



# Material investigations for safe hydrogen storage

Matthias Eichinger, Gregor Mori

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WHERE RESEARCH MEETS THE FUTURE

CHAIR OF GENERAL AND ANALYTICAL CHEMISTRY



# Montanuniversität Leoben



Leoben: smallest University town in Austria  
25000 inhabitants  
3500 students

## Studies:

- Mining
- Metallurgy
- Materials Science
- Petroleum Engineering
- Industrial Environmental Protection
- Energy Techniques
- Industrial Logistics
- Recycling Techniques

# Chair of General and Analytical Chemistry

Head: Thomas Prohaska

## 4 Research Groups:

### Element Analytics

Thomas Meisel

### Isotope Analytics

Johanna Irrgeher

### Technology & Methods

Thomas Prohaska

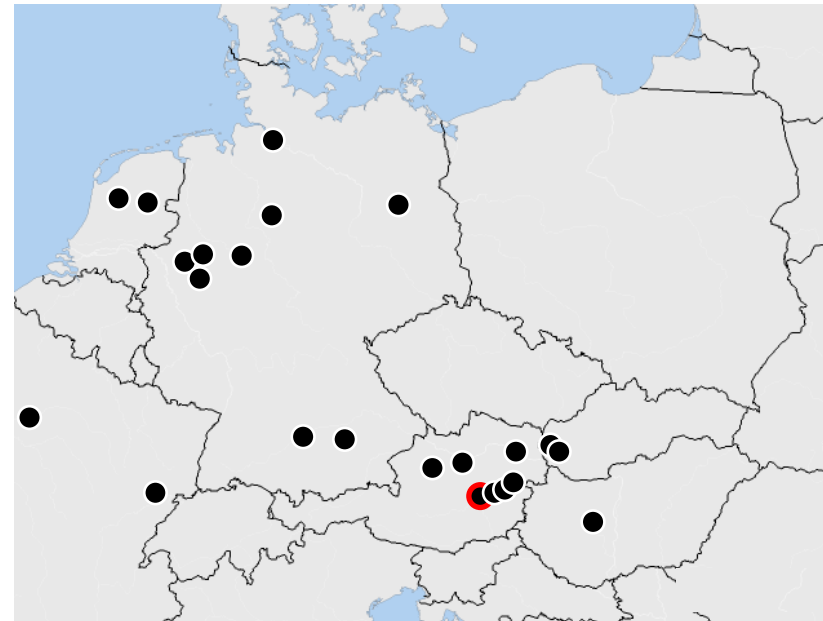
### Corrosion

Gregor Mori

## Main Research Topic in Corrosion:

### Hydrogen Embrittlement (HE) of Steels

#### Industrial Research Partners in HE:

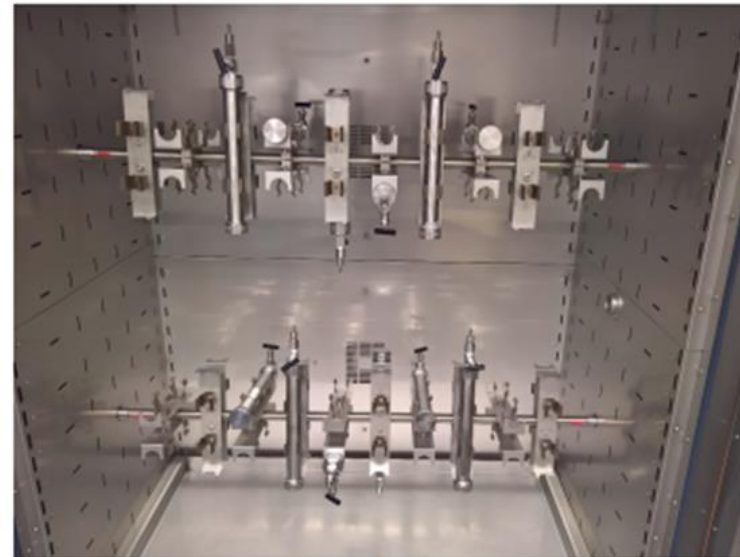


Astora, G  
BEG, A  
BMW, G  
BVEG, G  
DGMK, G  
E Stmk, A  
EWE, G  
Forvia, G  
Forvia, F  
Geostock, F  
HUS, HUN  
Nafta, SVK  
OMV, A  
RAG, A  
RWE, G  
Shell, NL  
SPP, SVK  
Storengy, G  
TNO, NL  
Uniper, G  
VAAD, A  
VAHP, A  
VASD, A  
VATub, A

# Autoclave testing facilities

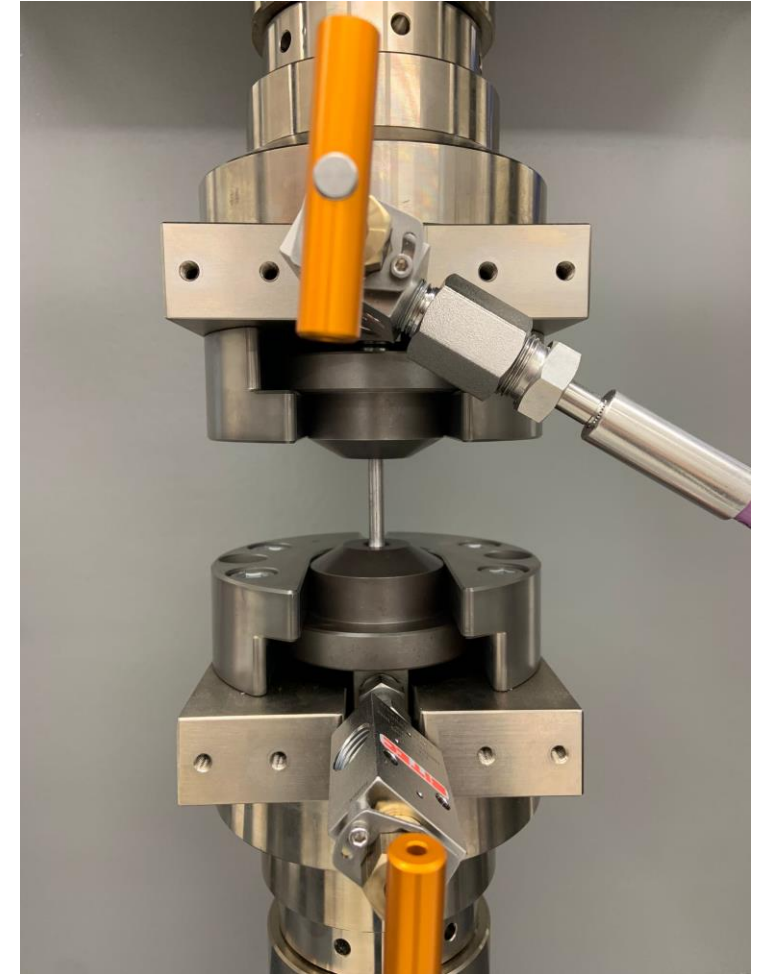
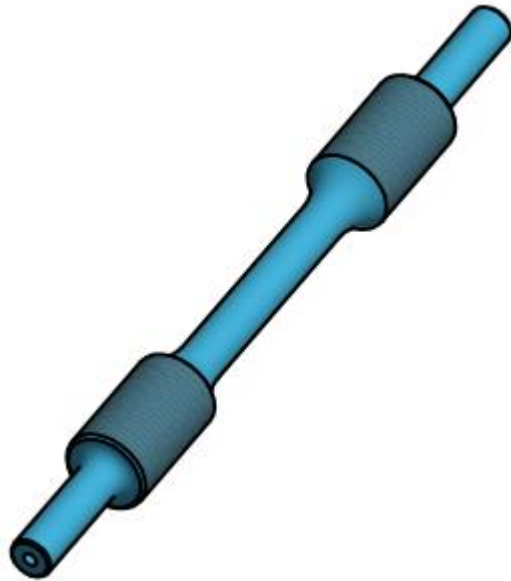


- Currently: 1 to 150 bar
- Future: up to 300 bar
- 25 to 120 °C
- Wet conditions possible
- Wet-dry cycles



# Hollow probe testing

- Currently: 1 to 300 bar
- Future: up to 500 bar
- SSRT
- Low-cycle Fatigue





# High pressure – High temperature autoklave test bench



➔  $p_{\max} = 1000 \text{ bar}$       ➔  $T_{\max} = 200 \text{ °C}$

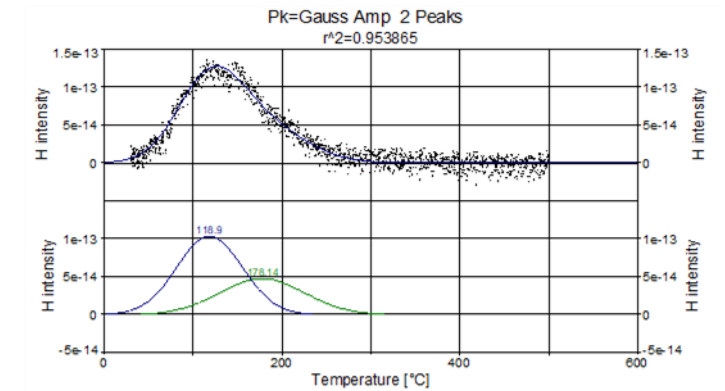


Autoclave Volume = 62 mL

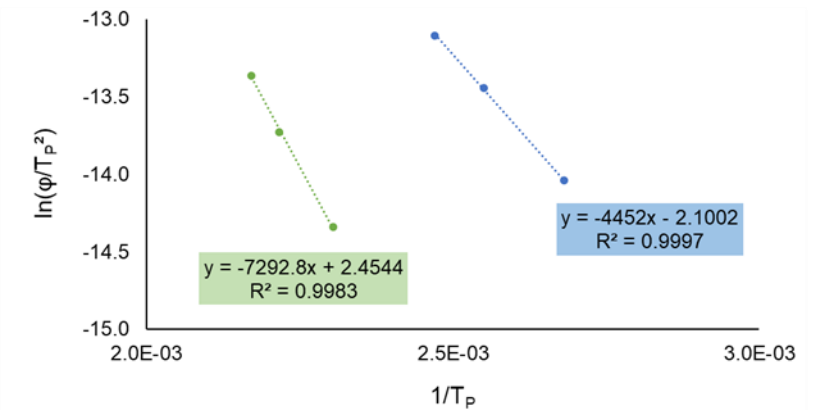


# Hydrogen Analytics

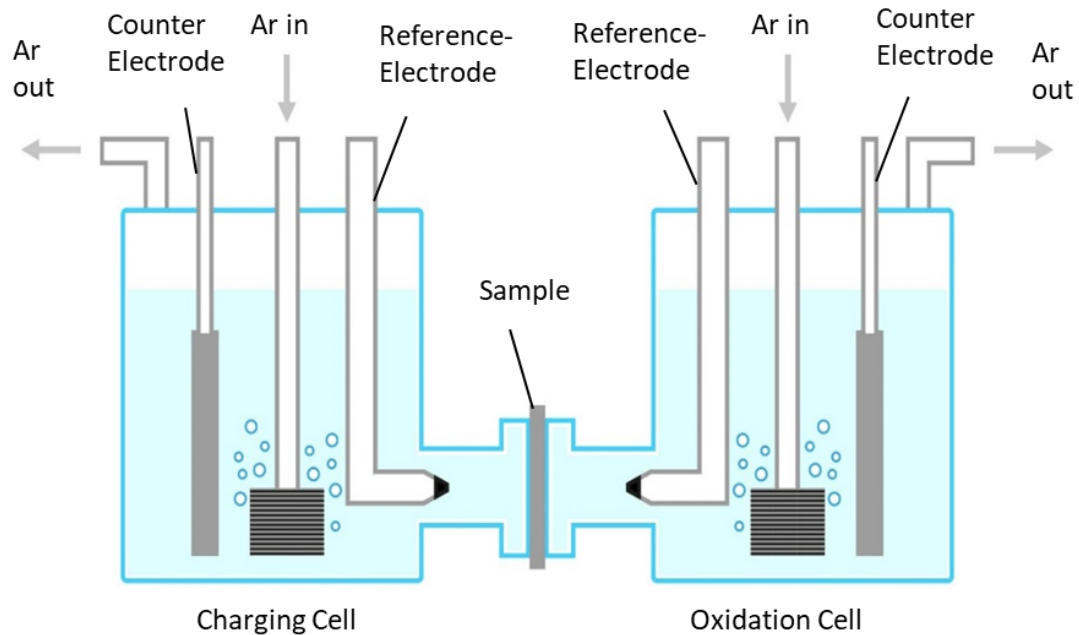
- Hot Carrier Gas Extraction



- Thermal Desorption Spectroscopy



# Electrochemical permeation measurement



## Charging:

3.5 % NaCl + 1 g/l  $\text{CH}_4\text{N}_2\text{S}$

1 mA/cm<sup>2</sup>

Purge gas: Ar

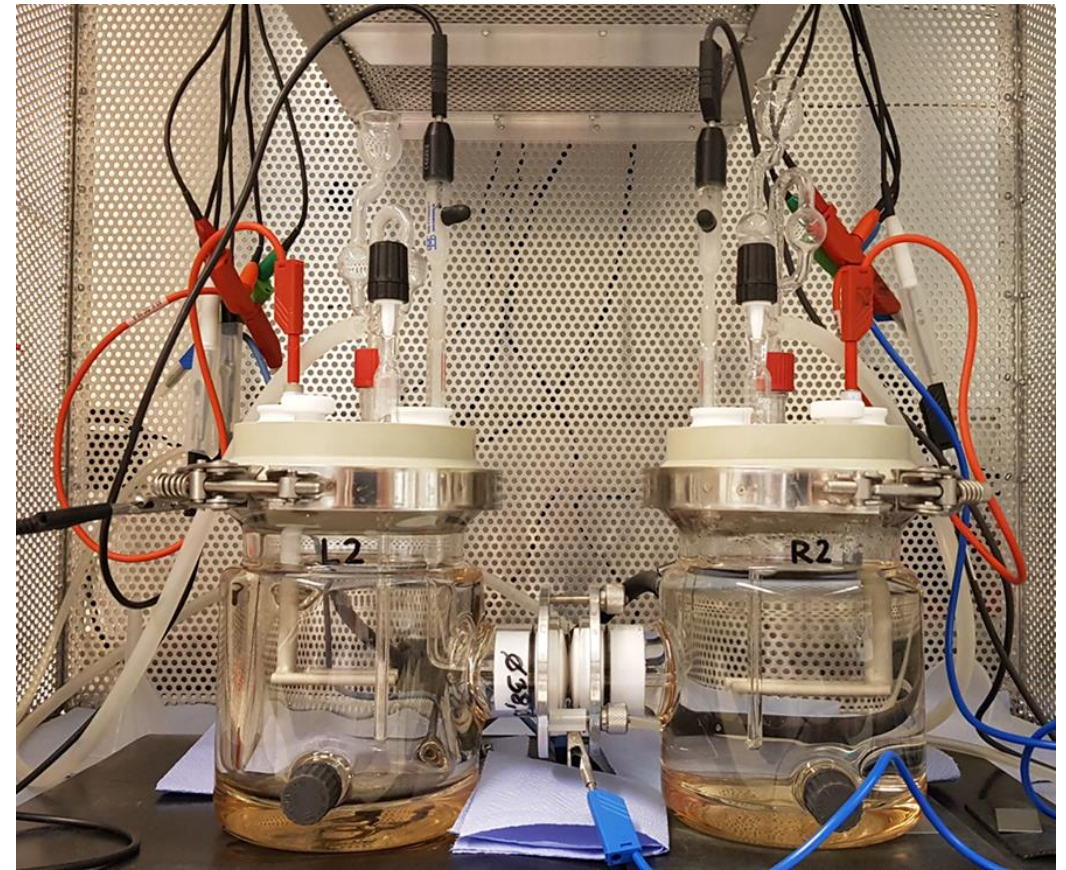
## Oxidation:

0.1 M NaOH

Purge gas: Ar

100 nm Pd at oxidation side

Testing Temperature: 60 °C





# Requirement Specification – Test Conditions

## ➤ Hydrogen Charging:

- High pressure gaseous hydrogen charging between 4 and 25 MPa (40 – 250 bar)

## ➤ Materials:

- Base material
- Weld material
- Heat affected zone

## ➤ Fluids:

- Real reservoir water with salinities between 10 and 30 g/l
- Influence of H<sub>2</sub>S

## ➤ Testing Temperature:

- Room Temperature

# Requirement Specification – CLT + TDS

Steel	Note	Origin	Testing conditions	Base material	Weld material
12022.1	Shell of Separators	From Operation	10 MPa, RT	x	
11416.1	Bottom of separator	From Operation	10 MPa, RT	x	
13030	Pipeline DN500	From Operation	4 MPa, RT	x	x
12021.1	Pipeline DN300	From Operation	4 MPa, RT	x	x
12022.1	Pipe DN350	From Operation	10 MPa, RT	x	x
11503.1	Pipeline DN700	From Operation	8 MPa, RT	x	x
<hr/>					
L290NM/NB		From Manufacturer	25 MPa, RT	x	
13126.1		From Manufacturer	25 MPa, RT	x	
L415NE/ME		From Manufacturer	10 MPa, RT	x	
11523.1		From Manufacturer	10 MPa, RT	x	

# Requirement Specification – SSRT + HEI

Steel	Note	Origin	Testing conditions	Base material	Weld material
12022.1	Shell of Separators	From Operation	10 MPa, RT	x	
11416.1	Bottom of separator	From Operation	10 MPa, RT	x	
12022.1	Pipe DN350	From Operation	10 MPa, RT	x	x
11503.1	Pipeline DN700	From Operation	8 MPa, RT	x	x
L290NM/NB		From Manufacturer	25 MPa, RT	x	
13126.1		From Manufacturer	25 MPa, RT	x	
L415NE/ME		From Manufacturer	10 MPa, RT	x	
11523.1		From Manufacturer	10 MPa, RT	x	

# Requirement Specification – Autoclave test +TDS

Material	Origin	Testing conditions	Base material
Spiral wound gasket	From Operation	10 MPa, RT	x
Metal sealing ring RTJ	From Operation	25 MPa, RT	x
Al sealing	From Operation	10 MPa, RT	x



# Experimental Plan

Material	CLT +TDS	SSRT + HEI	Autoclave + TDS	Metallographic investigation	SEM investigation	Hardness testing
Spiral wound gasket			4			
Metal ring RTJ			4			
AI sealing			4			
12022.1 - BM	4	4		1	If a fracture occurs	1
11416.1 - BM	4	4		1	If a fracture occurs	1
13030 - BM	4			1	If a fracture occurs	1
13030 - WM	4			1	If a fracture occurs	1
12021.1 – BM	4			1	If a fracture occurs	1
12021.1 – WM	4			1	If a fracture occurs	1
12022.1 – BM	4	4		1	If a fracture occurs	1
12022.1 – WM	4	4		1	If a fracture occurs	1
11503.1 - BM	4	4		1	If a fracture occurs	1
11503.1 - WM	4	4		1	If a fracture occurs	1
L290NM/NB - BM	4	4		1	If a fracture occurs	1
13126.1 - BM	4	4		1	If a fracture occurs	1
L415NE/ME - BM	4	4		1	If a fracture occurs	1
11523.1 - BM	4	4		1	If a fracture occurs	1
<b>Total tests</b>	<b>56</b>	<b>40</b>	<b>12</b>	<b>14</b>		<b>14</b>





**Thank you for your attention !**

Matthias Eichinger  
Chair of General and Analytical Chemistry, Montanuniversitaet Leoben  
Corrosion