4D materials and process characterization. A challenge to nanoscale materials analysis.

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The goal of the lecture is to provide knowledge about advanced analytical techniques that are applied for materials and process characterization in silicon-based semiconductor industry and other fields of nanotechnology and thin-film technology, and to explain the role of process and quality control for manufacturing yield and product reliability. Particularly high-resolution analytical techniques like electron, ion and X-ray microscopy are essential for both development and introduction of new nanotechnologies and thin-film technologies as well as for the integration of advanced materials into high-tech products. Nanoanalysis is more and more needed for process and materials characterization during manufacturing of nanostructured systems and devices as well as for the understanding of the nanoscale microstructure of materials. Application-specific developments show often that the combination of several analysis techniques is needed to ensure both process control in nanotechnology as well as performance and reliability of new products.

The focus of this lecture will be primarily on challenges for 4D materials studies, i. e. three-dimensional (3D) studies of kinetic processes – a future need for a much better understanding of solid-state physical, reliability-limiting processes in materials. In-situ microscopy and tomography studies are essential to establish kinetic models for damage evolution in high-tech products. Particularly interface delamination at Cu/Si interfaces of 3D-stacked integrated circuits under thermal load, sub-critical crack growth, as a basis for the explanation of degradation mechanisms and eventual failure of Cu/ULK on-chip interconnect stacks under mechanical load, and electromigration, a damage mechanism in electrical interconnects that is based on directed atomic transport, will be explained. Analytical techniques that have to be developed further are nano X-ray microscopy and tomography as well as electron microscopy and tomography. The role of advanced materials analysis for the evaluation of the reliability of microelectronic products will be demonstrated.

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