Understanding of and opportunities for electrical characterization of scaled devices using Scanning Spreading Resistance Microscopy

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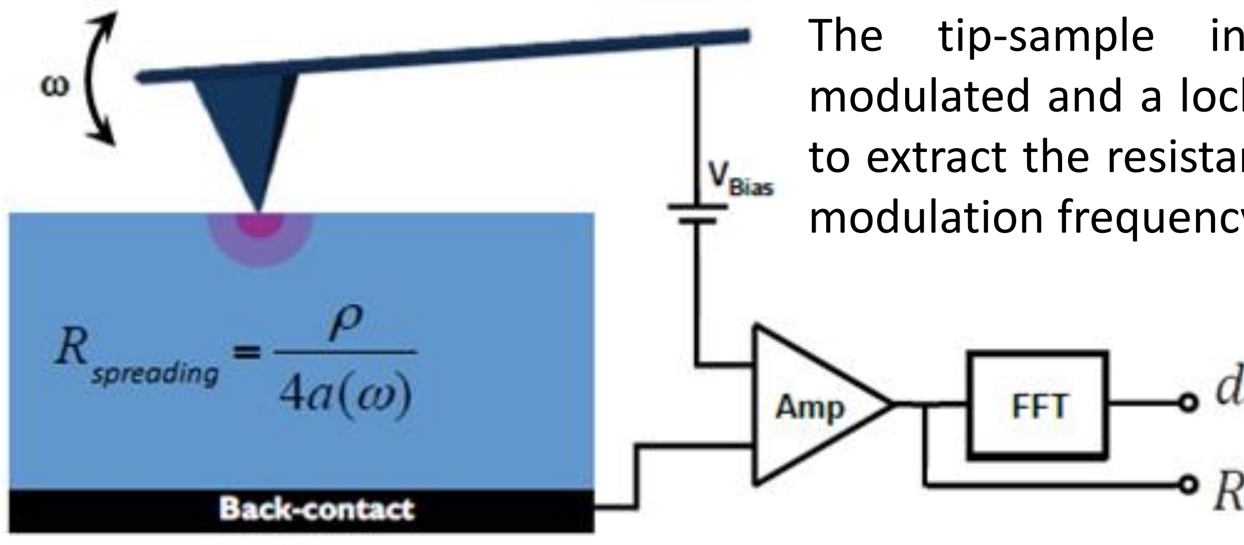
1. Introduction

Two-dimensional profiling of active dopant concentrations in semiconductor devices is key for semiconductor process development and failure analysis, especially pertaining to dopant incorporation, diffusion, activation, and their interactions with crystallographic defects. Scanning spreading resistance microscopy (SSRM) is a well-established technique that enables repeatable quantitative carrier profiling [1–3], providing sub-nanometer resolution with a very large dynamic range [4–8]. However, faced with the further reduction of dimensions and increasing architecture complexity, the assumptions that enable quantitative measurements are being challenged, both from physical and technical point of view. A first hurdle is the direct electrical contact to the region of interest, as it is quite challenging to establish a low resistive current path to a nanoscale device. **FFT-SSRM** relaxes these requirements. Secondly, scaling the Si inevitably leads to strong interface effects impacting the measured resistance of **confined volumes** and thirdly, it is becoming more and more challenging to expose the device of interest. FIB provides a powerful option for **single device analysis**, but the Ga irradiation is expected to strongly impact our SSRM measurements. Lastly, the key for high resolution measurements lies in the probes, hence **ultra sharp diamond probes** allow to measure consistently at high resolution on ultra scaled devices.

2. FFT-SSRM



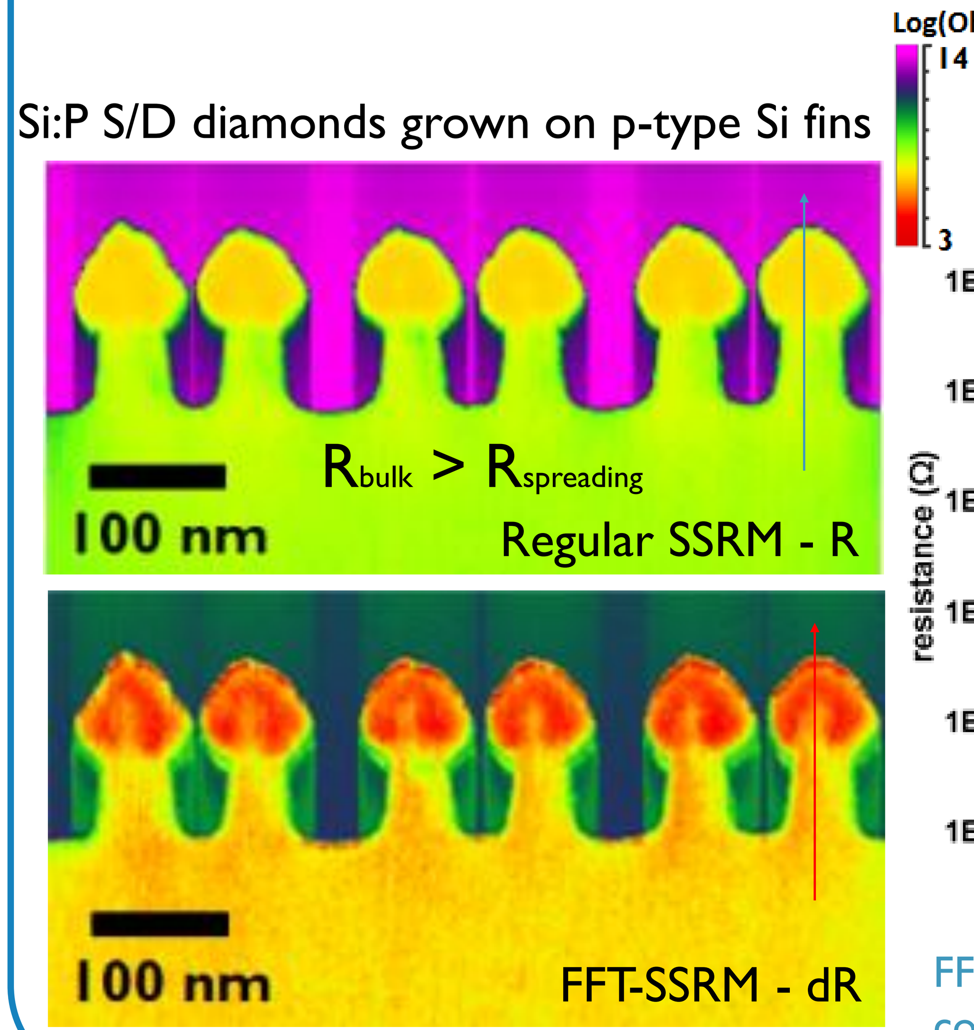
The tip-sample interaction force is modulated and a lock-in amplifier is used to extract the resistance amplitude at the modulation frequency.

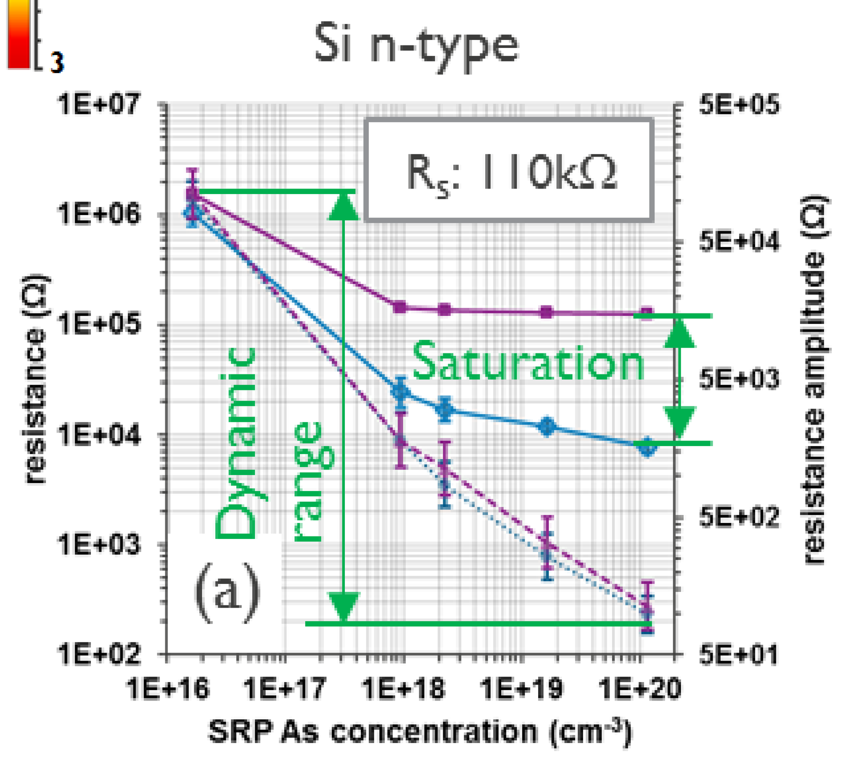
$R_{SSRM} = R_{contact} + R_{spreading} + R_{bulk} + R_{tip} + R_{back\text{-}contact}$

constant

$\Rightarrow dR \sim R_{contact} + R_{spreading}$

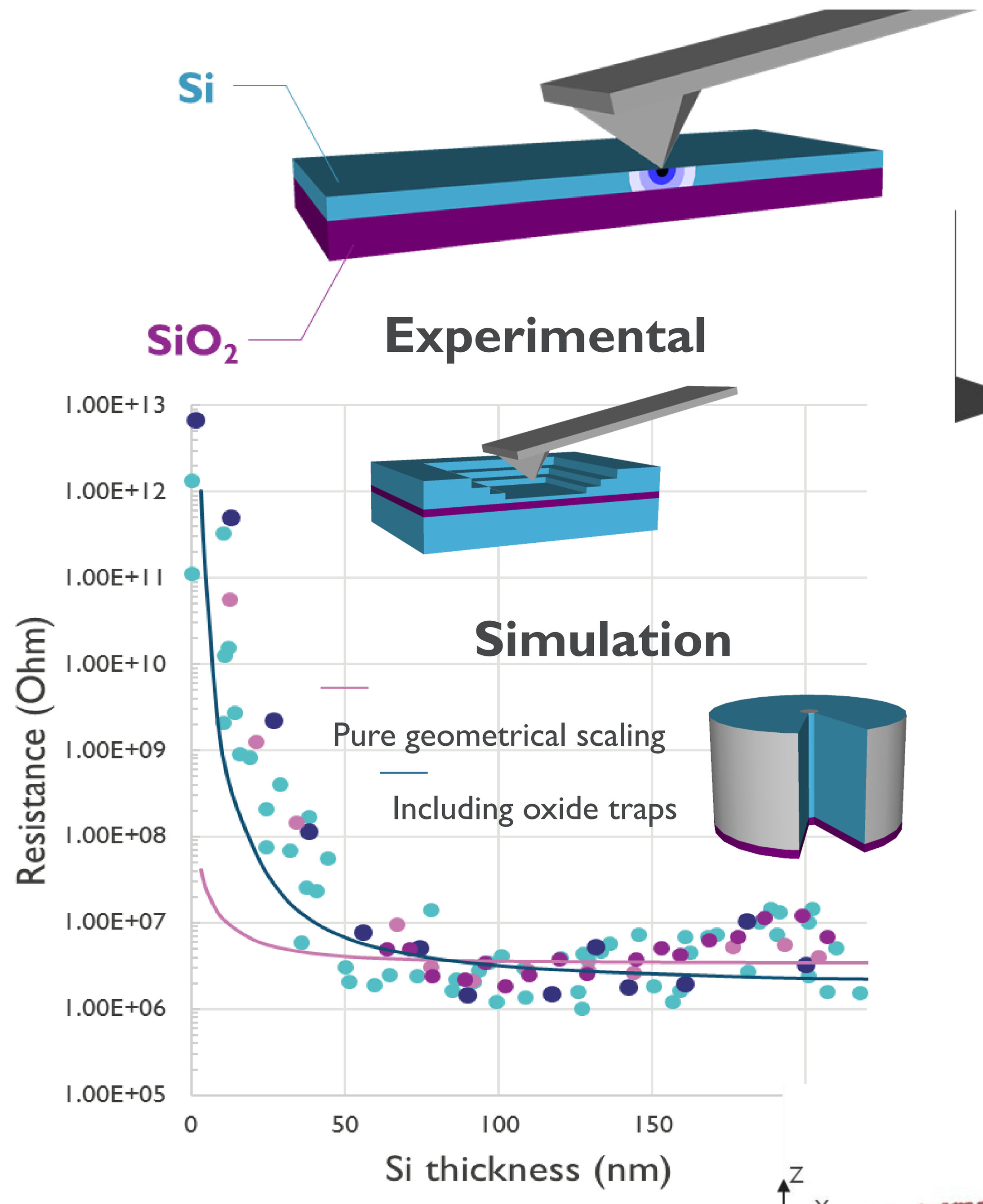
Si:P S/D diamonds grown on p-type Si fins

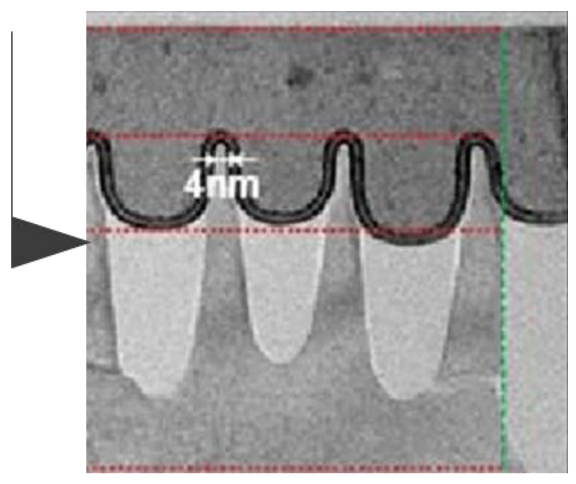




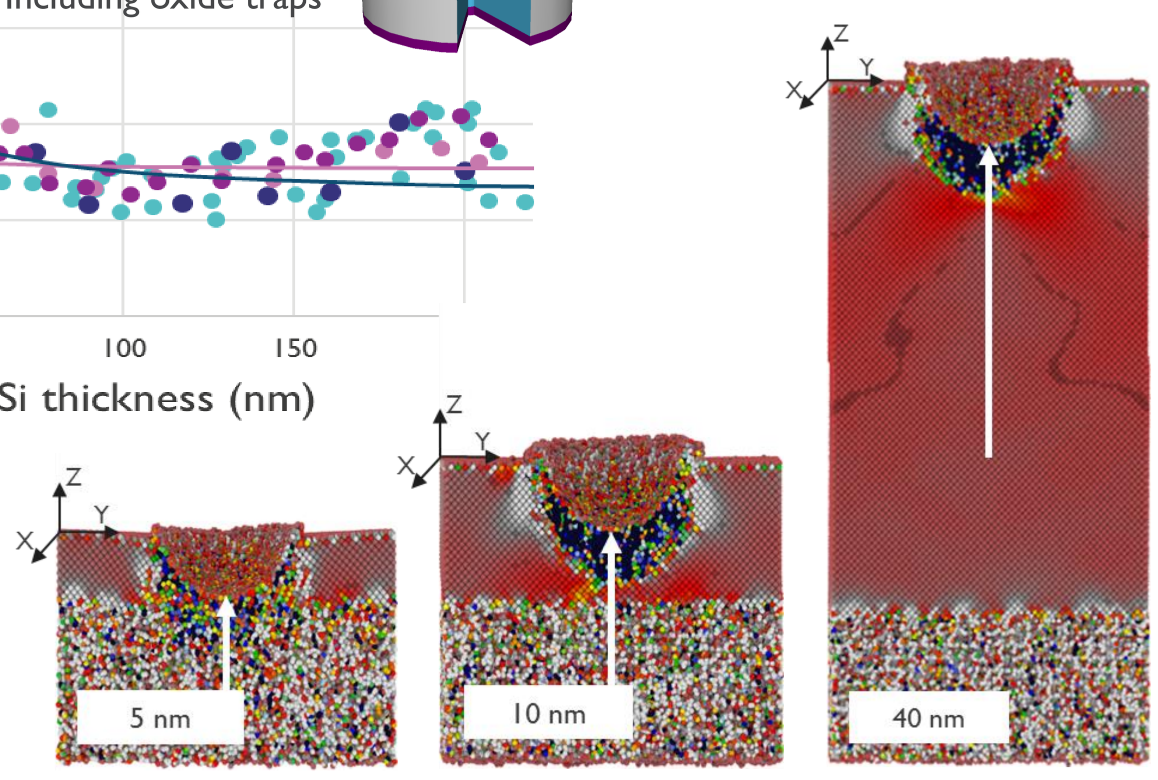
FFT-SSRM relaxes constraints on back contact for Si, Ge and III-V

3. Confined volumes



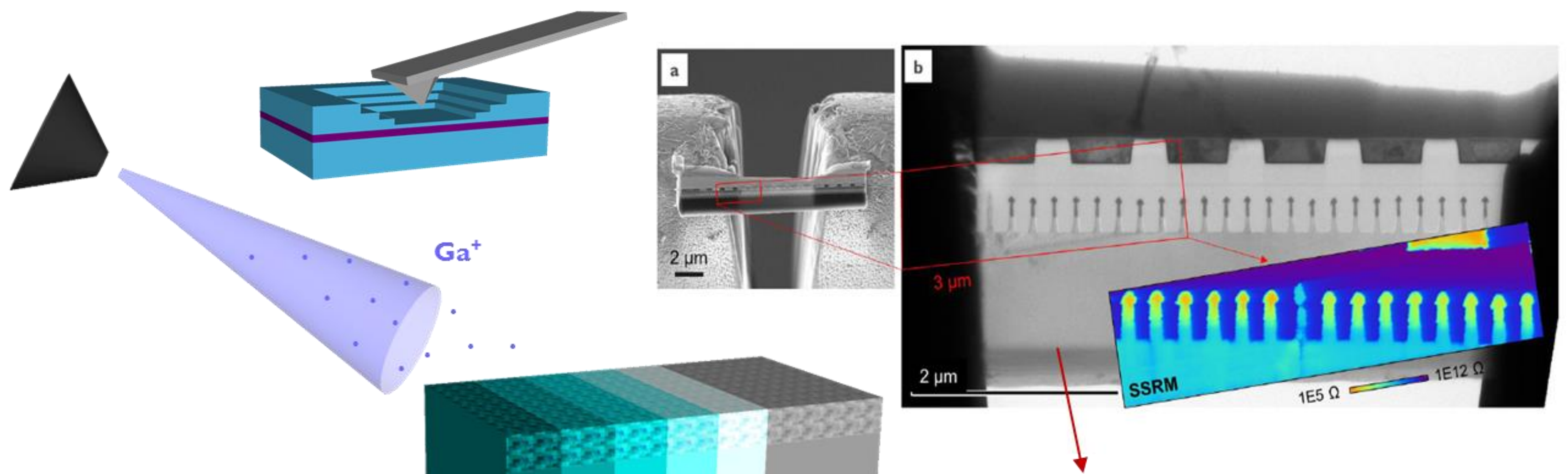


- Geometrical scaling < 20 nm
- Interface traps < 35 nm
- Experiment < 50 nm

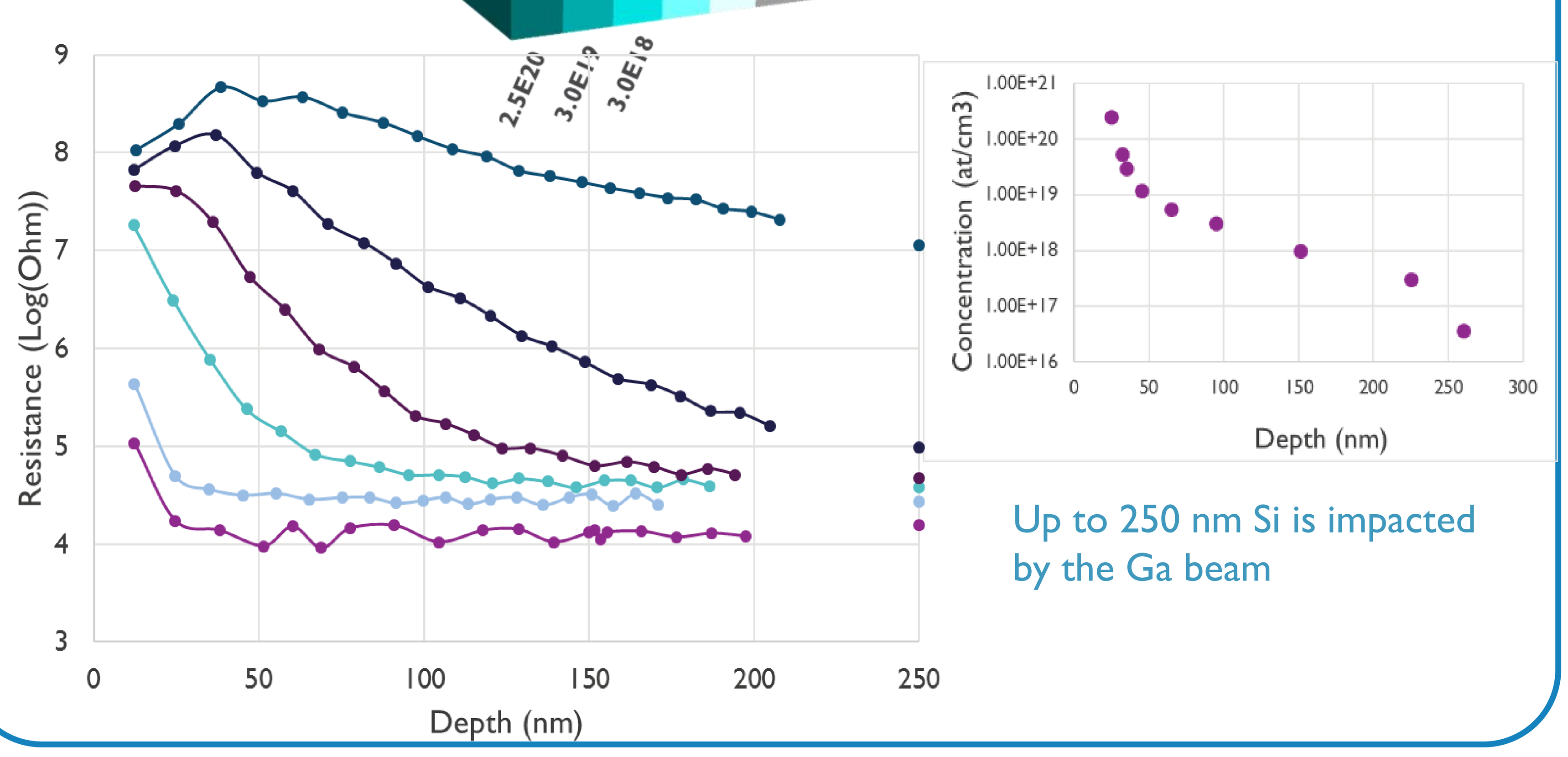


Oxide Absorbs Stress below 10nm

4. Single device analysis

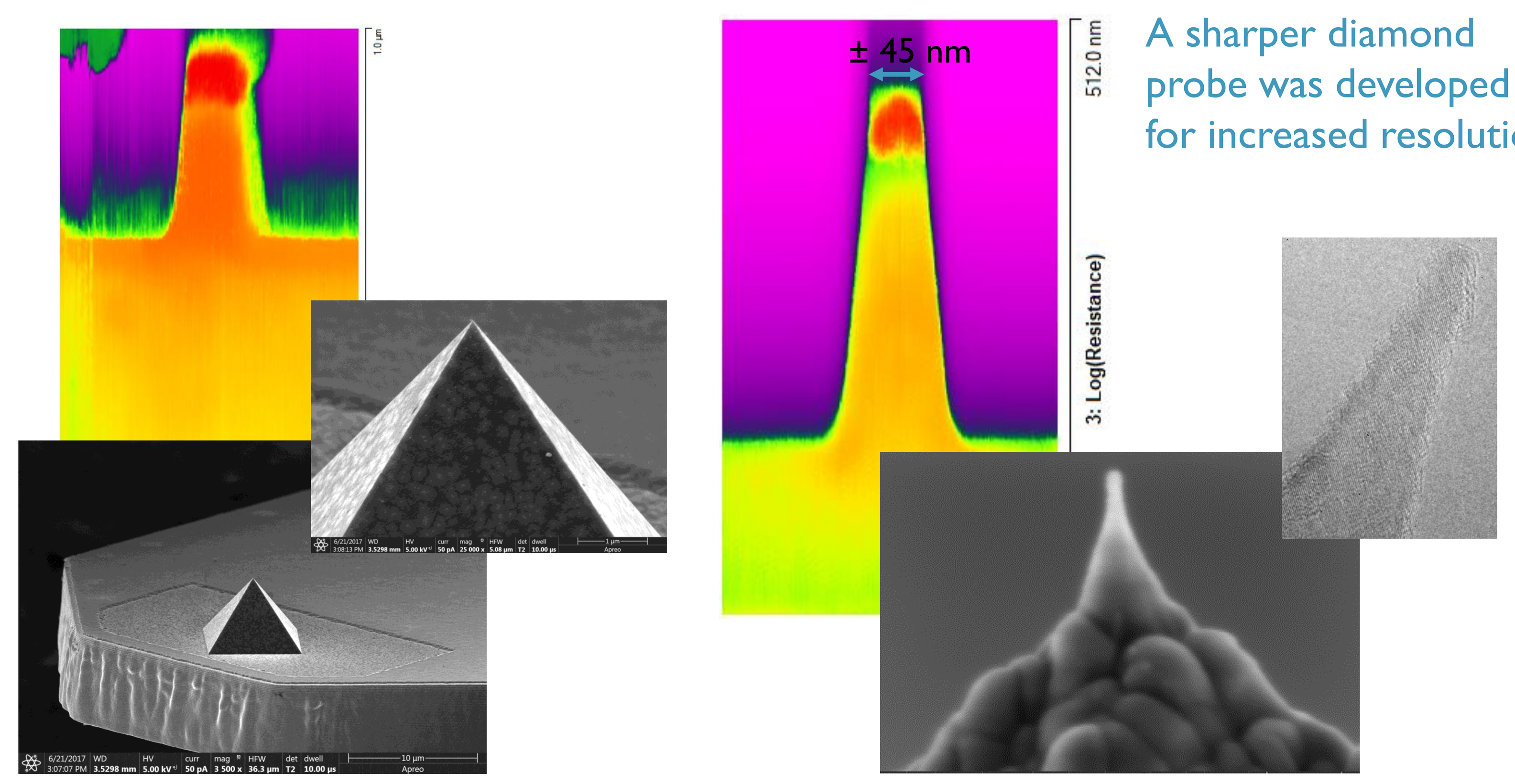


SSRM & TEM Analysis on the same lamella



Up to 250 nm Si is impacted by the Ga beam

5. Ultra sharp diamond probes



A sharper diamond probe was developed for increased resolution

6. Conclusion

This work discusses the challenges for SSRM when targeting nanoscale devices. FFT-SSRM provides a powerful improvement to regular SSRM, increasing sensitivity and relaxing the back contact quality. FIB is a promising method for future sample preparation and single device characterization, however it shows a huge impact on the measured resistance that cannot be neglected. Our studies also reveal the impact of interfaces to the measurement and the formation of the B-Sn pocket. A newly developed super sharp probe can further increase the resolution of SSRM.

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