Institute of Strength Physics and Materials Science of Siberian Branch of Russian Academy of Sciences

THE EFFECT OF INTERPHASE (AUSTENITE/FERRITE) AND INTERGRANULAR BOUNDARIES ON HYDROGEN EMBRITTLEMENT OF A HIGH-NITROGEN AUSTENITIC STEEL

Marina Yu. Panchenko,

Ph.D. student of Institute of Strength Physics and Materials Science

Scientific supervisor:
Elena G. Astafurova,

Doctor of sciences (Phys&Math), Laboratory of Physics of Structural Transformations

Institute of Strength Physics and Materials Science

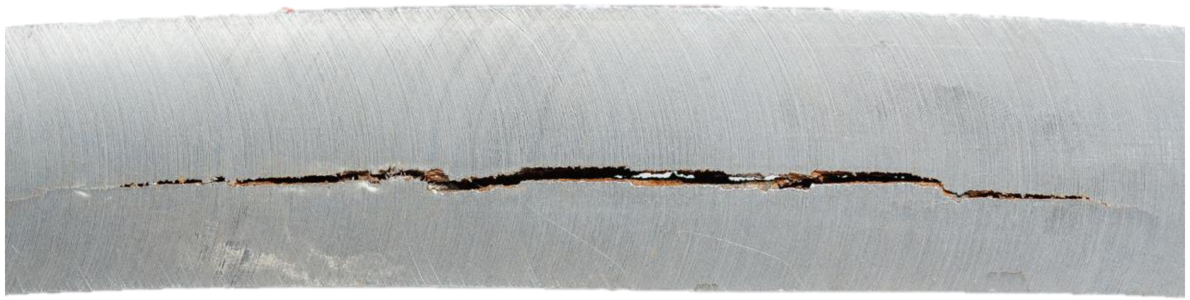
Tomsk 2020

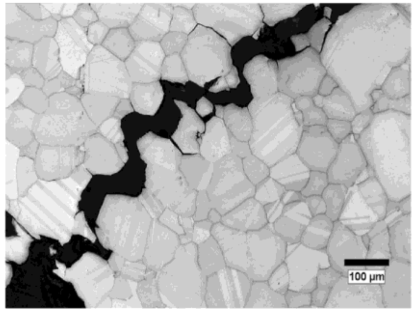
Outline

- Motivation
- Materials and methods
- Results:
- Microstructure characterization
- Mechanical properties of steel before and after hydrogen-charging.
- Fractographic analysis
- Summary

Motivation

- **Hydrogen embrittlement**(HE), also known as **hydrogen assisted cracking** (HAC) and **hydrogen-induced cracking** (HIC) was discovered by Johnson in **1875.**





*Hydrogen-Induced Cracks (HIC)**

Diffusible hydrogen is harmful to the plasticity of steels

The harmful influence of diffusible hydrogen can be mitigated:

by preventing its entry into steel

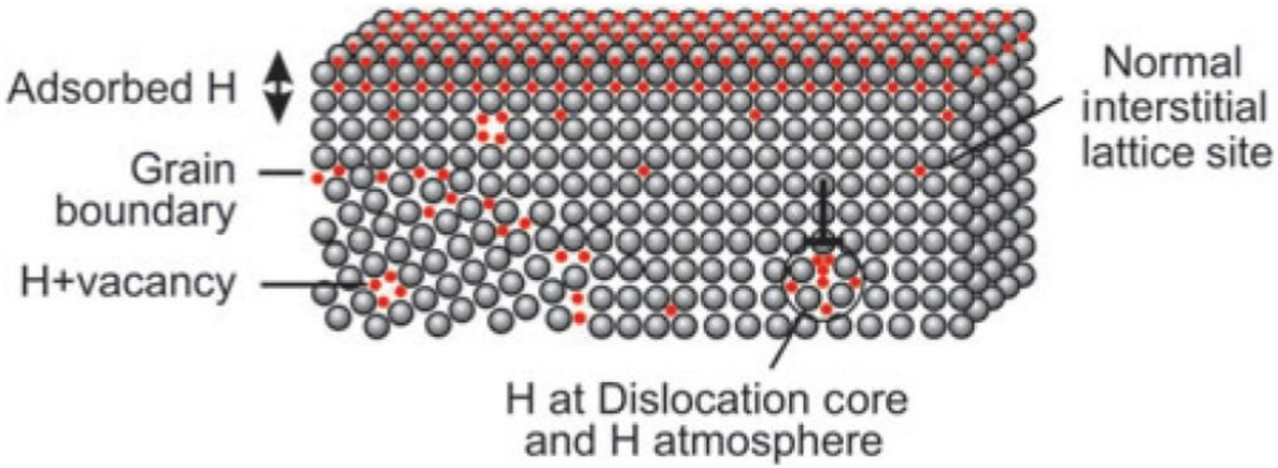
or

by rendering it immobile once it penetrates the material

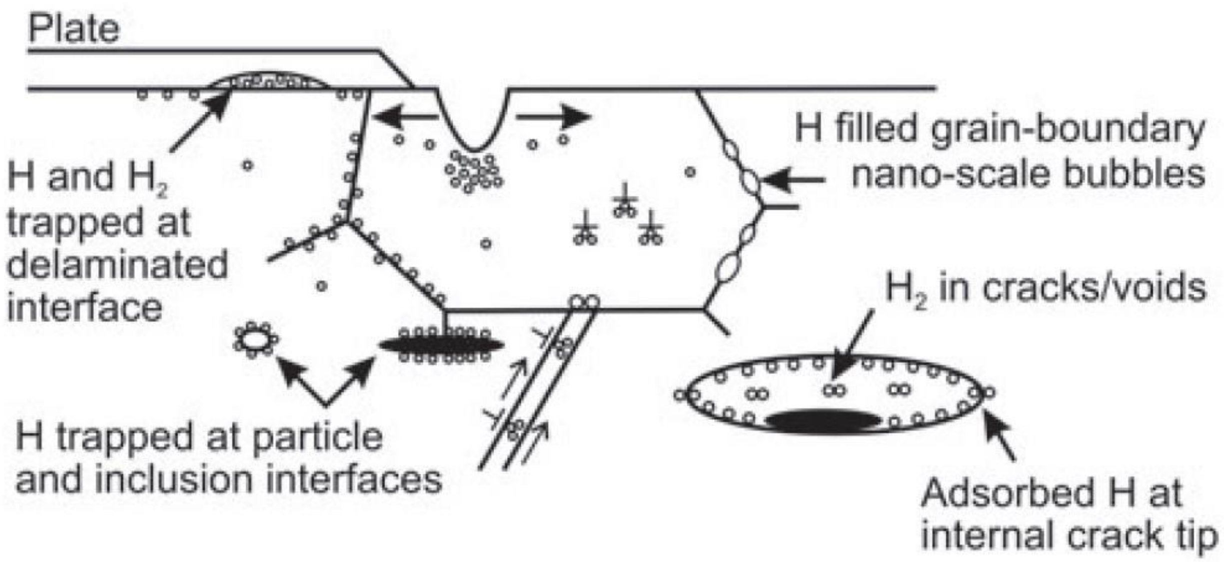
*Iannuzzi, M., Barnoush, A., & Johnsen, R. (2017, April 28). Materials and Corrosion Trends in Offshore and Subsea Oil and Gas Production. https://doi.org/10.1038/s41529-017-0003
**https://seblog.strongtie.com/2015/10/hydrogen-embrittlement-in-high-strength-steels

Sites and traps for hydrogen

(a) - on an atomic scale



(b) – on a microscopic scale*

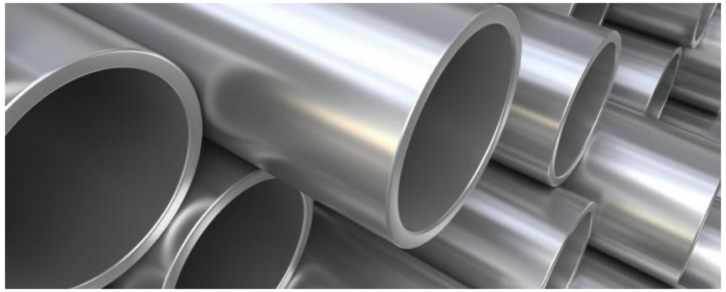


Shematic illustrations of sites and traps for hydrogen in materials

*Lynch S. Hydrogen embrittlement phenomena and mechanisms // Corrosion reviews. – 2003 – Vol.30. – P.105–123.

High nitrogen austenitic steels (HNS):

- high strength
- corrosion resistance
- wear resistance



ferrite

High hydrogen diffusivity

Low hydrogen solubility

↓

path to transport hydrogen

austenite

Low hydrogen diffusivity

High hydrogen solubility

↓

sink, trapping hydrogen

THE AIM OF THE RESEARCH

to establish the effect of volume fraction of δ-ferrite and the density of interphase (austenite/δ-ferrite) and grain (austenite/austenite) boundaries on the mechanical properties and fracture mechanisms of a high-nitrogen austenitic steel before and after hydrogen-charging

Materials and methods

- High-nitrogen austenitic steels steel was chosen as an object of the investigation: Fe-23Cr-17Mn-0.1C-0.6N steel (wt.%) (**HNS**).

Solid-solution treatments (SST):

- **T_{sst}=1050 °C, 0,5 h**
- **T_{sst}=1100 °C, 0,5 h**
- **T_{sst}=1150 °C, 0,5 h**
- **T_{sst}=1200 °C, 0,5 h**

+H

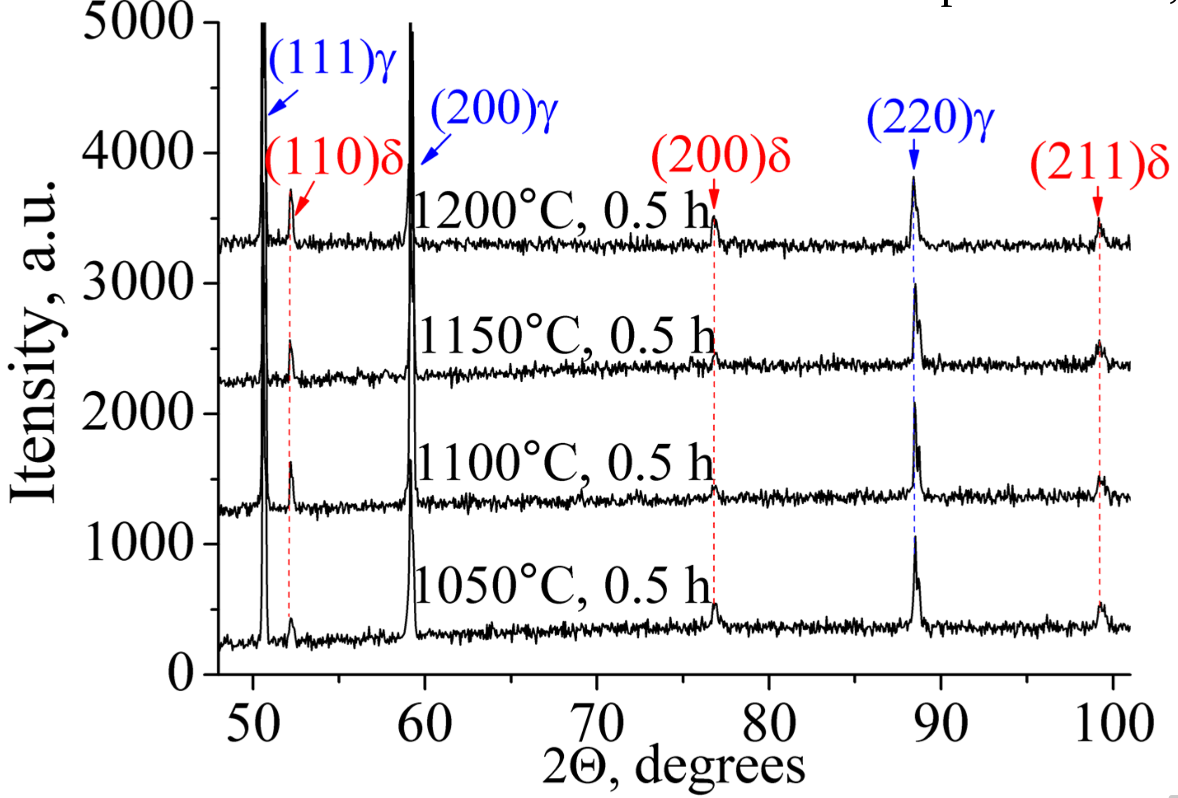
Electrochemical hydrogen-charging for 100 h

Methods:

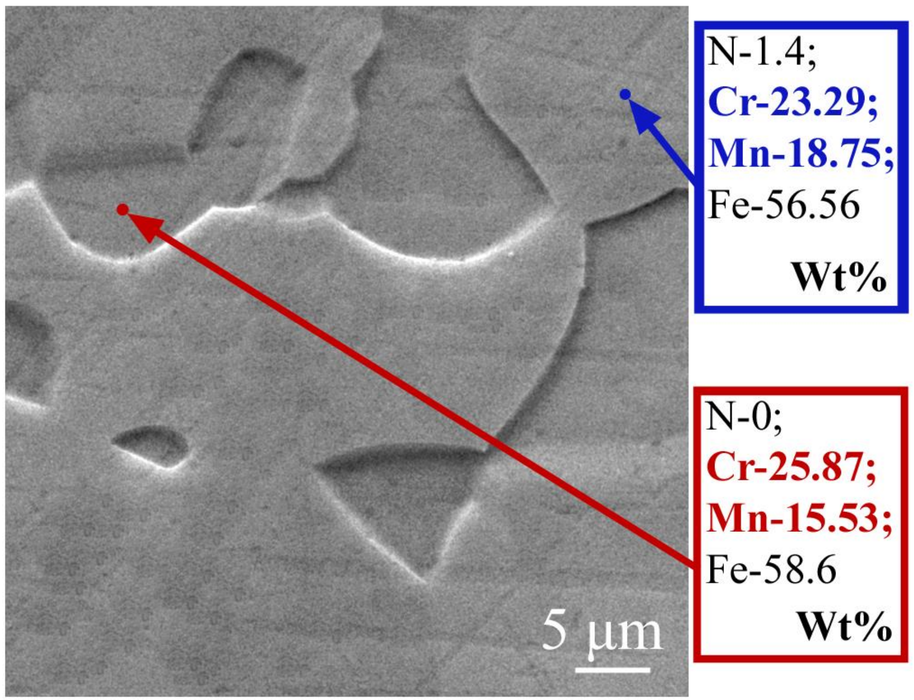
- X-ray diffraction (XRD) phase and structural analyses
- Light microscopy (LM)
- Transmission electron microscopy (TEM)
- Tensile tests
- Scanning electron microscope (SEM)

HNS microstructure after different regimes of solid-solution treatment

Austenite (γ-phase) with a lattice parameter a=3,63 Å,
18-23% **δ-feritte** with the lattice parameter 2,88 Å.

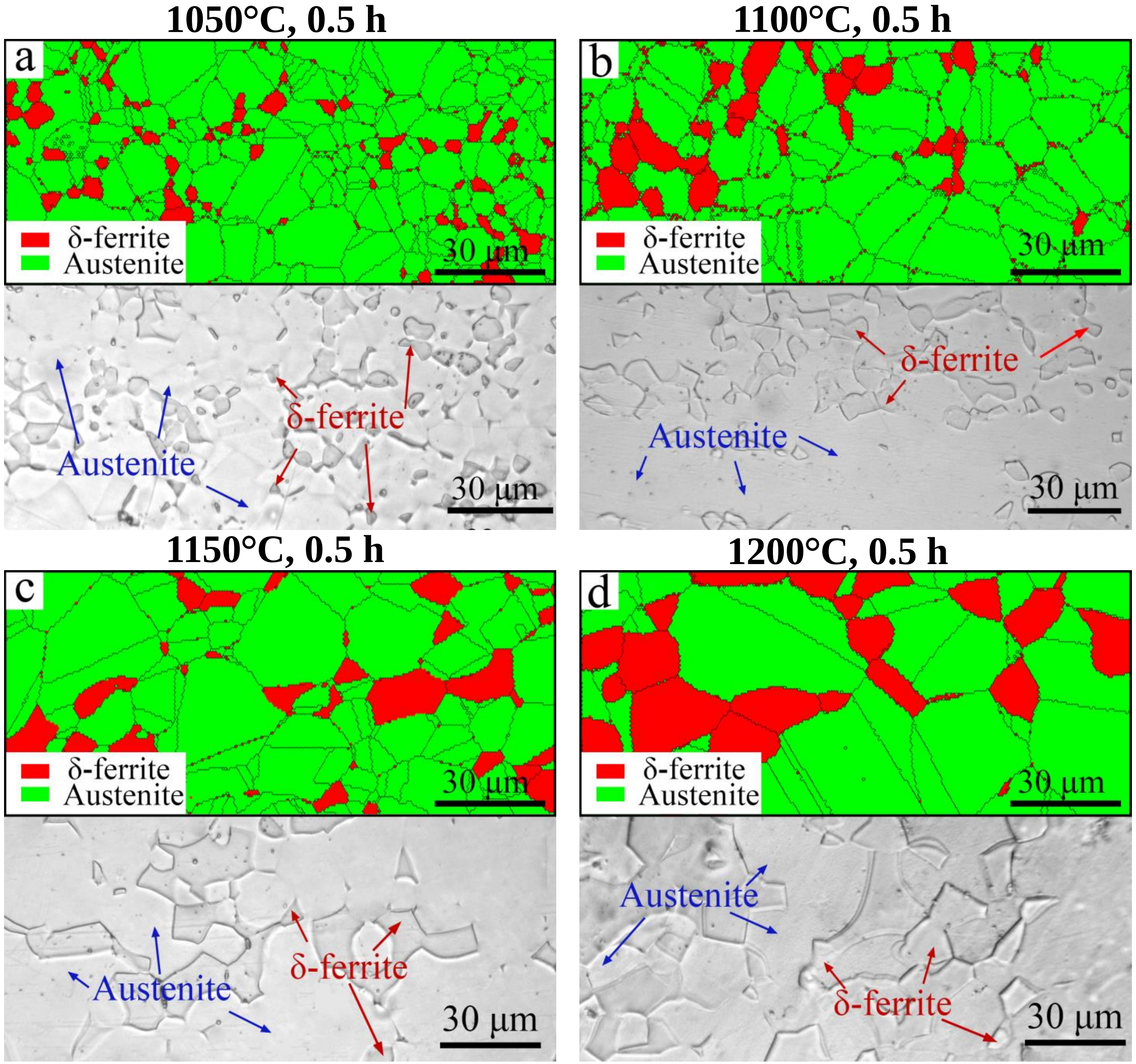


XRD patterns of HNS solution-treated in different regimes



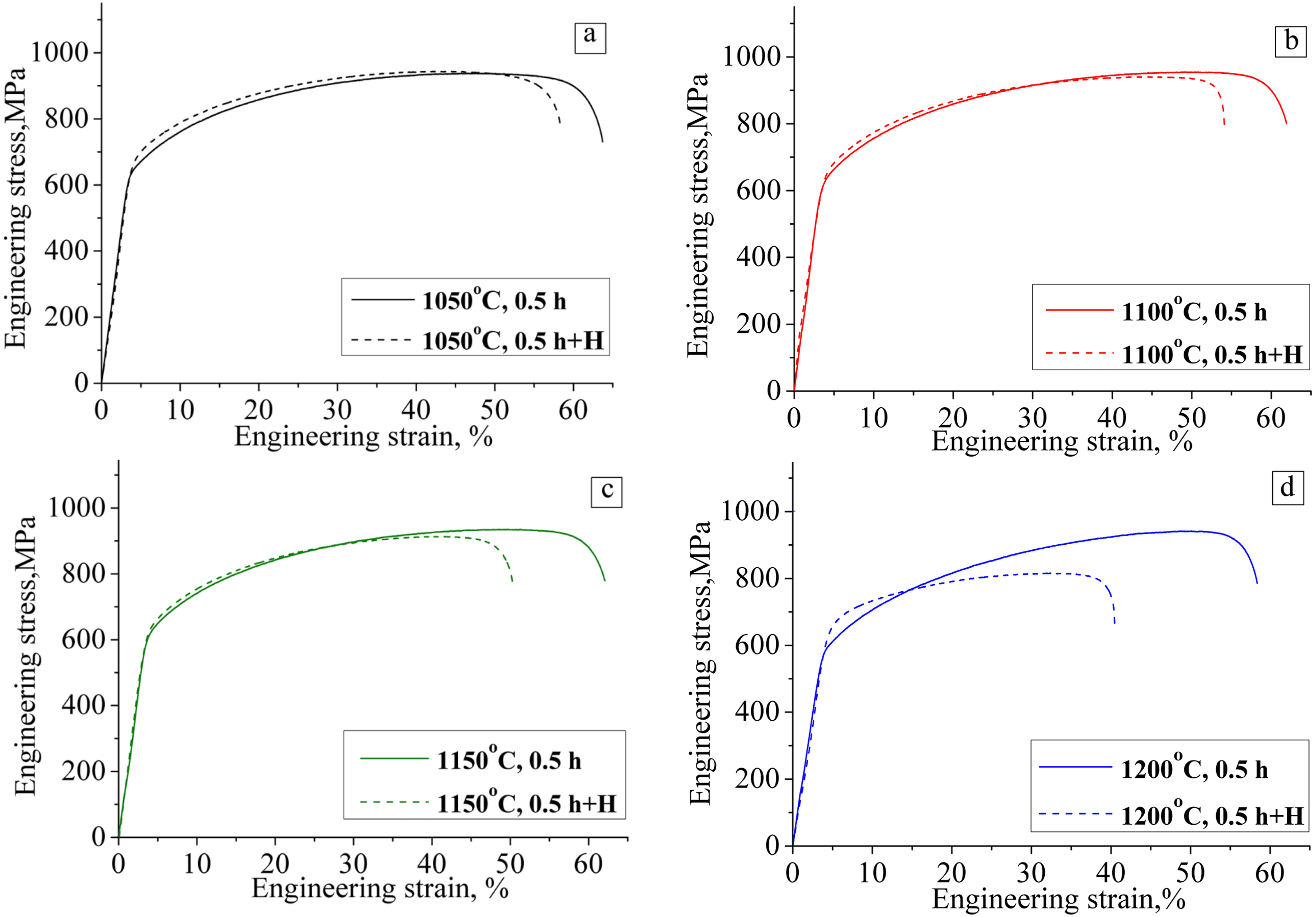
SEM image of a surface of solid-solution treated (1150°C, 0.5 h) specimen combined with results of Energy-Dispersive X-Ray Spectroscopy

EBSD phase maps and light microscopy images of HNS after different regimes of solid-solution treatment



T_{sst}	Average grain size γ-ferrite, µm	Average grain size δ-ferrite, µm	Volume fraction δ-ferrite, %
1050°C, 0.5 h	9.7±5.2	4.9±2.8	18.3
1100°C, 0.5 h	11.7±6.6	6.1±2.5	19.5
1150°C, 0.5 h	16.3±7.9	7.4±4.5	21.3
1200°C, 0.5 h	25.7±13.3	9.5±5.2	23.4

The dependence of mechanical properties of HNS on hydrogen-charging after different regimes of solid-solution treatment

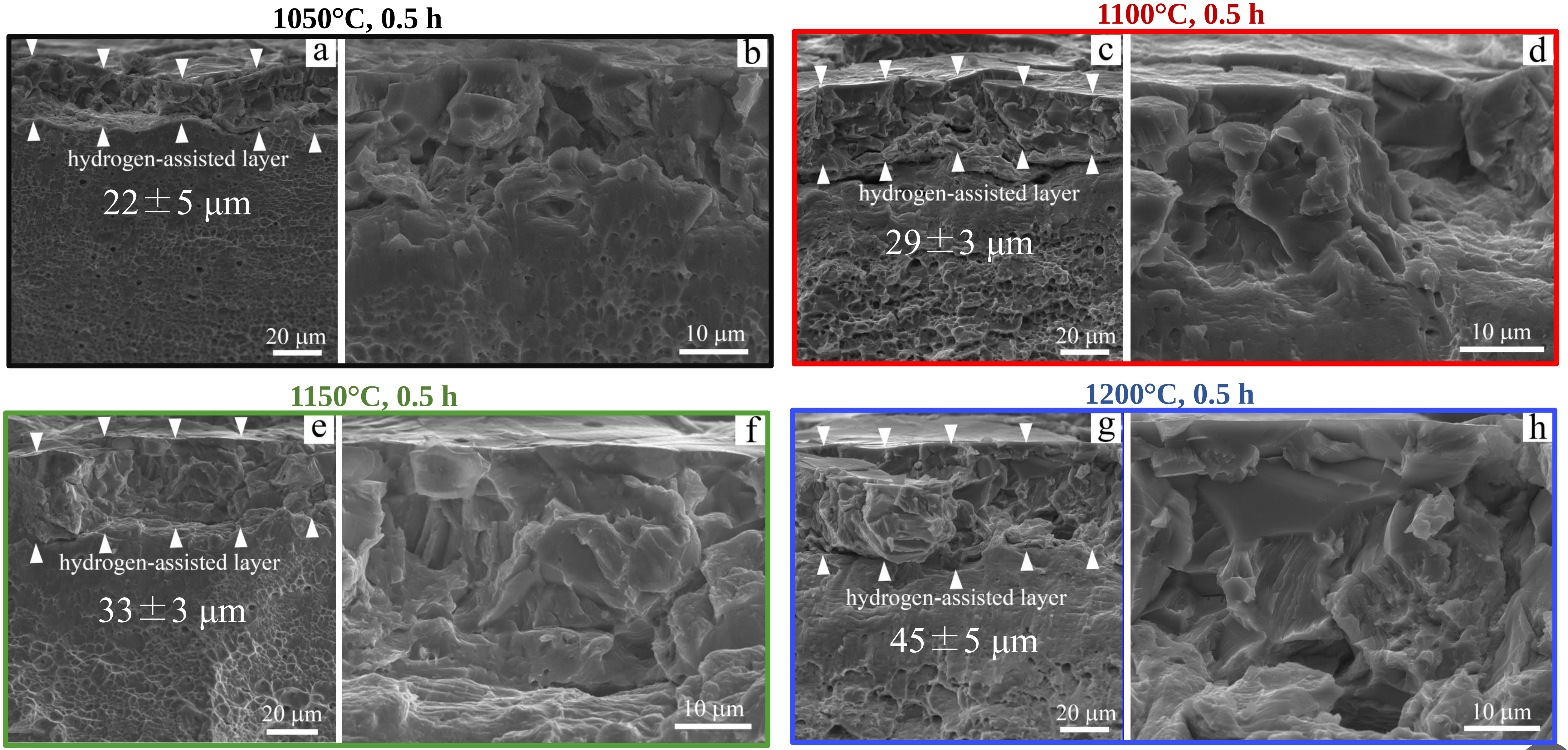


T_{sst}	I_H
1050°C, 0.5 h	10 %
1100°C, 0.5 h	15 %
1150°C, 0.5 h	23 %
1200°C, 0.5 h	32 %

Hydrogen embrittlement index:
$I_H = [(\delta_0 - \delta_H) / \delta_0] \times 100\%$,

δ_0 and δ_H - total elongation before failure of hydrogen-free and hydrogen-charged specimens, respectively.

SEM micrographs of fracture surfaces in hydrogen-charged specimens of HNS after different regimes of solid-solution treatment



SUMMARY

- The decrease of the grain size of δ-ferrite and austenite and the volume fraction of δ-ferrite in HNS contributes to the decrease of the diffusion of hydrogen atoms deeply into the samples and causes the decrease of the effects of hydrogen embrittlement.
- The decrease of the density of interphase and grain boundaries in HNS specimens leads to the change in the fracture mechanism of the hydrogen-assisted layer – it promotes the contribution of intergranular fracture.

THANK YOU FOR YOUR ATTENTION!