ESRF	**Experiment title:** Stability of individual grains in low alloyed TRIP steels under combined thermal and mechanical stimuli	**Experiment number**: MA-829
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Report:

Low-alloyed transformation-induced plasticity (TRIP) steels have attracted significant interest for automotive applications due to their high strength and good formability. At room temperature, TRIP steels exhibit a microstructure composed of ferrite, bainite and retained austenite, where the austenite is present in a metastable state. The remarkable combination of strength and ductility comes from the stress-induced transformation of the metastable austenite into martensite.

The aim of this experiment was to monitor in-situ the stability of individual austenite grains embedded within the complex multiphase TRIP steel under applied stress at different temperatures (from room temperature down to 150 K). We have performed synchrotron X-ray diffraction measurements in transmission geometry at the ID11 beamline using a high energy of 88 keV. Two types of experiment were performed: (1) powder diffraction measurements with a relatively large beam of 100×100 μm^2 to obtain the average response of the phases and (2) microbeam diffraction experiments with beam sizes of 20×20, 30×30 and 40×40 μm^2 in order to monitor single diffraction peaks from individual metastable austenite grains. A dedicated microtester with a maximum load of 2 kN was used to perform in-situ tensile tests. The tester was recently modified to allow the samples to be cooled under vacuum. This modification was tested successfully during the present experiment and allowed us to simultaneously monitor the influence of applied stress and variable temperatures on the stability of the metastable austenite grains.

The chemical composition of the studied TRIP steel was 0.22C-1.54Mn-0.27Si-0.02P-1.75Al (wt.%). The material was machined into cylindrical samples with a diameter of 1 mm and a gauge length of 10 mm. The scattered intensity was recorded on a 2D detector (CCD) placed behind the sample at a distance of about 35 cm. The diffraction patterns were recorded continuously during a rotation of 0.25° around the tensile axis perpendicular to the X-ray beam. Equivalent rotation steps were repeated to cover a total angular rotation range of 90° on each side of the tester (in total an angular range of 180° was monitored).

Temperatures of 298, 213 and 153 K were selected to perform in-situ tensile tests. After reaching the selected temperature, the samples were strained in steps of 10-30 μm. After each deformation step, the displacement of the sample with respect of the beam was monitored by scans in the horizontal and vertical sample positions, and the sample rotation. The intensity of a selected reflection from a stable ferrite grain (used as a reference grain) was used in these scans to retrace the same illuminated sample volume during the entire experiment. A LaB_6 standard was placed on the surface of the TRIP steel sample to assess possible variations in the sample-to-detector distance during the tensile experiment. The three microbeam sizes of 20×20, 30×30 and 40×40 μm^2 were used in order to validate whether individual reflections originate from a completely illuminated grain.

The powder diffraction patterns have been analyzed by the Rietveld method after transforming the recorded 2D diffraction patterns into 1D data with Fit2D. This allowed us to simultaneously analyze seven ferrite reflections and eight austenite reflections. Fig. 1 shows the average response of the constituent phases of the TRIP microstructure as a function of strain at room temperature and a temperature of 213 K, together with the overall response of the material. Fig. 1a shows the macroscopic stress-strain curve at both temperatures and Fig. 1b the austenite fraction as a function of the applied strain. The initial amount of metastable austenite is around 10% for both samples. By decreasing the temperature to 213 K about 3% of the austenite transforms into martensite. The austenite fraction subsequently transformed by tensile strain is about 3% at room temperature and about 7% at a temperature of 213 K. Related to that, the macroscopic elongation increases for a higher austenite fraction transformed. This indicates that temperature has a pronounced influence on the TRIP effect. In Fig. 1c and 1d, the corresponding change in average lattice parameter of austenite and ferrite are shown, respectively. Cooling results in a significant change in lattice parameter for both phases, caused by the thermal expansion (and the austenite transformation). The strain partitioning between the austenite and ferrite phases is found to be strongly influenced by the progressive transformation of metastable austenite into martensite.

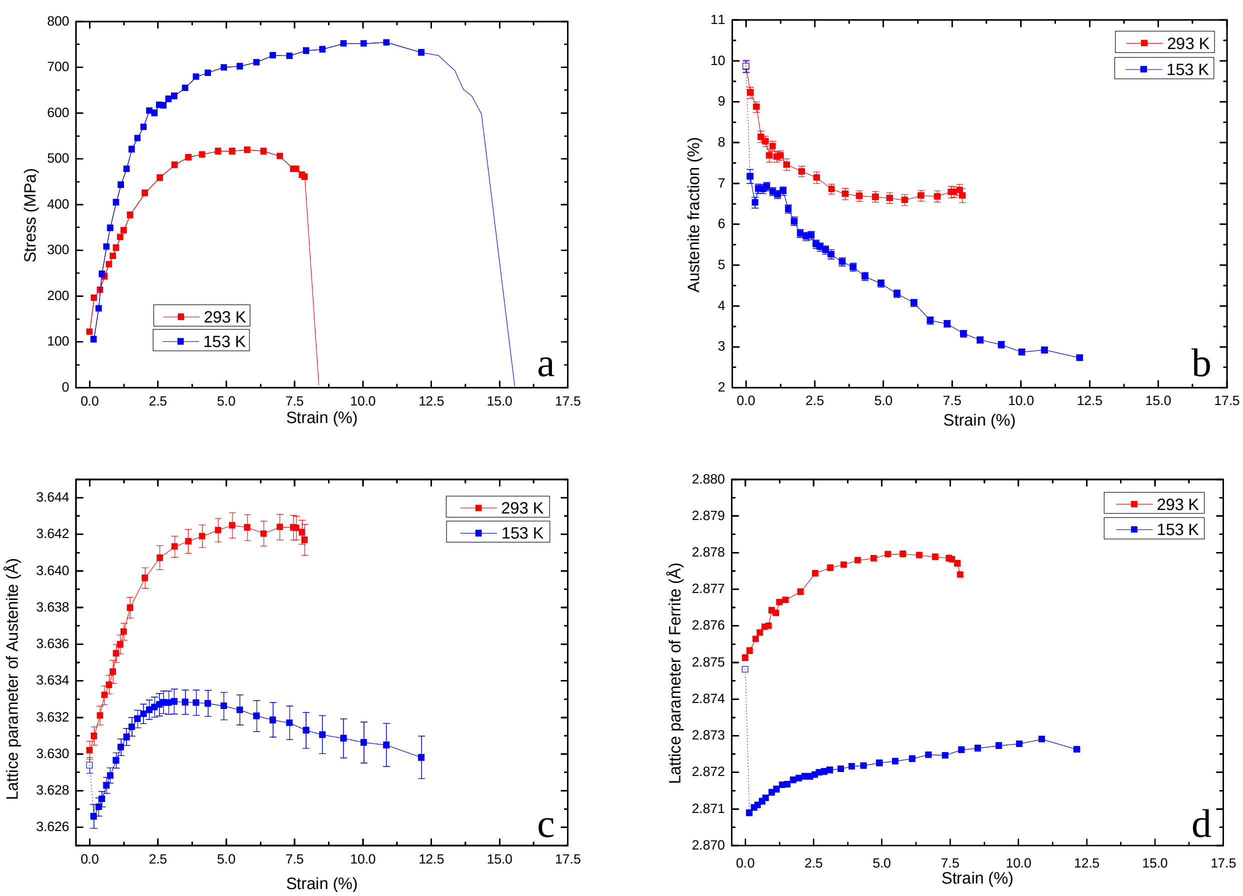

Figure 1: (a) Stress-strain curve of the studied TRIP steel at a temperature of T = 293 and 153 K. (b) The fraction of metastable austenite, (c) the average austenite lattice parameter and (d) the average ferrite lattice parameter as a function of the applied strain at T = 293 and 153 K. The effect of cooling is indicated by the dotted line (room temperature data are indicated by an open symbol).

The analysis of the mechanical stability of single grains at different temperatures is in progress.