Advanced Characterisation and Modelling for Degradation Processes in Copper BEoL Stacks of next-generation Power Devices

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In the field of current as well as next-generation power electronics device metallization, understanding and mitigating degradation processes like void formation and cracking in copper (Cu) Back-End-of-Line (BEoL) stacks due to thermomechanical loading cycles is one of the most crucial challenges. This talk focusses on the advanced characterization and modelling strategies aimed at unravelling the multi-physical and multi-scale mechanisms underlying Cu degradation. This leads the path towards enhanced metallization process optimization and advanced lifetime prediction for next-generation power devices.

The presentation will provide an introduction to the criticality of power metallization, highlighting its significance in contemporary technological landscapes. It sets starting point for an in-depth exploration into the methodologies and findings stemming from lab- and synchrotron-based X-ray techniques like nano-X-ray tomography (nanoXCT) with high photon energies as well as Dark-Field X-ray Microscopy (DFXM). These methodologies, combined with in-situ testing strategies, provide unprecedented insights into the structural evolution and degradation phenomena within Cu BEoL stacks, unveiling new facets of the degradation processes and kinetics.

Furthermore, the utilization of advanced electron-probe techniques based on Scanning Transmission Electron Microscopy (STEM) will be discussed in their usage for in unravelling high-resolution details of Cu degradation, like dislocation movement and stacking, offering complementary perspectives to the X-ray methodologies. Through the shown examination and analysis, the electron-based techniques vastly enrich the understanding of the nano- and micro-scale physics of thermal cycle induced Cu degradation and fatigue.

A central aspect of this discourse revolves around the integration of multi-physics and multi-scale simulation frameworks tailored to model Cu degradation. By incorporating mechanical, thermal, and chemical aspects, these simulations offer a holistic view of the degradation processes, enabling comprehensive analysis of the degradation processes and predictive capabilities. The convergence of experimental insights with validated modelling approaches promises to yield towards a robust toolkit for a deep understanding and mitigating of Cu degradation phenomena with unparalleled depth.
In summary, the presented work encapsulates a transformative journey towards comprehensively addressing Cu degradation in power device metallization structures. Through the development of specifically adapted methodologies and workflows rooted in X-ray and electron-based techniques, coupled with the establishment of multi-physics simulation frameworks, a profound understanding of Cu degradation is envisaged. The aimed goals of this studies are not only to optimize metallization processes but also improve advanced lifetime prediction for power devices, fostering a new generation reliable and efficient power electronic devices.

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