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Buckling structures of thin films at the nanometer scale, a relevant signature of mechanical properties of film/substrate systems

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Abstract

Thin films and coatings are used in a wide range of technological applications, such as microelectronics or optics. They often develop high residual stresses during the deposition process, sometimes about few GPa in compression. Such large compressive stresses may cause the nucleation and growth of buckling structures [1] that generally result in the loss of functional properties initially conferred to such film/substrate composites. The most common buckling structures are the circular blisters, the straight-sided buckles and the telephone cords. The aim of our studies is consequently to have a better understanding of the buckling phenomenon, by identifying the relevant parameters to prevent, to limit, or to control its occurrence. Our studies concern the effect of elasticity [2,3] of the substrates on the maximum deflection of the buckles, the philosophical question of vacuum below the buckling structures [4], the effect of a pressure mismatch between the buckled film and its substrate [5,6], the limit of the elastic theory framework to understand the buckling when plasticity is taking place in the film [7], the morphology of a buckle in a thickness gradient [8], or even the buckling of 2D materials, such as graphene for which no thickness can be obviously defined. From an experimental point of view, the fine investigations of the morphology of the buckling structures, by optical or atomic force microscopies, can be of great interest in order to qualitatively, or even quantitatively, extract some mechanical parameters of the film/substrate systems. One can cite for instance the elastic Young modulus of either the film or the substrate, or the interfacial film/substrate toughness, a key

parameter for industry. A focus will be done here on the effect of the pressure mismatch between the film and the substrate. It is first demonstrated that the maximum deflection of a buckle may decrease at the atomic scale due to the atmospheric pressure outside. It is also shown that some specific circular buckles experimentally observed can be relevant markers of this pressure mismatch.

Keywords:

Buckling Stress Thin films Interfacial toughness Delamination

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