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Process Quality Control of Large-Scale Silicon Sensor Productions for Future HEP Experiments

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Silicon sensors for applications in tracking and calorimetry for HL-LHC experiments will enter the series production stage in just a few years. To ensure the quality and stability of the manufacturing process, critical parameters must be monitored throughout sensor production. Important properties are measured directly on the sensors, but many process indicants cannot reasonably be studied on the real devices. Thus, a large part of process quality control is performed on small test-structures that are located on the empty parts of the wafer around the main sensor. For example, the expected properties of sensors exposed to high radiation doses in HEP experiments can be deduced directly from measurements of non-irradiated test-structures.

The presented work aims to optimize measurement techniques as well as test-structure layout to facilitate adequate monitoring of the process quality and provide extensive diagnostic tools to trace arising problems. We study different methods to extract critical process parameters like the full depletion voltage, bulk resistivity, doping concentration, and oxide charge concentration on non-irradiated p-type semiconductor devices. We look at ways to improve the performance and precision of measurement techniques using standard test-structures like diodes and MOS capacitors. Additionally, we study the reduction of test-structure size. Some process indicants cannot be measured with sufficient accuracy, if the corresponding test-structures become too small. We investigate this effect and look at ways of measuring sensitive parameters like the interstrip resistance on alternative, smaller test-structures. Conclusively, we present the compared results of the varying methods and give a first lookout on optimized process quality control for the upcoming HL-LHC sensor series production.

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