A material strength depends on its microstructure, which in turn, is controlled by an engineering process. Strengthening mechanisms like work hardening, precipitate and grain boundary strengthening can alter the strength of a material in a predictive, quantitative manner and are readily linked to the deformation mechanism. This quantification strongly depends on the characteristic length scale of a particular microstructure, thereby dictating bulk material's strength as a function of, for instance, grain or precipitate size, twin boundary spacing, or dislocation density. This microstructural, or intrinsic, size governs the mechanical properties and post-elastic material deformation at all sample dimensions, as the classical definition of 'ultimate tensile strength' deems it to be 'an intensive property, therefore its value does not depend on the size of the test specimen'. However, in the last years, the vast majority of uniaxial deformation experiments and computations on small-scale structures unambiguously demonstrated that at the micron and sub-micron scales, this definition no longer holds true. In fact, it has been shown that in single crystals the ultimate tensile strength and the yield strength scale with external sample size in a power law fashion, sometimes attaining a significant fraction of material's theoretical strength, and exhibiting the commonly-known phenomenon called size effect (smaller is stronger). Understanding of this phenomenon at small scales is not yet mature and is currently a topic of rigorous investigations. As both the intrinsic (i.e. microstructural, internal size effect) and extrinsic (i.e. sample size, external size effect) dimensions play a non-trivial role in the mechanical properties and material deformation mechanisms, it is critical to develop an understanding of their interplay and mutual effects on the mechanical properties and material deformation, especially in small-scale structures.

An interesting filed in which the size effects can be investigated are nanocrystalline materials. A nanocrystlline material is a polycrystalline material with a crystallite size of only a few nanometers. These materials fill the gap between amorphous without any long range order and conventional coarse-grained materials. Definitions vary, but nanocrystalline material is commonly defined as a crystallite (grain) size below 100nm. Grain sizes from 100 to 500 nm are typically considered "ultrafine" grains. In the project it is assumed that the changes of external as well as internal (i.e. grain sizes) dimensions can lead to very strong materials. There are, however, a few questions: What are the external and internal dimensions of a sample, which leads to the highest strength? What is the highest strength of an investigated material in the case of tensile tests, bending tests or compressive tests? Is the materials strength a superposition of external and internal size effect or there is any synergy occurring?

In order to find answers for these questions sophisticated experimental equipment is going to be used. The most important device in the project will be the atomic force microscope (AFM). AFM is a powerful microscope that provides high-resolution (highly magnified) images of a wide-range of samples. The technique works by scanning the sample under a very fine tip, in a similar way to which a record stylus tracks over a vinyl record. An image of the surface is produced line-by-line, the process typically takes about 10 minutes. The position of the tip on the sample is monitored by a laser beam focused on the highly reflective supporting arm to which the tip is fixed. As the tip goes over a high feature on the surface, the laser falls on a different part of the detector, changes the voltage signal and accordingly lowers the scanner and sample. In this way, the force between the tip and sample is kept constant.

However, the AFM can be also used to exert forces on small structures in order to perform some nanomechanical tests. For example the forces can be exerted by the AFM cantilever tip onto sample pillars with dimensions of a few tens of nanometers while the cantilever deformations are monitored quantitatively by the same instrument. It is thereby possible to bend the pillars until the threshold for triggering fracture is reached, and to determine the mechanical properties at different stages of this process. In this experiments the cantilever moves across the sample surface along a line forming a 90o angle with the cantilever axis. The cantilever is bent by the vertical force it exerts to the pillars and undergoes torsion flexure due to the frictional forces occurring by the scanning motion of the cantilever tip across the sample. This approach allows the determination of interesting properties of investigated materials.