# In situ Extreme Micromechanics – Recent Innovations and Prospects

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**Abstract**

*In situ* SEM micro- and nanomechanical testing is an indispensable technique for materials design as well as for fundamental mechanics research. Many new protocols and testing geometries beyond traditional nanoindentation now enable the study of microstructure–property relationships, material intrinsic behaviour including orientation-dependence and plasticity, fracture dynamics, or the performance of novel micro-3D-printed metamaterials, to name but a few.
Thanks to its versatility, *in situ* SEM-based micromechanics is contributing to numerous scientific domains, including thin films and coatings, metallurgy, glasses and ceramics, semiconductors, biomechanics, or architectured materials. Performing micromechanical tests in situ in a SEM offers two important advantages: (1) unmatched control, stability, and positioning accuracy, and (2) the possibility to perform unique correlative experiments based on, for example, the combination of mechanical data with direct imaging or EBSD measurements.

An increasingly important branch of micromechanical testing can be found in the simulation of real-world, extreme operation conditions, such as high temperatures in engines, cryogenic temperatures in hydrogen storage, dynamic loading under shock or impact, high frequency cyclic fatigue, or a combination thereof. Progress in the understanding of material behaviour at such conditions is clearly linked to the availability of laboratory equipment that can perform reliable tests under such conditions.
We present the most recent developments in instrumentation for in situ extreme mechanics testing at the micro and nanoscales. In the focus is a testing platform capable of strain rate dependent testing over the range from 0.0001 s-1 up to 10'000 s-1 (8 orders of magnitude) with simultaneous high-speed actuation and sensing capabilities with nanometer and micronewton resolution, respectively. Furthermore, the challenges and solutions to performing extreme micromechanics over the temperature range from -150 ∘C to 1000 ∘C, and the inherent advantages of using small volumes of sample material will be discussed. Finally, we present examples of such extreme micromechanical in situ tests and discuss future research directions in the field of extreme micromechanics.

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