Study of Multi-cracking of brittle Thin Films and brittle/ductile Multilayers on Compliant substrate

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Thin films coatings are used in many high technology applications particularly in microelectronics devices. Using flexible polymers as a substrate on which thin films (metal, oxides or organic) are bonded can give rise to new industrial applications such as OLED, flexible electronics or flexible photovoltaics devices. The mechanical stability and failure behavior of multilayer structures deposited on flexible substrate has been extensively studied both experimentally and theoretically [1-3]. Several relaxation mechanisms in thin films have been identified such as channel cracks, debonding or buckle delamination.

The objective of this study is to understand the multi-cracking of the silver and/or zinc oxide layers of various thicknesses coated on elastoplastic substrates (ETFE). In the process of cracking many parameters should be taken into account such as the elastic modulus mismatch between the film and the substrate, the plasticity of the substrate and the ductile or brittle nature of the film.
In the literature several experimental and analytical studies can be found. In [4], after experimental investigations, the existence of three different fracture stages was confirmed, the third one being a saturation stage of the cracks density at high strain with large opening of the existing cracks. Conventional models in literature such as Xia & Hutchinson model [3] and the “Shear lag” formalism [1,2] do not account for those experimental observations. We show that taking into account the plasticity in the substrate allows for capturing the crack density at the saturation regime.

To further validate this new model and the experimental observations, we present a numerical study which uses a cohesive zone model for the interface and to simulate the cracking of the film. This model also takes into account the plastic behavior of the substrate (Fig1). The different stages of cracking observed experimentally, including the nucleation stage were simulated (Fig2). A relationship between the properties of the film toughness, the saturation stress level in the film and the saturation distance between the cracks under deformation has been evidenced.

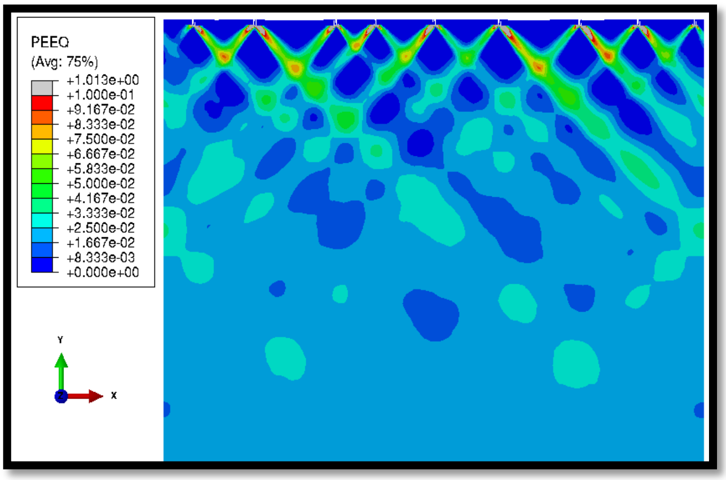

Fig 1: Plasticity distribution and cracks in the numerical model

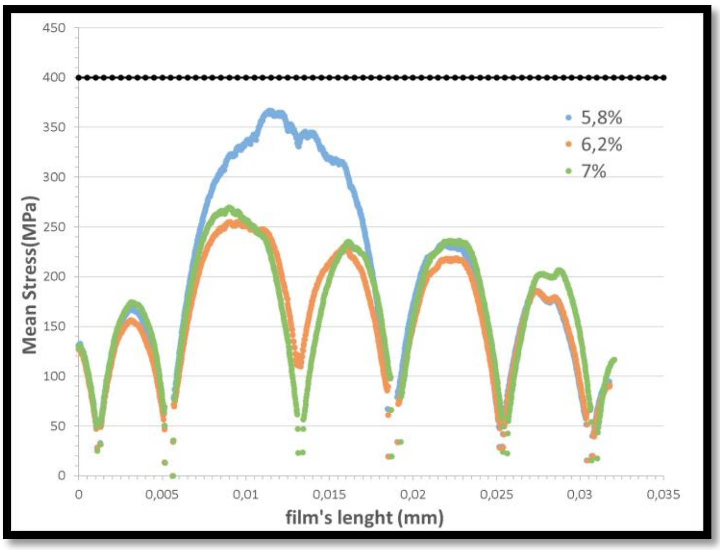

Fig 2: stress redistribution in the film averaged in thickness under deformation

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