INVESTIGATING ADHESION OF POLYIMIDE IN SEMICONDUCTOR DEVICES WITH CROSS-SECTIONAL NANOINDENTATION

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In the semiconductor industry polyimides find wide use as protective layers as well as interlayer dielectrics due to their excellent properties. Their use as a protective layer stems from their good chemical, mechanical and thermal characteristics, which provide the necessary protection of the device. Furthermore, their ability to planarize topographical features while possessing a high dielectric strength makes them useful as interlayer dielectrics. As it is well known that semiconductor devices can fail due to delamination of the many layers they are composed of, the adhesion of polyimides to the layers beneath is of great importance and needs to be investigated.

It was shown that cross-sectional nanoindentation (CSN) can be used to investigate interface adhesion in semiconductor backend of line structures but no work so far has investigated adhesion of polymer-based layers. The method uses a pyramidal nanoindentation tip which is pushed into the sample near the interface until a threshold force is reached. At this force a wedge of the material fractures from the bulk and pushes into the deposited layers, thus giving rise to cracks that advance between the two neighboring layers with the lowest adhesion. Taking into account how far the wedge was pushed out of the substrate, wedge size and the crack length, the energy needed for crack advance can be calculated.

To investigate the usefulness of the CSN method for systems with polyimide layers, two different material stacks were tested. The first system consists of a 750µm Si wafer with a 100 nm silicon-oxide layer, a 40nm silicon-nitride layer followed by a 6µm polyimide layer, the second system contains the same layers, but has a 300nm aluminum layer inserted between the silicon-oxide and the silicon-nitride. For further optimization of the CSN method the influence of different indenter geometries, especially cube corner tips, and the variation of the indent to interface distance was investigated. Lastly finite element simulations were conducted to gain insight into the relaxation of the polymer layer and the resulting crack closure after tip removal.

These experiments form the foundation for the investigation of different combinations of polyimide and metal thin film layers, which will result in better understanding of the adhesive properties of polyimides.