Functional materials in the light of *in situ* synchrotron X-ray diffraction

Thomas W. Cornelius

IM2NP UMR 7334 CNRS, Aix-Marseille University, Marseille, France

The functional properties of materials are strongly influenced by their crystalline state, including strain and defects. While strain and defects can sometimes be detrimental to these properties, their controlled application allows for elastic strain engineering and defect engineering. At the nanoscale, it has been shown that nanomaterials can exhibit ultra-high yield strength before entering the plastic regime, opening new possibilities for elastic strain engineering.

To better understand how crystalline structure, strain, and defects affect material properties at the nanoscale, it is essential to investigate these parameters under various external stimuli. X-ray diffraction is an ideal tool for studying the structure-property relationship due to its high sensitivity to crystalline structure, strain, and defects. Recent advancements in focusing optics at synchrotron sources now enable hard X-ray beams to be routinely focused down to the sub-100 nm scale, facilitating nanoscale or individual nanostructure characterization. *In situ* and *operando* measurements allow for real-time monitoring of structural variations in materials under mechanical stress, electrical fields, or thermal excitation. Furthermore, the current upgrades of 3rd generation synchrotrons to extremely brilliant 4th generation sources have increased the coherent flux by one to two orders of magnitude, significantly enhancing coherent X-ray diffraction imaging methods.

This work showcases *in situ* studies of the structural properties of materials using synchrotron X-ray diffraction methods, particularly during the application of mechanical or electrical stresses to ferroelectric materials and individual micro- and nanostructures.