BEYOND THE LIMITS – ALTERNATIVE TESTING CONCEPTS IN NANO MECHANICS

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Abstract
The given project summarizes different approaches for implementing alternative ways of probing material properties in the micro and nano scale. Progressive miniaturization has led to a growing need to determine the physical properties of microscopic volumes of materials. Nanoindentation has become an invaluable and prominent technique for testing the mechanical properties of thin films, MEMS devices and other features in the micro and nano scale. Originally developed for the determination of Young’s modulus and hardness of materials, the methodology has been continuously extended to characterize properties like adhesion, fracture, creep, scratch and wear.

The nano mechanical investigation of material characteristics often require advanced testing schemes with precise control of the test parameters that govern material deformation and failure. By adequately designing the test sequence, emulating alternative control paths (displacement, stress, etc.), and utilizing alternative data analysis, some limitations of “classical” techniques can be overcome. As a result, new testing techniques have been developed to address the complexity of modern engineering materials and structures used in areas such as aeronautics, semiconductor manufacturing, biomedical research, and optical applications. The aims pursued by such implementations are manifold but can commonly be broken down into a few categories:

1. Accessing material parameters not available by standard testing techniques
2. Adaptation of testing sequence and parameters to the specifics of a material or feature of interest
3. Improve reliability and reproducibility of tests
4. Increase sample throughput for better statistics
5. Enhance automation of testing and user friendliness

There are three main approaches for accommodating the mentioned objectives:

To a large extend, customized testing require a modification of the test flow such as detecting initial contact with the specimen and the loading or deformation history. Some tests on MEMS devices and microstructures (e.g. bending, shearing, and adhesion) will be shown for illustration.

In some cases an alternative way of probing mechanical properties can overcome issues within classical approaches. Testing the lateral stiffness of microstructures and accessing creep behavior are only two examples.

Creep testing at the nano scale is only one of many prominent examples. Macroscopic creep tests are commonly conducted over the time scale of hours, days or even weeks. In nano mechanics however, even minor temperature changes in a controlled environment can cause thermal expansion or contraction of the specimen well into the range of intentionally applied deformations. Therefore, techniques used in performing macroscopic creep tests do not directly translate to nano scale creep characterization and require alternatives [1].

In a recent project the lateral stiffness of microstructures has been accessed via two independent channels simultaneously. A case study will be introduced.

Sometimes modifications are also required for the analysis of data. A significant number of indentation experiments are now analyzed according to the Oliver and Pharr publication [2]. The model however is limited to a set of boundary conditions that are not always fulfilled by the given materials, structures and
experimental conditions (e.g. working on extremely thin films [3]). Hence incorporating refined models help to adapt for changes in the boundary conditions. When probing properties other than Young's modulus and hardness, adequate experiment specific models have to be incorporated for data analysis.

**Keywords**: nano, advanced testing, nanomechanics, experimental, automation, data analysis, alternative techniques, indentation, metrology, mechanics, micro, materials, coatings, MEMS

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