture toughness assessment [1,2,14,15], nano-scale residual stress depth profiling by the FIB-DIC method [16], scratch testing in thin films [17], high-strain rate nano-scale testing [18,19], brittle-ductile transition studies [20,21], recent refinements of nanoindentation protocols [22,23], combination between nano-mechanical testing and EBSD analysis [24], and mechanical testing of nano-architected materials [25,26].

The Nanomechanical Testing conference series begun in 2005 with the first meeting in Crete, Greece, continued in 2009 with the meeting in Barga, Italy; 2011 at Canary Islands, Spain; 2013 at Olkao, Portugal; and 2015 at Albufeira, Portugal. The next meeting is due to take place in Malaga, Spain 2019.

The Editors express their gratitude to the Scientific Organizing Committee members: K. Durst, TU Darmstadt, Germany; G. Pharr, Texas A&M, USA; M. Göken, FAU Erlangen-Nürnberg, Germany; G. Dehm, MPIE Düsseldorf, Germany; J. Michler, EMPA Thun, Switzerland; M. Legros, CEMES-CNRS, France.



Fig. 1. Group photograph from the Nanomechanical Testing VI meeting.

The collected articles showcase the relevance and potential impact of novel nanomechanical testing procedures for the design of materials and devices with improved performance.

The Editors are grateful to publishing colleagues at Elsevier, the editorial team of Materials & Design, and all reviewers and contributors for creating this body of published work.

The collection of papers attributed to this Virtual Special Issue is found at <https://www.sciencedirect.com/journal/materials-and-design/special-issue/109XDXN8RL9>

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