



## Scanning Probe Microscopy for Site Specific Defect Localization in FinFET Devices

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Scanning Capacitance Microscopy (SCM) has proven itself as a critical technique for finding and understanding three dimensional dopant related root cause mechanisms. Three-dimensional device architectures in advanced node technology such as fin field-effect-transistors (FinFET), requires an analytical technique to map the dopant and carrier distributions accurately as their vertical positioning in the source/drain (S/D), channel, conformality and absolute concentration affects the device performance. In addition, physical failure analysis of FinFET devices frequently reaches a “dead end” with a No Defect Found (NDF) result when channel doping issues are the suspected culprit (e.g., high V<sub>TH</sub>, low V<sub>TH</sub>, low gain, sub-threshold leakage, etc.). In new technology development, the lack of empirical dopant profile data to support device and process models and engineering has had, and continues to have, a profound negative impact on these emerging technologies. Therefore, there exists a critical need for dopant profiling in the industry to support the latest technologies that use FinFET as their fundamental building block. Location-specific (i.e., specific fin) SCM doping profile of FinFET devices has not been resolved spatially before to individual fins level, therefore many challenges exist. Some of the critical issues are need of highly controllable material removal, SCM spatial resolution to accurately resolve the defect and strength of the doping signal. Here, we present the novel sample preparation techniques and analysis for advanced node FinFET devices using scanning probe microscopy (SPM).



## Context microscopy and spectroscopy to advance semiconductor devices – conductive AFM linked to a wealth of other analytical techniques via nanoGPS technology

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The design complexity of electronic components and the heterogeneity of new materials constantly increase with decreasing device sizes even down to the nanometer scale. Engineering of novel devices will account for a high level of reliability, sustainability, and longevity as part of quality standards which have to be met. In the related device optimization endeavor the detection and classification of nanoscale material imperfections as well as scale bridging material and device properties will be success critical and require the use of complementing

analytical methods.

Here, the true correlation of electron- ion-, optical- and x-ray microscopy and complementing spectroscopies (optical, mass) is constantly emerging including the use of atom probe techniques in this analytical context. To account for truly correlative analytics, the application of the nanoGPS technology is an enabler when rigorously be applied for the aforementioned analytical modalities.

We will demonstrate the use of the nanoGPS technology to correlate analytical and imaging modalities for selected examples of silicon based ASICs. The underlying preparative and consecutive analytical workflows will be demonstrated. In addition, we will show the application of machine learning strategies to aforementioned heterogeneous data to further improve efficient material and device optimization.



Enabling electrical SPM for advanced nanoelectronics device characterization

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Scanning probe microscopy (SPM) has become an indispensable tool for the development of next generations of nanoelectronics devices given the achievable nanometre spatial resolution and its high versatility to probe a broad range of signals (e.g. topography, electrical properties, magnetic fields, temperature).

This talk concentrates on the use of dedicated SPM methods for the nanoscopic electrical characterization of semiconductor device structures. The scanning spreading resistance microscopy (SSRM) method is discussed which supports the development and fine tuning of advanced fabrication nodes by measuring the carrier concentration inside transistor device structures with 1 nanometre spatial resolution in a quantitative manner. Furthermore, the conductive AFM (CAFM) approach is presented which helps us to study and understand the formation mechanism of nanoscopic filament structures in advanced memory structures.

We show that the establishment of high-performance conductive diamond tips and the development of SPM nanotomography have been two important enablers for these advances. Finally, we introduce the promising reverse tip sample (RTS) configuration which overcomes the single-tip limitation of conventional SPM.