Influence of elasto-plastic behavior of thin films on buckling delamination of circular blisters

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Abstract

Thin films and coatings are now currently used in a very large number of technological applications such as for instance micro-electronics devices, protective layers or thermal barriers for turbine engines. Some deposition techniques now widely used in industrial processes, such as physical vapor deposition, are known to induce high internal stresses, sometimes about few GPa in compression.

This may lead to some mechanical damages with adverse consequences for the functional properties of these film/substrate systems. One of them, the buckling delamination of thin films has been widely studied by the past, analytically in the framework of the Föppl-von Kármán equations describing the equilibrium states of thin plates or numerically by finite element method (FEM) simulations. Three main elementary buckling structures have been evidenced and experimentally observed: the straight-sided buckles (SSB), the telephone cords (TC) and the circular blisters.

The circular blisters are the most frequently observed since they form spontaneously, sometimes just after the deposition process, but usually quickly evolve into TC, or SSB, because of a delamination front instability bove a critical diameter (at a given stress). Whatever the buckles morphology, their study was confined to the framework of elasticity. Only a few works were focused on the effect of plasticity, confirming the unstability of the circular shape.

However, in ductile films like Au, two **paradoxal** observations are made: 1) the dimensions of the circular blisters (especially the heigth) fail to be predicted by linear-elastic buckling models and 2) the circular shape seems to be able to propagate in a stable way, which is known to be impossible in a purely elastic framework.

In this presentation, we focus our attention on circular blisters forming on gold ductile thin films. Spontaneous circular blisters on Au 500 nm thick films on Si wafers observed by optical and atomic force microscopies are presented. Their maximum deflections are compared to what would be expected from a purely elastic plate theory. The Au film elasto-plastic behavior is determined by finite elements simulations based on nanoindentation experiments. The impact of plasticity on the buckled circular morphology is then finally studied using numerical simulations, and compared to our experimental observations. Additionaly it is shown by numerical calculations that plastic deformations in the film during blister delamination help stabilizing the circular shape of the delamination front (see Fig 1.).

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