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In-situ electrical characterization of MOSFET transistors using AFM-in-SEM solution

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Background incl. aims

The semiconductor industry is continuously working on improving the performance of modern electronics and new components development. Key physical parameters like dopant concentration levels, carrier types, and crystalline defect densities are fundamental factors that influence the electrical performance of semiconductor devices. To improve device performance, novel methodologies, instrumentation, and workflows are being developed. The key requirement is the ability to investigate samples with nanoscale features to characterize device reliability or failure root cause. One example of a progressive approach for characterizing complex physical and electrical properties of semiconductor materials is correlative in-situ microscopy. A combination of different imaging systems provides a comprehensive understanding of the sample properties without the need to move the sample between multiple instruments.

Methods

The AFM-in-SEM approach, combining Atomic Force Microscopy (AFM)-based techniques with Scanning Electron Microscopy (SEM)-based or Focused Ion Beam (FIB)/SEM-based techniques, provides means to integrated correlative approach for studying semiconductor materials and devices. This solution allows for non-destructive mapping of diverse electrical properties of trenches, measuring gate dimensions, or localizing defects, which could help to understand the device processes. This approach provides the advantages of combining the benefits of capabilities of site-specific sample preparation by FIB, and ultra-high resolution imaging by SEM and AFM techniques. This integration helps in revealing the structures below the sample surface and measuring various properties at the exact location under in-situ conditions. Additionally, it provides quantitative 3D information while avoiding sample or environmental changes such as differential pressure or sample contamination.
Using the AFM module LiteScope, integrated inside the FIB/SEM, it is possible to measure high-resolution topography, and various electrical properties using techniques such as Conductive Atomic Force Microscopy (C-AFM), Scanning Spreading Resistance Microscopy (SSRM) and Kelvin Probe Force Microscopy (KPFM). C-AFM enables electrical conductivity measurement with nanoscale resolution, while SSRM can provide valuable information on dopant concentration profiles in semiconductors. KPFM is a non-destructive technique that measures surface potential, giving insight into electronic properties.

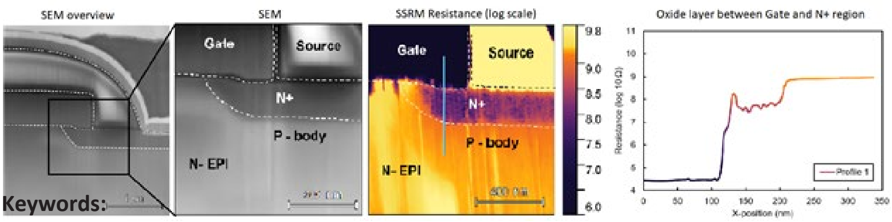
Results

With such an instrumentation, the samples are either in-situ lifted-out, or bulk x-sectioned. First we calibrated the probe measuring SSRM resistance on p- and n-doped silicon substrate, reference samples for dopant concentration measurement in SEM. Then, we analyzed MOSFET high power transistor by SSRM, showing the resistance of different components of the sample, see Fig. 1. The resistance can then be calculated to the dopant concentrations, using the calibration data from reference samples. This workflow proves that the dopant concentration steps of transistors can be safely measured under in-situ conditions in SEM, thus, enabling quality control and failure analysis of semiconductor components.

Conclusion

In summary, integrated AFM-in-FIB/SEM is a valuable instrumental combination for studying semiconductor materials or devices in order to improve device performance and enhance failure analysis success.

Graphic:



Keywords:

in-situ, semiconductors, SSRM, AFM, SEM