EVOLUTION OF THICKNESS DEPENDENT BUCKLE GEOMETRIES

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Interfaces determine the overall reliability of multi-material components since they have to bear the distinct physical and chemical properties of the different adhering materials. In microelectronic applications, where several materials are implemented at small length scales, the main interest is on identifying the weakest interface, since it dictates the overall reliability of the implemented packages. The focus of the present study is set on a multi-layer stack composed of a rigid Si substrate with dielectric borophosphosilicate glass (BPSG) and a thin TiW film acting as adhesion promoter and diffusion barrier to the copper film, which are finally covered with 6 µm of polyimide (PI). Of main interest is a thorough characterization of the delamination of the various interfaces, which allow for a better understanding of the adhesion and the stress states present in the complex material stack. As a first step to study the interfacial behaviour, a peeling test was carried out to reveal the weakest interfaces resulting in three different delamination zones. Zone 1 delaminated at the BPSG-TiW interface and Zone 2 delaminated at the copper-PI interface (Fig 1a). An intermediate Zone 3 (Fig 1a) was identified, where straight buckles formed in the Cu-TiW layer parallel to the peeling direction at the TiW-BPSG interface (Fig 1b). Using these Zone 3 delaminations, the evolution of the buckle shape as a function of film thickness and layer stress was investigated using atomic force microscopy and X-ray diffraction. Of great interest is that with the Cu layer the buckles have a straight geometry (Fig 1b) indicating an isotropic stress. However, when the Cu layer is removed with chemical etching, the buckle morphology changes to a telephone cord geometry (Fig. 1c), maintaining the outer boundaries from the previous straight buckles shape. The change in geometry could be due to the change in film stress from isotropic to biaxial as well as the fact that the out of plane plasticity is constrained while the copper film is present. Both topics will be further discussed along with how the interfacial adhesion measurements may also be influenced by the change in buckle geometry.

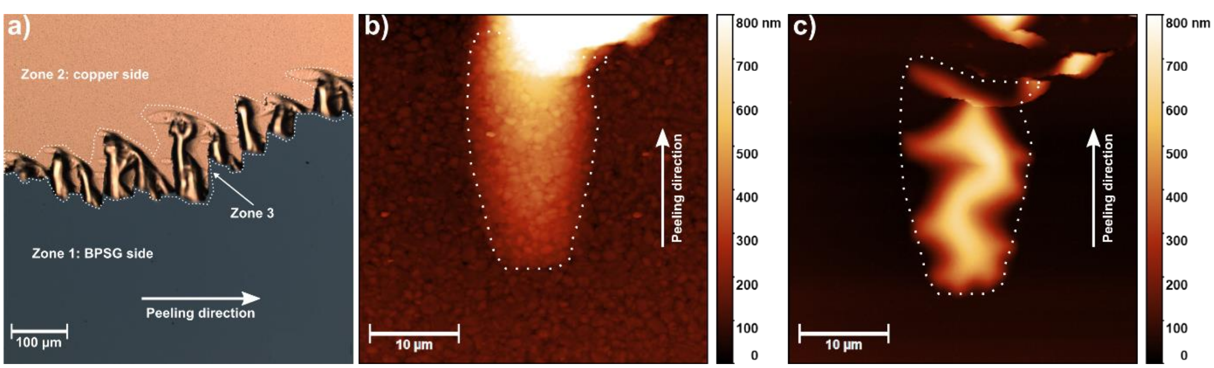

Figure 1. (a) Overview of peeled Cu/BPSG surface indicating three characteristic zones: Zone 1: BPSG side, Zone 2: Cu side, and Zone 3 with straight buckles parallel to the peeling direction and big, cracked buckles perpendicular to peeling direction (b) AFM image of straight buckle (with Cu layer) (c) AFM image of same buckle after removal of Cu layer (telephone cord morphology).