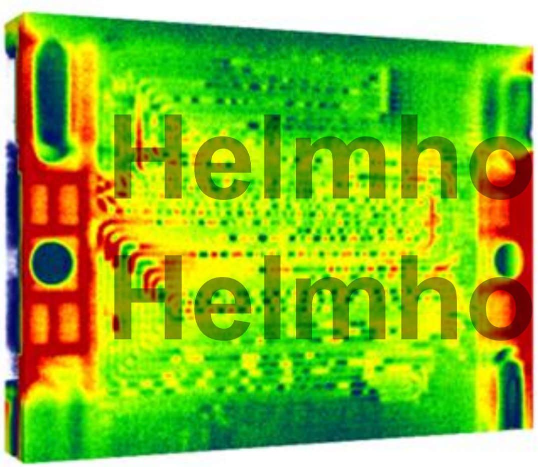
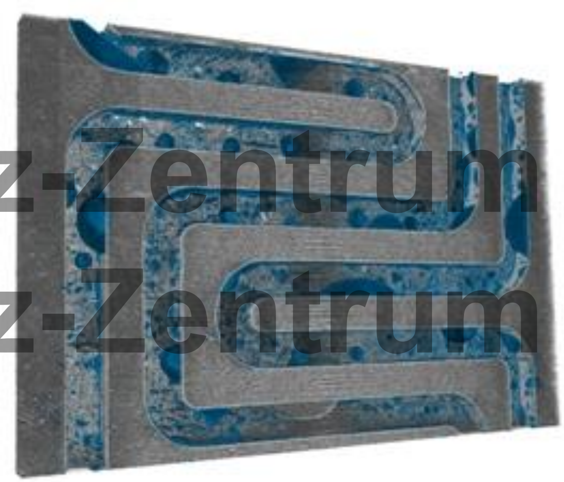
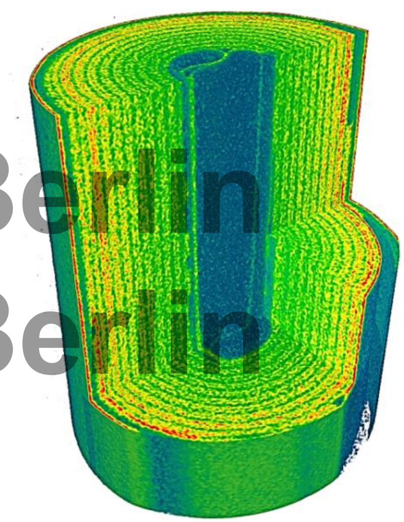
Zerstörungsfreie Untersuchung von Brennstoffzellen und Batterien mit bildgebenden Röntgen- und Neutronen-Verfahren

Ingo Manke
Helmholtz-Zentrum Berlin für Materialien und Energie

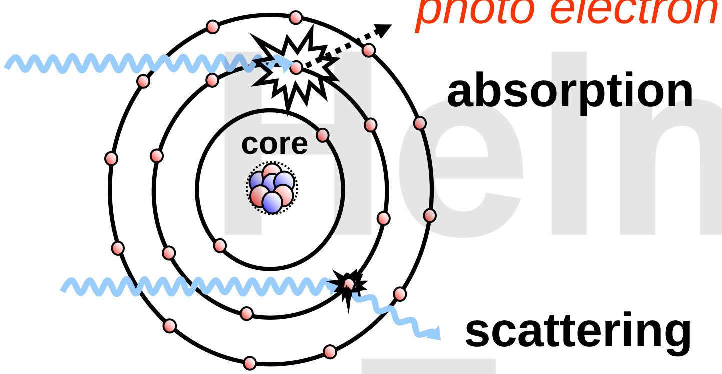




Helmholtz-Zentrum Berlin

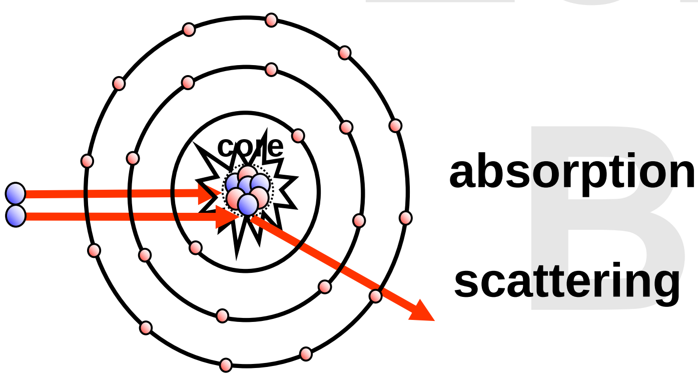
ÜBERSICHT

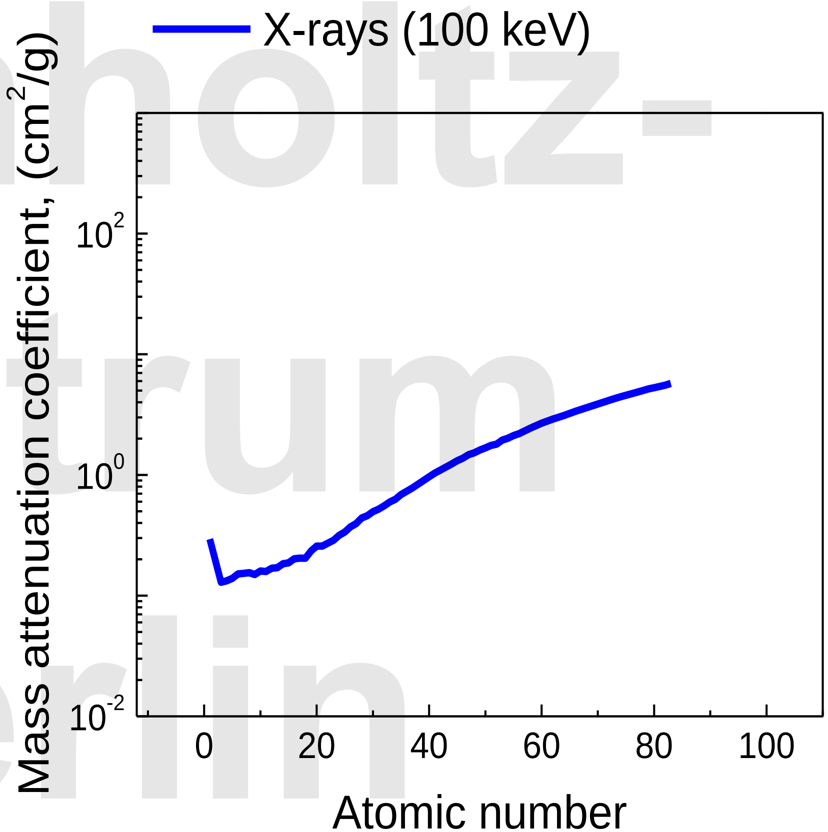
- Prinzip der Tomographie
- Eigenschaften von Neutronen
  und (Synchrotron-)Röntgenstrahlung
- Anwendungsbeispiele
    - Brennstoffzellen
    - Batterien

X-rays



neutrons



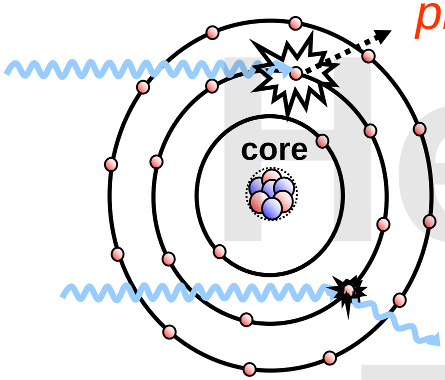


J. Banhart, A. Borbély, M. Dzieciol, I. Manke, N. Kardjilov, A. R. Kaysser-Pyzalla, et al.
International Journal of Materials Research 2010, 9, 1069-1079 (2010)

(Synchrotron-)Röntgen-Strahlung und Neutronen

X-rays

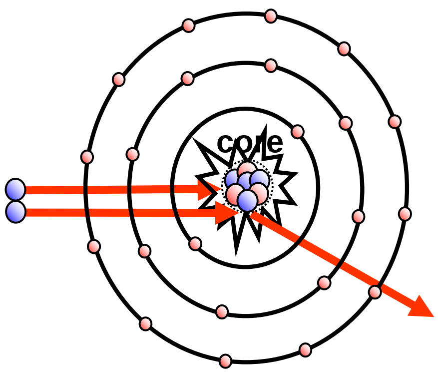
photo electron



absorption

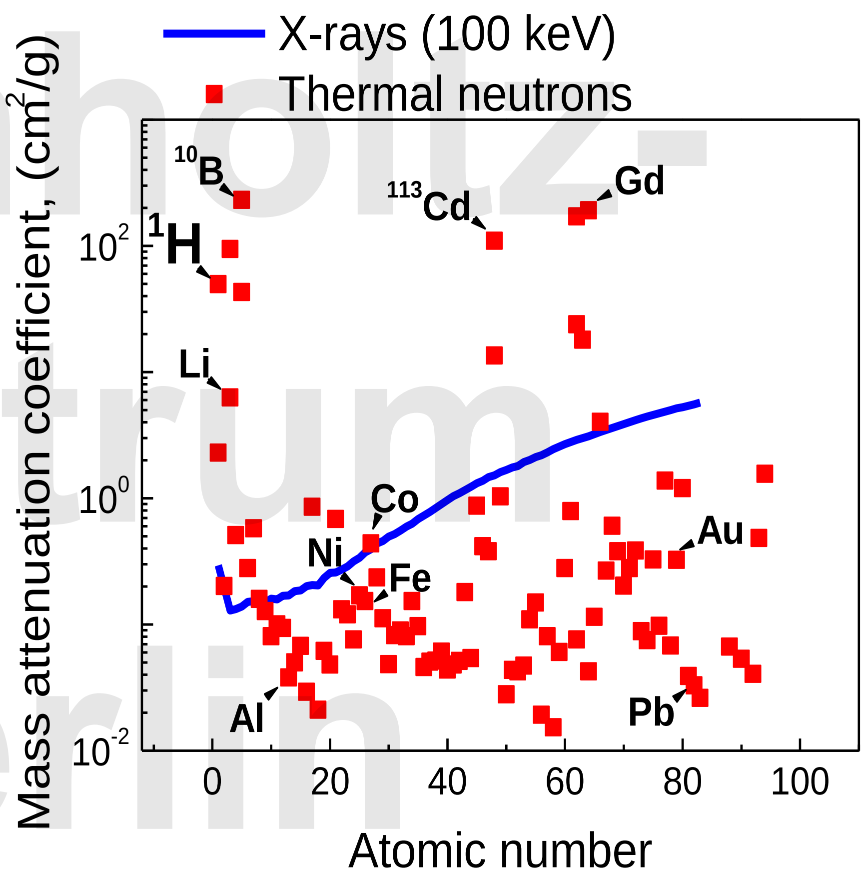
scattering

neutrons

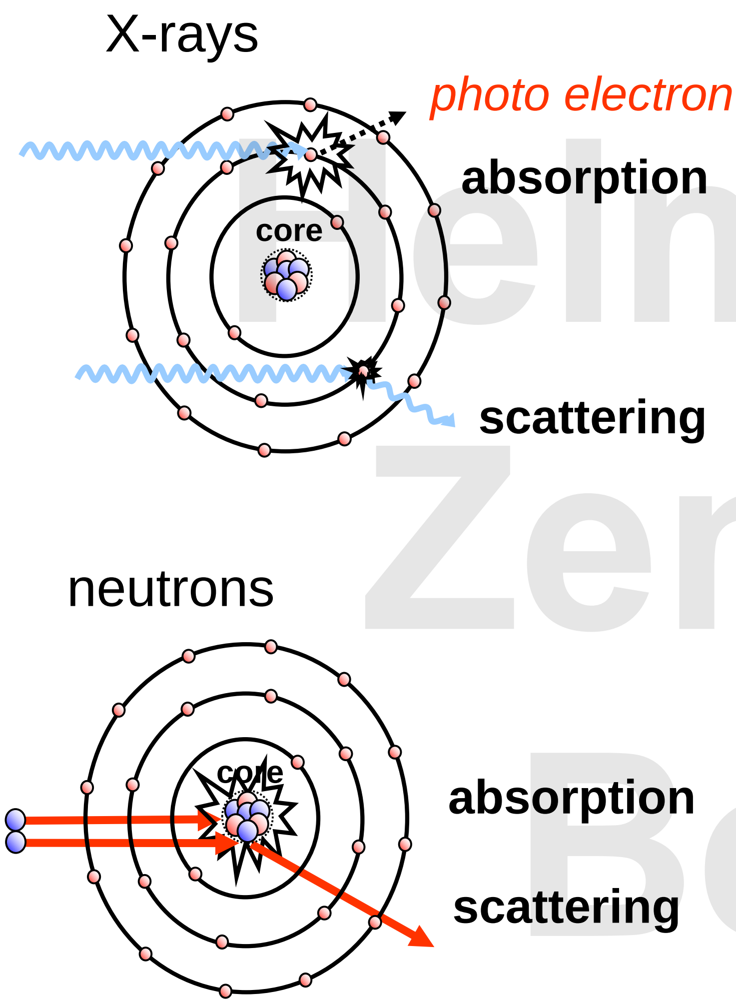


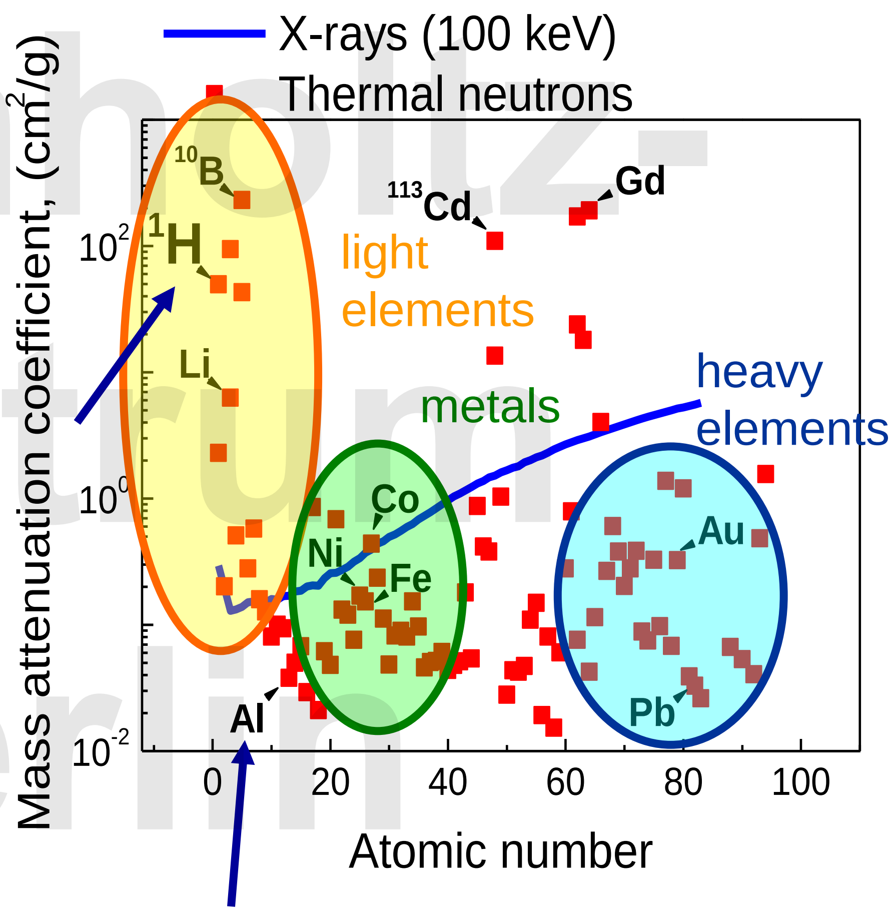
absorption

scattering



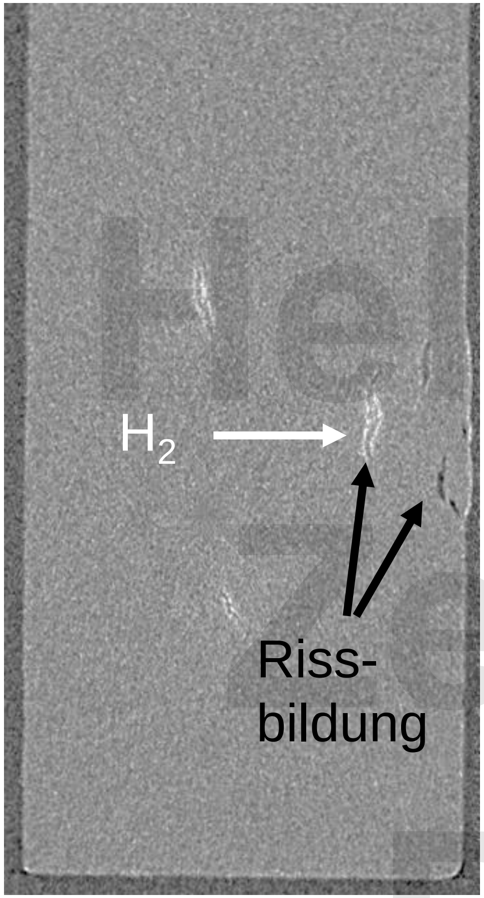
J. Banhart, A. Borbély, M. Dzieciol, I. Manke, N. Kardjilov, A. R. Kaysser-Pyzalla, et al.
International Journal of Materials Research 2010, 9, 1069-1079 (2010)





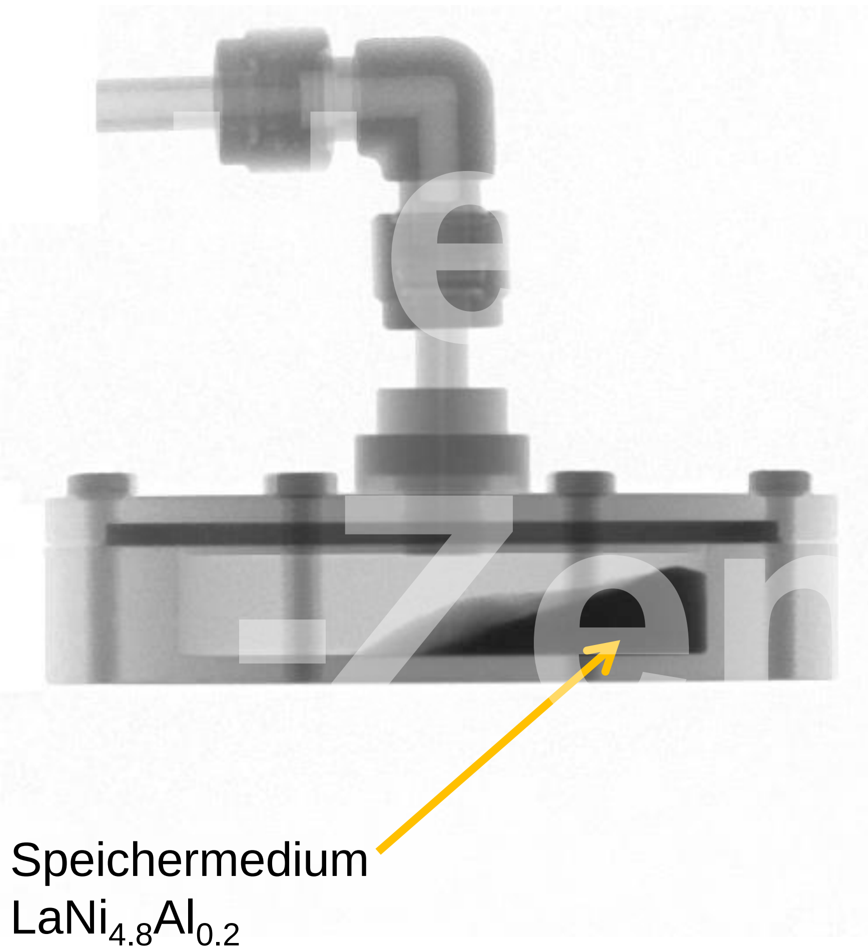
J. Banhart, A. Borbély, M. Dzieciol, I. Manke, N. Kardjilov, A. R. Kaysser-Pyzalla, et al.
International Journal of Materials Research 2010, 9, 1069-1079 (2010)

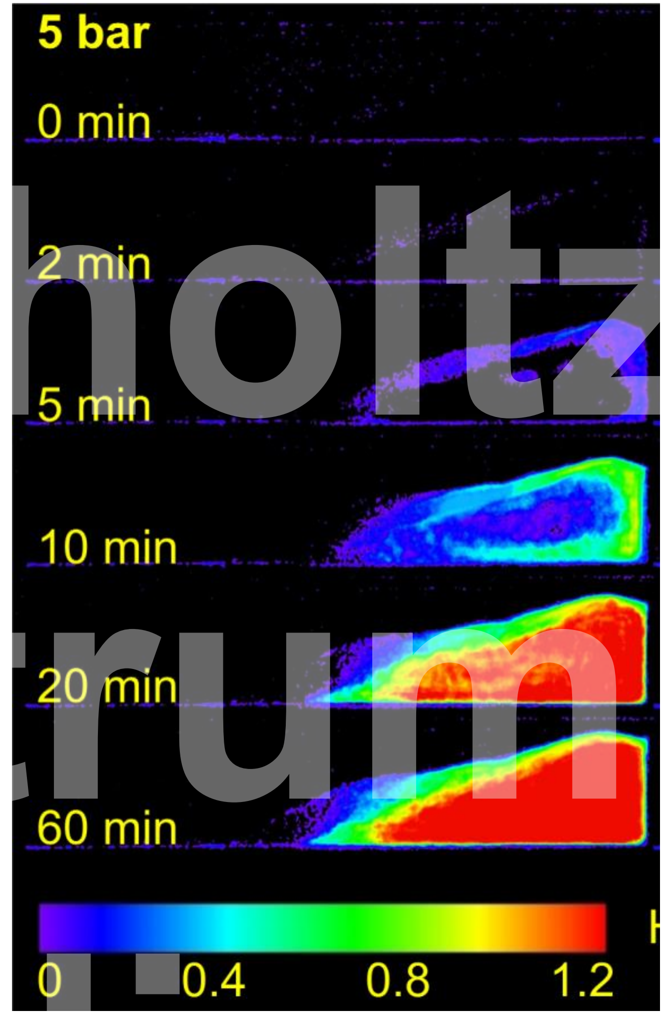
Wasserstoffverteilung im Stahl



Rot = Wasserstoff

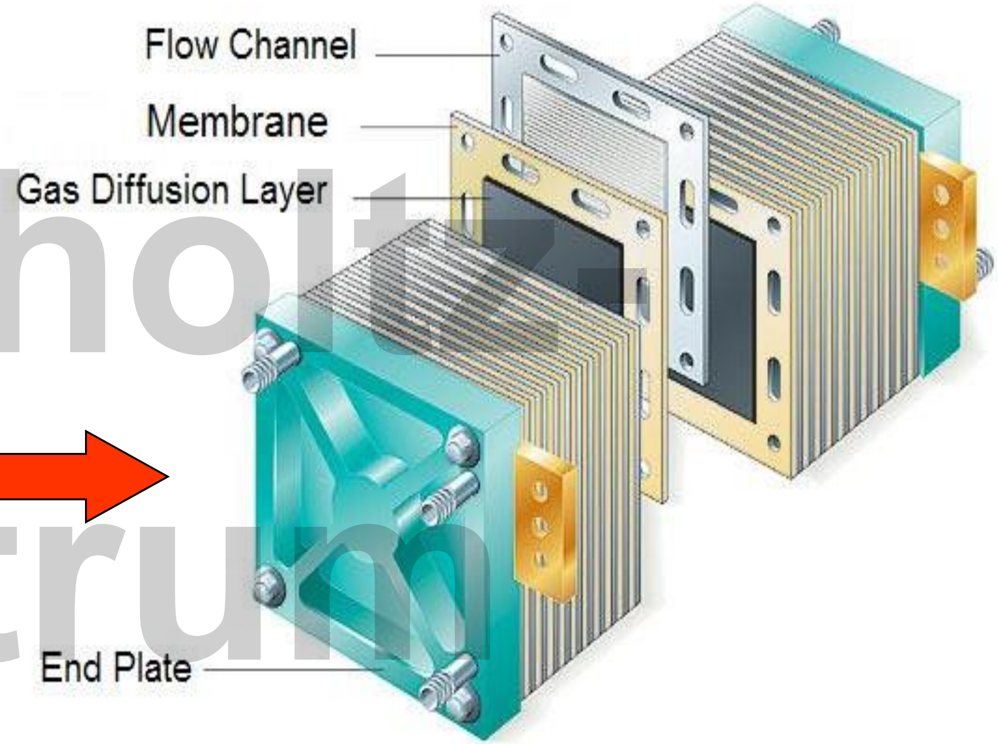
A. Griesche, E. Dabah, Th. Kannengießer, N. Kardjilov, A. Hilger, I. Manke
3D-imaging of hydrogen blister in steel with neutron tomography
Acta Materialia, 78, p. 14-22 (2014)





L. Gondek et al.
International Journal of Hydrogen Energy, 36, 16, 9751-9757 (2011)

Polymer-Elektrolyt-Membran Brennstoffzelle (PEM-BZ)

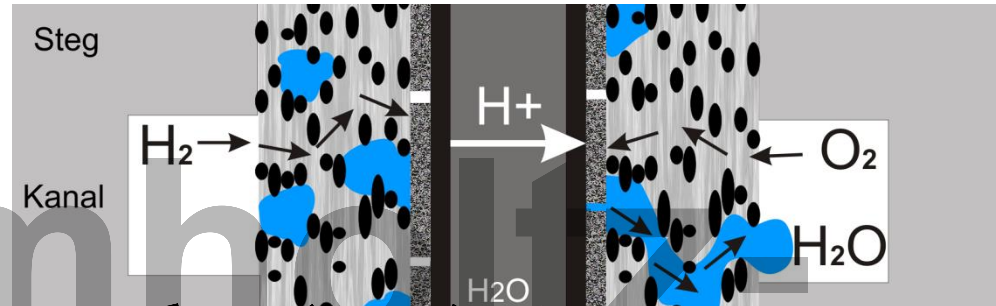


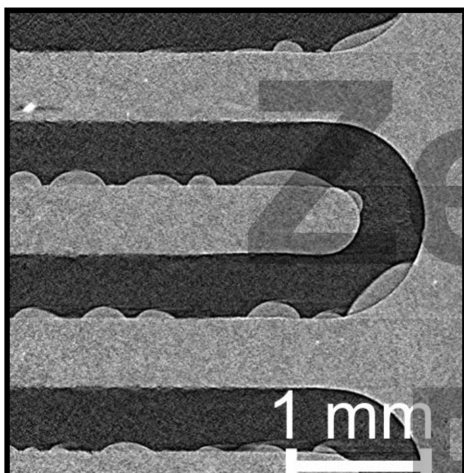
Brennstoffzellen-Stack

Anwendung z. B. im Automobilsektor

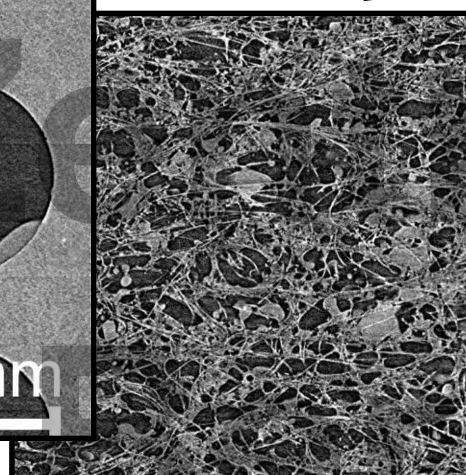
Wasser-Management

Polymer-Elektrolyt-Membran Brennstoffzelle (PEM-BZ)

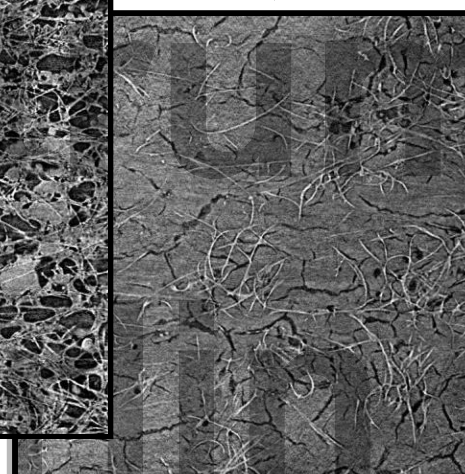




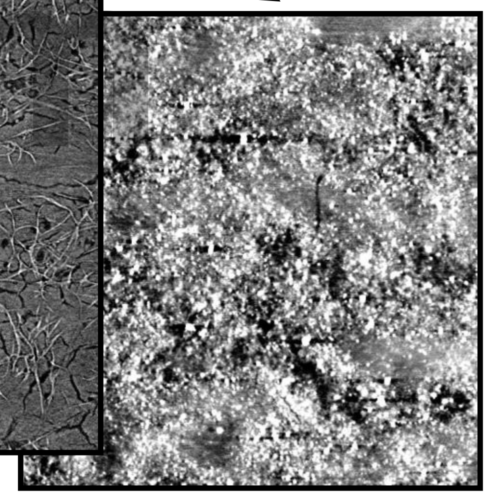
Strömungsfeld



GDL
Gas Diffusionslage



MPL
Mikro poröse Lage



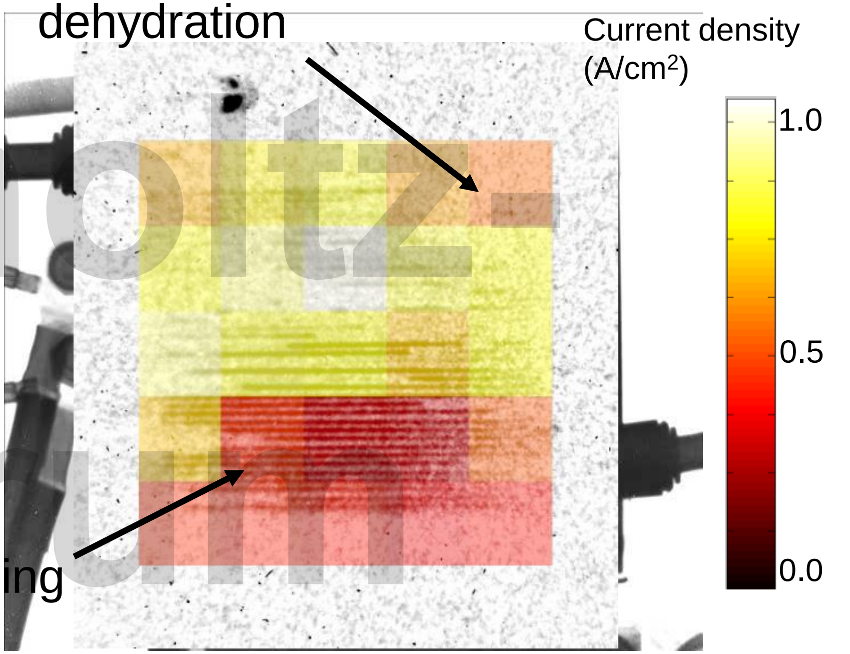
Elektrode

Gas-Diffusions-Medium

Neutronen-Radiographie

PEM Fuel Cell (ZSW)	Neutron radiography (fast motion)

14 cm



Simultanoues current density measurement

C. Hartnig, I. Manke, N. Kardjilov et al
Journal of Power Sources **176**, 452-459 (2008)

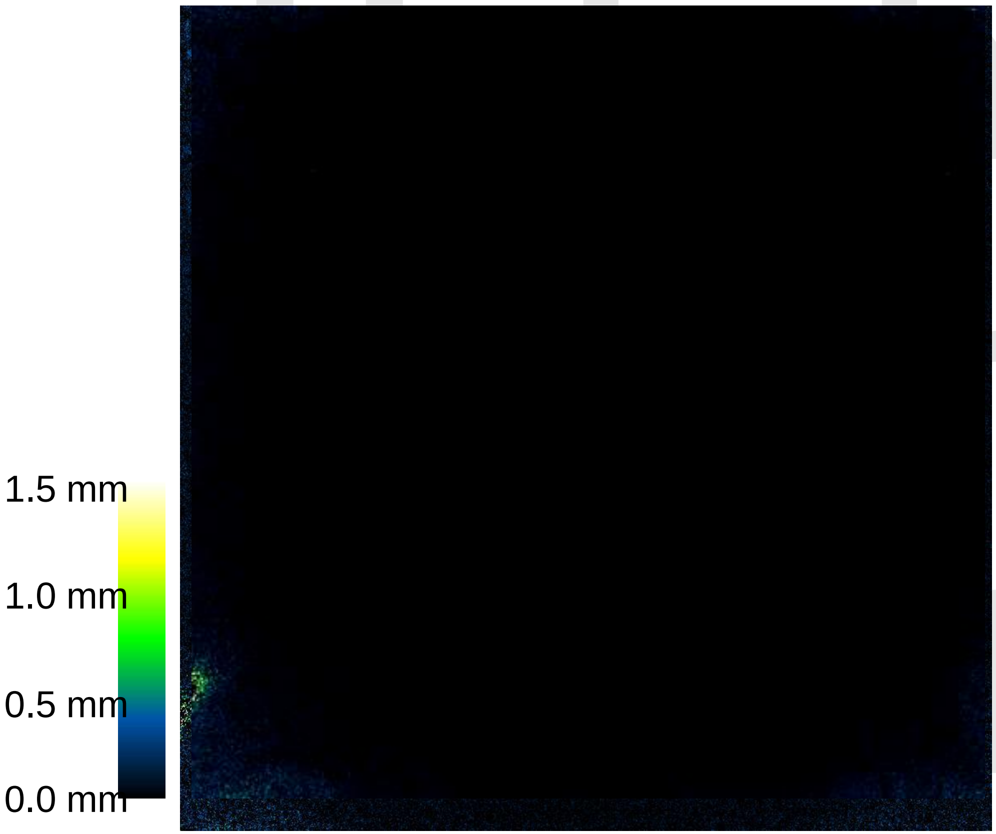
Einfluß der Hydrophobizität

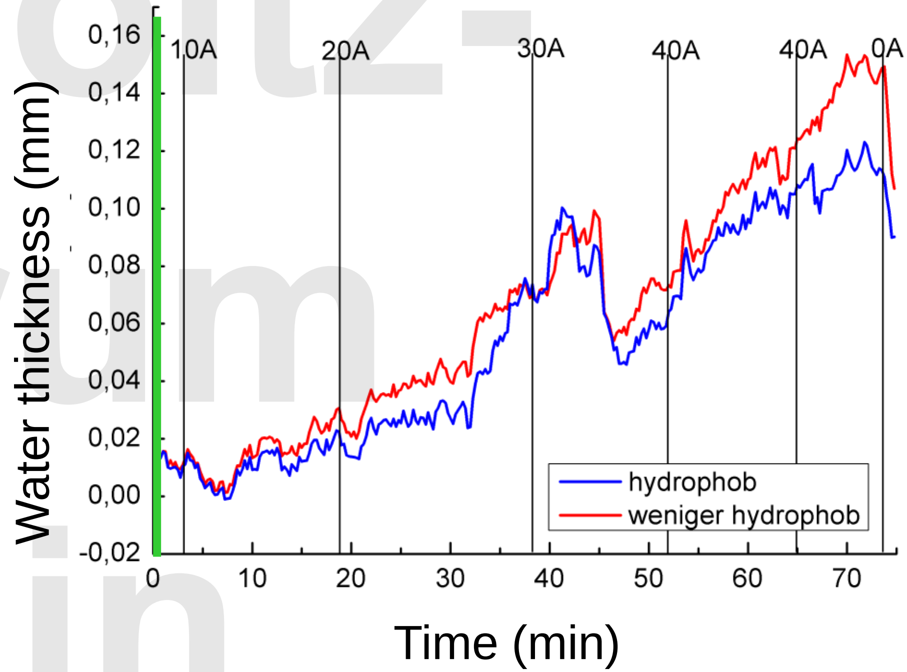
weniger hydrophob

hydrophob

GDL Hydrophobizität

hoch niedrig

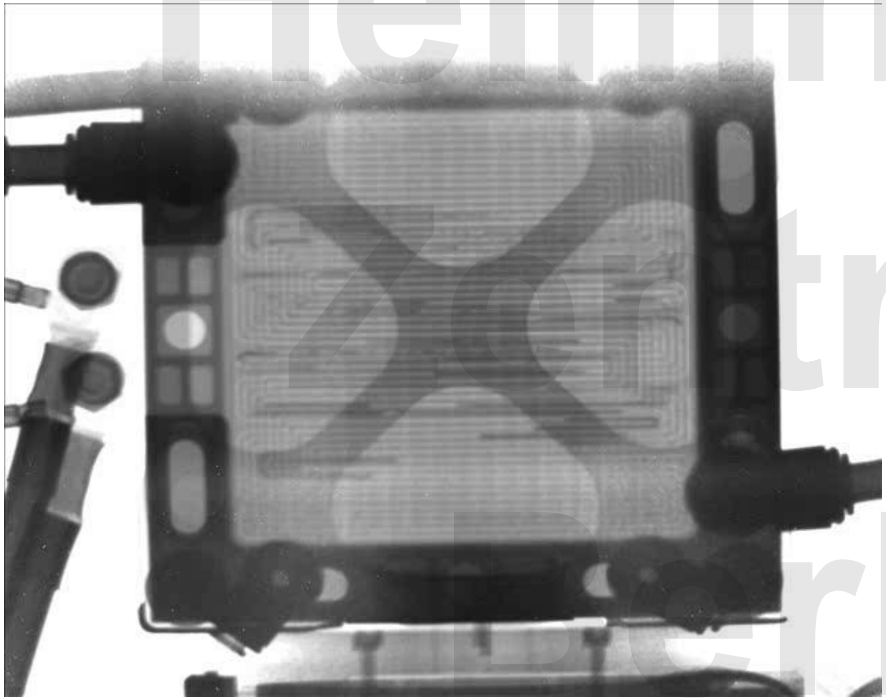




Neutronen-Tomographie

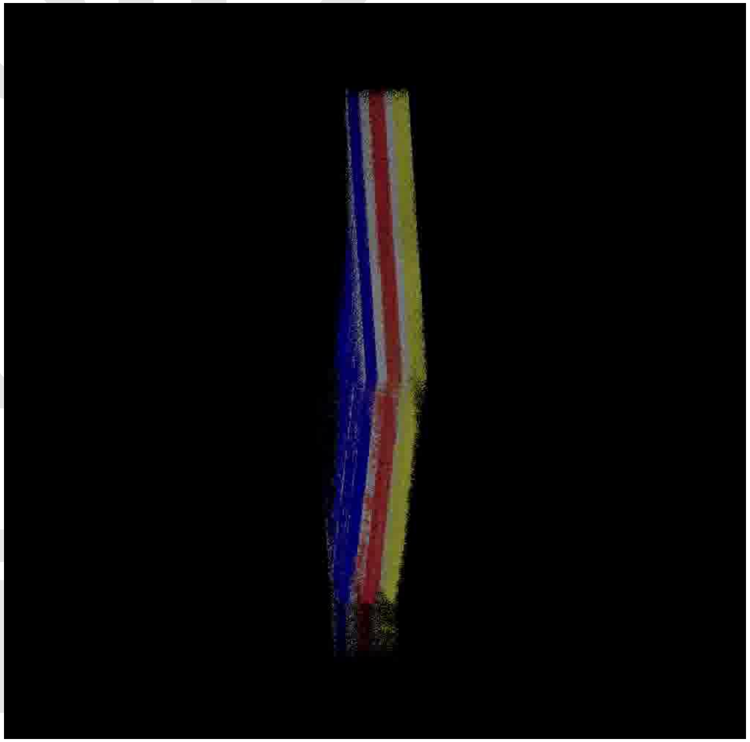
Einzelzellen

2D



Brennstoffzellen-Stacks

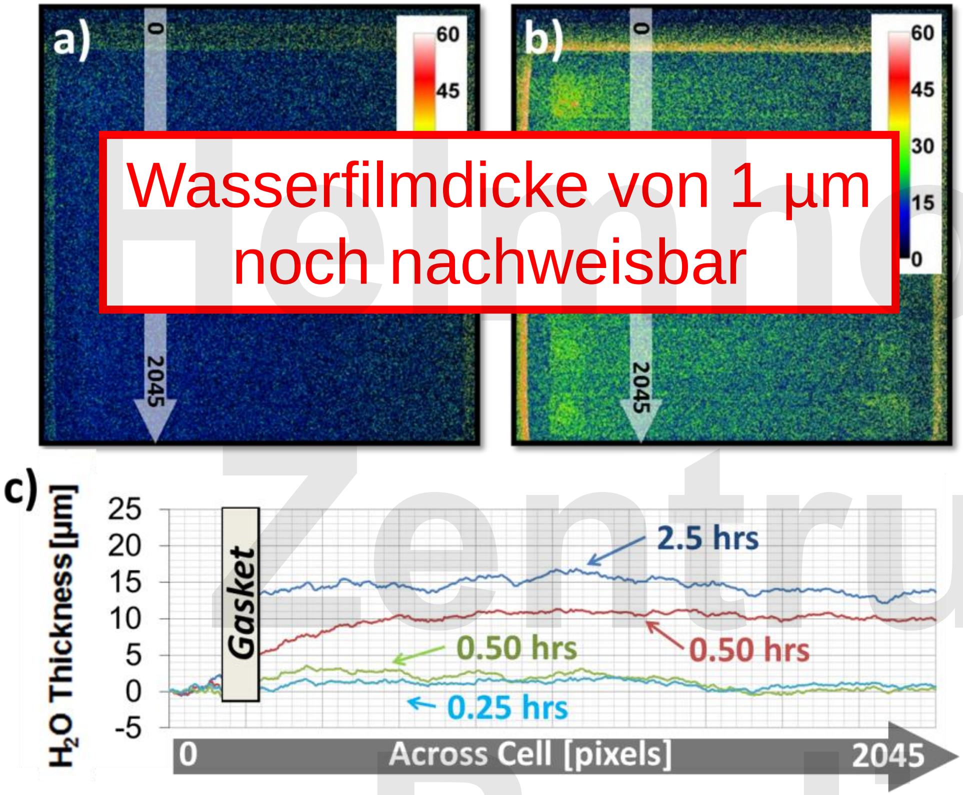
3D



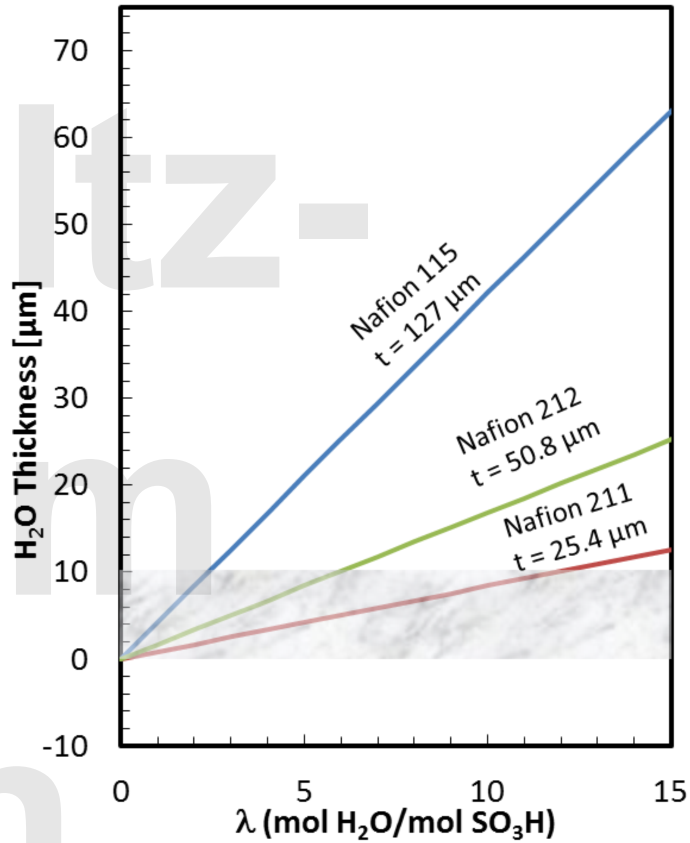
I. Manke et al. , Applied Physics Letters 90, 184101 (2007)

Quantifizierungsgenauigkeit für Wasser

Membran: trocken befeuchtet



Wasserfilmdicke von 1 µm noch nachweisbar

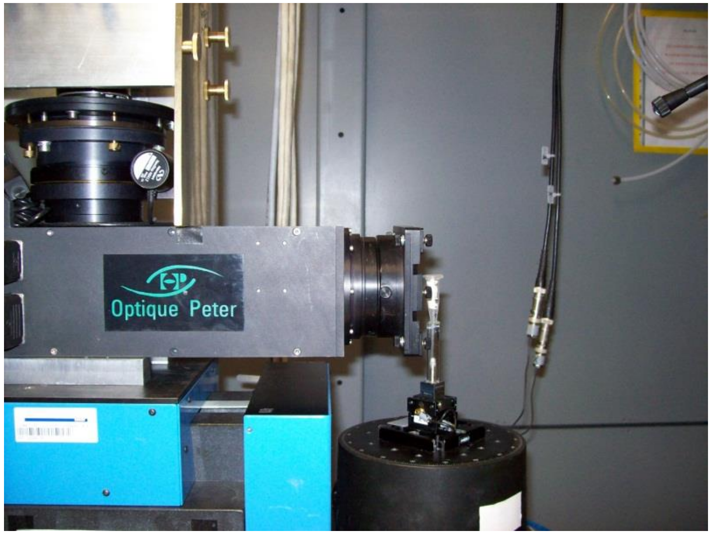


J.R. Bunn, D. Penumadu et al.
Detection of water with high sensitivity to study PEM fuel cell membranes using cold neutrons at high spatial resolution
Applied Physics Letters, to be submitted (2013)

Synchrotron-Röntgen-Tomographie

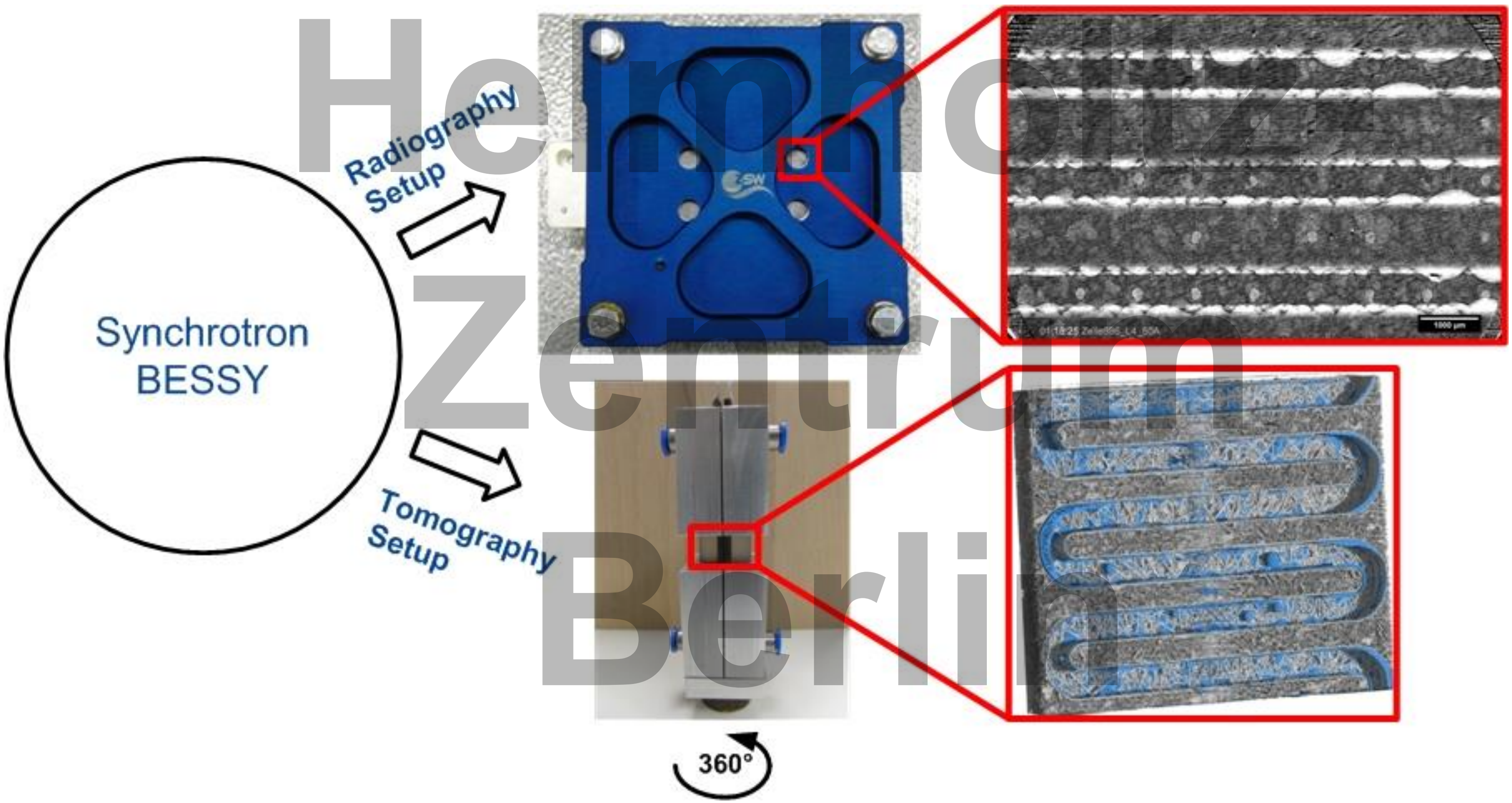
BESSY

- Hohe Strahlintensitäten
- Monochromatische Strahlung
- Hohe Kohärenz



- Hohe Abbildungsgenauigkeit/Bildqualität
- Exzellente Quantifizierungsgenauigkeit
- Elementselektivität

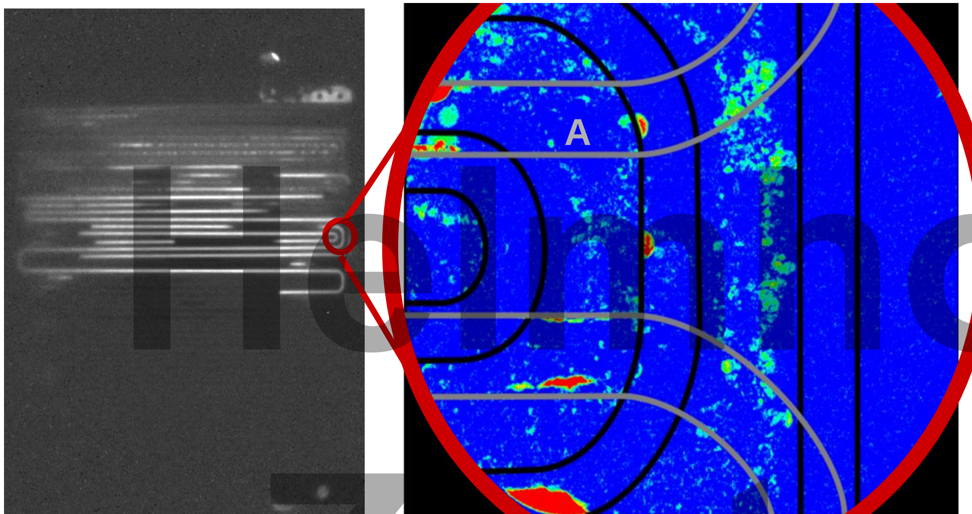
Synchrotron-Röntgen-Radiographie und -Tomographie

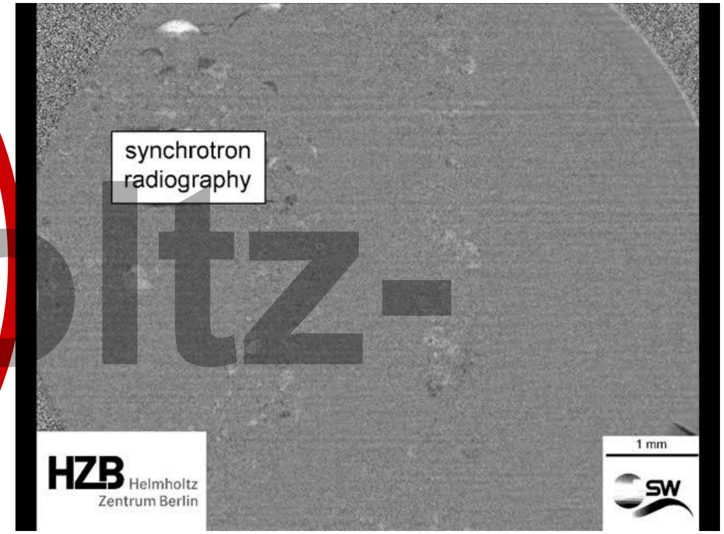


Synchrotron-Röntgen-Radiographie

neutron radiography

In-situ synchrotron radiography

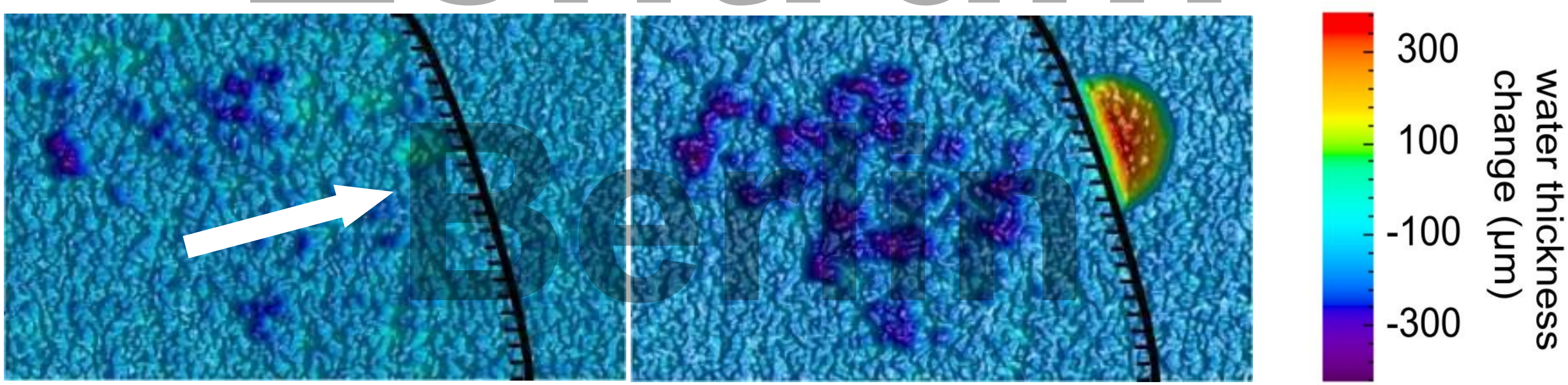




← 120 mm → ← 7 mm →

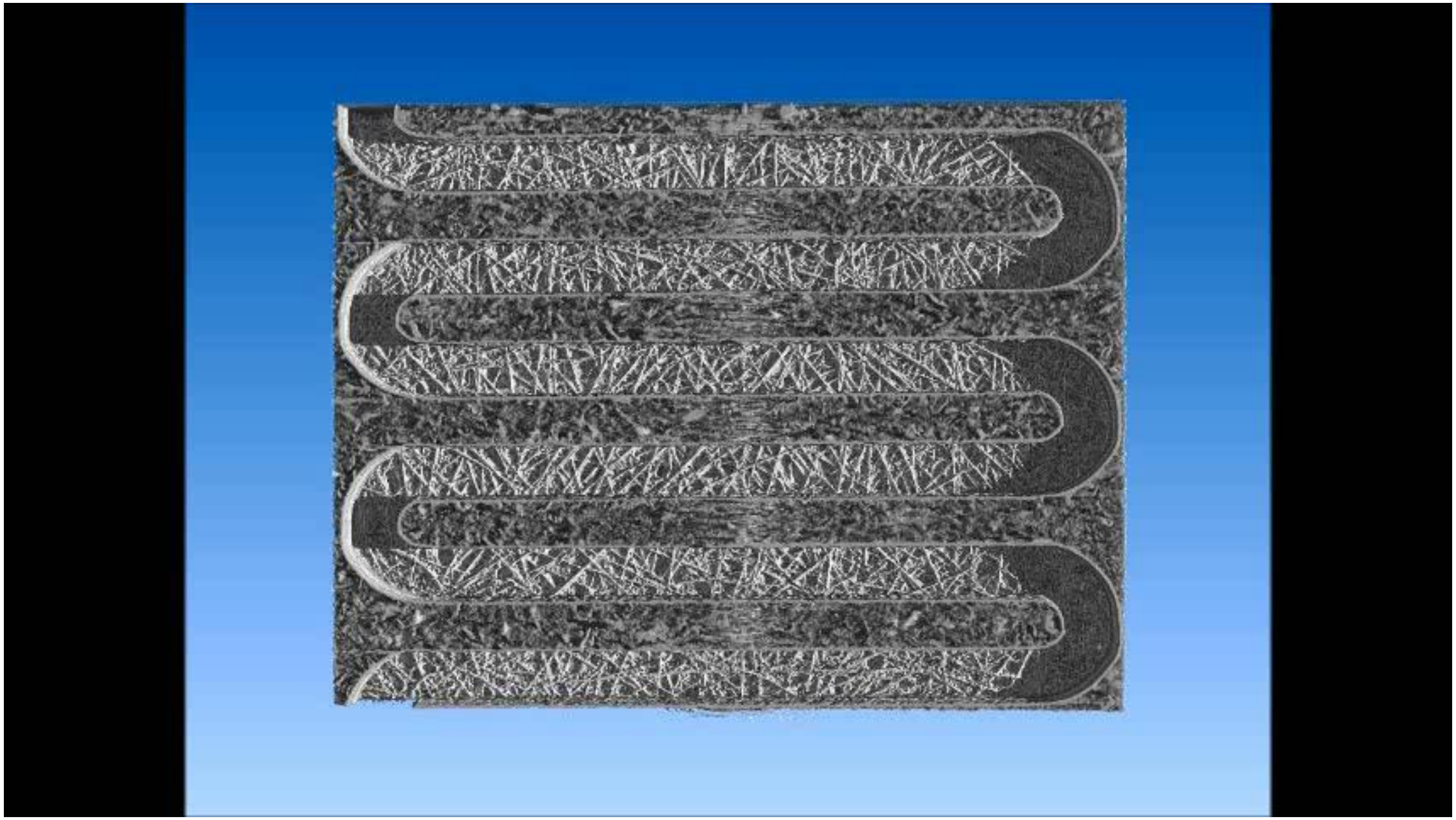
150 times fast motion

Water droplet dynamics



I. Manke et al., **APL** 90, 174105 (2007), Ch. Hartnig et al., **APL** 92, 134106 (2008)
Ch. Hartnig et al., **J. Power Sources** 188 (2009), I. Manke et al., **APL** 92, 244101 (2008)

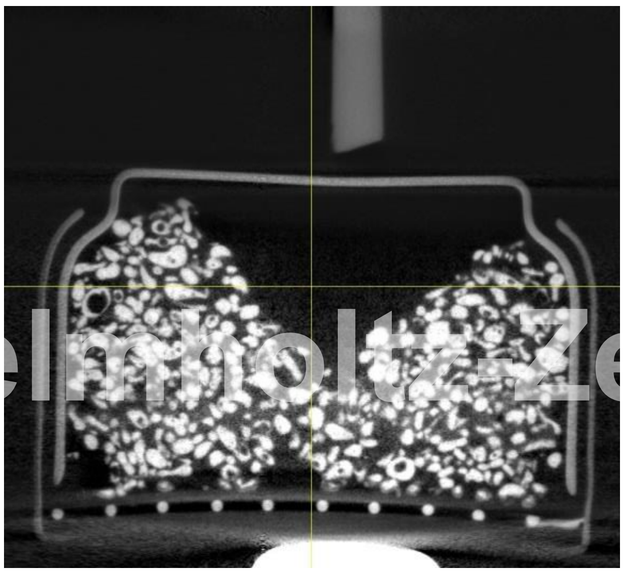
Synchrotron-Röntgen-Tomographie



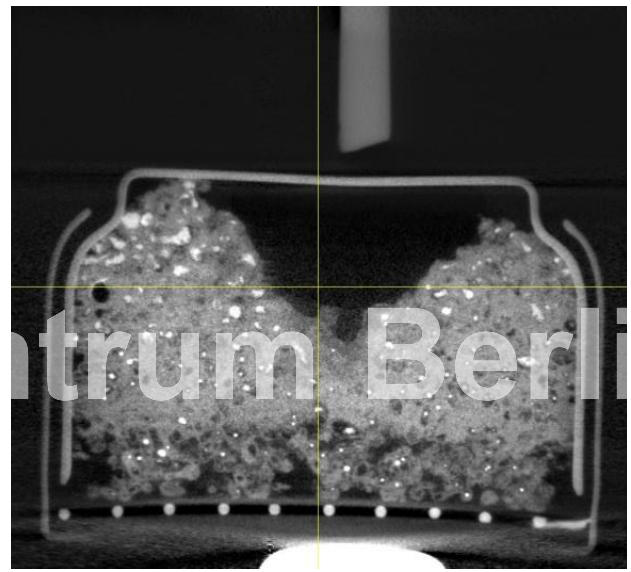
Quantifizierung der Wassermengen
mittels Differenz-Tomographie

Wiederaufladbare Zink-Luft-Batterien

Voll geladen



Entladen



Zerstörungsfreie Prüfung

Neuwertig

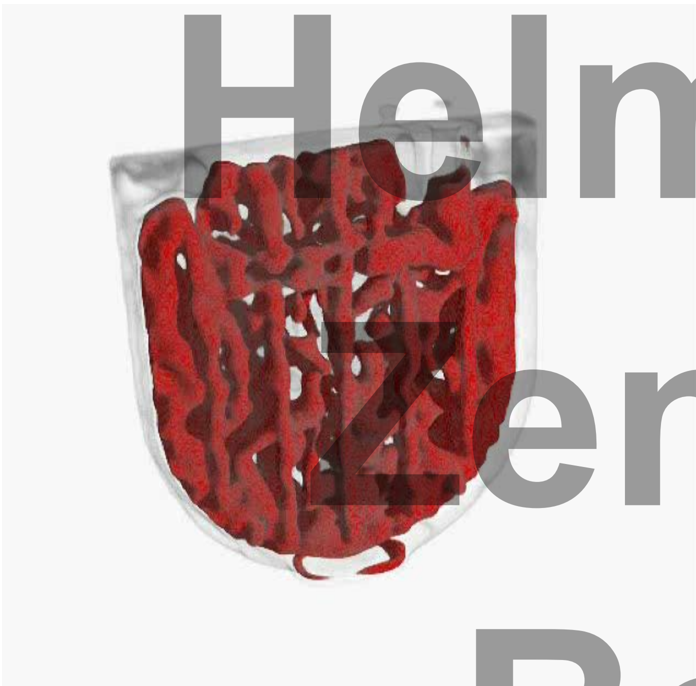
Überladen

Lithium-Verteilung in Batterien

HZB Helmholtz Zentrum Berlin

Neutronen-Tomographie

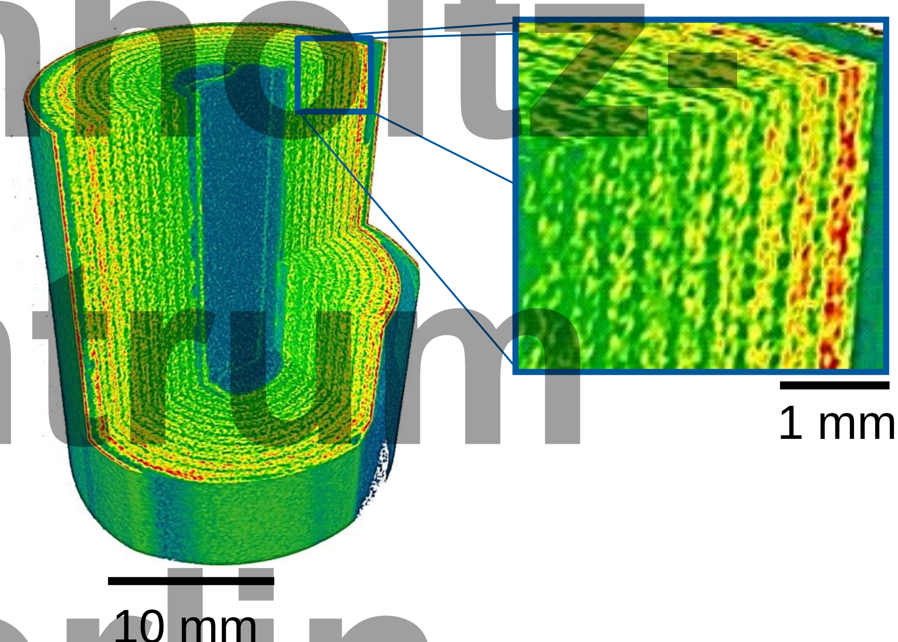
LiJ-Batterie



Lithium

$LiCoO_2$-Batterie

Lithium/Elektrolyt



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TU berlin

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