

The growth kinetics and the structure of expanded austenite in AISI316L stainless steels characterized by in-situ XRD

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Introduction and objectives

Austenitic stainless steels are cheap, reasonably corrosion resistant materials with good workability. Their low hardness however leads to wearing and low lifetime [1]. Expanded austenite (EA) can be formed by low temperature N/C treatment. In EA N/C atoms occupy a large fraction of the interstitial sites [2] without the formation of nitrides/carbides, thus conserving the good corrosion resistance.

Recently significant effort is contributed to understand the properties of the EA, but it is far from being a closed topic. Key difficulties lie in the fact the multiple phenomena (diffusion of different species, trapping by matrix atoms e.g) happens parallel to each other, in a material with sharp composition and stress gradients [3].

We carried out experiments to study the growth of EA layer. Our central question was whether the process is diffusion limited or not? If diffusion limited, is it possible to characterize the process by a single (inter)diffusion coefficient? If other phenomena controls the growth of the EA is it possible to determine which?

Materials and methods

We used AISI316L stainless steel samples which were de-passivated ex situ and protected by a Ni layer on their surface. We carried out in-situ nitrocarburising in a custom built chamber (see Fig. 1). This chamber was attached to a Bruker D8 Advance diffractometer, with a Cu K α source and a Vantec-1 PSD. Mixtures composed of four different gases (N₂, H₂, NH₃ and C₂H₄) can be applied at atmospheric pressure. The maximum possible temperature is 600 °C.

We collected data in the 35-45° 2 θ range, including the 111 peaks of both the γ -Fe and EA. The thickness of the EA was determined by intensity loss of the γ -Fe peak. The EA is modelled as a multilayer stack, where each 0.5 μ m thick layer has a homogeneous lattice parameter. The EA XRD peak was fitted by Gaussians.

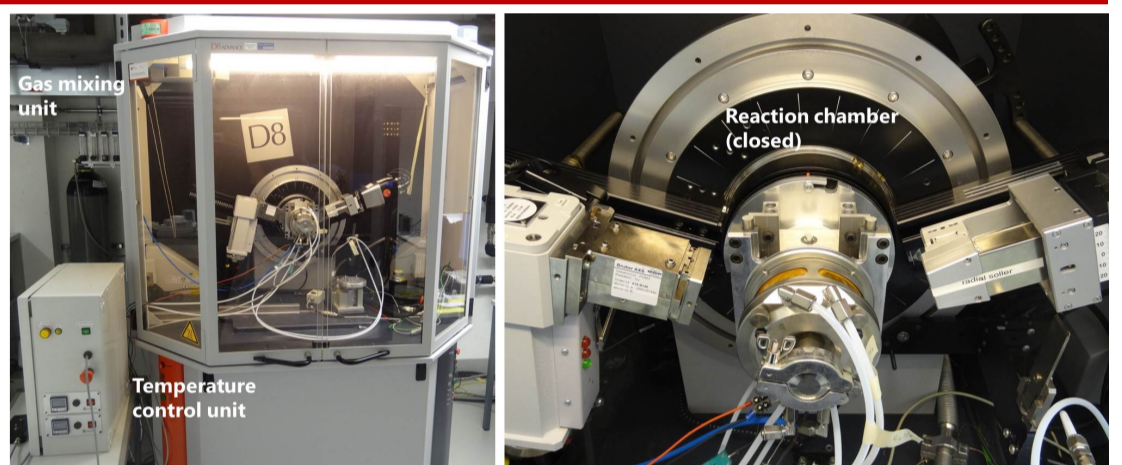


Figure 1: The reaction chamber attached to the diffractometer (right) and the control units of the nitrocarburizing process (left).

Results

As expected, the γ -Fe signal is reduced during the processing while the EA signal has grown and shifted towards lower angles. The linear-parabolic model offered a good description for the growth of the EA (Fig. 2).

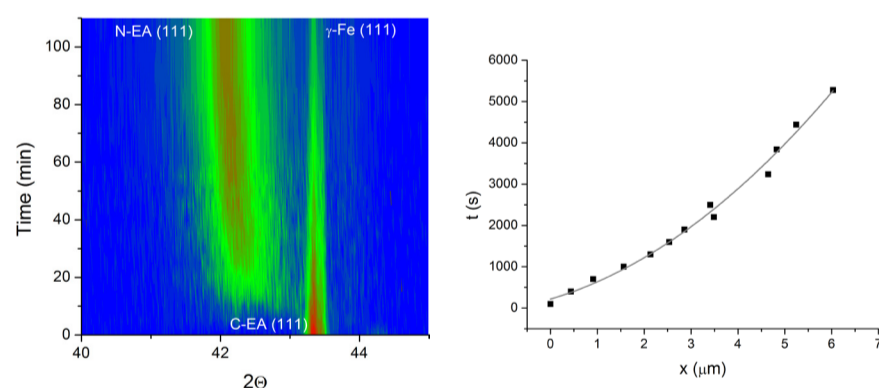


Figure 2: The evolution of the XRD spectra (right) and the growth rate fitted by the linear-parabolic model (right). Processing temp: 400 °C.

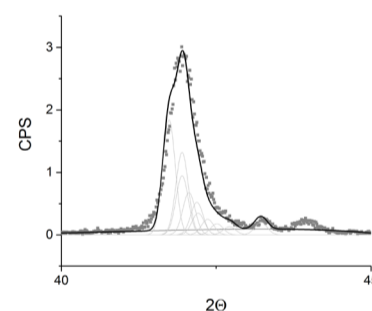


Figure 3: The EA and the γ -Fe peak fitted with a series of Gauss-funtions. The peak on the right hand side is from the Ni layer on the surface.

From the above fitting it was possible to model the lattice parameter at different depth (at different times). Fig. 4 a-c show the results of this for the 380 °C processing. After the Boltzmann-transformation it is clear that the interface between the base material and the EA “does not move” (Fig. 4b). Normalizing with the lattice expansion of the first layer leads to “master curve”.

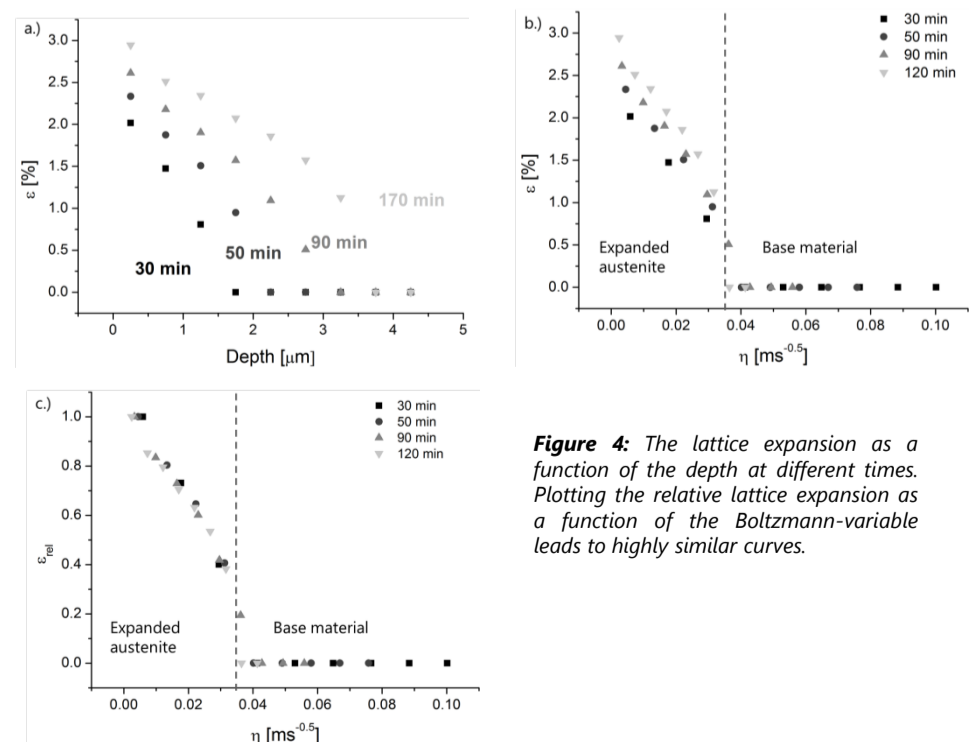


Figure 4: The lattice expansion as a function of the depth at different times. Plotting the relative lattice expansion as a function of the Boltzmann-variable leads to highly similar curves.

Fig. 3 shows an example of the peak fitting. The peak position was the only free parameter in the fitting procedure.

Conclusions

Our results indicate that two processes plays a key role in the growth. The thickness is determined by diffusion within the layer, while the exact composition by the uptake at the surface.

Literature :

- [1] J. Buhigar et al., Surf. Eng. 23 (2007) 313.
- [2] T. Christiansen, M.A.J. Somers, Metall. Mater. Trans. A, 37 (2006) 575.
- [3] D. Manova, et al., J. Phys. D: Appl. Phys., 47 (2014) 365301.