Hydrogen Storage Activities in Geesthacht

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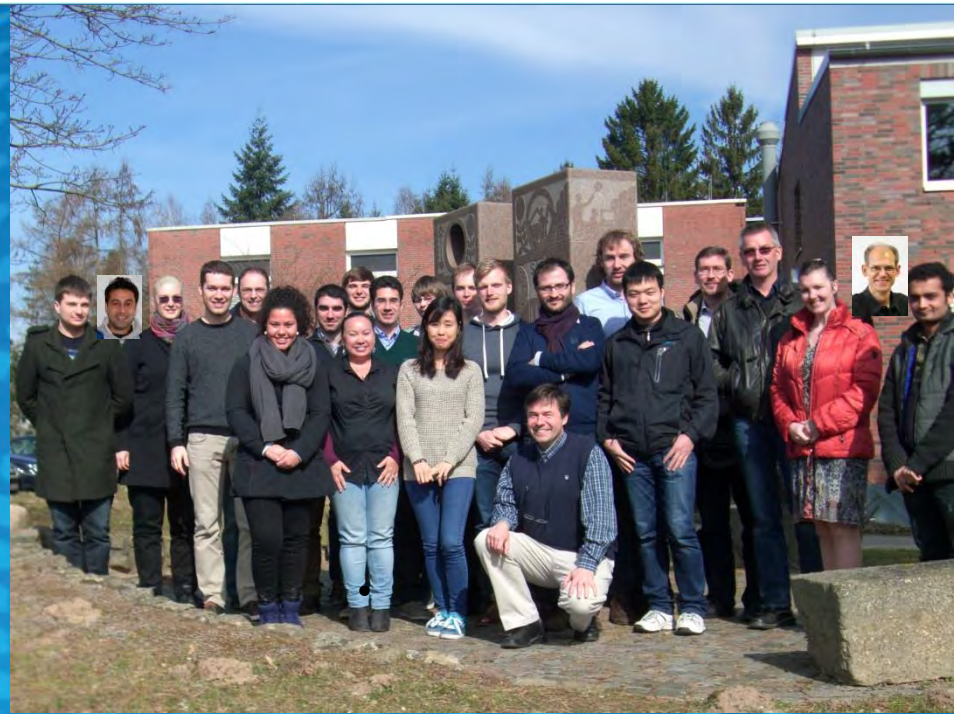


Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Non-university public research in Germany

Max Planck (1858-1947)
theorecital physicist: quantum theory

Max-Planck-Association

80 Institutes,
13 300 Employees
Budget ~ 1,3 bill. €

optician and physicist: Fraunhofer lines,
excellent optical glass and instruments

Joseph von Fraunhofer
(1787-1826)

Fraunhofer Society

60 Institutes,
18 000 Employees
Budget ~ 1,6 bill. €

Hermann von Helmholtz (1821-1894)
great natural scientist
„Kanzler der deutschen Physik“

Helmholtz-Association

18 Research Centres,
40 000 Employees
Budget ~ 4 bill. €

Leibniz Association

87 Institutes,
16 100 Employees
Budget ~ 1,3 bill. €

Gottfried Wilhelm Leibniz (1646-1716)
great universal scholar

HELMHOLTZ | GEMEINSCHAFT

Helmholtz Research Centres:

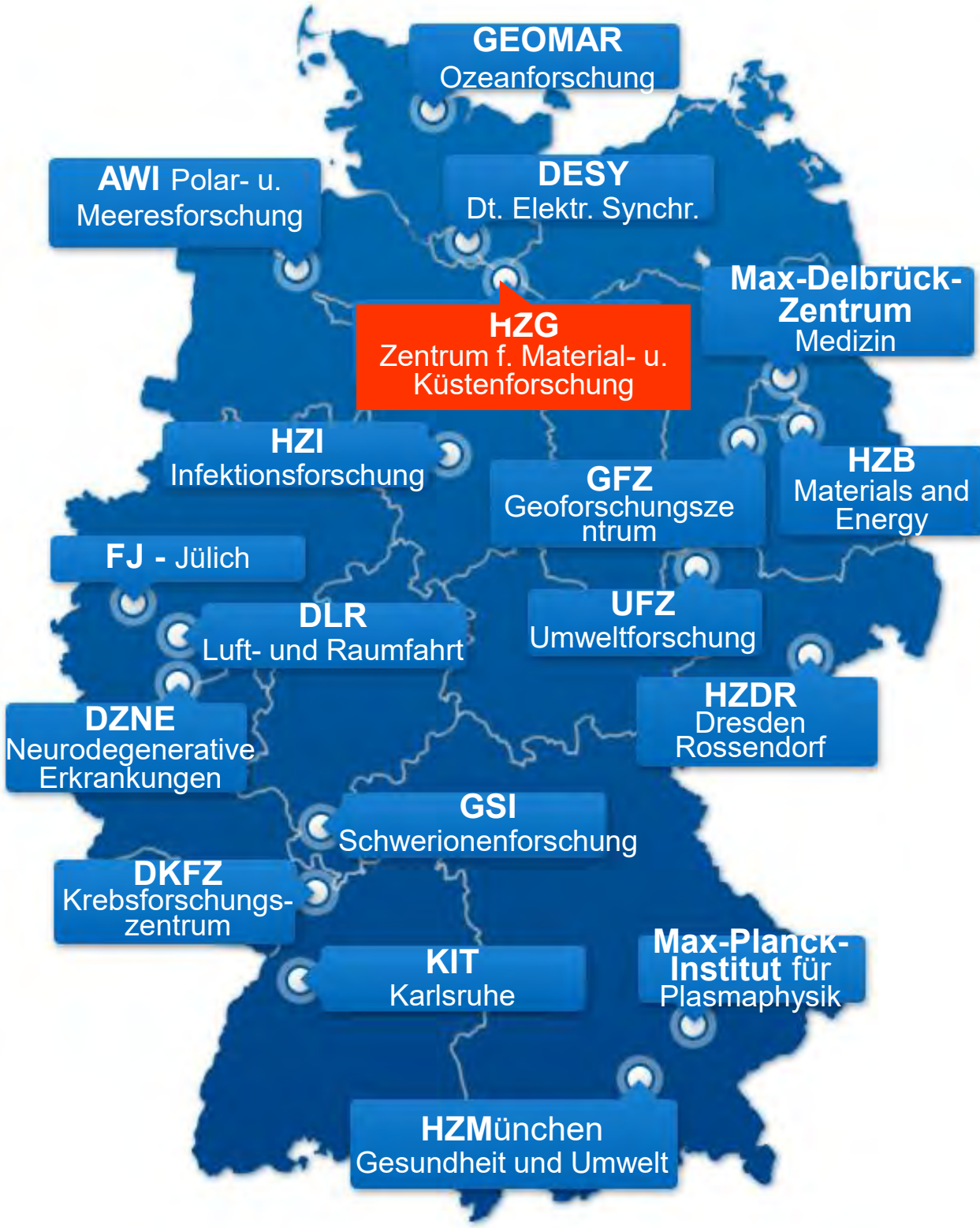
18 medium and large scale research centres

Employees: **40000**

Budget: **4.3 Bill. €**

Mission:

- → Solving **major challenges** with cutting-edge research
- → Developing and operating **complex infrastructure** and **large-scale facilities** for the national and international scientific community
- → **Creating wealth** for society and industry through knowledge transformation and innovation



Prehistory of the site – Alfred Nobel

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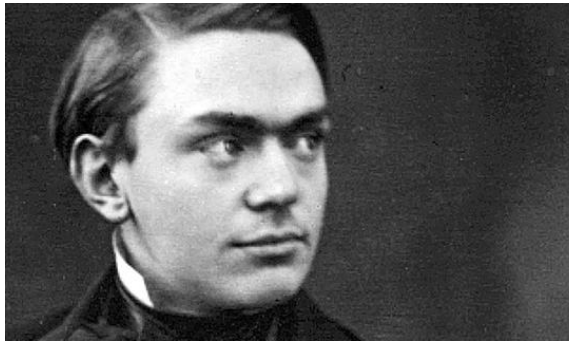
Centre for Materials and Coastal Research

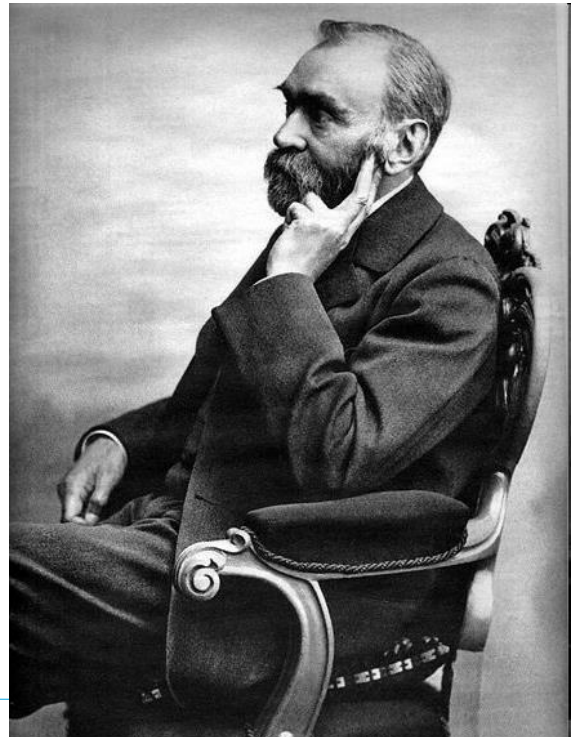
First fabric of explosives of Alfred Nobel **(since 1865) outside of Sweden**

Until 1910 **fabric Krümmel:** largest munition fabric of Europe



Alfred Nobel (1833-1896)
swed. Chemist und Engineer

Inventor of Dynamite
Founder/Donor of the Nobel prize

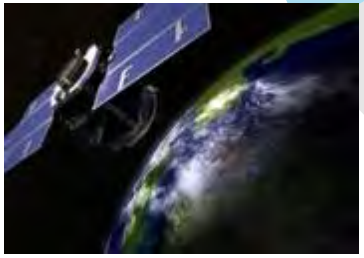


•Manufacture and export of a liquid combination of nitroglycerin and gunpowder known as "Blasting Oil„
(extremely unstable and difficult to transport, as shown in numerous catastrophes.
The buildings of the factory in Geesthacht itself destroyed in 1866 and again in 1870)
•October 1866 Experiments on a raft on the Elbe river
•Alfred Nobel & Company's development of dynamite in 1867, made by mixing the nitroglycerin with the diatomaceous earth (*kieselguhr*) found in the Krümmel hills.
•Several other inventions
•after World War II demolition of the fabric

Portfolio of the Helmholtz-Zentrum Geesthacht

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

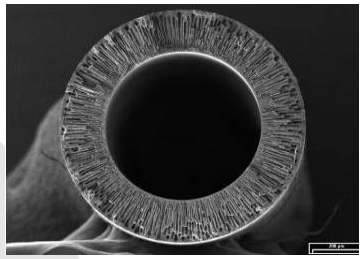
1/3
Coastal and Climate Research



Total budget
100 Mio €

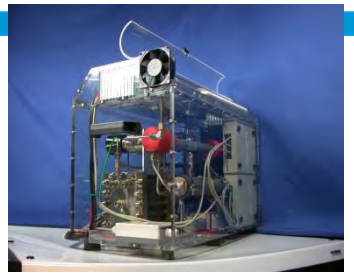
Employees
950

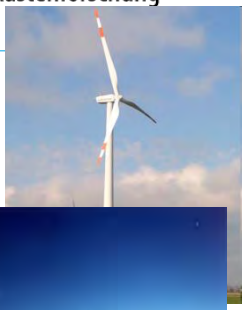
2/3
Materials Research



Hydrogen Storage @ Helmholtz-Zentrum Geesthacht
From Basic Research Towards Applications

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung





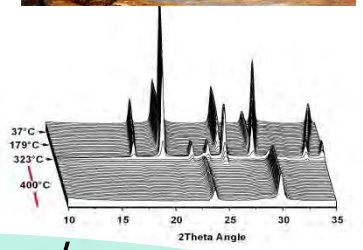
Tank tests & demonstration

Tank design

Application

Tank system

Characterization and optimization of tank relevant material properties



Scale up and cost efficient material preparation

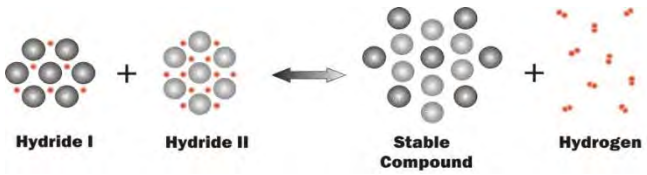
Kinetic optimization / development of suitable catalysts

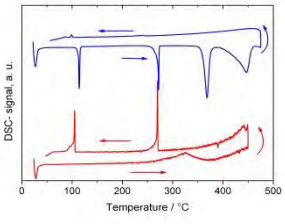
Material

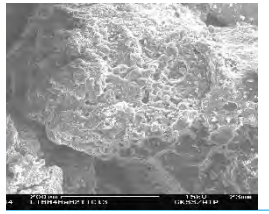
Thermodynamic modification

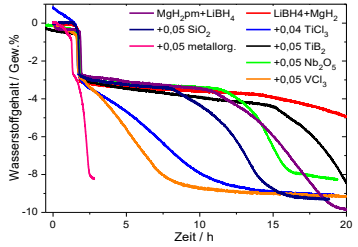
Identification and optimization of novel hydrogen storage materials

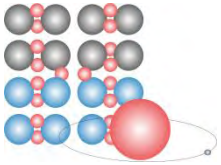
Basic Research











Material Characterisation

Characterization: in-situ XRD

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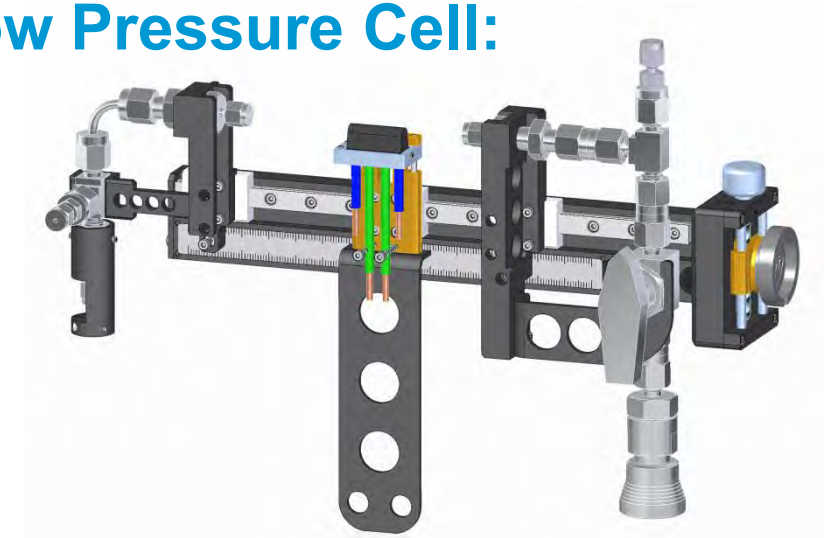
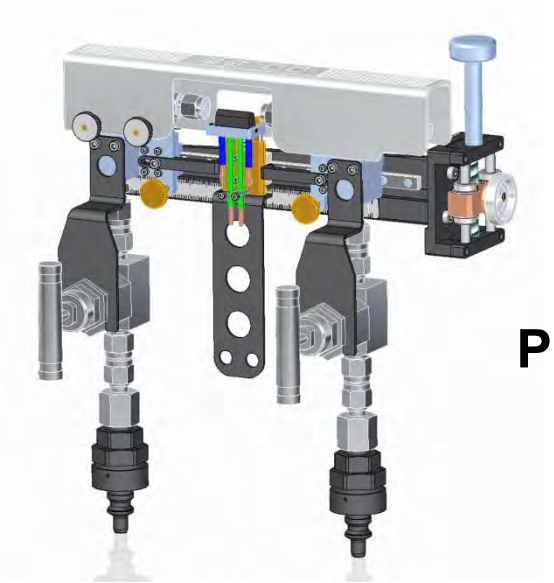
Centre for Materials and Coastal Research

Low Pressure Cell:



HIgh Pressure Cell:



Pmax. = 650 bar

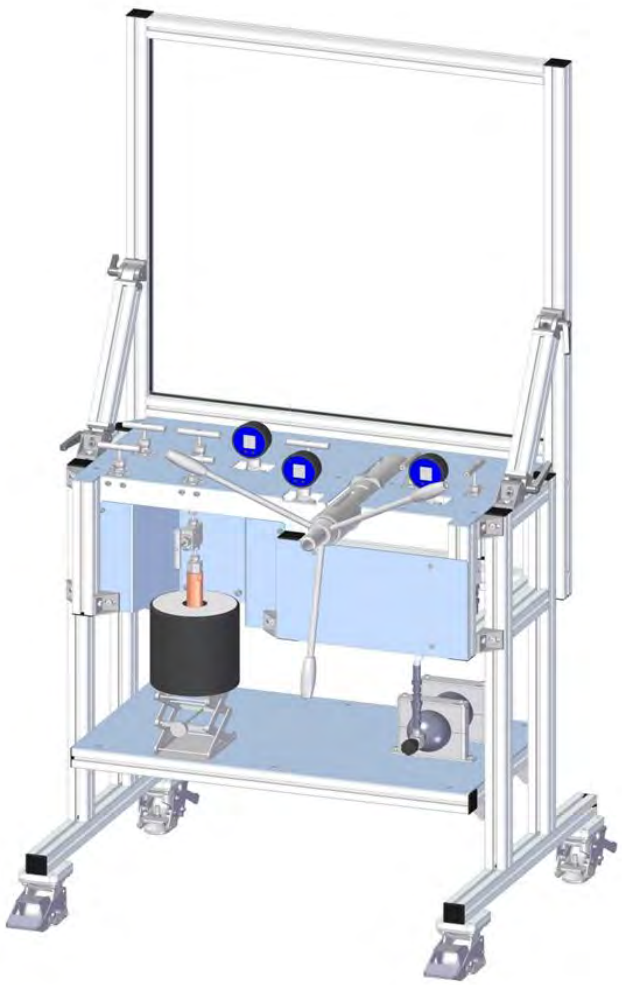
Claudio Pistidda

Christian Horstmann

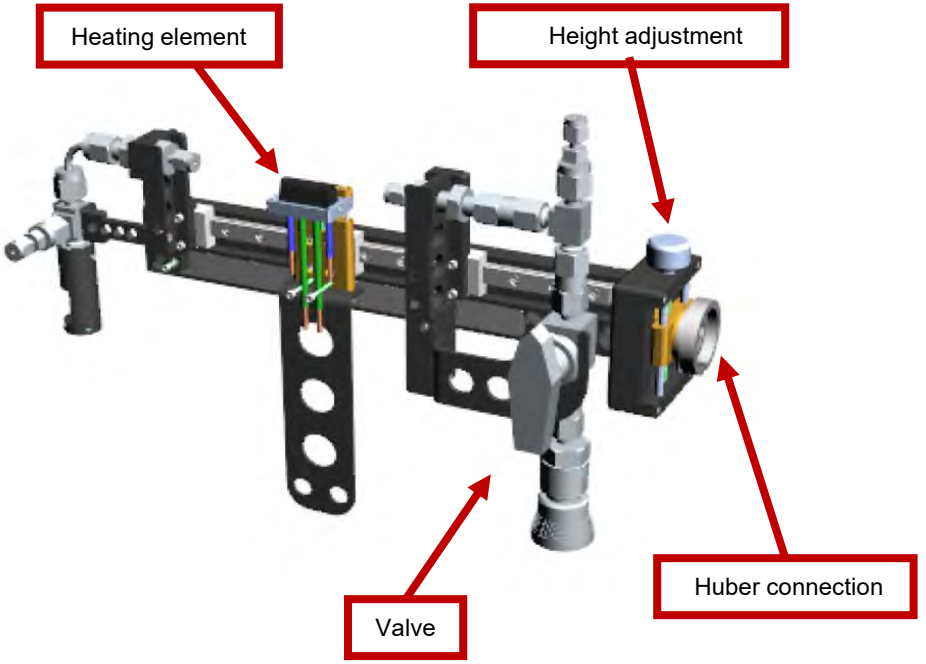
In situ SR-PXD equipment

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Gas Loading Station



Low pressure cell



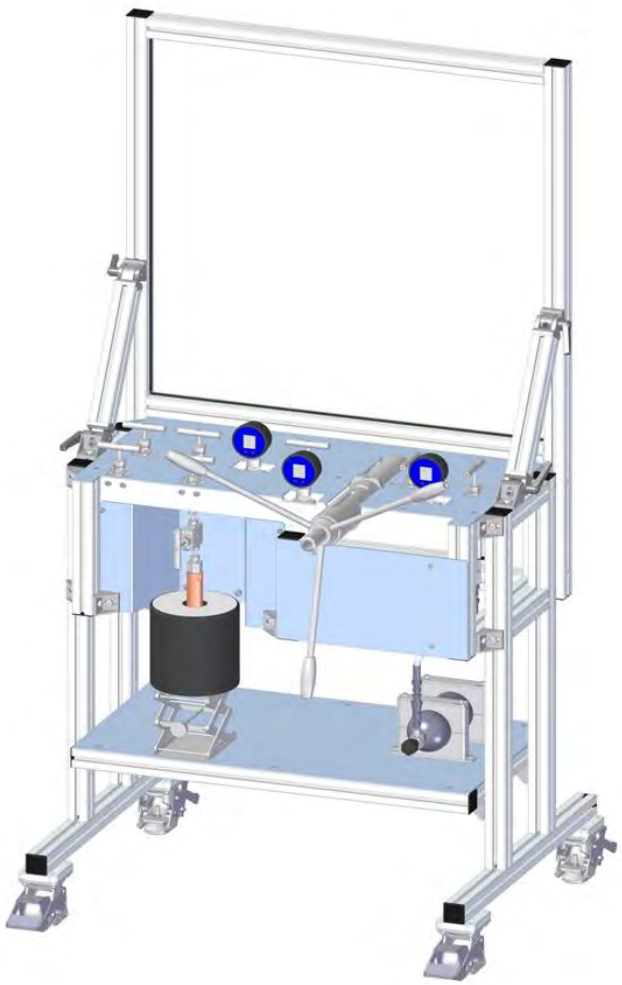
2 *in situ* cells

Pressure: from 10^{-2} up to 200 bar

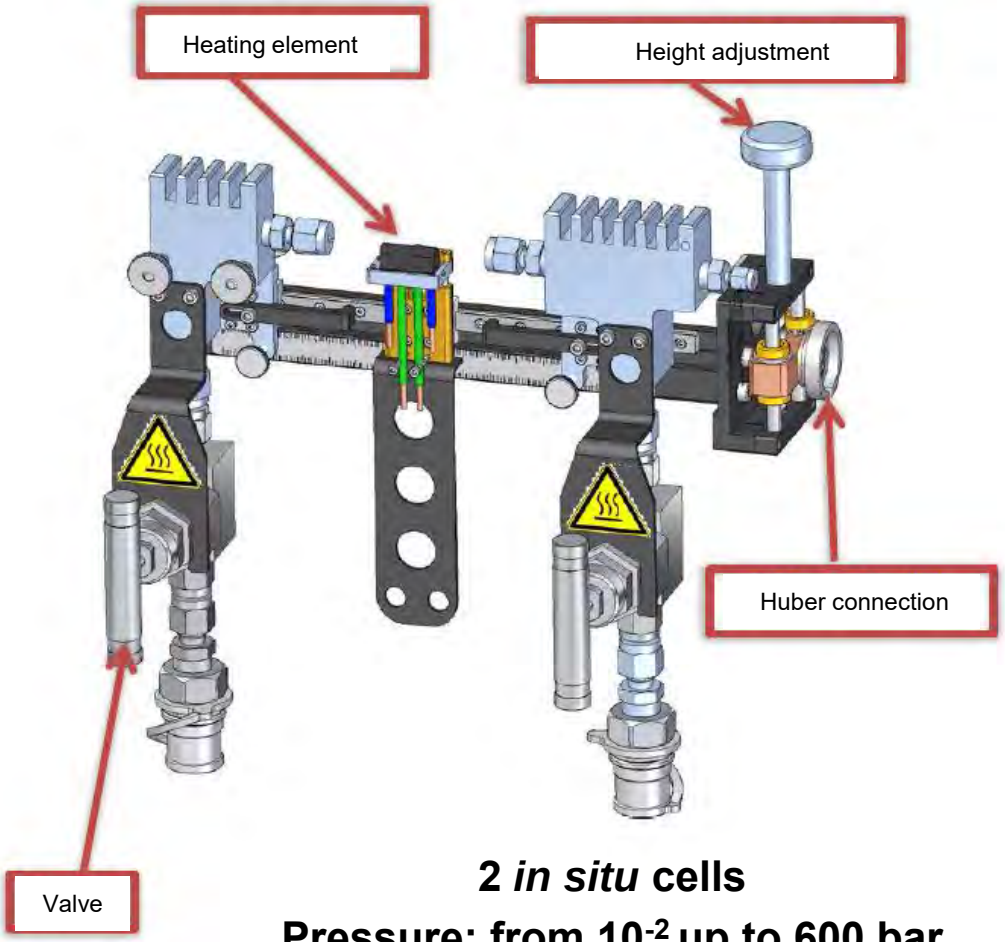
In situ SR-PXD equipment

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Gas Loading Station



High pressure cell



2 *in situ* cells

Pressure: from 10^{-2} up to 600 bar

Reversible Reactive Hydride Composites:

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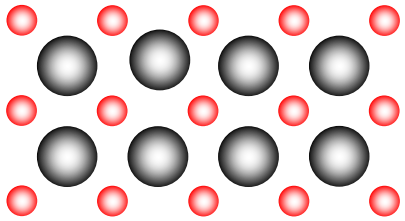
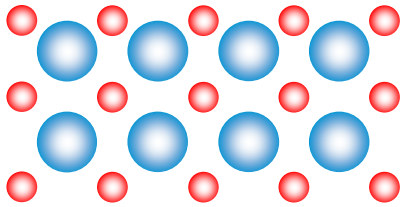
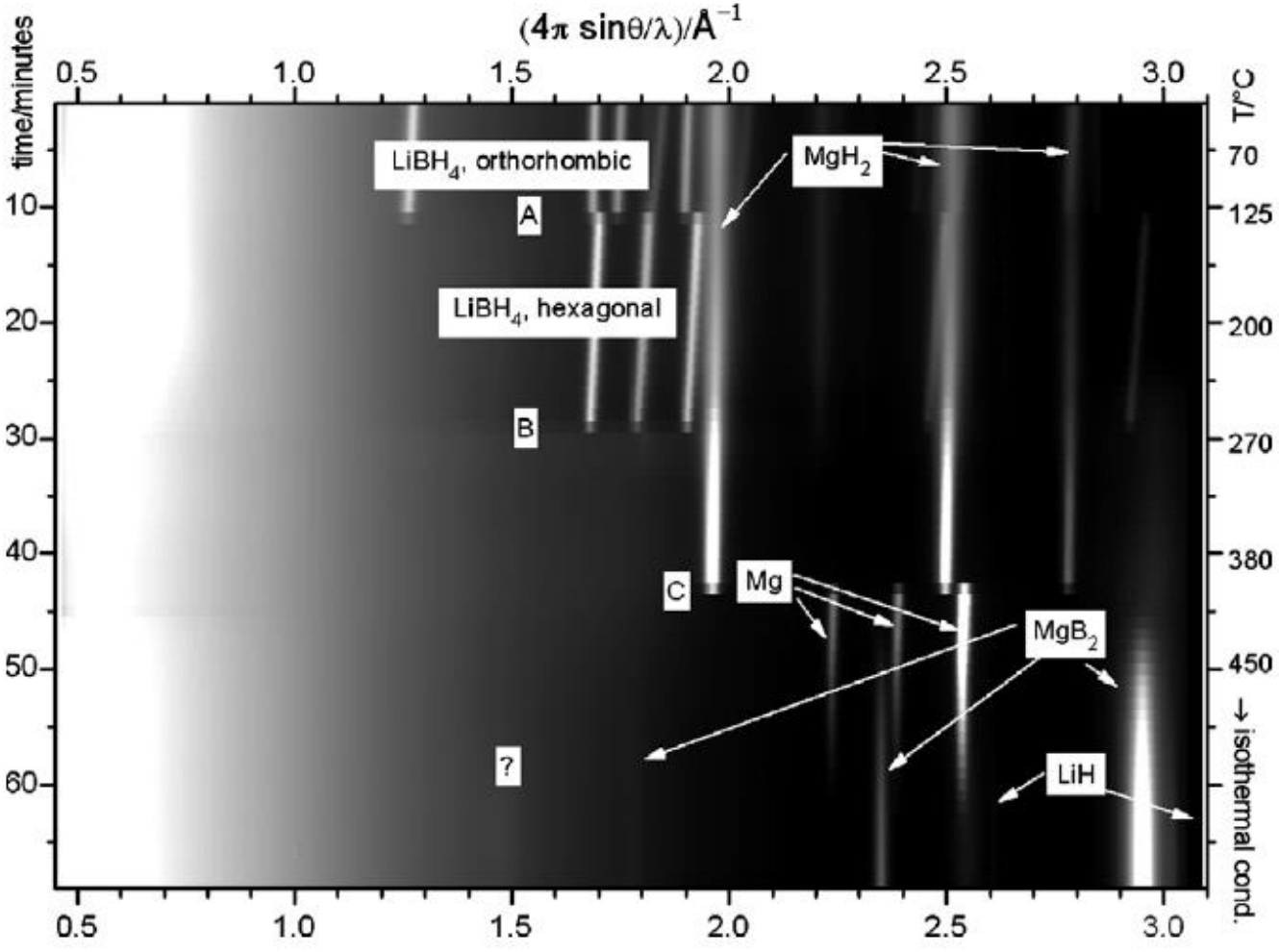
Centre for Materials and Coastal Research

Hydrogen Storage Materials:
Reactive Hydride Composites







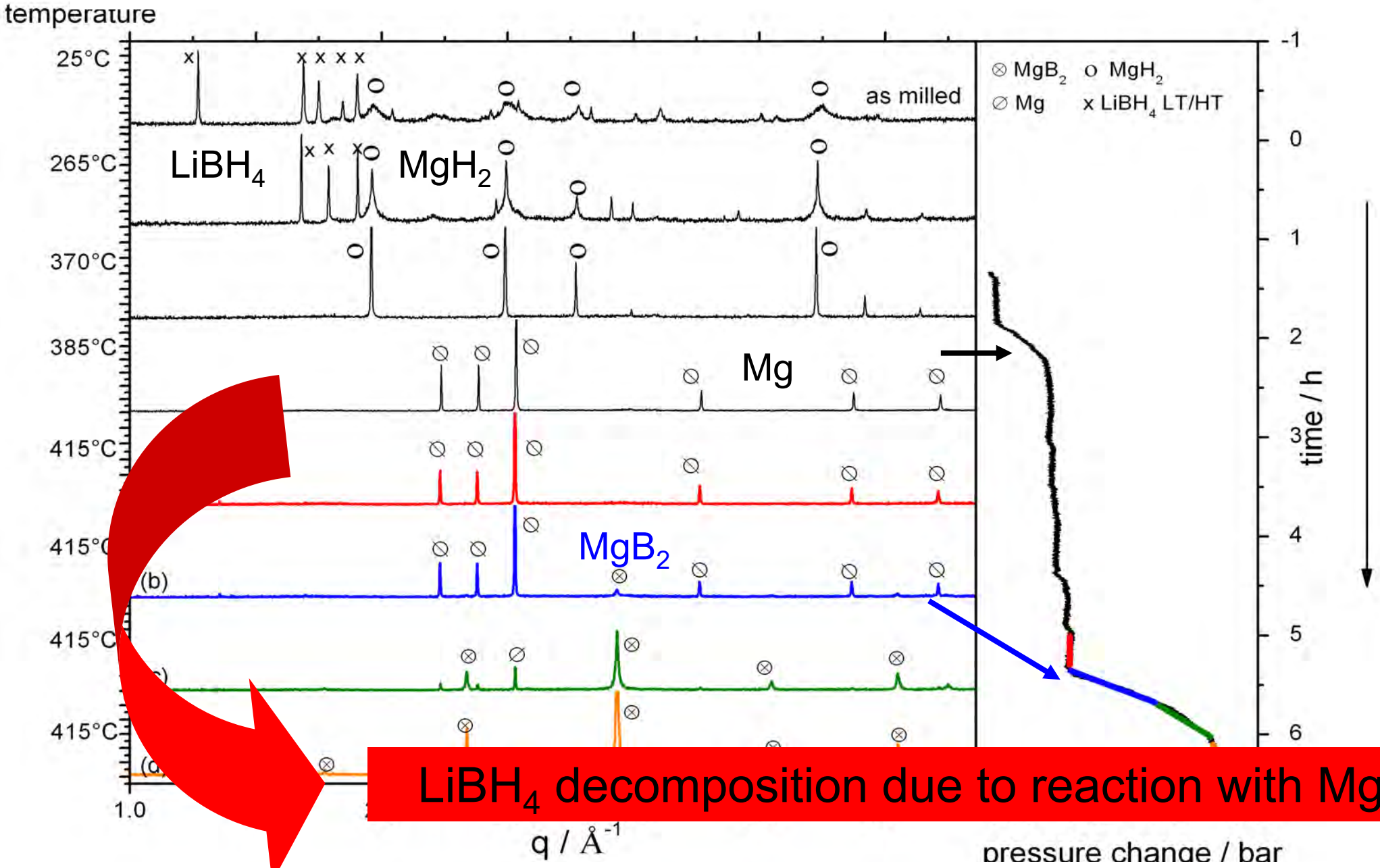
U. Bösenberg in Acta Materialia 2007, 55:3951–3958

Reaction pathway

– 5 bar hydrogen, 415 °C isothermal –

Helmholtz-Zentrum Geesthacht
Materials and Coastal Research

$2LiBH_4+MgH_2$, heating to 415°C with 5K/min, then isothermal, 5 bar H_2-pressure



$LiBH_4$ decomposition due to reaction with Mg!

U. Bösenberg et al., Measured at SNBL B, ESRF, Grenoble, France

Scale Up Material Synthesis

Lab-scale ball-milling

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Spex mill: capacity ~5 g

Fritsch P7: ~50g
Fritsch P5: ~200 g

Principle of mechano-chemical synthesis

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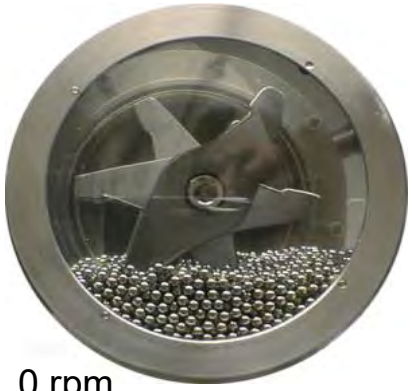
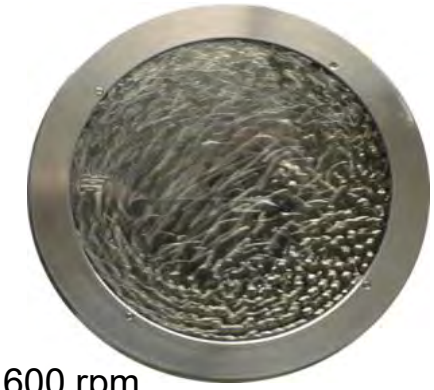
Centre for Materials and Coastal Research

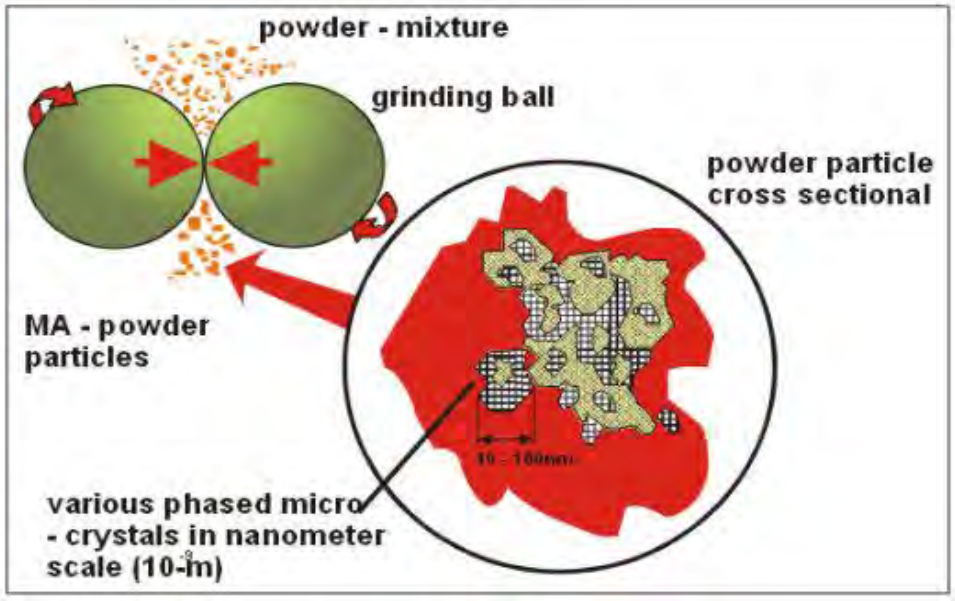

0 rpm


255 rpm


600 rpm


1700 rpm

Materials synthesis by High Kinetic Processing
by HEM, MA, RM

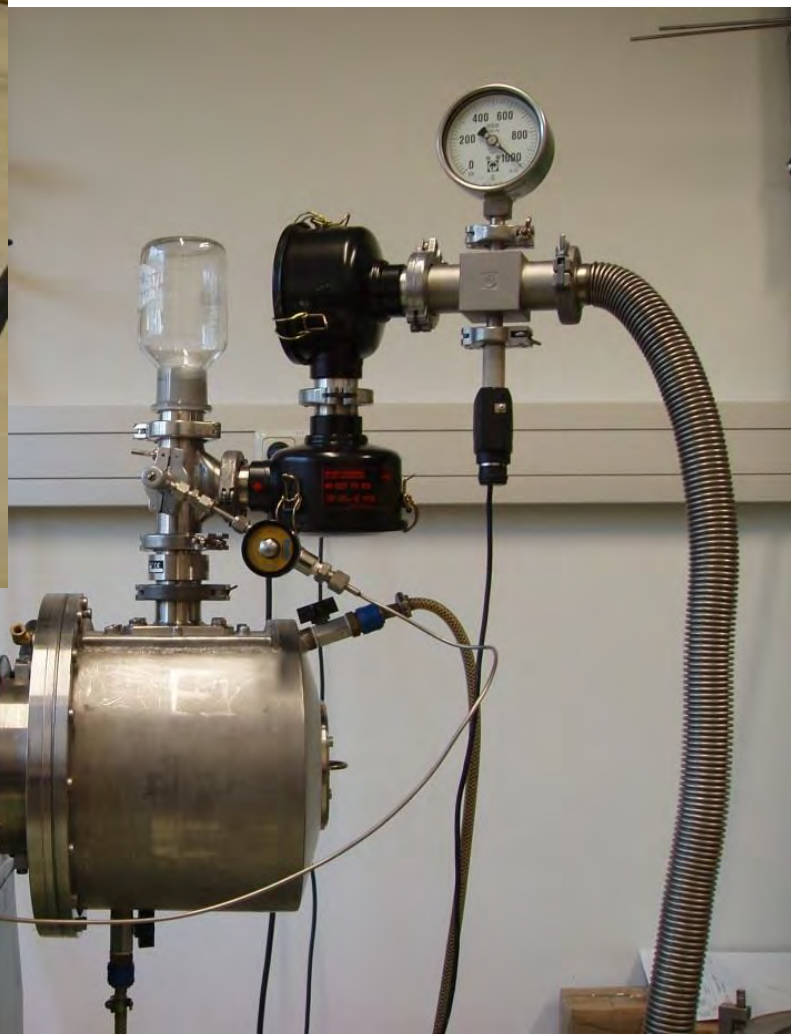


Principle of collision of grinding media

Quelle: ZOZ GmbH

ZOZ Simoloyer CM01 , CM08:

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



Siebtechnik ball-mill

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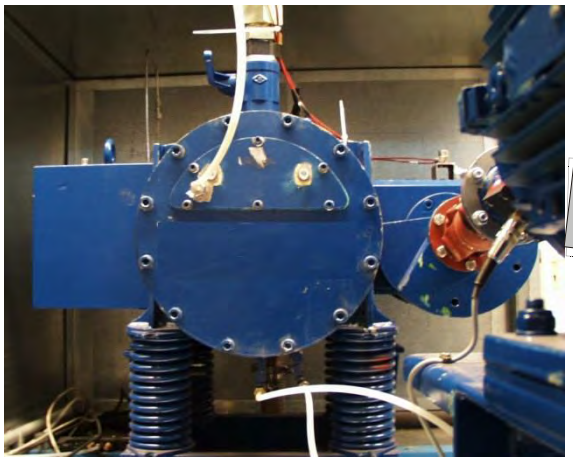
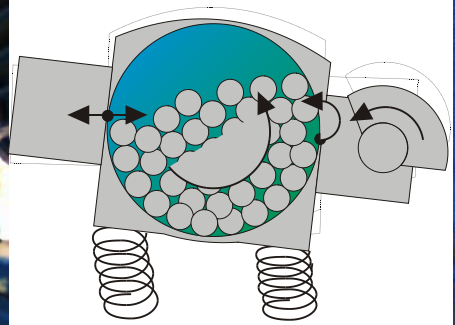
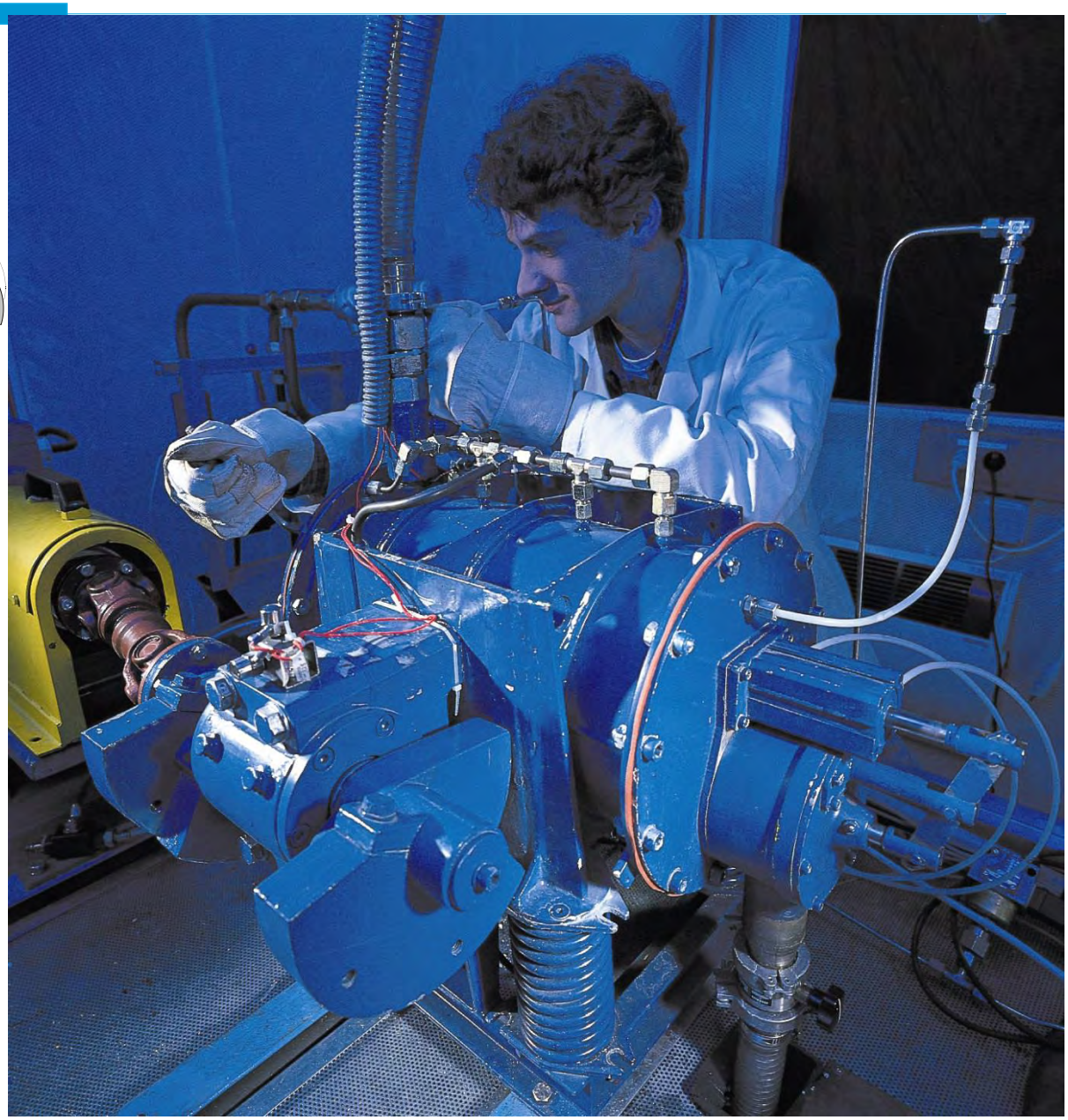
Centre for Materials and Coastal Research





Siebtechnik vibration mill

- bis zu 10 kg Pulverchargen
- hochskalierbar
  bis in den Tonnenmaßstab
- kontinuierlicher Betrieb
  möglich



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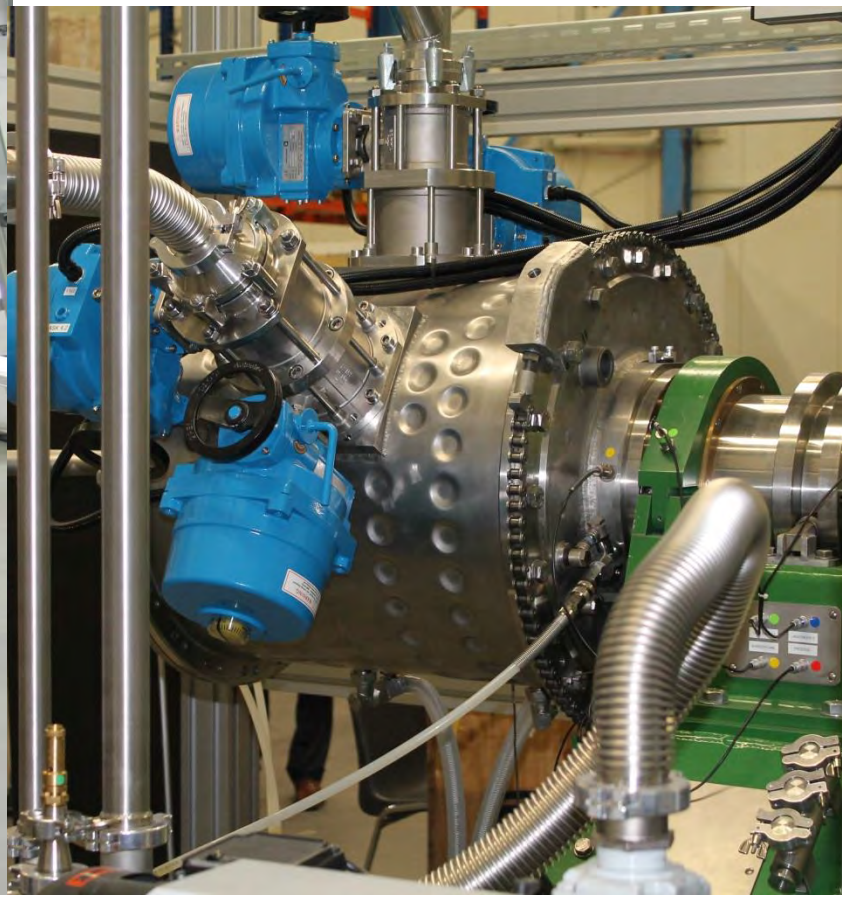
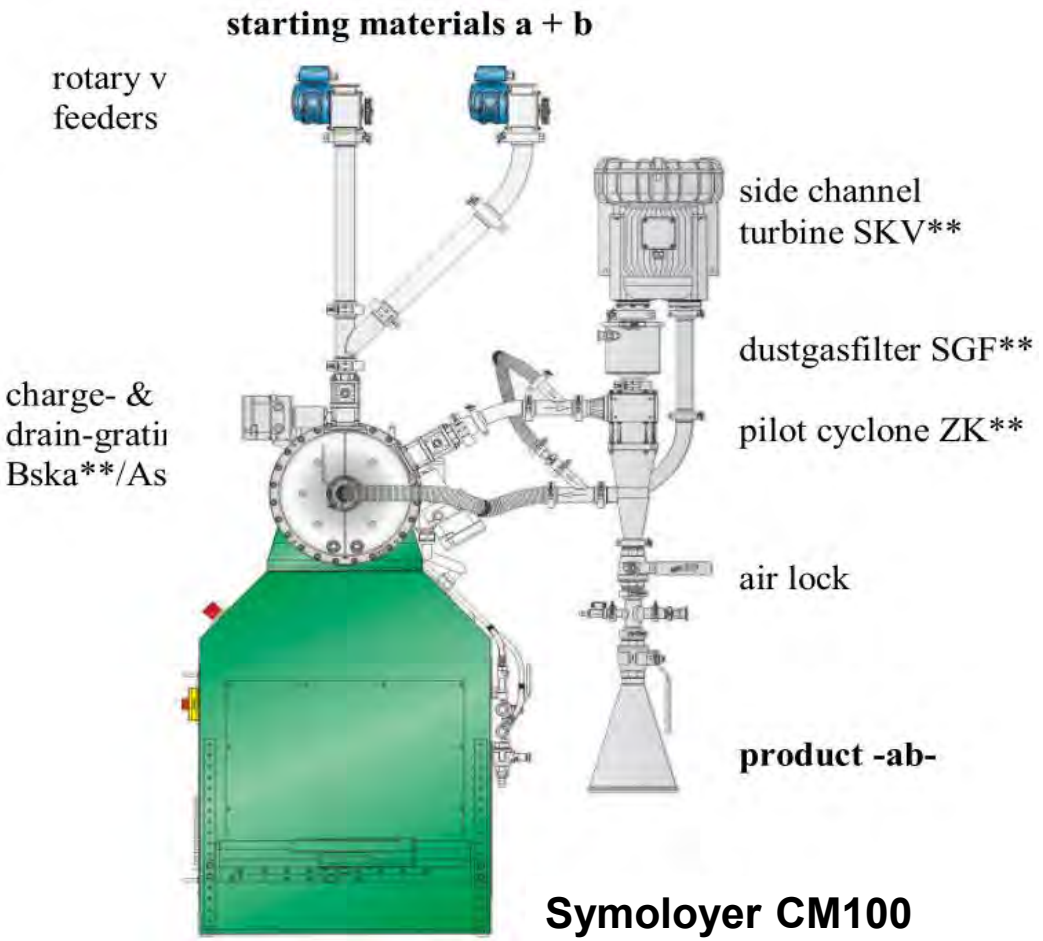
Hydrogen Technology
Centre Olpe

Helmholtz-Zentrum
Geesthacht
re for Materials and Coastal Research



Industrial scale production costs

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



Symoloyer CM100

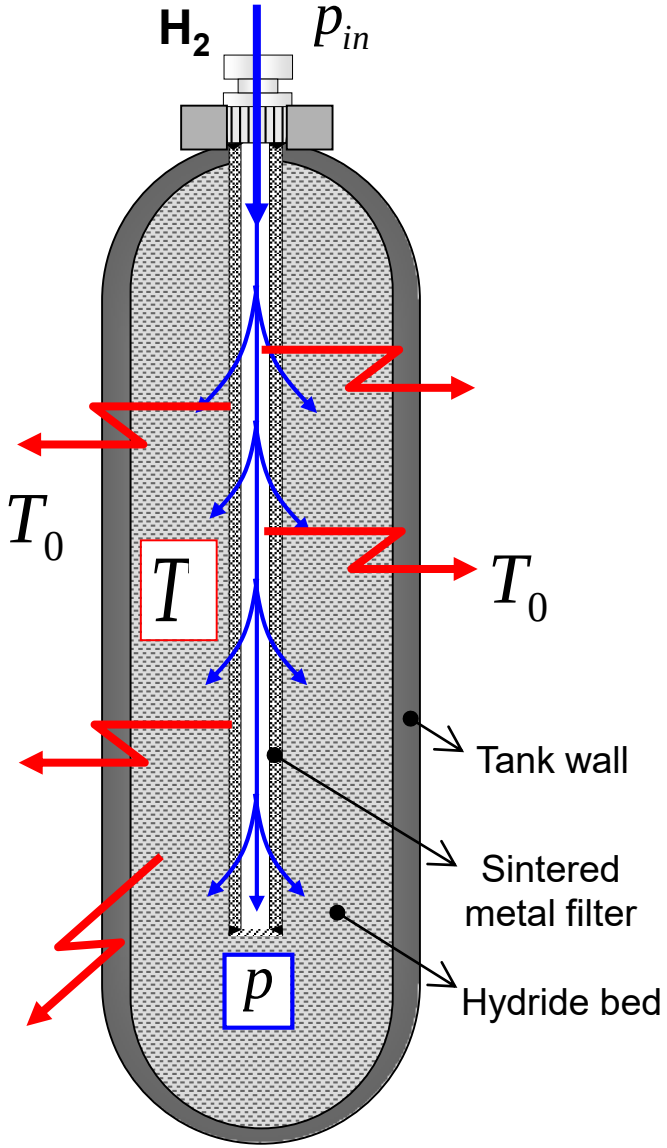
		CM100	CM400	CM900
powder production	[kg/h]	5	20	45
production capacity	[to]	480	1920	4320
~ processing costs	[€/kg]	2,09 €	0,98 €	0,68 €

Hydride Based Storage System
Simulation, Development, Test and Demonstration

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

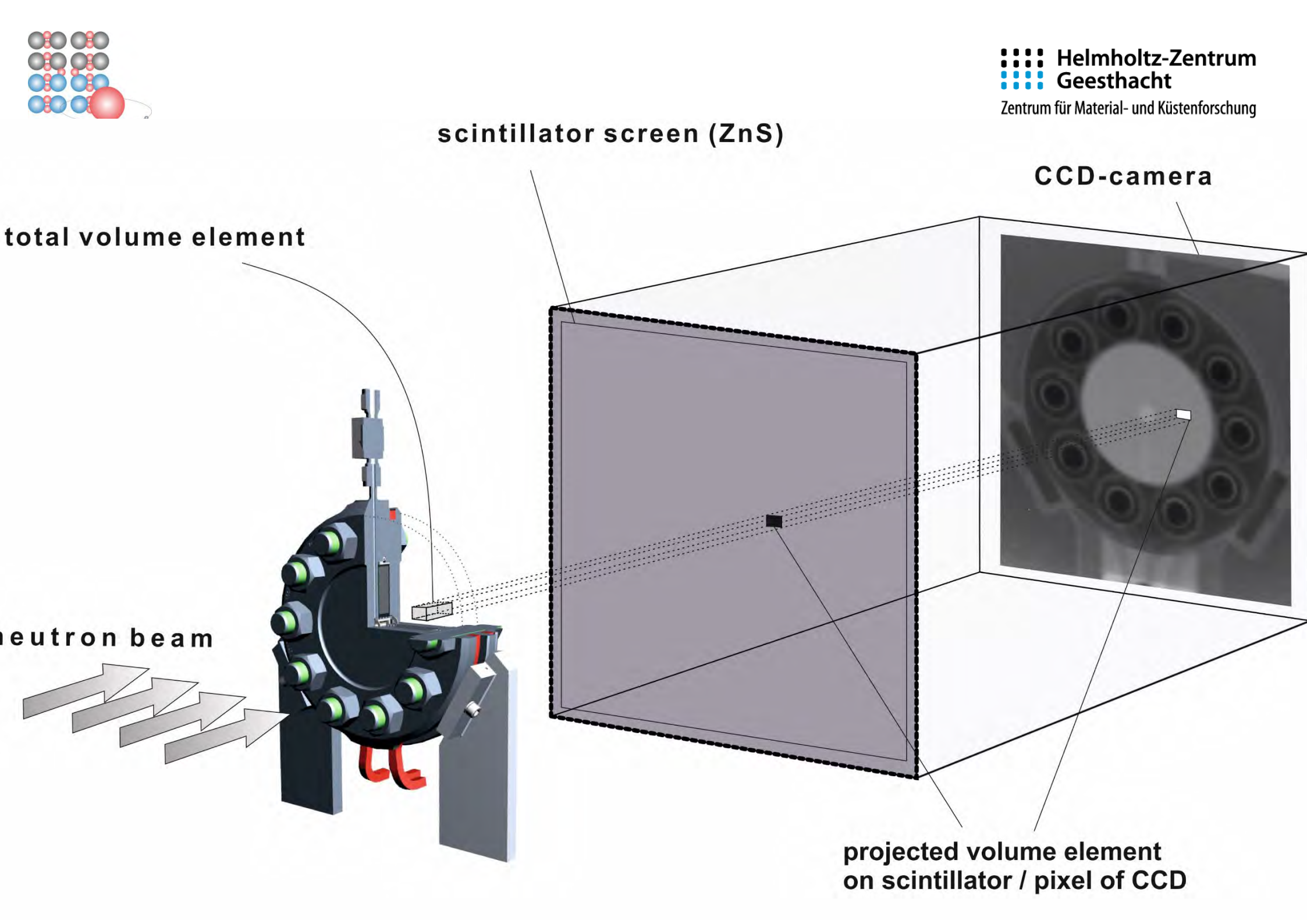
Process of Hydrogen Sorption

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



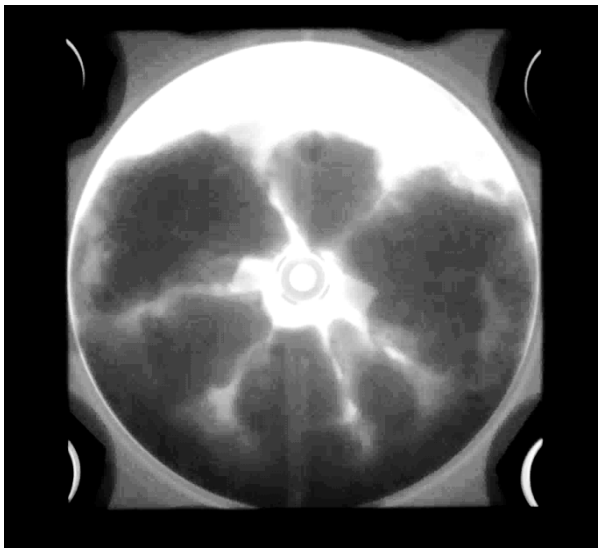
3 sequential subprocesses with different driving forces (d.f.):

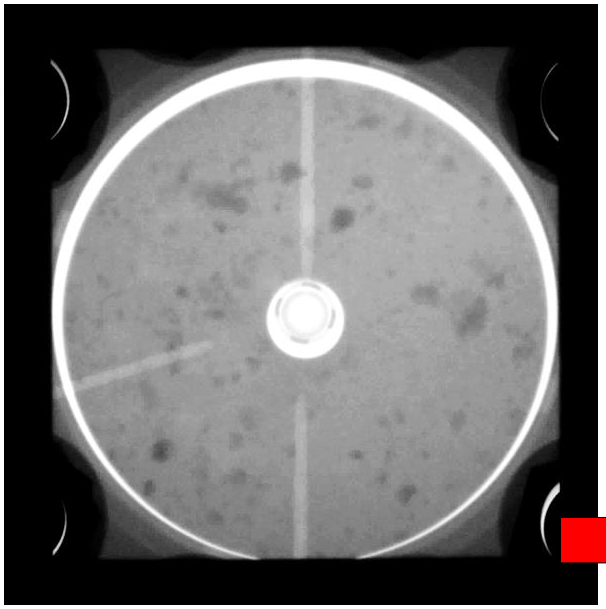
1. **Hydrogen flow**
2. **Intrinsic kinetics**
3. **Heat Transfer**


Helmholtz-Zentrum
Geesthacht
Zentrum für Material- und Küstenforschung
scintillator screen (ZnS)
CCD-camera
total volume element
neutron beam
projected volume element
on scintillator / pixel of CCD

Optimisation of Storage Tanks: Compaction

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung





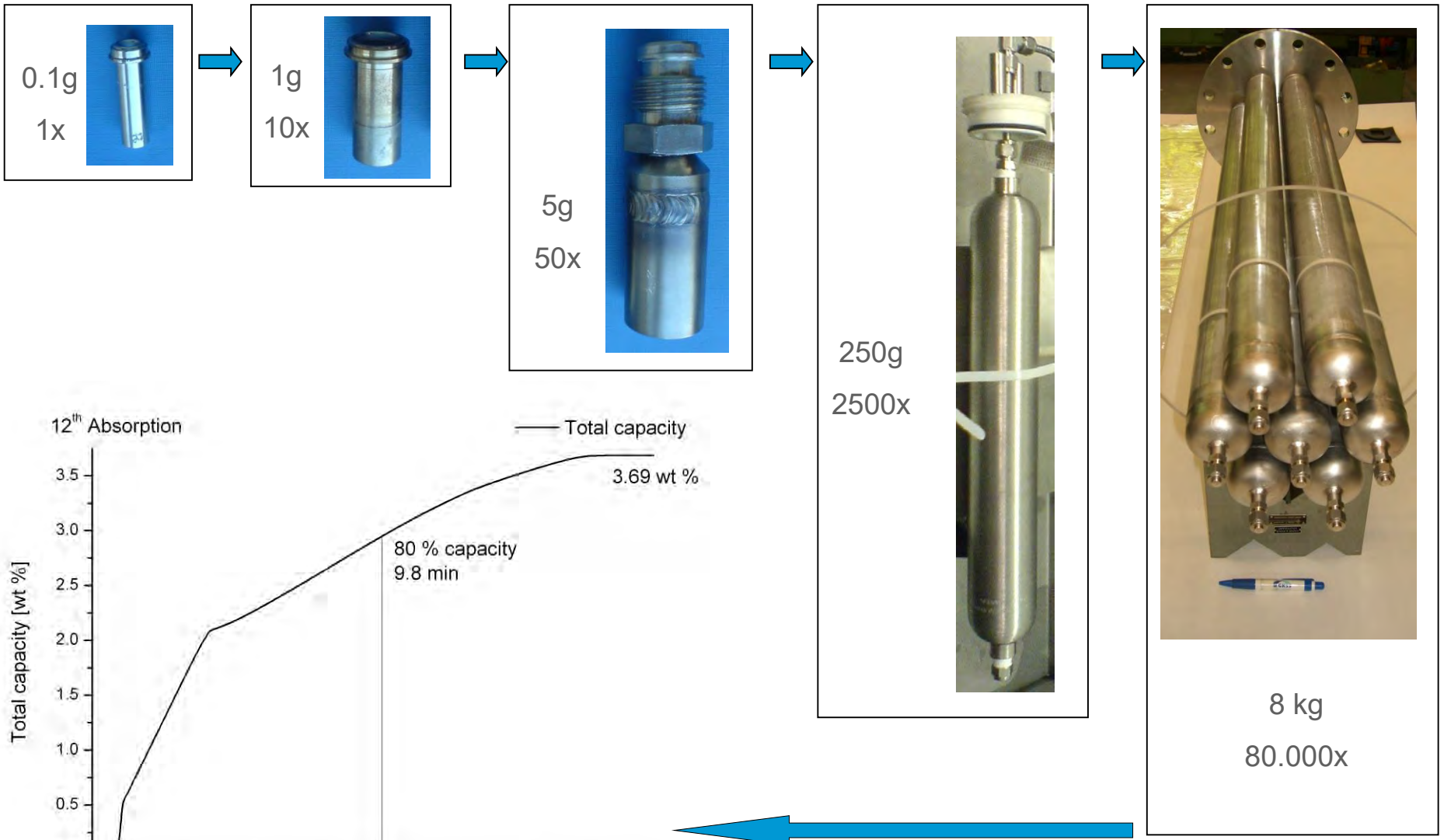
BERII; Conrad

Oliver Metz

Compaction important for increasing volumetric and gravimetric storage density!

Upscaling of Materials Testing

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



N. Eigen, C. NaRanong, J. Bellosta von Colbe, L. Gustavo, O. Metz et. al.


GKSS

Hydrogen Storage Tank based on Complex Hydrides (NESSHY Project)

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- Tube and shell design with external cooling, following previous successful design of the 8 kg alanate tank
- Lightweight materials studied for both the internal and external vessels
- Alanate compacted to tablets to increase capacity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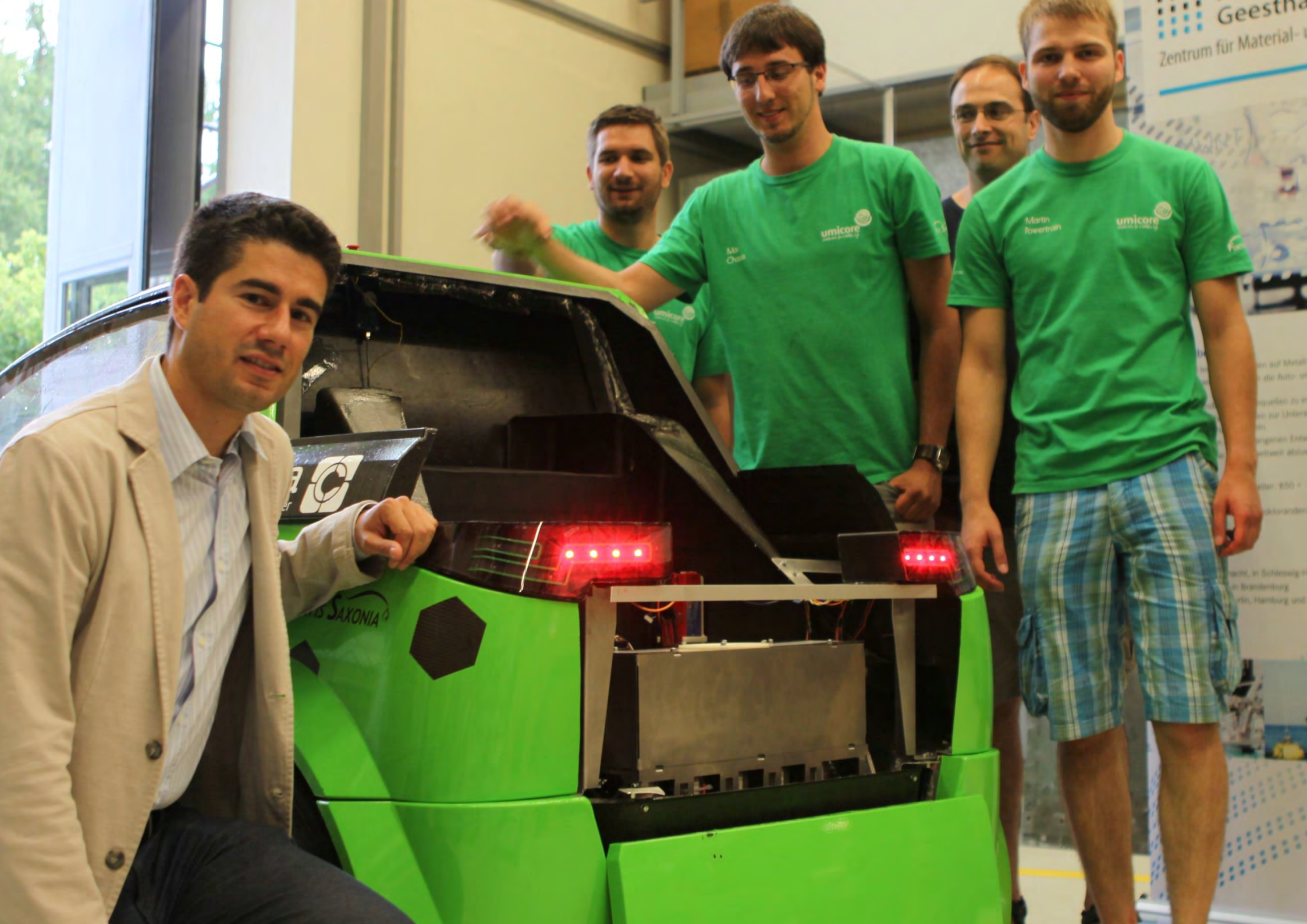
Geesthacht
Zentrum für Material- und Küstenforschung
TECHNISCHE UNIVERSITÄT
CHEMNITZ
FORTIS SAXONIA


umicore
Martin
Powertrain
umicore
Zentrum für Material-

The Ecobee car

EcoBee

- Urban Concept car
- Year of construction: 2014
- Weight: < 200 kg
- Fuell cell power: ca. 1 kW
- Max. speed: 50 km/h
- 1st Shell Eco-marathon: 2014
- Best result: 30 km/kWh

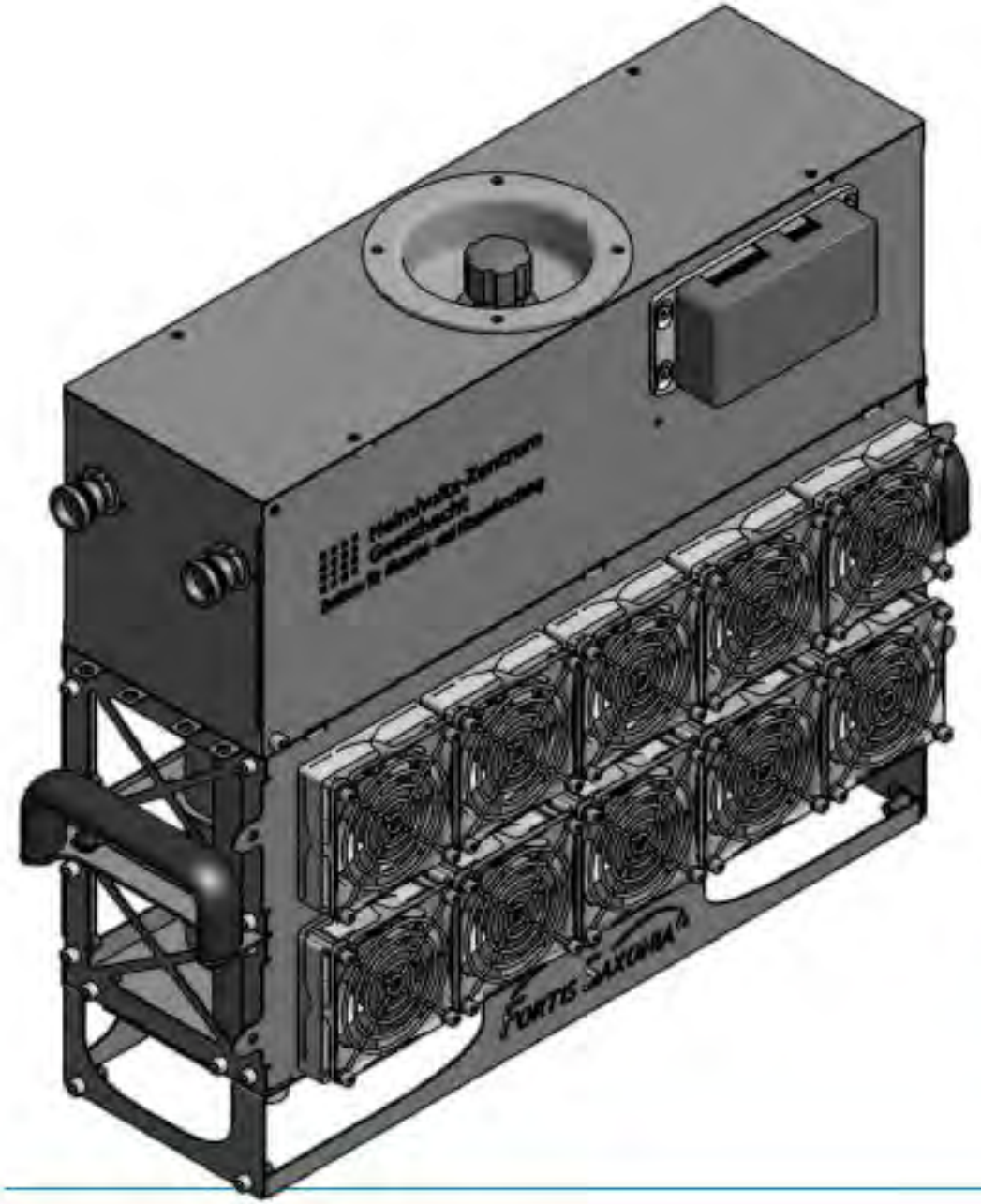
FORTIS SAXONIA

- Tank: 1 L compressed H_2 at 200 bar *…until today!*


6
2
3
4
9

The storage system

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



1 Module:
- 0,285 L and 960 g of hydride
- ~17 g H_2 stored
- Positive results

5 Modules:
- 4720 g of hydride and ~85 g of H_2
- Relief valve added

10 Modules:
- ~10 Kg hydride and ~ 170 g H_2
- Positive full scale testing

Frame and casing:
- Stable and robust
- Ancillaries and connections

Hydrogen Tank Testing Facility (HTTF) Schematic overview

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

- Flow controller
- Data recording
- Process control

- Test chamber
- Hydride tank
- Vacuum pumps

- Thermal generator
- Heating and cooling
- Thermal fluid

Current and recently finished third party projects on metal hydrides / hydrogen storage

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Federal Ministry for Economic Affairs and Energy	2018-2021	H2Hybridtank: Development of a cost efficient hybrid high pressure – hydride hydrogen storage system for mobile applications **Coord.:** Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research
MARIE CURIE ACTIONS	2018-2020	MSCA-Rise: Hydride4Mobility: Hydr. fueled utility vehicles and support systems using metal hydrides
Karl-Vossloh-Stiftung	2018-2020	High Efficient Adiatic Hydrogen Storage Tank
Alexander von Humboldt Stiftung/Foundation	2017-2019	Optimised hybrid hydrogen storage reservoir with opt. capacity
Federal Ministry of Education and Research	2016-2018	BmBF "HyScore": Eff. H2-Storage through hierarchical porous core shell structures with incorporated light metal hydrides
iea H I A	2013-2018	IEA Hydrogen Implementation Agreement Task 32
HELMHOLTZ ASSOCIATION	2012-2017	Helmholtz Energy Materials Characterization Platform
InnovationsFonden FORSKNING, TEKNOLOGI & VÆKST I DANMARK	2012-2017	HyFill-Fast": Fast efficient H2 storage 
MARIE CURIE ACTIONS	2013-2017	EU ITN "ECOSTORE" **Coord.:** Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research
HELMHOLTZ ASSOCIATION	2014-2017	Helmholtz-CAS Project "RevHy"
DAAD	2016-2017	PPP Australien
Nanostructured materials for solid-state hydrogen storage	2011-2015	EU MPNS COST Action "MP 1103"
New Energy World JU	2012-2015	FCHJU Project "BOR4STORE" **Coord.:** Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research
	2013-2015	Concert Japan CP iTHEUS