Ablation Study for Depth Profiling of a Structured Multiphase System

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The striving for increased performance and miniaturization of logic and memory devices demands from the semiconductor industry the redesign of integrated circuit architectures towards three-dimensional (3-D) stacked wafer/chip systems. In this context, the so-called through-silicon via (TSV) technology provides a promising integrating concept, which allows for the further increase of the packing density of the circuit with lower power consumption.[1] However, these through wafer interconnects show high aspect ratios (e.g. channels of Ø = 5 µm and depth = 60 µm), which challenges the electrochemical filling process of Cu. One important drawback that the semiconductor industry is facing with this technology is the formation of defects within the interconnect material. The source of these defects is so far not yet understood and believed to be caused by impurity incorporation during the electrochemical deposition of Cu. To verify this hypotheses chemical composition analysis of the embedded material is required, which is highly demanding due to the geometrical structure of the feature and the rather distinct physical properties of the two main materials present in such structures.

The chemical composition was investigated by means of a top-down laser depth-profiling methodology on using a miniature reflectron-type time-of-flight mass spectrometer (LIMS technique) that is coupled with a fs- laser system ($\tau \sim 190$ fs, $\lambda = 775$ nm, laser spot diameter Ø ~ 15 µm) used for clean ablation and ionization of the analyte.[2-4] An empirical ablation study involving the laser irradiance and the number of applied single laser shots was conducted on the major phases, Si and Cu, providing information on the distinct ablation behavior of these two materials with remarkably different physical properties (semiconductor vs. metal). Compared to layered samples, the distinct materials form a complex 3-D multiphase structure that has to be eroded uniformly and measured simultaneously to preserve the quality of the chemical depth-profile. An alternative approach, in which the chemical composition was analyzed over the TSV cross-sections, is presented as well.

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