EASIMECA project - Web summary

Freestanding submicron films are currently used to achieve mechanical functions in micro-electromechanical systems (MEMS). In parallel, thin film nanostructured materials are also widely used in new systems in order to improve their performances, such as corrosion or wear resistance, thus contributing to the reliability improvement of such systems

An important challenge relies on the combination of a high degree of reliability and the optimization of their mechanical properties according to the targeted application. In this field, MEMS can be highly reliable, but their failure modes still need to be understood. In the same way, new nanostructured materials used in thin films usually show original properties compared to their bulk counterparts. This can be explained by various mechanisms, but scientific challenges still exist in order to fully understand these mechanical properties.

Nevertheless, reliability and qualification of systems can be much more complex than for conventional devices. Whether deposited on a substrate or freestanding devices, the investigation of the intrinsic mechanical properties of nanostructured thin films still remains a hard task.

Several methods like wafer curvature or nanoindentation have been extensively used, but such techniques present major shortcomings and may not be considered as an accurate answer:

- for dimensioning freestanding structures used in micro- and nano-technologies
- to address reliability issues of such devices
- to easily access the intrinsic mechanical properties of nanostructured thin films and further explore the role of the interfaces.

The direct characterization of freestanding thin films makes it possible to overcome most of these drawbacks. Several methods are already exploited but these techniques hardly provide useful data for fundamental research and/or the results are strongly dependent on the geometry of the specimen.

The microtensile test is actually considered as a key technology for the standardized development of MEMS. The method is the best way to diminish the impact of geometry defects on the stress/strain relationship. Insights provided by micro-tensile testing have a great potential in fields such as biological attachment devices, size-dependent plastic behaviour in single-crystalline metals, deformation mechanisms in nanocrystalline metals where phenomena such as short diffusion paths, multiaxial stress states, cyclic loading and elevated temperatures are thought to have implications at the component scale and generate the need for intensive investigations.

Among the microtensile tests identified in the literature, a promising experimental set-up is currently under development. The targeted capabilities of this test bench should allow to:

- investigate freestanding nanostructured thin films with thickness down to 200-300 nanometres
- evaluate the influence of thermally-induced mechanisms (creep, relaxation,…) on the mechanical performances and thermal ageing
- address reliability issues by studying rheological behaviour of thin films after ultimate stress and by developing cycling solicitations (fatigue at ambient and non-ambient temperature),

The project aims at assessing the implemented set-up and thus at validating the technical developments that are under progress. Microtensile testing of model materials with well-known mechanical properties as freestanding thin films will be carried out in order explore the performances and limitations of the new set-up. In order to assess the performance and relevance of the developments, comparisons with other testing methods and alternatives will be performed.

In a second step, complex Al-Ti-Ta-N nanocomposite thin films will be investigated. These quaternary compounds are state-of-the-art hard coatings. They combine nc-MN_x hard phases embedded in a thin TaN_y matrix. The resulting properties include super-hardness even at high temperature, excellent wear resistance and high oxidation resistance.

The film structure is highly tunable according to the alloying element content: the structure and phase content can be adjusted from a highly crystalline to a mainly amorphous film. This is associated to a decreasing crystallite size, down to some nanometres, which has a significant impact on the related mechanical properties. The link between structure and mechanical properties is commonly understood to be based on the balance between the crystallite size and amorphous phase, but still need to be further investigated in order to optimize the film properties for industrial applications.

From a scientific point of view, the project outputs may open the door to new considerations on plastic deformation of nanocrystalline materials and strain measurements at non-ambient temperature where only few results have been published so far.