HELMUT SCHMIDT UNIVERSITÄT
Universität der Bundeswehr Hamburg

Renewable Hydrogen Production by Photoactive Surfaces

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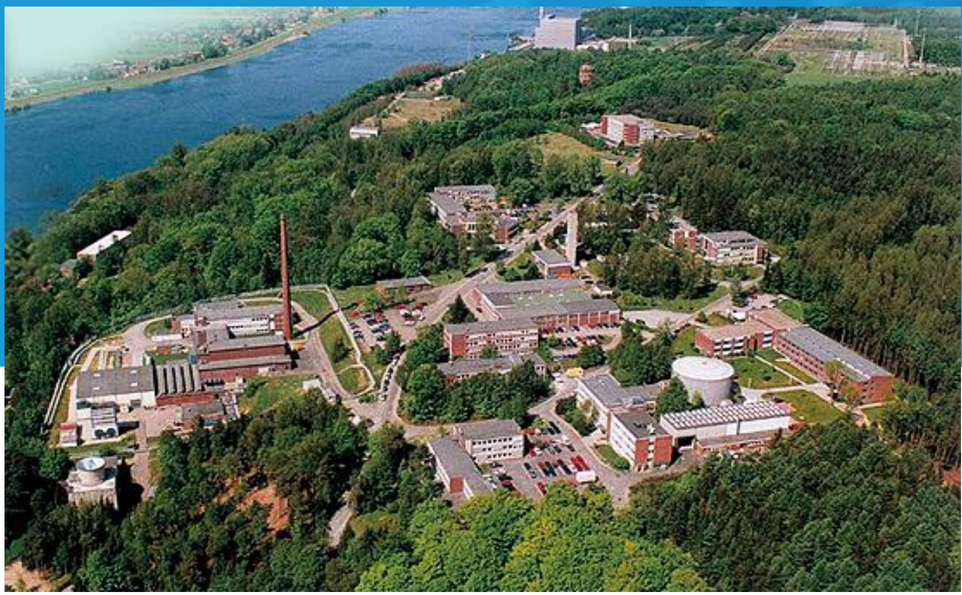
Helmholtz-Zentrum Geesthacht

10th IPHE Education & Outreach Event
April 26, 2017, TUHH



Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Materials Technology

Thomas Klassen

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

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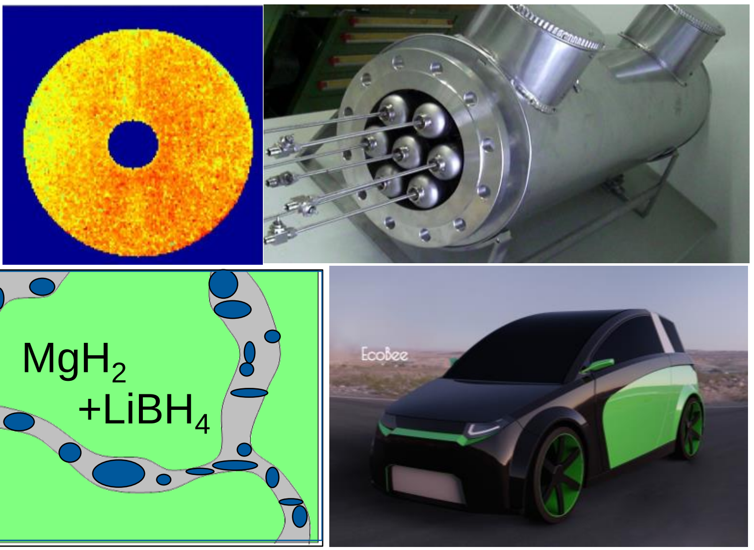
Hydrogen Storage in Metal Hydrides

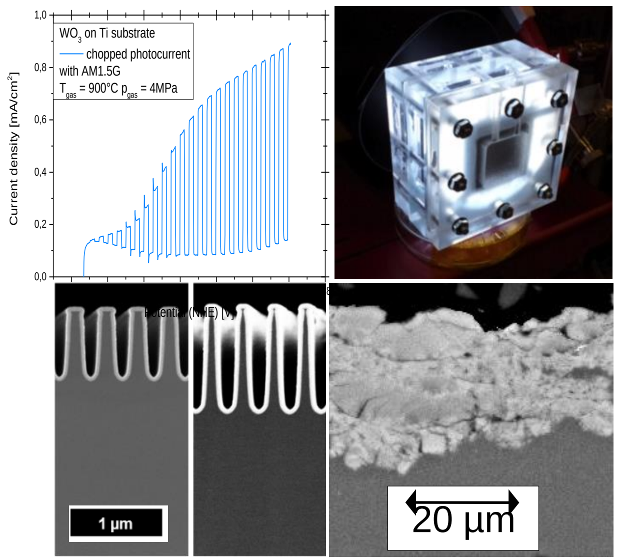
M. Dornheim, K. Taube, G. Capurso, J. Bellosta, C. Pistidda, A.-L.Chaudhary



from materials and tank design to demonstrator tanks

Photoactive Coatings for Hydrogen Production

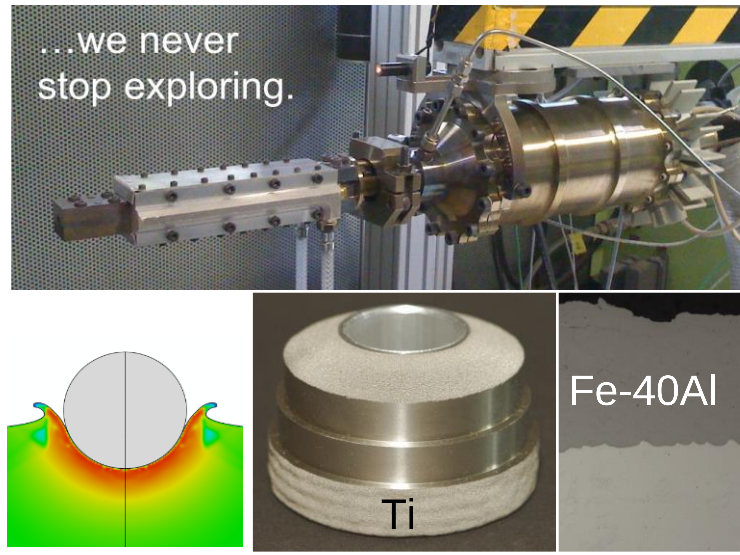
(**Thomas Klassen**)
M. Eich, M. Schieda



from basic processes at surfaces and interfaces to demonstrator modules

Advanced Functional Coating Technologies

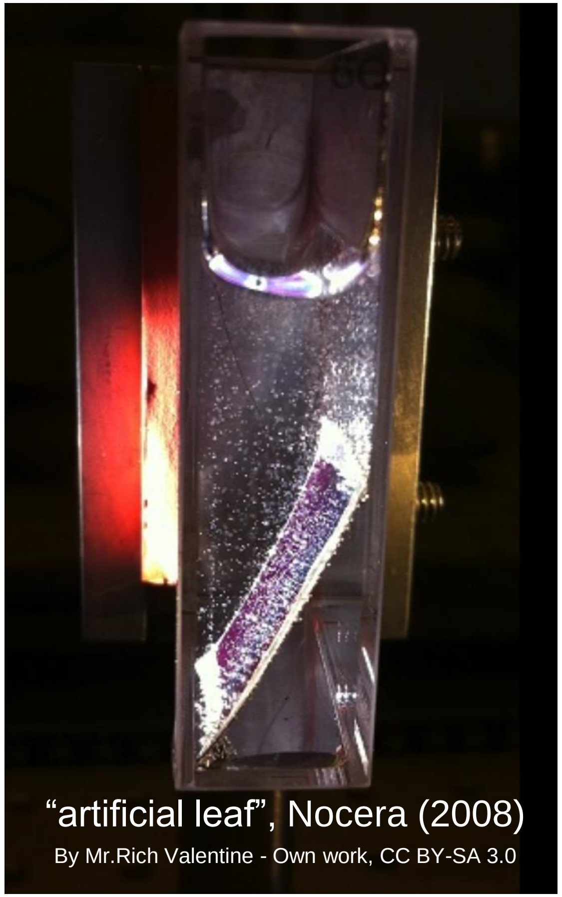
M. Störmer, **F. Gärtner**
M. Villa, H. Gutzmann



from material selection and process development to tailored coating properties

Hydrogen

photo: Nature 2012



“artificial leaf”, Nocera (2008)

sustainable and affordable
H_2 generation by artificial leaves:

from photocatalysts and tailored surfaces
to efficient photo-electrochemical cells

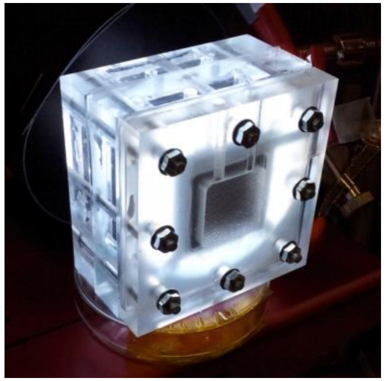
Efficient Photoelectrochemical H_2 Generation

From photo catalysts and tailored semiconductor interfaces to efficient photoelectrochemical cells

- **high activity**
  by binderless deposition using kinetic spraying

- **better light harvesting**
  using tailored surface structures

technology demonstration



- **higher efficiency**
- kinetically sprayed electrode reaches 7x higher efficiency

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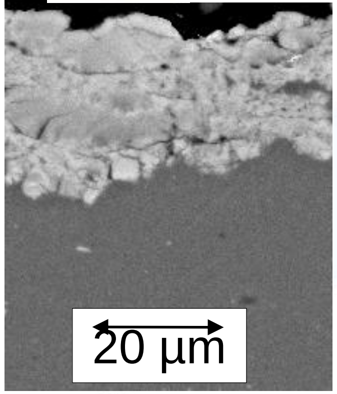
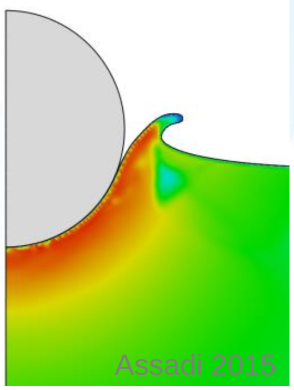
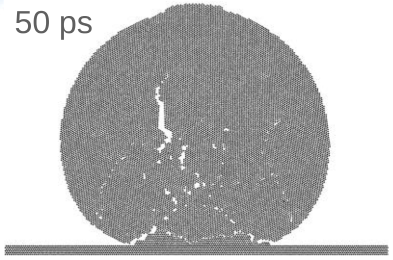
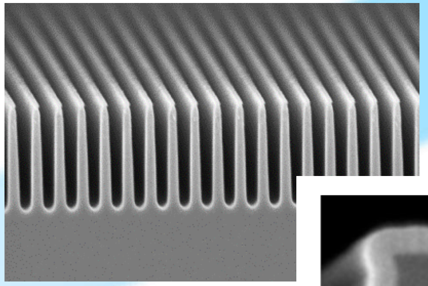
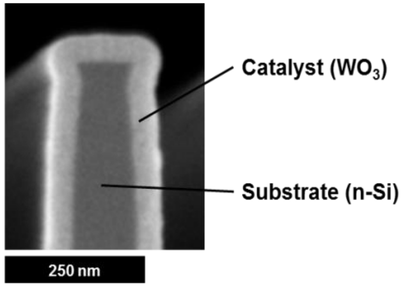
HZB Helmholtz Zentrum Berlin
BERKELEY LAB







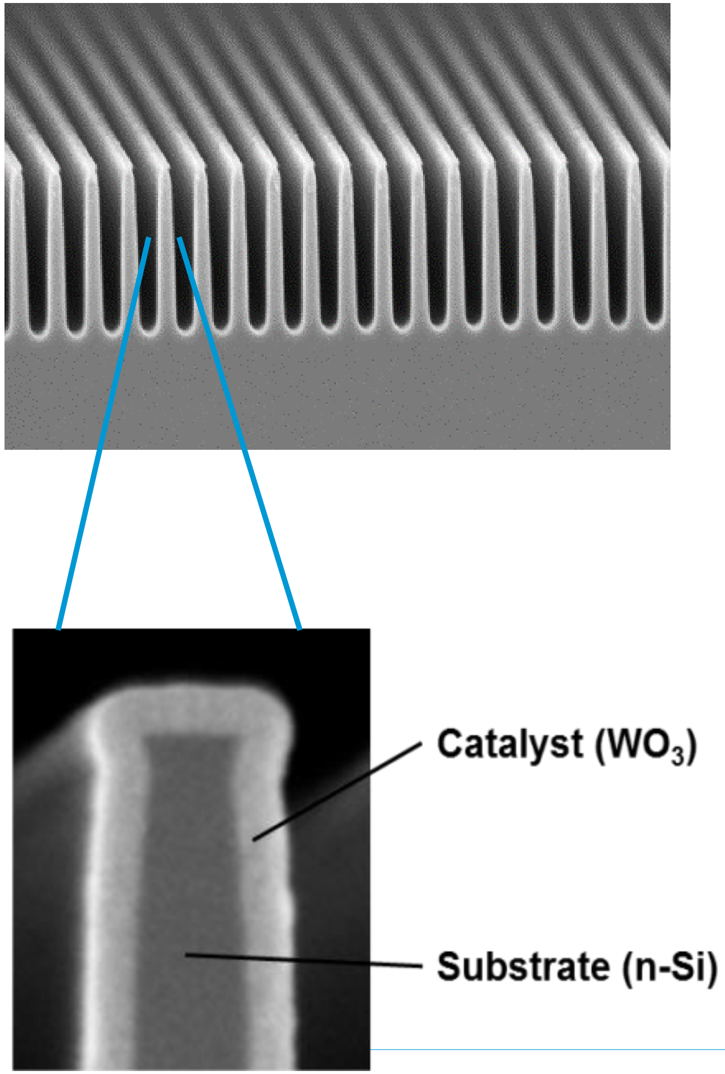


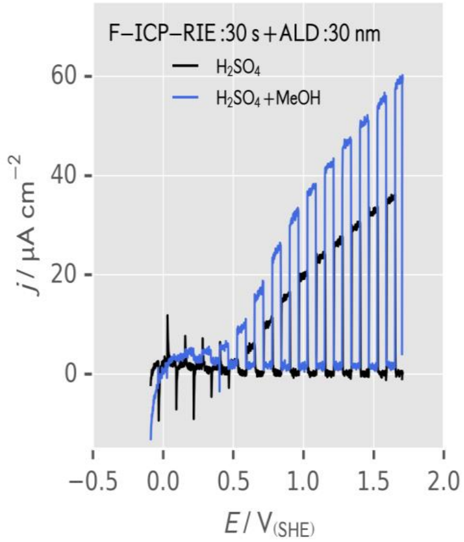


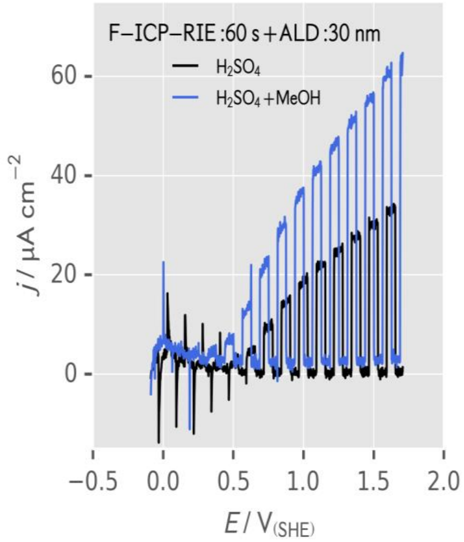
B. Daneshian and H. Assadi, J. Thermal Spray Techn. 23 (2013) 541

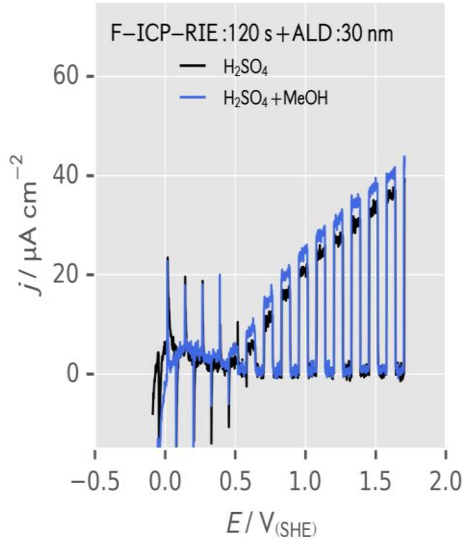
role of surface aspect ratio

Model Surface Structures

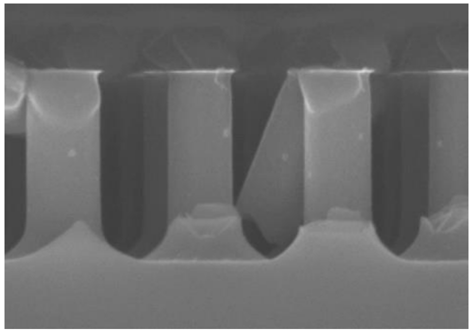




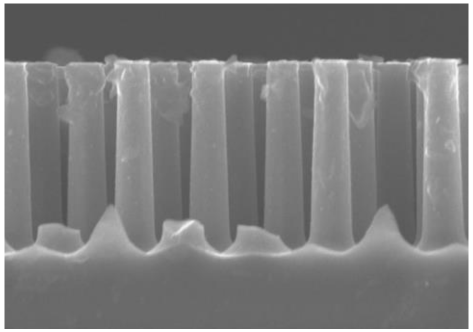




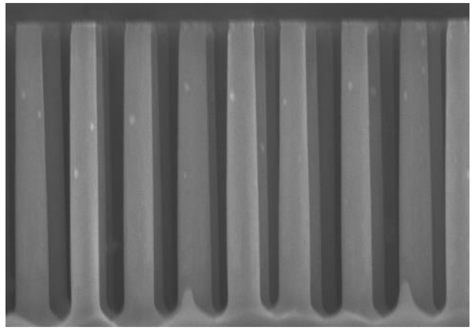
Etch time: 30 s (~330 nm)



Etch time: 60 s (~1.9 µm)



Etch time: 120 s (~3.7 µm)



disruptive technology: supersonic kinetic particle deposition

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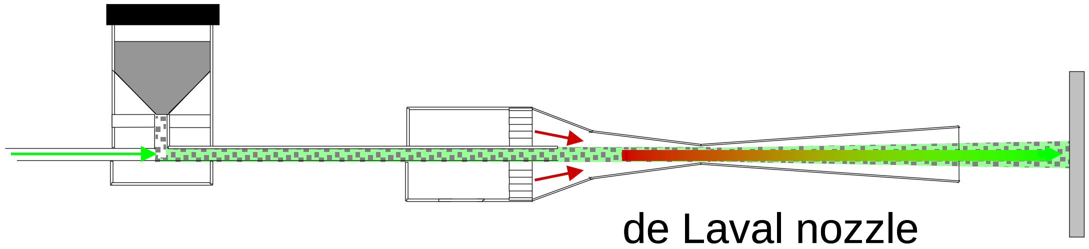
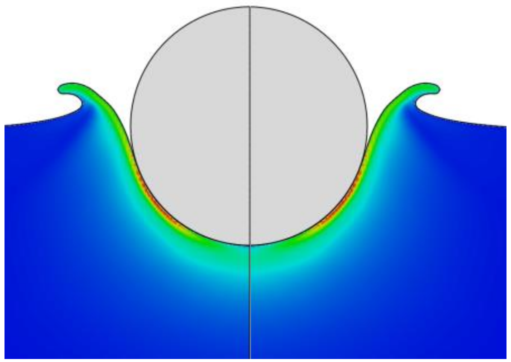
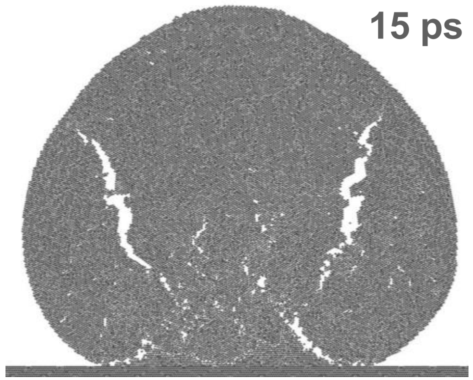


on µ-scale
FE-Simulations:
Deformation Heat induces Bonding



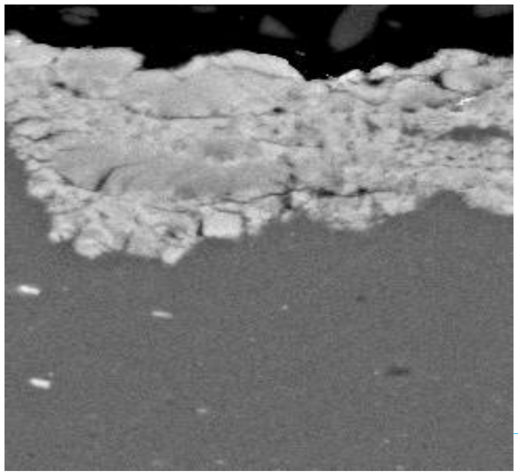
- ✓ binderless coupling of photoelectrocatalyst
- ✓ Ideal interface contact for charge carrier transport
- ✓ easy to scale-up for large photoelectrodes

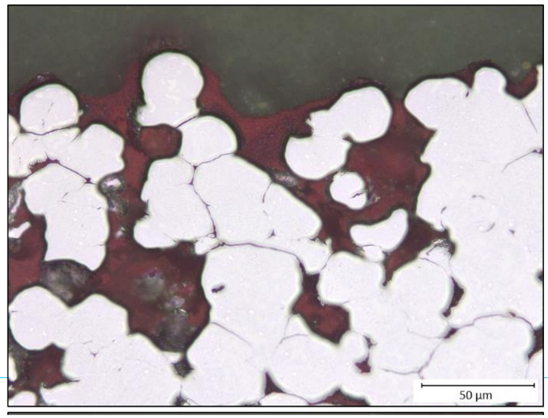
on nanoscale
MD-Simulations:
„Fracture & Fusion“

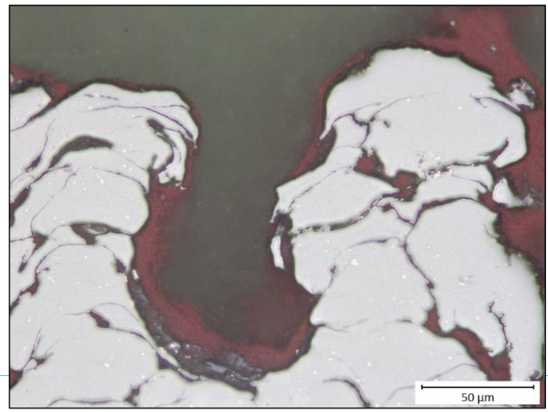


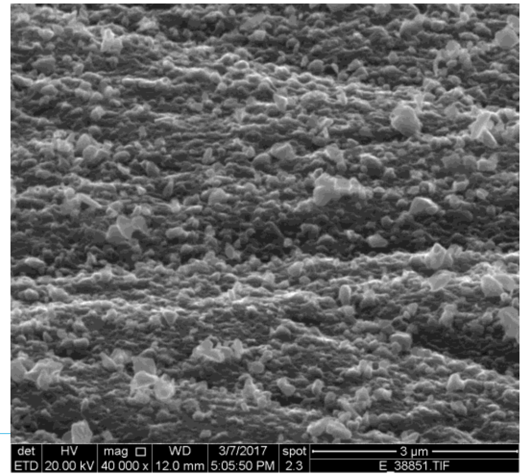
Daneshian, JTST 23 (2013) 541

hierarchically porous structures
with high efficiency









Kinetic spraying: up to 7x gain in efficiency

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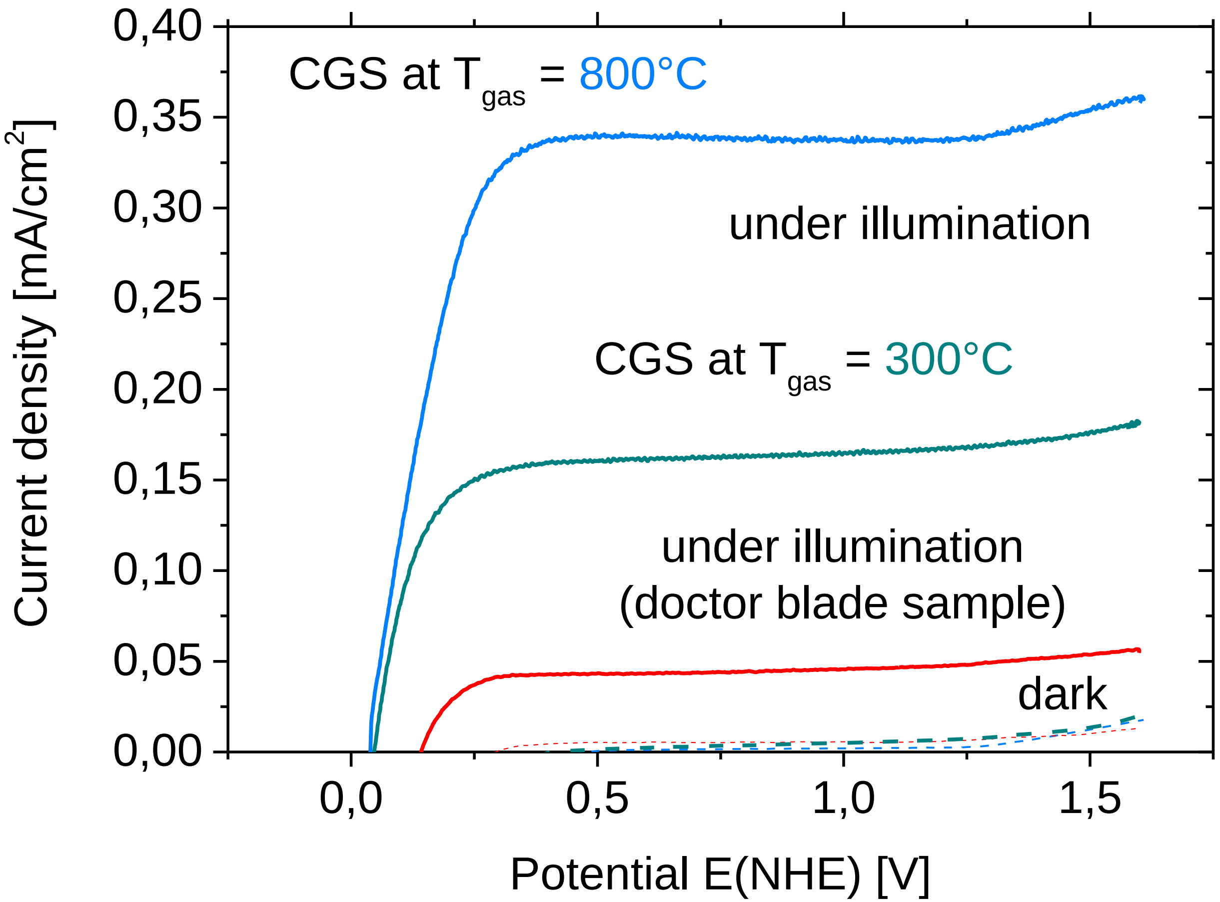


Voltammetry (20 mV s^{-1} in H_2SO_4 0.5 M) under simulated sunlight (AM1.5G) for CGS-TiO_2 electrodes sprayed using N_2 as carrier gas at different temperatures. The results for a knife-cast sample are included for comparison.

- Increasing process gas temperature results in higher photocurrent (better particle-substrate bonding, penetration of native oxide layer).
- Onset of the photocurrent for knife-cast sample shifted to anodic potentials: native oxide layer.

Next Generation: Plasmonic Enhancement

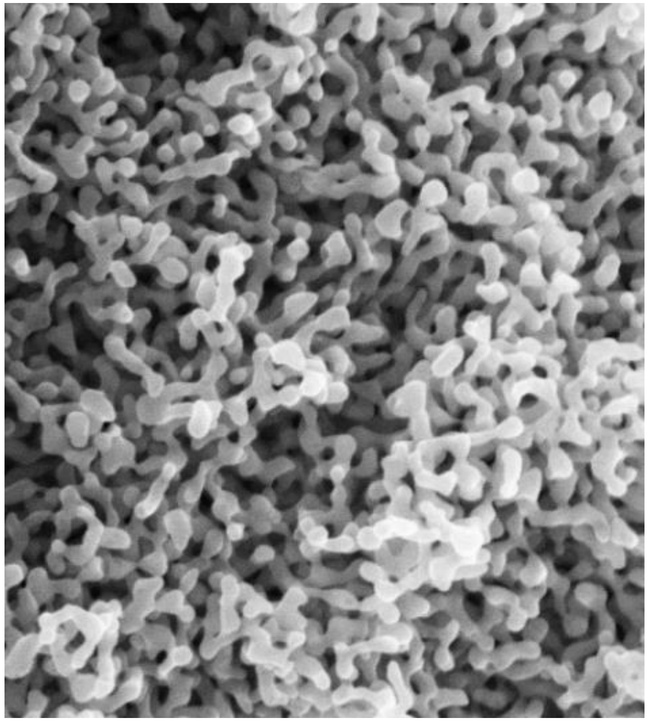
Jalas, Weissmüller, Eich, et al.: „Electrochemical tuning of the optical properties of nano-porous gold“,
NATURE SCIENTIFIC REPORTS 7, 44139; doi: 10.1038/srep44139 (2017)

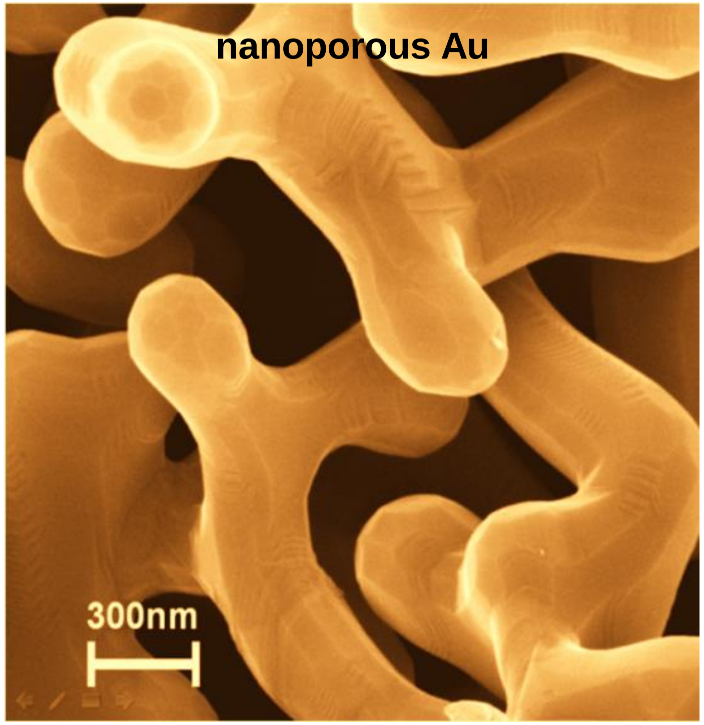
nature.com SCIENTIFIC REPORTS

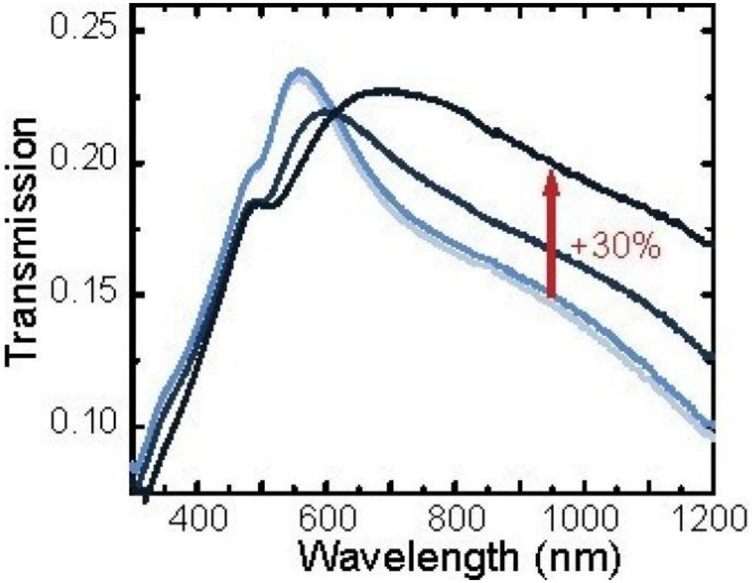
Plasmonic Enhancement of Charge Carrier Separation using Metamaterials:

⇒ Reduction of Recombination Losses

⇒ Potential for Significantly Enhancing Efficiency of Photoelectrochemical Cells







Change in optical transmission of up to 30 percent @ 1 V. (light blue: -0,9 V, blue: -0,5 V, dark blue: 0,5 V, black: 0,9 V) (M. Eich)

Hydrogen Technology Centre (HTC); bis 2017; 3,9 Mio €

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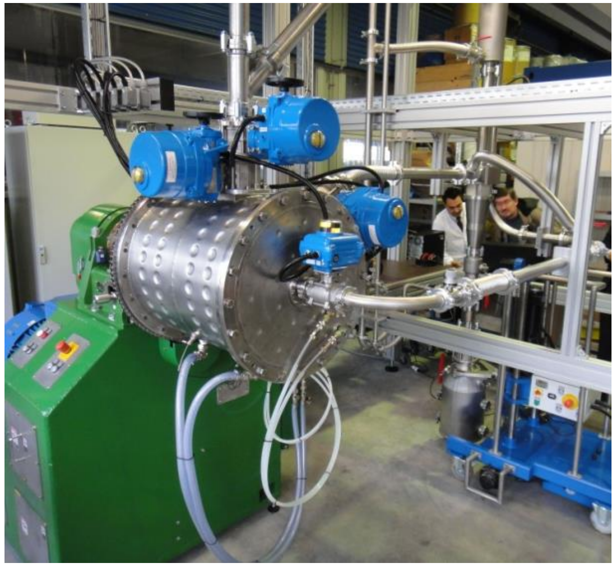
motivation: comprehensive understanding, scale-up and technology demonstration

ready in 2017

commissioned 2015



- investigations on highly reactive surfaces for photoelectrochemical H_2-production
- hydrides in polymer-scaffolds for H_2-storage

scale-up investigations:

- storage materials on 100 kg scale
- photoelectrochemical cells up to 1 m^2

Extension Hydrogen Technology Centre (EHTC); 2020-2025; 3,1 Mio €

motivation E-HTC (2020-2025): system integration and long term stability

research on long-term effects (e.g. corrosion or undesired side reactions) and establishing respective problem solutions

40 Mio one-of-a-kind infrastructure: Helmholtz Energy Materials Foundry (HEMF)

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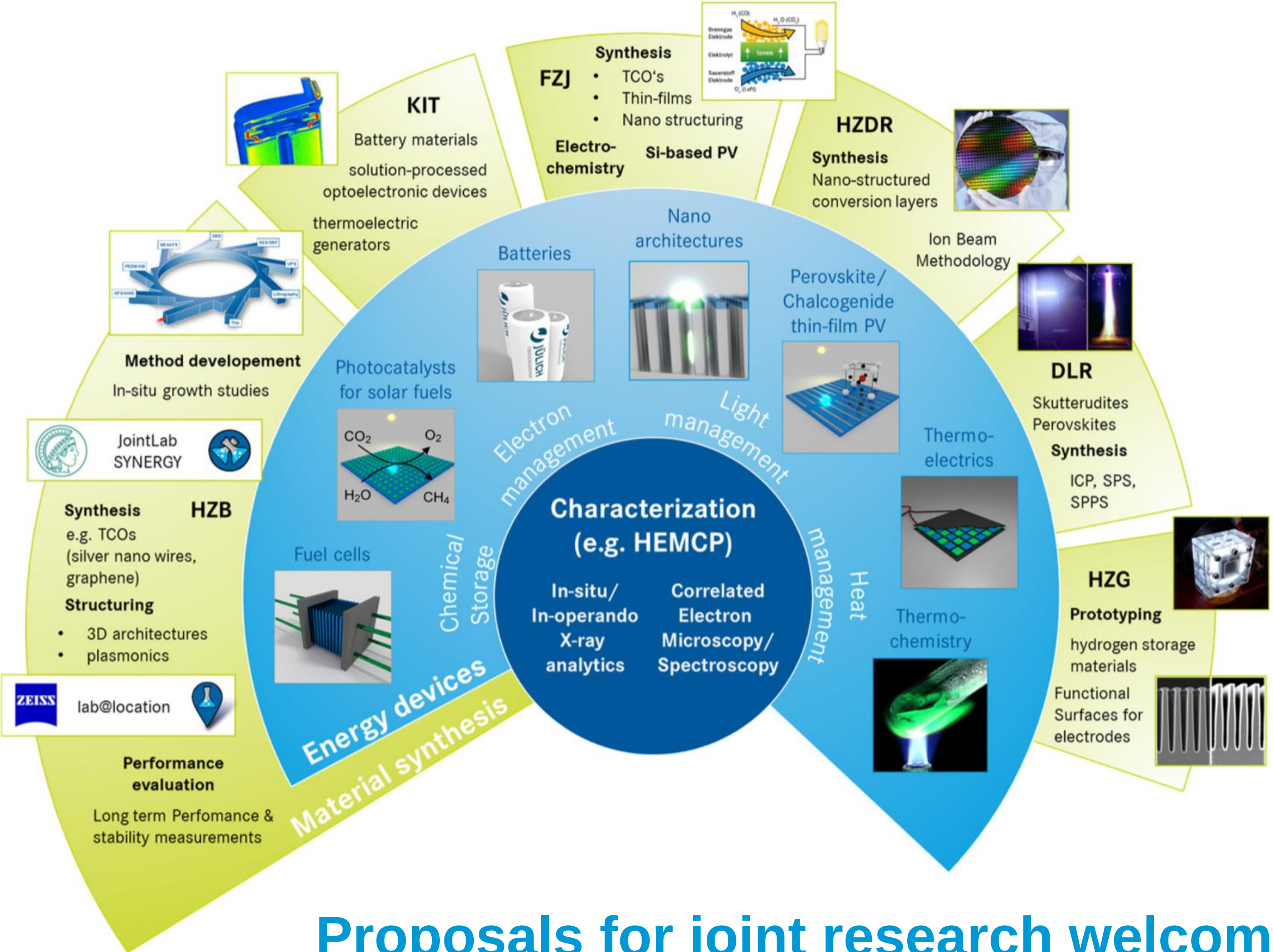

Proposals for joint research welcome!!

Climate Research: EU-Project IMPACT2C

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- About the IMPACT2C web-atlas
- About the IMPACT2C project
- Glossary

Start tutorial

A A A Contact

Menu

Discover the IMPACT2C web-atlas

Search for...

The IMPACT2C web-atlas summarises in maps and texts the impact of global 2°C warming on the following stories:


Climate


Tourism


Energy


Health


Agriculture, Forest and Ecosystems

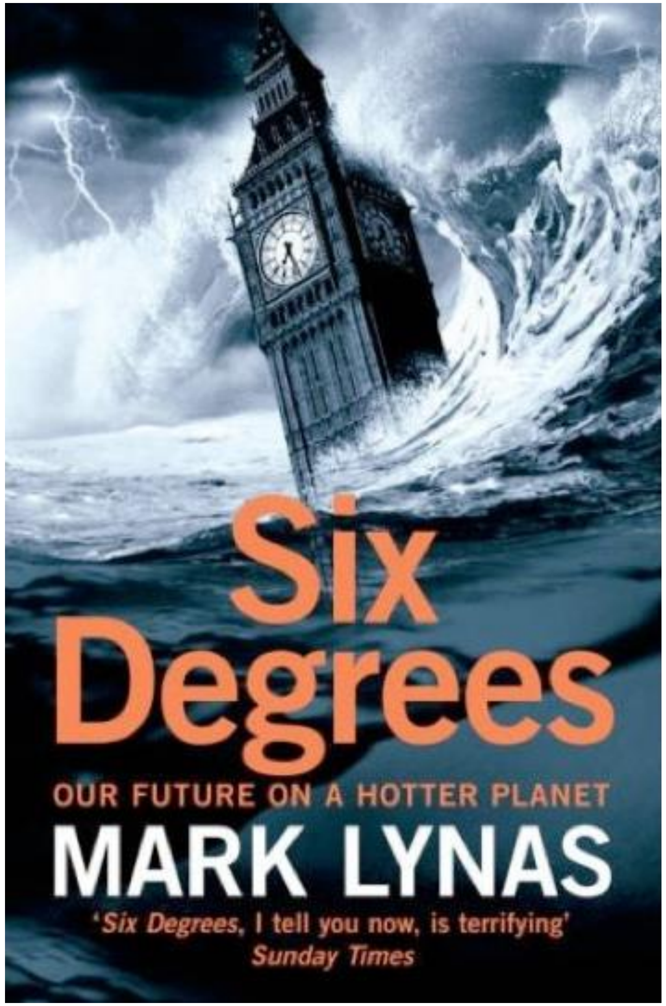

Water


Coastal Themes


Non-European Hotspots

Climate Change: Carbon Footprint

- the average carbon footprint of a West-European is ≈12 tonnes per year
- global average is ≈4 tonnes per year
- 0.33 to/year necessary in 2055 to stabilize climate!
- 2016 was 3rd year in a row to break temperature record:
  + 1.1 K already reached as compared to pre-industrial time
- a tipping point may soon be reached:
  CO_2 emissions have to peak by 2025
- yes, we can:
  deploying technologies for climate stabilization
  would only cost ≈1% of our income!
  [Prof. Hermann Held, UniHH, lead author IPCC-Report]



https://www.youtube.com/watch?v=R_pb1G2wIoA

Demonstration Projects

FORTIS SAXONIA

2552 km with equivalent

of 1 liter gasoline (= 6000 mpg)

H_2 in metal hydride, PEM fuel cell

9th (of 255) in Shell Eco Challenge 2009

50 kg, 600 W, v_{max}= 43 km/h, 269 km/kWh

EcoBee

Urban Concept Car

H_2 in metal hydride, PEM fuel cell

232 kg, 1 kW, v_{max} = 50 km/h, 30 km/kWh