

# 151 Martensite crystallography and chemistry in dual phase and fully martensitic steels

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## Abstract

The crystallography and alloying element distribution of lath martensite in DP steel has been studied by electron backscattered diffraction, transmission electron microscopy, and atom probe tomography. Its implications for lath martensite plasticity have been investigated.

## Introduction

Lath martensite is important in industry because it is the key strengthening component in many advanced high strength steels.[1,2] The study of crystallography and chemistry of lath martensite is extensive in the literature, however, mostly based on fully martensitic steels.

## Methods

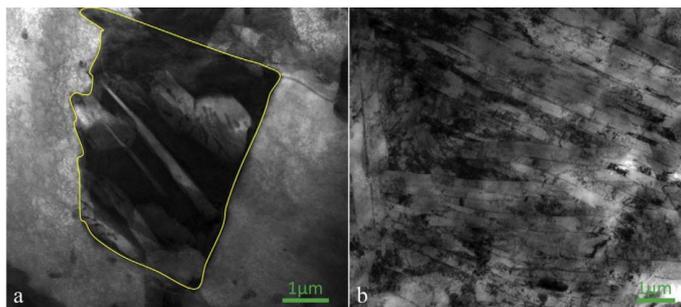
Lath martensite in dual phase steels is investigated focusing on substructure identification of martensite islands and microstructural bands using transmission electron microscopy and electron backscattered diffraction, see, e.g., Figs. 1 and 2, and on the influence of the accompanied tempering process during industrial coating process on the distribution of alloying elements using atom probe tomography, see, e.g., Fig. 3.[3] The micro-mechanics of lath martensite in DP steel was studied with micro-tensile testing.[4]

## Results

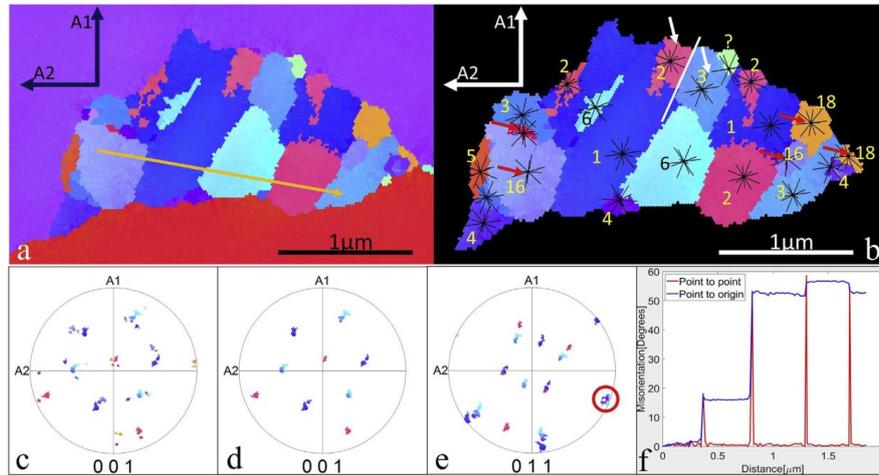
Unlike findings for the fully martensitic steels, no martensite islands with all 24 Kurdjumov-Sachs variants were observed. Almost all martensite islands contain only one main packet with all six variants and minor variants from the remaining three packets of the same prior austenite grain. Similarly, the martensite bands are typically composed of connected domains originating from prior austenite grains, each containing one main packets (mostly with all variants) and few separate variants. The effect of tempering at ~450°C (due to the industrial zinc coating process) was also investigated. The results show a strong carbon partitioning to lath boundaries and Cottrell atmospheres at dislocation core regions due to the thermal coating process. In contrast, auto-tempering contributes only limited to the carbon redistribution.[3]

The substitutional elements are all homogenously distributed. The phase transformation process has two effects on the material: mechanically, the earlier-formed laths are larger and softer and therefore more ductile (as revealed by nanoindentation); chemically, due to the higher dislocation density inside the later-formed laths, which are generally smaller, carbon Cottrell atmospheres are predominantly observed.[3]

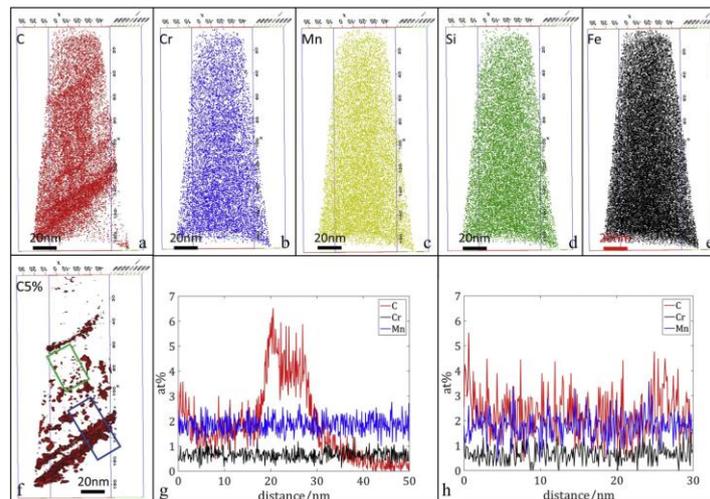
The implication of this particular crystallography of lath martensite of the possible plasticity mechanisms of lath martensite have been investigated.[4,5,6] Two deformation mechanisms of lath martensite were identified, namely, intra-lath crystallographic slip and apparent substructure boundaries sliding, that compete with each other to carry the overall plasticity. The probability for sliding of lath martensite boundaries was estimated by boundary orientation characterization and micro-tensile tests. The results suggest that the apparent boundary sliding is important for lath-martensite-containing multi-phase steels, which would explain prior reports in the literature of unexpectedly high local strains in the martensite regions.[6]



**Figure 1:** TEM image of lath martensite from (a) commercial DP 600 steel and (b) fully martensitic (FM) steel. The island marked with the yellow line is lath martensite in (a). The laths with parallel length directions in (b) are likely belonging to the same packet.[3]



**Figure 2:** (a) Typical EBSD measurement of a lath martensite island in DP steel. The small martensite grains are identified in (b).  $\{110\}$  plane traces are marked for every block for identification of the variants belonging to the same packet. (c)  $\{001\}$  pole figure of the complete area. (d)  $\{001\}$  and (e)  $\{110\}$  pole figure of only the variants V1–V6. The projection point marked in red denotes the common habit plane. (f) Relative and absolute misorientation values along the orange arrow in (a).[3]



**Figure 3:** 3D element distribution maps of specimen DPCA taken from early-formed martensite in DPC. (a) Inhomogeneous layerwise C distribution is visible. (b–d) Substitutional elements (Cr, Mn, Si) distribution and (e) map of the base element Fe. (f) Iso-surfaces of C with 5 at.% of specimen DPCA. (g, h) the element distribution proxigram in the highlighted blue and green volumes in (f).[3]

## Conclusions

The crystallography and alloying element distribution of lath martensite in DP steel has been studied in detail by EBSD, TEM, and APT. Its implications for the different lath martensite plasticity mechanisms have been investigated. These results sheds new light on lath martensite literature, triggering interesting questions.

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