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Oxide Scale Evolution and Breakaway Oxidation in Mn-Rich AISI 201LN Stainless Steel

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Introduction

High-temperature oxidation resistance in stainless steels relies on a protective Cr_2O_3 scale . However, in low-nickel AISI 201LN, replacing Ni with Mn promotes less protective, spallation-prone Mn-rich oxides and Mn–Cr spinels (Jiao; Zhang; Wen, 2019; Ma et al., 2013, Bamba et al., 2006). Despite its widespread industrial use, the oxidation behavior of commercial AISI 201LN remains poorly understood, as previous studies focused on model alloys with high silicon contents (>3 wt.% Si).

Objectives

- Evaluate the oxidation behavior of commercial AISI 201LN stainless steel exposed to static air at 700, 750, and 800 °C for up to 300 hours;
- Characterize the transition from an initially partially protective Mn- and Cr-rich oxide scale to catastrophic Fe-rich oxidation (breakaway oxidation);
- Determine the impact of the low silicon content and the influence of residual δ-ferrite on the stability of the protective oxide scale.

Methodology

- Solution annealing at 1100 °C for 1 h followed by water quenching, surface grinding up to 1200-grit finish, and placement in alumina crucibles.
- Assessment of the austenitic matrix and residual δ-ferrite fraction using OM, XRD, and SEM/EDX.
- Exposure in a muffle furnace under static air at 700 °C, 750 °C, and 800 °C for durations ranging from 0.5 h to 300 h, monitoring specific mass variation over time to determine parabolic rate constants k_p.
- Surface and cross-sectional analysis of oxide morphology, elemental distribution, and crystalline phase identification using SEM/EDX, XRD.

Results and Discussions

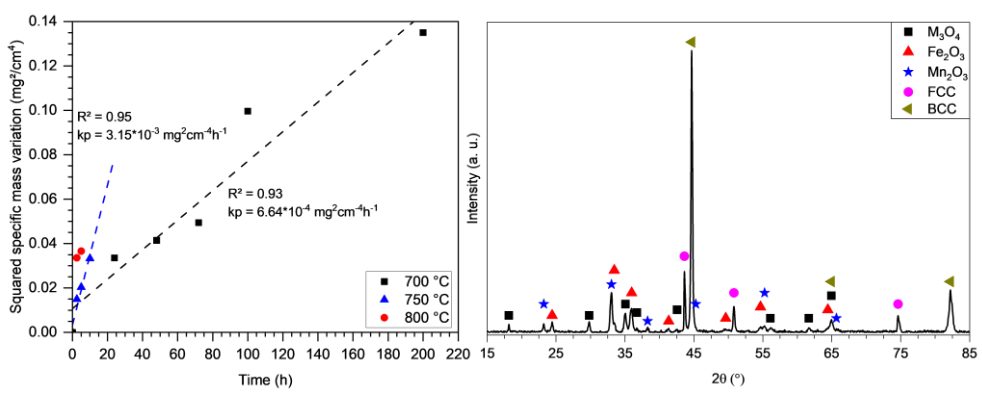


Figure 1. Squared specific mass-variation plots for samples exposed at 700, 750 and 800 °C and XRD diffractogram of sample exposed for 300 h at 700 °C.

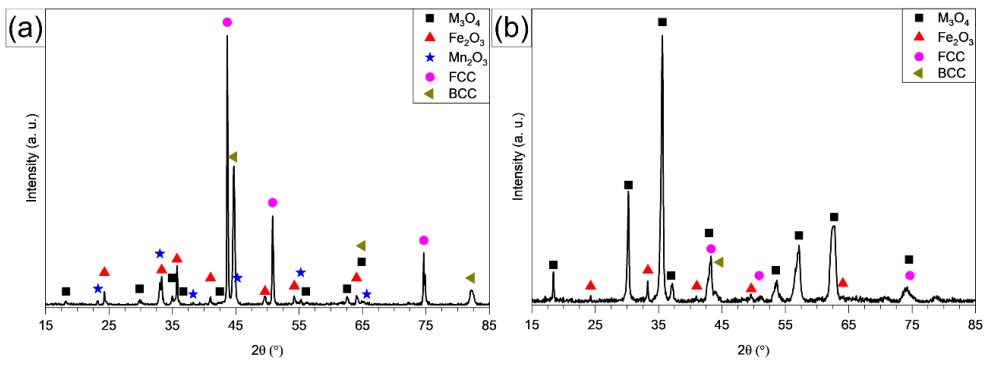


Figure 2. XRD diffractogram of an AISI 201LN sample exposed for 10 h (a) and 24 h (b) at 750 °C.

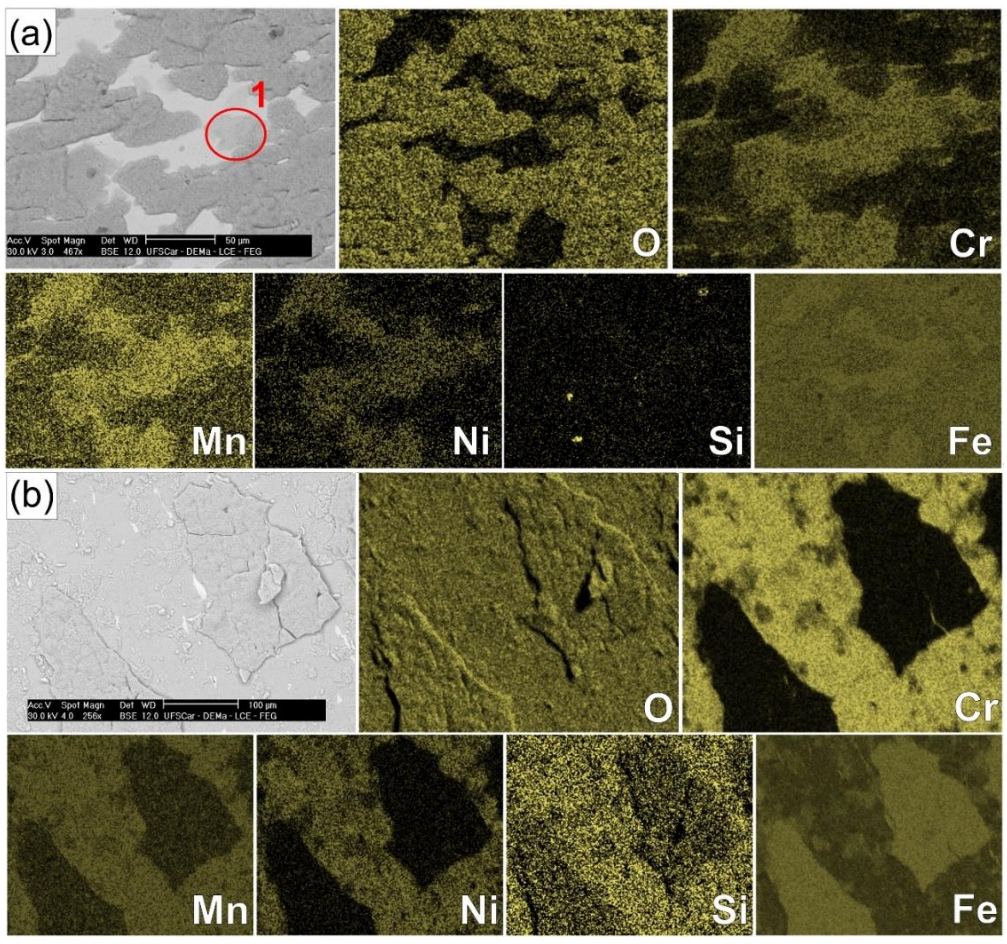


Figure 3. SEM images and EDX maps of the oxidized surface of a sample exposed to 700 °C (a) and 750 °C (b) for 1 h.

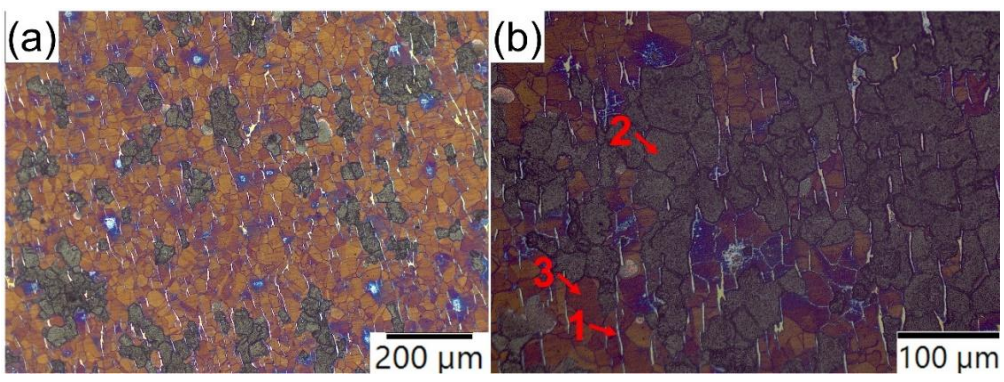


Figure 4. OM images of a sample exposed for 1h at 700 °C (a) and a higher magnification showing veins of residual ferrite (1), thick oxide islands (2) and regions that are uncovered or covered by a very thin oxide (3).

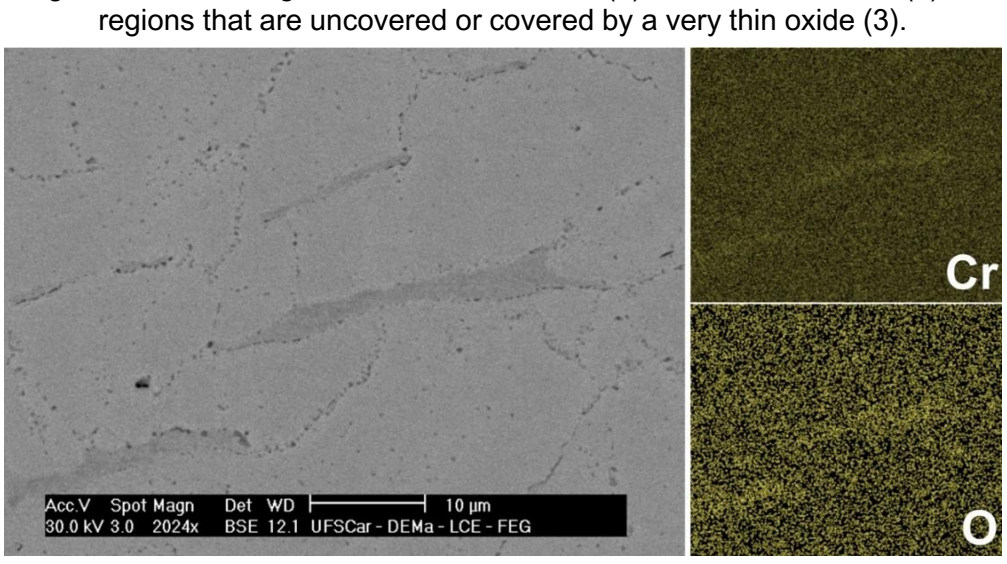


Figure 5. SEM image (BSE detector) showing darker regions on the surface of a sample exposed for 1h at 700 °C.

Conclusions

At 700 °C, AISI 201LN exhibits diffusion-controlled parabolic oxidation kinetics with a substantially elevated rate constant compared to conventional chromia-forming stainless steels, whereas at 750 °C and 800 °C it undergoes a rapid loss of selective oxidation and transitions to catastrophic breakaway oxidation within 5-10 h. This behavior forms thick, non-protective Fe- and Mn-rich oxide scales accompanied by deep internal oxidation, driven by severe Cr depletion at the reaction front, low silicon content (~0.4 wt.% Si), and initial scale heterogeneity promoted by residual δ-ferrite.

References and Acknowledgment

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