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Evaluation of the corrosion behavior of low-temperature nitrided AISI 316L austenitic stainless steel

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INTRODUCTION & AIM

When **nitriding** is carried out at **low temperature** (**<450 °C**) on austenitic stainless steels, nitrogen atoms can freely diffuse in the metal lattice, while the diffusion of substitutional atoms, such as chromium, is significantly slowed down. As a consequence, **the formation of chromium nitride is hindered**, and hence the corrosion resistance can be preserved. Nitrogen atoms are retained in the fcc lattice of austenite well beyond their solubility limit, forming a **supersaturated solid solution**, known as **expanded austenite** (γ_N) or **S-phase**.

The corrosion behavior of the nitrided layers depends on their microstructure and phase composition, the environment characteristics, and even on the testing conditions.

The **aim** of the present study is to evaluate the **corrosion behavior** of nitrided AISI 316L in **NaCl solution**, and, in particular, to assess its **repassivation capability**.

MATERIALS & METHODS

Material: AISI 316L (40×17×0.7 mm, polished up to 6 µm diamond paste)

Nitriding treatment: dc glow-discharge process
T: 380 °C; p: 130 Pa; t: 5 h; 80 $\%_{vol}$ N_2 + 20 $\%_{vol}$ H_2

Microstructure characterization

- Light microscopy
- X-ray diffraction analysis (XRD) (Bragg-Brentano configuration, CuKα)
- Knoop surface microhardness (load: 25 g_f)

Corrosion testing

Solution: 5 wt.% NaCl, aerated

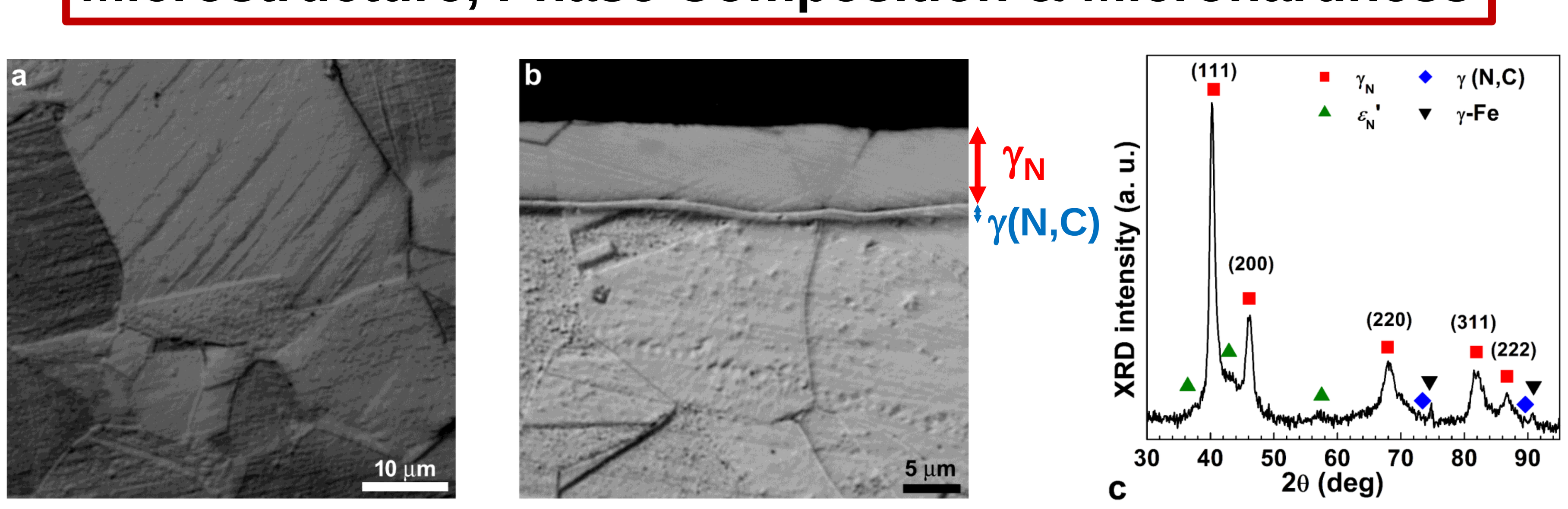
Surface area: 1 cm^2 **Delay before the test**: 20 h

Test Methods:

- **Electrochemical Impedance Spectroscopy (EIS)** (at open circuit potential (OCP); *ac* amplitude (peak-to peak): 2.5 mV; f: 10kHz-12mHz)
- **Cyclic potentiodynamic polarization** (rate: 0.3, 1 mV s^{-1}; polarization up to 100 µA cm^{-2})
- **Galvanostatic test** (anodic current: 100 µA cm^{-2}; t: 3000 s)

RESULTS & DISCUSSION

Microstructure, Phase Composition & Microhardness



The formation of the nitrided layer causes **local plastic deformations** observable at the **surface (a)**. The **nitrided layer (b)** consists of expanded austenite, γ_N, a less expanded austenite, γ(N,C), and a N-rich hcp martensite, ε_N' **(c)**, due to a fcc-to-hcp martensitic transformation.

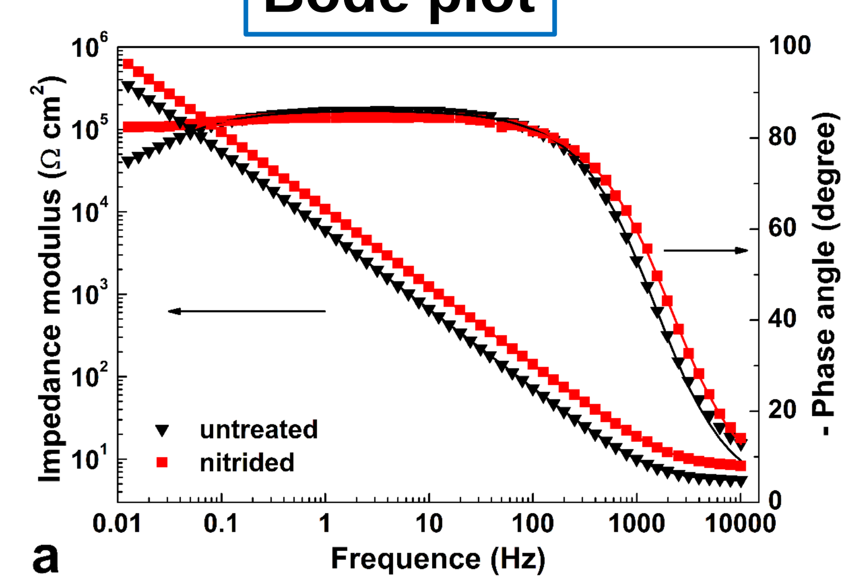
Thickness of the nitrided layer (γ_N + γ(N,C)): 7.8 ± 0.5 µm

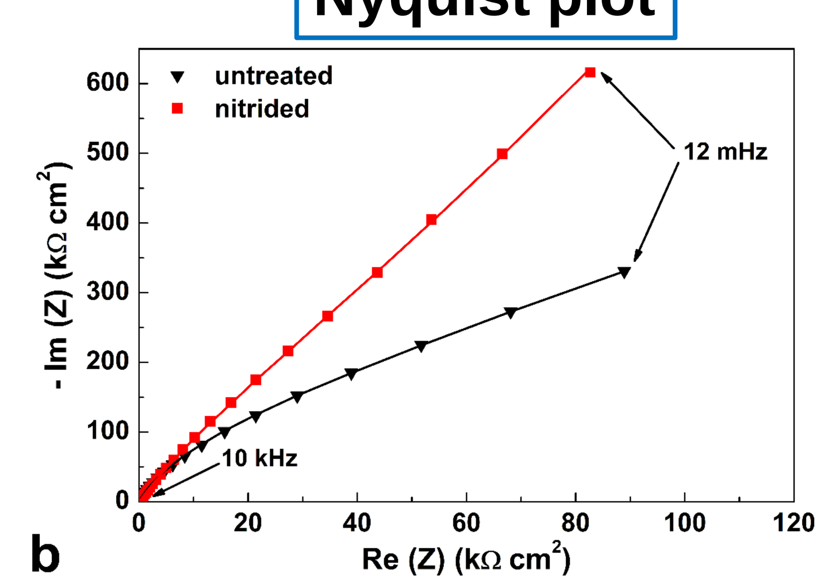
Surface hardness: 1473 ± 108 kg_f mm^{-2} (untreated: 268 ± 4 kg_f mm^{-2})

RESULTS & DISCUSSION

EIS analysis

Bode plot **Nyquist plot**





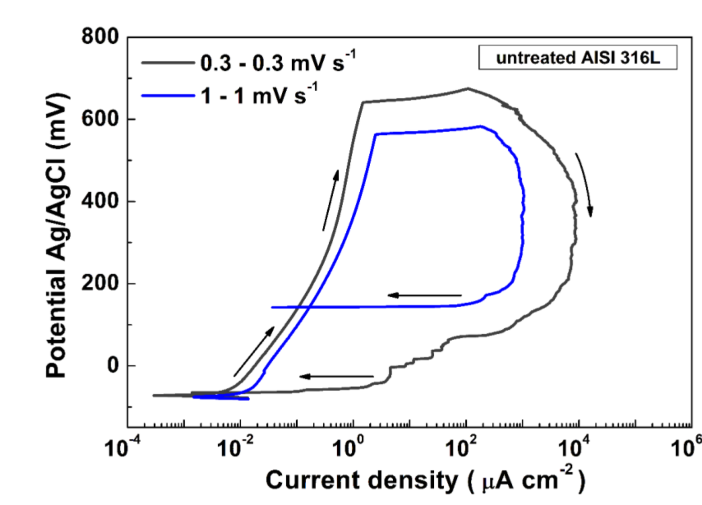
The **nitrided samples** have a **higher resistance to general corrosion**.

Cyclic potentiodynamic polarization

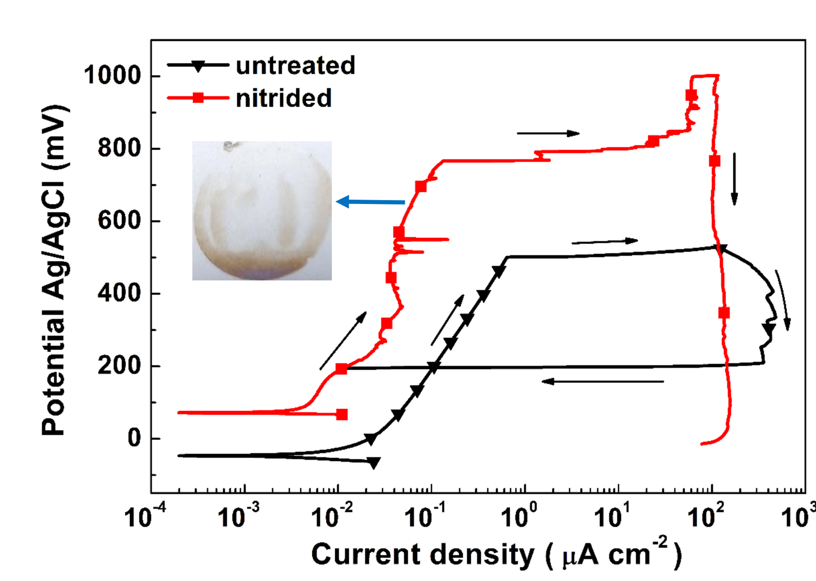
As observed for the untreated steel, the **scan rate** (forward and backward) **influences the repassivation capability**

→ scan rate for further tests:

- **forward scan**: 0.3 mV s^{-1}
- **backward scan:** 1 mV s^{-1}

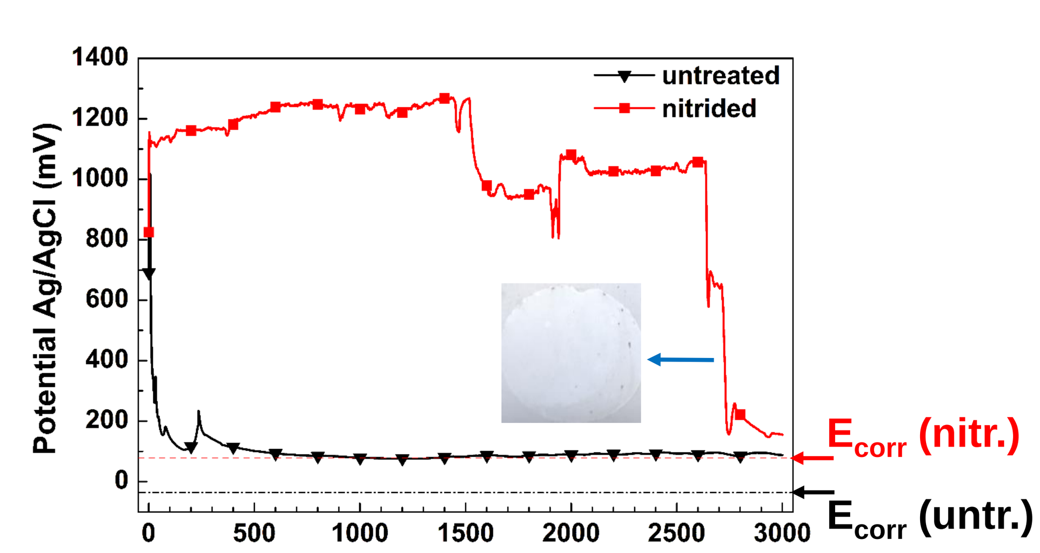


The **nitrided samples** have a **higher resistance to localized corrosion phenomena**, but they are not able to repassivate using these test conditions. Large colored regions are observed.



Galvanostatic tests

Potential values fluctuate due to transient passive film breakdown/repair. The **nitrided samples** have **potential values higher than the corrosion potential** of both the nitrided and untreated steel samples. **They could be able to repassivate.** Small pits are observed.



CONCLUSIONS

The **repassivation capability** of nitrided AISI 316L is particularly **sensitive to the extent of damage**. When **minor damage** happens, from, for example, using the galvanostatic technique, **high corrosion resistance** is maintained and **repassivation could occur**. However, fairly **significant corrosion damage**, such as that produced in cyclic potentiodynamic tests, **hinders repassivation**.