Science 4 Technology – Poster Exhibition 2024

Department General, Analytical and Physical Chemistry

Chair of General and Analytical Chemistry

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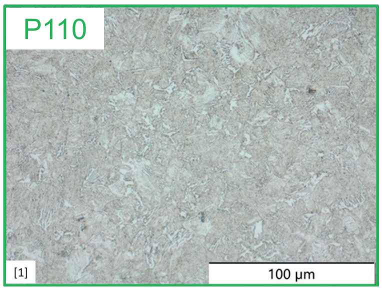
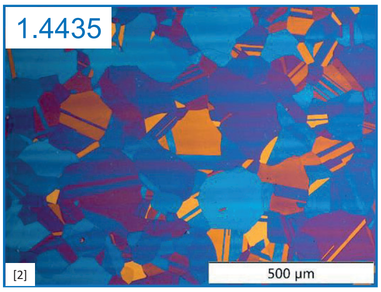
Hydrogen uptake and embrittlement of steels under highest pressures

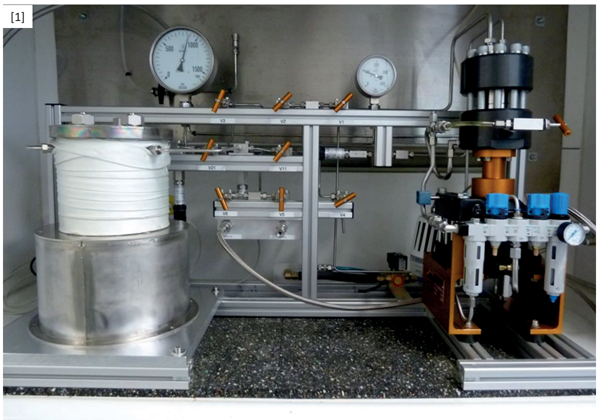
Matthias Eichinger, Gregor Mori

Hydrogen may be the most promising energy source for replacing fossil energy carriers in industry. Hydrogen must be stored and transported under high pressures to provide the energy needed for this transition. Most of the steels used for pipelines and tanks are carbon steels prone to hydrogen embrittlement. Although austenitic stainless steels show superior resistance they are also not immune to hydrogen embrittlement. Therefore, it is of crucial importance to know how much hydrogen is taken up under the highest pressures and if this content can cause material deterioration.

Material	Chemical Composition [%]								
	C	Si	Mn	P	S	Cr	Ni	Mo	N
P110	0.31	0.21	1.36	0.011	0.007	0.24	0.03	0.01	<0.01
1.4435	<0.02	0.31	1.80	0.018	0.001	17.50	14.70	2.80	0.1





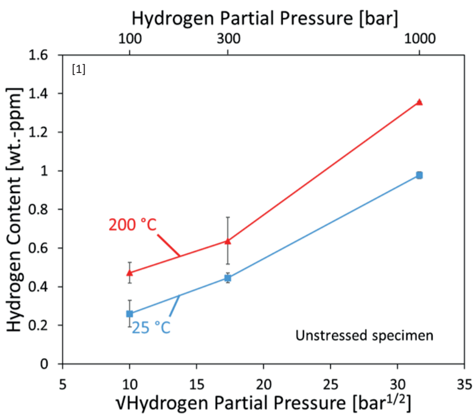


To analyse the hydrogen uptake of the steels as function of H_2 partial pressure and temperature a high pressure high temperature autoclave test bench, with an operation range up to 1000 bar and 200 °C was installed. One advantage of the new device is that it is also possible to conduct constant load tests (CLT) under high pressure gas atmosphere. Furthermore, ex-situ SSRT tests were conducted to investigate the hydrogen embrittlement susceptibility of austenitic stainless steels. Additionally the effective diffusion coefficients of all steel grades were determined by electrochemical permeation measurements. This diffusion coefficients were further used for the numerical simulation of diffusion profiles.

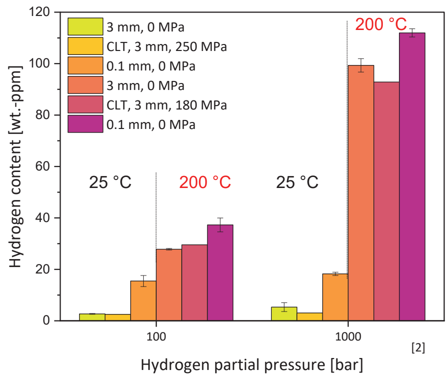
Conclusions

- Highest hydrogen contents of **P110**:
  - **1.0 wt.-ppm** at 25°C
  - **1.4 wt.-ppm** at 200°C
- Highest hydrogen contents of **1.4435**:
  - **18.3 wt.-ppm** at 25°C
  - **112.0 wt.-ppm** at 200°C
- This hydrogen contents did not lead to a failure in CLTs at 90 % YS
- The effective hydrogen diffusion coefficients at 25 °C are:
  - **$1.1 \cdot 10^{-10}$ m²/s** for **P110**
  - **$9.4 \cdot 10^{-16}$ m²/s** for **1.4435**

P110



1.4435



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Research focus:

- Corrosion science
- Hydrogen – Material interactions

Allgemeine Analytische Chemie

AG Korrosion

[1]: M. Eichinger, J. Pengg, S. Raab, G. Mori; On the hydrogen uptake of line pipe steels L80 and P110 under gaseous hydrogen charging up to 1000 bar and 200 °C; International Journal of Hydrogen Energy; 50; 2024; 388-399

[2]: M. Eichinger, D. Zwittnig, J. Pengg, G. Mori; Hydrogen diffusivity, uptake and embrittlement of solution annealed and cold deformed austenitic stainless steel A220 at hydrogen pressures up to 1000 bar and 200 °C; Currently under Review in Corrosion Science; Manuscript number: CORSCI-D-23-03008

Poster Exhibition 2024

Science 4 Technology @MUL

Influence of surface treatments on hydrogen embrittlement of tempered martensitic steels

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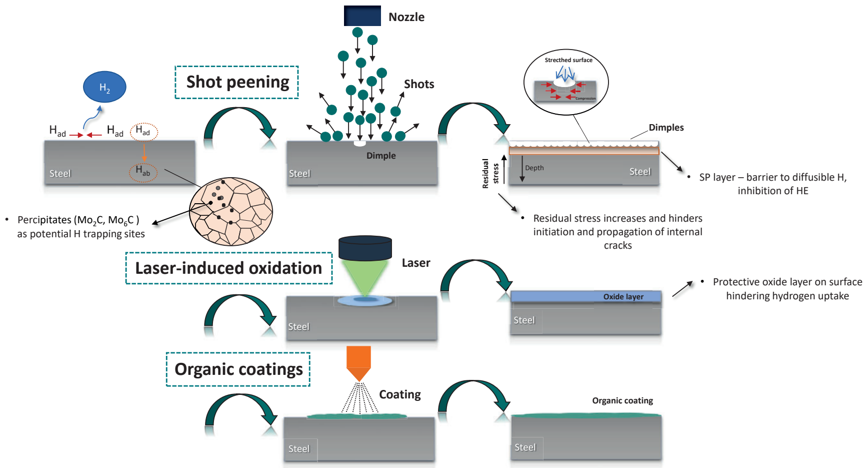
Introduction

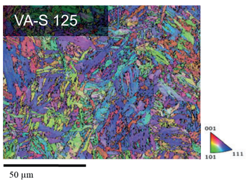
In the recent years, hydrogen appears to be a promising clean energy carrier to substitute fossil fuels. In order for hydrogen to become a viable energy source, transportation of hydrogen in substantial amounts and through great distances should be assured. To achieve this, high-strength martensitic steels can be used as material for pipelines. However, these steels have an elevated susceptibility to hydrogen embrittlement (HE), what can have a detrimental influence on their performance. To reduce the penetration of hydrogen in material, surface treatments (such as shot peening, laser oxidation and organic coatings) can be employed as hydrogen barriers and increase the resistance to HE.

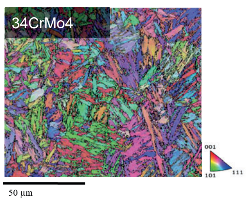


Methodology

- Investigated materials are two tempered Cr-Mo martensitic steels (VA-S 125 and 34CrMo4) with different chemical compositions and heat treatments.

Material	Chemical composition (%)								UTS (MPa)
	C	Si	Mn	Cr	Mo	S	P	Ni	
VA-S 125	0.21	0.04	0.84	0.98	0.97	0.002	0.005	0.14	1045
34CrMo4	0.31	0.09	0.70	0.94	0.16	0.008	0.009	0.002	910



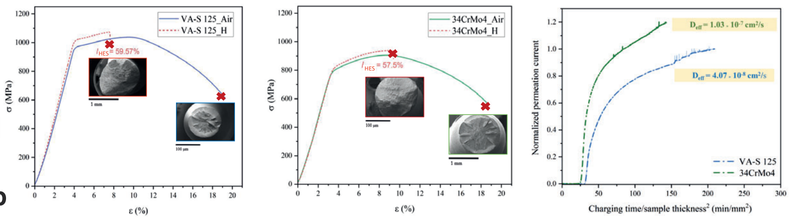


- Hydrogen uptake → Electrochemical H charging; Gaseous hydrogen charging
- Hydrogen trapping → Thermal Desorption Spectroscopy (TDS)
- Mechanical properties → Slow Strain Rate Test (SSRT)
- Diffusion coefficient → Permeation experiments

Results

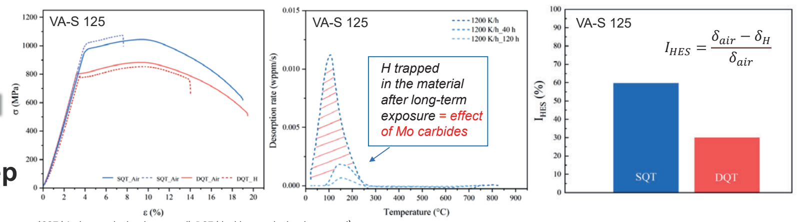
Mechanical properties of the materials

I. step



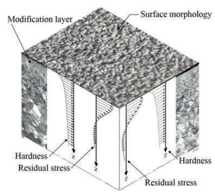
Effect of changing heat treatment and Mo carbides

II. step



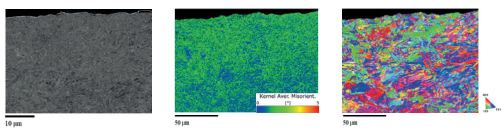
*SQT (single quenched and tempered), DQT (double quenched and tempered)

Implementation of surface treatments



Shot peening [1]

[1] S. Yang, W. Zeng, J. Yang, https://doi.org/10.1016/j.ijfatigue.2020.105621.



Surface layer as permeation barrrier

Increase of dislocation density

Grain refinement

Conclusions

- In the as-received condition investigated medium carbon martensitic steels, VA-S 125 and 34CrMo4 are highly susceptible to HE.
- Mo carbides play the role of hydrogen traps and affect hydrogen-steel interaction.
- Higher Mo content and double Q&T tempering methodology improve significantly the resistance of the alloy VA-S 125 to HE.
- Surface treatments should implement a barrier to hydrogen uptake and reduce HE susceptibility.

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voestalpine ONE STEP AHEAD.

COMET

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From circular economy to soil health?

Carbon from Methane Plasmalysis (CMP) as a potential soil amendment

Aim of the project

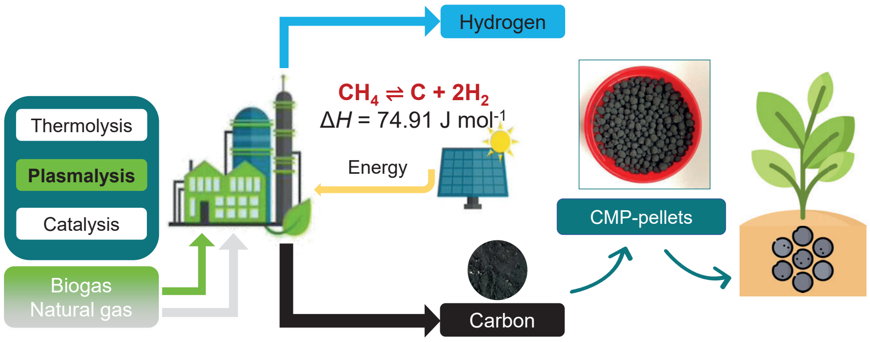


Fig. 1. Pyrolysis of methane.

CMP production → CMP application in soil

The production of hydrogen from CH_4 results in an important by-product: **solid carbon**.

The aim of this study is to investigate the application potential of CMP as soil amendment. **CMP is a highly pure material** and can be applied without any concerns.

Through a **series of experiments** - in a greenhouse, in the field, and in a multi-sensor growth chamber - the effects of CMP on soil and plant performances were investigated.

Growth experiments on CMP treated soil & sand

Greenhouse experiment

After the characterisation of CMP, the effect of CMP on maize was tested in a greenhouse trial, with three different soils. Various amounts of pure CMP and combined with additives, were analysed for their impact on soil properties and plant characteristics.

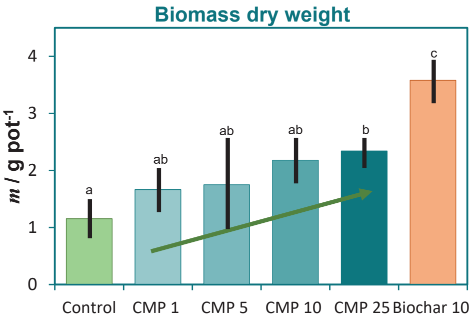


Fig. 2. Dry weight of the aboveground maize biomass CMP in % to soil and in comparison to biochar. SD (n = 3). a, ab, b, c indicate significant differences ($p < 0.05$).

Field experiment

The effects of CMP on maize and subsequently on wheat were investigated in a 16-month field trial. The crops were grown in soil mixed with CMP, with two main harvests and several soil samples taken to assess the effects on yield and soil properties.

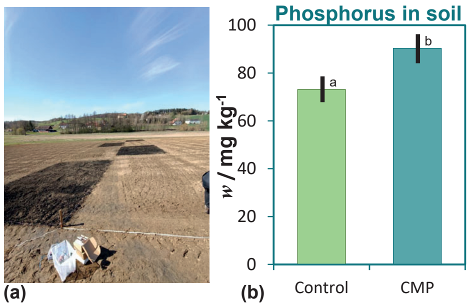


Fig. 3a. Image of the field with and without CMP treatment. **Fig. 3b.** Plant-available P in control and CMP-treated soils. Error bars: SD (n = 4). a, b indicate significant differences ($p < 0.01$).

Growth chamber experiment

The effect of pelletized CMP on wheat grown in agricultural soil and barley in quartz sand was analysed in a growth chamber. This research aimed to determine CMP's potential to mitigate drought stress in plants, focusing on its impact under controlled conditions.

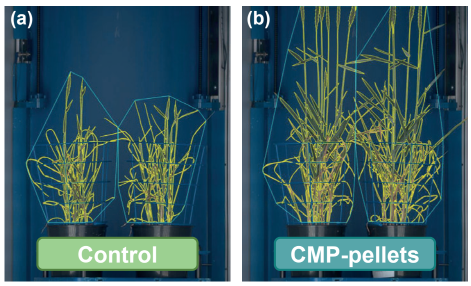
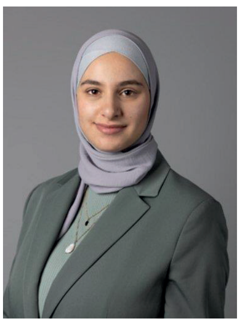


Fig. 4. RGB images of the leaf area 47 days after planting on (a) control soil and (b) after CMP-chicken manure treatment under drought stress without fertilization.

Conclusions

The benefits of applying CMP to soil were clearly seen in all three studies. In the **greenhouse experiment**, adding CMP led to a noticeable increase in biomass. During the **field experiment**, CMP increased the amount of plant-available phosphorus in the soil. Lastly, in the **growth chamber experiment** the application of CMP-based pellets has led to an improved resistance against drought stress. The reduction of the leaf surface temperature under drought conditions, which might have reduced the water consumption as a result of lowered water evaporation.



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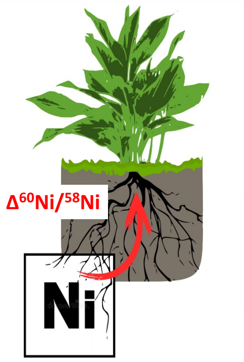
rag AUSTRIA AG
SCHENREITER NATUR UMWELT NACHHALTIGKEIT



Mobilization of Nickel by hyperaccumulating plants

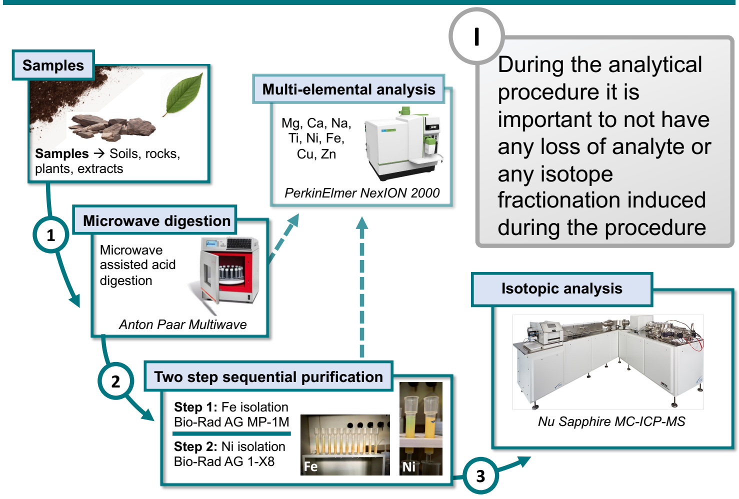
DO PLANTS ACTIVELY MOBILIZE Ni IN SOIL?

Source: *www.icnnational.com/*

INTRODUCTION

In a collaborative project between the University of BOKU, Tulln and Montanuniversität Leoben, the focus is to investigate Ni solubilisation processes in the rhizosphere of Ni hyperaccumulating plants. Hyperaccumulation of Nickel was observed to lead to isotope fractionation [1]. Thus, investigating Ni and Fe isotope compositions in soil and plant materials may shed light onto the processes in the rhizosphere, elucidating interactions in the plant soil microbe system. In the project, MUL is responsible for the development of analytical methods for isotope ratio analysis.

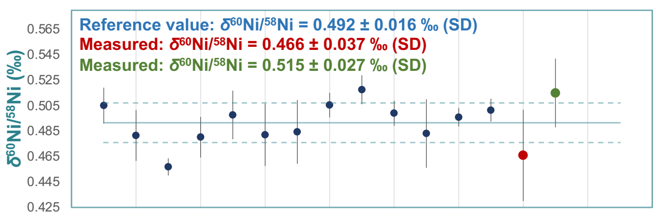
ANALYTICAL PROCEDURE



FIRST RESULTS

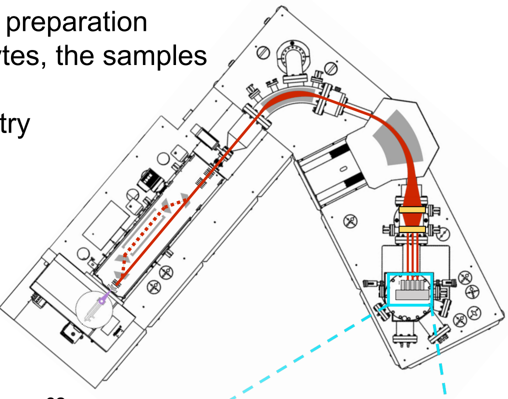
To validate our measurement procedures, an in-house Ni solution was measured using Cu as an internal calibrator. The obtained values (**red** and **green**) were compared to previous measurements of the same Ni solution (**blue**).

The obtained results allowed us to determine the **repeatability** ($\delta^{60}Ni/^{58}Ni$ = 0.020 ‰) and the **intermediate precision** ($\delta^{60}Ni/^{58}Ni$ = 0.027 ‰)



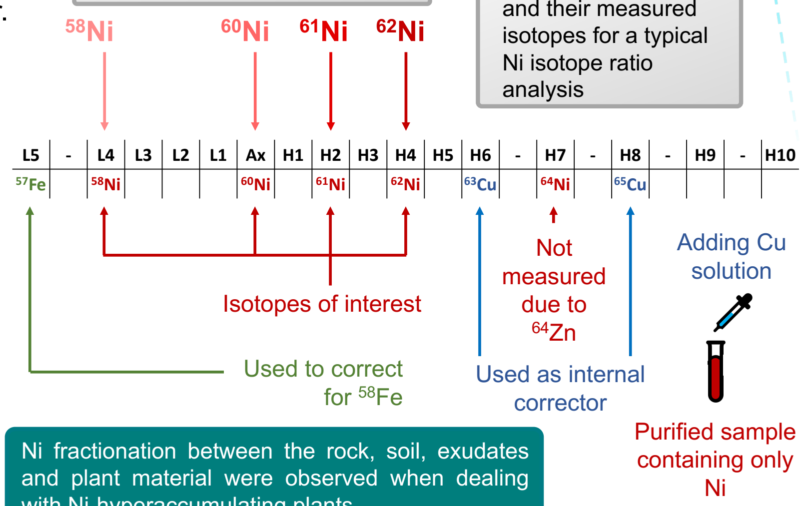
NU SAPPHIRE MC-ICP-MS

- After the sample preparation isolation of analytes, the samples are analysed by mass spectrometry (MC-ICP-MS).
- This allows the simultaneous measurement of the isotopes of interest
- In our case ^{58}**Ni**, ^{60}**Ni**, ^{61}**Ni, and** ^{62}**Ni**



II Ion beam arriving from plasma source arrive to the Faraday cups where the intensity of each beam is measured in volts

III Here is a visualisation of all the elements and their measured isotopes for a typical Ni isotope ratio analysis



Ni fractionation between the rock, soil, exudates and plant material were observed when dealing with Ni-hyperaccumulating plants.

Typically, in nature the isotopic variation of Ni in major inorganic compartments ranges are:

$$\delta^{60}Ni/^{58}Ni_{SRM986} \text{ from } -0.1 \text{ to } +0.6 \text{ ‰}$$

Thus, repeatability and intermediate precision obtained during our measurements suggest the analytical protocol and measurement procedure are fit for purpose for the study of Ni fractionation by Ni-hyperaccumulating plants

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FWF Project P 34719

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Science 4 Technology @MUL

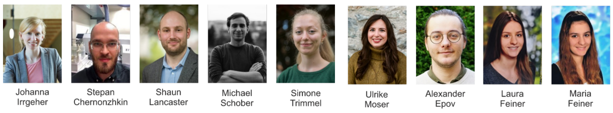
CHAIR OF GENERAL AND ANALYTICAL CHEMISTRY

RESEARCH GROUP ISOTOPIC ANALYSIS

Head: Assoc.Prof. DI Dr. Johanna Irrgeher

Team, infrastructure and research overview

TEAM / INFRASTRUCTURE



MU Leoben laboratories for elemental and isotopic analysis

IMPRESSIONS FROM THE GROUP

TEACHING

Our team is especially entrusted with courses in the field of Analytical Chemistry, both in bachelor and master programs. There are always opportunities to join the team within project-based courses in the lab. Bachelor and master projects are embedded into our research projects in different fields of basic and applied sciences.

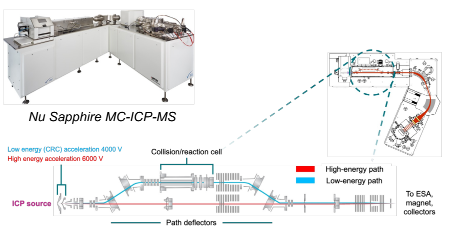
RESEARCH

The research group isotope analysis deals with the development and application of new analytical methods for isotope analysis. The research includes fundamental method development with a main focus on mass spectrometric methods ((MC) -ICP-MS, TIMS). The applications cover tracing, spiking and fingerprinting in the area of strategic/critical elements and raw materials, provenance studies of environmental and geomaterials in the context to support the UN sustainable development goals.

MAIN RESEARCH TOPICS

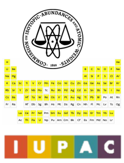
Fundamentals of Isotope Ratio Analysis

Our group specializes in advancing MS-based techniques and refining sample preparation protocols. We're dedicated to crafting meticulously validated methods, including precise analyte/matrix separation, innovative calibration strategies, exhaustive interference analysis, meticulous consideration of measurement uncertainties, pioneering the development of reference materials, and state-of-the-art data processing.



Atomic Weights of the Elements

Isotope ratio measurements are the basis for the determination of the Atomic weights of the Elements. Formally established in 1899, the Commission on Isotopic Abundances and Atomic Weights remains one of the oldest continuously serving scientific bodies. Our group is currently chairing CIAAW within IUPAC.



Tracing – Spiking - Fingerprinting

Isotope ratios of many elements can be used in environmental sciences, archaeometry and material sciences to trace the fate of a certain element. Alternatively, enriched stable isotopes are used to alter the isotopic composition and label a selected element. This help to understand natural and technological processes.

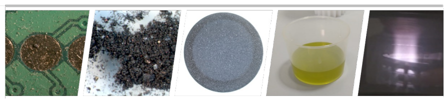
Our projects in this field span from tracking inorganic pollutants in river systems (e.g. the Mur River), to investigating the biological mechanisms behind Nickel hyperaccumulating plants used for phytoremediation to tracing sources of non-metallic inclusions in the steel production.

Furthermore, we include Citizen-scientists in our research projects and support activities to foster passion for STEM subjects.

Sustainable Chemistry & Beyond

Today, analytical chemistry contributes more than ever to addressing the global challenges we face by supporting the achievement of the United Nations Sustainable Development Goals (SDGs).

Through precise measurements and the identification of pollutant sources, analytical chemistry enables us to take targeted measures for environmental improvement and sustainable development in support of the EU Green Deal.



Our projects in this field aim at identifying conventional and modern sources of pollutants, the interaction between solid and liquid phases and the identification of specific pollutant carriers.

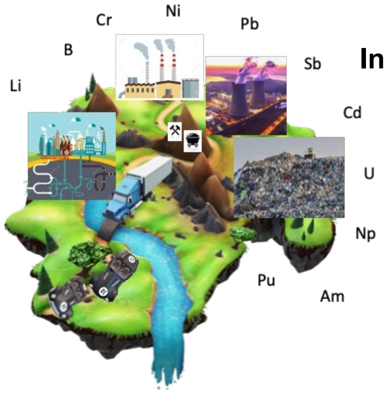
In the context of the EU Green deal, we develop analytical methods to accurately determine (technology-)critical elements in electronic waste in order to support recycling possibilities.

Inclusion in lab

Our team is also dedicated to promote inclusion in the analytical laboratory and support actions to reduce barriers in order to promote access to science to everyone passionate about science.

MetroPOEM

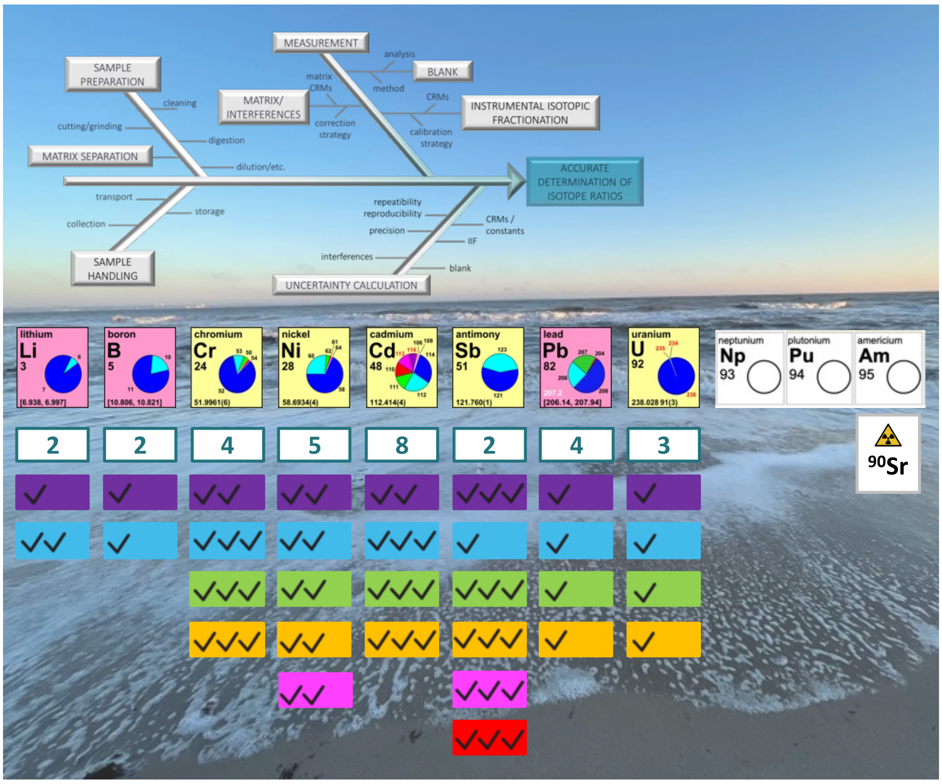
Metrology for the harmonisation of measurements of environmental pollutants in Europe



In a consortium of 20+ metrology and non-metrology institutes MetroPOEM AIMS at:

- Bridging the gap between radiometric techniques and mass spectrometry by comparing and linking both techniques
- Development of highly sensitive and state-of-the-art detection techniques for radionuclides and stable isotopes in seawater
- Determine ultra-low amounts of pollutants in the environment
- Development and characterization of seawater CRMs (SI-traceabaility)

The **RG Isotope analysis at the Chair of General and Analytical Chemistry** is particularly involved into developing and establishing methods related to ^{90}Sr, stable Ni and Pb isotope ratio analysis. Research is condcuted in the new clean room facilities at MUL using high-end mass spectrometers.



CHALLENGES OF METROPOEM:

number of isotopes

absolute isotope ratio data required

complex seawater matrix

ultra-low levels of analyte

large quantities of CRM required

lacking, exhaust CRMs

lacking 0-anchors (e.g. Sb)

CONSORTIUM:

AARHUS UNIVERSITY, DTU, hereon, HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF, IFE, PTB, BAM, cea, CZECH METROLOGY INSTITUTE, IFIN-HH, Jožef Stefan Institute, Ljubljana, Slovenia, Leibniz Universität Hannover, MONTAN UNIVERSITÄT LEOBEN, NMBU, University of Helsinki, ETH zürich, LNE, NML, NPL National Physical Laboratory, stuk, TÜBİTAK UME, VINČA

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The project (21GRD09 MetroPOEM) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

Funder name: European Partnership on Metrology

Funder ID: 10.13039/100019599

Grant number: 21GRD09 Metro POEM

EURAMET

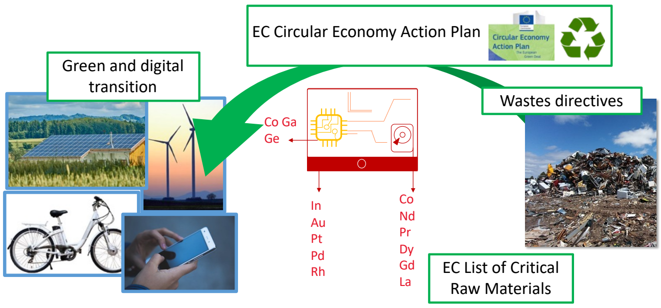
Website: https://www.npl.co.uk/euramet/metropoem

Email: metropoem@nmbu.no

Metrology for the recycling of Technology Critical Elements to support Europe's circular economy

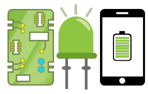
MetroCycleEU

Technology critical elements (TCEs) are irreplaceable raw materials that are vastly used in consumer products throughout society; including phones, computers, and renewable energy products. Dwindling supplies of TCEs, as well as rapidly changing geopolitical climates, threaten to disrupt technology production worldwide. Therefore, the European Union (EU) strives for a circular economy approach.



The MetroCycleEU project aims to **develop new reference methods** and **materials** to:

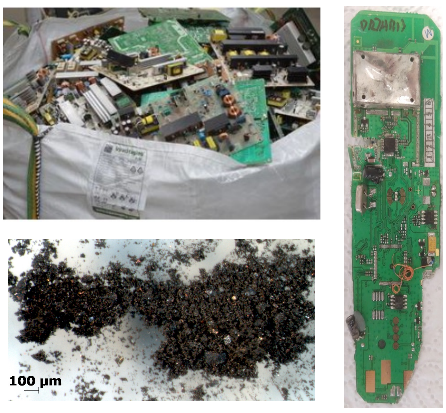
- Enable reliability, traceability, and comparability of sampling strategies and analytical results.
- Improve knowledge of TCE stocks in the recycling industry and inform on the recycling process.
- Target matrixes:
  - printed circuit boards (PCBs),
  - light emitting diodes (LEDs), and
  - Li-ion batteries.



THE CHALLENGES

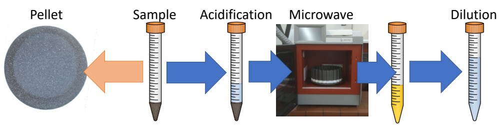
SAMPLING

The first major challenge for the analysis of electronic waste is to obtain a representative sample. E-wastes, such as PCBs, are extremely heterogeneous materials. 10-400 kg of material was sampled for producing certified reference materials in this project.



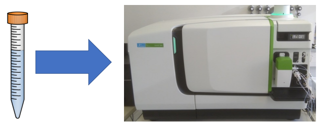
SAMPLE PREPARATION

Samples must be prepared depending on the analysis technique., e.g. acid digestion and pelletizing material. Complete digestion of e-waste is very difficult and typically requires harsh, toxic reagents, such as hydrofluoric acid. As such, the development of improved digestion methods are a key focus.

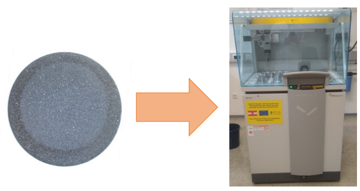


ANALYSIS

1) Inductively coupled plasma tandem mass spectrometry (ICP-MS/MS) is a widely used tool for routine analysis that is able to resolve interferences from other elements and provide reliable results.



2) X-ray fluorescence spectrometry (XRF) requires minimal sample preparation and can provide rapid analysis of materials. However, low sensitivity makes detection of low quantities of TCEs challenging.



The project MetroCycleEU is currently in the final project phase where the candidate materials for PCB, LED and LiB are being characterized in interlaboratory comparisons for technology-critical elements.

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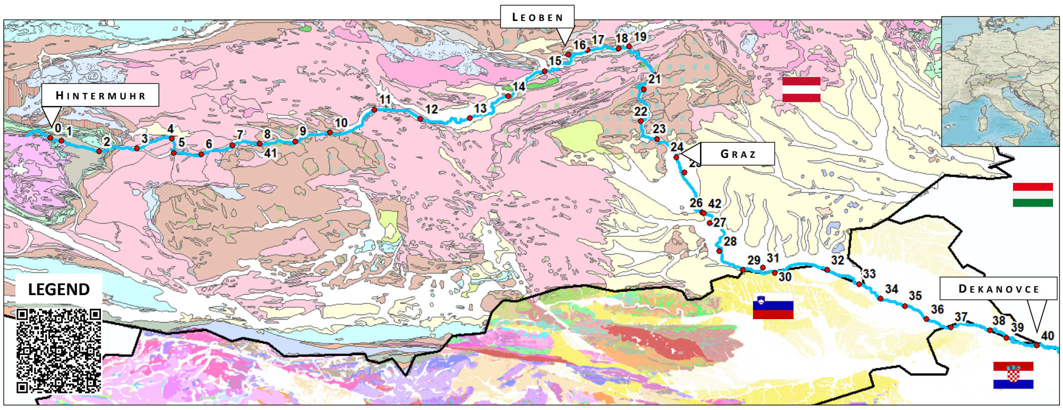
This project (20IND01 MetroCycleEU) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

Funder name: European Partnership on Metrology

EURAMET

Comprehensive (geo)chemical characterization of the Austrian-Slovenian Mur/Mura River catchment

The project "**MURmap**" aims to shed light on the spatial and temporal distribution of elemental mass fractions in the Mur River. In three campaigns, representing high, medium and low water tide investigations on influences on the river from



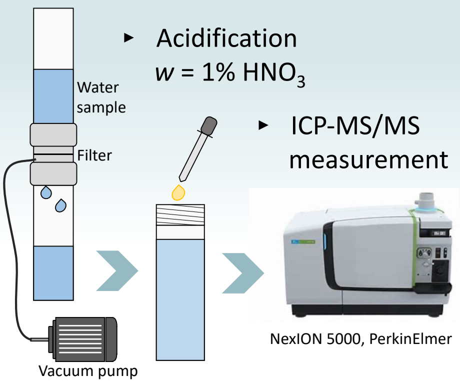
(1) natural geochemical background of the catchment
(2) historical and recent anthropogenic sources and
(3) solid/liquid phase interaction of chemical elements were carried out.

In order to comprehensively characterize the Mur River catchment

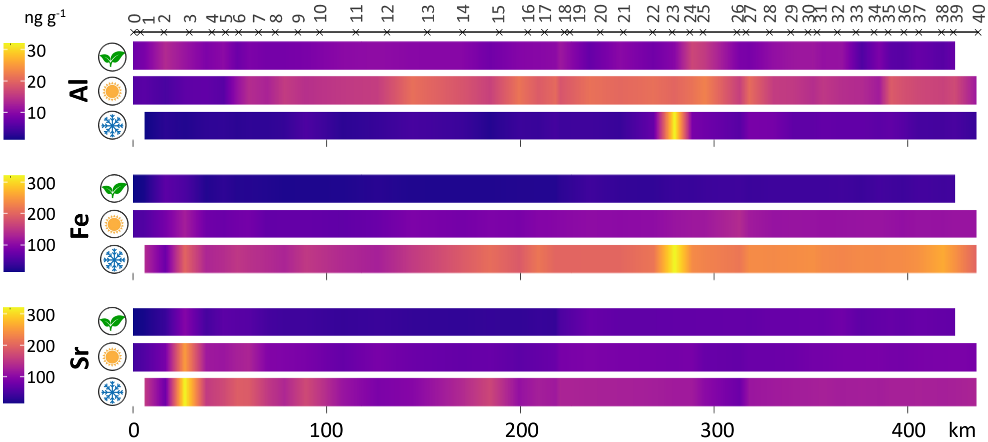
- water samples
- suspended particulate matter, and
- alluvial and stream sediment samples were taken and processed.

Methods

- Vacuum filtration (0.45 µm)
- Acidification w = 1% HNO_3
- ICP-MS/MS measurement



Results



Interpretation

- COMPARISON OF SEASONS
  - Significant differences in water discharge
  - Significant dilution/concentration effects in high/low water regime
- GEOLOGY
  - The change of geological units throughout the flow of the Mur River is detectable within the water.
- INSIGNIFICANT INFLUENCE OF CONSTRUCTION SITES
  - A construction site next to the river shows elevated signals on spot due to higher sediment load.

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GeoZS Geološki zavod Slovenije
AVAW Abfallverwertungstechnik & Abfallwirtschaft
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Chemical imaging in materials science

Novel DGT LA-ICP-MS approach for mapping of localized Al corrosion

Motivation

Intermetallics, i.e. heterogeneous precipitates of alloying elements, initiate the formation of micro holes (pits) and cavities in Al alloy, and may lead to leakage or fatigue crack initiation (Fig. 1).

Existing imaging methods lack information about the metal release from corroded regions.

Therefore, a novel approach based on Diffusive Gradients in Thin Films (DGT) in combination with Laser Ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was developed.

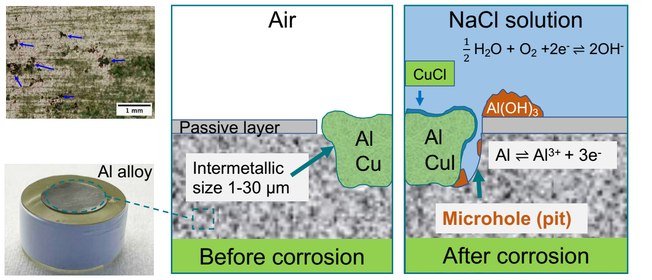

Fig. 1. Mechanism of pitting corrosion for Al alloy

Method development

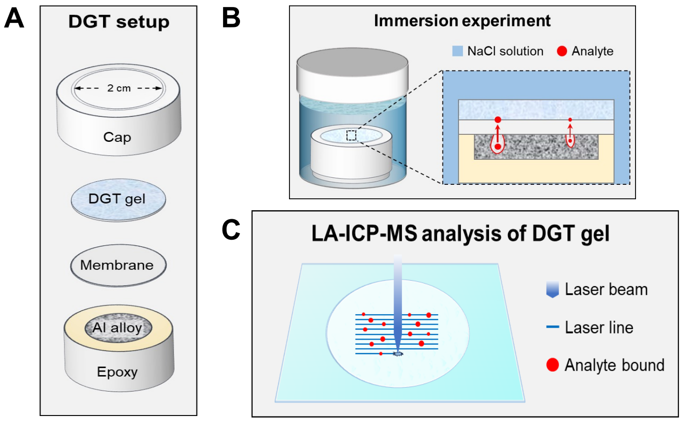

Fig. 2. DGT LA-ICP-MS method development

- DGT is a passive sampling technique, that uses a hydrogel with resin to bind analytes released from the sample.
- The sample (Al alloy) is covered with a membrane, the DGT gel and sealed with the DGT cap (Fig. 2 A).
- The setup is immersed in a NaCl solution for 15 min to induce corrosion and to bind released analytes (Fig. 2 B).
- LA-ICP-MS is used to ablate the surface of DGT gel after immersion test (Fig. 2 C)
- The data is visualized as chemical image (Fig. 3).

Results & Conclusions

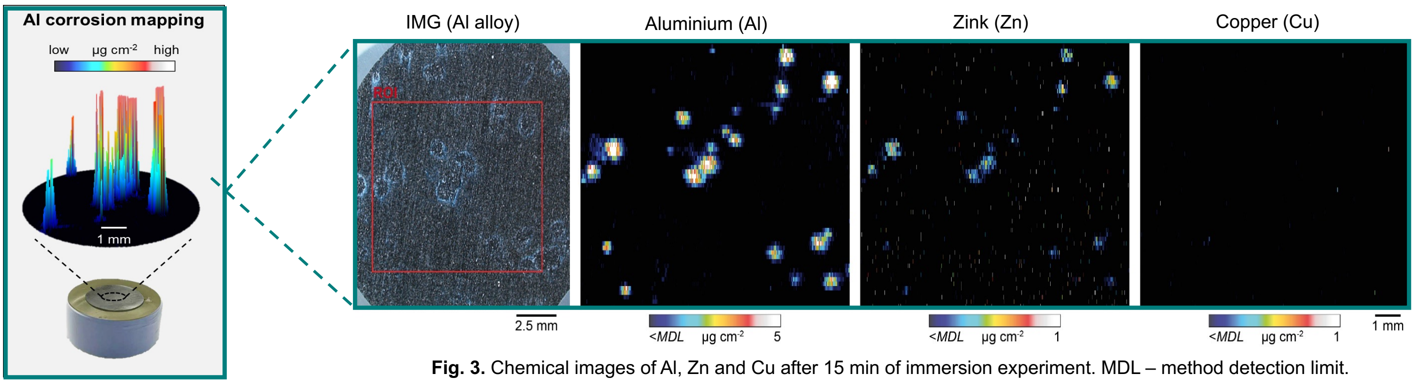

Fig. 3. Chemical images of Al, Zn and Cu after 15 min of immersion experiment. MDL – method detection limit.

Cathodic passivation of Cu-based intermetallic results in absence of Cu on the chemical image, whereas anodic oxidation of Al and Zn in alloy matrix explains their localized release into solution.

The DGT LA-ICP-MS approach enables quantitative mapping of localized metal release during pitting corrosion.

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CHAIR OF GENERAL AND ANALYTICAL CHEMISTRY

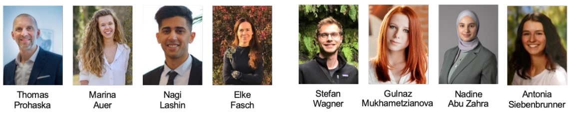
RESEARCH GROUP METROLOGY - TECHNOLOGY

Head: Univ.-Prof. Dipl.-Ing. Dr. techn. Thomas Prohaska

Team, infrastructure and research overview

TEAM / INFRASTRUCTURE

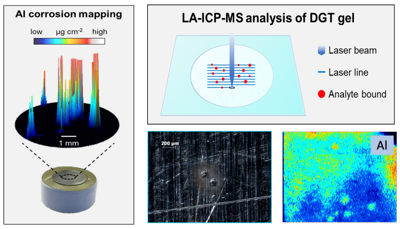
RG Metrology-Technology



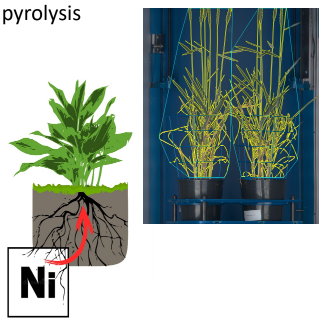
MU Leoben laboratories for elemental and isotopic analysis

NEWS

The application of carbon in agriculture is one of the most promising applications of carbon produced by methane pyrolysis



Diffusive Gradient in Thin Films (DGT) provide a promising tool for in-situ imaging of surface processes



Ni isotope spikes are used for investigating Ni hyper-accumulating plants

TEACHING AND RESEARCH

Fundamental teaching activities are within the first year for all bachelor studies in the field of general chemistry.
Basic and advanced courses in analytical chemistry complement the teaching activities.

In the context of Life Long Learning, a course in "Quality Assurance in the chemical Laboratory" is offered as e-learning course.

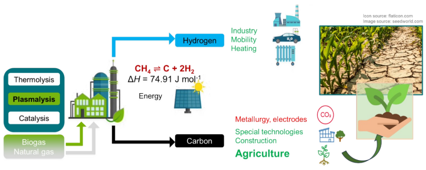
Sound metrological principles are developed and transferred to analytical routines. Innovative analytical tools and technologies are assessed and developed.

A special focus is set on chemical imaging of surfaces using LA-ICP-MS, LIBSN and recently on diffusive gradient in thin film technologies (DGT). Novel materials are investigated for their chemical properties and effects.

MAIN RESEARCH TOPICS

Chemistry of New Products: Technological Carbon in Agriculture

Within the hydrogen core activities of the Montanuniversität Leoben, one pathway is the production of H_2 and C via different processes of CH_4 pyrolysis. Whereas the application of H_2 as energy source or valuable chemical is straight forward, the usage of the achieved amounts of pure C as value product is manifold.



In a joint project between the Montanuniversität Leoben and the University of Natural Resources and Life Sciences, along with other partners, a project to apply technologically produced carbon by methane pyrolysis (CMP) in agriculture has been set-up with first convincing observations, which result in the major hypothesis:

- Addition of CMP leads to an improvement in soil quality and consequently improved plant growth.
- Addition of CMP leads to an improvement in the soil water balance and consequently to reduced drought stress in plants and reduced irrigation requirements.

Chemical Imaging

LA-ICP-MS and LIBS

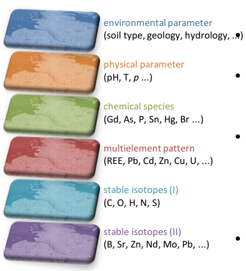
Chemical imaging captures spatially resolved chemical data. Techniques like LA-ICP-MS and LIBS use lasers to selectively analyze materials, providing high sensitivity and spatial resolution in the µm range. They are crucial for elemental and isotopic mapping of a wide variety of samples.

Diffusive Gradient in Thin Films (DGT)

DGT is a powerful method as it enables precise measurement of labile metal concentrations in various environments. Its controlled diffusion process provides spatial information, enhancing our understanding of e.g. metal release both in environmental and technological samples.

Physicochemical Maps

The combination of chemical and physical properties of a region allow for a multitude of interpretations such as :



- Provenance and authenticity of products
- Movement and migration pattern of past and present humans and animals
- Prediction and interpretation of changes (e.g. climate change adaptions) in geo- and biospheres
- Modelling of chemical fluxes

Metrological Principles

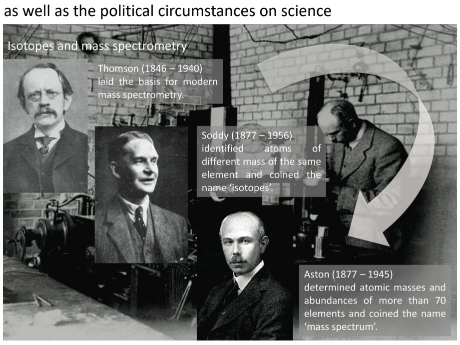
(Metrology = The Science of Measurements)

The development of metrological principles is of major importance in order to achieve sound analytical results and to avoid that conclusions are drawn form analytical artefacts.

A major focus is the development of uncertainty calculation tools for analytical data.

History of mass spectrometry

In the context of a cross-disciplinary topic, to rework the contribution of past scientists on analytical science, has reopened a new aspect and understanding of the todays state-of-the art analytical chemistry. It is the in-deep understanding of the complex interaction between scientific development and society as well as the political circumstances on science



Technology-critical elements – are anthropogenic emissions increasing due to increased use?

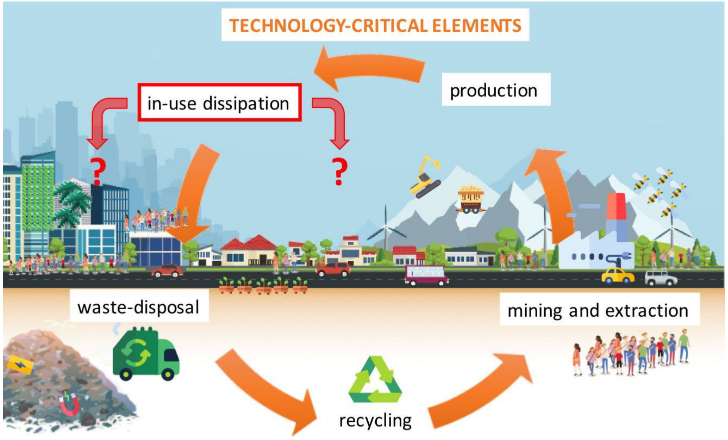


Fig. 1: TCE lifecycle stages potentially leading to release

Technology-critical elements (TCEs) are used in, e.g., information and telecommunication (ITC) technologies, healthcare and transport. There are substantial knowledge gaps related to released quantities, environmental cycles and potential health hazards.

In the project TecEUS (Technology-critical Elements in Urban Spheres), the release and distribution of selected TCEs is assessed in the urban environment of Vienna. Thereby, urban greening is applied as model system due to its particular exposure to anthropogenic pollution. For this purpose, advanced analytical techniques based on inductively coupled plasma tandem-mass spectrometry (ICP-MS/MS) are applied in combination with models for material flow analysis.

Method development

- Microwave-assisted acid digestion and ICP-MS/MS
- Comprehensive method validation with 7 certified reference material
- Challenges:
  - Low levels of TCEs (pg g^{-1})
  - Scarce reference values

Field experiments

- 292 plant samples from green facades in Vienna taken over 1 year
- Effects of plant species, season and sampling height investigated
- Challenges:
  - High natural variation
  - Limited sample availability

Conclusions & outlook

- Validated method for TCE analysis
- First comprehensive data on rarely analysed elements in plants
- Highest TCE levels in lower levels of the buildings
- Highest level after winter season

Fig. 2: Leaf washing in the lab

Fig. 3: Sampling sites in Vienna: MA31 (left) and MA48 (right)

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FWF P 33099-N Der Wissenschaftsfonds.
EMPIR
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States
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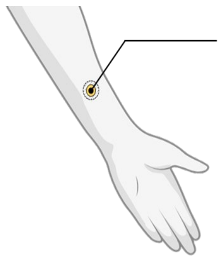
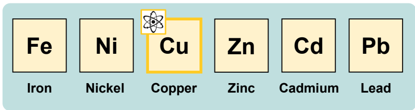
microPatch  Non-Invasive Diagnostics

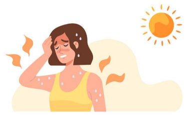
Selective Skin Patches for Elemental and Isotopic Analysis in Sweat

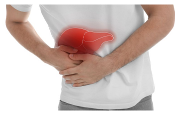
INTRODUCTION

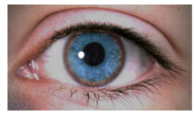


This project aims at the development of skin patches based on **diffusive gradients in thin-films (DGT)** technologies. It is an innovative approach to a new diagnostic tool for the non-invasive and quantitative assessment of **trace elements and isotopic signatures (Cu) as biomarkers** in **single drops of sweat** on human skin, potentially enabling early diagnosis of diseases.



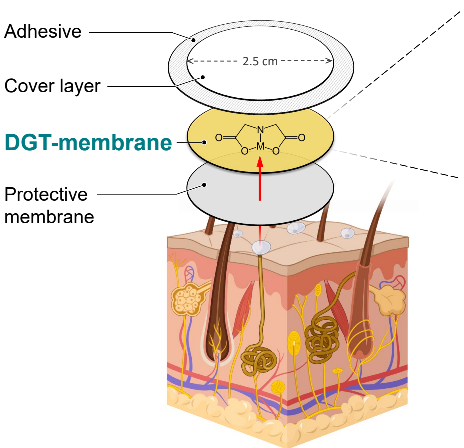






Picture/icon credits: biorender.com, Adobe Stock, dpa, NewAfrica, Pinterest

SAMPLING SWEAT

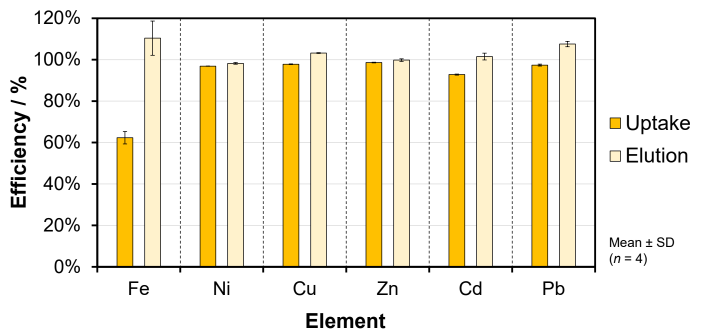


Analytical advantages

- High selectivity
- Time-integrated (min-d)
- Spatially resolved (µm)
- Low combined uncertainty
- Low cost

Skin model credit: biorender.com

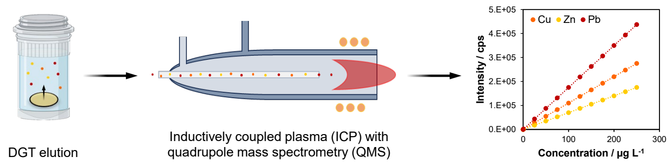
FIRST RESULTS



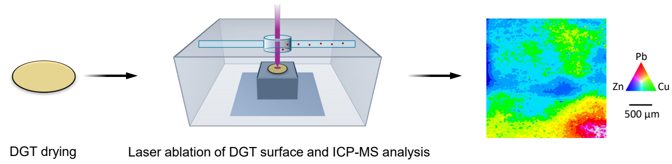
- Selective uptake of Ni, Cu, Zn, Cd, and Pb from synthetic sweat using biocompatible polyurethane membranes with iminodiacetate (metal-chelating) functionality; Fe remains challenging
- Quantitative analyte elution by immersion and shaking in dilute HNO_3 (c = 1 mol l^{-1}, V = 5 ml, t = 24 h)

ELEMENTAL AND ISOTOPIC ANALYSIS

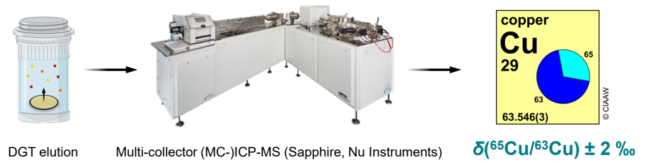
I DGT elution and analyte quantification by ICP-QMS



II Spatially resolved analysis by LA-ICP-MS



III High-precision Cu isotope analysis by MC-ICP-MS



SUMMARY

First results demonstrated the capability of DGT for **selective, quantitative, and simultaneous sampling** of **Ni, Cu, Zn, Cd, and Pb** from a complex sweat matrix. Further characterization and combination with high-end mass spectrometric methods will show the technique's full potential for non-invasive medical diagnostics.

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PN08 "UFO – Unkonventionelle Forschung" 2023

TRISKEM Expertise in Separation Chemistry

AAC

Sustainability of Carbon steel in Underground Hydrogen Gas Storage Facilities

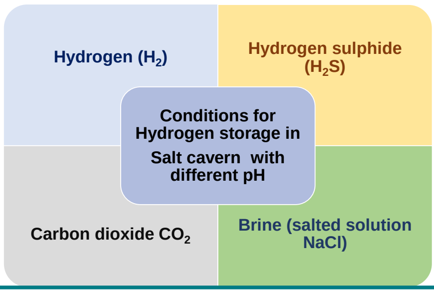
S. Bhosale, G. Mori

INTRODUCTION

Companies within the energy sector are focusing on hydrogen as a replacement for fossil fuels in an effort to successfully transition energy supply to reach a zero-carbon future. For the storage of hydrogen, oil and gas companies are looking into repurposing former gas storage sites within salt caverns as well as establishing new ones. There is insufficient research data on the materials for hydrogen underground storage facilities. “Sustainability of carbon steels in Underground Hydrogen Gas Storage Facilities" is one of the projects on which our team is working.

MATERIALS & CONDITIONS IN SALT CAVERNS

- ❑ **Carbon Steels (API 5CT) and welds**
- ❑ Sulphide reducing bacteria produce the H_2S in underground conditions.
- ❑ Carbon dioxide CO_2 is formed and emitted from limestone and some other rocks.
- ❑ NaCl in aqueous solutions
- ❑ pH = 4.0 to 6.5

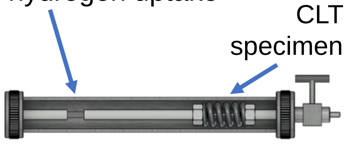


EXPERIMENTAL METHODS

Constant Load Testing (CLT)

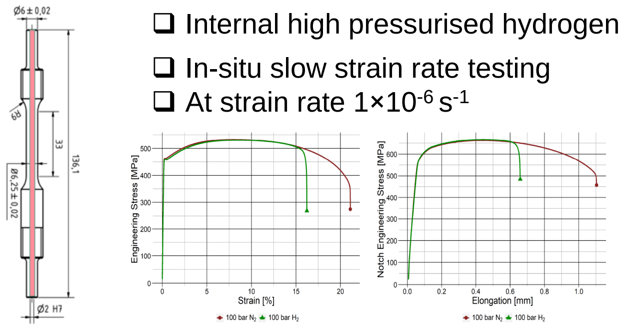
Specimen for measurement of hydrogen uptake

CLT specimen



- ❑ load at 90,100, and 110% of yield strength.
- ❑ Rotation of Autoclaves – 1cycle/1min
- ❑ In pure Hydrogen and in mixed gases.
- ❑ Dry and wet conditions

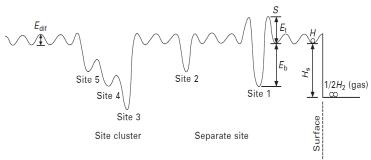
Slow Strain Rate Testing with Hollow Probes



- ❑ Internal high pressurised hydrogen flow
- ❑ In-situ slow strain rate testing
- ❑ At strain rate 1×10^{-6} s^{-1}

Hydrogen Measurement

- ➢ Pre-cooling after H-charging by liquid nitrogen
- ➢ Thermal Desorption Spectroscopy
- ➢ Testing at different temperatures
- ➢ Desorption energy calculations of hydrogen traps



- ❑ Binding Energy (E_b)
- ❑ Trapping Energy (E_t)
- ❑ De-Trapping Energy
- ❑ Trapping Sites

Objectives

- ❑Checking susceptibility of welds and heat affected zones in hydrogen environment
- ❑Characterization of steels in hydrogen
- ❑Determine the hydrogen content and diffusivity
- ❑Cross verification of susceptibility of steel pipes in hydrogen environment which are used in the oil and gas industry

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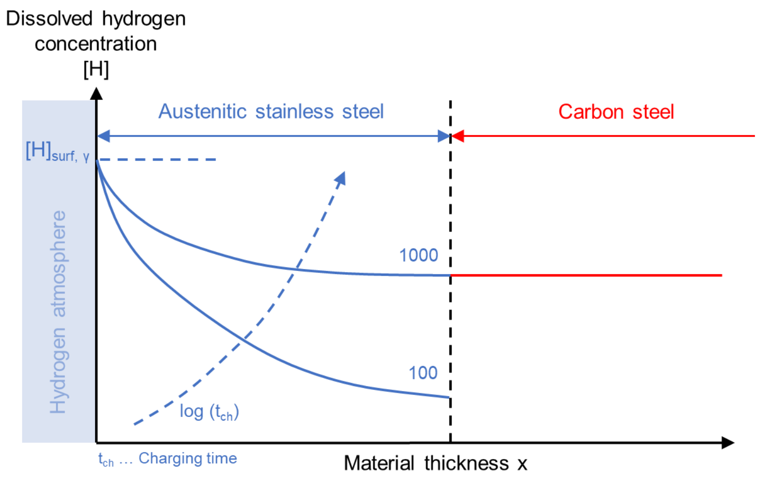
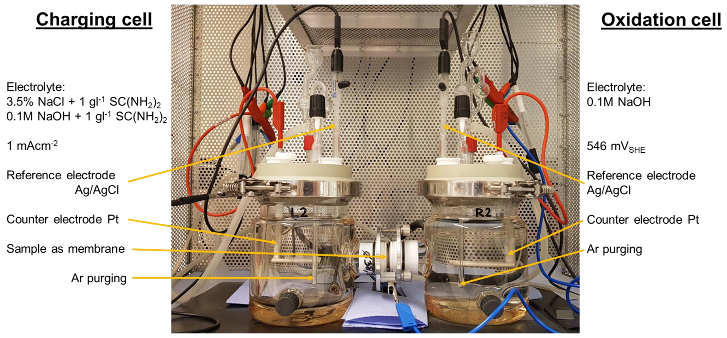
gasunie crossing borders in energy
nafta
storengy Eine Gesellschaft von engie
uniper
EWE
Fraunhofer IWM
DGMK
Institut de la Corrosion French Corrosion Institute

Hydrogen embrittlement and permeation of clad plate

D. Zwittnig, G. Mori, M. Mülleder, C. Schindler, R. Egger

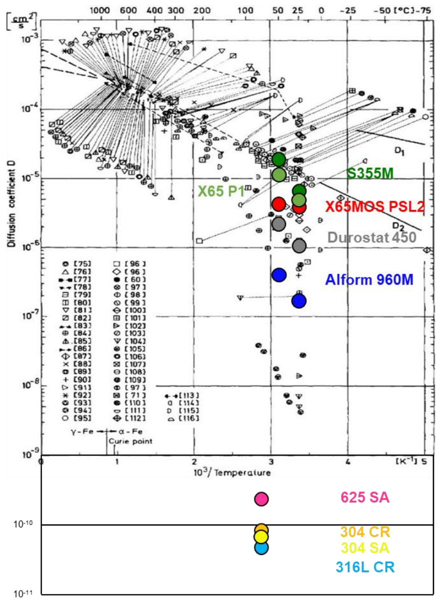
The energy transition in Europe from fossil fuels to hydrogen will need tremendous storage and transport capacities for high-pressure hydrogen gas. Storage and transportation infrastructure is normally made of carbon steels, which are susceptible to hydrogen embrittlement. With an increasing strength, the susceptibility to hydrogen embrittlement is increasing as well. Austenitic stainless steels are less susceptible to hydrogen embrittlement, in addition, they show a significantly lower hydrogen diffusion rate in comparison to carbon steels. Therefore, the use of austenitic stainless steel cladding is one way of increasing the service lifetime of storage facilities.

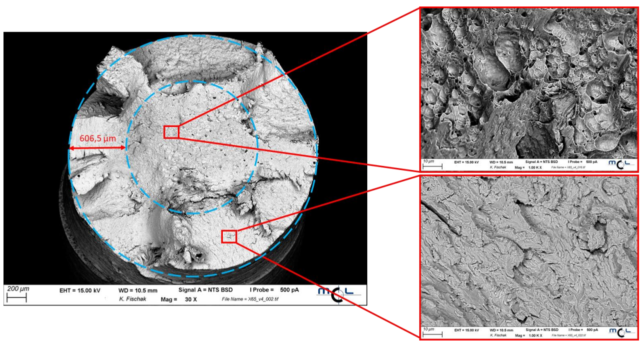


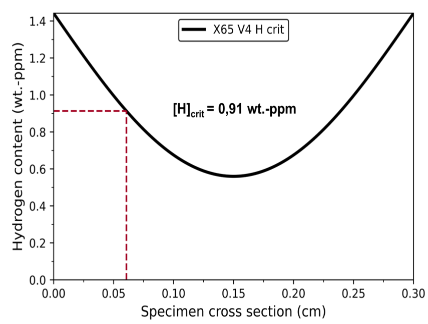


Different carbon and austenitic stainless steels are investigated regarding their hydrogen diffusion coefficients using electrochemical permeation testing in a Devanathan-Stachursky cell. The diffusion coefficients determined for bcc materials are between 3 and 5 orders of magnitude higher than those for fcc materials. These effective diffusion coefficients are used to calculate hydrogen concentration profiles according to second Fick's Law as a function of time.

Critical hydrogen contents of carbon steels are determined by performing slow-strain-rate tests with in-situ electrolytic hydrogen charging. At the fracture of the sample, the fracture surface shows a partially brittle fracture pattern. Hydrogen embrittlement depth is measured using SEM, subsequently the critical hydrogen content can be calculated using second Fick's law and the analyzed total hydrogen content of the charged sample.







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voestalpine
ONE STEP AHEAD.

The Hydrogen Uptake of L360 Pipeline in Varied H_2 Environments

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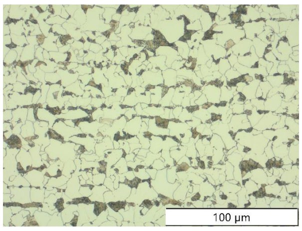
Introduction

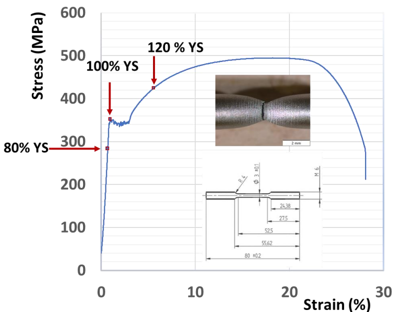
HyGrid2 is the first project in Austria to repurpose an existing natural gas pipeline for pure hydrogen transport. The project is supported by the Austrian Research Promotion Agency (FFG) as a crucial step towards achieving the goal of carbon neutrality by 2050. Our role as Montanuniversität aims to test the existing pipeline materials (base and weld) to hydrogen embrittlement susceptibility under all the expected operation conditions. The project outcomes will help in making the right decision towards the repurposing process and provide a manual for the recommended operating conditions in the future.

Materials and Methods

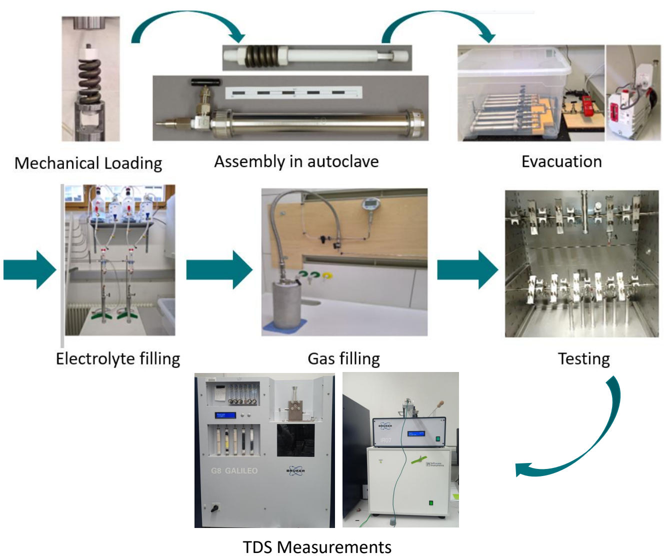
L360 material characterization

C	Si	Mn	P	S	Cu
0.16	0.22	1.27	0.013	0.003	0.03
Cr	**Ni**	**Mo**	**Ti**	**V**	**Al**
0.06	0.05	0.01	0.002	0.06	0.0226

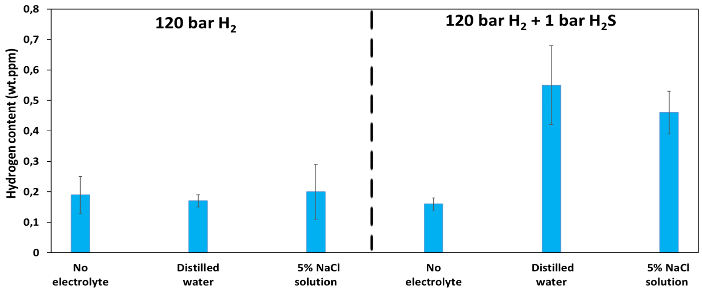


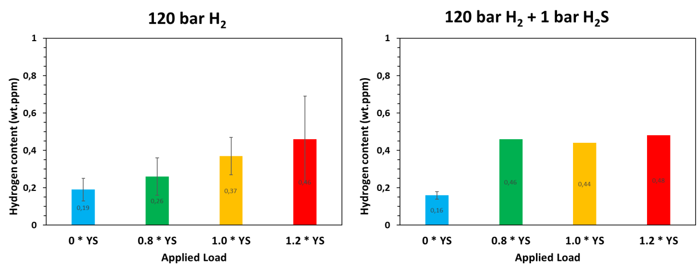


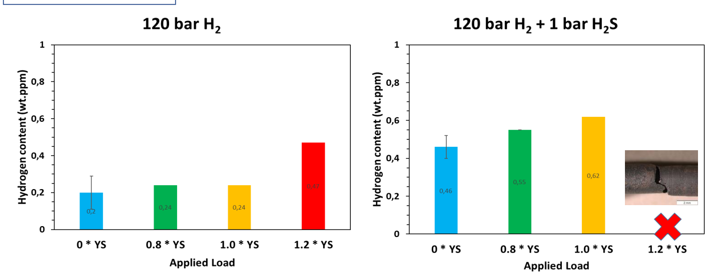
Autoclave and Constant Load Tests

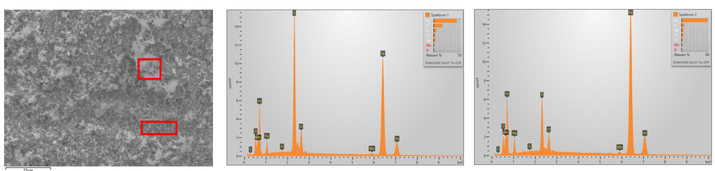


Results









Conclusions

- Dry conditions show a low hydrogen uptake.
- No failure occurred in dry conditions up to a load of 1.2 * YS
- The presence of H_2S increases hydrogen uptake in wet conditions.
- In 5% NaCl + 120 bar H_2 + 1 bar H_2S at a stress level of 1.2 * YS there is failure.
- Only H_2S + electrolyte environments produced uniform corrosion.
- The investigated L360 shows high applicability to be repurposed for pure hydrogen transport from the static loading condition point of view. Further dynamic investigations will be performed.

MSc

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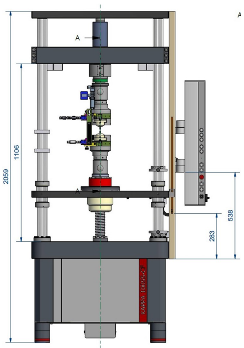
ENERGIE NETZE STEIERMARK · BILFINGER · ÖVGW · DVGW DBI · MONTAN UNIVERSITÄT · HyCentA Hydrogen Center Austria · MCL · WIVA P&G

EUH2STARS – European Underground Hydrogen Storage Reference System

Anna-Carina Seitlinger, Florian Arbeiter, Gregor Mori, Gerald Pinter

Introduction

The project consortium, comprising of natural gas storage operators, technology providers, utility, research- and governmental organizations, is entrusted by the European Commission to demonstrate a competitive, complete and qualified underground hydrogen storage in depleted porous natural gas reservoirs at technical readiness level 8 by the end of the decade. EUH2STARS is a European flagship project for the conversion of existing underground natural gas into hydrogen storages.



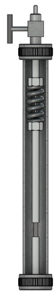
Materials & Methodology

Carbon steels

- Constant Load Testing in Autoclaves
- Ripple Load Testing with Hollow Probes
- Fracture Mechanics

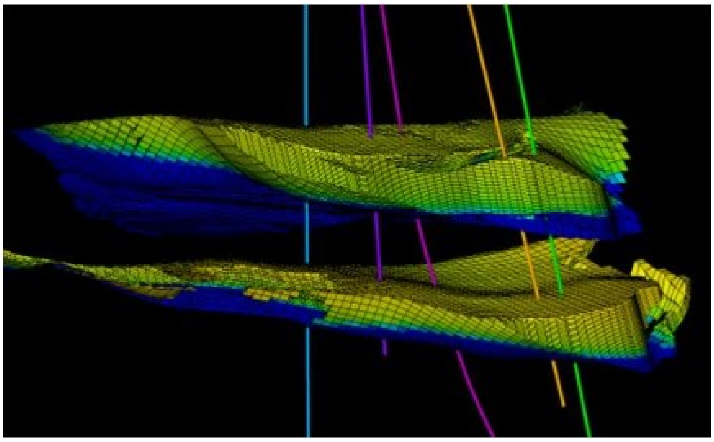
Polymers

- Rapid Decompression Tests



Goals

Demonstrate the storage of 100 percent hydrogen in depleted, porous reservoirs by operating four seasonal storage cycles at RAG's demonstrator and two storage cycles at HGS's replicator site. Each storage cycle considers different operational characteristics to demonstrate marked-driven underground hydrogen storage operation at the end of the project.



Dipl.-Ing.

Anna-Carina Seitlinger

Chair of General and Analytical Chemistry

Chair of Materials Science and Polymer Testing

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Clean Hydrogen Partnership

Project Duration

2024 - 2029

Co-funded by the European Union

Poster Exhibition 2024

Science 4 Technology @MUL

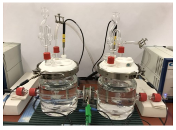
MONTANUNIVERSITÄT LEOBEN

CHAIR OF GENERAL AND ANALYTICAL CHEMISTRY

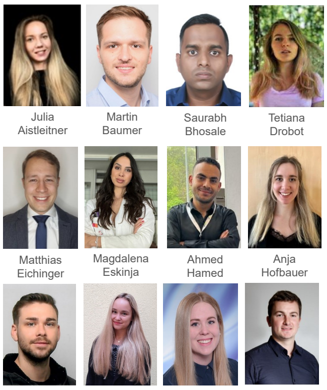
RESEARCH GROUP CORROSION

Gregor Mori

TEAM / INFRASTRUCTURE



Electrochemical Permeation



Julia Aistleitner, Martin Baumer, Saurabh Bhosale, Tetiana Drobot, Matthias Eichinger, Magdalena Eskinja, Ahmed Hamed, Anja Hofbauer, Lukas Niedermayer, Stefanie Pichler, Anna-Carina Seitlinger, Dino Zwittnig

High Pressure High Temperature Autoclaves

Slow Strain Rate Testing

Constant Load Testing

Thermal Desorption Spectroscopy

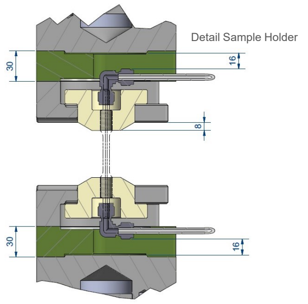
Autoclave Testing

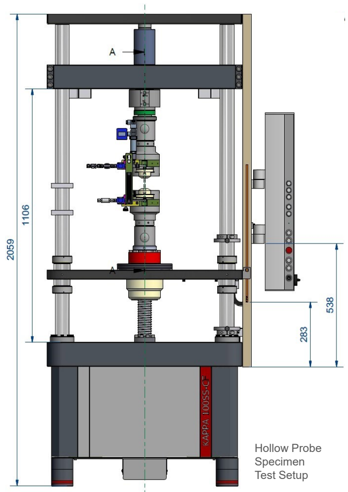
NEWS

Establishment of Hollow Probe Specimen Technique

Just recently it was possible to do first tests on hydrogen embrittlement with hollow probe tensile specimens used as autoclaves for hydrogen. By use of a universal tensile testing machine in the future not only constant load tests but also slow strain rate tests and tests under cyclic loads can be performed.

By a new compressor in the future hydrogen pressures as high as 500 bar can be reached pushing the limit of the method.





Hollow Probe Specimen Test Setup

TEACHING

Basic corrosion principles and **prevention of corrosion** are taught in the early master studies. Lectures on methods in corrosion testing give students a deeper insight into the world of corrosion at a Ph.D. candidate level. All lectures are accompanied with **exercises and seminars** to deepen theoretical knowledge.

We believe that **joy** is a key element in teaching to generate high value corrosion learning and we try to create joy.

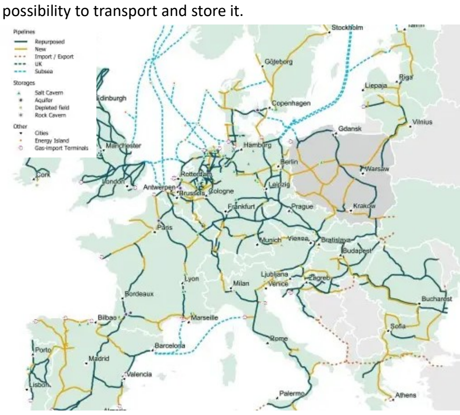
The bi-annual "**KorrosionsExpert**" is held as a post-graduate education to support life-long learning. More than **20 lecturers from academia and industry** bring their knowledge in "basics in physical metallurgy", "basics in chemistry", "fundamentals in corrosion", "applied corrosion in special industries" and "corrosion protection" to the participants.

In **small groups** the theoretical knowledge is strengthened by laboratory hands-on exercises.

MAIN RESEARCH TOPICS

Hydrogen Embrittlement

In the energy transition from fossile to green energy fuels, hydrogen is one of the most prosperous energy carriers. Hydrogen use is currently limited due to availability and the possibility to transport and store it.



European Hydrogen Backbone

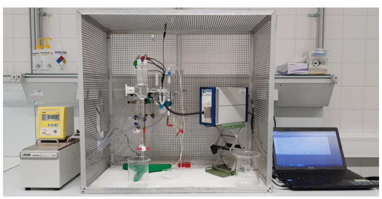
European gas transport and storage industry takes huge efforts to repurpose and to renew their natural gas infrastructure for hydrogen usage.

More than 15 industrial and institutional partners in Austria, Germany, The Netherlands, France, and Slovakia do research work to investigate qualification of existing pipelines and storage facilities for hydrogen usage. Also investigation of new and already existing materials for their hydrogen applicability is done.

Electrochemical Corrosion Testing

Since decades the Research Group uses fundamental electrochemical methods to investigate corrosion processes such as potentiodynamic investigations, electrochemical impedance spectroscopy, galvanic corrosion investigations by using Evans diagrams, electrochemical potentiokinetic reactivation method, and the electrochemical scratch technique for repassivation investigations.

Types of corrosion investigated are uniform, galvanic, pitting, crevice and intergranular corrosion beside to hydrogen permeation and charging tests for investigation of hydrogen embrittlement.

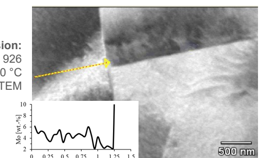


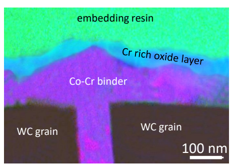
Electrochemical Test Setup

Localized Corrosion Investigations

There is a long tradition of investigating passivity and many types of localized corrosion, such as pitting, stress corrosion cracking, corrosion fatigue, intergranular corrosion and others. Investigations are often connected with high resolution characterization methods for mechanistic purposes. Some examples are shown below.

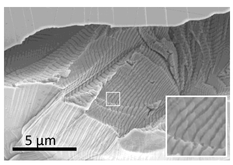
Intergranular Corrosion: Mo depletion along Mo6C in Alloy 926 after 20 h at 760 °C EF-TEM





Passivity: Passive layer on chromium alloyed cemented carbide WC-Co8-Cr0.7, EELS

Chloride induced SCC: Slip steps formed in stainless steel FeCr18Mn20Mo1.5N0.8 after 6 h in 45% $MgCl_2$ at 123 °C HR-SEM



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Microplastic analysis

General and Analytical Chemistry

- Everyday plastic items can degrade into micro- (1 µm – 5 mm) and nanoplastic (< 1 µm) particles
- Degraded plastic particles are highly variable making analysis very difficult

Size	Additives	Product types	Color	Morphology	Eco-toxin	Polymer
<5mm … nano	filler, colorant, plasticizer…	primary, secondary	red, blue, brown…	fiber, sphere, fragment…	PAHs, PCBs, DDT, heavy metal	PP, LDPE, PVS, PU, PET, PS…

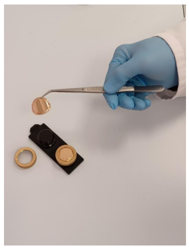
- Potential implications for human health and environment
- Emerging contaminants by the World Health organization
- Research needs: toxicological studies, concentration, size distribution, chemical identity

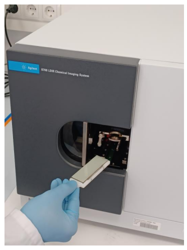
New instrumental approach for microplastic analysis

Laser Direct Infrared (LDIR) Spectroscopy:

- ✓ new, fast, automated approach for chemical identification and particle size distribution
- ✓ spectral range 1800 – 975 cm^{-1}
- ✓ resolution down to 1.5 µm (ATR), 5.5 µm (reflection)
- ✓ various applications for liquid and solid samples in environmental, earth and material science
- ✓ sample collection ways: gold / aluminium coated membrane filter Ø 25 mm and IR-reflective “Kevley slides”



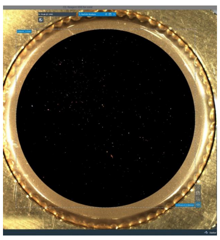


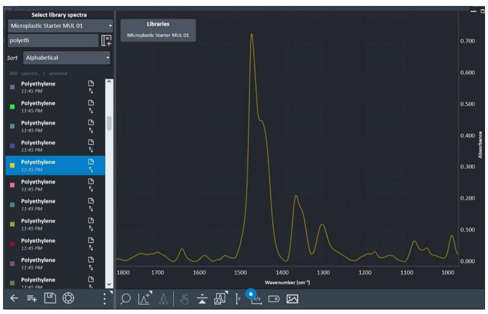
Current studies at our chair

Samples for microplastic analysis:

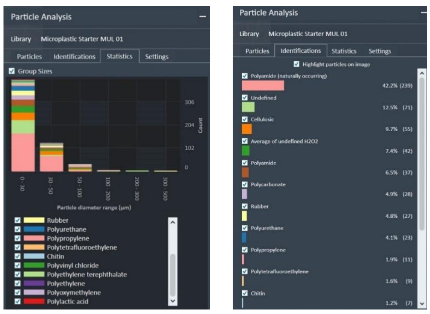
- ✓ release from household plastic kettles
- ✓ biological tissues
- ✓ corals



Filter surface with detected particles by LDIR



IR spectrum of polyethylene by LDIR



Particle statistics and identification by LDIR

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