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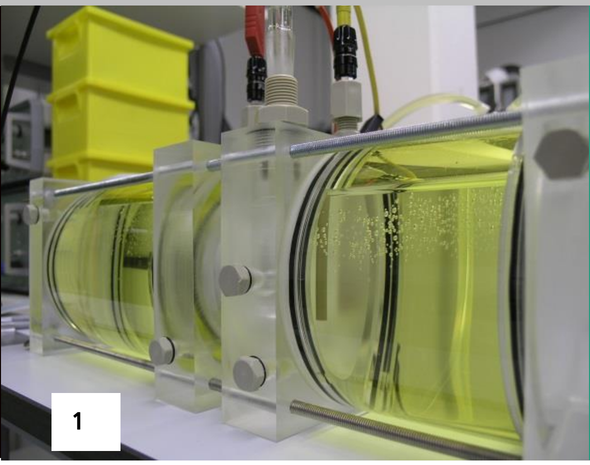

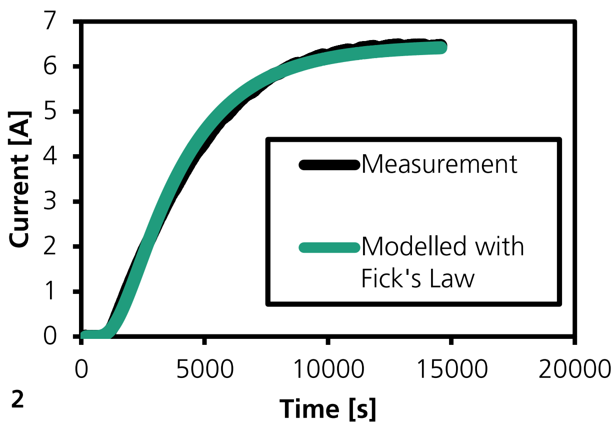

1 *Permeation cell for the measurement of the H-diffusion coefficient.*
2 *Measured permeation curve in comparison to modelled curve.*

Hydrogen Embrittlement

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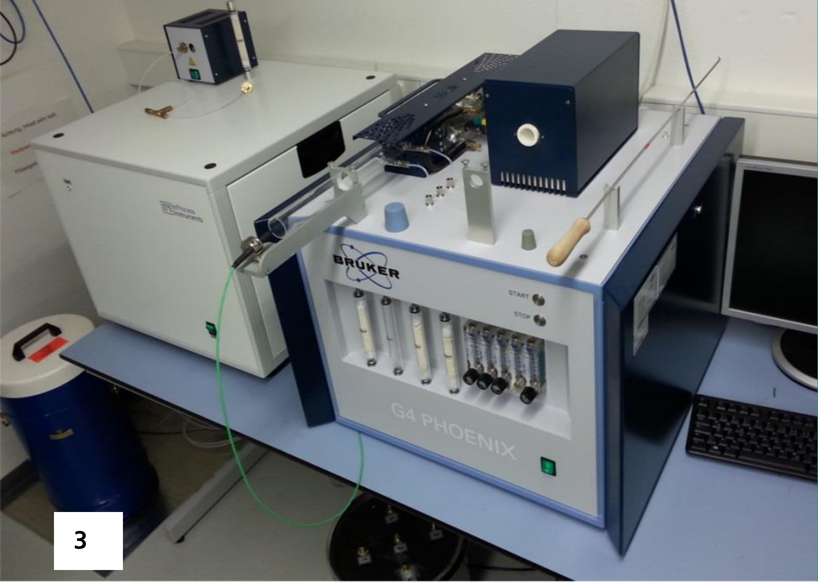
Objective

Hydrogen reduces the ductility and durability of many metals. This is generally referred to as hydrogen embrittlement. Hydrogen embrittlement is gaining increasing importance for advanced technical solutions in the energy, automotive and aerospace industries. Hydrogen is a potential replacement for fossil fuels and, consequently, solutions for the generation, distribution and storage of hydrogen are sought. The car and airplane industries look for light weight construction by using high strength steels with ultimate tensile strengths above 1200 MPa. Those high strength steels can be prone to the hydrogen embrittlement. Therefore, there is a need for hydrogen resistant materials.

Focus of the Fraunhofer IWM

IWM has extensive experience in the investigation and explanation of hydrogen embrittlement mechanisms and in the simulation of the underlying diffusion processes. To determine the hydrogen permeation and trapping parameters **electrochemical permeations cells** are available, see figures 1 and 2. An economic and reliable measurement of the total hydrogen concentration in metallic materials can be done by **carrier gas hot extraction**. Through **thermal desorption spectroscopy**, the hydrogen binding energies can be determined, see figures 3 and 4. The degradation of strength properties can be quantified by in-situ **slow strain tensile tests** with **constant hydrogen charging**, see figure 5. Experimental results are coupled with advanced **atomistic simulation** of binding energies and **FE modeling** of diffusion and local enrichment of hydrogen, see figure 6.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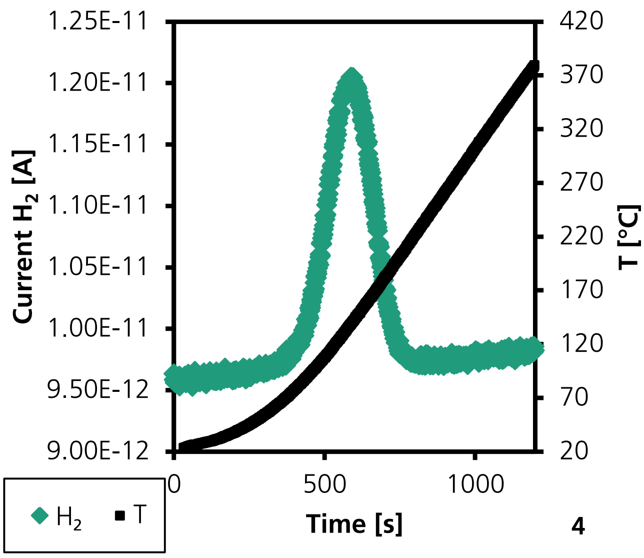

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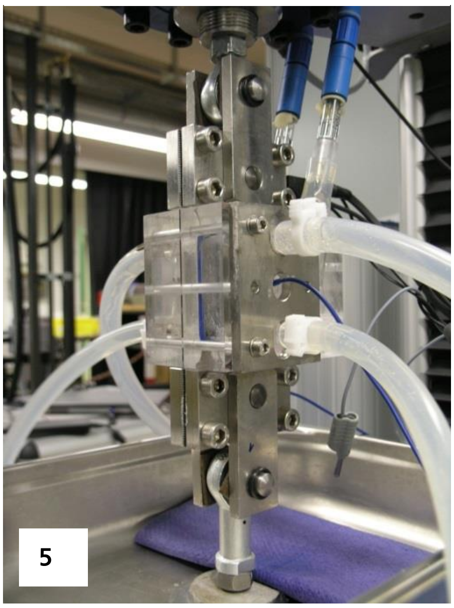
Advantages for Your Research

Fraunhofer IWM helps its clients with the selection and qualification of materials and manufacturing techniques, with assessments of operating life and, in the event of failure, with the identification of the causes of component failure.

Production processes can lead to increased hydrogen concentration in metals. For example coating processes can introduce hydrogen. With the thermal desorption spectroscopy it is possible to determine necessary heat treatment temperatures and times to desorb the hydrogen. The result is a cost effective heat treatment against hydrogen embrittlement.

The renewable energy sector looks for hydrogen resistant materials for hydrogen pipelines and storage solutions. With the in-situ slow strain tensile testing machine with constant hydrogen charging it is possible to evaluate those conditions in the laboratory. Hydrogen resistant materials are identified and life time prediction models developed.

In welding processes hydrogen often concentrates in the heat-affected zone. This concentration can lead to hydrogen embrittlement in combination with tensile stresses and a susceptible microstructure to the failure of the weld. The combination of permeation experiments to measure the hydrogen diffusion coefficient and input parameters for FE models allows the determination of critical local areas and the sensitivity for the formation of cold cracks in these welds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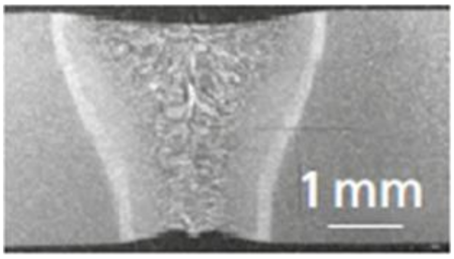
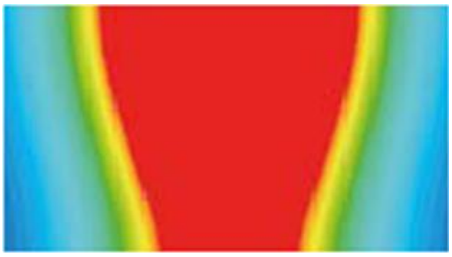
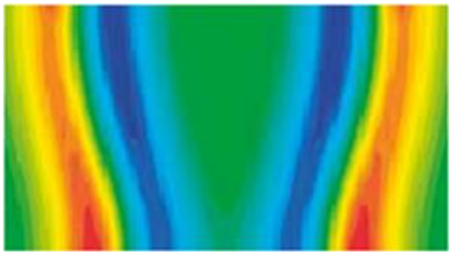
3 *Thermal desorption spectroscopy from Bruker to measure hydrogen.*
4 *Determination of dissolved hydrogen by constant specimen heating using thermal desorption spectroscopy.*
5 *In-situ slow strain tensile test with constant hydrogen charging.*



6.1 *SEM of laser welded high strength of steel.*


6.2 *Calculated residual stresses.*


6.3 *Simulated temperature field and development metallurgical phases.*


6.4 *Calculated hydrogen distribution involving trapping phenomena.*