Precise force sensors for micro and nanotensile tests.

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1. Introduction

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 now-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) and extrinsic (i.e. sample size) 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. Therefore, in recent years much research has focused on designing the machines capable of measuring the mechanical properties of extremely small structures. In this paper we presents our achievements in the field of design of precise force sensors which can be applied for micro and nanotensile tests.

2. Experimental

One of the biggest problem with precise force sensors is to overcome the friction force. The friction force can significantly reduce the forces which can be measured by microtensile testers. Therefore, we have designed a special device for testing and calibration of the force sensors of our design (Fig. 1). The device consists of the extremely precise MEMS nanonewton force sensor, which is capable of measurement of forces down to nanonewtons, and the displacement capacitance sensor with resolution higher than 1nm. We have tested a few geometries of force sensors made of thin flat springs and a linear magnetic motor, which can be used as almost frictionless linear guide. We have also tested a few commercially available linear guides with extremely low friction coefficients (down to 0.001). We have measured the real static and kinetic friction coefficients and the hysteresis caused by friction.

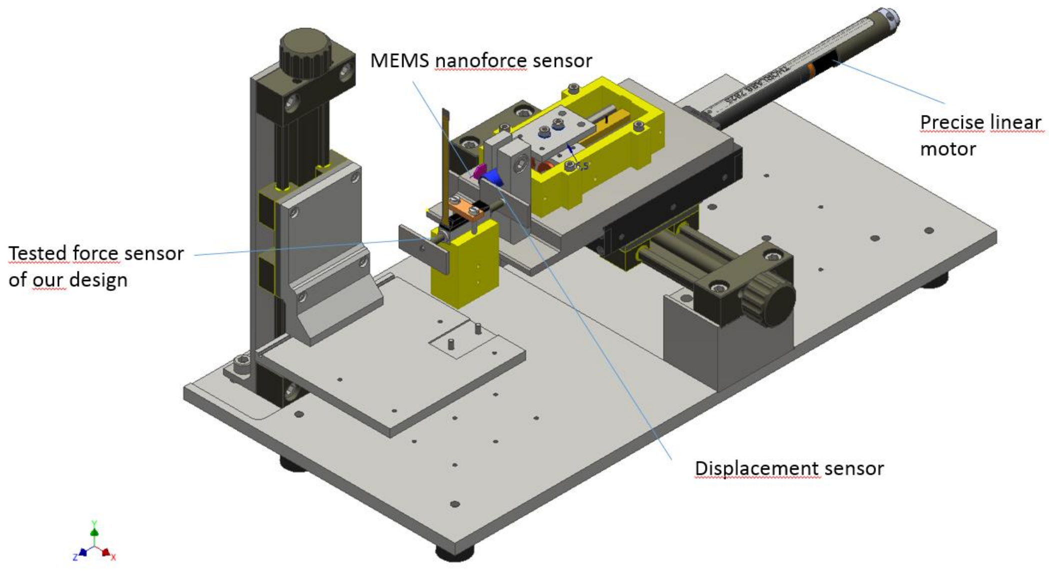

Figure 1. The scheme of the testing device.

Furthermore, we mounted our force sensors in the micro – nanotensile tester of our own production and we investigated in-situ under the optical microscope the tensile of microwires made of copper by precise electro etching (Fig. 2).

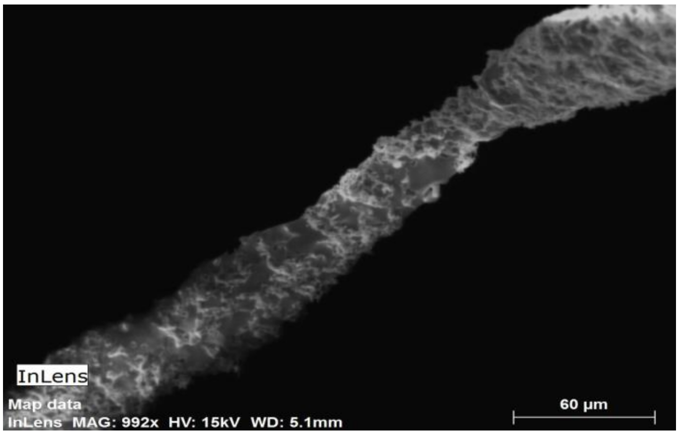

Figure 2. The SEM picture of a microwire made of copper.

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5. References

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