Institute of Strength Physics and Materials Science,
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Laboratory of physics of structural transformations

The characterization of surface layers produced by ion-plasma treatment in CrNiMo austenitic stainless steel with different microstructures

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OUTLINE

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Motivation

Material and experimental procedure

II

Different microstructures in 316L-type steel formed by thermal-mechanical treatments

- TEM analysis
- EBSD analysis

III

Features of IPT-assisted surface layers in 316L-type steel with different microstructures:

- SEM analysis
- X-ray diffraction analysis
- AES and nanohardness results

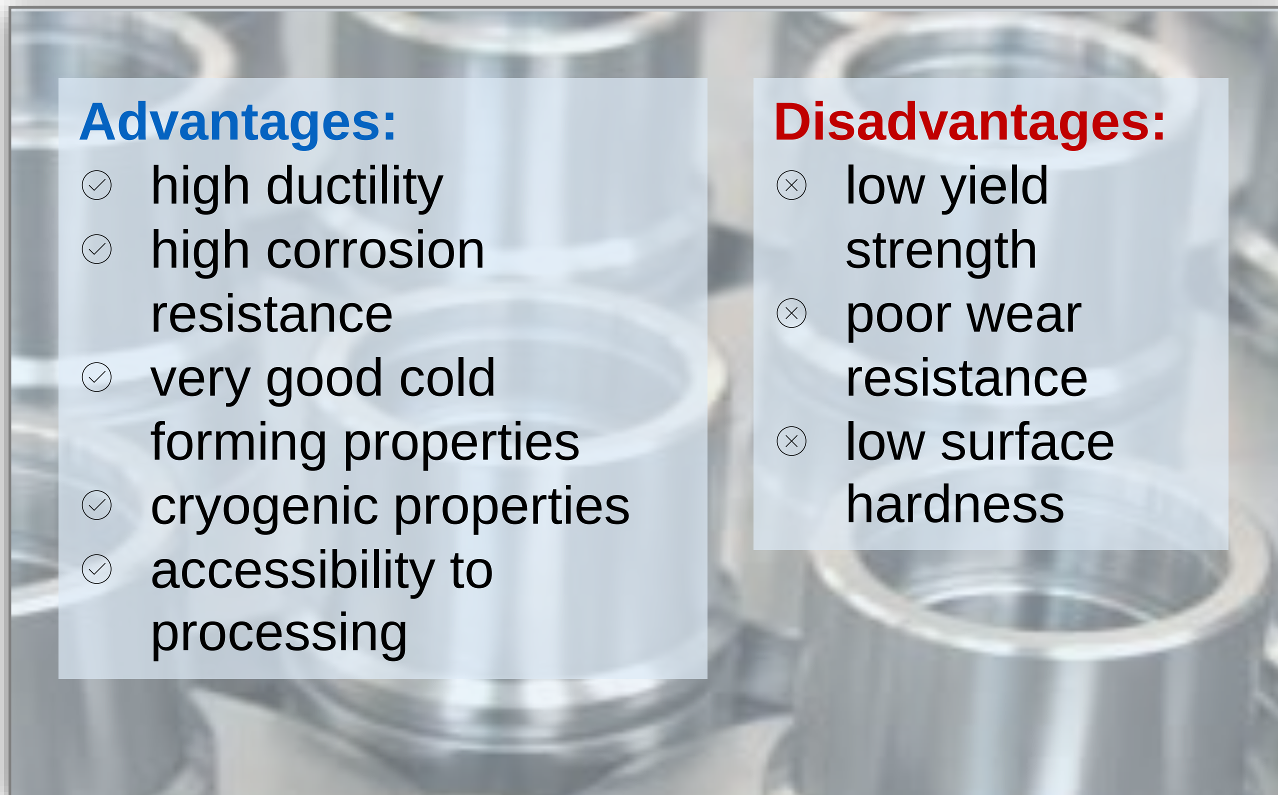
IV

Summary

I

Austenitic stainless steels

Fe + C → Steel → **Fe + C + Cr** → Stainless steel → **Fe + C + Cr + Ni** → Austenitic stainless steel



Advantages:

- high ductility
- high corrosion resistance
- very good cold forming properties
- cryogenic properties
- accessibility to processing

Disadvantages:

- low yield strength
- poor wear resistance
- low surface hardness

Ion plasma treatment (IPT)

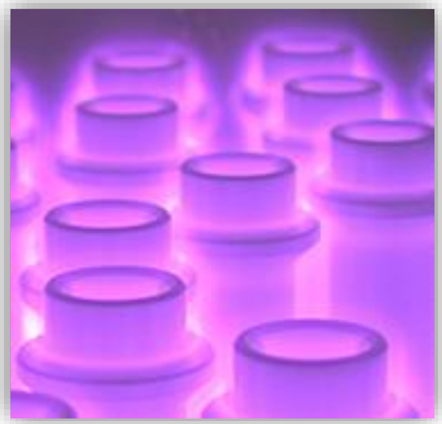
Ways to improve properties of austenitic stainless steels:

- alloying
- strain hardening
- precipitate strengthening
- diffusion gaseous and ion-plasma surface saturation

Ion-plasma diffusion saturation of the steel surface with interstitial atoms (**N, C, N + C**) results in surface hardness and tribological properties improvement

THE AIM OF WORK

To evaluate the effect of deformation defects on elemental and phase composition, nanohardness and microstructure of stable austenitic stainless steel (316L-type) subjected to ion-plasma surface treatment.



What about the role of deformation-induced defects and grain boundaries in the hardened layer formation of ion-plasma treated steels?

Austenitic stainless steel - Analogue AISI 316L

(Fe-17Cr-13Ni-2.7Mo-1.7Mn-0.6Si-0.01C mass %)

Formation of different microstructures

Thermomechanical treatments

Regime 1 (R1)

Regime 2 (R2)

Ion-plasma treatment (IPT) of R1 and R2 specimens

Formation of surface layers

Working gas: Ar +N_2+C_2H_2

Pressure: P = 300 Pa

Temperature: T = 540°C

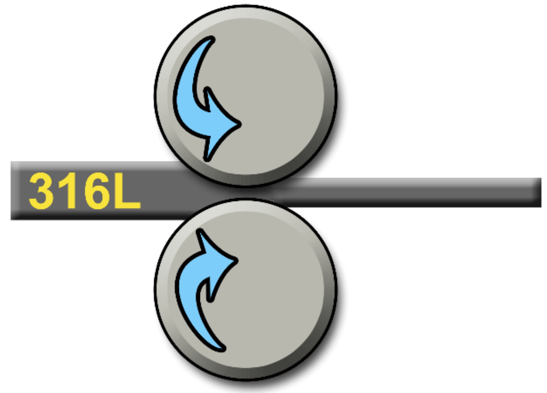
Duration: t = 12 hours

Thermomechanical treatments

Formation of different microstructures

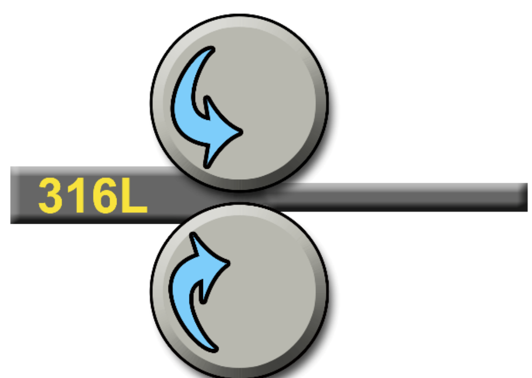
Regime 1
(R1)

Cold rolling to reduction of 80 %

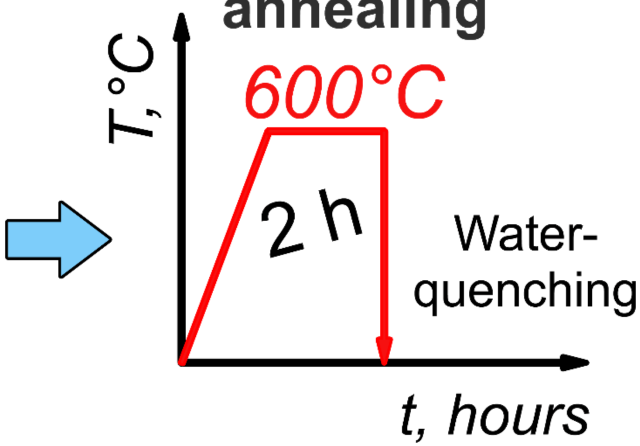


Regime 2
(R2)

Cold rolling to reduction of 80 %

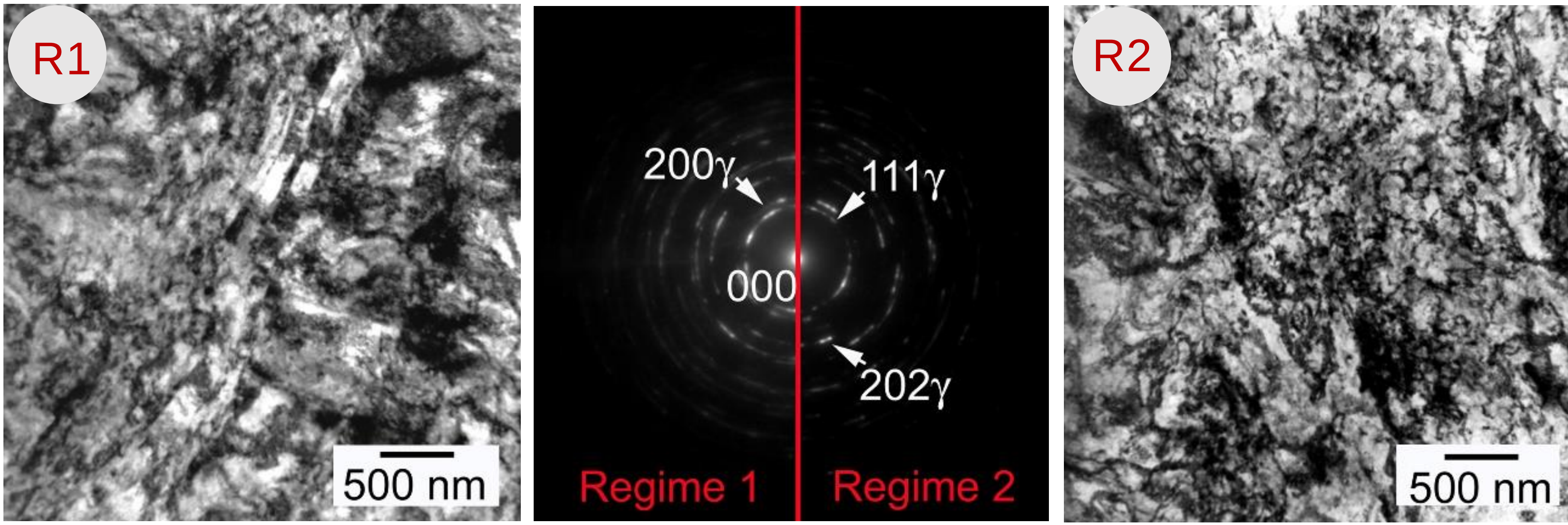


Post-deformation annealing



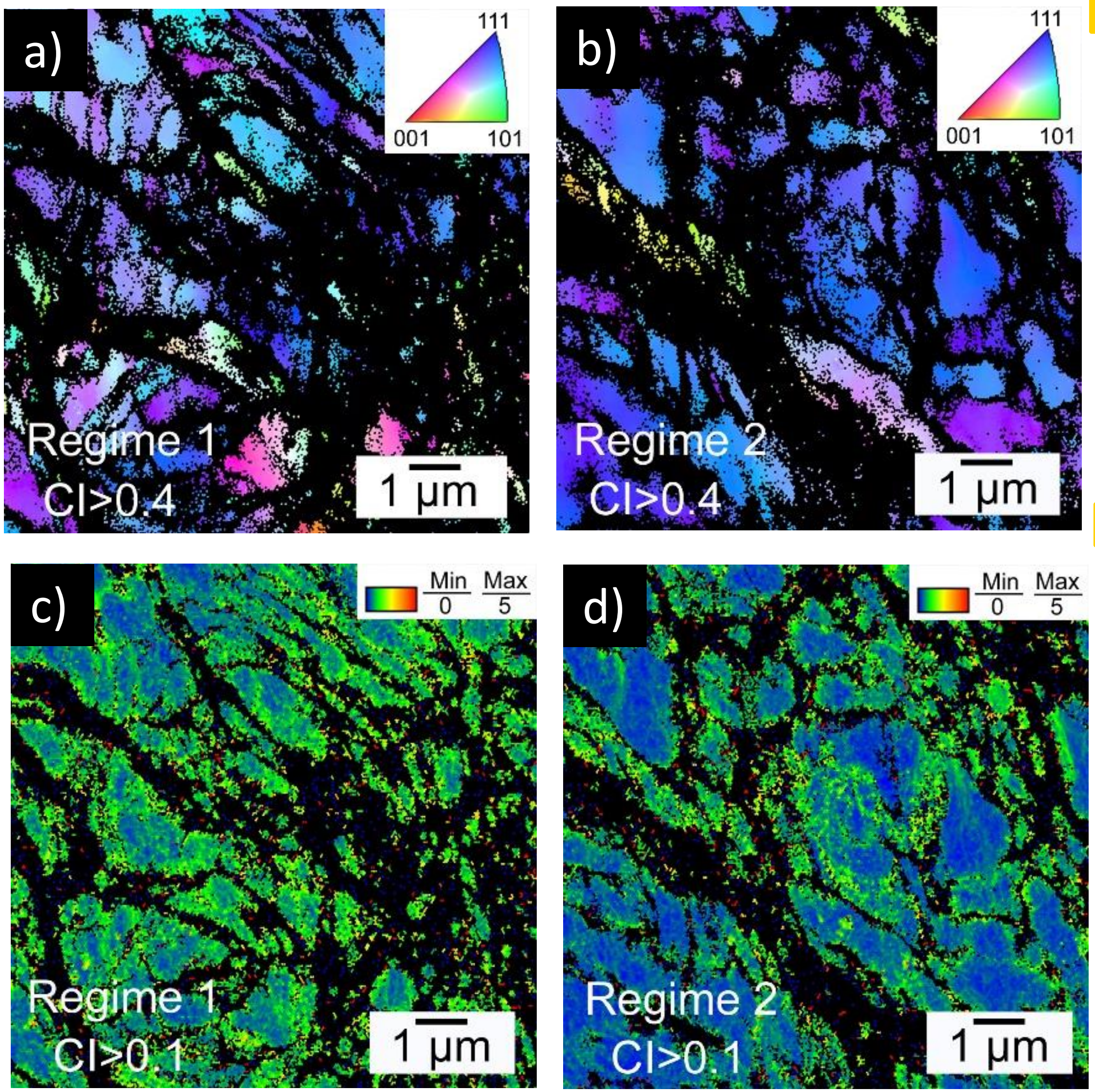
Different microstructures in 316L-type steel formed by thermomechanical treatments

TEM bright-field images with SAED patterns of the different microstructures in 316L-type steel



Two types of grain-subgrained structures in steel

EBSD OIM (a, b) and KAM (c, d) images for the R1(a, c) and R2 (b, d) specimens



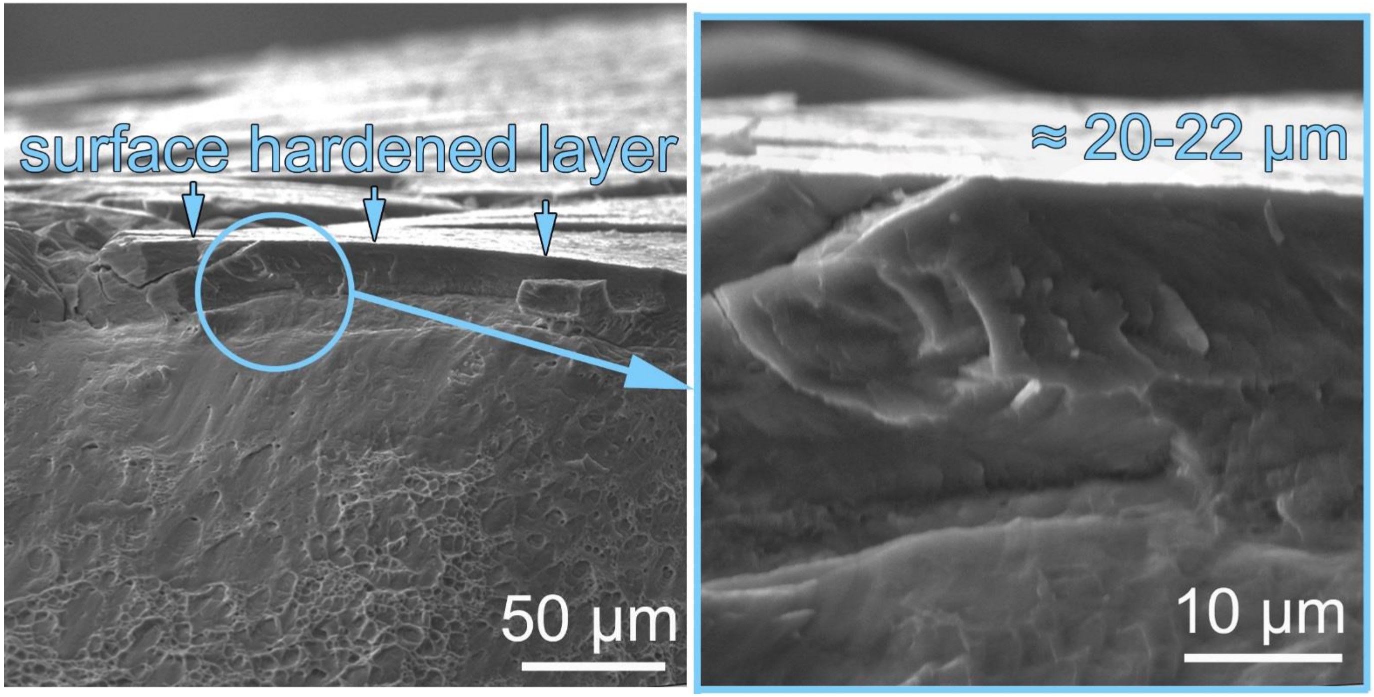
EBSD patterns are given with a different "confidence index" - CI, with CI > 0.4 (a, b) and with CI > 0.1 (c, d)

Black regions correspond to points with low CI

III

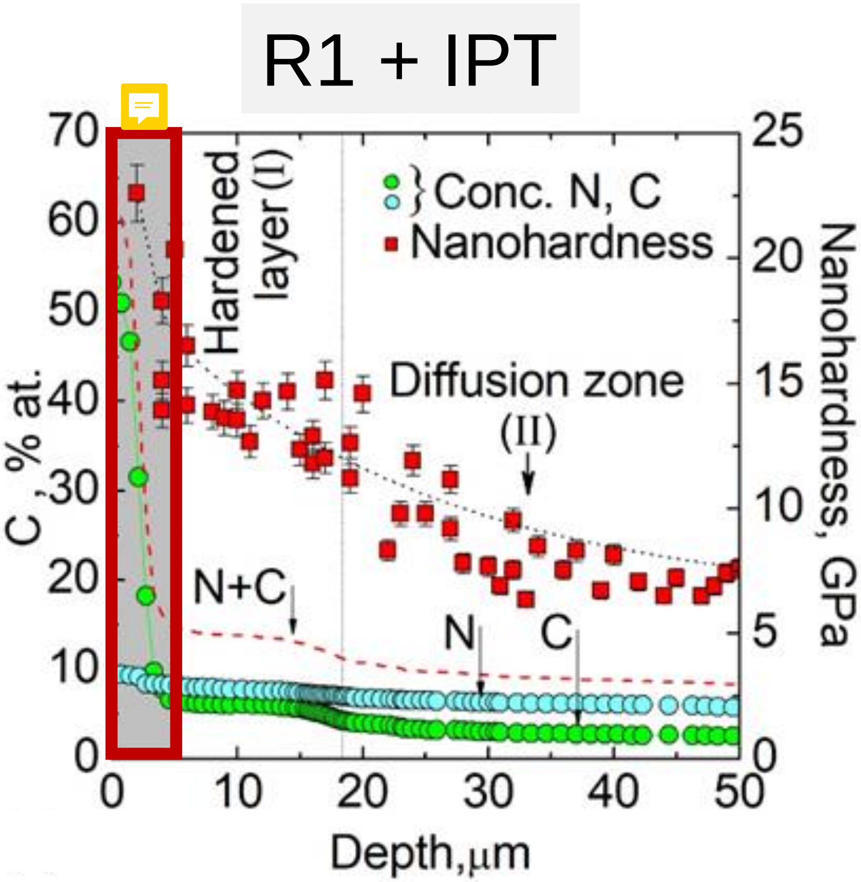
Features of IPT-assisted surface layers in 316L-type steel with different microstructures

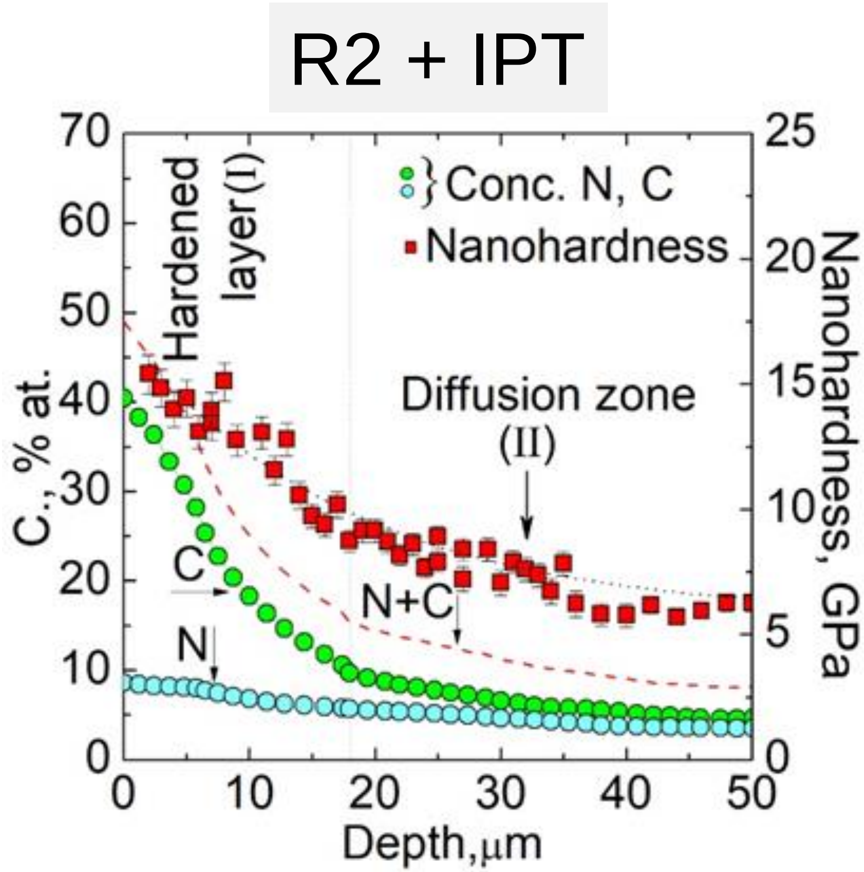
SEM cross-sectional images of fractured surfaces of R1 specimen after ion-plasma treatment



IPT facilitates a formation of composition hardened surface layer ≈ 20-22 µm in thickness

Auger electron spectroscopy results (carbon and nitrogen concentration) combined with nanohardness depth profiles for R1 and R2 specimens (cross-sectional direction)

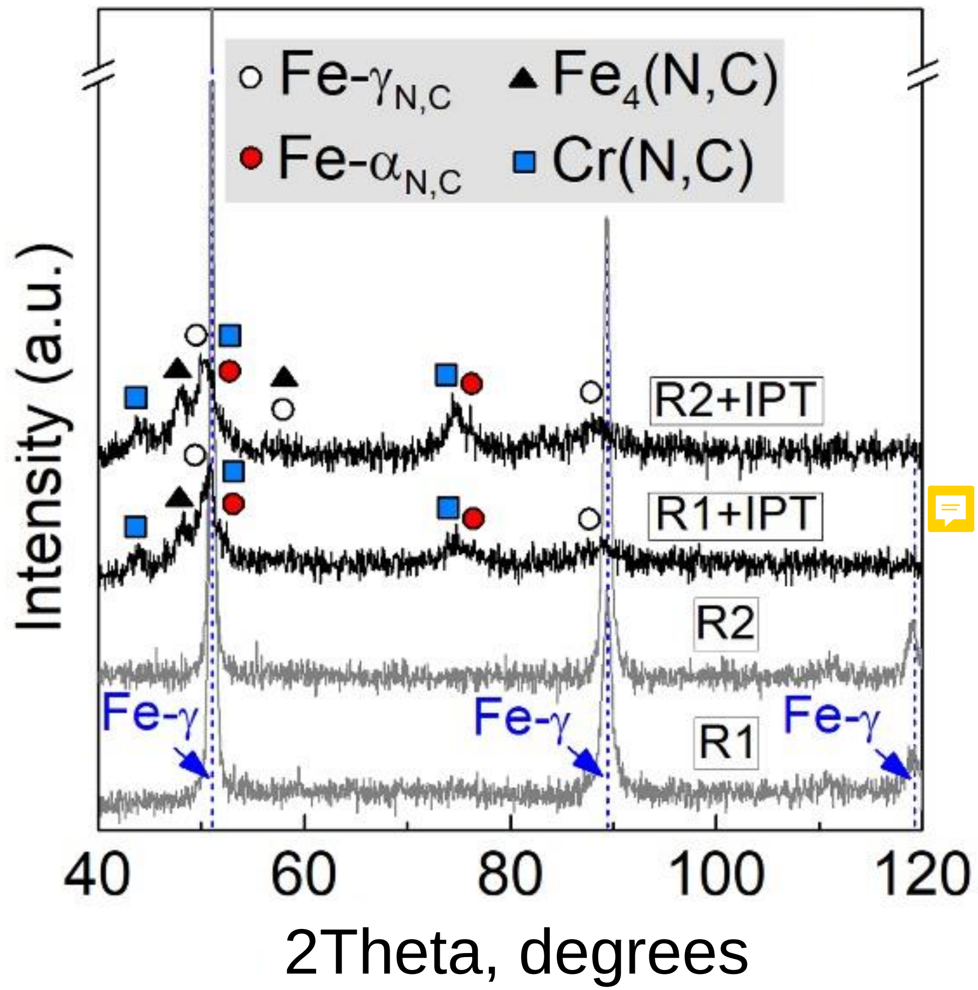




X-ray diffraction analysis of R1 and R2 specimens after ion-plasma treatment

Phase composition in surface layers after ion-plasma treatment:

Fe-$\gamma_{N,C}$ + $Fe_4(N,C)$ + Cr (N,C) + Fe-$\alpha_{N,C}$



SUMMARY

- The surface layers of both specimens underwent IPT-processing possess similar phase composition: expanded austenite (Fe-$\gamma_{N,C}$), ferrite (Fe-$\alpha_{N,C}$), $Fe_4(N,C)$ and Cr(N,C) phases
- Pre-deformation stimulates an accumulation of interstitial atoms (N and C) under ion-plasma treatment
- Deformation-assisted defects suppress bulk diffusion of carbon under IPT
- High density of dislocations, boundaries and subboundaries provide high surface nanohardness in 316L austenitic stainless steel under ion-plasma treatment

These results provide experimental support for key role of deformation-assisted well-developed microstructure in accumulation and bulk diffusion of interstitials under ion-plasma treatment of steel

Characterization of the surface layers produced by ion-plasma treatment in CrNiMo austenitic stainless steel with different microstructures

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Thank You

For Your Attention