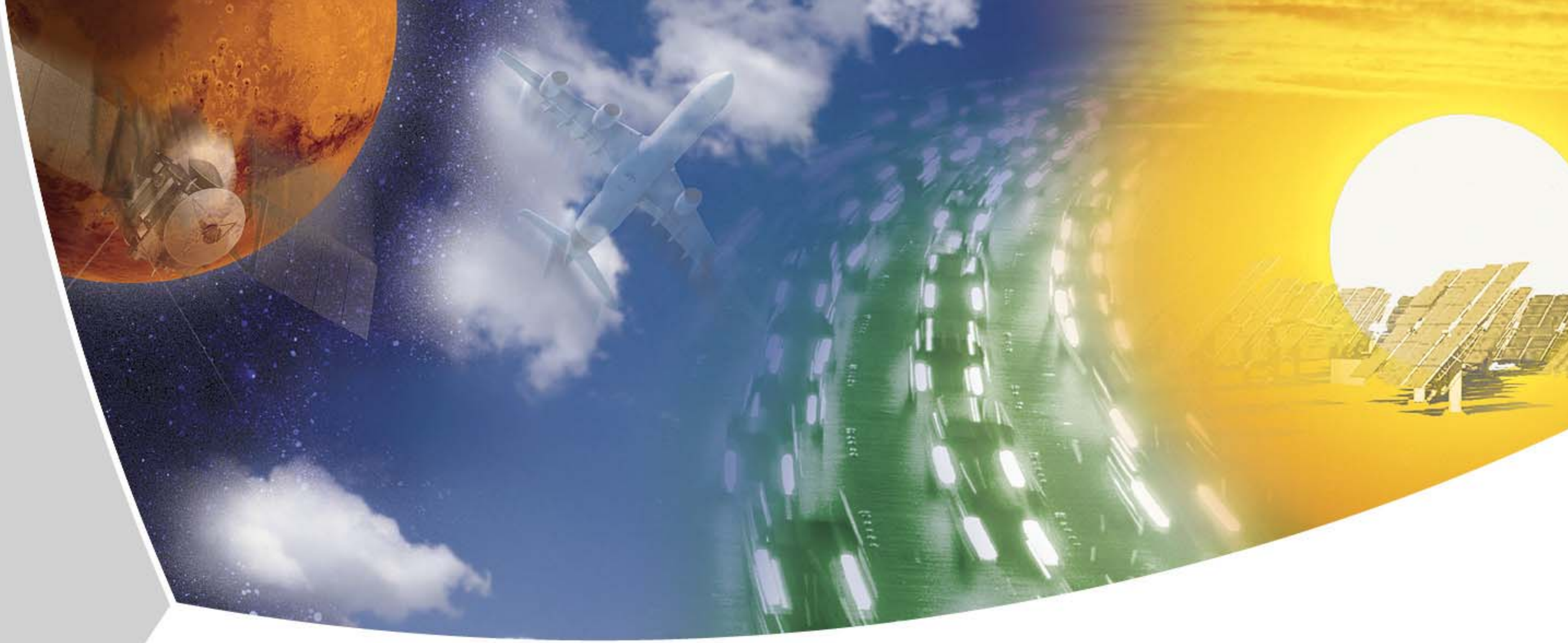


Aktuelle Trends internationaler Brennstoffzellenforschung

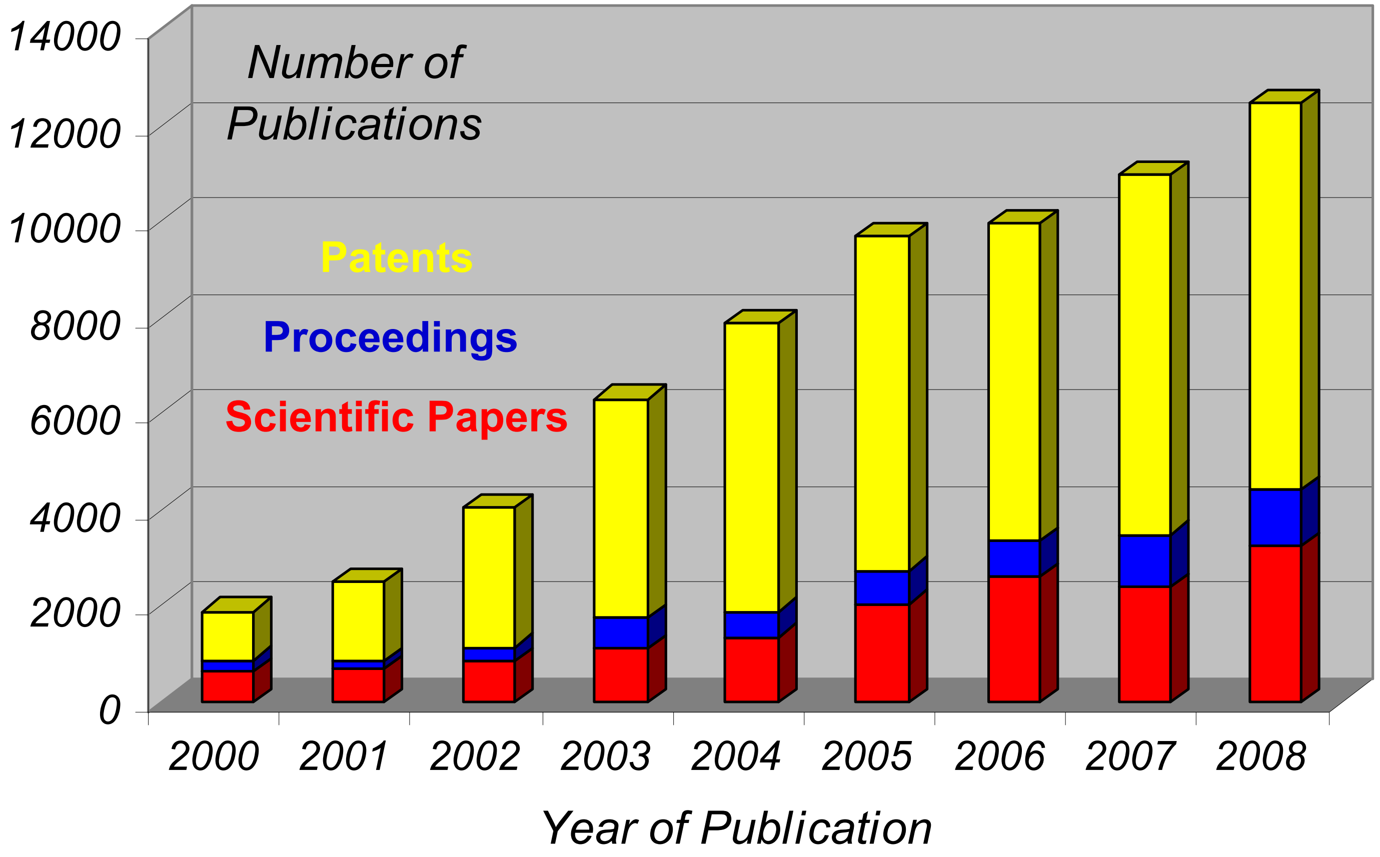
Werner Schnurnberger, K.A. Friedrich
Deutsches Zentrum für Luft- und Raumfahrt e.V.
Institut für technische Thermodynamik Stuttgart

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

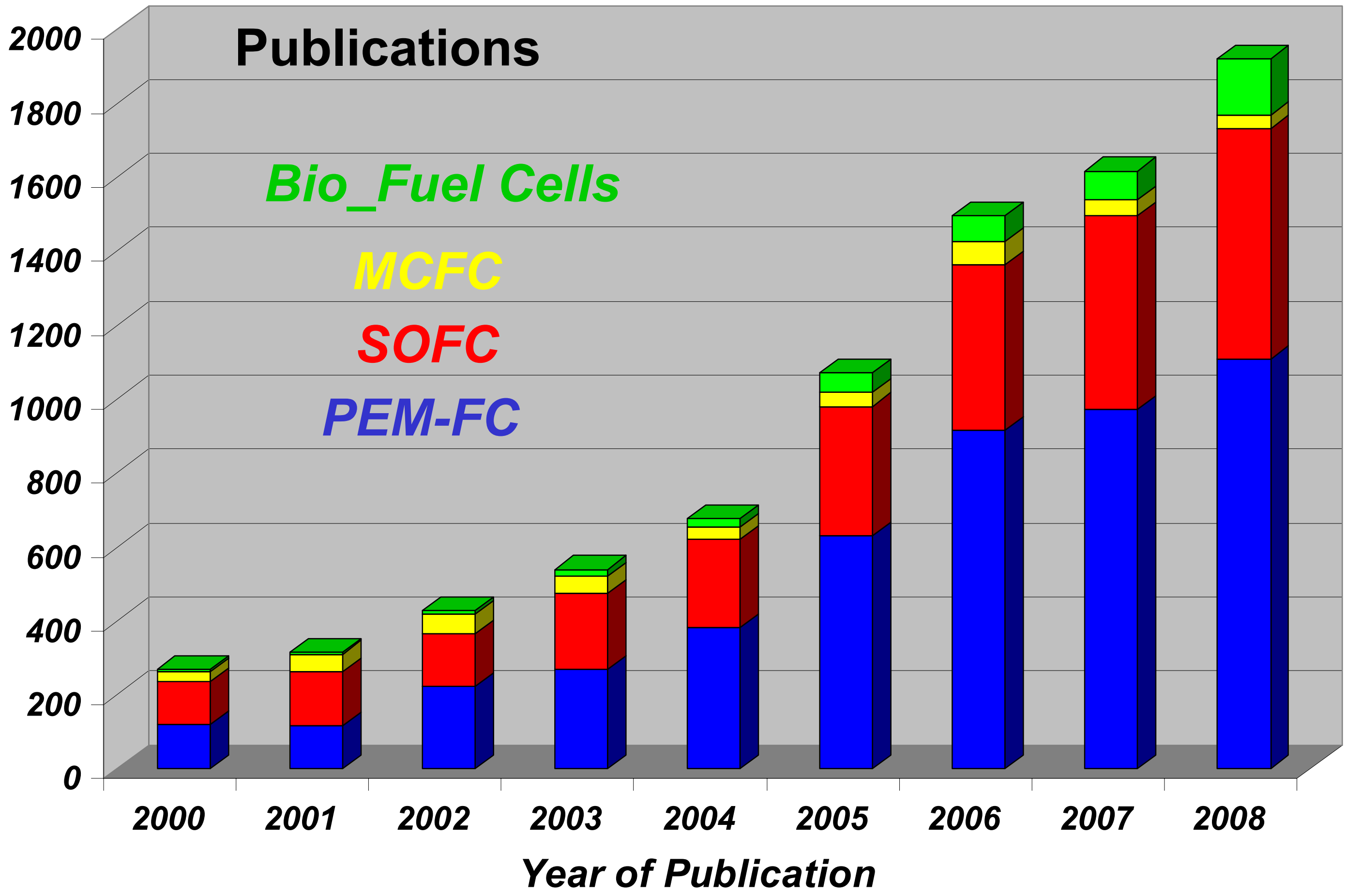
Überblick

- Die Dynamik der Brennstoffzellen Forschung
- Zur Architektur von Brennstoffzellen
  - Nanotechnologien
  - Modelling und Simulation
- Elektrokatalyse
- Wege zu unkonventionellen Brennstoffzellen:
  - Biofuel-Cell oder Bio-FuelCell
  - Direct Carbon Fuel Cell

Fuel Cells: Growth Rate of Publications

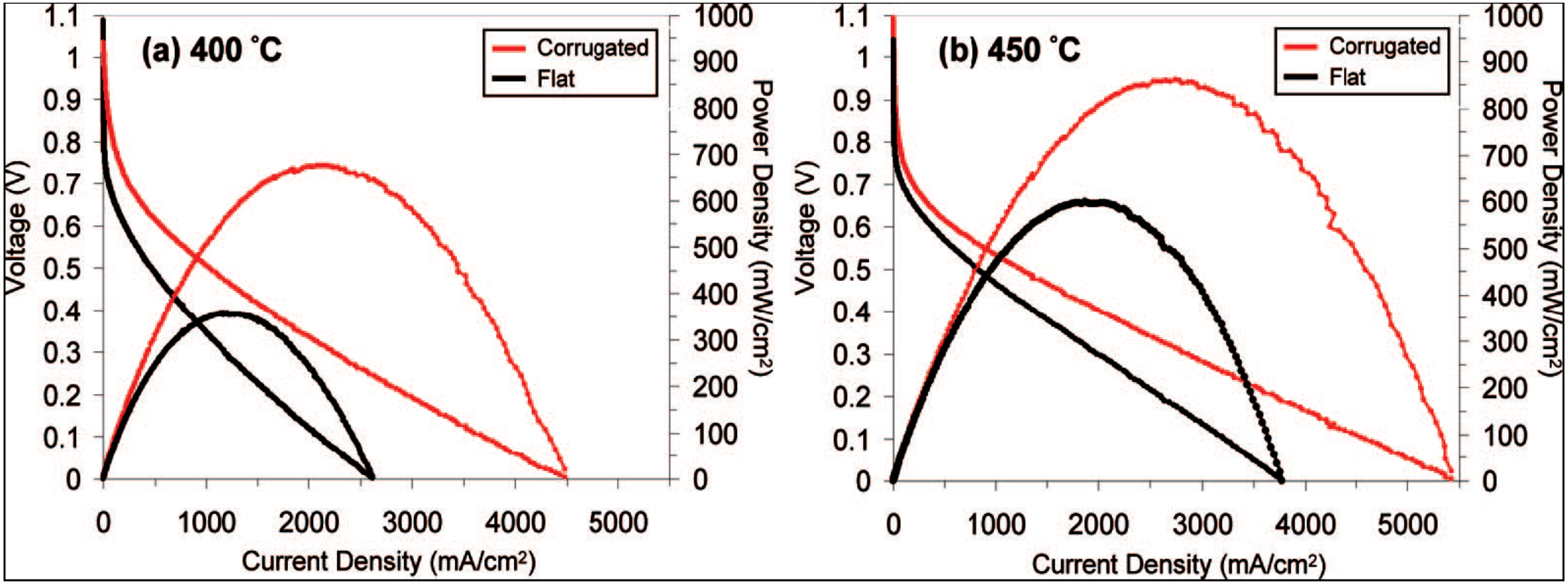


Fuel Cells Scientific Publications



Architecture of Fuels Cells I:

Low temperature micro SOFC cell with corrugated electrolyte membrane

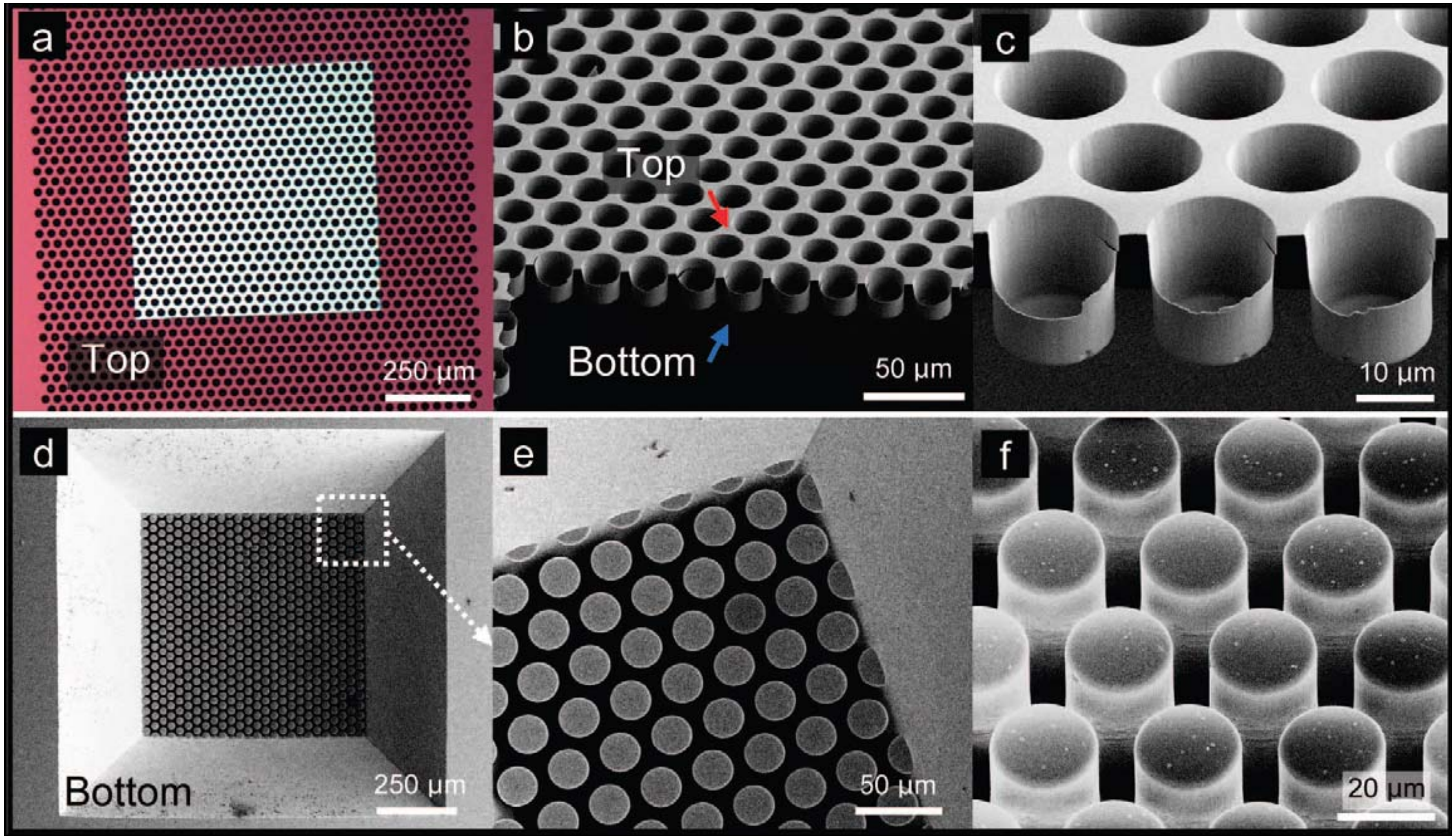


Fuel cell performance of corrugated (red line) and flat (black line) YSZ electrolyte at (a) 400 °C and (b) 450 °C. The membrane size is 0.0036 cm2 (600 *μ*m × 600 *μ*m). The size of the cups embedded is 15 *μ*m in diameter and 20 *μ*m in depth. Maximum power densities of corrugated YSZ are slightly less than two times that of flat ones.

Prinz et al. 2008 Stanford

Architecture of Fuels Cells I:

Low temperature micro SOFC cell with corrugated electrolyte membrane

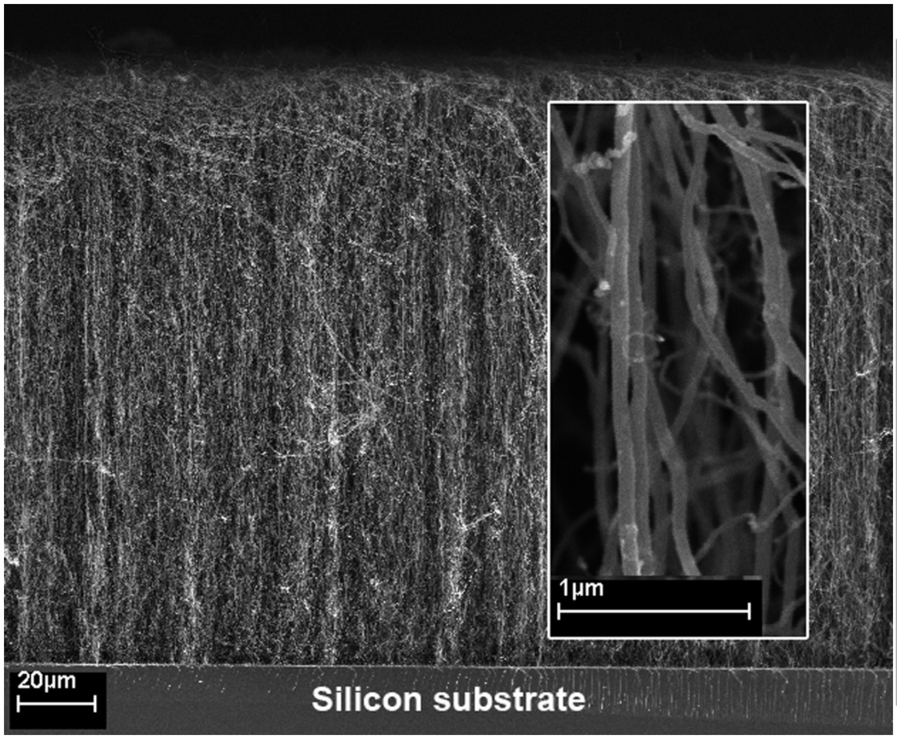


Images of corrugated YSZ membrane, view from top (a-c) and bottom (d-f). (a) Optical microscopy image of free-standing corrugated YSZ membrane. The white square in the middle is the free-standing YSZ membrane released after KOH etching. The black dots represent cup-shaped trenches. (b,c) Cross section of cups in corrugated membrane. (d) Bottom view of membrane after silicon removal. (e) Bottom corner view of membrane, (f) perspective after tilting 40°.

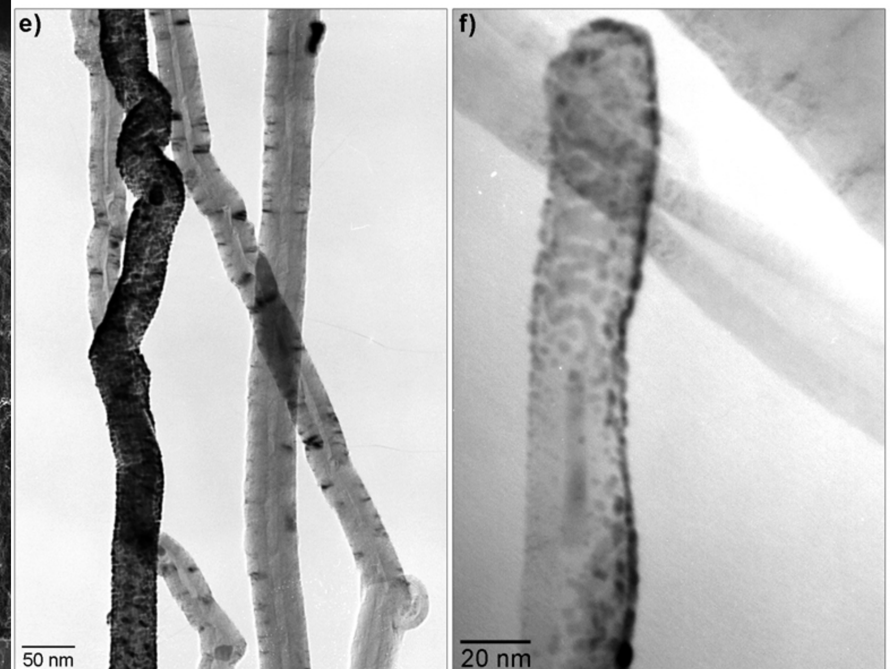
Prinz et al. 2008 Stanford

Architecture of Fuels Cells II:

Micro PEFC with CNT (Carbon Nano Tubes) based Electrodes



Aligned CNT carpet on a silicon substrate including CNT image with higher resolution (SEM pictures)

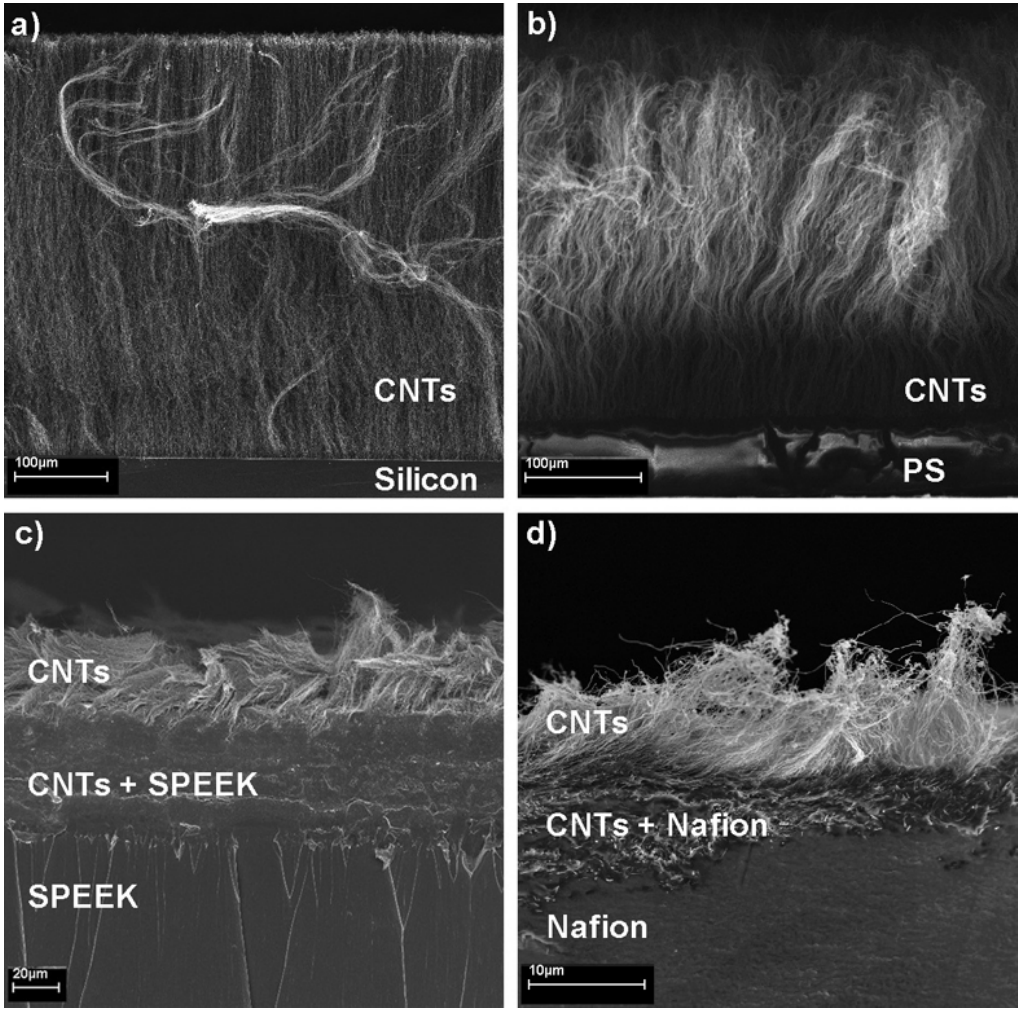


CNTs prepared with 2 wt% ferrocene solution
1 h growth and 0.034mg/cm2 Pt deposition (e.)
45 min growth and 0.017mg/cm2 Pt deposition (f.)
(TEM-Pictures)

Prehn et al. 2008 Hamburg/Kiel/Ulm/Geesthacht

Architecture of Fuels Cells II:

Low temperature micro PEFC with CNT based Electrodes



Process steps of the MEA fabrication:

(a) CNTs on a substrate

(b) CNTs partly covered with PS,

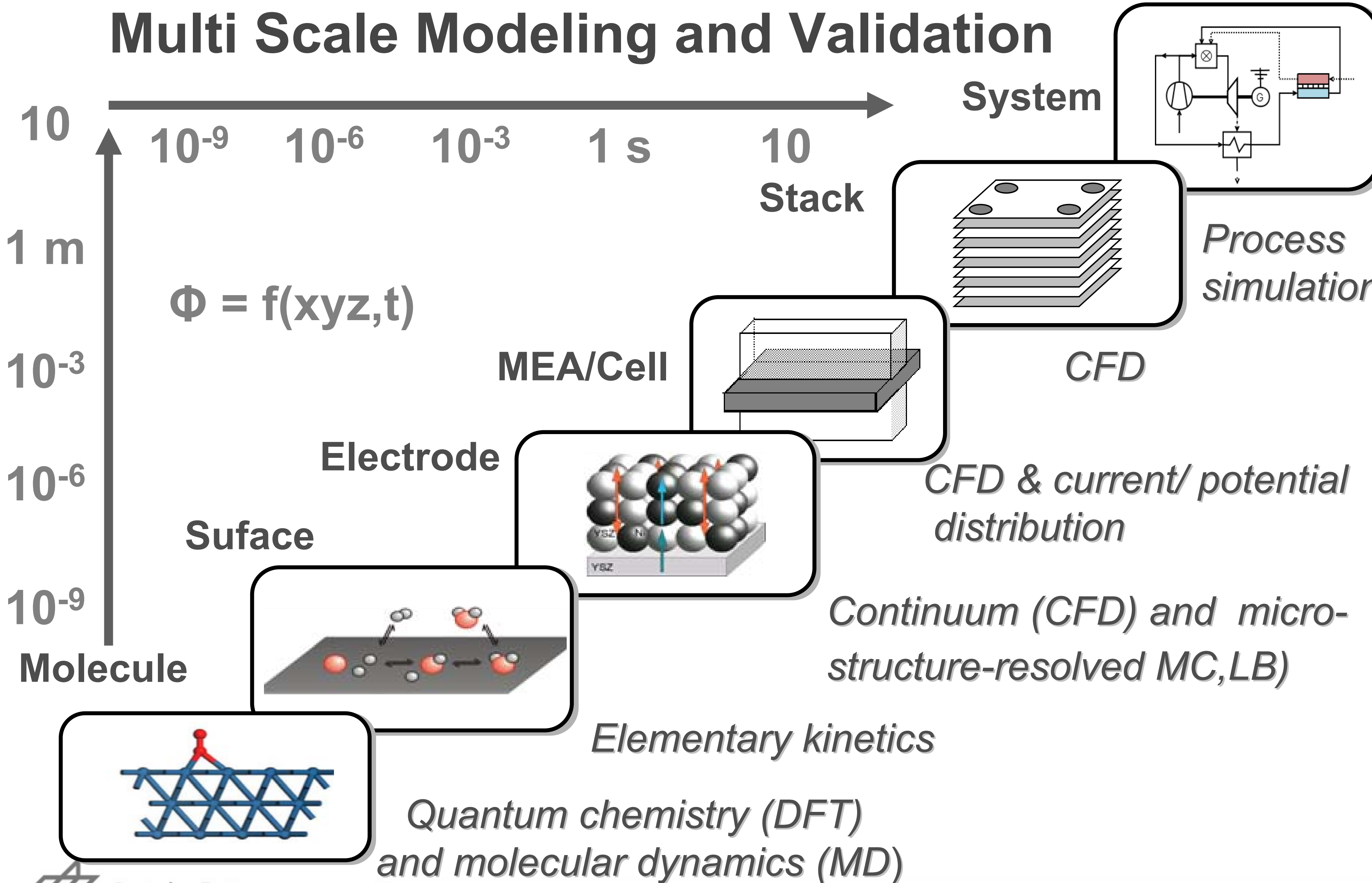
completed membrane with

(c) SPEEK and

(d) Nafion.

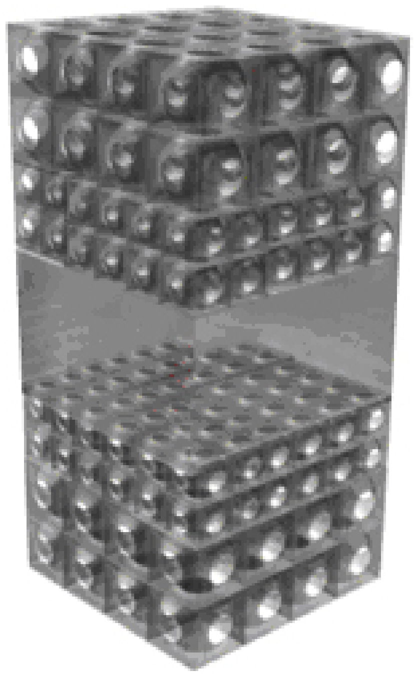
Prehn et al. 2008 Hamburg/Kiel/Ulm/Geesthacht

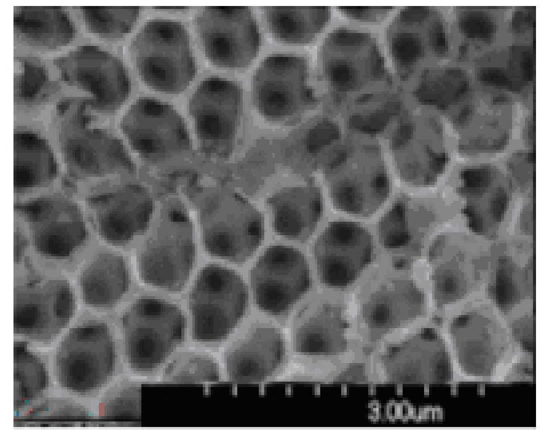
Multi Scale Modeling and Validation



Based on: Bessler 2008, DLR

Nanoscale Architectural Engineering for High Performance Solid Oxide Fuel Cells





Inverse Opal structures constructed from CeO_2 -YSZ

Schematic of an SOFC_MEA with non-tortuous, high surface area electrodes

Goodwin and Haile, 2008 CALTECH

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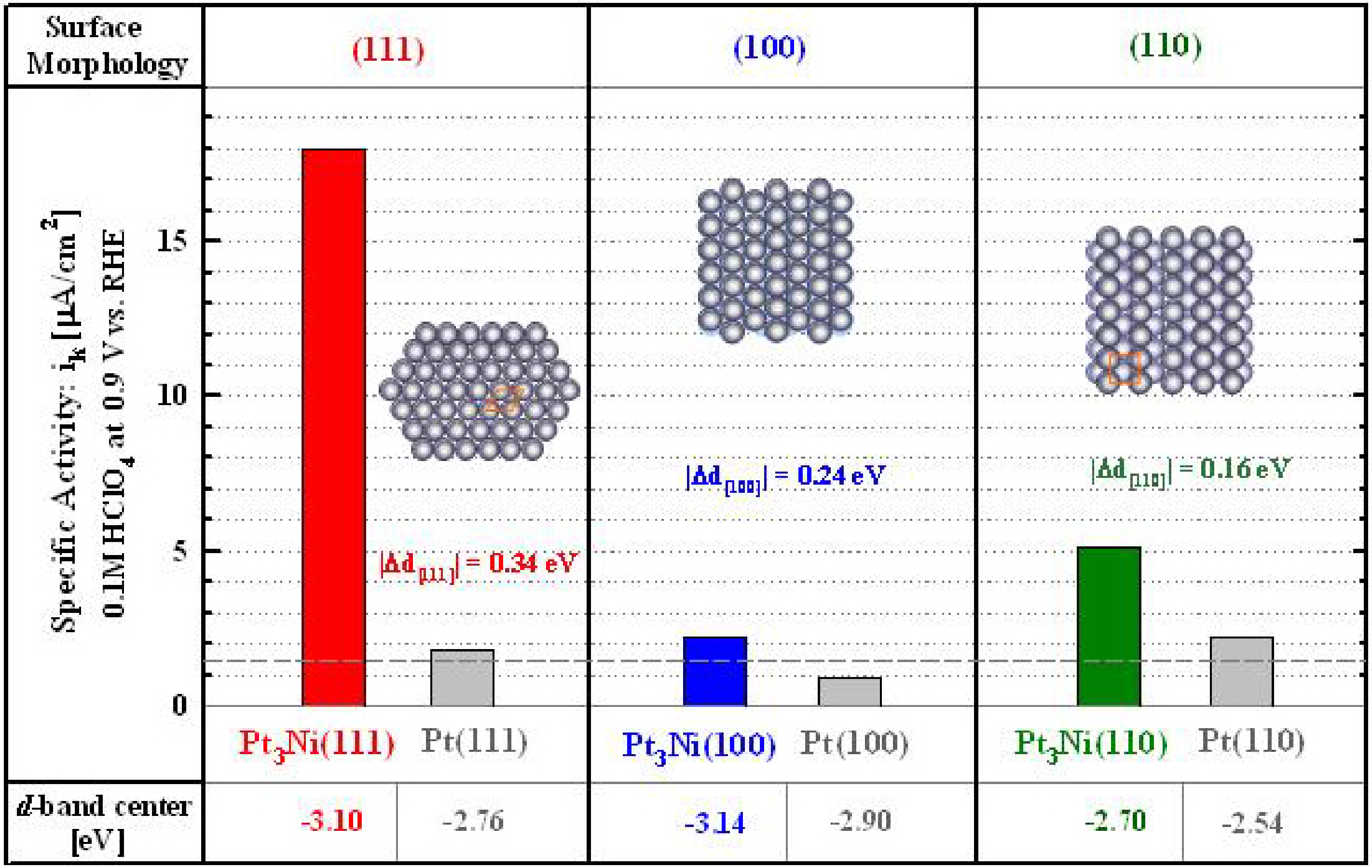
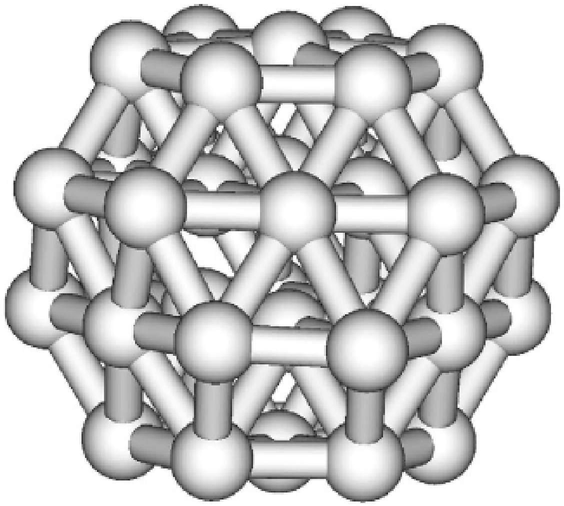
Electrocatalysis I: Oxygen Reduction Reaction (pH 0)

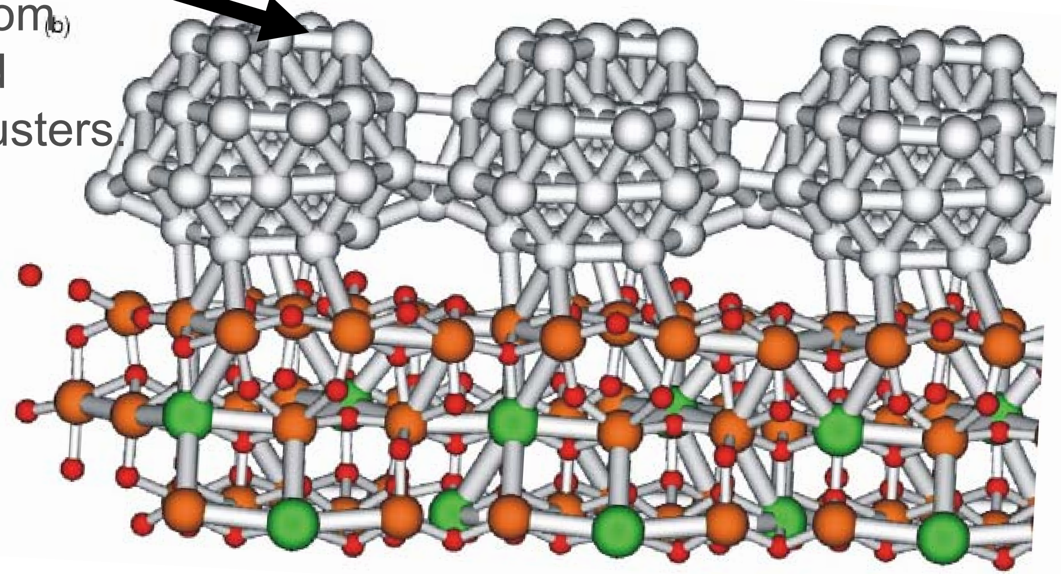


Electrocatalysis II:
Magic Numbers of Metal Clusters and thermal stability



Pt38 cluster after relaxation in vacuum.
Termination is by low energy
(1 1 1) and (1 0 0) planes

Three supercells of Pt38/YSZ after a Pt atom has been removed from the top corner of the cluster and Placed between neighboring clusters.



Pt atoms shown in grey,
Zr in brown,
O in red,
Y in green

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Unconventional Fuel Cells

Fuel Cell

$$H_2 + 0.5\ O_2 \rightleftarrows H_2O$$

Electrolysis

Microbial Fuel Cell e^-

$$(H\text{-}C\text{-}OH)_n + n\ O_2 \rightleftarrows n\ H_2O + n\ CO_2$$

Hydrocarbons
n = 6: Glucose

Photosynthesis hν

DCFC

$$C + O_2 \rightleftarrows CO_2$$

?

Biofuel Cell: MCFC/SOFC Fueled with Biogas or Synfuel from Biomass

or *Bio* FuelCell ➡ *Microbial* FuelCell *MFC*

In vivo power supply: ***blood glucose/oxygen***

► Pacemaker, glucose sensor, actuator power supply

Biosensors: ***target molecule/oxygen***

► specific biosensors: enzyme or microbe based

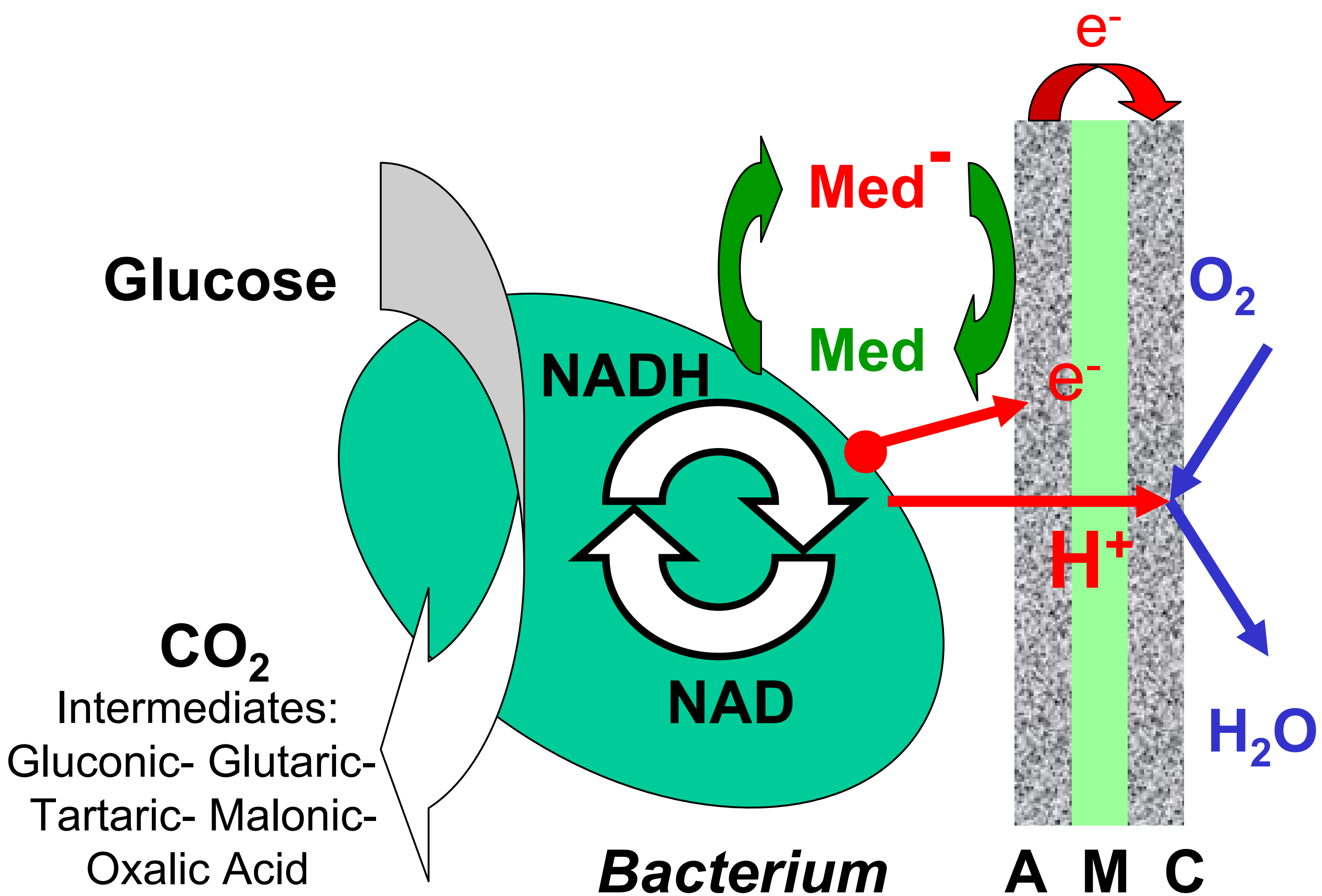
Waste remediation: ***cellulosic materials, sewage***

► power generation from organic materials/waste

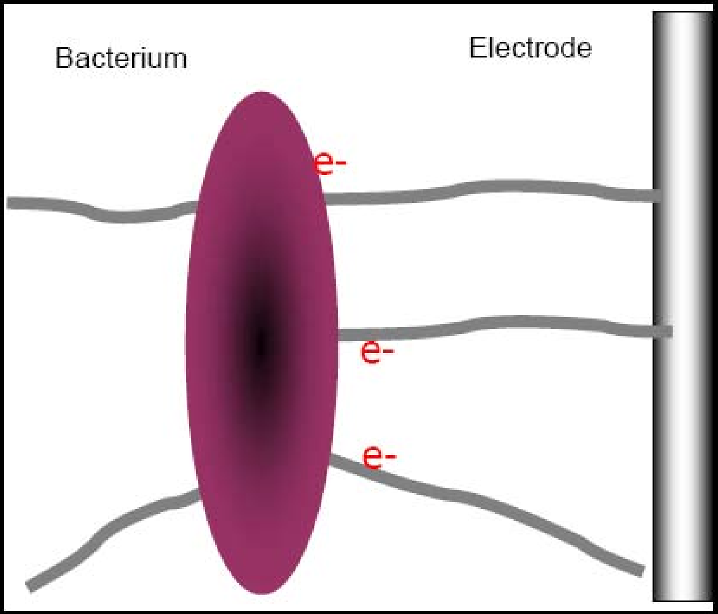
Portable power cells: ***alcohol/oxygen***

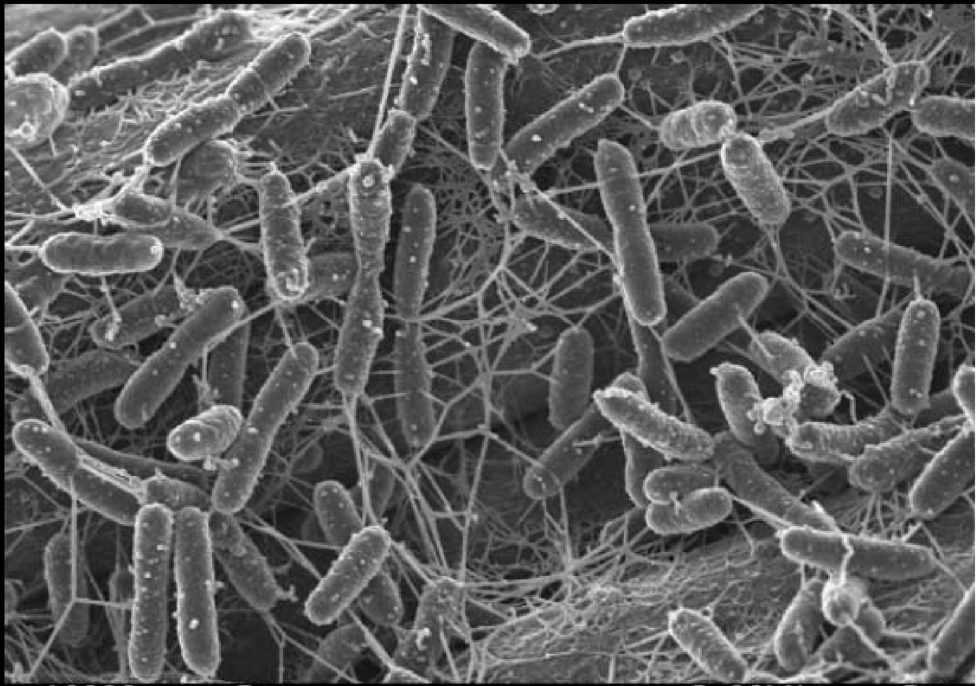
► consumer electronics

Principle of Microbial Fuel Cells MFC



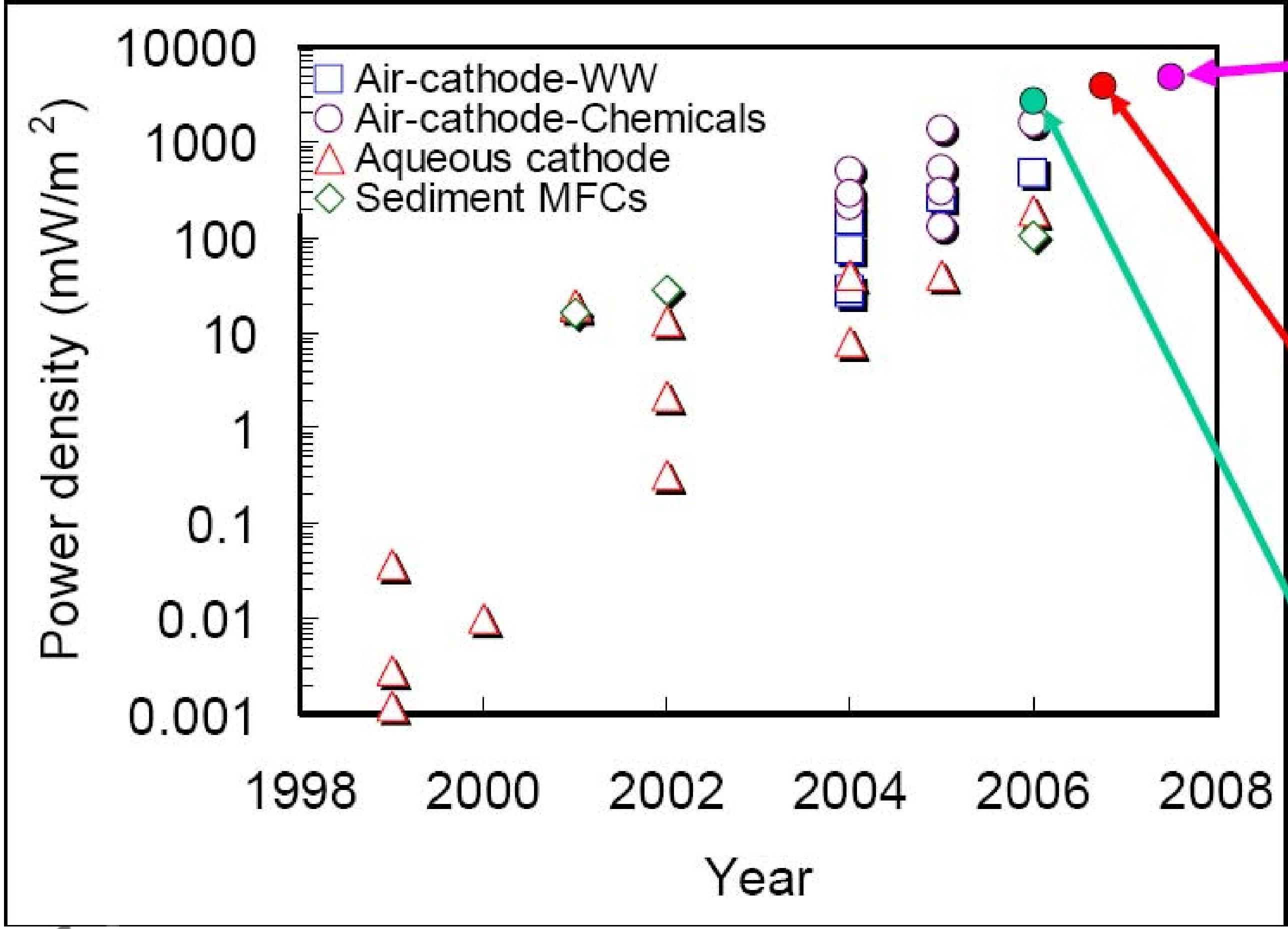
Is it all about "nanowires" ?





Challenge: Electrical conductivity so far shown only in the *z*-direction (top of the "wire") not *along* the wire!

Power production in MFCs worldwide



2008:
2700 mW/m²

2007:
2400 mW/m²

End of 2006:
1970 mW/m²

Logan 2008, PSU

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Direct Carbon Fuel Cell technologies 2003 - 2008

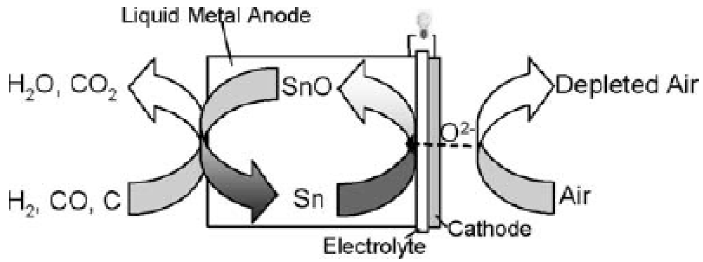
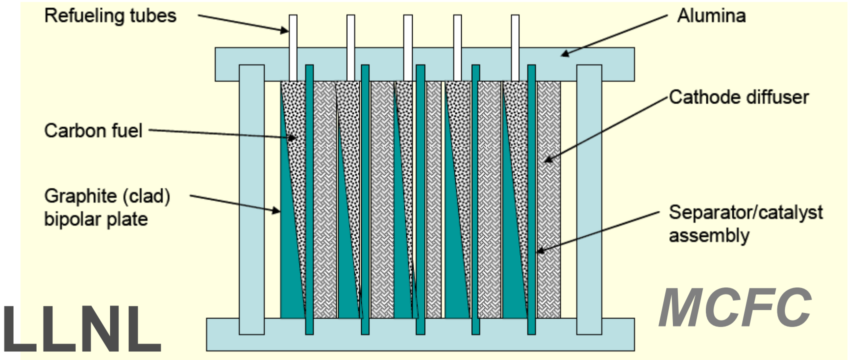


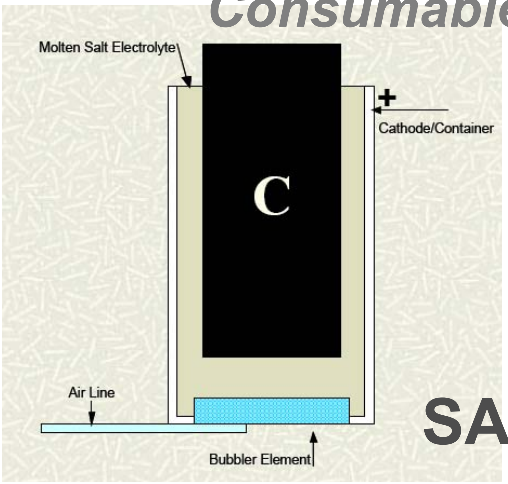
Fig. 3 Anode process of CellTech LTA-SOFC

Celltech LTinAnode

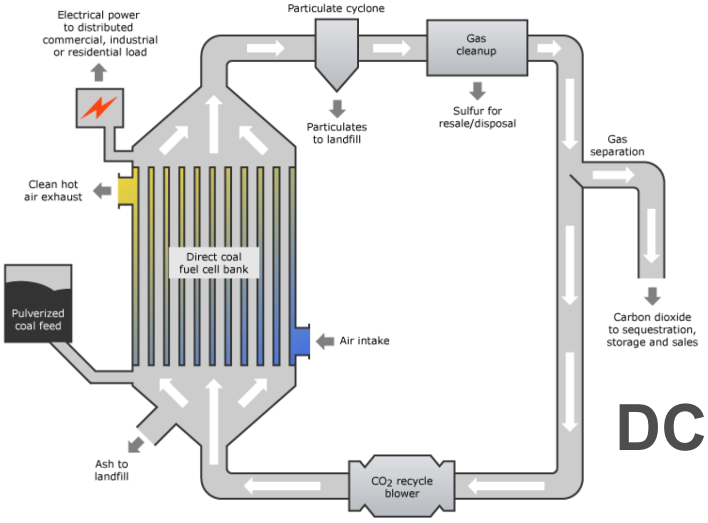
LLNL



Consumable C-anode



SARA

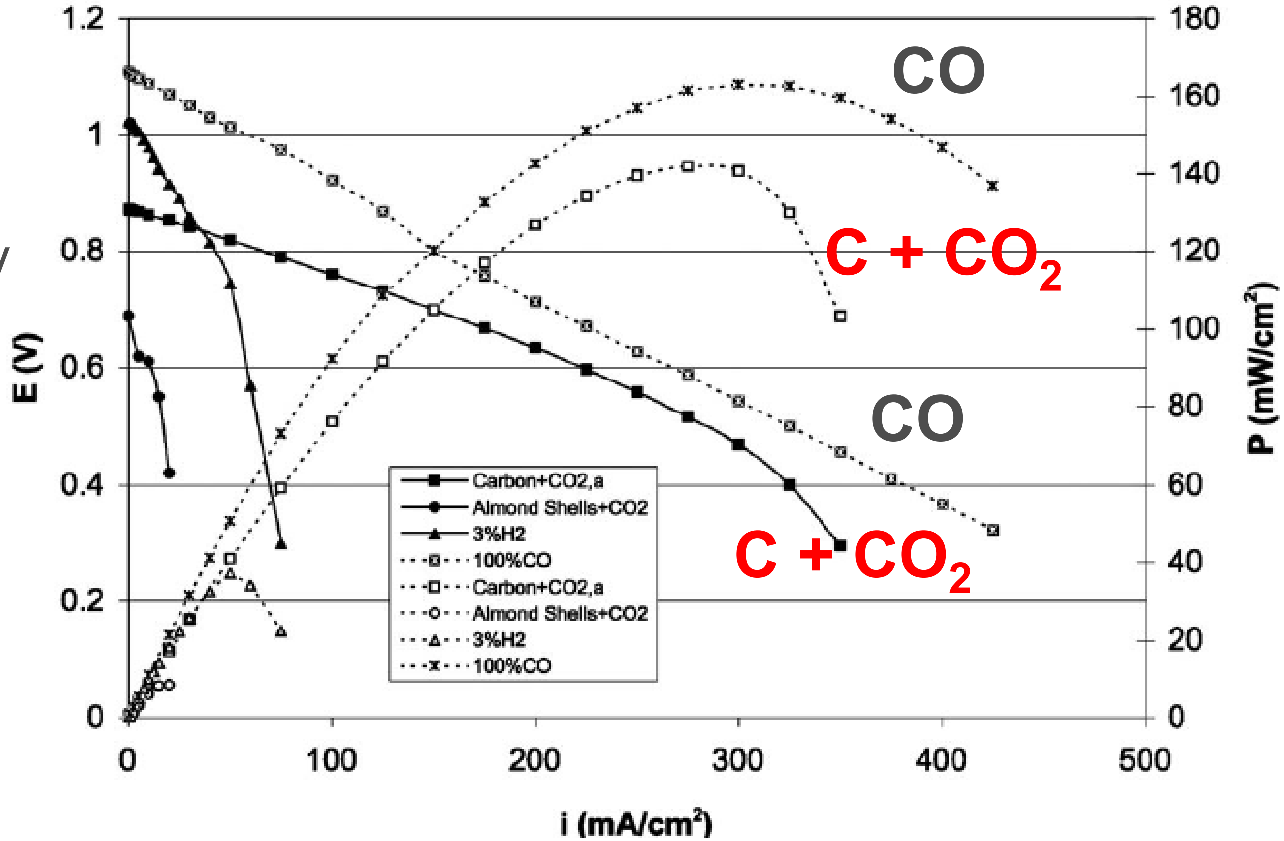


DCT

From: Celltech, LLNL, SARA, Stanford/DCT

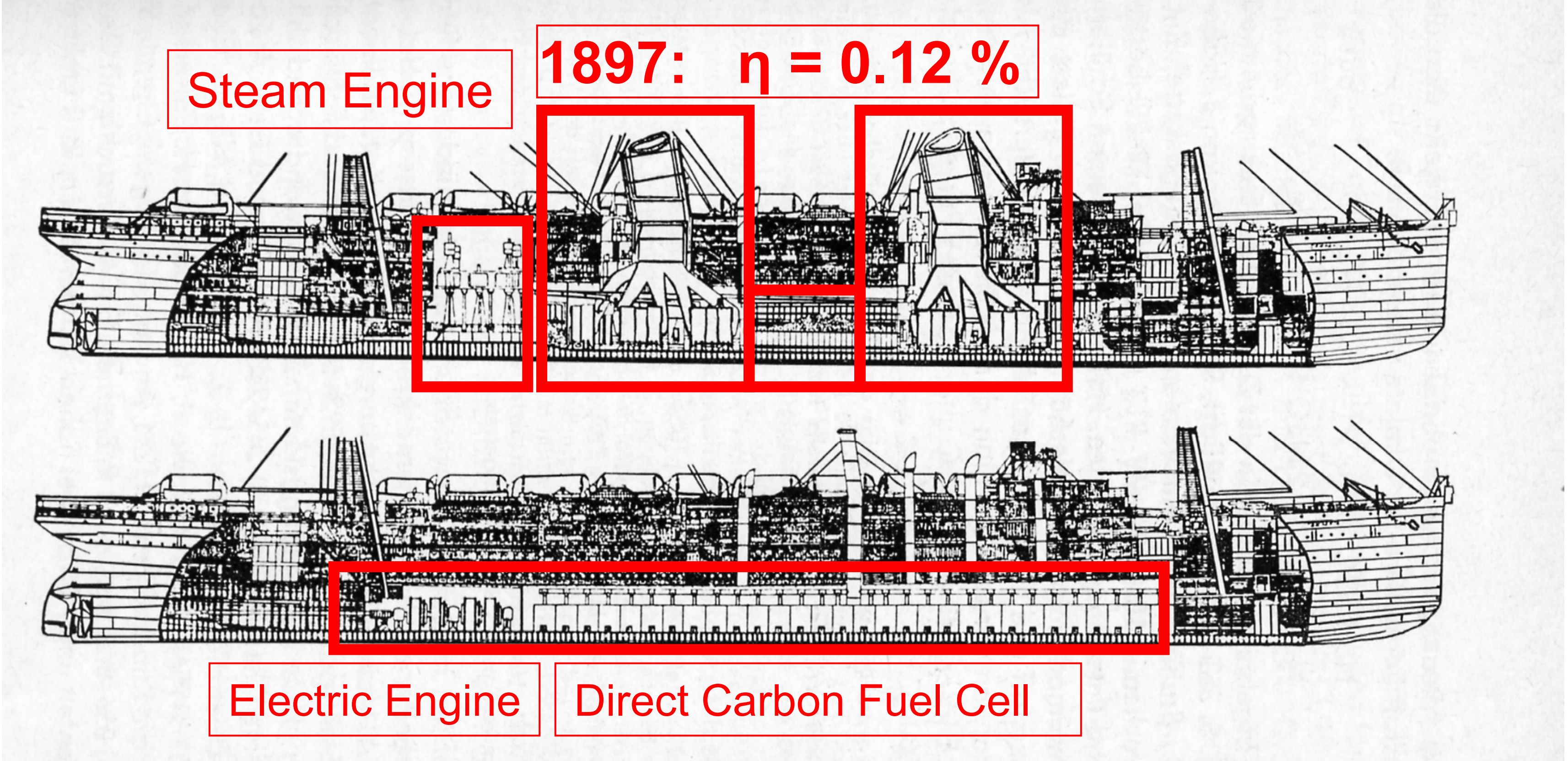
SOFC
Fluidized Bed
C + CO2 ⟹ CO
Boudouard

I-V-P behavior of type I cell anode inside with synthetic carbon and biomass agitated by flowing CO2 at 900°C. For benchmarking, cell performance with only gaseous fuels 3% H2 balance N2 and 100% CO is also included. Solid lines: *I-V*; dashed lines: *I-P*.



Lee et al. 2008, Stanford, Direct Carbon Technologies

Early Visions of DCFC Technology….1896



1892-1897 Helmholtz-Gibbs-Ostwald-Nernst: ***DCFC η_{th} = 1,0***