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Multiscale structural understanding through high-resolution X-ray diffraction methods in semiconductor materials

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Nano- and micro-sized structures such as nanowires and epilayers are used in many fields of application due to their excellent electrical and optical properties. These materials often exhibit complex geometries and manufacturing processes, which affect the crystal lattice coherence introducing strain and defects. The accumulation of defects and their mobility in these materials reduce the reliability of devices in applications, as the physical properties are connected to the crystal structure. Especially for nanomaterials used in extreme conditions such as space, the investigation of the crystal structure turns out to be fundamental.

Different systems of semiconductor materials ranging from silicon nanowires to CVD diamond layers, and bonded layers have been investigated through high-resolution X-ray diffraction methods to evaluate the impact of novel fabrication processes. Complementary characterization techniques such as micro-CT and confocal microscopy have been used to strengthen the results obtained via diffractometric analyses. To probe the elastic strain fields and lattice defects within materials, acquisition strategies and different analytical approaches for a multiscale analysis have been performed using both synchrotron and laboratory sources. Specific analytical tools were adopted and pushed to their limits after the collection of a variety of diffraction patterns. Methods such as reciprocal space mapping in 1-, 2-, and 3-dimensions were exploited to study the coherent and the diffuse component of the X-ray scattering. All analyses performed on the different semiconductor systems allowed the qualification and quantification of lattice strain and defects, confirming the success both in manufacturing processes and in the development of suitable analytical tools.

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