Kinetics and mechanism of austenite decomposition in carbonitrided low-alloy steel

Hugo P. Van Landeghem[1,2], Simon D. Catteau[2,3], Julien Teixeira[2], Jacky Dulcy[2], Muriel Véron[1], Abdelkrim Redjaïmia[2], Sabine Denis[2], Marc Courteaux[3]

[1] Univ. Grenoble Alpes, CNRS, Grenoble INP, SIMAP, F-38000 Grenoble, France

[2] Institut Jean Lamour, UMR CNRS-Université de Lorraine 7198, F-54000 Nancy, France

[3] PSA Peugeot-Citroën, Centre Technique de Belchamp, F-25420 Voujeaucourt, France

Email: hugo.van-landeghem@grenoble-inp.fr

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Gear applications typically require high wear and fatigue resistance in order to optimize service times. This combination of properties is obtained by carburizing or carbonitriding of low alloy steel. In particular, the latter has notably been proved more effective than the former [1]. For this reason, carbonitriding is widely deployed in the industry. In spite of that, the metallurgical origin of the observed property improvements with the addition of nitrogen remains poorly understood. While the literature dealing with the effect of carbon content on the microstructural evolution of low-alloy steel is rather comprehensive [2], such is not the case for nitrogen.

In order to better understand the effect of nitrogen on austenite decomposition in low alloy steel, specimens of 23MnCrMo5 were homogeneously enriched in either nitrogen, carbon or both and were isothermally transformed at temperatures ranging from 200 °C to 750 °C after re-austenitization. The transformation progress was monitored *in-situ* by HEXRD and *post-mortem* microstructures were characterized using SEM and TEM. In all cases, nitrogen reduces the incubation time of the transformation of austenite into ferrite and speeds up its completion.

In nitrogen containing samples, large volume fractions of CrN, both inter- and intragranular, were observed at all temperatures with different morphologies and wide size distributions. The size and shape of these nitrides depend on the stage of the thermal schedule at which they form. It has also been shown that other nitrides precipitate during the various stages of the treatment, notably AlN, VN and $MnSiN_2$. Those other nitrides precipitate heterogeneously on grain boundaries or other preexisting nitrides.

For all interstitial contents, the range of transformation temperatures can be split in two based on the morphology of the ferritic product, the delimiting temperature being assimilated to B_S. Ferrite formed either as equiaxed grains at higher temperature or laths at lower temperature.

Above Bs, nitrogen leads to a pronounced refinement of the ferritic microstructure at identical carbon content. Combined with the absence of incubation for ferrite nucleation, this suggests that CrN precipitated in austenite during nitriding stimulate the nucleation of ferrite. This hypothesis is supported by the Baker-Nutting orientation relationship and the coherent interfaces $(100)_{CrN}//(100)_{\alpha\text{-}Fe}$ observed between ferrite and coarse CrNs. The ferrite that is formed is still supersaturated in nitrogen and numerous (~10^{22} m^{-3}) CrN platelets precipitate intragranularly. This intense precipitation is thought to be mostly responsible for the enhanced hardness of nitrogen-containing materials over nitrogen-free ones in this range of temperature.

Below Bs, the presence of nitrogen changes the arrangement of the ferrite laths which do not show an organization in packets or sheaves. Instead, the laths are strongly entangled in a fashion reminiscent of acicular ferrite, but at a much finer scale. The presence of nitrogen also seems to inhibit the formation of cementite, which is found in nitrogen-free specimens at similar carbon content. Additionnally, it also causes very intense nanotwinning of the ferrite laths. Those twins are thought to be transformation twins as the only two twins found in each twin set are those that verify the Kurdjumov-Sachs orientation relationship with the parent austenite.

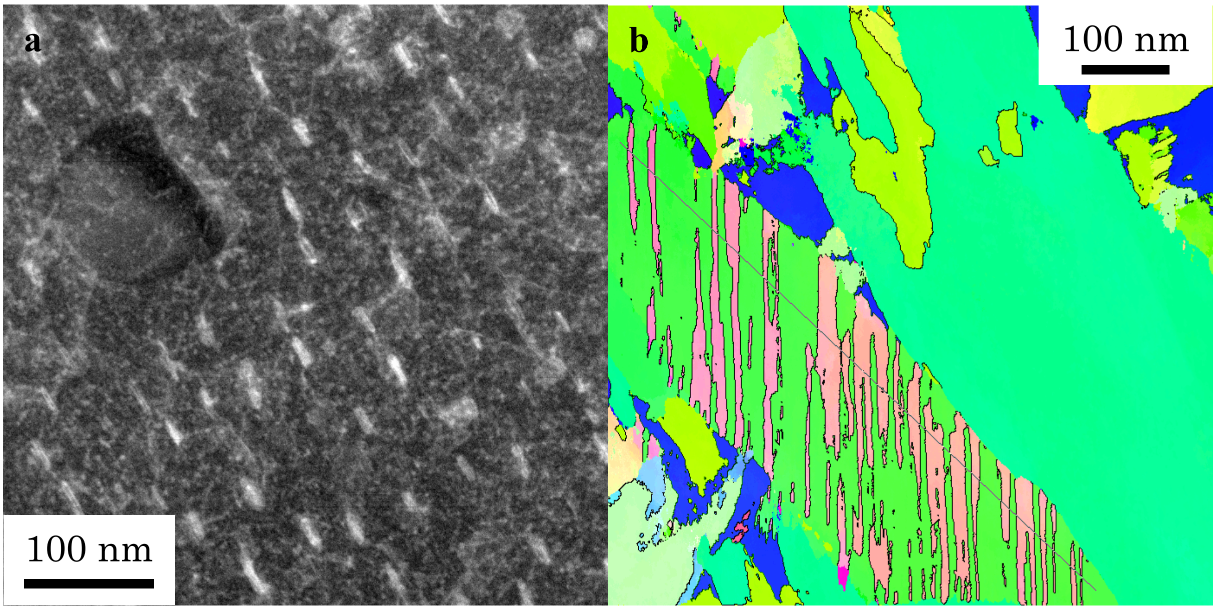

Figure 1 *– a) Annular dark field scanning transmission electron micrograph of a 23MnCrMo5 specimen transformed at 650 °C (> B_S) for 3 h (ZA = $[001]_{\alpha\text{-}Fe}$) showing two CrN morphologies: a coarse spheroid (dark) and fine platelets (bright). b) Ferrite orientation map in a carbonitrided 23MnCrMo5 specimen transformed at 400 °C (< B_S) for 2 h showing abundant nanotwins.*

References

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