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Influence of previous heat treatment on the AISI 420 steel low temperature nitriding kinetics

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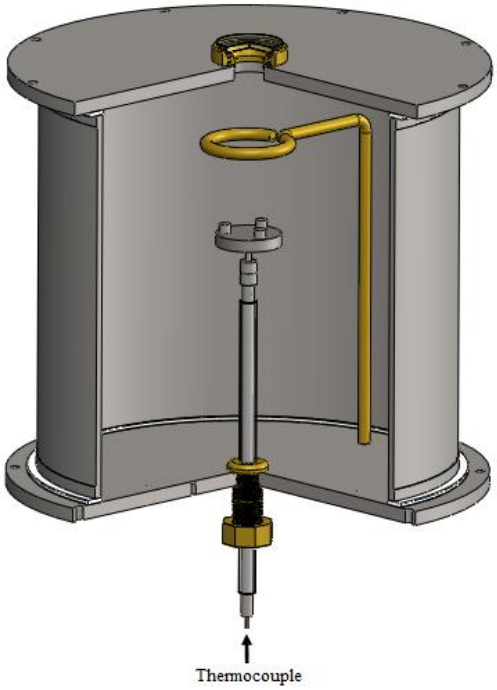
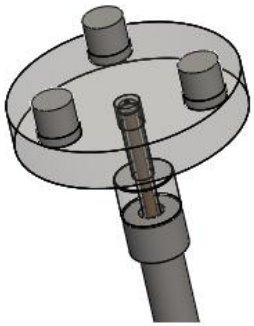
Motivation

- Diffusion and precipitation process affects the nitriding process.
- To study the influence of previous heat treatment on the kinetics of low temperature nitriding of the AISI420 martensitic stainless steel.
  - Layer growth kinetics
  - Chromium nitride precipitation that causes sensitization (to be avoided)

Experimental apparatus





Fixed parameters:

- Pulse frequency: 4.2 kHz
- Peak voltage: 600V
- Gas mixture: 10%Ar+20% H_2+70% N_2
- Gas flow rate: 200 sccm
- Pressure: 3 Torr

Samples:

As-quenched (air quenched from 1050 ºC)
Tempered (1h 400 ºC)
Annealed (as received) -> lower chromium

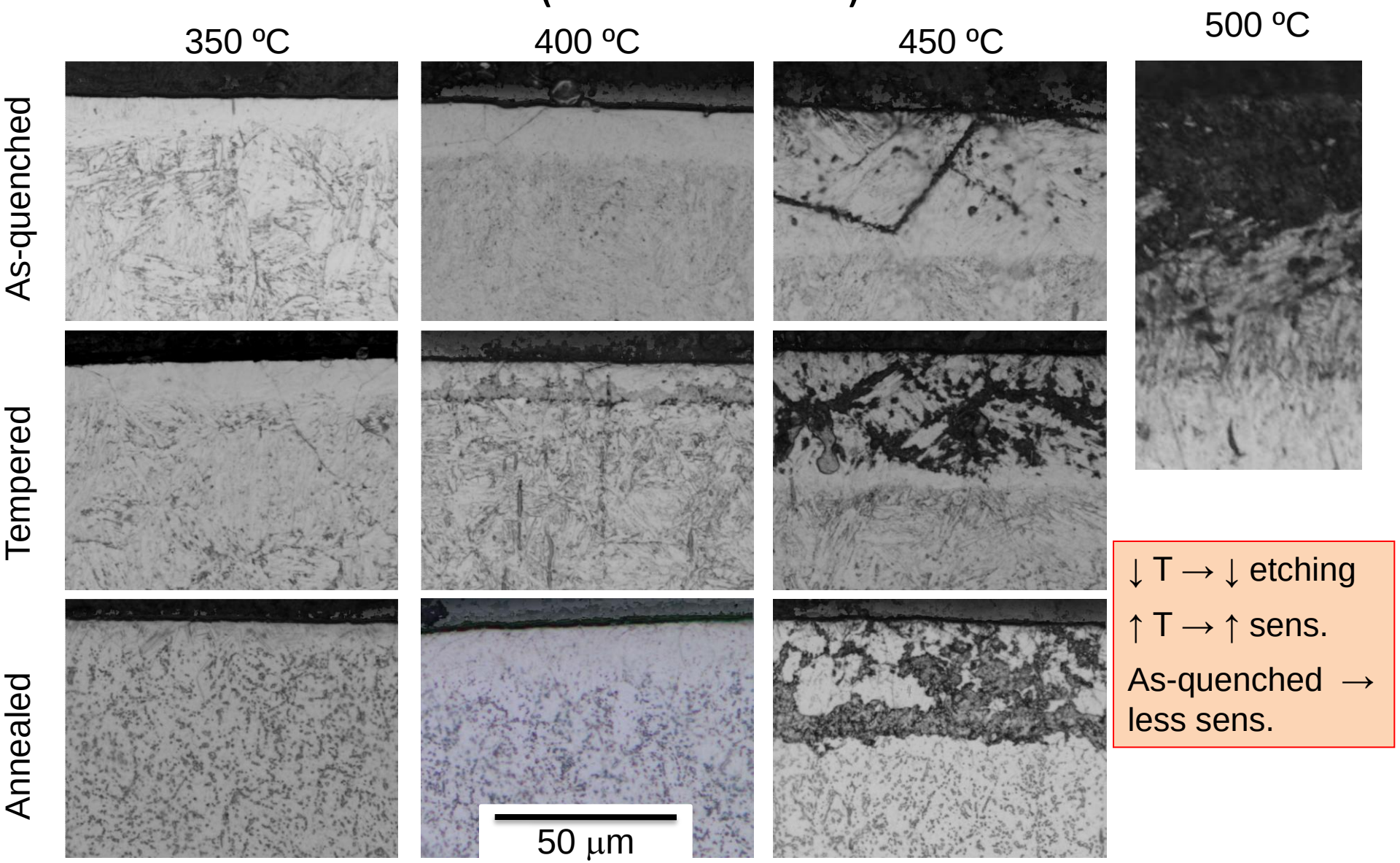
Treatment conditions:

- Temperature: 300, 350, 400, 450 and 500 ºC for 4h
- Time: 2, 4, 6 and 12 h at 350, 400 and 450 ºC

Characterization: microstructural analysis, microhardness test and XRD.

Microstructural analysis

(4h treatment)



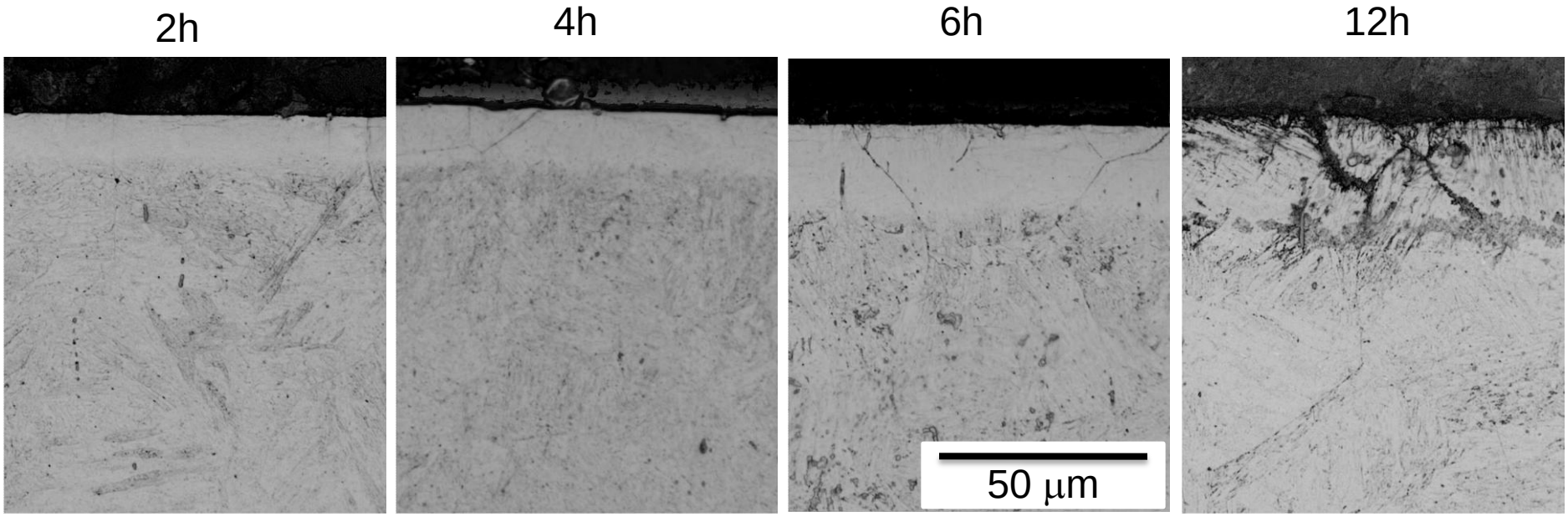
↓ T → ↓ etching

↑ T → ↑ sens.

As-quenched → less sens.

Microstructural analysis

- Time evolution -> As-quenched samples treated at 400 °C

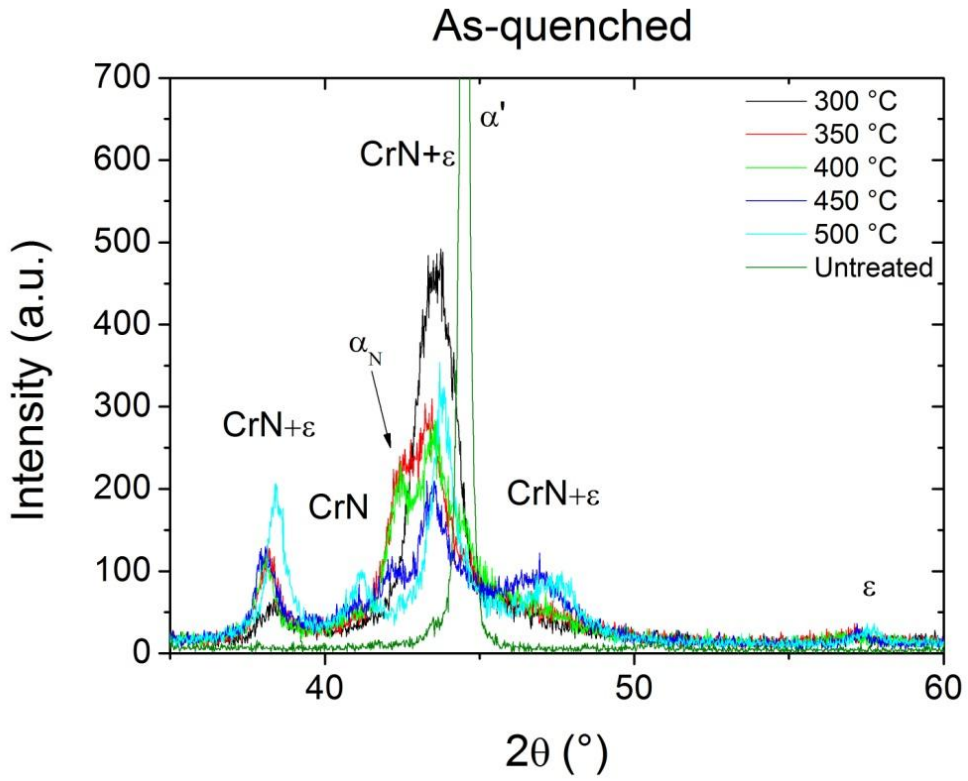


➢The sensitization starts at the grain boundary for 4h

➢The sensitization is generalized for 12h

XRD Patterns

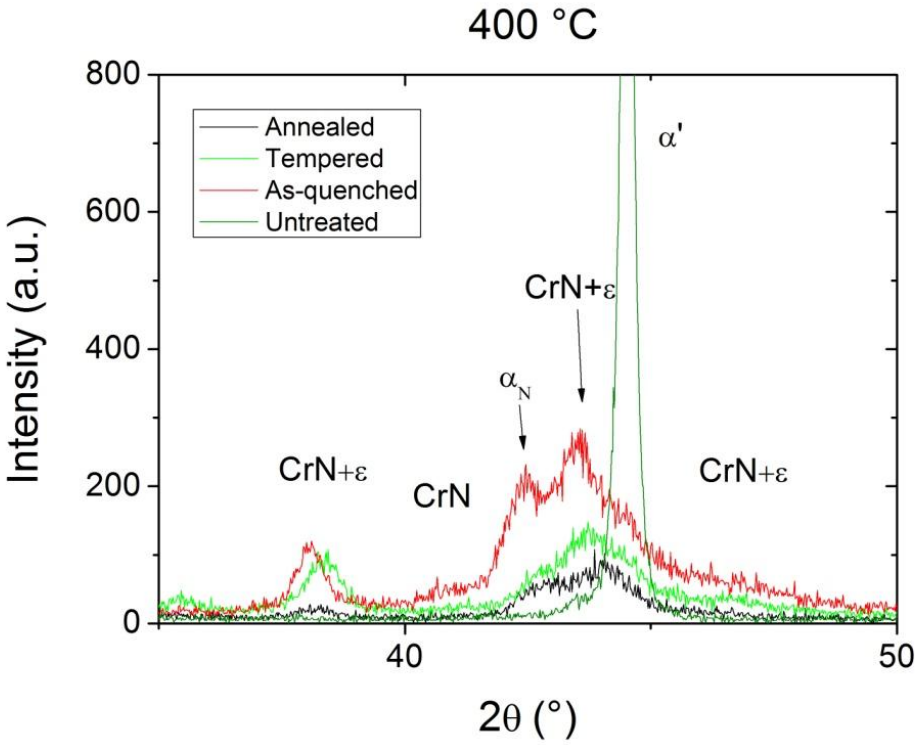
(Temperature dependence)



- For low treatment temperature the main phases are ε and expanded martensite
- For high treatment temperature peaks of CrN are also observed (sensitization)
- The peak of expanded martensite disappears for high temperature, what is expected for a metastable phase

XRD Patterns

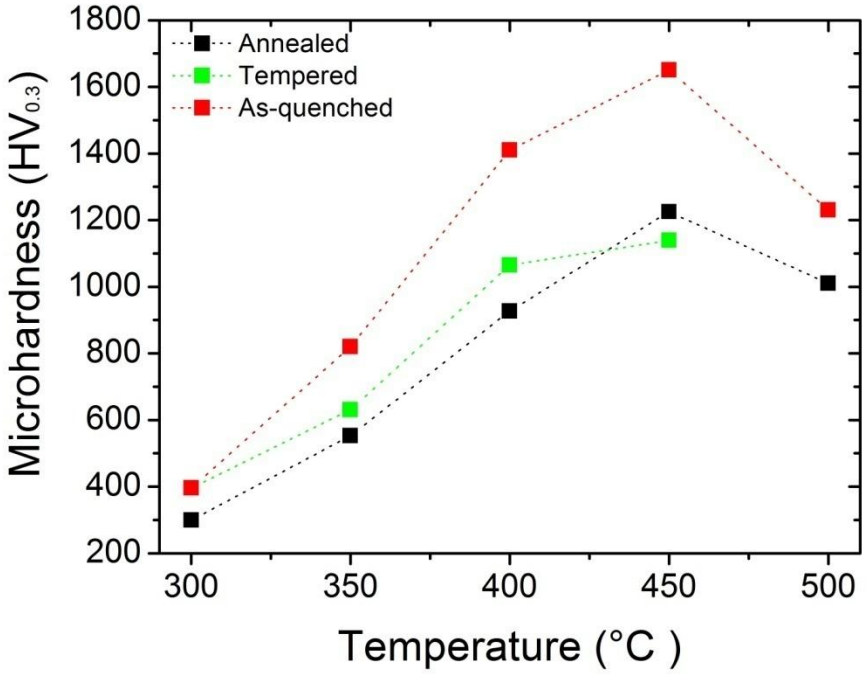
(Influence of the previous heat treatment)



➢The as-quenched samples present a more intense peak of expanded martensite → higher solid solution chromium content → higher nitrogen super-saturation

Microhardness

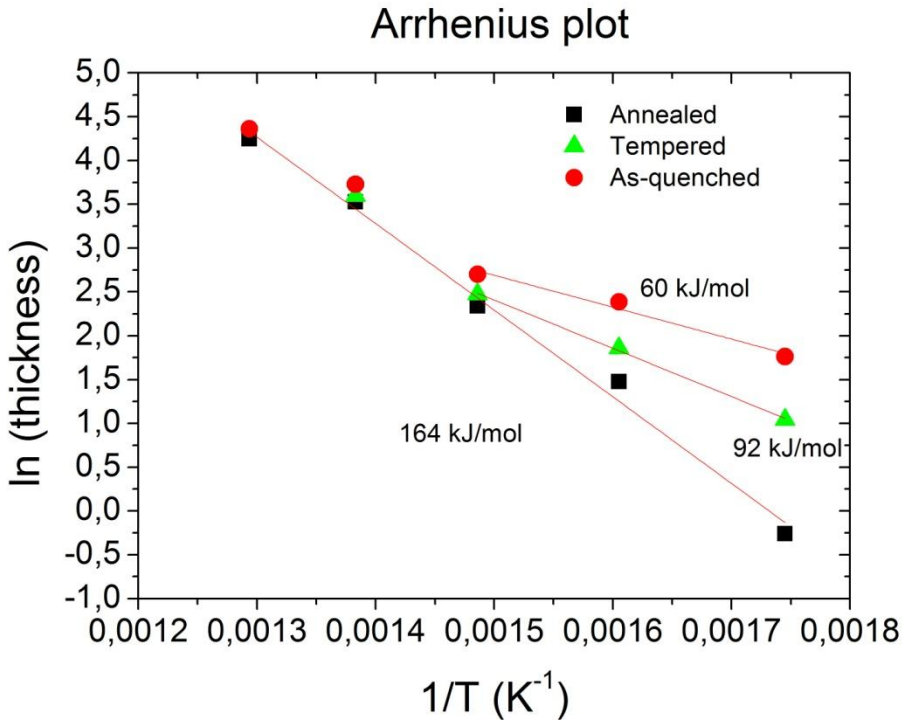
(Temperature dependence – 4h treatment)



- The effective hardness grows with the temperature up to 450 °C
- The effective hardness is always higher for as-quenched samples
- After chromium nitride precipitation, intense at 450 °C, the effective hardness decreases, indicating that expanded martensite has important hardening effect

Layer thickness evolution

(Temperature dependence)



$$\ln(d) = ct. - \frac{Q}{2R}\frac{1}{T}$$

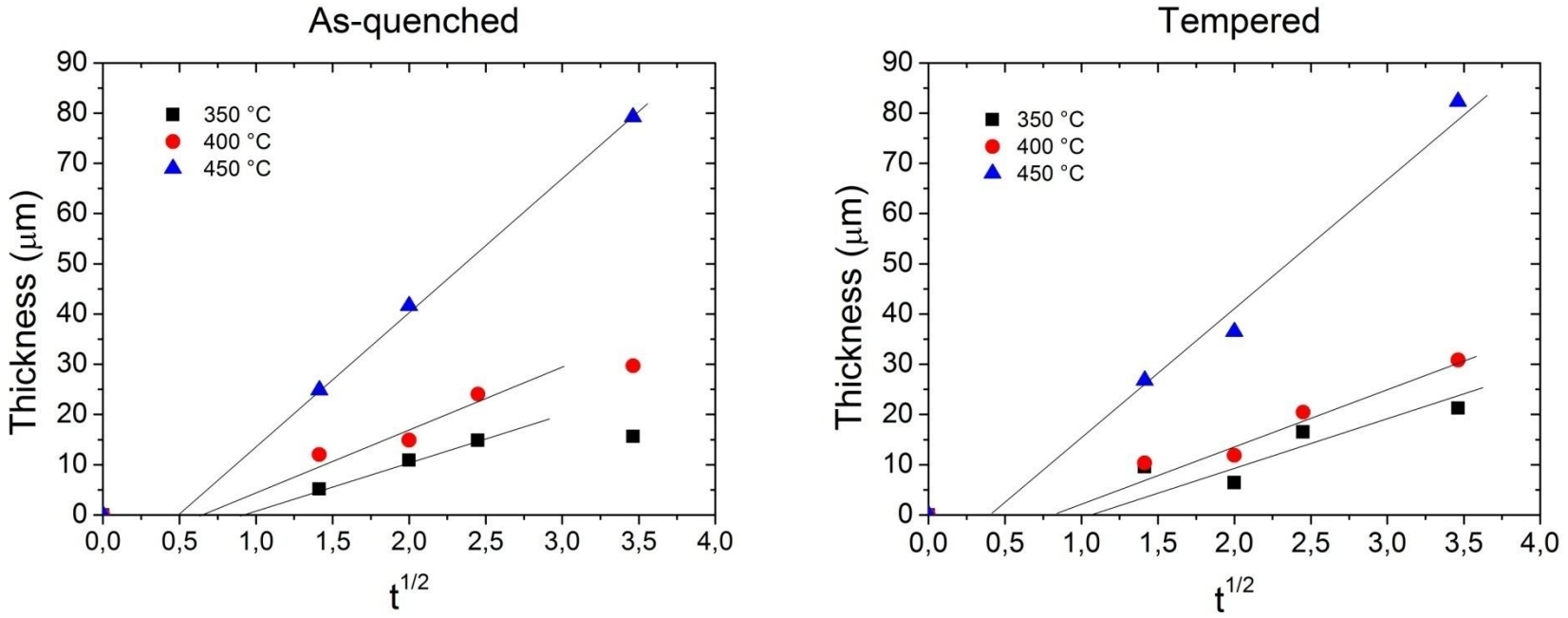
Arrhenius equation
Linearization considering:

$$d \propto \sqrt{Dt}$$

- At high temperature the limiting process for the layer growth tends to have the same activation energy (tending to thermodynamic equilibrium)
- Activation energy for annealed samples do not change (equilibrium)
- At low temperature the activation energy is lower for as-quenched and tempered samples when compared to the annealed samples (defects density, residual stress and/or chromium content in solid solution)

Layer thickness evolution

(Time dependence)



- The incubation time for nitride layer formation is higher for lower treatment temperature
- For low temperatures, precipitation occurs for high treatment time changing the layer growth kinetics
- The temper state do not play an important role on the layer thickness time behavior for the studied condition

Closing remarks

- The pretreatment dramatically affects the low temperature nitriding of martensitic stainless steel
  - The best results have been obtained for as-quenched samples (simultaneous tempering and nitriding)
- The chromium content in solid solution and/or residual stress plays an important role on the expanded martensite formation

THANK YOU!