A5 Microstructure and Mechanism Maps

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Plan 3. Phase

Objective

- The microstructural effect will also be taken into account to predict the deformation mechanism in steels with multiphase matrix.
- The synchrotron x-ray diffraction methodology will be introduced for a detailed understanding of microstructural evolution during deformation and along heat treatment cycles.

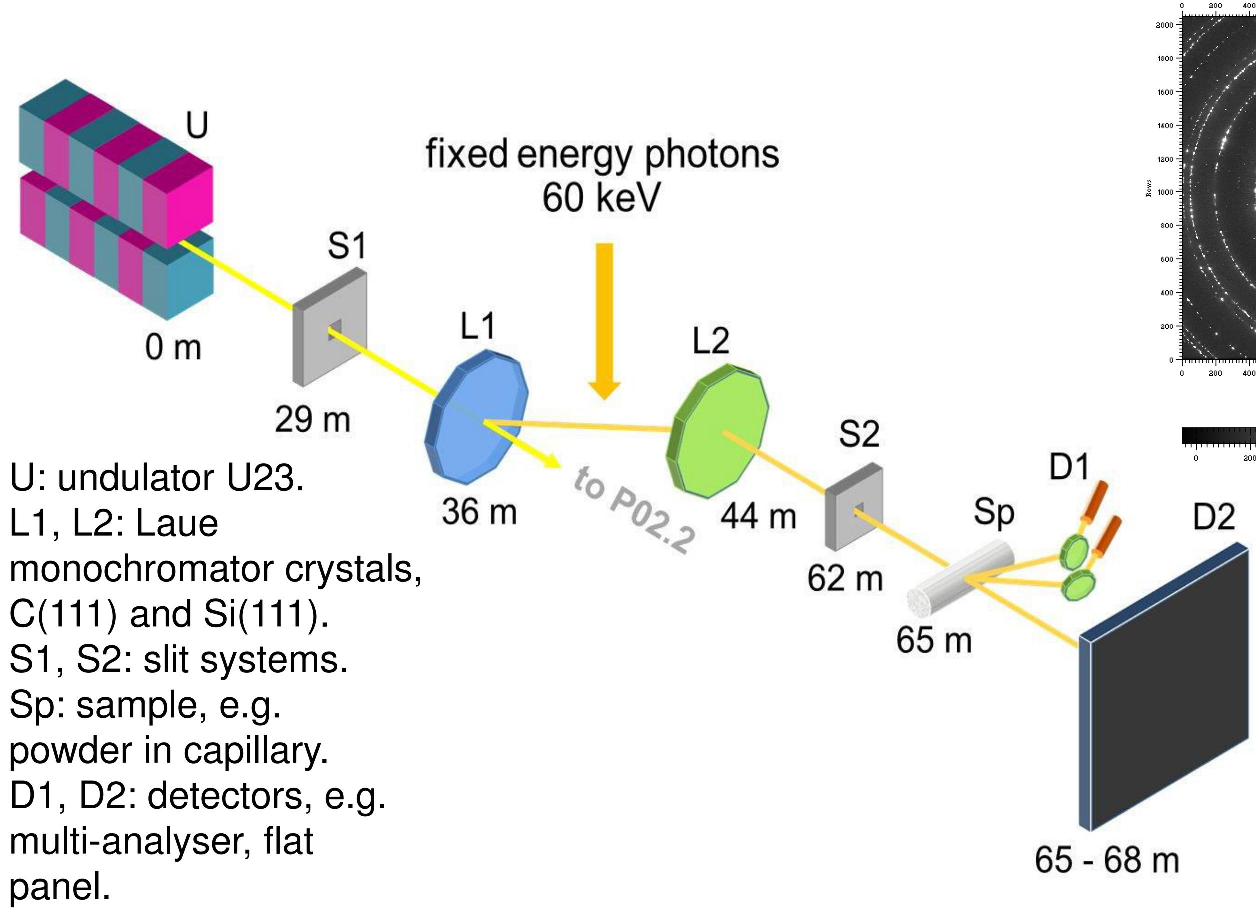
Microstructure	Deformation mechanism	Control parameters
γ	SLIP TRIP TWIP	SFE • Thermodynamic calculation
γ + Kappa phase	MBIP	SFE + κ morphology +size effect • Thermal equilibrium • Synchrotron methodology • Atom probe tomography
γ + α'	SLIP (α') SLIP TRIP TWIP	SFEγ + elemental partitioning +size effect • Thermal equilibrium • Phase field modelling • Atom probe tomography

- Deformation mechanism (SLIP/TRIP/TWIP) = f (chem., T)
- Deformation mechanism (SLIP/TRIP/TWIP + MBIP) = f (chem., T, pre-treatment (T, t))
- Deformation mechanism + microstructure = f (chem., T, pre-treatment (ε, T, t))

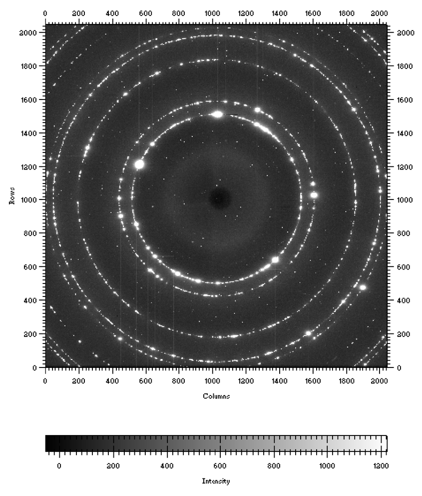
Overview of the material design by the upgraded deformation mechanism maps

New methodology

- Beam time at DESY has been allocated.
- The first measurements have been done.



U: undulator U23.
L1, L2: Laue monochromator crystals, C(111) and Si(111).
S1, S2: slit systems.
Sp: sample, e.g. powder in capillary.
D1, D2: detectors, e.g. multi-analyser, flat panel.



High resolution synchrotron X-ray powder diffraction for the characterization of polycrystal materials.

Input

A1
Gibbs free energy state for a quaternary (FeMnAlC) system

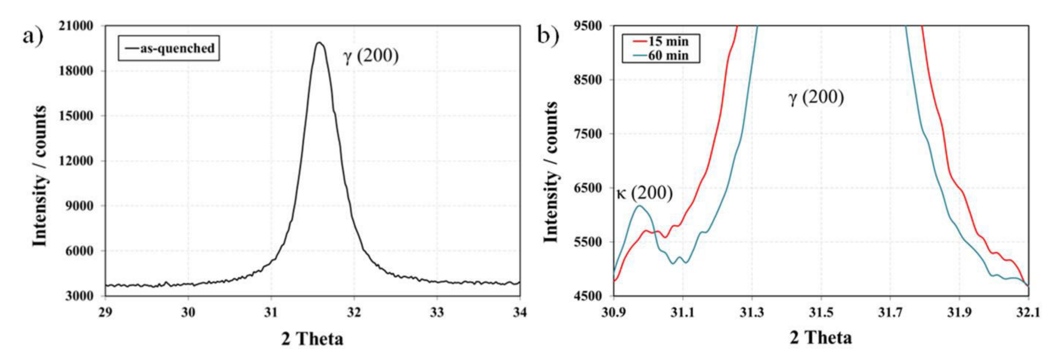
A2
CalPhaD stacking fault energy

A3
Thermodynamic data for kappa phase equilibrium

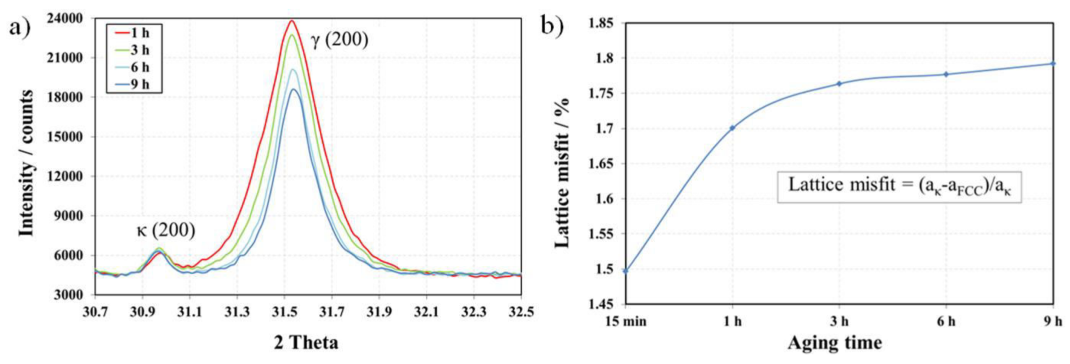
C1
EBSD, HRTEM

C3
Combinatoric alloy design in Fe-Mn-Al-C system

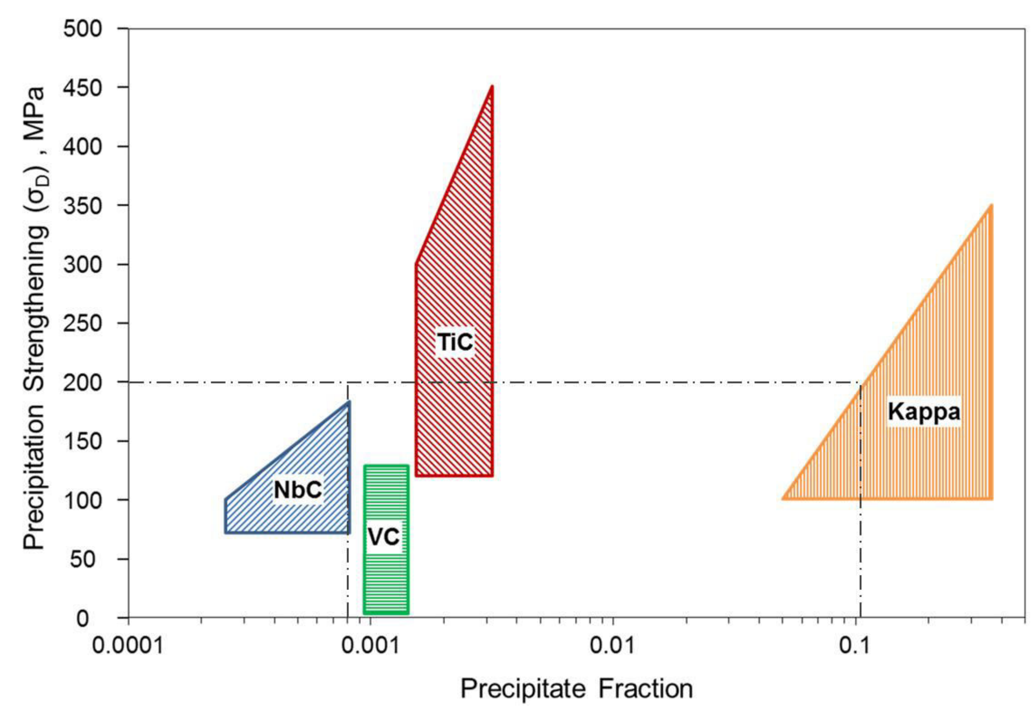
Example in WP1: *What is the formation mechanism of kappa phase and how does it influence the strain hardening behavior of MBIP steels?*



- ❑ The long-range ordered kappa phase already starts precipitating from the austenitic matrix as early as 15 min during aging at 600 °C in Fe-30Mn-8Al-1.2C steel.



- ❑ Up to 9 hours aging, the lattice misfit between the kappa phase and the austenite matrix still maintains being very small (less than 2 %) which may lead to an effective coherent precipitation hardening.



- ❑ The Fe-30Mn-8Al-1.2C alloy exhibits an improved combination of strength and ductility, with respect to conventional HSLA, DP and TRIP steels.

	$\Delta\sigma_y$	ΔA
HSLA	200 MPa	-50%
MBIP ?	200 MPa	-5%

Output

A7/A10/B1/B2/B4/B6
SFE and mechanism maps

A8
Phase field simulation

C6
Multiaxial/cyclic properties of HMnS

C8
Diffraction data for coherence stress assessment

C10
Tensile properties (under high strain rate) of MMnS

Goal/Impact

- ❑ **Extension of mechanism maps (precipitation, microstructure evolution, κ-phase)**
- ❑ **Simulation of microstructure evolution using phase field models**
- ❑ **Validation of mechanism maps in the design of multiphase steels (MMnS)**

Work package

- **WP1: Synchrotron X-ray diffraction of kappa phase precipitation.**
- **WP2: Experimental validation of modeling results by atom probe tomography, EBSD and metallography.**
- **WP3: Phase field modeling of microstructure evolution during phase transformations in MMnS steels.**
- **WP4: Integration of the microstructural and partitioning features into Microstructure- and mechanism maps.**

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