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

We are delighted to introduce this virtual special issue (VSI) focused on nanomechanical testing, featuring contributions from the 2022 Nanomechanical Testing in Materials Research and Development VIII meeting held in Split, Croatia. With nearly 130 delegates from 15 countries from across the globe in attendance after the Covid19 pandemic, this conference provided one of the first opportunities for the community to meet again and exchange ideas in person. In this way, it continued the tradition of serving as a platform for sharing advancements in nanomechanical testing through 67 oral presentations and 59 poster contributions. The event fostered scientific discussions, networking opportunities, and received active participation and sponsorship from numerous companies showcasing their latest developments in the field, including Alemnis AG, Bruker Nano GmbH, FemtoTools AG, KLA, NanoMEGAS SPRL, Micro Materials Ltd., SURFACE systems + technology GmbH + Co KG, and ZEISS Microscopy.

This conference series began nearly two decades ago and has witnessed exciting developments in nano- and micromechanical testing, revolutionizing research and development in the field. Some of the key advancements comprise instrumentation, in-situ and operando testing including different environments, testing across multiple scales with progressive miniaturisation as well as application of small-scale testing to ever increasing areas and volumes, advancements towards high-throughput methodologies and data-driven approaches. The development of advanced nanomechanical testing instruments has enabled precise and accurate measurements of mechanical properties down to the nanoscale. With the integration of imaging techniques, such as electron microscopy and optical microscopy, with mechanical testing we can now perform real-time observations of material deformation and failure mechanisms, providing valuable insights into mechanical behaviour. These are now available for very different and well-controlled conditions, such as elevated temperatures, corrosive environments, and dynamic loading conditions, providing a more comprehensive understanding of material response in real-world applications. The ability to cross multiple length-scales in this way has facilitated a deeper understanding of the size-dependent mechanical properties and deformation mechanisms of materials. The development of automated testing platforms and methods including rapid screening across wide ranges of composition, microstructure and test parameters continues to contribute to these important advances. At the same time, the integration of data science and machine learning now enables the analysis and interpretation of such large volumes of mechanical testing data, leading to the discovery of new relationships, trends, and predictive models.

Overall, these developments have continued expanded our knowledge of material behaviour and continue to fascinate and attract researchers from many areas of materials science. They strive to understand and design materials with tailored mechanical properties for a wide range of applications, including structural materials microelectronics, biomaterials, energy and many other functional materials.

All of these aspects form part of the collection of papers in this virtual special issue and we are particularly delighted to include the important contributions of the early career researchers who contributed outstanding research, providing a tough challenge for the juries of the respective best poster and newly created oral presentations awards.

The applications of nanomechanical testing covered in this special issue range from the basic deformation mechanisms over studies of materials that possess intrinsically small length scales from their processing history to advancing the test methods and correlations with other ex- and in-situ methods. **Fundamental deformation mechanisms** have been studids experimentally and by different modelling approaches relating to different classes of materials, such as fcc [1,2] and bcc metals [3] including after charging with hydrogen [4], bulk metallic glasses [5,6], Laves phases [7], silicon [8,9], a CrCoNi medium entropy alloy [10], Ni-Mn-Ga shape-memory alloys [11], barium

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titanate thin films [12]. Several contributions also consider composites or materials intrinsically structured at the microscale. This includes lath martensite [13], bainitic and ferritic HSLA steel constituents [14], Ni/Al nanolaminates [15], nanoporous gold [16], particle composites [17], supercrystalline nanocomposites [18], and brittle coatings and Al/Al_2O_3 multilayers on flexible substrates [19,20]. The **properties and mechanisms encountered for different material processing methods** are included in this special issue with respect to additive manufacturing [21,22], laser welding [23], multi-metal carbide coatings [24], 3D printed micorpillars [25], high-pressure torsion [26] and strain-path dependent damage [27]. Nanomechanically testing is traditionally also closely related to the **use of other ex- and in-situ characterisation methods** to give a holistic picture of the mechanisms giving rise to the properties of structural or functional materials. Here, in-situ microscopy for imaging of high-temperature processes [28] and in-situ x-ray tomography to characterise damage [29] are among the topics covered in this issue. In the future, we look forward to many applications also of the **new or improved characterisation methods** that have been developed recently, such as to advance fracture testing [30,31,32], enable high-throughput fracture testing at small scales [33],to study creep and fatigue using bulge testing of freestanding thin films [34], to enable the quantitative determination of directional elastic properties from nanoindentation [35], and to explore temperature- and rate-dependent properties by high-temperature scanning indentation [2] and strain rate sweeping [36]. In the application of microstructural and nanomechanical characterisation, the use of **artificial intelligence** is also on the rise. Examples of this covered in this issue include a study on the three-dimensional nature of damage [37], mapping hierarchical and heterogeneous micromechanics [38].

The Nanomechanical Testing conference series began in 2005 with the first meeting in Crete, Greece, and continued in 2009 in Barga, Italy; 2011 on Lanzarote, Spain; 2013 and 2015 in Olhao and Albufeira, Portugal, 2017 in Dubrovnik, Croatia, and 2019 in Malaga, Spain before returning to Split in Croatia in 2022 after the Covid19 pandemic.

The Editors express their gratitude to the Steering Committee members: George Pharr, Texas A&M, USA; Mathias Göken, FAU Erlangen-Nürnberg, Germany; Gerhard Dehm, MPIE Düsseldorf, Germany; Johann Michler, EMPA Thun, Switzerland; Marc Legros, CEMES-CNRS, France; Karsten. Durst, TU Darmstadt, Germany; and Jon M. Molina-Aldareguia, IMDEA Materials Institute, Spain. The Editors are also grateful to publishers at Elsevier, the editorial teams of Materials & Design and Materials Science and Engineering A, and all reviewers and contributors for creating this body of published work.

Group photo of all participants and awardees of the best poster and oral presentation awards.

CRediT authorship contribution statement

Sandra Korte-Kerzel: Writing - original draft. **Marco Sebastiani:** Writing - review & editing.

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