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JustH_2Transit material studies

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JustH2Transit WP3: Enable technologies

- Systemic H2 transition requires tackling technology bottlenecks related to H2 production, transfer, storage and utilisation.
- WP3 focuses on fundamental materials research and provides resource-efficient solutions for the H2 value chain.

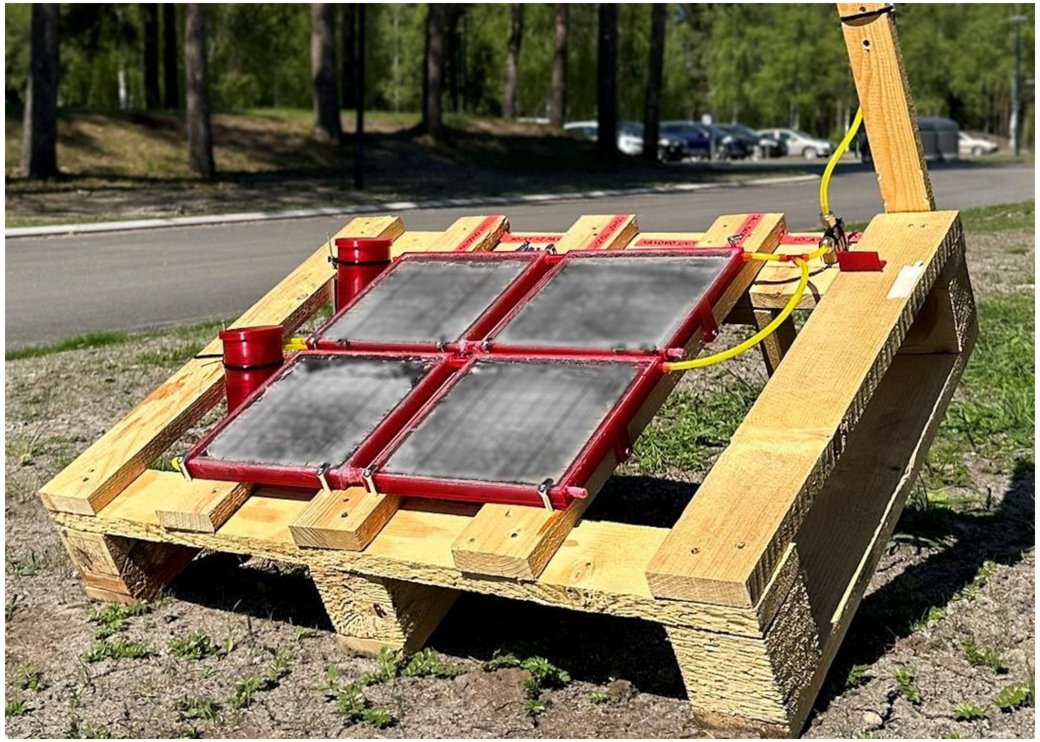
- Task 3.1: Emerging H2 production technologies
- Task 3.2: Infrastructure for H2 storage and transfer
- Task 3.3: Emerging H2 utilization technologies

WP3-Task 3.1: Emerging H_2 production technologies, lead: Varsha Srivastava/UO, partners: VTT, LUT.

- Development of catalysts materials by using biomass and waste streams for **thermal catalytic decomposition (TCD) of methane and biogas** to produce H_2 and high-value carbon sidestreams.
- Biomass and waste streams are inexpensive sources for the development of catalysts material. Purpose is to develop catalysts which are efficient and highly stable in TCD approach. We use hydrothermal and pyrolysis approach for production of carbon support from biomass waste and then it is used for catalysts development using different metal precursors.
- Testing of support material on catalysts efficiency towards H_2 production.
- Testing of different catalysts on quality and yield of H_2 and carbon sidestreams

WP3-Task 3.1: Emerging H_2 production technologies, lead: Varsha Srivastava/UO, partners: VTT, LUT.

- Development of semiconductor based photocatalytic materials for the **solar driven photocatalytic water splitting** into oxygen and hydrogen
- Development and design of the photocatalytic panel reactors.
- Testing of the developed semiconductor based photocatalytic materials in real outdoor application for water splitting



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Task 3.2 Infrastructure for H_2 storage and transfer

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T3.2 Infrastructure for H_2 pipelines (VTT, OU)

- Focus: **pipeline steels**
  - Grades: X52, X60, X65 (vintage natural gas pipeline), X70 (two different sizes/deformation levels)
- Experimental:
  - Characterisation of materials microstructures
  - H_2 permeation tests (different electrochemical charging conditions vs gaseous H_2)
  - Mechanical behaviour at various gas pressure levels
    - Gaseous hydrogen: SSRT, miniature tests by small punch; 20, 50 & 100 bars, reference: nitrogen
    - Electrochemical charging: fracture toughness testing for ranking the materials, investigation in HE as a function of temperature (Nordic design temperatures, Arctic environments)
  - Outcome: Understanding of the influence of…
    1) Pipeline steel microstructure & history,
    2) Operation pressure,
    3) Low temperatures.
  - Parallel projects: BF-NER MatHias, JTF UTAH2

T3.2 Infrastructure for H_2 containers (VTT, OU)

- Of special interest: role of H_2 in **fatigue and fracture** behaviour of candidate container materials
  - Fatigue behaviour of high-strength steels in pressurized H_2 (comparison: air, pressurized N_2, EC)
  - Fracture behaviour of high-strength steels under electrochemical H-charging conditions
  - Fatigue behaviour of austenitic stainless steels in pressurized H_2 (comparison: pressurized N_2)
  - Fracture behaviour of austenitic stainless steels in pressurized H_2
  - In all: microstructural characterization, H permeation tests, analysis of fracture surfaces, determination of H_2 contents, …
- Outcome:
  1) Design life for structures under dynamic loads,
  2) Role of H_2 in fracture
  3) Facilitating the use of ultrahigh-strength steels for H_2 applications
- Parallel projects: BF MASCOT, BF HydroMat, EU HyWay, JTF H2 TuSiVa, JTF H2Steels, MJ KoViS, JAES+TAHS AS4G, AOF PROFI7 H2FUTURE, …

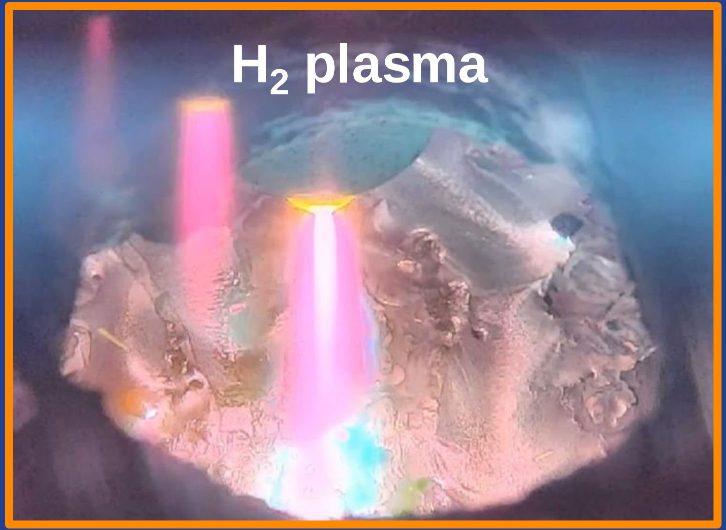
WP3-Task 3.3 Utilisation technologies: OuluMET

H_2 flames

Projects

HyInHeat (Horizon Europe)
TWINGHY (Horizon Europe)

<u>Aims</u>: to replace fossil fuels by H_2; to characterize H_2-flames; compare 100%H_2 flames to H_2/NG mixtures; study the scale formation on steel slabs when using H_2-burners in reheating furnaces



H_2 plasma

Projects

H2PlasmaRed (Horizon Europe)
HELIOS (Horizon-MSCA-DN)
PlasmArc4Green (COMET Austria)
TOCANEM2 (Business Finland)
Zerosteel (Horizon Europe)

<u>Aims</u>: to develop H2 plasma technology (TRL4-5) for (low-grade) iron ore reduction and steelmaking sidestream recycling; chromite reduction; process optimization; H_2-plasma modeling

H_2 Reduction

Projects

Sustainable Hydrogen - H2SUS (Interreg)

Towards Fossil-Free Steel 2 - FFS2 (Business Finland)

Hydrogen Future as a Climate Change Solution - H2FUTURE (RCF)

<u>Aims</u>: to study the effect of different parameters on the hydrogen reduction of iron ores and compare it to reduction with CO; develop H-DRI based steelmaking practices; to establish the durability of refractory materials in H_2 atmospheres at high temperature

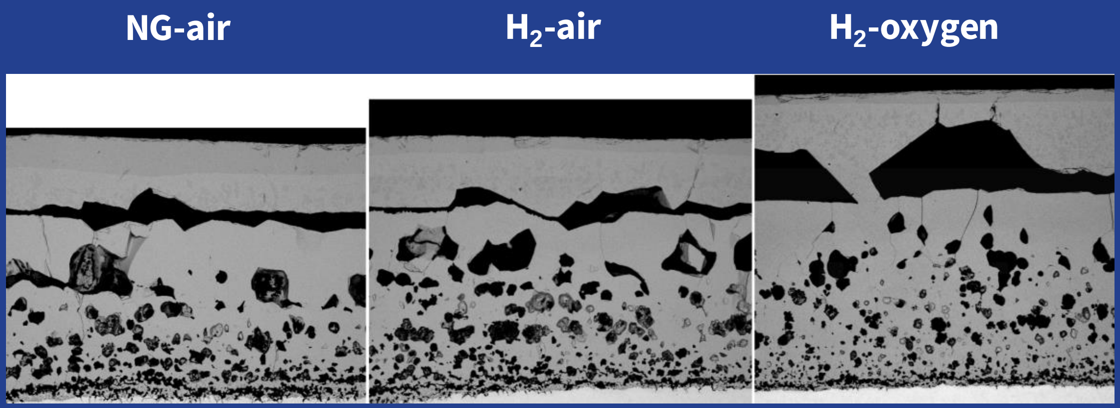
WP3-Task 3.3 Utilisation technologies: OuluMET

H_2 flames — Oxide scale formation on steel slabs

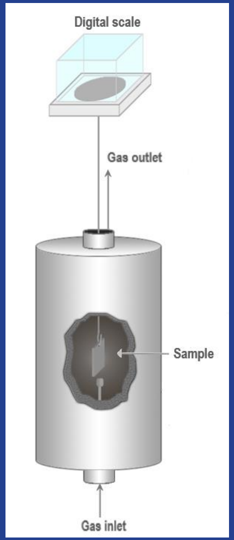
- Steel producers must find CO_2 neutral ways to reheat steel slabs before hot rolling, such as hydrogen fueled or electrical reheating
- Transition to H_2 combustion increases the proportion of water vapor in furnace gas atmosphere compared to natural gas

Fuel gas	Oxidant gas	CO_2	H_2O	N_2	O_2
NG	Air	8.1	16.3	72.6	3.0
H_2	Air	-	29.8	67.2	3.0
H_2	O_2	-	97.0	-	3.0

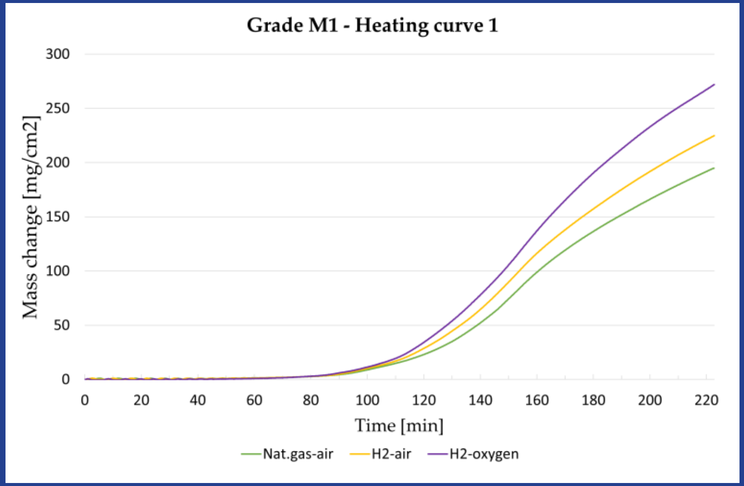
- Water vapor affects all aspects of steel oxidation: e.g. kinetics, oxidation mechanism, pore and crack formation, plasticity, and adhesion to steel
- Reheating simulations using different furnace gas atmospheres are performed in laboratory TG furnace to reveal differences between heating methods



Changes to morphology, pore structure and adhesion of scale



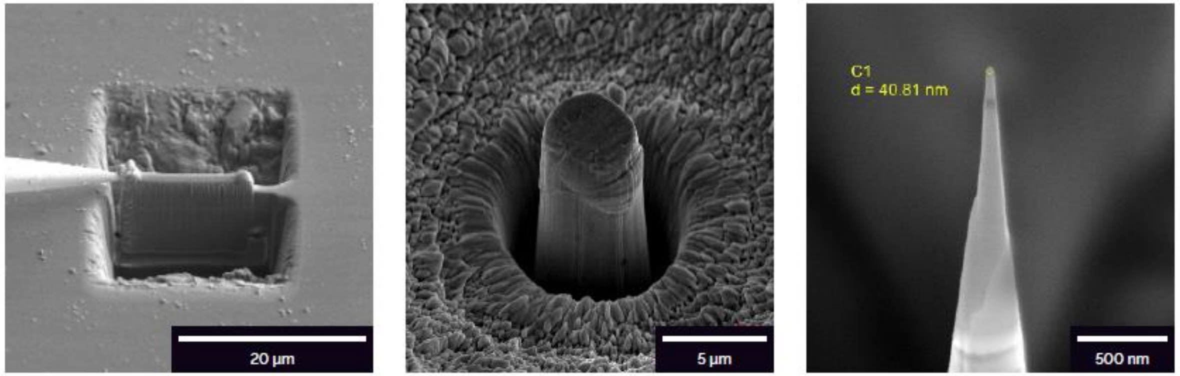
TG setup



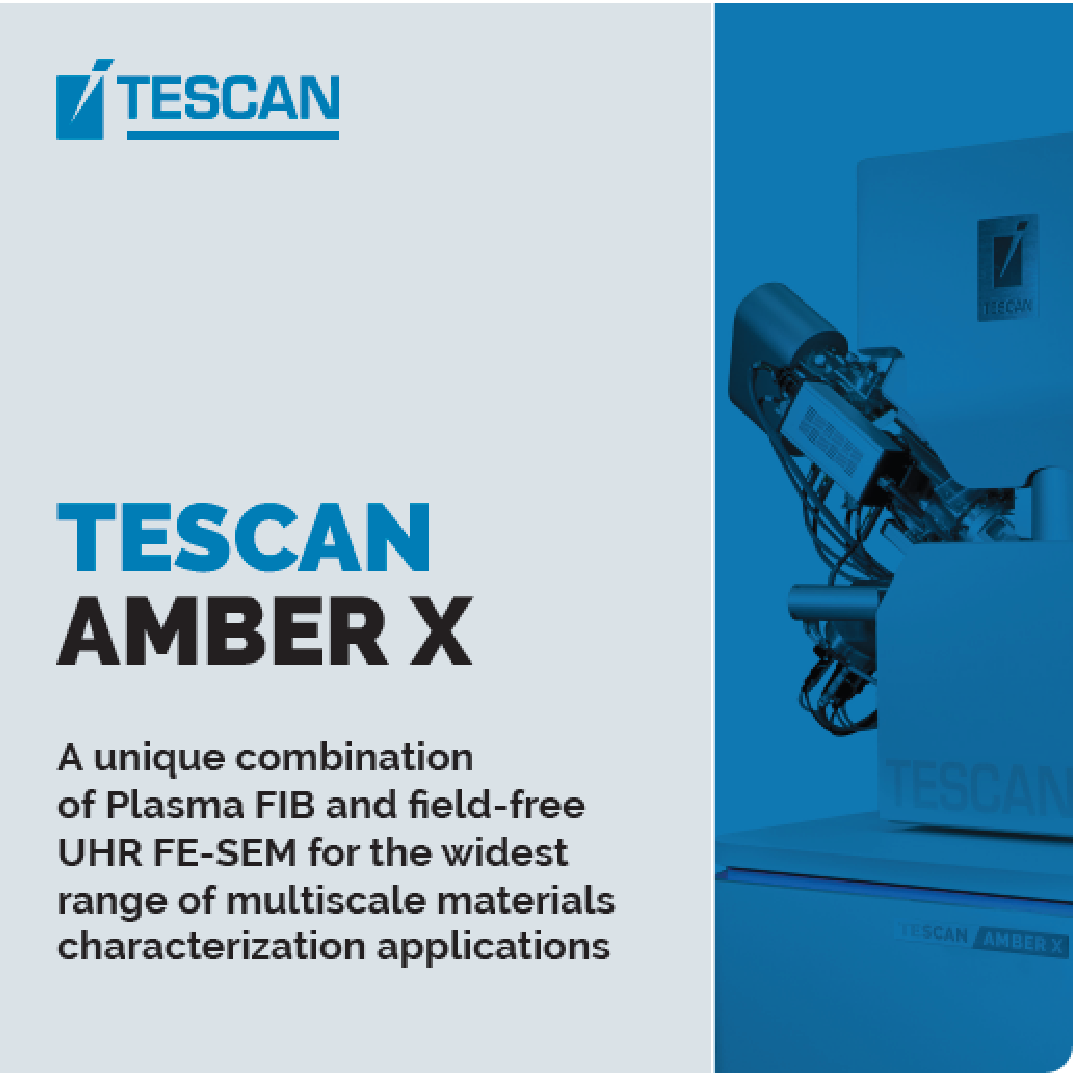
Influence on oxidation rate and material losses

Advanced characterization, VTT & OU

- Combination of plasma-FIB and UHR FE-SEM enables:
  - Examination of surface films of various characteristrics
  - In-situ studies during micro-mechanical tests
  - Easy preparation of, e.g., TEM



▲ (Left) A TEM lamella prepared using plasma FIB, (Center) A micro-pillar prepared from ultra-fine grain aluminum after compression testing, (Right) Ga-free atom probe tip sample preparation using plasma FIB



TESCAN

TESCAN AMBER X

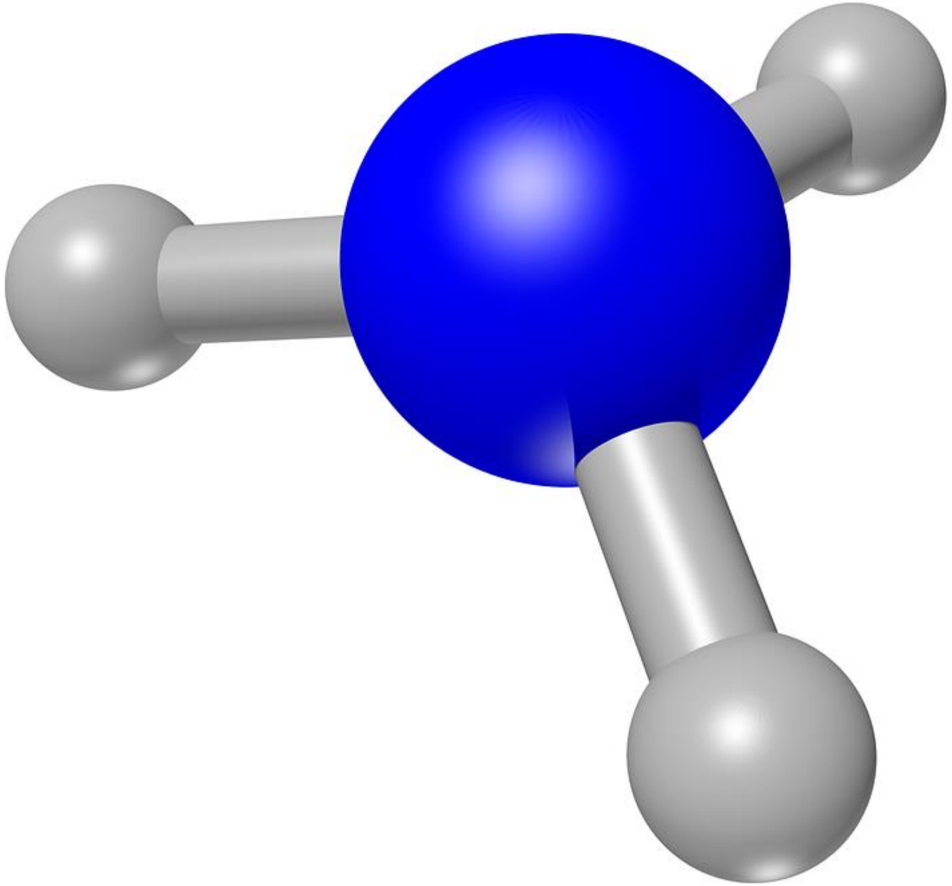
A unique combination of Plasma FIB and field-free UHR FE-SEM for the widest range of multiscale materials characterization applications

Task 3.3 Hydrogen utilization

- Ammonia is an efficient energy carrier
- Many utilization technologies employ elevated temperatures, e.g., combustion, SOFC,… → High-temperature corrosion by nitridation, influence on tribology,…

→ *Need to understand the lifetime & performance of materials*

→ Parallel projects: BF_MASCOT, SA_HYDROGENATE,…



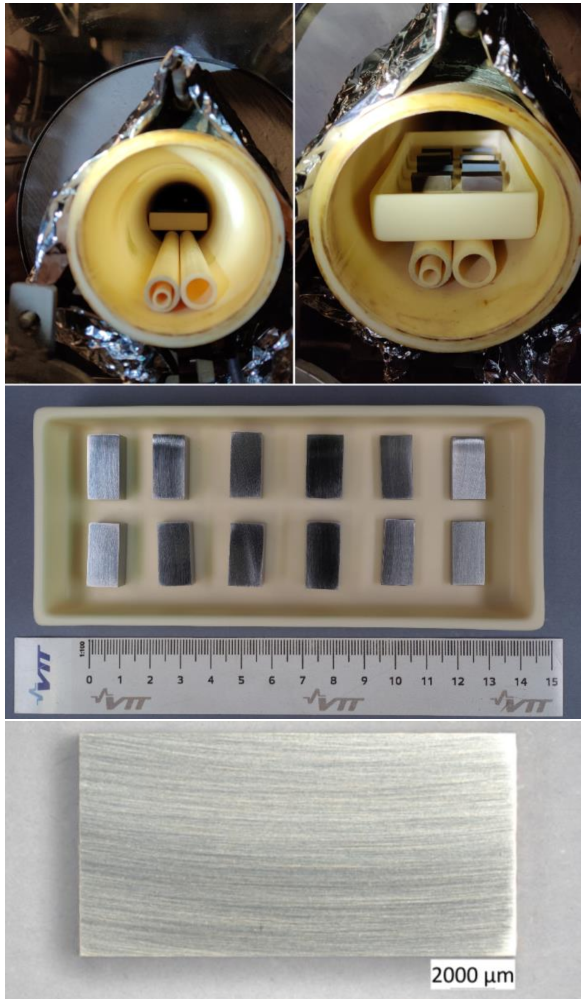
High-temperature corrosion of steels in SOFCs

Need for a wider understanding for possible metallic interconnect materials in SOFCs

Aim: understanding the effect of different alloying elements and microstructure
Characterisation: SEM/EDS/EBSD, TDS/hot melt, microindentation, XRD, and more

MATERIALS	
Outokumpu Core 4513	**Ferritic** stainless steels
Outokumpu Core 4622	
AISI 441	
Crofer 22H	
Sanergy HT (coated)	
253MA	**Austenitic** stainless steels
Nimonic 80A	
AISI 904L	

FURNACE EXPERIMENTS	
600 °C	**600 ± 50 °C**
Dry, gaseous environment free of oxygen	
$14\%\ NH_3 - 64\%\ H_2 - 22\%\ N_2$	
100, 300, and 1000 hours exposure	
10 litres/hour gas flow rate	
Ferritic and austenitic tested separately	



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Thank you!

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