# Mechanisms of plastic deformation in multiphase steels revealed using *in situ* high-energy synchrotron diffraction

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Although steels are more than 5,000 years old, they still belong to the most commonly manufactured and used construction materials. The main reasons for their popularity are their outstanding mechanical properties, *e.g.*, high elastic modulus, high yield strength or high ductility, which are frequently based on a multiphase nature of these typically thermodynamically metastable iron-containing alloys, and additionally enhanced by the presence of specific lattice defects, microstructure features and their mutual interactions. Examples of the steels utilizing the above phenomena are the dual phase steels with ferritic-martensitic microstructure, bainitic steels consisting of dislocation-rich ferrite and cementite ($Fe_3C$), the quenching and partitioning (Q&P) steels containing martensite and retained austenite, and the high-alloy stainless steels showing the transformation induced and/or twinning induced plasticity (TRIP/TWIP) effect.

As the mechanical properties of the multiphase steels are controlled by their phase composition and as they are strongly affected by the kind and density of the present lattice defects as well as by their interaction with other microstructure features like phase and grain boundaries, the in-depth microstructure characterization of these materials is essential to understand the relationship between the mechanical properties and the microstructure of these materials that is the first step towards the efficient materials design. As the microstructure of the multiphase steels varies typically during their deformation and/or thermal treatment, *in situ* techniques of microstructure characterization are required to explain the changes in the mechanical properties during material's processing and operation.

In the last decades, high-energy synchrotron diffraction methods were systematically developed, and became an established and powerful tool for *in situ* microstructure analyses of engineering materials. The high energy of the synchrotron radiation provides a large penetration depth of the primary beam into the interior of the material under study. This enables performing the diffraction measurements in the transmission mode that emphasizes the information coming from the bulk of the sample and makes large parts of the sample orientation space accessible. The short wavelength of the X-rays guarantees the accessibility of a large part of the reciprocal space even for a small range of the diffraction angles, *e.g.*, when working with a stationary two-dimensional detector. This is beneficial in particular for microstructure studies on materials with a small unit cell, where the microstructure information obtained from the *q* and *hkl* dependences of the line positions, line broadening and diffracted intensities measured in different macroscopic directions can be obtained.

In this contribution, the capabilities of the high-energy synchrotron diffraction in transmission mode and the information content of the two-dimensional diffraction patterns will be illustrated on the example of the TRIP/TWIP steels studied *in situ* during the deformation tests. It will be shown, how a microstructure-model-based evaluation of the line positions, line broadening and diffracted intensities along the entire Debye rings can unveil the formation of perfect dislocations in metastable austenite ($Fm\bar{3}m$), their dissociation to Shockley partials, the formation, widening and partial ordering of stacking faults on the {111} planes, the directionally dependent phase transformation of austenite to ε-martensite ($P6_3/mmc$) and to α'-martensite ($Im\bar{3}m$), and the preferential orientation of crystallites in individual phases. In this context, the impact of the interaction between the strain fields generated by individual lattice defects and the microstructure features on the stress factors used for the description of the stress state in continuously deformed samples will be discussed.

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