Size and structure dependent ductility, strength and toughness of thin hybrid nanolaminated films

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The improvement of the thermomechanical performances of coatings is more than ever a major challenge in energy production, transportation, environment and biomedical engineering fields in the context of withstanding severe tribological solicitations. The durability of coatings often controls the durability of the devices and structures, hence their safety, efficiency and environmental impact. Research in this field has been revitalized with the emergence of 2D nanostructured coatings "nanolaminates" which offers new degrees of freedom to produce high strength / high toughness films [1], [2]. The alternate combination of crystalline and amorphous layers has been proposed in order to enhance the global wear resistance of thin films [3]. By carefully designing the mechanical properties mismatch as well as the interface strength between the materials' layers constituents, new combinations of ductility, strength and toughness can be attained offering ways to optimize scratch, erosion and wear resistance under different operating conditions.

In this research, the focus is put on two types of nanolayered materials: Al/Al_2O_3 and amorphous-C/Cr stacks. The relationship between the film composition/structure and its mechanical properties is investigated through nano-indentation, micro-scratch, in-situ scanning and transmission electron microscopy (TEM) and lab-on-chip testing combined with numerical simulations. The mechanical behavior of individual layer is primarily assessed and confronted to the tri-layers and n-layers systems to highlight the cooperative effects regarding deformation and fracture mechanisms. In particular, we will show and explain the extreme ductility that can be attained with Al/Al_2O_3 stacks and the high versatility of the amorphous-C/Cr system.

Keywords: nanolaminates, thin films, ductility, strength, toughness, nanoindentation, scratch, lab-on-chip, TEM

References

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